Forest Ecology and Management 303 (2013) 113–120

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Using a deterministic population model to evaluate population stability and the effects of fruit harvesting and livestock on baobab (*Adansonia digitata* L.) populations in five land-use types

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ARTICLE INFO

Article history:
Received 12 December 2012
Received in revised form 17 February 2013
Accepted 9 April 2013
Available online 11 May 2013

Keywords:
Baboons
Climate change
Recruitment
Rainfall
Seedling protection
Tolerance level

ABSTRACT

The subsistence and commercial use of baobab (*Adansonia digitata*) fruit is important to many thousands of marginalized people in the arid tropics of Africa, yet sustainable harvest levels have not previously been studied. Size-class distributions of baobab populations tend to be stable, suggesting high tolerance to fruit harvesting. However, environmental conditions have changed substantially over the last 100 years. Increasing livestock numbers, land modification and climate change are new threats which may affect tolerance to fruit harvesting. To investigate this, a deterministic stage-based population projection matrix model was developed using (a) long term baobab monitoring data from 2 sites, (b) radiocarbon age calculations, (c) extensive field surveys of population structure and fruit (and seed) production, and (d) experimental field trials on seed banks and seedling and sapling survival in relation to the presence of livestock. Projected population growth (λ) was then evaluated for five land-use types (nature reserves, rocky outcrops, plains, fields, and villages) under three levels of livestock (none, moderate and high stocking rates). Response to fruit harvest intensity was tested for each scenario by decreasing seed availability by 10% from 100%. High livestock numbers resulted in baobab population declines, with $\lambda < 1$ in all land-use types. Under moderate and zero livestock numbers, baobab populations in plains, rocky outcrops, villages and fields were able to tolerate between 33% and 90% fruit harvest rates. In nature reserves there was already high predation on immature fruit by baboons, another cause of population decline, with the model showing no tolerance whatsoever to fruit harvesting. These results show that fruit harvesting can be sustainable in production landscapes under moderate livestock levels. However the future is uncertain, as a predicted lowering of rainfall due to climate change is a further concern, with likely negative impacts on fruit yields and recruitment and consequently population projections. Thus active planting and protection of seedlings should take place to mitigate current and future negative impacts facing baobab populations.

1. Introduction

Sustainable utilization means, essentially, that take-off rates should not damage the productive potential of the resource, and that harvesting can be maintained indefinitely (Carter, 1996). The term ‘ecological tolerance’ is used to describe the degree to which plant populations can recover from harvesting (Ticktin, 2004). Many studies have found that the utilization of NTFPs (non-timber forestry products) is unsustainable at current levels of harvest (Hall and Bawa, 1993; Peters, 1996). However, the harvesting of fruit and seed has the least impact on population structure with high degrees of tolerance, except for non-sprouting species. For long-lived tree species, extraction rates of between 86% and 92% are commonly calculated (Bernal, 1998; Zuidema and Boot, 2002; Emanuel et al., 2005). High tolerance levels are attributed to four factors: fruit harvesting does not damage the plant itself; adult trees have high survival potential; recruitment is continuous, even if episodic; and trees are long-lived with extensive reproductive periods.

Baobab fruit are being wild-harvested for commercial and subsistence use in many parts of Africa, and this has become very important to the livelihoods of thousands of marginalized people (Buchmann et al., 2010; Venter and Witkowski, 2013a). Recently the global demand for baobab fruit derivatives, namely fruit powder and seed oil, has grown substantially with exports to Europe, Asia and North America. This has made significant contributions to alleviating poverty and yet sustainable harvest levels have not been evaluated (Gruenwald and Galizia, 2005; Venter and

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http://dx.doi.org/10.1016/j.foreco.2013.04.013

Witkowski, 2013a). Due to the long history of human use of baobab fruit, its importance as a subsistence product and the stability of baobab populations, the impact of fruit harvesting has seldom been of concern (Wickens, 1982; Venter and Witkowski, 2010). However, recent changes in the environment, such as land cover and land use changes (Coetzer et al., 2010), increasing livestock numbers and climate change have raised the alarm about the future of baobab populations (Dhillion and Gustad, 2004; Cuni Sanchez et al., 2011; Venter and Witkowski, 2013b).

In many parts of Africa poor baobab recruitment is associated with high livestock numbers (Dhillion and Gustad, 2004; Chirwa et al., 2006). Venter and Witkowski (2013b) found that consumption and trampling by livestock resulted in up to 87% sapling mortality. Poor rainfall and drought are also known to severely reduce recruitment and can lead to adult tree death (Gijsbers et al., 1994; Caplan, 1995; Maranz, 2009; Venter and Witkowski, 2013b). A loss of up to 85% of fruit has been found in areas where baboons predate immature fruit and this, too, may contribute to poor recruitment in some land-use types (Venter and Witkowski, 2011, 2013b). Furthermore, climate change predictions suggest that current suitable habitat for baobab populations in Africa could be reduced by up to an alarming 95% (Cuni Sanchez et al., 2011). In light of these threats, there is clearly a need to re-assess the state of baobab populations and to evaluate the impact that baobab fruit harvesting will have on these populations in the future.

Population projection matrix models can be used to understand plant population dynamics, the importance of different life history processes and to answer 'what if' questions within different scenarios (Desmet et al., 1996; Drechsler et al., 1999; Caswell, 2001). They can be used to assess the impact of different levels of harvesting and determine the maximum harvest intensity that a population can tolerate (Bernal, 1998; Emanuel et al., 2005). The advantage of such models is that they have a standardized form, relatively low data requirements and can quantitatively predict the direction of population change in response to changes in fecundity, growth and survival (Desmet et al., 1996; Caswell, 2001).

A study aimed at assessing the sustainability of baobab fruit harvesting was initiated in 2006. This study evaluated population size, fruit production, phenology, recruitment and socio-economic

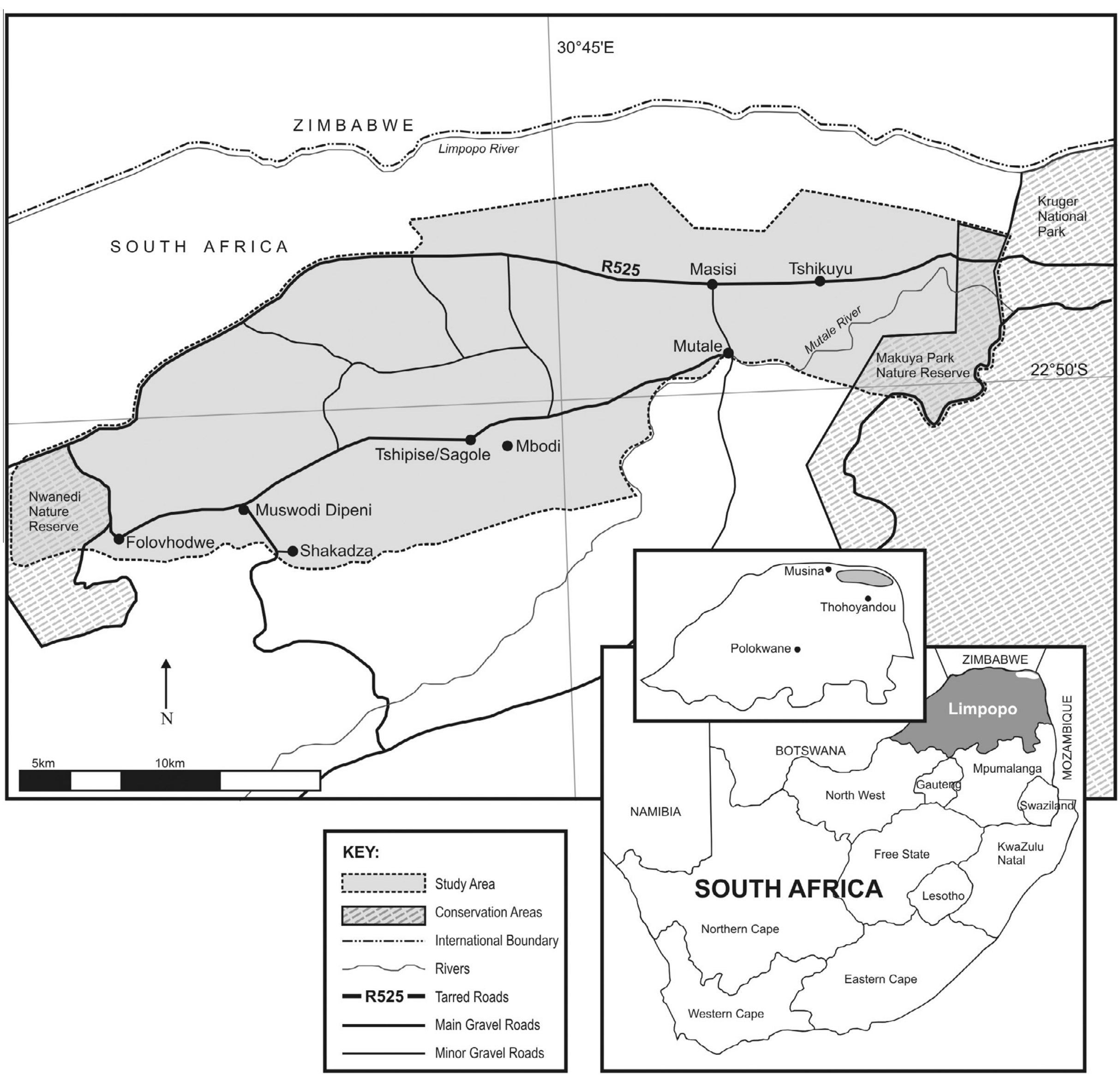

Fig. 1. Map indicating location of study area in Limpopo Province, South Africa.