Abundance, structure and uses of Baobab (Adansonia digitata L.) populations in Omusati Region, Namibia

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Abundance, structure and uses of Baobab (*Adansonia digitata* L.) populations in Omusati Region, Namibia

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ABSTRACT

The baobab (*Adansonia digitata* L.) tree has multiple uses and is highly valued in Southern Africa, particularly in the rural communities where people depend on this resource for their livelihoods. However, few studies have been conducted on the usefulness of this high value plant species in Namibia. The aim of this study was to document the biology and local uses of baobab populations in Outapi and Onesi sites in Omusati Region, Namibia. A comparison of densities, distribution patterns, structure, phenology, stem conditions and uses of baobabs between the two sites was done.

Road transects were used to identify focal trees which in turn were used to determine the placement of circular plots. In each plot, diameter at breast height (dbh) of adult and sub-adult trees, height of adults, sub-adults and saplings and their stem conditions, number of fruits on each fruiting baobab tree, occurrence data and the land-use types where baobabs occurred were recorded.

The results revealed significant differences in the dbh-size and height classes between the two study sites. The bell-shaped distribution curve in dbh size-classes in the two sites suggests poor recruitment. The results revealed that Onesi villagers made more use of the baobab tree than Outapi urban residents. Some of the common uses of baobabs in both study sites included the use of baobab fruit for human consumption and the use of the baobab bark and leaves as livestock fodder. Additionally, the people of Outapi and Onesi use the baobab fruit and bark to treat certain ailments such as cold, flu and diarrhea.

1. Introduction

The baobab (*Adansonia digitata* L.) tree has multiple ecological and socioeconomic uses, particularly in the rural areas of Africa where local communities heavily rely on indigenous resources for survival. It is among the nine global species of baobab in the genus *Adansonia* namely *Adansonia gibbosa* A. Cunn., *Adansonia grandidieri* Baill., *Adansonia madagascariensis* Baill., *Adansonia rubrostipa* Jum. & H. Perrier, *Adansonia perrieri* Capuron, *Adansonia suarezensis* H. Perrier., *Adansonia za* Baill. (Sidibe & Williams, 2002), as well as *Adansonia kilima* sp. nov. that was discovered in Limpopo Province, South Africa (Pettigrew et al., 2012).

Baobab products particularly seed oil and fruit pulp are increasingly being commercialized and exported around the world which has led to increased pressure on this resource (Sidibe & Williams, 2002). Sustainable management of this species is vital to avoid over-exploitation. In order to institute sustainable harvesting regimes of this species, there is a need to fully understand its biology (Venter & Witkowski, 2010). According to Gouwakinnou et al. (2009), better management decisions can be based on the use of population structures in investigating the demographic health of harvested populations together with information related to patterns of use and harvest. Therefore, this study was aimed at understanding the population structure of the baobab, including its abundance and uses in order to improve management practices in Omusati Region, Namibia.

2. Materials and methods

2.1. Study sites

This study focused on two sites in the Omusati Region, namely Outapi and Onesi, where significant populations of wild baobabs thrive (Fig. 1). The sites were selected based on the differences in human population densities, land-use patterns and rainfall regimes. Outapi comprises mainly of an urban centre which is the capital and economic hub of Omusati Region and has the highest population density in the Region (Government of Namibia [GRN], 2011). (See Table 1.)

The region is within a semi-arid climatic zone (Mendelsohn et al., 2000). Rainfall varies greatly from year to year (Kangombe, 2010) and is restricted to the summer months (November to April). Subsistence farming is practiced by the majority of people in the Region. In the

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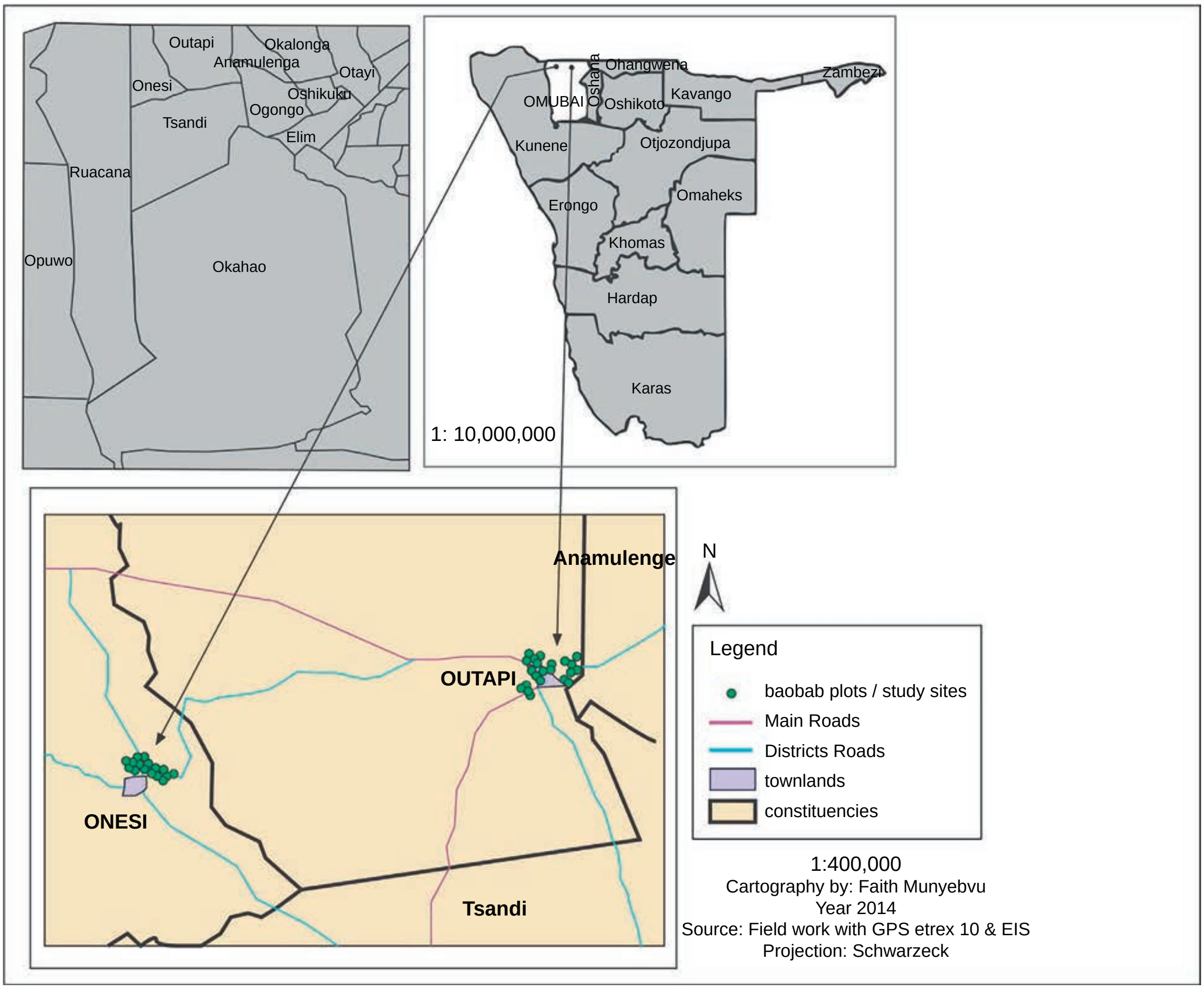

Fig. 1. Location of study area and the position of sampled baobab individuals in Omusati region.

villages, each household has a fence (barbed wire and/or brushwood) around crop-fields, homesteads and exclusive grazing areas allocated by the Traditional Authority (Mendelsohn et al., 2000). Other farming practices include large-scale subsistence farming and commercial farming on privately owned land (Mendelsohn et al., 2000).

2.2. Study species

Adansonia digitata has medicinal properties and numerous uses of various plant parts (Dhillion & Gustad, 2004; Wickens & Lowe, 2008). It is an important source of income, especially in the dry season and

Table 1
Characteristics of the two study sites where *Adansonia digitata* is distributed in Omusati region.

	Outapi	Onesi
Population	37,000	13,200
Area	985.5 km ^{2}	601.9 km^2
Main settlement type	Urban	Rural
Main vegetation	Woodland, palm savanna	Woodland, bush mopanesavanna
Rainfall	~550–600 mm	~250–300 mm
Main soil types	Cambisols	Arenosols

Government of Namibia [GRN] (2011); Mendelsohn et al. (2000).

during times of drought (Sidibe & Williams, 2002; Duvall, 2007). The baobab is a deciduous, tropical fruit tree which ranges between 6 and 10 m in diameter for adult trees (Wickens, 1982; Chadare et al., 2009) that can reach up to 23 m in height.

The African baobab occurs naturally in most sub-Saharan countries and is especially associated with the drier parts of savanna. In West Africa, *Adansonia digitata* is found in Mali, Benin, Senegal, the Ivory Coast, Cameroon and Burkina Faso while in East Africa, the plant is found in countries such as Kenya, Uganda and Tanzania. In southern Africa, the species is commonly found in Malawi, Zimbabwe, Mozambique and South Africa especially in the warm parts of the Limpopo Province (Sidibe & Williams, 2002). Baobabs also occur in Botswana, Angola and Zambia. In Namibia, sizeable populations of mature baobabs occur in the north-western parts and smaller populations in the far north-eastern parts. Specifically, baobabs in Namibia occur mainly in parts of Kunene, Omusati, Zambezi, Kavango West and Kavango East Regions.

2.3. Experimental design and sampling

Sampling of baobabs was done in the eastern area of Outapi including within the nearby villages of Omusjii and Oukwa and the town area of Ombalantu as well as in the eastern villages of Onesi namely Oshima, Ohalumbele and Oshihau. (Fig. 1).

Road transects were used to sample baobabs in the two sites by purposely finding the next available road to gain access to the next focal tree following an approach by Mpofu et al. (2012) and Munondo

(2012). The first transect was purposefully laid out where baobabs were occurring at the eastern part of each study site. In the built-up area of Outapi, all the available roads including foot paths were used to get to the next focal tree. Baobabs sighted on either side of the road within and outside homesteads were measured by demarcating circular plots of 30 m in radius from the edge of the canopy of each focal tree following an approach by Selanniemi et al. (2000). A minimum target of 100 circular plots was reached in each of the two sites. A total of 118 baobabs were sampled in Outapi in 101 circular plots whilst 112 baobabs were sampled in Onesi in 100 circular plots. Each baobab plant was considered a sampling unit.

2.3.1. Assessment of population structure and abundance

Adult trees were defined as having diameter at breast height (dbh) of equal to or more than 150 cm and sub-adults with less than 150 cm and more than 1 cm in dbh following Schumann et al. (2010). Saplings and seedlings were identified and distinguished from each other by their vegetative and morphological characteristics such as the number of leaves and the size of the plant (Fig. 2). All baobabs identified within each plot were counted and their heights measured. The heights of seedlings and saplings were measured using a 1 m measuring pole. For adult and sub-adult baobabs, a traditional method was used which involves measuring horizontal distance to the tree and angles from horizontal to the top and base of the tree, while standing at a distance (Larjavaara & Muller-Landau, 2013). The dbh was then measured using a diameter tape and at 1.3 m above ground level according to the international practice (Agriculture, Fisheries and Conservation Department, Conservation branch, 2006).

2.3.2. Assessment of individual plant condition, phenology and land-use types

Each baobab encountered within a circular plot was assessed for evidence of debarking, fire scars and any other disturbances in general without measuring the proportion of damage per stem. Stem condition was then scored as intact (without any damage), debarked (either old or new) and other (e.g., termite infestation, man-made cuts and natural holes) having modified an approach by Dovie (2003).

Fruit counts were conducted in April when most of the baobab fruits had matured and were almost ready for harvest. Trees were categorized as fruiting or non-fruiting based on fruit presence or absence. Fruits per individual tree were estimated through randomly selecting and visually counting the fruits on 50% of the crown cover divided vertically and then multiplying by two to get an estimate of the whole tree. This sample was used in order to manually determine the best estimate of fruit numbers both at the top and bottom parts of the tree.

The land use type where each sampled tree occurred was also noted (Table 2). Three major land-use types were categorized as (a) field (crop cultivation areas), (b) pasture (grazing areas) and (c) settlement (homesteads and surrounding areas (following Schumann et al., 2010). The settlement area for Outapi, as an urban area, included the business centre as well as open spaces between buildings.

2.3.3. Socioeconomic survey

Questionnaire interviews were conducted in April 2014 with nearby households and households that had baobabs in their fields and/or homesteads in order to understand the local uses of baobab trees. Respondents were purposely selected when the next focal tree was found within or nearby the respondent's household or field. A total of 37 structured interviews were conducted in Outapi and 30 in Onesi. Interviews were conducted in the local language and all respondents were at least 18 years old, with the oldest respondent being over 80 years. The respondents were asked, among other issues, about the:

- number of baobab trees they have,
- main uses of the species and the parts utilized,
- evidence of recruitment ever seen, and
- factors affecting baobab sapling survival

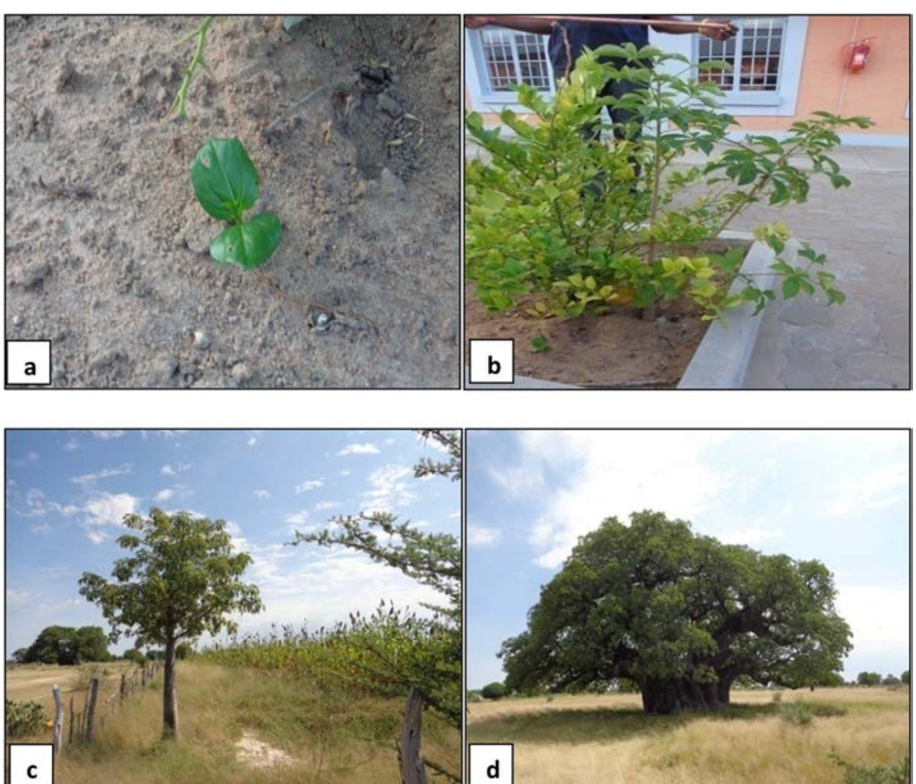

Fig. 2. Different baobab size-structures identified in the study sites: seedling (a), sapling (b), sub-adult (c) and adult baobab (d). Photo credit: Ruben Ulbrich.

Table 2
Number of baobabs enumerated within different land use types in Outapi and Onesi.

Land use type	Outapi	Onesi	Total
Field	32	38	70
Pasture	27	71	98
Settlement	59	3	62
Total baobabs	118	112	230

The different uses of baobabs mentioned by respondents were classified as follows: human consumption for food (fruit pulp and seed), fodder (mainly the baobab bark and leaves), handicraft (baobab fiber from the bark, fruit shells and seeds), commercial purposes (baobab fruit and handicraft), sniffing (baobab shell ground into powder), medicinal (fruit pulp to cure diarrhea, coughs), spiritual (e.g. hanging the baobab fruit in the room to scare away evil spirits), shelter (animals living inside the hollow trunk), medico-magical (e.g tying baobab fiber string around babies for fast growth of premature babies) and shade (people and animals using the tree for shade), (Fig. 6).

2.4. Data analyses

The density of baobabs in each plot was calculated and expressed on a per hectare basis. Mann–Whitney *U* test was used to test for differences in baobab densities between the two sites. The distribution of baobabs was mapped using Arc Map 1.0 to produce the baobab distribution maps of Outapi and Onesi.

Each sampled adult and sub-adult baobab was assigned to one of the nine 100 cm wide diameter at breast height classes, ranging from 1 to 100 cm, 101–200 cm up to ≥801 cm dbh. The dbh size-class intervals used by Schumann et al. (2010) of 50 cm were modified to 100 cm because the baobabs in Omusati Region were much larger. Chi-square test of Independence was used to test for differences in the dbh frequency distributions and stem conditions between Outapi and Onesi.

All plants were assigned to height classes of ≤5, 5.1–10, 10.1–15, 15.1–20 and 20.1–25 m following Ravindranath and Ostwald (2008). Chi-square test of independence was used to test for differences in height class distributions between the two study sites.

Comparing the two sites, Chi-square tests were also conducted to test for any significant association between the stem condition and the dbh size-classes and between stem condition and land-use types.

All trees that had started fruiting were allocated into one of the seven fruit classes: 0–4, 5–24, 25–49, 50–99, 100–199, 200–299 and 300–400 following Venter and Witkowski (2011). No tree exceeded 400 fruits at the time of the survey. All the adult trees (dbh > 150 cm) that had reached the reproductive stage and had no fruits were also assigned into the fruit class 0–4. A Mann–Whitney *U* test was used to test for significant differences in the medians within each fruit class.

Irrespective of sites, Chi-square tests of association were also performed to check for any significant association between land-use types and stem condition, and between land-use types and fruiting class.

Ten categories of the uses of baobabs in the two sites were used to assign each use that was captured during the socioeconomic survey (Fig. 6). In order to determine the differences in the uses of baobabs between the two sites, a Chi-square test of independence was used.

3. Results

3.1. Comparison of the baobab density and spatial distribution pattern

The results revealed that there was no significant difference in the density of baobabs between the two sites ($U = 4713.0$, $p > 0.05$). Outapi had a mean of 4.13 trees/ha while Onesi had a mean of 3.96 trees/ha.

Baobab abundance in each site was not evenly distributed across the habitats as some baobab stands were in a clustered pattern whilst some were more dispersed.

Fig. 3 (a) shows that Onesi had the highest proportion of trees within the 201–300 cm dbh size-class while no trees were recorded in the largest size-class (>801 cm) in that site. There was a significant difference in the dbh frequency distributions between Outapi and Onesi ($\chi^2 = 33.038$, df = 8, $p < 0.001$).

Overall, the highest proportion of trees (40%) recorded in Onesi were within the 15.1–20 m height class whilst Outapi recorded its highest tree proportion (38%) within the 11–15 m height-class (Fig. 3 (b)). There was a significant difference in the height frequency distribution between the two sites ($\chi^2 = 16.295$, df = 4, $p < 0.05$).

3.2. Comparison of stem conditions

There was a significant difference in the stem condition between Outapi and Onesi ($\chi^2 = 22.705$, df = 2, $p < 0.001$). Outapi site had more intact stems than Onesi (Fig. 4). In Outapi, the number of stems with other disturbances (such as termite infestation, man-made cuts and natural holes) were fewer than the expected by 10.8% whilst the same stem conditions had higher observed than expected counts in Onesi by 11.4%.

A Chi-square test of the association between stem conditions of sampled baobabs in the three land-use types showed a significant difference ($\chi^2 = 274.552$, df = 9, $p < 0.001$). There were more intact stems (44%) in the settlement area than those found in the field and pasture. The highest proportion of debarked stems (45%) and those with other disturbances or conditions (52%) was observed in the pasture area whilst the settlement area had the least proportion of de-barked stems (18%).

3.3. Comparison of fruit production

There was no statistically significant difference in the average fruits produced per tree between Outapi and Onesi ($U = 5550.5$, $p > 0.05$). However, there was a significant difference in fruit production between different land use types ($\chi^2 = 26.114$, df = 12, $p < 0.05$). In the fields, fruiting was 5.7% lower than expected within the 0–4 and 5–24 fruit production range and 7.5% higher than expected in the 100–199 fruit production range. Irrespective of sites, 11 baobabs sampled in the pasture and settlement areas had less than four fruits per tree whilst only eight trees had more than 300 fruits per tree in all three land-use types (Fig. 5).

3.4. Uses of baobabs

The number of mentioned uses within categories differed significantly between the two sites ($\chi^2 = 31.022$, df = 9, $p < 0.001$), but in both sites human consumption for food was the most common use category of baobabs (Fig. 6). Nineteen percent (19%) of the respondents in Outapi and 47% in Onesi mainly sold the baobab fruits for cash income.

4. Discussion

4.1. Baobab population distribution and structure

The comparable densities and distribution patterns may imply that the two sites experience almost similar natural and anthropogenic factors. The high levels of urban development taking place in Outapi and land clearing for agricultural activities in Onesi likely affects the survival and consequently the density and distribution pattern of baobabs. Such human activities also play a significant role in affecting the population structure of baobab stands. The dbh size-classes of Outapi and Onesi displayed a more bell-shaped curve (Fig. 3 (a)). Higher proportions of baobabs were found within the largest size classes in Outapi and this could imply that more baobabs survive into larger-size classes or there

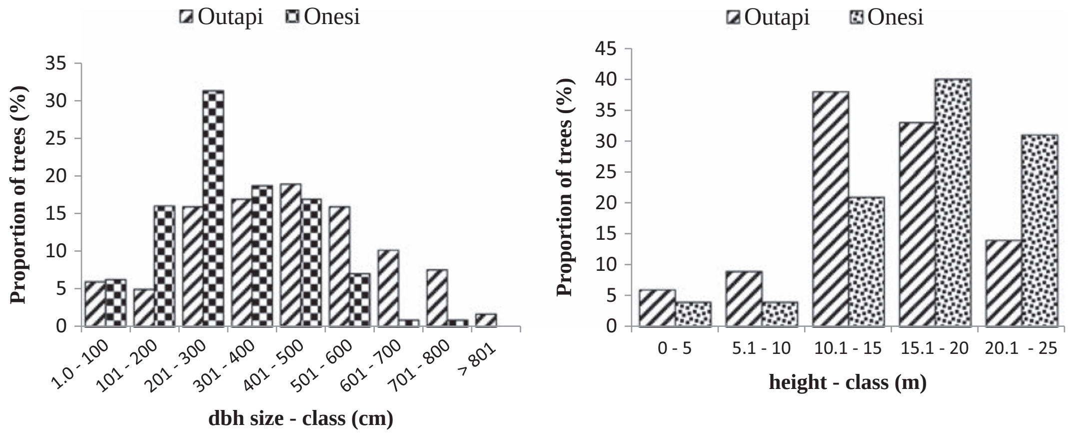

Fig. 3. The size-class distribution of baobab individuals in Outapi and Onesi sites, as defined by (a) diameter at breast height (dbh) and (b) height.

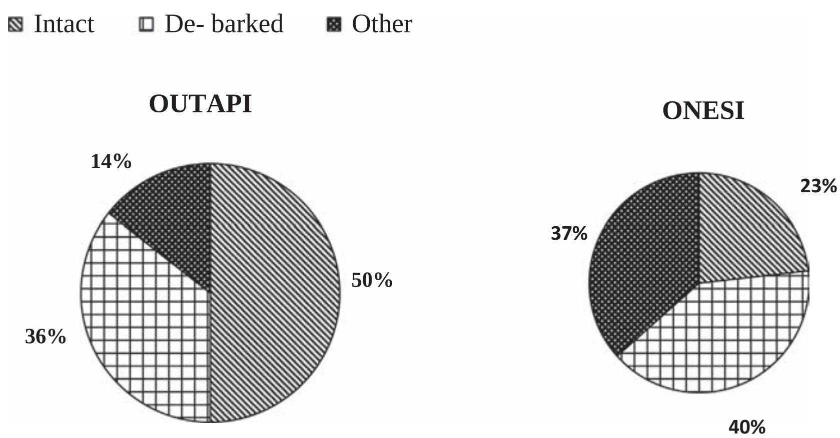

Fig. 4. Proportions of baobabs with varying stem conditions in Outapi and Onesi sites.

could be a disproportionate cutting of some size classes especially due to human development and urbanization. Lack of smaller size classes (dbh: 1–100 cm) in Outapi and Onesi indicates a population recruitment bottleneck which is possibly caused by intensive exploitation (Rocky & Mligo, 2012). This result is consistent with other studies conducted elsewhere, for example, Hofmeyer (2003), Chirwa et al. (2006), and Venter and Witkowski (2010) who conducted studies in Malawi and South Africa did not find any baobab seedlings in their study areas due to herbivory. In a recent study conducted in northern Namibia by Lisao et al. (2017), they concluded that it was evident that local communities had a role in shaping the baobab population structure as they contributed to lack of regeneration of baobabs. The bell-shaped distribution curve in dbh size-classes in the two sites studied suggests poor recruitment. According to Venter and Witkowski (2010), low recruitment rates and bell-shaped or positively skewed size-class distributions which are typical of baobab populations across Africa have raised concern about the maintenance of baobab populations. However, this may be of less concern due to the long-lived nature of baobabs and extremely low adult mortality rate (Venter & Witkowski, 2010).

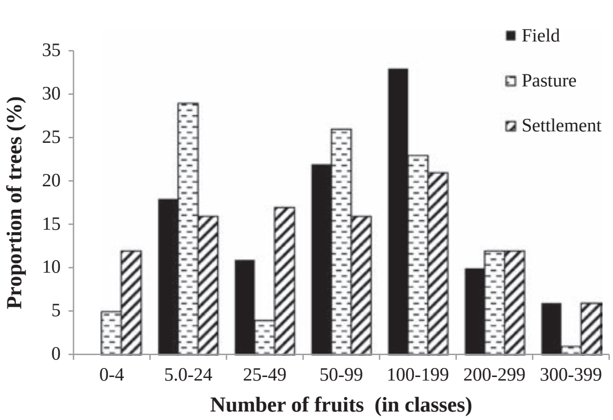

Fig. 5. Fruit production within different land-use types of Outapi and Onesi sites.

Outapi site had higher proportion of trees within the lower to middle height classes (0–15 m) compared to Onesi site that had the highest proportion within the taller height classes (16–25 m) (Fig. 3 (b)). This suggests that Outapi constituency may experience more favorable conditions that facilitate speedy growth of young trees such as higher rainfall. During good years, the north-east parts of Omusati region where Outapi is located receives between 550 and 660 mm per year compared to the south-western parts (250–300 mm per year) where Onesi is situated (Mendelsohn et al., 2000).

4.2. Comparison of plant condition between study sites and within land use types

More respondents from Onesi than from Outapi indicated that they debark the baobabs to feed livestock during dry periods. Outapi as a more urbanized site incurs less damage to baobab stems than the rural settlement area of Onesi (Fig. 4). This indicates that there is high

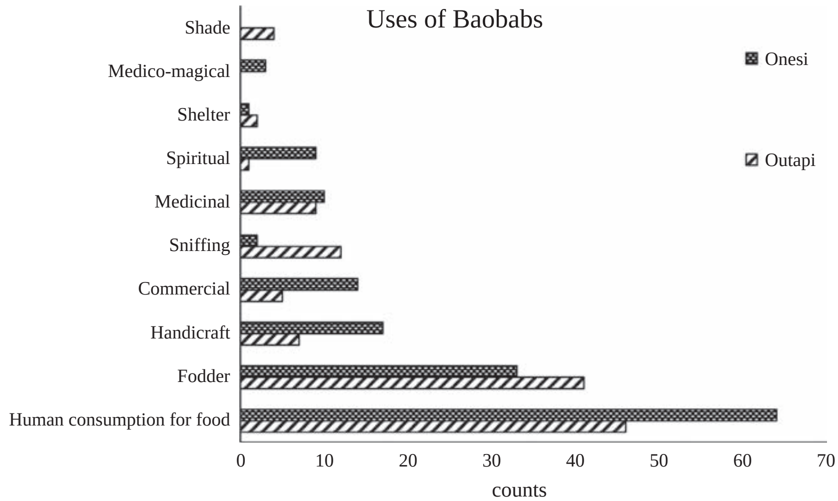

Fig. 6. Comparison of the number of times a use-category of baobab was mentioned by various respondents in Outapi and Onesi sites.

pressure on baobabs by both humans and livestock in Onesi. Onesi villagers tend to make use of the baobab products more because of limited socioeconomic options and heavy reliance on natural resources in rural settlements compared to urban areas (Schumann et al., 2012).

Respondents highlighted that cattle and goats are the livestock that mostly feed on the baobab leaves and bark in drought periods which is probably why the highest proportion of debarked and damaged stems were found within the pasture areas. Such exploitation of baobab parts emphasizes the role of the baobab as a multi-purpose species (Schumann et al., 2010). According to Delvaux et al. (2009), harvesting of vegetative structures (like leaves and bark) significantly threatens the survival of plant populations as the plant parts that affect photosynthesis are damaged or removed. This corroborates with the findings of Peters (1996) that when bark, fruit, wood and other parts of a species are harvested for various uses, there may be significant impacts on the population structure and distribution of the species. The lowest proportions of disturbed baobab stems were enumerated in the settlement areas in both sites which could imply that baobabs within settlements are more protected by people and within fences such that damages by livestock are limited.

4.3. Variability in baobab fruit production

In both sites, adult baobabs that were found without fruits either did not produce fruits at all or did not produce every year. Swanepoel (1993) reported that baobabs in Mana Pools (Zambezi Valley) did not produce any mature fruit during a four-year assessment which was attributed to trees not having enough reserves to produce fruit after leaf flush and flowering or elephant stripping the bark. Fruit production in Outapi and Onesi could also be affected by similar ecological or biological patterns such as insufficient pollination, fruit abortion, predation of the fruits by animals and resource limitation such as moisture.

An observation that was made during field work of this study was that there were a lot of fallen premature fruits on the ground under the baobabs. The villagers attributed this to the windy weather combined with heavy rainfall which was experienced during the previous rainy season in the two sites. This is corroborated by a previous study where Venter and Witkowski (2011) reported that in the year 2007–2008, baobabs in Limpopo province South Africa produced the fewest fruits during a period that the area received the highest rainfall. The respondents of Outapi and Onesi highlighted that the trees normally produce more fruits than the quantities that were found during the fruit inventories.

The significant difference in fruit production classes within land-use types shows that fruit production is to a certain extent influenced by land-use types. The open pasture areas tend to be more susceptible to fruit predation by animals than the fenced fields and settlements. The greatest proportion of baobabs that had less than 25 fruits was found in the pasture area and the greatest proportion of baobabs with fruit production range of 100–399 was enumerated within the fields which suggests that trees within the fenced fields are protected from animal predation (Fig. 5). This is supported by the results of Venter and Witkowski (2011) who found a significant difference in mature fruits between land-use types in Limpopo, South Africa which was attributed to fruit predation.

4.4. Uses of baobabs

The study findings revealed that there was a higher frequency of baobab usage in Onesi than in Outapi (Fig. 6) which corresponded with the levels of employment (17% in Onesi and 59% in Outapi). According to Omotesho et al. (2013), households with higher income are less likely to make use of the baobab due to the fact that they are likely to see the baobab as an inferior product. The respondents in Outapi (65%) were 40 years and younger whilst the majority in Onesi (78%) were 41 years and older hence younger age groups may not be fully versed in various traditional sociocultural uses of baobabs. The significant difference in the uses of baobabs could imply that Onesi as a rural settlement makes use of the baobab more than Outapi which is a more urbanized area. People in rural settlements rely more on natural resources for dietary and livelihood sources than those in more urbanized areas.

The people of Outapi and Onesi use the baobab fruit and bark to treat certain ailments such as cold, flu and diarrhea among others. Such medicinal uses have been documented elsewhere in Africa, for instance the people of Gulimanceba, Burkina Faso use the baobab for the treatment of cough, diarrhea and as a strengthening agent for babies (to have energy) (Schumann et al., 2012). The use of baobab roots to make strings to tie around premature babies in order to speed up growth seems to be described and documented for the first time in this study.

5. Conclusions

Our results show that Outapi and Onesi have similar baobab density and distribution patterns as well as fruit production. Fruit production in both sites tends to be higher in human-modified landscapes such as fields and settlement areas than in the pasture area where the fruits are more exposed to predation by animals.

The bell-shaped size-class distribution in Outapi and Onesi suggests poor recruitment which is mainly due to livestock browsing. The saplings and seedlings that were encountered in the two sites were within the settlements where they are protected from livestock and farming disturbances. Apart from livestock browsing, human development and extreme weather conditions (due to climate change) may lead to increased baobab seedling and sapling mortality in the near future if proper action such as seedling propagation and protection to reduce mortality is not taken.

The villagers from Onesi make more use of the baobab bark for medicinal, craft, spiritual and other uses as well as for livestock feeds especially during droughts than in the more urbanized Outapi where people have a wider array of alternatives.

The interviews revealed that the socioeconomic potential of the baobab is not fully appreciated by the inhabitants of Omusati because of lack of awareness of other uses of this resource that are already being explored in other countries, such as Zimbabwe and South Africa. Such awareness would invariably create more opportunities for the local communities as well as the need to treasure and conserve this indigenous resource.

Conflict of interest

The authors have declared that there is no conflict of interest.

Acknowledgments

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