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Emerging issues and challenges associated with conservation of the African baobab (*Adansonia digitata* L.) in the semi-arid areas of Tanzania

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Abstract

The aim of this review is to discuss the emerging issues and challenges in baobab conservation based on the climate change, emerging challenges related to herbivory and human use such as emerging of new markets for baobab products and land use changes.Specifically, the review summarizes scientific questions and challenges for the conservation of one of the most important indigenous fruit tree species, *Adansonia digitata* in Sub-Saharan Africa. It highlights on new information on the status of *A. digitata* in Tanzania with a strong focus on ethno-botanical issues, traditional and modern uses as well as challenges for the management and conservation of the tree species.We have done that by using facts from different parts of the geographical ranges of Africa and other parts of the world. The review is based on the belief that understanding the factors underpinning the use and management of *A. digitata* is an essential step towards development of credible strategies and plans that would advance and lead to sustainable management of baobabs.

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Introduction

Baobab (*Adansonia digitata* L.) is a flamboyant tree plant that often grows in areas of human habitation in semi-arid regions of Africa. Despite the high economic and nutritional importance of *A. digitata* to rural residential communities (Sidibe and Williams, 2002; Aluko *et al.,* 2016), its conservation is challenging. Having various uses and being of high commercial value, *A. digitata* has been well-known as one of the supreme essential trees in the world and hence, there is a need for sustainable utilization and its conservation.

Increases in harvesting, processing and exporting of *A. digitata seed* oil and fruit pulp (Plate 1) is likely to cause unsustainable use of the *A. digitata* tree (Sidibe and Williams, 2002), and this pressure makes conservation initiatives critical to ensure species' survival (Sanchez *et al.,* 2010; De Smedt *et al.,* 2011). To date, most studies have focused on the agronomical, botanical and biochemical characteristics of *A. Digitata* (Gebauer *et al.,* 2002; Kamatou *et al.,* 2011; Parkouda *et al.,* 2012) and few studies have investigated the population abundance and potential future distribution (Mpofu *et al.,* 2012; Kupika *et al.,* 2014).

The declining baobab populations, caused by changes in both climate and land use, have significantly negative effects on the survival of the species as well as the livelihoods of African communities. Therefore, it is vital to understand the baobab's current population abundance and challenges associated with its conservation in order to develop future strategies for the conservation. Proper ecosystem management and sustainable use requires a full understanding of the tree's species population status across its geographic range (Zhang *et al.,* 2015) as well as the development of suitable conservation measures.

For many centuries, baobab trees have been felled, or parts of trees such as barks have been harvested to provide food, medicine and raw materials for making ropes, baskets, tools and handicrafts (North *et al.,* 2014). High demand for baobab tree-based products has led to overharvesting, especially in unprotected areas of Tanzania. Despite the higher economic opportunities offered by the high demand and value of the baobabs and challenges arising from its occurrence, there has been little effort to geographically characterise its population or ethno-botanical importance across different land uses or ethnic groups. The challenges discussed in this review have been organized in 3 sections namely: (1) Emerging challenges related to the environment such as land use change and the decline in baobab populations and the influence of climate change on baobab species; (2) Challenges related to herbivory: Baobab - elephant interactions; and (3) Emerging challenges related to man.

This includes challenges related to new markets for baobab products, traditional medicinal use of *A. digitata*, the use of baobab products and the commercial value of baobab. All this aims at developing sustainable management strategies for the baobabs. In so doing, we will draw on examples from different countries in the semi-arid regions of Africa, where most baobab trees grow.

This review is motivated by the premise that acquiring a better understanding of the issues and challenges underpinning the current status of *A. digitata* is a key step towards developing credible strategies and plans for the sustainable utilisation, effective management and conservation of baobabs. Importantly, this review offers options for key measures that can be taken to improve baobab conservation and management.

Materials and methods

Study area description

This review covered the semi-arid areas of Tanzania located in Latitude: 2°39' 5.225" S, Longitude: 34°8' 29.364" E and Latitude: 8°2'53.048' S, Longitude: 35°3' 18.731"E (Fig. 1). In this review, we summarized scientific questions and challenges for the conservation of one of the most important indigenous fruit tree species in Sub-Saharan Africa by drawing experience from different parts of geographical ranges of Africa.

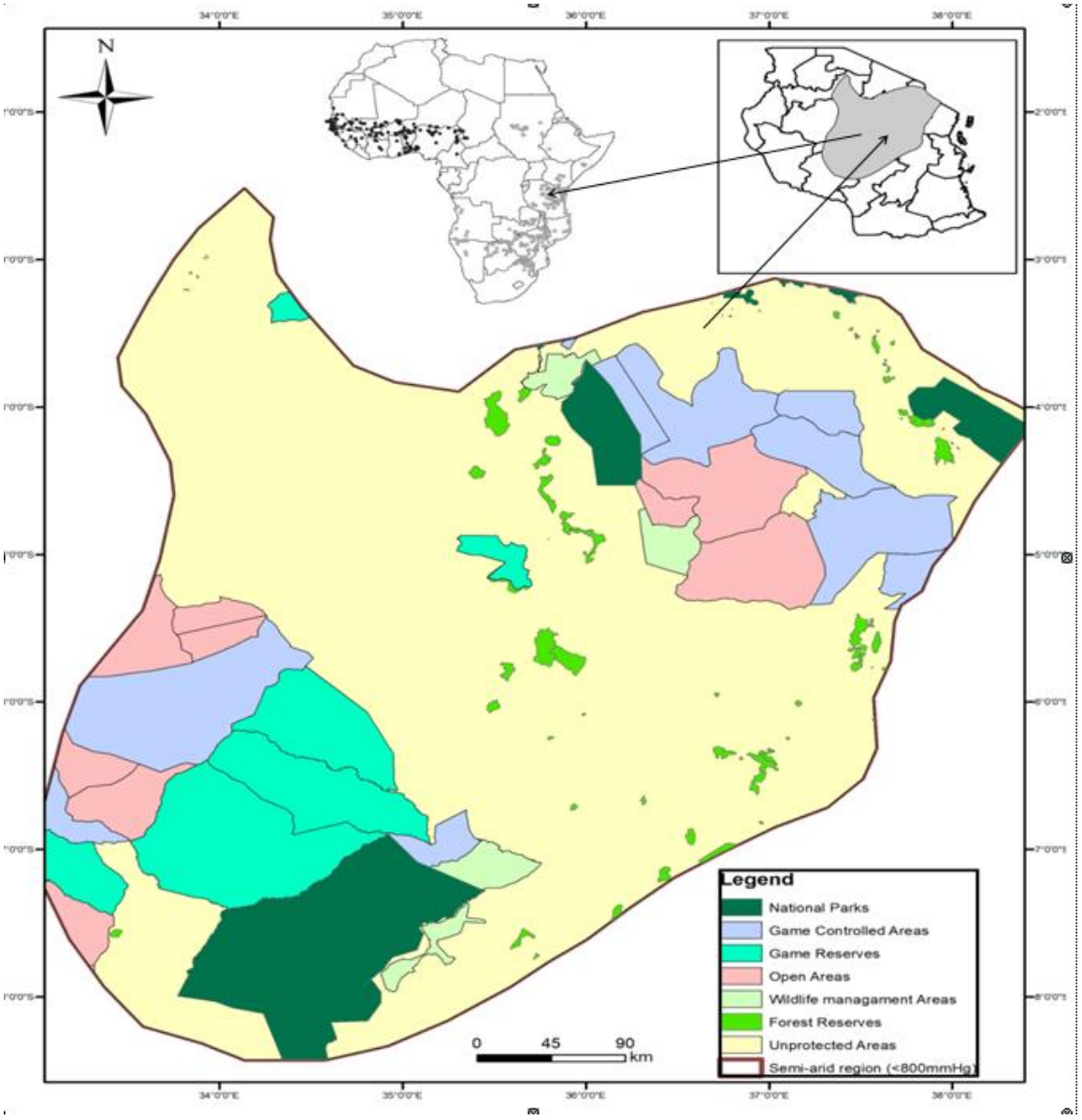

Fig. 1. Distribution map of baobab in Africa. Black dots: West Africa records, grey dots: East Africa records (Source: Sanchez *et al.*, 2011). Inset: Location of semi-arid region within Tanzania.

Data collection

This study was carried out using a variety of bibliographic database to search for relevant articles and published reports. Quantitative and qualitative methods were used to obtain information on emerging issues associated with conservation of the *A. digitata* in the Semi-arid areas of Tanzania. The search of titles and abstracts, and then full articles were examined and retained if the contents were relevant. We conducted a review of existing literature from peer-reviewed journal articles, books, edited book chapters, electronic academic theses, technical reports from Google Scholar, Scopus and Web of Science covering issues on the importance of baobab as beneficial and valued tree crop, its distribution and associated uses, emerging issues and challenges related with baobab conservation. We also focused on the influence of climate change and land use change on baobab, challenges associated with herbivory by elephant and use of baobab products by human. Finally, we proposed conservation strategies and sustainable utilization of baobab in Tanzania. Facts were also obtained from unpublished internal scientific reports and management plans from Tanzania and external reports from policy documents related to baobab, conservation, ethno-botany and

sustainable utilisation in Tanzania. Technical reports and public publications from key stakeholders, such as the International Centre for Underutilized Crops (ICUC), Food and Drug Authority of Tanzania and BAOFRUIT were also reviewed. The following keywords or phrases were used: "baobab", "biology of baobab", "baobab populations", "traditional medicinal use of *A. digitata"*, "baobab ethno-botany", "use of baobab products", "baobab distribution", "sustainable utilisation", "markets for baobab products", "commercial value of baobab", "baobab elephant interactions", "herbivory", "land use changes and the decline in baobabs", "climate change and baobabs", "baobab conservation", "conservation strategies", "sustainable utilization of baobabs" with a combination of "AND" between the keywords to retrieve the relevant literature. Literature obtained from all the documents were categorized under the following themes: (1) Distribution and associated uses (3) Emerging issues and challenges associated with baobab conservation, (4) The emergence of new markets for baobab products, (5) Emerging challenges related to the environment, (6)Land use change and the decline in baobab populations Traditional medicinal use of *A. digitata,* (7) Challenges associated with the use of baobab products, (8) The commercial value of baobab, (9) Emerging challenges related to herbivory: Baobab - elephant interactions, (10) The influence of climate change on baobab species, (12) Conservation strategies and sustainable utilization of baobab.

A total of 147 scientific articles and review papers, 15 books, book sections, reports were revised in developing this review.

Data analysis

Data were analysed qualitatively and presented in the results and discussion section. The emerging issues and challenges associated with conservation of *A. digitata* in the Semi-arid areas of Tanzania were organised in three sub-headings: 1) emerging challenges related to the environment, 2) emerging challenges related to herbivoryand 3) emerging challenges related to human activities.

Results and discussion

Emerging issues and challenges associated with baobab conservation

Deforestation especially clearance of woodlands is a growing trend in virtually all savannah ecosystems. It has been reported that losses of natural vegetation and the related changes in the environment have been more alarming in the past 50 years than ever before in human history and many plant populations have declined in numbers, geographical distribution, or both (Ruddiman, 2003.). MEA (2005) reveals further that the recent decline in biodiversity are the outcomes of human actions and activities that have increased the extinction rate more than the natural rate. Reduced seedling survival resulting mainly from browsing by herbivores, felling by humans and climate changes has been reported to hinder baobab recruitment (Munyebvu, 2015). *A. digitata* like other tree species is vulnerable to overexploitation of baobab fruits resulting from man-made, animal and environmental emerging challenges as discussed in this review.

Emerging challenges related to the environment

The influence of climate change and variability on baobab populations

Climate change and variability has been reported to be a major threat to the forestry resources including Non-timber Forest Products (Msalilwa *et al.,* 2013). Variations of annual rainfall and temperature affect the growth and development of forestry resources, which lead to change in its abundance and distribution (Amissah *et al.,* 2015). It has been predicted that Africa is likely to experience marked climatic changes and variability with the drying and warming in the sub-tropical regions and small increases in precipitation in the tropics (Hulme *et al.,* 2001; Boko *et al.,* 2007). Climate change related events such as drought have affected ecosystems and people (Boko *et al.,* 2007; Msalilwa *et al.,* 2013). In recent years, African continent has been reported to be highly exposed to the predicted climate changes due to weak adaptive ability and interactions of additional confounding challenges to climate change such as temperature and rainfall.

Temperature influences the plant growth, abundance and distribution of a number of several species. Plant growth may be affected indirectly by changes in temperature due to its effects in increasing the occurrence of plant diseases, other pests and the influence on photosynthetic processes. Table 1 shows the projected impact of climate change on plant species. Pollination is one of the most sensitive phenological stages to temperature extremes across all species and during this developmental stage, temperature extremes greatly affect production. Every plant species has a specific temperature range represented by a minimum, maximum and optimum for the plant growth and development. For example, the optimal growth day temperature for baobabs ranges between 19°C and 35°C (Orwa *et al.,* 2009). It is predicted by the Intergovernmental Panel Climate Change (IPCC) (2007) that the expected changes in temperature for the next 30-50 years will range of 2-3°C. A study by Doughty & Goulden (2008) found that in short-term, leaf-level measurements of carbon assimilation in a number of tropical forest regions showed that net carbon assimilation declined with an increase in daytime temperatures.

In many countries where seasonal variability in temperature is large compared with daily variation, an increase in temperature may affect the distribution of a limited number of species (Lewis and King, 2014; Vasseur *et al.,* 2014). However, in areas with larger temperature variation, increases in temperature are likely to shift the distribution of plant species (Toledo *et al.,* 2012; Amissah *et al.,* 2015). Therefore, there is a need to conduct studies on the effect of the temperature on baobabs so as to develop appropriate recommendations for the conservation of this important tree species.

The amount and regularity of rainfall affect the occurrence of the certain plant species as well as their growth and development. Rainfall in form of water is one of the components of the photosynthesis and it affects plant growth of several plant species. The less the amount of water the less the photosynthetic process, hence low plant growth. The suitable average annual rainfall that baobab can grow better is between 300 and 500 mm (Orwa *et al.,* 2009) although the African baobab may still survive between the average annual rainfall condition ranging from 90-1500 mm (Orwa *et al.,* 2009; Bosch *et al.,* 2004).

A study by Msalilwa *et al.* (2019) revealed that baobab populations are more strongly influenced by rainfall than by temperature. Furthermore, regardless of the land use, the annual rain is the main factor that determines baobab distribution in semi-arid areas of Tanzania (Msalilwa *et al.,* 2019). However, research evidence suggests that due to climate change and variability, unpredicted higher rainfall associated with floodshas been reported in various parts including the semi-arid areas (Kupika *et al.*,2014; Thornton *et al.,* 2014) where baobab is grown. Generally, baobab cannot withstand seasonal flooding or severe waterlogging as such events may kill even the mature trees (Bosch *et al.*, 2004; *Heuzé et al., 2016)*and result in the decline in baobab population.

Climate change could have negative effect on baobab productivity hence negative effect to people's livelihoods (Cuni Sanchez *et al.,* 2010). A study by Cuni Sanchez *et al. (*2010) predicted that there will be no areas in Namibia suitable for baobab growth in future due to effects of climate change caused by change in land use and global warming.

It has been further reported that the baobab populations are threatened by climate change and indicated that better conservation strategies are needed (Wickens and Lowe, 2008). A study by Bomhard *et al. (*2005) addressed the potential consequences of the future climate changes on plant biodiversity and suggested the mitigation of appropriate management strategies.

Among the most vulnerable species to reductions in suitable habitat are those with delayed maturation and reduced ability to recover from population reductions, difficult to inhabit new suitable areas and/or those that are already under human pressure (Araujo *et al.,* 2006). The baobab tree meets all the

suggested criteria including its long life-span (Patrut *et al.,* 2007), it is naturally dispersed by animals and it is under considerable threat from human use. In view of current global trends related to climate change, there is a need for assessing the climatic factors that control the population dynamics and its uses in order to recommend sustainable management practices for future conservation of the species.

Table 1. Projected impact of climate change and variability on plant species.

Projected impacts	Model	Source
About 50,000 African plant species impacted: substantial reductions in areas of suitable climate for 81 - 97% of the 5,197 African plants examined, 25 - 42% lose all area by 2085	Africa Hadley Centre Third Generation Coupled GCM (HadCM3) for years 2025, 2055, 2085, plus other models - shifts in climate suitability examined	1PCC, 2014
Future distribution in 2050 of 975 endemic plant species in Southern Africa distributed among seven life forms endemic flora of Southern Africa on average decreases with 41% in species richness among habitats and with 39% on species distribution range for the most optimistic scenario	SDMs were fitted to climatic data using the BIOMOD package in SPLUS	Gandiwa, 2011
Fynbos and succulent Karoo biomes: losses of between 51 and 61%	Africa for years 2025, 2055, 2085, plus other models - shifts in climate suitability examined	Tafangenyasha, 1997
Projected losses by 2050, critically endangered taxa (e.g. Proteaceae) in South Africa: losses increase, and up to 2% of the 227 taxa become extinct increase, and up to 2% of the 227 taxa become extinct	(HadCM2 IS92aGGa)	IPCC, 2014

Source: Adopted from IPCC, 2014.

Table 2. Traditional medicinal uses of *A. digitata*in different types of aliments.

Aliments	Parts	Preparation	References
Diarrhoea, fever, inflammation, kidney and bladder diseases, blood clearing, asthma	Leaves	Decoction, infusion	(Brendler, Gruenwald, and Jaenicke, 2003)
Malaria, fever	Leaves	Mixed with water	(Watt and Breyer-Brandwijk, 1962)
Toothache, gingivitis	Leaves	Decoction	(Tapsoba and Deschamps, 2006)
Diaphoretic, fever remedy	Leaves	Decoction	(Abbiw, 1990)
Diaphoretic, kidney and bladder diseases, asthma, insect bites	Leaves	Decoction	(Wickens, 1982)
Fever, diarrhoea	Seeds	Mixed with water	(Watt and Breyer-Brandwijk, 1962)
Anaemia	Bark	Aqueous extract	Adesanya*et al.*1988
Coughs	Powdered seeds	Decoction	(Watt and Breyer-Brandwijk, 1962)
Wound healing	Stem bark	Decoction	(Baillon, 1876)

Land use change and the decline in baobab populations

In Africa, baobab is found in all land usesincluding protected and unprotected areas. It has been reported that the survivor and presence of the baobab populations depends on the land uses in specific area. Anthropogenic activities for example deforestation, agricultural activities, harvesting of some Non-timber Forest Products have an effect on land cover changes as well as land use. Land-use intensification has been predicted to cause more pressure on baobabs (Wilson, 1998; Schumanna *et al.,* 2010; Schumanna *et al.,* 2012). A study by Schumanna *et al. (*2010) found that land use type had a significant impact on the populations of the baobabs between protected area and the unprotected communal area. Human activities on land affect land and natural resources due to population growth and food requirement. Transformation of wild lands into agriculture lands, settlements and other uses due to the human

population growth results into competition of land. These activities result into pressure on other land resources including baobab populations. It has been shown that not only land use type impact the population structure of the baobab but also human activities through socio-cultural and economic uses of the tree impact the population (Wilson, 1988; Schumann *et al.,* 2012).

The semi-arid areas of Africa face intractable challenges related to practical pathways to social and environmental sustainability in rangelands. The rangelands makeup ~90% of habitat for the species and the rangeland area is currently undergoing a seismic change in scientific understanding of their dynamics, and shifts from communal to private tenure, coupled with the effects of climate change. Therefore, studying the population composition and dynamics of the baobabs across different land use types, is necessary to understanding the factors that shape the population structure on which the tree conservation strategies can be modelled.

Raising the status of land use to a more strictly protected area (i.e., National Park and forest reserve) may save the baobab populations from unsustainable utilization and hence stable population. A stable population is the one showing an inverse '*J*-shape' diameter distribution. This indicates good recruitment or increase in population i.e. higher numbers of seedlings and juveniles compared to the adults while its opposite is true for the *J*-shape' diameter distribution. Though, for the long-lived species, like the baobab, may show a bell-shaped distribution, *i.e.* a large number of trees in the middle size classes (Venter and Witkowski, 2010).

The bell-shaped distribution is considered to be normal for baobab (Venter and Witkowski, 2010). In Schumanna *et al.* (2010) studythey observed an inverse '*J*-shape' for the park stands while the curve of unprotected area stands was bell-shaped, suggesting lack of recruitment. Baobabs need to be protected against animals, especially during the juvenile stage (ICUC, 2006). Thus, there is an urgent need to conduct studies across land use to compare stands of baobab populations in the protected areas against those in the surrounding communal areas to determine its effects on the populations of the baobab.

Emerging challenges related to herbivory: Baobab - elephant interactions

Elephants have been known to destroy baobab trees leading to the death and reduction in densities (Edkins *et al.,* 2008; Mpofu *et al.,* 2012). *A. digitata* is broadly prone to elephant destruction (Owen-Smith, 1988). It has been observed that elephants frequently kill baobab trees through debarking the stem and then make deep holes into the trunk (Weyerhaeuser, 1985; Swanepoel, 1993). Lisao *et al. (*2018) observed that elephant destruction accounted for about 41% of the damaged baobab stems. Furthermore, Barnes (1980) reported that baobab abundances decline as the elephant densities increase and the species recover when elephant densities decline due to illegal killing. Moreover, a study by Edkins *et al. (*2008) concludes that the impact of the increase of elephants on baobabs is confounded by other interventions such as drought, impacts of other herbivores and fire (Plate 2C). Extensive destruction to baobabs (Plate 2A) may indicate that elephant population, regardless of its absolute density, has reached a level at which it has already initiated major vegetation changes (Swanepoel and Swanepoel, 1986). The incomparable lifespan of the baobab means any short-term alteration in mortality resulting from elephant attack may have long-term consequences (Weyerhaeuser, 1985). While recent studies (Gandiwa *et al.,* 2011; Kupika *et al.,* 2014) have reported elephant impacts on baobab, no studies have assessed the impact of elephant activities on baobab population structure, recruitment and associated elephant damage in semi-arid regions of Tanzania.

Several studies (e.g., Bond and Keeley, 2005; Mapaure and Campbell, 2002; Sankaran *et al.,* 2008; Gandiwa *et al.,* 2011) have confirmed that elephants play an important role in vegetation changes in African savannahs and elsewhere. For example, elephants cause a direct impact on natural vegetation by feeding on trees, pushing stems over, snapping and

debarking (Barnes, 1980; Swanepoel and Swanepoel, 1986; O'Connor *et al.,* 2007; Shannon *et al.,* 2008; Boundja *et al.,* 2010). The pattern of elephant effects on baobabs has been reported to be unpredictable especially on small trees (Swanepoel, 1993; Weyerhaeuser, 1985; Barnes *et al.,* 1994). Scholars (Swanepoel, 1993; Barnes *et al.,* 1994; Wilson, 1998) have documented the distribution and population structure of *A. Digitata* whichis determined by the elephant population. As Swanepoel (1993) notes, the impact of elephant activities on large trees such as baobabs is of concern since the trees are conspicuous and are aesthetically appealing. Baobab densities have declined in numbers within the protected areas, while some mature individual trees preferred by elephants have remained intact in human dominated areas (Guy, 1982; Mpofu *et al.,* 2012).

In protected areas, elephants utilize baobab, especially in times of resource inadequacy (Owen-Smith, 1988; O'Connor *et al.,* 2007; Hayward and Zawadzka, 2010; Biru and Bekele, 2012). A study by Barnes *et al. (*1994) found that baobab densities declined due to elephant browsing in Ruaha National Park. Baobab trees were also slightly affected for the same reasons in Lake Manyara in 1969 and 1981 (Owen-Smith, 1988). During this period, only 13% of the trees remained undamaged, but the annual tree mortality stood at 1% per annum (Owen-Smith, 1988). There is a need to conduct a study on the impact of elephants on baobab population structure in protected areas.

Plate 1. Processed baobab products in Central Tanzania: (A) Baobab powder extracted from fruit pulp, (B) Baobab oil extracted from seed.

Emerging challenges related to human activities

Impact of fire on baobab populations

In ecological terms, fire acts as a huge herbivore consuming biomass and affecting the world's biome distribution. Forest fires are considered to be a potential hazard with physical, biological, ecological and environmental consequences (Jaiswal *et al.,* 2002). The impact of fire on the environment and biota depends on the timing, behaviour, intensity and frequency of occurrence. Regarding the timing, if wild fire is set during the dry seasons, its intensity and behaviour will be higher which may have more negative effects on plant species including baobabs. A study by Mpofu (2012) reveals that wild fire is among the other factors that potentially destroy the juvenile and seedlings before recruiting to the large trees. Fire recurrence shapes the composition and distribution of ecosystems in the world (Bond *et al.,* 2005) and this may have a serious impact on baobab population. Fires enter forests through human activities. These may be purposeful or accidental fires (Carment *et al.,* 2011). For instance, the indigenous communities may set fire to aid in the collection of honey (Narendran *et al.,* 2001; Saha, 2002) and, hence, causing negative impact to the baobab and other plant populations. This is due to the fact that Baobab trees support the production of the honey in trunk holes (Rashford, 2015; Ribeiro *et al.,* 2019) and baobab branches are also good in supporting the bee hives (Ribeiro *et al.,* 2019). In view of the above, it is important to manage fire incidences in protected and unprotected areas in semi-arid areas where baobabis grown.

The emergence of new markets for baobab products

A. digitata grows naturally throughout the semi-arid regions of Africa (IFAD, 2011) and forms a significant source of livelihoods during drought (Duvall, 2007; Adam *et al.,* 2012). Its nutrient-rich fruit has the likelihood of playing a significant role in household diet and food safety in relegated marginalized communities (Jamnadass *et al.,* 2011). It has been established that the fruit pulp contains high quantities of essential minerals and vitamin C (Stadlmayr *et al.,* 2013) and antioxidant functions (Gebauer *et al.,* 2002).

In addition, local communities have been making sweets, juice and snacks from baobab fruit pulps (Gebauer *et al.,* 2013). However, the key questions here are how do different ethnic groups perceive baobab and put its products to use, and how does this influence the uptake and promotion of the plant as a food crop to unleash the potential of mitigating food and nutritional insecurity in these communities? Baobab also has a variety of other uses including the production of traditional medicine and raw materials for making ropes, baskets, tools and handicrafts (Wickens and Lowe, 2008; North *et al.,* 2014). Recently, the pulp form baobab fruit has been recognized as an exceptional food component in Europe and in the US markets (FDA, 2009; North *et al.,* 2014). This is likely to lead to a momentous growth of the demand and the establishment of a vital condition for market availability thus increasing the possibility of its market. The realization that baobab has an extraordinary potential economic value may provide an inducement to local populations to manage, plant and conserve the baobabs and hence sustain their livelihood. Nevertheless, constraints against the full utilization of the economic potential of baobab products have been identified; and these include: lack of knowledge on sustainable resource management techniques, poor fruit processing technologies, limited availability of planting material and lack of well-organized market chains (Wickens and Lowe, 2008).

The existing role of products from baobabs to food safety, local diets and income generation need to be examined further in Tanzania. Also, the marketing pathways and market value chains for baobab products are poorly developed and the species are largely abandoned by research, extension agents and institutions. Information on baobab products and markets and utilization has not been comprehensively disseminated. Therefore, research on baobab marketing is essential at local and international scale.

Traditional medicinal use of A. digitata

A. digitata is an important tree which is accredited in Africa for its medicinal value (Table 2). Several authors (e.g., Gruenwald and Galiza 2005; De Smedt *et al.,* 2011) have reported on the traditional medicinal use of the baobab plant parts. The products extracted from baobabs are used to treat various diseases such as diarrhoea, malariaand microbial contaminations (Gruenwald and Galiza 2005; Kamatou *et al.,* 2011). Moreover, bioactivity investigations on baobab have shown different beneficial effects, such as anti-oxidant and anti-inflammatory properties, prebiotic, analgesic, antipyretic, anti-diarrhoea and ant-dysentery properties and excipient (Milza, 2002). Despite all the reports regarding the extensive uses of baobabs in traditional medicinesince the ancient times (De Caluwé *et al.,* 2010), ethno-medicinal uses of different parts of baobab tree among ethnic groups in semi-arid zones of Tanzania are still limited.

For the past decade, the baobab tree has attracted the curiosity of a number of scientists and pharmaceutical corporations due to its numerous medicinal uses (Adesanya *et al.,* 1988; Sidibe and Williams, 2002; Wickens and Lowe, 2008; Kaboré *et al.,* 2011). These properties have made the products of baobab tree to have wide application in both traditional and modern medicines. Interestingly, the tree is valued among many indigenous communities; and some even consider the tree as delightful (Wickens and Lowe, 2008). There is potential for promotion as cash crop and hence expand its distribution in the semi-arid areas. Further studies are necessary to investigate the medicinal values of different baobab products.

Challenges associated with destructive harvesting methods of baobab

Baobab tree parts (roots bark and leave) have been harvested for different uses. Root harvesting for the medicinal uses is detrimental to the baobab tree as may result into killing of the tree hence reducing their population. Baobab barks are harvested for many uses including: making brooms, ropes, threads and baskets. Intensive bark harvesting is detrimental to the baobab heath and survival. Leaves are harvested for food and medicinal purposes. Intensive leave harvesting may result into plant damage which affects the growth and survival of the baobab tree.

Plate 2. Severely elephant damaged baobab trunk in Ruaha National Park, Tanzania (A), harvested baobab fruits in Central Tanzania (B) and felling of baobab trees and use of fire to create a farmland (C).

Destructive harvesting methods are detrimental to the tree hence reducing the baobab population. Currently, local communities use traditional harvesting techniques of baobab fruit including shaking the branches and knocking the fruits using sticks, which frequently result in substantial losses. An increase of baobab ingredients both in food and *phamathetical* industries has caused local community harvest all fruits leaving nothing in the field (Plate 2B). This may result in unstable populations in the future. Moreover, cultural practices including debarking and root harvesting for various uses may have an impact on the tree growth and survival. There is a need to conduct a thorough investigation on the impact of the cultural practices on the sustainability of the baobab in the semi-arid regions of Tanzania.

Conservation strategies and sustainable utilization of baobab

The higher demand for baobab tree-based products will probably lead to overharvesting of baobab products in all land uses. Gruenwald and Galizia (2005) projected a global growth in the demand of baobab products. Appropriate management of the resources is therefore vital to avoid over-exploitation resulting from the global increase in the demand of baobab products.

Therefore, conservation action of baobab is urgently needed since only a limited part of the current range of the baobab tree would retain suitable habitable conditions for viable populations of baobab in the future. Different conservation strategies could be implemented to preserve the baobab tree and, maintain not only the diet, pharmaceutical and income resources of many local people but also the ecosystem where the baobab tree thrives. There is a need to implement diverse conservation programmes including *in situ* conservation in protected areas; *ex-situ* conservation in the seed banks and conservation through sustainable use. For example, establishment of protected areas has been suggested to be an important strategy which is often considered in conservation (Sanchez *et al.,* 2011). Moreover, current levels of protection within a protected area might not seem to be enough for the baobab tree. Elephants have been reported to kill both adults and seedlings in the protected areas (Barnes and Kapela, 1994; Edkins *et al.,* 2008), and the protection of baobab trees from elephant destruction is very uncertain (Barnes 1994).

Baobab seedlings could be protected from other herbivores through fencing and/or through planting. Baobab fruit and bark harvesting in different protected areas is another problem which has remained remarkably high (Schumann *et al.,* 2010). In areas where the baobab tree is extensively used by local people living around the protected area, the baobab utilization could be limited to fruit harvesting.

Alternative possible conservation scheme, especially in areas with high threat of habitat loss, might be *ex situ* conservation in germplasm collections (Duarte *et al.,* 2018). Hampe and Petit (2005) cite the importance of management of the populations at the edge of shrinking ranges. Considering that baobab seeds are reported to remain viable for several years (Sacande *et al.,* 2006), seeds from wild populations could be collected and preserved in seed banks. Training of local communities in sustainable harvesting of baobab products could be organized as suggested by Buchmann *et al., (*2010). Similar training has successfully guided local harvesters in

Namibia towards sustainable management of the Devil's Claw, *Harpag ophytum procumbens* (Strohbach, 1999; Hammond, 2000). Giving value to the baobab tree and promoting its conservation could also help preserve the ecosystem where the baobab tree thrives and the plant and animals that feed, shelter, or live in it.

Conclusion

The African baobab is known to be an important source of income, as well as dietary supply for local communities, particularly during the times of limited food supply. There is increasingly growing demand for baobab products in the world (North *et al.,* 2014). Despite that the use of baobab products is increasing and gaining popularity due to its medicinal value as well as food, there are emerging issues and challenges associated to its uses; including climate change and variability, land uses change, baobab new markets, medicinal and destructive harvesting methods.

It has been established that baobab losses are mainly attributed to elephant damage, fire damage, over-exploitation, overgrazing, and lack of natural regeneration. Systematic studies on the population dynamics of the baobabs across different land use types are necessary for generating information which is needed to update policy and practices on matters related to the status of baobab populations, habitat conservation and its importance to people's livelihoods. There is a need for awareness raising on the importance of baobab to people's livelihoods and extending conservation efforts outside protected areas.

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References

Abbiw DK. 1990. Useful plants of Ghana. London: Intermediate Technology Publications & the Royal Botanic Gardens, Kew.

Adam YO, Eisa MA, Ahmed DM. 2012. Role of *Adansonia digitata* L. fruits in development and forest conservation in Rashad locality, Nuba Mountains, Sudan. Journal of Agricultural Science **20,** pp. 314-328.

Adesanya SA, Idowu TB, Elujoba AA. 1988. Antisickling activity of *Adansonia digitata*. Planta Medica **54(4),** p. 374.

Akinnifesi FK, Ajayi OC, Sileshi G, Kadzere I, Akinnifesi AI. 2007. Domesticating and commercializing indigenous fruit and nut tree crops for food security and income generation in Sub-Saharan Africa. World Agroforestry Centre 39 pp.

Aluko AJ, Kinyuru LM, Chove LM, Kahenya P, Owino W, 2016. Nutritional Quality and Functional Properties of Baobab (*Adansonia digitata*) Pulp from Tanzania. Journal of Food Research **5(5),** pp. 23-31.

Amissah L, Mohren GMJ, Kyereh B, Poorter L, 2015. The Effects of Drought and Shade on the Performance, Morphology and Physiology of Ghanaian Tree Species. PLoS ONE **10(4),** e0121004.

Araújo MB, Thuiller W, Pearson RG. 2006. Climate warming and the decline of amphibians and reptiles in Europe. Journal of biogeography **33(10),** pp. 1712-1728.

Baillon HE.1876. *Adansonia madagascariensis*. Adansonia **11,** 251pp.

Barnes RFW, Barnes KL, Kapela EB. 1994. The long-term impact of elephant browsing on baobab trees at Msembe, Ruaha National Park, Tanzania. African Journal of Ecology **32,** pp. 177-184.

Barnes RFW. 1980. The decline of the baobab tree in Ruaha National Park, Tanzania. African Journal of Ecology **18,** pp. 243-252.

Biru Y, Bekele A. 2012. Food habits of African elephant (*Loxodonta africana*) in Babile Elephant Sanctuary, Ethiopia. Tropical Ecology **53(1),** pp. 43-52.

Boko M, Niang I, Nyong A, Vogel C, Giteko A, Medany M, Osman-Elasha B, Tabo R, Yanda P. 2007. Africa Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Forth assessment Report of the Intergovernmental Panel on Climate Change Ed Parry ML *et al.* (Cambridge: Cambridge University Press) pp. 433-67.

Bomhard B, Richardson DM, Donaldson JS, Hughe SGO, Midgley GF, Raimondo DC,Thuiller W. 2005. Potential impacts of future land use and climate change on the Red List status of the Proteaceae in the Cape Floristic Region, South Africa. Global Change Biology **11(9),** pp. 1452-1468.

Bond WJ, Keeley JE. 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. Trends in ecology and evolution **20(7),** pp. 387-394.

Bond WJ, Woodward FI, Midgley, GF. 2005. The global distribution of ecosystems in a world without fire. New Phytologist **165(2),** pp. 525-538.

Bosch CH, Sié K, Asafa BA. 2004. *Adansonia digitata* L. Record from Protabase. Grubben, G.J.H. & Denton, O.A. (Editors). PROTA (Plant Resources of Tropical Africa/Ressourcesvégétales de l'Afriquetropicale), Wageningen, Netherlands.

Boundja RP, Midgley JJ. 2010. Patterns of elephant impact on woody plants in the Hluhluwe Imfolozi Park, Kwazulu Natal, South Africa. African Journal of Ecology **48(1),** pp. 206-214.

Brendler T, Gruenwald J, Jaenicke C. 2003. Herbal remedies. Stuttgart: Medpharm GmbH Scientific Publishers.

Buchmann C, Prehsler S, Hartl A, Vogl CR. 2010. The importance of baobab (*Adansonia digitata* L.) in rural West African subsistence-suggestion of a cautionary approach to international market export of baobab fruits. Ecology of Food Nutrition **49,** pp. 145-172.

Carment R, Parry L, Blackburn A, Vermeylen S, Barlow J. 2011. Understanding human-fire interactions in tropical forest regions: a case for interdisciplinary research across the natural and social sciences. Ecology and Society **16(1),** pp. 53.

Cuni Sanchez A, Haq N, Assogbadjo. 2010. Variation in baobab (*Adansonia digitata* L.) leaf morphology in relation to drought tolerance. Genetic Resources Crop Evolution **57,** pp. 17-25.

De Caluwé E, Halamová K, Van Damme P. 2010. *Adansonia digitata* L. a review of traditional uses, phytochemistry and pharmacology. Afrika Focus **23,** pp. 11-51.

De Caluwé E. 2011. Market chain analysis of baobab (*Adansonia digitata* L.) and tamarind (*Tamarin dusindica* L.) products in Mali and Benin. Ph.D. thesis, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium.

Doughty CE, Goulden ML. 2008. Seasonal patterns of tropical forest leaf area index and CO_2 exchange. Journal of Geophysical Research Biogeosciences **113,** pp. G00B06.

Duarte E, Rondán BG, Rubenich R, Rocha P. 2018. Vegetative Propagation Method for *Ex Situ* Conservation of *Sidara moniana* (Malvaceae): an Endemic Species with Medicinal Potential in Danger of Extinction. International Journal of Agriculture Biology **20,** pp. 2779-2784.

Duvall CS, 2007. Human settlement and baobab distribution in south-western Mali. Journal of Biogeograph **34,** 1947-1961.

Edkins MT, Kruger LM, Harris K, Midgley JJ. 2008. Baobabs and elephants in Kruger National Park: nowhere to hide. African Journal of Ecology **46,** pp. 119-125.

FDA. 2009. Agency response letter GRAS notice no. GRN000273, 25/July/2009. US Food and Drug Administration.http://www.fda.gov/Food/IngredientsPackagingLabeling/GRAS/NoticeInventory/ucm174945].

Gandiwa E, Magwati T, Zisadza P, Chinuwo T, Tafangenyasha C. 2011. The impact of African elephants on *Acacia tortilis* woodland in northern Gonarezhou National Park, Zimbabwe. Journal of Arid Environments **75,** pp. 809-814.

Gebauer J, El-Siddig K, Ebert G. 2002. Baobab (*Adansonia digitata* L.): A review on a multipurpose tree with promising future in the Sudan. Gartenbauwissenschaft **67(4),** pp. 155-160.

Gebauer J, Luedeling E. 2013. A note on baobab (*Adansonia digitata* L.) in Kordofan, Sudan. Genetic Resource Crop Evolution **60,** pp. 1587-1596.

Gruenwald J, Galizia M. 2005. Market brief in the European Union for selected natural ingredients derived from native species. *Adansonia digitata* L, Baobab. United Nations Conference on Trade and Development, UN.

Guy PR. 1982. Baobabs and elephants. African Journal of Ecology **20,** pp. 215-220.

Hammond E. 2000. Biodiversity for Sale - Dismantling the Hype about Benefit Sharing. GRAIN and The Gaia Foundation, Barcelona & UK.

Hampe A, Petit RJ. 2005. Conserving biodiversity under climate change: the rear edge matters. Ecology letters **8(5),** pp. 461-467.

Hayward MW, Zawadzka B. 2010. Increasing elephant (*Loxodonta Africana*) density is a more important driver of change in vegetation condition than rainfall. Acta Theriologica **55(4),** pp. 289-298.

Heuzé V, Tran G, Archimède H, Bastianelli D. *2016.* African baobab *(Adansonia digitata).*Available at https://www.feedipedia.org/node/525.Data accessed on September 12, 2019.

Hulme MR, Doherty T, Ngara W, New M, Lister D. 2001. African climate change: 1900-2100. Climate Research **17,** pp. 145-68.

IFAD. 2011. Enabling poor rural people to overcome poverty in Kenya. International Fund for Agricultural Development, Rome, Italy.

International Centre for Underutilized Crops (ICUC). 2002. Fruits for the future baobab (Fact Sheet No. 4). Retrieved 12 September 2018 from http://www/icuc-iwmi.org/Publications/ Centre for Underutilized Crops, ICUC (2006). Technical manual for small-scale processor.

International Centre for Underutilized Crops (ICUC). 2006. Technique manual for small scales processer. International Center for Underutilized Crop (ICUC) Southampton, UK, 94pp.

IPCC, Cambioclimático. 2014. Impactos, adaptacióny vulnerabilidad-Resum enoarare sponsables de políticas. Contrib. delGrup. Trab. II al Quinto Inf. Evaluación del Grup. Intergub. Expert. sobre el Cambio Climático; Geneva; 2014. pp. 34.

IPCC. 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Jaiswal RK, Mukherjee S, Raju K, Saxena R. 2002. Forest fire risk zone mapping from satellite imagery and GIS. International Journal of Applied Observation. Geoinformation **4**, pp. 1-10.

Jamnadass RH, Dawson IK, Franzel Z, Leakey RRB, Mithöfer D, Akinnifesi FK, Tchoundjeu Z. 2011. Improving livelihoods and nutrition in sub-Saharan Africa through the promotion of indigenous and exotic fruit production in smallholders' agroforestry systems. A review. Introduction Forestry Revision **13,** pp. 1-17.

Kaboré D, Lingani HS, Diawara B, Compaoré CS, Dicko MH, Jakobsen M. 2011. A review of baobab (*Adansonia digitata*) products: Effect of processing techniques, medicinal properties and uses. African Journal of Food Science **5(16),** pp. 833-844.

Kamatou GPP, Vermaak I, Viljoen AM. 2011. An updated review of *Adansonia digitata*: a commercially important African tree. South African Journal of Botany **77,** pp. 908-919.

Kupika OL, Kativu S, Gandiwa E, Gumbie A. 2014. Impact of African elephants on baobab (*Adansonia digitata* L.) population structure in northern Gonarezhou National Park, Zimbabwe. Tropical Ecology **55(2),** pp. 159-166.

Lewis SC, King AD. 2017. Evolution of mean, variance and extremes in 21st century temperatures. Weather and Climate Extremes **15,** pp. 1-10.

Lisao K, Geldenhuys CJ, Chirwa PW. 2018. Assessment of the African baobab (*Adansonia digitata* L.) populations in Namibia: Implications for conservation. Global Ecology and Conservation **14,** pp. e00386.

Mapaure IN, Campbell BM. 2002. Changes in miombo woodland cover in and around Sengwa Wildlife Research Area, Zimbabwe, in relation to elephants and fire. African Journal of Ecology **40(3),** pp. 212-219.

MEA. 2005. Millenium Ecosystem Assessment: Ecosystems and Human wellbeing: Biodiversitysynthesis. World Resource Institute, Washington, D.C.

Milza P. 2002. Unapianta per ilfuturo: Il Baobab. Erboristeriadomaini **10,** pp. 40-51.

Mpofu EE, Gandiwa E, Zisadza-Gandiwa P, Zinhiva H. 2012. Abundance, distribution and status of African baobab (*Adansonia digitata* L.) in dry savanna woodlands in southern Gonarezhou National Park, southeast Zimbabwe. Tropical Ecology **53,** pp. 119-124.

Msalilwa U, Augustino S, Gillah PR. 2013. Community perception on climate change and usage patterns of non-timber forest products by communities around Kilolo District, Tanzania. Ethiopian Journal of Environmental Studies and Management **6(5),** pp. 507-516.

Msalilwa UL, Munishi LK, Makule EE, Ndakidemi PA. 2019. Pinpointing baobab (*Adansonia digitata* [Linn. 1759]) population hotspots in the semi-arid areas of Tanzania. African Journal of Ecology.00:1–13.
https ://doi.org/10.1111/aje.12709

Munyebvu F. 2015. Abundance, structure and uses of baobab (*Adansonia digitata* L.) populations in Omusati Region, Namibia. PhD thesis, Faculty of biodiversity management and research, University of Namibia 152 pp.

Nordeide MB, Hatloy A, Folling M, Lied E, Oshaug A. 1996. Nutrient composition and nutritional importance of green leaves and wild food resources in an agricultural district, Koutiala, in southern Mali. Introduction of food science nutrition **47,** pp. 455-478.

North R, Darr D, Gebauer J, Mithöfer D, Owino WO, Rimberia FK, Kehlenbeck K, Siddig ME, Mahmoud TE, Taha ME, Triebel A, Johnson H, Maina A, Ahmed MF, Adam YO, ChimulekeM, Elwasila EM, Habte T, Krawinkel MB, Mbugua NJ, Muendo KM, Sanjak E, Schüring M. 2014. Promoting the Use of Baobab (*Adansonia digitata* L.) in Rural Communities in Eastern Africa. Conference on International Research on Food Security, Natural Resource Management and Rural Development organized by the Czech University of Life Sciences Prague pp. 1-4.

O'Connor TG, Goodman PS, Clegg B. 2007. A functional hypothesis of the threat of local extirpation of woody plant species by elephant in Africa. Biological Conservation **136(3),** pp. 329-345.

Orwa C, Mutua A, Kindt R, Jamnadass R, Anthony S. 2009. Agroforestry Database: a tree reference and selection guide version 4.0. World Agroforestry Centre, Kenya.

Owen-smith RN. 1988. Megaherbivores. The influence of a very large body size on ecology. Cambridge University Press.

Parkouda CH, Sanou A, Tougiani A, Korbo D, Nielsen K, Tano-Debrah A, Ræbild B, Diawara B, Jensen J. 2012. Variability of baobab (*Adansonia Digitata* L.) fruits' physical characteristics and nutrient content in the West African Sahel. Agroforestry Systems **85,** pp. 455-463.

Patrut A, Von-Reden KF, Lowy DA, Alberts AH, Pohlman JW, Wittmann R, Mitchell CS. 2007. Radiocarbon dating of a very large African baobab. Tree Physiology **27(11),** pp. 1569-1574.

Rashford J. 2015. The Uses of the Baobab Flower (*Adansonia digitata* L). Ethnobotany Research & Applications **14,** pp. 211-229.

Ribeiro NS, Snook LK, Nunes de CarvalhoVaz I, Alves T. 2019. Gathering honey from wild and traditional hives in the Miombo woodlands of the Niassa National Reserve, Mozambique: What are the impacts on tree populations. Global Ecology and Conservation **17,** pp. e00552.

Ruddiman WF. 2003. The Anthropogenic Greenhouse Era Began Thousands of Years Ago. Climatic Change **61,** pp. 261-293.

Sacande M, Rønne C, Sanon M, Jøker D. 2006. *Adansonia digitata* L. In: Seed leaflet, vol 109. Forest and Landscape Denmark, University of Copenhagen, Frederiksberg.

Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Leemans R. 2002. Global biodiversity scenarios for the year 2100.Science **287(5459),** pp. 1770-1774.

Sanchez AC, Osborne PE, Haq N. 2010.Identifying the global potential for baobab tree cultivation using ecological niche modelling. Agroforestry systems **80(2),** pp. 191-201.

Sanchez AC, Osborne PE, Haq N. 2011. Climate change and the African baobab (*Adansonia digitata* L.): the need for better conservation strategies. African Journal of Ecology **49,** pp. 234-245.

Sankaran M, Ratnam J, Hanan N. 2008. Woody cover in African savannas: the role of resources, fire and herbivory. Global Ecology and Biogeography **17(2),** pp. 236-245.

Schumann KW, Wittig R, Thiombiano A, Becker U, Hahn K. 2010. Impact of land-use type and bark- and leaf-harvesting on population structure and fruit production of the baobab tree (*Adansonia digitata* L.) in a semi-arid savanna, West Africa Forest Ecology and Management **260,** pp. 2035-2044.

Schumann KW, Wittig R, Thiombiano A, Becker U, Hahn K. 2012. Uses, management and population status of the baobab in eastern Burkina Faso. Agroforestry Systems **85,** pp. 263-278.

Shannon G, Druce DJ, Page BR, Eckhardt HC, Grant R Slotow R. 2008. The utilization of large savanna trees by elephant in southern Kruger National Park. Journal of Tropical Ecology **24,** pp. 281-289.

Sidibé M, Williams JT. 2002. Baobab – *Adansonia digitata*. Fruits for the future.Int. Centre Underutil. Crops, Southampton, UK. 96 Pp.

Stadlmayr B, Charrondiere UR, Eisenwagen S, Jamnadass R, Kehlenbeck K. 2013. Nutrient composition of selected indigenous fruits from sub-Saharan Africa. Journal of the Science of Food and Agriculture **93(11),** pp. 2627-2636.

Strohbach M. 1999. The Sustainably Harvested Devil's Claw Project – Ecological Survey February 1999. CRIAA SA-DC, Windhoek.

Swanepoel CM, Swanepoel SM. 1986. Baobab damage by elephant in the middle Zambezi valley, Zimbabwe. African Journal of Ecology **24,** pp. 129-13.

Swanepoel CM. 1993. Baobab damage in Mana Pools National Park, Zimbabwe. Africa Journal of Ecology **31,** pp. 220- 225.

Tafangenyasha C. 1997. Tree Loss in Gonarezhou National Park (Zimbabwe) between 1970 and 1983. Journal of Environmental Management b, pp. 355-366.

Tapsoba H, Deschamps JP. 2006. Use of medicinal plants for the treatment of oral diseases in Burkina Faso. Journal of Ethnopharmacology **104(1),** pp. 68-78.

Thornton PK, Ericksen PJ, Herrero M. Challinor AJ. 2014. Climate variability and vulnerability to climate change: a review. Global Change Biology **20(11),** pp. 3313-3328.

Toledo M, Peñaclaros M, Bongers F, Alarcón A , Balcázar J, Chuviña J, Leaño C, Licona JC, Po orter L. 2012. Distribution patterns of tropical woody species in response to climatic and edaphic gradients. Journal of Ecology **100,** pp. 253-263.

Vasseur DA, DeLong JP, Gilbert B, Greig HS, Harley CDG, McCann KS, Savage V, Tunney TD, O'Connor MI. 2014. Increased temperature variation poses a greater risk to species than climate warming. Proc. R. Soc. B: Biol. Sci. **281 (1779)**.

Venter S, Witkowski E. 2010. Baobab (*Adansonia digitata* L.) fruit production in communal and conservation land-use types in Southern Africa. Forestry Ecology and Management **261,** pp. 630-639.

Watt JM, Breyer-Brandwijk MG. 1962.The medicinal and poisonous plants of southern and Eastern Africa. Second ed. Edinburgh and London: E. and S. Livingstone Ltd.

Weyerhaeuser FJ. 1985. Survey of elephant damage to baobabs in Tanzania's Lake Manyara National Park. African Journal of Ecology **23(4),** pp. 235-243.

Wickens G E. 1982. The baobab: Africa's upside-down tree. Kew Bull **37,** pp. 173-209.

Wickens GE, Lowe P. 2008. The baobabs: pachycauls of Africa, Madagascar and Australia. Springer, UK.

Wilson RT. 1998. Vital statistics of the baobab (*Adansonia digitata*). African Journal of Ecology **26,** pp. 197-206.

Wilson WRS. 2002. Status report on the postharvest handling, processing and marketing of underutilized fruit crops in Sri Lanka. In: Haq, N, Hughes, A. (Eds.), Fruits for the Future in Asia: Proceedings of the Consultation Meeting on the Processing and Marketing of Underutilised Tropical Fruits in Asia. International Centre for Underutilized Crops (ICUC), Southampton, UK. pp. 199-204.

Zhang P, He L, Fan X, Huo P, Liu Y, Zhang T, Pan Y, Yu Z. 2015. Ecosystem service value assessment and contribution factor analysis of land use change in Miyun County, China. Sustainability **7,** pp. 7333-7356.