

## **Abundance, distribution and status of African baobab (*Adansonia digitata* L.) in dry savanna woodlands in southern Gonarezhou National Park, southeast Zimbabwe**

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**Abstract:** The abundance, distribution and status of baobabs (*Adansonia digitata* L.) in three land categories namely, (i) plains, (ii) riverine and rocky outcrops, and (iii) development areas, in southern Gonarezhou National Park (GNP), southeast Zimbabwe, were determined. Baobabs were sampled between April and August 2010 using transects along existing roads and the Mwenezi River. Height, basal circumference and elephant damage for each baobab tree was measured. A total of 117 baobabs were sampled using 17 transects with a combined length of 238 km. Mean baobab density was significantly higher in the development areas as compared to the plains, riverine and rocky outcrops. However, there were no significant differences in mean diameter at breast height and height for baobab trees across the three land categories. Elephants and possibly fire among other factors may be influencing baobab structure, abundance and distribution in southern GNP. Baobab densities in southern GNP do not seem to indicate that baobabs are in danger of extirpation.

**Resumen:** Se determinaron la abundancia, la distribución y el estatus de los baobabs (*Adansonia digitata* L.) en tres tipos de terreno, a saber (i) planicies, (ii) sitios ribereños y afloramientos rocosos, y (iii) áreas desarrolladas, en el sur del Parque Nacional Gonarezhou (PNG), sureste de Zimbabue. Los baobabs fueron muestreados entre abril y agosto de 2010, usando transectos a lo largo de caminos y del río Mwenezi. A cada árbol se le midió la altura, la circunferencia basal y el daño hecho por elefantes. En total se muestrearon 117 baobabs en 17 transectos cuya longitud combinada fue de 238 km. La densidad promedio de los baobabs fue significativamente más alta en las áreas desarrolladas en comparación con las planicies, los sitios ribereños y los afloramientos rocosos. Sin embargo, no hubo diferencias significativas en el diámetro a la altura del pecho y en la altura de los baobabs entre las tres categorías de uso del suelo. Los elefantes, y posiblemente el fuego, entre otros factores, pueden estar influenciando la estructura, la abundancia y la distribución del baobab en la porción sur del PNG. Las densidades de los baobabs en la porción sur del PNG no parecen indicar que estos árboles estén en peligro de extirpación.

**Resumo:** A abundância, distribuição e status dos baobás (*Adansonia digitata* L.) em três categorias de terra a saber: (i) as planícies, (ii) zonas ribeirinhas e afloramentos rochosos, e (iii) as áreas de desenvolvimento, no sul do Gonarezhou National Park (GNP), no sudeste do Zimbabwe, foram determinadas. Os Baobás foram amostrados entre Abril e Agosto de 2010

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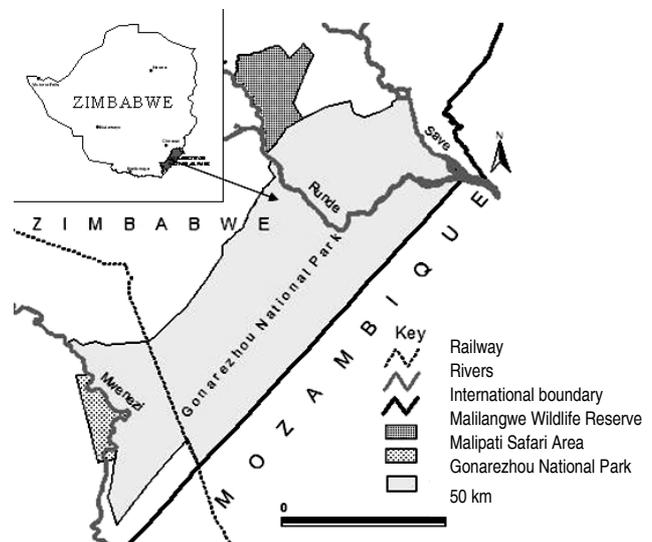
utilizando transeptos ao longo das estradas existentes e do Rio Mwenezi. Foram medidos a altura, circunferência basal e danos de elefantes para cada árvore baobá. Um total de 117 baobás foram amostradas em 17 transeptos com um comprimento total de 238 km. A densidade média dos baobás foi significativamente maior nas áreas de desenvolvimento, em comparação com as planícies, zonas ribeirinhas e afloramentos rochosos. No entanto, não houve diferenças significativas no diâmetro médio à altura do peito e altura dos baobás nas três categorias de terra. Os elefantes e eventualmente, os incêndios, de entre outros factores, podem estar a influenciar a estrutura dos baobás, a sua abundância e distribuição no sul do GNP. As densidades dos baobás no sul do GNP não parecem indicar que aquela espécie esteja em perigo de extinção.

**Key words:** Elephants, Malvaceae, mortality, plains, rocky outcrops, savanna.

The African baobab (*Adansonia digitata* L.) is an iconic tree (Venter & Witkowski 2010). It is a tropical angiosperm belonging to the Malvaceae, subfamily Bombacoideae and is widespread south of the Sahara, especially in savanna regions (Patrut *et al.* 2007). It has a mean height of about 20 m, but some individuals can reach over 20 m in girth (Baum 1995). Earlier studies show that elephants *Loxodonta africana* can severely damage baobabs (Swanepoel 1993; Swanepoel & Swanepoel 1986). In particular, where elephant populations are high, tree-dominated savannas can be converted to a grass-dominated state (Edkins *et al.* 2007). The increasing elephant population in Gonarezhou National Park (GNP), southeast Zimbabwe, has been a cause for concern. Elephant population in GNP was first estimated at 3,100 in 1969 (Department of National Parks and Wildlife Management 1998). In 2009, the elephant population was estimated at 9,123 with a density of 1.84 elephants km<sup>-2</sup> (Dunham *et al.* 2010). The increase in elephant population is likely to have resulted in some negative impacts on vegetation in GNP. Accordingly, in this paper, the abundance, distribution and status of baobabs in three land categories namely, (i) plains, (ii) riverine and rocky outcrops and (iii) development areas, in the southern section of GNP were determined.

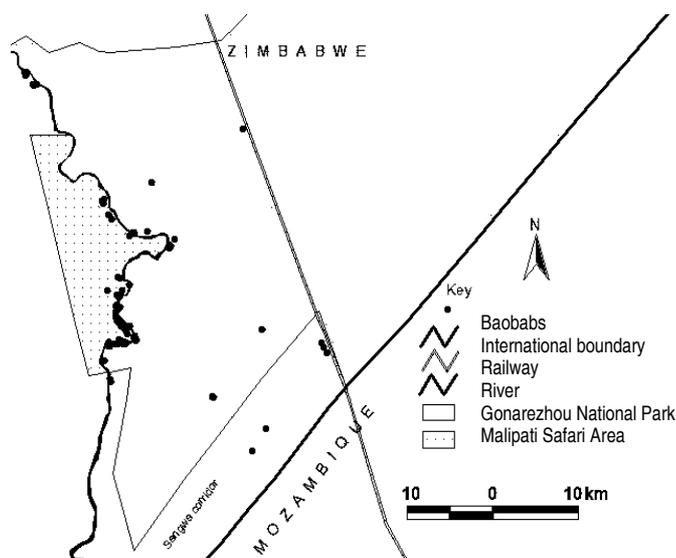
Created in the 1930s, the GNP is a protected area for wildlife conservation in southeast Zimbabwe (Fig. 1). The park covers 5,053 km<sup>2</sup> and lies between 21° 00' - 22° 15' S and 30° 15' - 32° 30' E. Altitude varies between 165 and 575 m above sea level. The vegetation has been described by Sherry (1977). The major vegetation type is *Colophospermum mopane* woodland, which covers approximately 40 % of GNP. Average annual precipitation

for the park is 466 mm. Three climatic seasons can be recognized: hot and wet (November to April), cool and dry (May to August) and hot and dry (September to October). Average monthly maximum temperatures are 25.9 °C in July and 36 °C in January. Average monthly minimum temperatures range between 9 °C in June and 24 °C in January (Gandiwa & Kativu 2009).



**Fig. 1.** Location of the Gonarezhou National Park and surrounding areas in southeast Zimbabwe.

Baobabs were sampled between April and August 2010. In this study, baobab trees occurring in the southern section of the GNP particularly the area south of the railway line, including a small section of the Malipati Safari Area adjacent to the Mwenezi River and part of the Sengwe Corridor



**Fig. 2.** The spatial distribution of baobabs in southern Gonarezhou National Park, southeast Zimbabwe.

were sampled. This area has a total spatial extent of about 900 km<sup>2</sup>. Three land categories were sampled namely: (i) plains (in the mainland area of the southern GNP, including part of the Sengwe Corridor), (ii) riverine and rocky outcrops (along the Mwenezi River, which is the only perennial river in the southern section of GNP) and (iii) development areas, including staff villages, offices and lodges situated near the Mwenezi River. Road transects were used to sample baobabs in the plains and development area whereas the Mwenezi River was used to sample baobabs in the riverine and rocky outcrops. Road transects were randomly selected from topographical maps for the southern GNP using random number tables. In the development areas, all the available roads were used. A vehicle was used to traverse the selected roads and baobabs sighted on either side of the road occurring within 250 m distances were recorded and their position logged into a Garmin Geographical Positioning System (GPS) unit. Sighting distances of baobabs either side of the road were truncated at 250 m in order to increase the detectability of baobabs in the sampling widths.

The distances to the baobab tree from the road and the Mwenezi River were measured using a GPS unit. The circumference at breast height (1.3 m above the ground level) of each tree was measured using a 50 m tape measure. If the circumference could not be measured because of elephant damage, or because the trunk forked below

the breast height, the circumference was measured at ground level (Weyerhaeuser 1985). Height for each tree was estimated to the closest 1 m using a 12 m graduated pole and baobabs whose heights were more than 12 m, the heights were visually estimated. For the purposes of this study, mature (or old) baobab trees were generally considered to be those that had a width of at least 1.5 m, a height of at least 10 m, and a clearly developed crown (Rhodes 2009). Juvenile trees were classified as those trees that had not developed a crown and usually less than 3 m in height whereas any tree failing to meet one or more of these requirements was classified as a sub-adult. Elephant induced damage on baobabs was assessed using the following scale: 0 = no damage; 1 = slight damage with few scars; 2 = moderate damage with numerous scars; 3 = severe damage with the tree scarred deeply and 4 = dead tree.

Baobab numbers were converted into densities (baobabs ha<sup>-1</sup>), and basal circumference were converted to basal diameter at breast height. STATISTICA for Windows, version 6 was used for univariate analyses. Baobab data on all measured variables were tested for normality using the Kolmogorov-Smirnov test and was found to be normal. In order to compare mean baobab densities, mean diameter at breast height and height across the three land categories, Two-level Nested analysis of variance (ANOVA) with unequal sample sizes tests were performed. Significant effects were further analyzed using the Fisher's Least Significant Difference (LSD) post-hoc tests to detect differences between the three land categories.

A total of 117 baobabs were sampled using 17 transects with a combined length of 238 km in three land categories (Table 1). In general, more baobabs were recorded in the development areas, riverine and rocky outcrops along the Mwenezi River (Fig. 2). No dead or decomposing baobab trees were recorded in the present survey. Juvenile baobabs were only recorded in the development areas, riverine and rocky outcrops (Table 1). In contrast, several sub-adult and mature baobabs were recorded in the plains, riverine and rocky outcrops. Additionally, a higher proportion of baobabs damaged by elephants were recorded in the plains as compared to the development areas, riverine and rocky outcrops. Mean baobab density was significantly higher in the development areas compared to the plains, riverine and rocky outcrops (Two-level Nested ANOVA,  $F_{2,14} = 5.98$ ,  $P < 0.05$ ; Fisher's LSD post hoc test,  $P = 0.004$  and  $P =$

**Table 1.** Survey effort and baobab status in relation to land categories in southern Gonarezhou National Park, southeast Zimbabwe.

Land category	Development area	Riverine and rocky outcrops	Plains	Total
Survey effort and results				
Number of transects	2	6	9	17
Total transect length (km)	14	55	169	238
Number of baobabs	24	73	20	117
Population composition (%)				
Juvenile baobab	66.67	10.96	0	–
Sub-adult baobab	8.33	30.14	45	–
Old baobabs	25	58.90	55	–
Damage by elephants (%)				
Baobabs damaged by elephants	37.5	65.42	94.29	–

0.020 for plains, riverine and rocky outcrops respectively compared with the development areas). In contrast, there was, no significant difference between the plains and riverine and rocky outcrops (Fisher's LSD post hoc test,  $P = 0.309$ ). There were no significant differences in mean diameter at breast height (Two-level Nested ANOVA,  $F_{2,14} = 1.50$ ,  $P > 0.05$ ) and mean height (Two-level Nested ANOVA,  $F_{2,14} = 0.77$ ,  $P > 0.05$ ) across the three land categories in southern GNP (Table 2).

The results from the present study showed significantly higher densities of baobabs in the development areas compared to the plains, riverine and rocky outcrops in southern GNP. The low density of baobabs particularly in the plains in the GNP is attributed to high elephant utilisation. Elephants are the only herbivores that can kill adult baobabs, and are frequently linked to the reduction in baobab densities, for example, in Mana Pools National Park, Zimbabwe (Swanepoel 1993). Elsewhere, Barnes *et al.* (1994), in a ten-year study in Tanzania, found that baobab populations declined as elephant numbers increased and that the baobabs recovered when elephant populations declined due to poaching. Apart from the present study, data on baobab density appear to have been reported in a few previous studies. For example, Barnes (1980) reported a median density of 0.69 baobabs  $\text{ha}^{-1}$  varying from 0.03 to 7.23 baobabs  $\text{ha}^{-1}$  along fifteen transects from a total of 328 baobabs in Tanzania whereas Wilson (1988) reported an average density of 0.11 baobabs  $\text{ha}^{-1}$  for ten transects covering 260 km along roads with each transect being about 500 m wide in a study conducted in Sudan. More recently, Venter & Witkowski (2010) reported densities varying

from 0.83 to 2.16 baobabs  $\text{ha}^{-1}$  in four land types namely, plains, rocky outcrops, fields and villages in northern Venda, South Africa.

A higher recruitment of sub-adult baobabs was recorded in the development areas compared to plains, riverine and rocky outcrops in southern GNP. The unusually low number of juvenile baobabs recorded in the study area particularly in the plains in southern GNP points to possible limitations of adequately sampling baobab seedlings using driven transects as used in this present study. Elsewhere, Venter & Witkowski (2010) reported higher juvenile densities in the villages and fields compared to the plains and rocky outcrops in northern Venda, South Africa. Several authors consider elephants as being responsible for the lack of baobab recruitment through the destruction of seedlings (e.g. Weyerhaeuser 1985; Wilson 1988). However, other animals such as baboons *Papio ursinus* and monkeys *Chlorocebus pygerythrus* are known to pull baobab seedlings and eat the tuber that constitutes the roots (Wickens 1982). Similarly where baboons are prevalent, they are known to destroy the majority of baobab fruit and hence greatly reduce seed production (Venter & Witkowski 2011). In GNP, juvenile baobabs were mostly found in inaccessible areas and in areas with high human occupancy particularly in the development areas. For instance, the limited usage of the development areas by elephants probably as a result of the existence of fences and human presence could have facilitated the high recruitment. Other authors have attributed the lack of recruitment of baobab populations to the eruption of elephant populations, long-term changes in land use or climate (e.g. Wilson 1988).

**Table 2.** Attributes of baobabs for the entire transects across the three land categories in southern Gonarezhou National Park, Zimbabwe (mean  $\pm$  standard errors, SE) and significant levels from Two-level Nested ANOVA with unequal sample sizes tests. Significance = statistical significance ( $P$  value), NS = not significant ( $P > 0.05$ ), \* =  $P < 0.05$ .

Land category	Density (baobabs ha <sup>-1</sup> )	Diameter at breast height (m)	Height (m)
Development area	0.48 $\pm$ 0.16	2.50 $\pm$ 1.30	9.21 $\pm$ 4.99
Riverine and rocky outcrops	0.13 $\pm$ 0.05	3.31 $\pm$ 0.23	15.28 $\pm$ 1.49
Plains	0.02 $\pm$ 0.003	2.78 $\pm$ 0.36	15.64 $\pm$ 2.60
Significance	0.013*	0.256 <sup>NS</sup>	0.480 <sup>NS</sup>

It was evident from this study that baobabs occurring in all the three land categories were to some extent damaged by elephants in southern GNP. Baobabs in the development areas showed evidence of slight elephant damage and had few scars, whereas baobabs in the riverine and rocky outcrops were moderately damaged by elephants and had numerous scars. Lastly, baobabs in the plains showed signs of severe damage from elephants with most of the trees scarred deeply. However, there were no significant differences in mean diameter at breast height and mean height of baobabs across the three land categories. This may be attributed to possible little variation in the abiotic factors and similar climatic conditions in the study area. Additionally, the plains, riverine and rocky outcrops had a higher proportion of mature baobabs compared to the development areas. There have been suggestions that baobab populations are unaffected by elephants in certain areas because of difficult access. In the neighbouring Kruger National Park, South Africa, density and recruitment of baobabs in plains are lower than on rocky outcrops (Edkins *et al.* 2007). In Lake Manyara National Park, Tanzania, the baobab population of the southern parts is less heavily damaged than the north. The southern escarpment is steeper, which restricts elephant access (Weyerhaeuser 1985). Elephants have a major impact on baobabs and rocky outcrops are often inaccessible to elephants and, thus, act as refuge sites (Edkins *et al.* 2007). Hence, in southern GNP, the rocky outcrops and development areas are probably to some extent restricting elephants from utilizing the baobabs due to difficult access and presence of

fences and humans, respectively.

The influence of fire on baobab structure, abundance and distribution has not been ascertained in the present study as little evidence of past fires was observed during the field assessments. Any consideration of fires as a confounding factor is only speculative. However, some studies have highlighted the significant interaction between fire and herbivory as important factors in shaping savanna woodlands (Guy 1989; Van Langevelde *et al.* 2003). Earlier studies in GNP suggest that fire is an important factor in structuring the woodland communities in the park (Gandiwa & Kativu 2009; Tafangenyasha 2001). It is likely that the development areas are the least impacted by fire whereas the plains region are the most impacted. Additionally, it is likely that fire would have an intermediate impact on baobabs in the riverine and rocky outcrops in southern GNP. Furthermore, it is also possible that the low numbers of juvenile baobabs recorded in the southern GNP could be a result of fires killing baobab seedlings.

During the surveys, no dead or decomposing baobab trees were recorded. This does not however, suggest that baobabs have not died within the park. Earlier studies show that baobab mortality is strongly linked to elephant numbers, and that drought causes episodic baobab mortality (Guy 1970; Whyte *et al.* 1996). It is unlikely that baobabs will ever become locally extinct in southern GNP due to elephants and fire because there are a number of trees growing in rocky outcrops and development areas, which may act as refugia. Because of the difficulty in identifying seedlings particularly when using driven transects, we cannot be conclusive about their actual abundance, distribution and the impact that elephants and fire may have on these in the southern GNP. Hence, caution should be taken in use of particularly the juvenile baobab abundance data in making management decisions for the park. Additionally, since the available roads in the southern GNP do not cover the entire park, it is likely that some baobabs, particularly, in the plains may have been missed during this study. Finally, the impact of elephants on baobabs may be confounded by interactions with drought, other herbivores, soil type and fire. Future studies should, therefore, focus on baobab, soil type, fire and elephant interactions in the entire GNP to allow for deeper understanding of the ecology of baobabs in the GNP.

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