HOUSEHOLD LIVELIHOODS, MARKETING AND RESOURCE IMPACTS: A CASE STUDY OF BARK PRODUCTS IN EASTERN ZIMBABWE

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Effects Of Commercial Bark Harvesting On *Adansonia Digitata* (Baobab) In The Save Odzi-Valley, Zimbabwe With Considerations For Its Management

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Abstract

Non-timber forest products (NTFPs) represent a major contribution to rural communities in eastern Zimbabwe. In this area, baobab markets have prospered due to drought and rural poverty. This paper integrates information form related disciplines regarding the baobab ecology, and the baobab bark harvesting, processing, and marketing in the study area of Mutsiyo, Nhachi and Gundyanga villages (42 km^2). Baobab tree densities and size-class distribution were established (8.41 trees/ha), along with the extent of harvesting (99% of individuals sampled had evidence of bark harvesting), and maximum harvested heights (almost 50% of the trees had been harvested up to 2 m). Times of bark and fibre quality regeneration after harvesting were calculated after a 4-year experiment (6 and 10 years to restore pre-harvesting conditions, respectively). An equation was designed to calculate available volumes of and fibre quality of baobab bark, both coming from regenerated scars and non-harvested sections of trees. A discussion is presented regarding the sustainability of the baobab harvesting practice. Ideas for the sustainable use of the baobab bark resource are outlined, based on the concepts of adaptive and community based management.

Introduction

Non-timber forest products (NTFPs) contribute to the welfare of a large and diverse group of people in the tropics (e.g. Falconer, 1992; Arnold, 1994; Arnold and Ruiz-Pérez, 1998). NTFPs often provide economic buffers when there is crops failure and furnish additional incomes seasonally when the benefits of other economic activities are reduced (e.g. Chambers and Leach, 1987; Hammett an Chamberlain, 1998; May *et al.*, 1985). In Zimbabwe, where crop failures and rural poverty are exceedingly common, several studies have shown that NTFPs represent a critical source of income for the rural poor (Campbell *et al.*, 1995).

NTFP-based income is particularly important to people in our study area, in the Save-Odzi Valley of southeastern Zimbabwe, where dry-land crop production for subsistence use and cash income is marginal, mostly due to low and erratic rainfall (Campbell *et al.*, 1995). The severe drought of 1991-1992 and the economic crisis during the late 1990s further increased local needs for additional non-agricultural income in this area. One of the sources of this income is the crafts industry with raw materials from bark fibre of *Adansonia digitata* L. (hereafter "baobab"). In recent years, researchers who have focused on the impacts of human use of baobab populations in Zimbabwe have highlighted the importance of this resource to the livelihoods of local people (e.g. Kwaramba, 1995; Luckert *et al.*, (in prep); Mudavanhu, 1998; Mukamuri and Kozanayi, (in prep).

Braedt and Standa-Gunda (2000) reported that marketing of baobab bark products substantially increased during the early 1990s. They also reported that the markets for baobab products are located on the Masvingo-Mutare road, near Birchenough Bridge. Similarly, Kwaramba (1995) noted that 80% of the vendors of baobab products in the Birchenough Bridge area in 1995 had established their markets during the previous decade.

In a study on the impacts of harvesting on the population structure of baobabs in the same Save-Odzi Valley area, Mudavanhu (1998) compared sites of different tree densities and harvesting intensities. He suggested that bark harvesting increased the vulnerability of the trees to a "sooty baobab" disease. Because of the perceived impacts of this bark-attacking fungal pathogen, he concluded that bark harvesting at the rates observed in the mid-1990 was not sustainable.

The full range of implications of commercialising baobab bark products for the resource base have not yet been adequately investigated. Natural resources, and more particularly, baobab bark management problems are currently being exacerbated by weak institutions and poverty. Additionally, there are reasons to believe that the baobab bark industry could be at risk of going into an economic boom and bust cycle such as has been well described for other NTFPs (e.g. Dove, 1993; Coomes, 1995). Arguments in favour of this opinion are the increased importance of baobab crafts in household economies (Veeman *et al.*, (in prep); Luckert *et al.*, (in prep)) and the apparent lack of active management by local communities. The deleterious impacts of over-exploitation of a renewable natural resource tend to be suffered largely by the rural poor, who are the most dependent on the resource (Arnold and Ruiz-Pérez, 1998). Therefore, in addition to environmental concerns about the depletion of the baobab resource base, there are social reasons for assessing the impacts of current harvesting practices on this locally important NTFP.

Lack of proactive natural resource management initiatives, especially in response to expanding markets, often leads to biological and ultimately economic impoverishment (Nepstad *et al.*, 1992). Active management programs may help to counter this trend and rescue natural resources from being undervalued and thus overexploited (Panayotou and Ashton, 1993). To be effective, however, active management for NTFPs needs to be based on sound biological and socio-economic information (Peters, 1996).

This paper represents an attempt to integrate information from diverse disciplines regarding the baobab industry, and aims to characterize baobab bark use from ecological, economic, and social perspectives. The rationale for this information will be to provide baseline information for the development of management guidelines for this important NTFP, for the benefit of the resource base and the inhabitants of the Save-Odzi valley.

Study site and the resource

Site description

The study area is located in the Mutambara Communal Land, Chimanimani District (*ca.* 19°30' S; 32° 30' W), at an altitude of 600 m.a.s.l. It has an extension of 42 km^2. Soils are derived from deep calcareous alluvial material with scattered areas of shallow gravel (Nyamapfene, 1991). Mean annual rainfall is 460 mm, but varies greatly from year to year; during the 1980-1998 period there was a maximum of 1000 mm in 1992-1993 and a minimum of 180 mm in 1982-1983. Due to low and erratic rainfall, the study area is classified as being only suitable for extensive ranching or agriculture with irrigation.

The vegetation type on level land is *mopane* woodland dominated by *Colophospermum mopane* (Kirk). Other common tree species include *Terminalia sericea* (Burch ex CD.), *Berchemia discolor* (Klotzsch), *Acacia nilotica* (L.) and *Combretum* spp. (Mudavanhu, 1998). Baobabs occur as scattered individuals throughout the area.

The most important economic activity of residents in the study area is subsistence farming. Less commonly, people participate in irrigated agricultural schemes run by the government. Local people also raise goats, cattle, donkeys and sheep (Luckert *et al.*, (in prep); Mukamuri and Kozanayi, (in prep)).

Baobab ecology

Baobabs occur at low altitudes in hot dry woodland (Wickens, 1981; Coates-Palgrave, 1983; Mullin, 1997). In Zimbabwe, baobab trees are found in the valleys of the Zambezi River and its major tributaries, and in the Save-Limpopo lowveld. The species apparently prefers deep well-drained soils at elevations between 450 and 600 m.a.s.l (Wickens, 1981).

The baobab is a deciduous species that grows up to be 6 m and more in diameter but rarely reaches heights > 20 m. Baobab bark is smooth, reddish-brown, or greyish-brown with a thin green photosynthetic layer immediately under the outer bark. The wood is characterized by an abundance of water-storing parenchyma tissue and moisture content of three times the dry weight (de Villiers, 1951; Wickens, 1981). Baobab trees reportedly start to flower at 22-23 yrs. Baobab flowers are large and showy, open only for a period of 24 hrs, and are pollinated by bats though visited by a range of other animals (i.e. moths, wasps, and bush babies; Owen, 1974; Wickens, 1981). Flowering occurs at the start of the rainy season, in November. Fruits are a preferred food for monkeys, baboons, elephants, and impala (Peters and O'Brien, 1980; Wickens, 1981), as well as food for humans. In areas where there is little wildlife, fruits hang on the trees for several months.

Baobab tree densities

To determine the baobab tree densities in the harvesting areas used by the villagers of Gundyanga, Mutsiyo and Nhachi, nine random 0.5 ha plots were established (3 plots per village). In these, the diameter at breast height (dbh in m) of all baobab trees was measured (data presented in Table 3, row 1).

Mean density was 8.44 trees/ha (Mutsiyo: 14.66 trees/ha; Gundyanga: 5.33 trees/ha; Nhachi: 5.33 trees/ha). No seedlings were found during the sampling. The smallest individual encountered during the survey was 0.25 m dbh. In a recent study in the same region, but for different villages, Mudavanhu (1998) estimated that populations ranged from 21 trees ha^{-1} in Nyanyadzi to 3 trees ha^{-1} further south at Birchenough Bridge. Mudavanhu (1998) also found no baobab regeneration in the study area.

Viability of baobab seeds is generally high (60%: Tietema *et al.*, 1993; 97%: Mudavanhu, 1998) and many trees in the study bore substantial numbers of fruits at the time of this study (in May 1999). Young seedlings are apparently eaten and killed by cattle and goats. On game ranches where cattle and goats have been excluded, seedlings are fairly abundant (Mudavanhu, 1998).

The primary cause of death of baobab trees is reportedly related to lack of soil moisture, and less frequently by lightning (de Villiers, 1951; Piearce *et al.*, 1993). Elephants are also known to kill baobab (Swanepoel and Swanepoel, 1986). However, our study site has no elephants. Annual mortalities range from 1.1% (Mana Pools National Park, Swanepoel, 1993) to 7.3% (Luangwa Valley in Zambia, Caughley, 1976), both sites with elephants. In the study area, baobab tree mortality rates were estimated (0.33 trees/ha/yr), assuming that trees fallen longer than one to two years ago would have already decomposed (Barnes, 1980; Mudavanhu, 1998).

Browsing damage

Studies by Mudavanhu (1998) and Mukamuri and Kozanayi ((in prep) together with information gathered using participatory rural appraisal (PRA) techniques in this study highlighted browsing by livestock as the major reason for the lack of recruitment of baobab. Young seedlings were reportedly also eaten by herdboys, monkeys, and baboons (Peters and O'Brien, 1980).

Mudavanhu (1998) recommended a reduction in livestock numbers or fencing of baobab management areas to promote survival of baobab seedlings and saplings. Perhaps not surprisingly, villagers stated that reducing stocking levels was not an acceptable option. Fencing was also not endorsed because it is costly and reduces available grazing grounds. Fire did not seem to represent a major threat to baobab populations in the study area because of lack of fuel load.

A major source of damage to baobabs is elephants, and this is consistent with findings from elsewhere in Africa (Owen, 1974; Caughley, 1976; Weyerhauser, 1985). Swanepoel (1993) showed that some baobab trees, mostly those individuals <7.5 m in girth, re-sprouted after elephant damage to stems. The same study also established that among the impacts of elephant damage on the development of baobab trees was the failure of elephant damaged trees to produce mature pods (Swanepoel, 1993).

Elephants reportedly strip the outer bark and chew the inner fibres, particularly in the dry season (de Villiers, 1951; Robertson-Bullock, 1960; Napier and Sheldrick, 1963). According to Weyerhauser (1985) in Tanzania, damage increased with increasing dbh of baobab trees, although mortality rates were higher among smaller trees.

Growth rates

Several studies have been carried out to assess stem diameter growth rates of baobabs (de Villiers, 1951; Guy, 1970). Growth rates seem to be positively related to rainfall (Piearce *et al.*, 1993), but are extremely variable and at times difficult to interpret. As pointed out by Guy (1970), a potential confusion in using dbh as a measure to assess growth is the seasonal shrinking and swelling which occurs in response to soil moisture availability. Debarking by humans and wildlife, in addition to deeper stem damage by elephants, contribute further to this variation.

In this study, the mean annual dbh increment of nine trees of known age (12-72 yrs) in three locations in Harare (National Botanical Garden, Greenwood Park, and David Livingstone School) was estimated to be 2.01 cm/yr.

To derive a more realistic estimate of baobab growth rates in the study area, the mean annual dbh increments from data presented by de Villiers (1951) and Guy (1970) for Messina (mean annual rainfall for 50 yrs: 411.4 mm), and by Guy (1970) for Hwange (mean annual rainfall: 550 mm) were recalculated. Remarkably, Guy's data on growth for the period of 1936–1967 showed that 7 of the 17 trees decreased in dbh over that 31-year interval (Table 1).

Other authors have determined baobab growth rates by using stem borers and counting rings, following Swart's statement that baobabs produced annual rings (Swart, 1963). Other authors established baobab growth rates (measured as radius increments) ranging from 0.15 cm/year (Kariba, Zimbabwe; Swart, 1963), to 0.75 cm/yr (Luangwa Valley, Zambia; Barnes, 1980), corresponding to dbh increments of 0.30 cm to 1.50 cm/yr, respectively. What is clear from these difficult-to-interpret data is that more information is needed about baobab growth rates before the future of baobab populations can be confidently predicted.

Coates -Palgrave (1983) stated that trees of 8 m dbh might be more than 3000 years old. A carbon-14 dating performed by Swart (1963) indicated that a tree with a dbh of 4.5 m in Kariba in the Zambezi valley was 1010 +/- 100 yrs old.

Table 1: Growth rates of baobab trees calculated from individuals of known ages in Messina (de Villiers, 1951; Guy, 1970), Hwange (Guy, 1970), and Harare (this study). The trees from Messina were divided into positive and negative growth rate categories.

Site	# of trees	Growth rate (cm/yr)
Messina	8	0.23
	7	-0.08
	15 (total)	0.08
Hwange	3	1.36
Harare	9	2.01

Disease

Baobabs are susceptible to infection by a sooty mould of the *Antennulariella* type (Matose and Clarke, 1991; Maulka *et al.*, 1995). The bark of infected trees becomes blackened or burnt in appearance, hence the term 'sooty'. Other symptoms of infection include "gum-sweating" through the bark and crown die-back (Sharp 1993). Based on the observation that sooty mould disease is particularly prevalent during and soon after drought years, Mullin (1997) suggested that the disease infected trees under environmental stress. Piearce *et al.* (1993) hypothesized that drought caused physical contraction of the bark leading to extrusion of the sap through weak points (i.e. cracks and wrinkles), where sooty moulds could colonize. To date, this hypothesis has not been tested.

Mudavanhu (1998) reported that there is a strong relationship between sooty disease infestation and bark harvesting, though offered no explanation of the mechanism involved. It was not clear, for example, whether high rate of infection of harvested trees is due to spread of the disease from tree to tree by harvesters, or whether the trees were rendered more susceptible to the disease through bark loss.

The mean proportion of trees infected by the sooty disease in the tree density plots in the harvesting areas in this study was 47.3% (77.6% in Nhachi; 0% in Gundyanga, and 64.3% in Mutsiyo villages, respectively). Bark had been harvested from all the infected trees in the plots making it impossible to establish a cause and effect relationship. The only tree encountered in the sampling area from which bark had apparently never been harvested was completely infected by the sooty mould disease.

Bark thickness

The relationship between bark thickness (in cm; measured with a Suunto bark gauge) and age for nine cultivated baobab trees of known ages (12-72 yrs) growing in Harare was established. The regression equation relating $\log_{10}$ transformed bark thickness data and age is the following:

Log_{10} bark thickness = 0.4077Ln (years) - 1.2238 (R^2= 0.8618; F= 8.5; df=1,8; $p<0.05$; Figure 1).

Likewise, the relationship between bark thickness and dbh (in m) was evaluated for 23 trees growing in different locations (Harare and Hot Springs). This relationship is represented by the following equation:

Log_{10} bark thickness = 0.2666 Ln (dbh) + 0.4094 (R^2 = 0.8051; F= 13.7; df=1,22; $p<0.005$; Figure 2).

Assessment of the impacts of bark harvesting

Baobab bark in the study area had been harvested from trees from a wide range of sizes (i.e. 25-330 cm in dbh). Harvesting is reportedly more prevalent during the dry season when villagers are less involved in agricultural activities. Trees that produce high-quality fibre are more likely to be over-harvested than trees from which less of the bark is usable. It is also believed that bark should not be harvested from the upper portion of the trunk, as this is likely to increase tree mortality. However, trees were frequently encountered with bark harvested up to 3 m above the ground, by constructing platforms and scaffolds close to the tree. Evidence of harvesting was not found above the first branching.

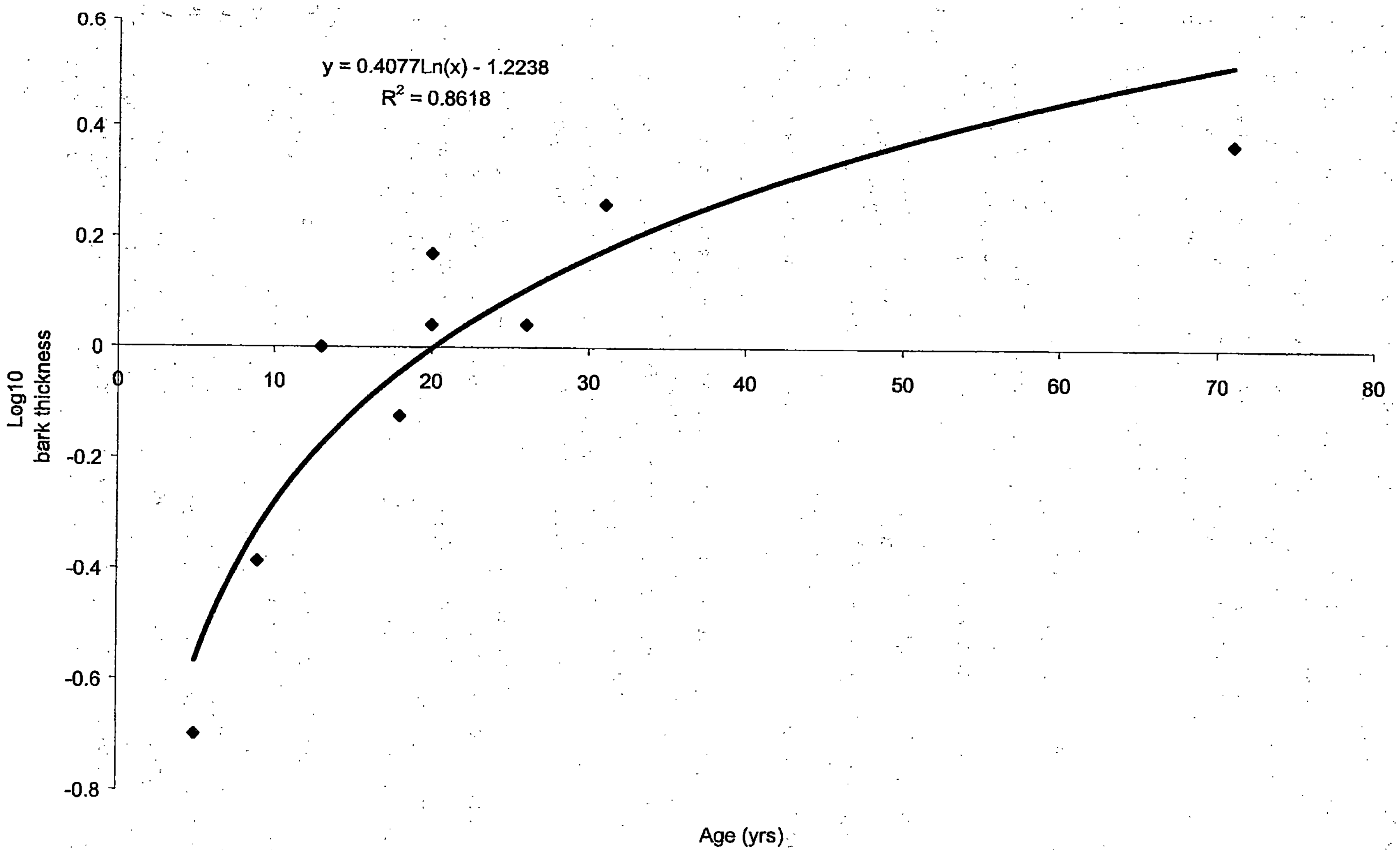

Figure 1: Relationship between baobab bark thickness and age of 9 trees grown in Harare.

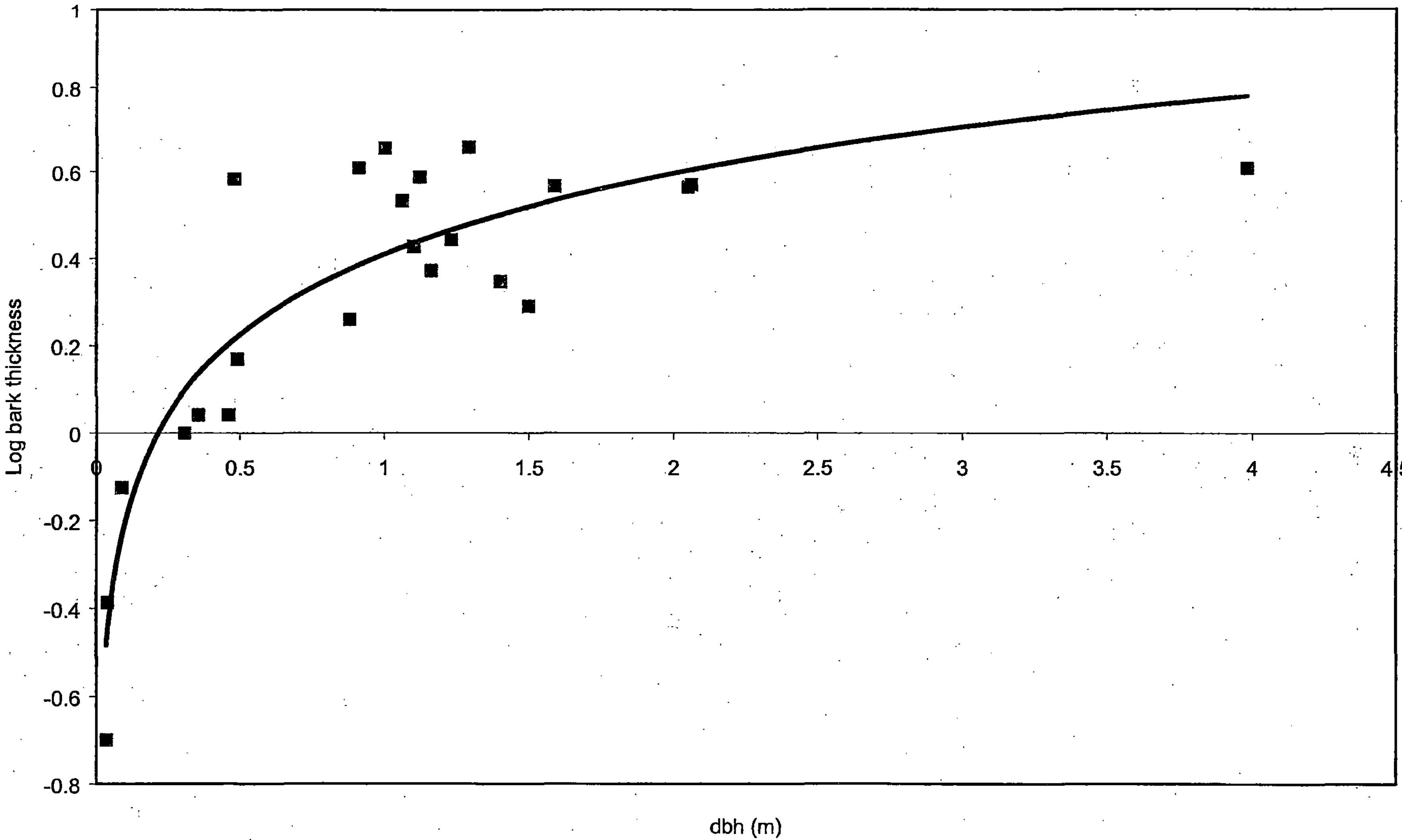

Figure 2: Relationship between bark thickness and diameter at breast height (dbh) for 23 trees growing in Harare and Hot Sprigs

Harvesting practices, fibre quantities and qualities

The various stages of the bark harvesting process were documented by monitoring four harvesters for several hours each. Harvesters were asked to harvest bark from a section on the tree that had apparently not been harvested before. Although it has been reported that only smooth bark is harvested (Matose and Clarke, 1991), this was seen not to be the case during field observations, as rough bark was also selected for harvesting. The four harvesters were each monitored concurrently and times spent on each type of activity recorded (Table 2). On average the total time spent to harvest an average 21.2 kg of bark from a mean size patch of 0.5 m^2 (max: 0.69 m^2; min: 0.36 m^2; SD: 0.13) was 83.2 min (max: 111; min: 67). Walking distances (time) between the trees and the harvesters' homesteads were recorded to be from 10 to 20 min.

The first stage of bark harvesting is marking the perimeter of the area to be removed (~ 1 m^2). The thin outer bark (0.5 – 1.0 cm) is then sliced off using an axe or machete and thereby exposing the more fibrous inner layer. After removing the outer bark, incisions are made around the edges of the marked portion of the bark down to the vascular cambium and sometimes penetrating into the outer layers of xylem. There are two main methods for removing the designated patch of bark. One is to remove an intact slab of bark from the tree and then strip out the innermost fibres using one's teeth and the fibres from the outer layers separated by pounding using the blunt back of an axe. In the second method, bark is gradually removed by levering the marked area of bark outwards from the trunk and pounding downwards on the exposed edge from the top with a large hammer (2 kg in weight), or using the back of an axe. On completion of the pounding process, the base of the slab is cut off the tree and the fibre layers are separated from the pulverized mass of other tissues.

Table 2: Types of baobab bark harvesting activities and their average durations (n= 4 harvesters).

Activity	Time (min)
Searching for a tree with harvestable bark	3.9
Building scaffolding	9.0
Removing outer bark with axe ("shaving")	9.3
Deep cutting around edges of piece of bark with an axe	7.6
Pounding with a hammer (or back of an axe)	25.0
Resting	20.3
Sorting	8.3
Total	83.2

Harvesters explained that the innermost white fibres, which are not dyed, were the most valuable and were preferred due to their softness. The outer fibres were rougher, and were usually dyed before use, mostly in mat-making. Because the fibres have to be rolled into rope before weaving hats and bags, they were made from the softer inner fibres. Baobab bark fibres were also used to bind small bundles of some species of grass, coiled and made into pet-baskets and wastepaper bins. The outermost bark and material remaining after fibre removal did not appear to be used in any way. Some trees yielded a higher volume of useable fibre than others, which was thought to be influenced more by site conditions (soil depth and fertility, and access to water) than by tree size or time after last bark harvesting. Once the fibres were separated from other tissues, they were sorted in usable and non-usable fractions. The non-usable fraction included the outermost bark, extremely rough and short fibres, and a variety of other tissues (e.g. parenchyma). To determine total and usable bark yields, all material harvested was air-dried in a glass-house and then oven-dried at 80° for 72 hrs; all values were presented as dry weights. The proportion of usable vs. non-usable material was estimated for 14 trees (x=31.4%; max: 79.2%; min: 10.9%; SD: 17.28). According to this proportion, the four harvesters each produced 6.96 kg of usable fibre in a mean time of around 1½ hrs. The usable fraction of bark was divided into four quality types: first or highest corresponding to the whiter or inner fibres (24.2%); second (47.6%); third (24.1%), and fourth (4.1%). Fibres of the third and fourth qualities were pounded after been soaked in water overnight to soften them.

Harvesters reportedly preferred bark from trees or portions of trees that had not previously been harvested because "they yield more soft, white fibres". During field-work, it was observed that trees that had not been previously harvested also yielded yellowish and red fibres. Previously unharvested bark was rare in the study area except high on trees where it was out of reach without scaffolding and thus required greater labour input. In many cases harvesters have no alternative but to use bark from old harvested scars.

Regenerated bark reportedly needed to be harvested very carefully because the fibre was more delicate. The regenerated outer bark was not removed initially, and pounding of the fibres was done slowly and carefully to soften them gradually and avoid breakage.

Intensity of harvesting

To determine the intensity of harvesting, the presence of harvest scars on all baobab trees in the tree density plots were recorded. The trees were categorized by the uppermost tiers from which bark was harvested. Bark was generally harvested in tiers near to the ground and progressing upwards by 80-100 cm tiers up the stem (Figure 3). In the 9 sample plots covering a total of 4.5 ha, it was found that bark from 97.4% of the trees had been harvested at least once in their lifetime. More than 50% of the trees had been harvested to heights of about 2 m and above. The only trees that were not harvested for fibre during this study were those with sooty baobab disease.

As an additional indicator of harvesting intensity the maximum height to which bark from each tree was harvested in the baobab density plots was recorded (i.e. the highest edge of the highest scar; Table 3, rows 2 and 3). The biggest trees were, on average, harvested to near 3 m in height.

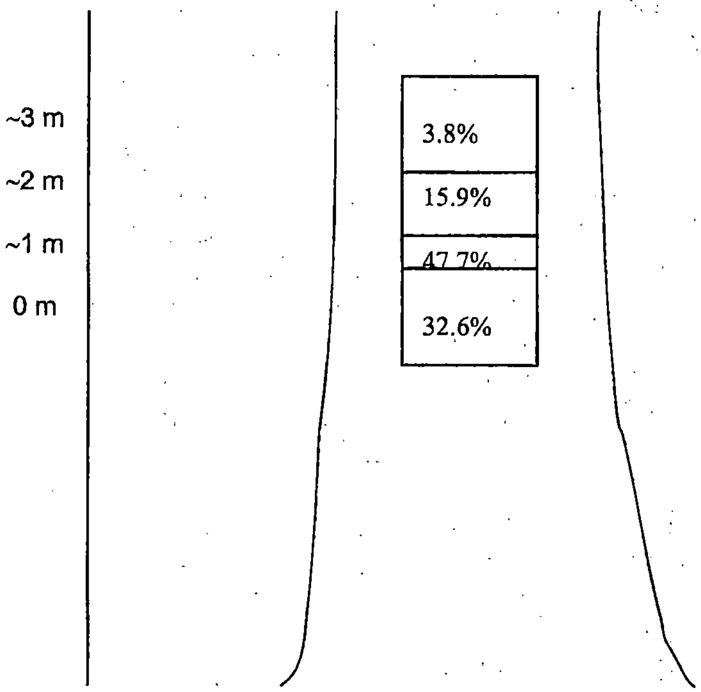

Figure 3: Proportion of trees that had been harvested to different heights (by tiers; n= in the harvesting areas of Mutsiyo, Gundyanga and Nhachi villages.

Table 3: Summarized results of baobab trees characteristics and bark harvest per hectare in the harvesting areas of Mutsiyo, Gundyanga and Nhachi villages.

Variables		dbh-class (cm)		
		0-50	51-100	101-150
1. Number of trees/ha[1]		1.77	3.55	1.55
2. Mean max. harvested height [2] (m)		1.55	1.98	1.93
3. Range – mean max harvested height[2] (m)		1.20-2.80	1.30-3.70	0.95-2.90
4. Bark thickness [3] (cm)		1.00 (n=2)	1.82 (n=4)	3.06 (n=4)
5. Mean circumference [2] (cm)		106.8	232.4	408.4
6. Mean amount of bark harvested	Volume [4] (cm^3/tree)	16,554	83,747	241,192
	Dry weight (kg/tree)	4.7	23.9	68.9
	Dry weight (kg/ha)	8.3	85.0	106.9
7. Mean amount bark that can be obtained from regenerated patches	Volume [5] (cm^3/tree)	19,037	52,917	90,644
	Dry weight (kg/tree)	5.4	15.1	25.9
	Dry weight (kg/ha)	9.6	53.7	40.1
8. Mean maximum un-harvested bole length[2] (cm)		166	174	212
9. Mean amount bark that can be harvested from virgin sections of trees	Volume [6] (cm^3/tree)	17,728	73,596	246,937
	Dry weight (kg/tree)	5.1	21.1	75.7
	Dry weight (kg/ha)	8.9	74.3	117.4

1 Data from nine 0.5 ha plots in three villages
2 Data from all baobabs in the nine 0.5 ha plots in three villages
3 Data from 18 trees that did not have evidence of ever been harvested ore received stem damage, in the study area and in remote areas in western Zimbabwe.
4 Calculated using formula: $\tau = (\alpha \times \beta \times \delta)$ (see text)
5 Calculated using formula: $\tau = (\alpha \times \beta \times \delta)$ (see text), with bark thickness $\alpha = 1.15$ cm.
6 Calculated using formula: $\tau = (\alpha \times \beta \times \delta)$ (see text), with bark thickness as in line 4.

A third way for assessing harvesting intensities was to estimate how much usable bark had been extracted from the harvesting area. For this purpose, the volume of bark was calculated according to the following formula:

$\tau = \sum_{i=1}^{5} (\alpha \times \beta \times \delta \times \varepsilon)$, where:

τ is volume of bark harvested (cm^3)

α is bark thickness (cm) (Table 3, line 4)

β is circumference (cm) (Table 3, line 5)

δ is maximum harvested height (cm) (Table 3, line 2)

ε is number of trees/dbh-class (Table 3, line 1)

i is dbh-class

This formula does not include a stem taper term. Baobab trees are noteworthy for their peculiar bole shapes, the most parsimonious assumption of stem shape being that of a cylinder. The weight to volume conversion of 0.286 g/cm^3 was derived by weighing oven-dried bark samples of known volume (n=2). The conversion factor was used to estimate the weight of the volume of bark extracted, and the number of bundles extracted from the total. One bundle of fibre was estimated to weigh 0.239 kg (n=15).

Based on bark scar data, the harvesting area yielded 693.8 Mg of usable fibre, equivalent to 2,903,000 bundles. Assuming 240,000 bundles extracted per year for those villages (1998-1999; Luckert *et al.*, (in prep), the total of fibre obtained based on the harvested patches corresponds to a period of about 12 years.

Bark regeneration rates after harvesting and fibre quality

An important consideration about bark harvesting is whether and how the tree regenerates or replaces lost bark, and at what rate. Unlike most trees that regenerate bark slowly from the vascular cambium on the margins of the wound, baobab bark is produced from parenchyma cells underneath the surface of the exposed xylem. This peculiar mechanism of baobab bark regeneration was apparently first described by Fisher (1981). The same regeneration process occurs in baobab trees severely damaged by elephants where bark was observed to re-grow at a depth of 1 m inside the xylem (F. Putz and C. Romero, pers. obs).

Local informants claimed that bark removed from the same area of the stem could be re-harvested after a recovery period of two years, or three during drier periods. A similar time period for bark regeneration was suggested for baobabs in Tanzania (Nkana and Iddi, 1991). These estimates contrast markedly with the 10-year regeneration-period reported by Matose and Clarke (1991) during their survey in the Birchenough Bridge area, south of this study site.

The rate of bark regeneration after harvesting was estimated by returning to a separate experiment initially set up by B. M. Campbell in 1995 in Jinga village, in the northern boundary of the study site. Ten trees were randomly located and their bark was harvested annually. Bark was harvested by removing rectangular pieces with a mean area of 1457 cm^2 (max: 2618 cm^2; min: 450 cm^2; SD: 447.7; n=50). Annual measurements included dbh, height, length, width, and depth of the harvested patch.

Regenerated bark from the scars on the experimental trees was harvested in May 1999. Bark thickness was measured with a Suunto gauge before bark was removed, and then separated into usable and non-usable fractions. The material harvested was air-dried in a glass-house and then oven-dried at 80° for 72 hrs before weighing.

For the following data analyses, bark thickness with values equal to zero (n=4) were excluded, on the basis that these values were obtained from scars that did not regenerate any bark. The relationship between bark thickness (in cm) and time since harvest was examined through regression analysis. The resulting equation was:
Log_{10} bark thickness = 0.386 Ln (years after harvest) - 0.1783 (R^2= 0.4562; F=22.1; df = 1,35; p<0.001; Figure 4).

According to this equation, harvested patches on baobab trunks recover to their pre-harvesting bark thickness after 6 years. The current bark thickness, four years after harvesting, was only 47.6% of the non-harvested bark thickness. The mean rate of bark regeneration was 0.67 cm/yr (max. 1.5 cm/yr; min. 0.1 cm/yr; SD: 0.30; n=36), and did not vary significantly over the four year period (p>0.05).

The regression equation (of arcsine transformed data) predicted that the proportion of usable bark observed on previously unharvested trees (31.4%) would be attained 9.7 years after harvesting {arcsine %usable bark = 0.0691Ln(years after harvest) + 0.0393; R^2= 0.1732, Figure 5}. The annual rate of increment in bark thickness did not vary significantly with time after harvesting (p>0.05). Mean % usable bark for four years after harvest was only 51.7% of the amount of usable bark from non-harvested trees. These data correspond with the perception of some harvesters, who suggested that there is a positive relationship between fibre quality for weaving and recovery time after bark harvesting (Mukamuri and Kozanayi, (in prep).

Management considerations and sustainability of bark use

Local perceptions about the management of the resource

Many local villagers were pessimistic about future availability of baobab bark. Their arguments were based on the lack of tree recruitment due to browsing by livestock. The following management strategies were suggested by male members of the communities.

- Increase availability of formal employment so as to reduce the number of families forced to depend on the income derived from crafts-making for their livelihoods.
- Increase access to irrigated agriculture to increase household incomes.
- Establish exclusion plots in the area so as to give saplings a chance to grow without being browsed. These plots should be removed after the baobab trees are large enough to withstand or avoid browsing, and located in areas with high saplings densities. It was felt that it was not necessary to plant additional trees, and de-stocking was not an option because of the value of livestock.

The female members of the communities, in contrast, did not perceive a need to implement any management strategies to secure or enhance the baobab resource base. They believed that continual replacement of older craft-makers by younger ones would ensure a sustainable level of harvesting, implying that the number of craft-makers would not increase.

The Chimanimani Rural District Council has drafted bye-laws prohibiting baobab bark harvesting but it is felt that the rules can only be effective if enforced by the traditional leaders. All villagers agreed that harvesters are not able to regulate use by themselves.

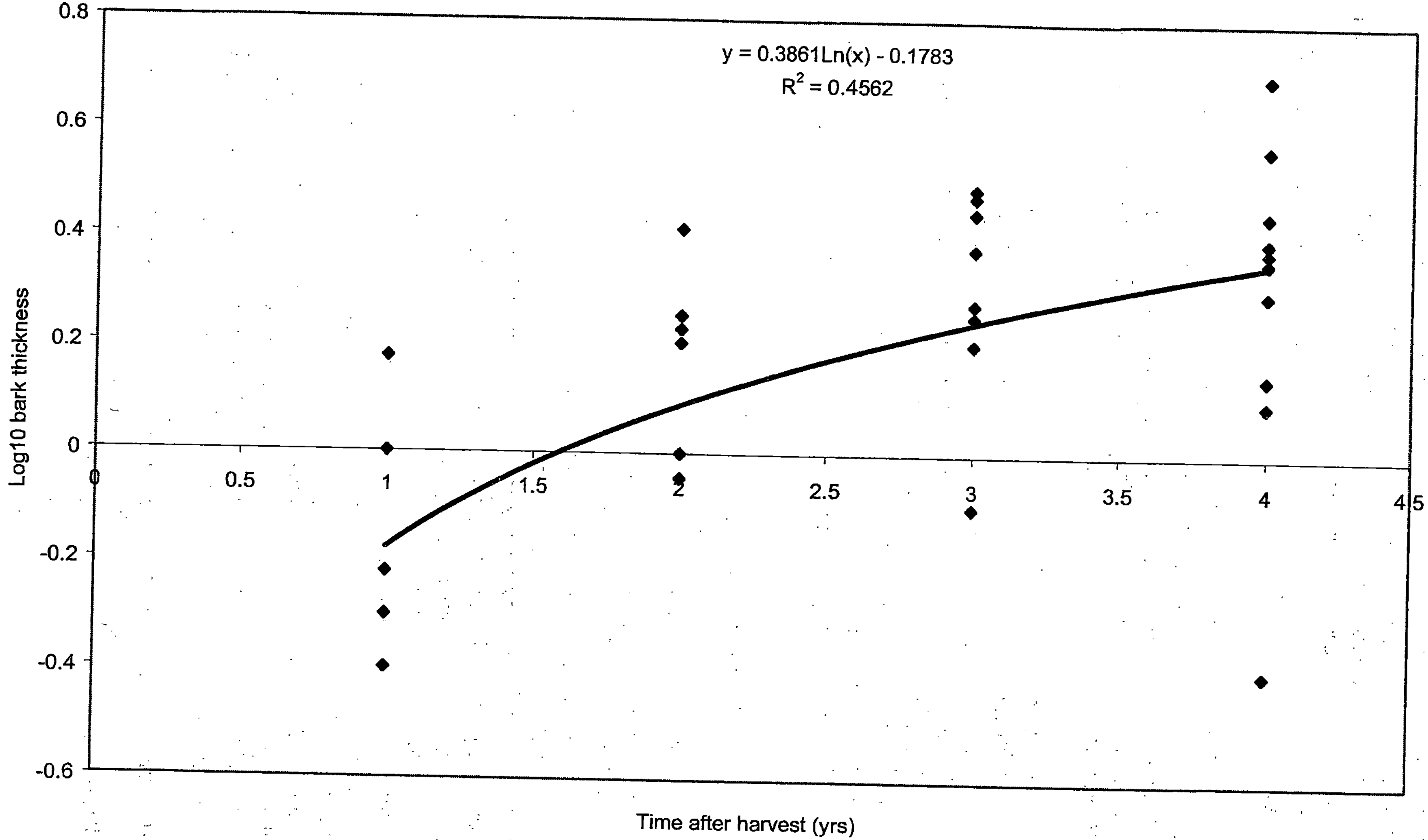

Figure 4: Relationship between regenerated bark thickness and time after harvest for 10 trees in Jinga village, in the northern boundary of the harvesting area of the villages of Mutsiyo, Nhachi and Gundyanga (eastern Zimbabwe).

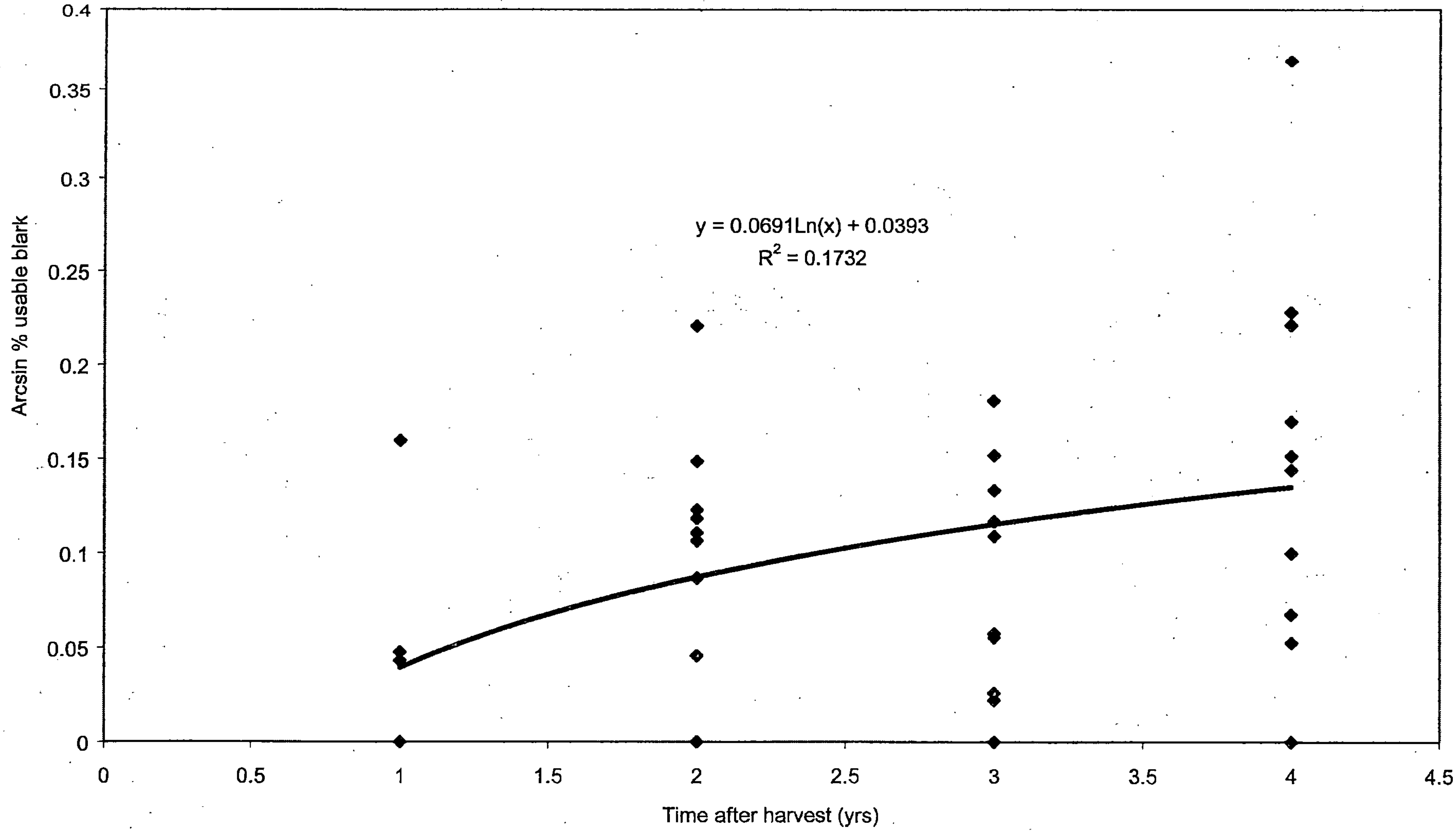

Figure 5: Relationship between % usable bark and time after harvest for 10 trees in Jinga village, in the northern boundary of the harvesting area of the villages of Mutsiyo, Nhachi and Gundyanga (eastern Zimbabwe).

Prior to intensive harvesting of baobab bark for commercial purposes, local people used to make similar handicrafts from the soft fibres of the succulent *Sansevierria pearsonii* ("mutsaa"; Mukamuri and Kozanayi, (in prep). Because of its slow growth and the fact that people uprooted the whole plants when harvesting, this species became scarce and people turned to baobab as an alternative. According to harvesters, baobab produces better quality fibre than "mutsaa", and is easier to process. For example, "mutsaa" requires initial soaking in a river for several days, which reportedly resulted in the poisoning of fish.

In some parts of the study area, where harvesting levels are high, there is a perceived shortage of baobab bark for craft-making. Nevertheless, people are reportedly looking for alternative sources of fibre. Many people reportedly believe that "the trees were given by God and that God will provide an alternative when the need arises."

Moving to local management of the baobab bark resource

Baobab bark in the study area seems to be regarded as a common property resource (CPR). There are apparently contradictions regarding the use of the resource. In some instances when rules are established, there is lack of appropriate enforcement (Nhira *et al.*, 1998; Mukamuri and Kozanayi, (in prep). If baobab bark is to be managed as a CPR, then the responsibility of its management should go to the local communities and their institutions, with the collaboration of the governmental agencies (e.g. Forestry Commission). Efforts to sustain the resource can be achieved within a framework of adaptive management, which has proved successful in several other situations (Walters and Holling, 1990) The delegation of the right to manage baobab bark resources to the communities needs to be accompanied by the acceptance of associated responsibilities as well. Several authors have identified this empowerment as a condition to obtain effective commitment from local stakeholders to conservation and sustainable management, particularly in those situations where there is insecurity of tenure (Lynch and Alcorn, 1994; Neumann, 1996; Ham and Theron, 1998).

Successful collective management proposals can be possible when specific conditions are met. Among these conditions, there are: the right to self-organize; the clear recognition of resource boundaries (i.e. harvesting areas for each village); the existence of rules that are clear and dynamic; the fact that rules are enforced; and finally, that there are established mechanisms for conflict resolution (Pinedo-Vásquez *et al.*, 1992; Pretty, 1994; McKean and Ostrom, 1995).

Bark availability

One way of establishing how much bark is available for harvesting is by evaluating the potential production from bark regenerated after previous harvests (regenerated bark) and the stock from patches that have never been harvested (virgin bark).

Regenerated bark

The estimates of the volume of regenerated bark were based on data shown in Table 3. Instead of using a different mean thickness value for each dbh-class, it was assumed that the scars in the harvesting area had all been harvested 2 years ago. It was also presupposed that bark regeneration rates did not vary with dbh (mean bark thickness for 2 year post-harvest period according to the regression equation = 1.15 cm;). The formula used to estimate the total volume of bark regenerated in the 42 km^2 harvesting area applied to establishing bark extracted in the harvesting area, as well as the mass-to-volume conversion factor.

To calculate the weight of usable fibre that could be obtained from all of the regenerated patches of bark (Table 3, line 7), the mean proportion of usable bark obtained from the regeneration experiment was used (i.e. 7.8% after 2 years; N=10). The 42 km^2 harvesting area has 66.3 Mg of usable fibre coming from previously harvested patches (277,300 bundles). This value is roughly the same as the harvest of 1998, as estimated by Luckert *et al.* ((in prep); i.e. 240,000 bundles).

Virgin bark stock

To estimate how much bark was available for harvest from trees that showed no signs of having been previously harvested (Table 3, line 9), the same formula to calculate volume of bark as adopted in the previous subsection was used, replacing the bark thickness values with the observed bark thickness data. The height data utilized are from the tree density plots in which it was established that the maximum potential bark height was up to the first branch (Table 3, line 8).

The weight of bark that can be obtained from virgin sections of the boles in the harvesting area is 1,999.8 Mg. From this value 628.7 Mg are usable fibre (31.44%; mean of proportion of usable bark in trees never harvested; N=14). The number of bundles that could be obtained is therefore 2,630,544.

The total weight of usable virgin and regenerated fibre that could be harvested at one time from the 42 km^2 study area is therefore 694.6 Mg, or 2,906,276 bundles. This value is slightly higher to what was estimated as harvested (i.e. 2,400,000 bundles) over the ten years prior to this study.

Sustainability of the resource and management

From the results presented in the above sections it is clear that the harvest of regenerated bark could barely provide the current annual needs of fibre (240,000 bundles/yr). The major limitation for using regenerated bark, in spite of the assumption that such bark was harvested 2 years earlier, would be time to generate pre-harvest conditions for bark thickness (6 years) and fibre quality (10 years).

There could be sufficient fibre from virgin bark to provide harvesters for another 12 years, provided that the same rate of harvesting would be maintained (i.e. no increase in the intensity of the activity), with no incidence of sooty baobab disease. After that period (i.e. year 13), the stock of regenerated bark could be partitioned into 12 years harvest, and get included into the harvesting cycles.

The concept of assigning a predetermined amount for the harvest of a forest product, and therefore, to limit the number of resource users, has been used successfully in other situations, such as the resources from the mangrove forest off Matang, Peninsular Malaysia (Gan, 1995). Notwithstanding, the implementation of a management plan would have to be based on strong community involvement and commitment.

As part of the management of a natural resource, there should be a close monitoring of bark regeneration rates (Peters, 1996), as well as an assessment of unexpected impacts of harvesting and other environmental factors (i.e. sooty baobab disease, drought). The results of these monitoring activities should be incorporated into the adjustment of the annual harvest and harvesting cycles, setting the basis for the adaptive nature of the management strategy. Given that sustainability is a concept grounded on a time scale (Noss, 1993), the fact that there is no current recruitment of baobab in the study area suggests that the resource cannot be managed sustainably in the long term. Since large part of the seedling mortality seems to be due to browsers and not to poor germination rates, there should be ways to elucidate a solution to that critical limitation.

As will be pointed out in the final section of this paper, there are more uncertainties to the management guidelines for baobab bark, than current knowledge. This situation indicates that resource managers should act with caution and responsibility, but nevertheless act: after all, sustainable use deals with making choices (Johnson, 1993).

Conclusions

> "Because the Forest Act of 1941 declared the baobab a reserved tree which was not allowed to be felled without the permission of the Minister, its conservation has been assured for posterity. The tree has no local economic value" (de Villiers, 1951, for South Africa).

The present document constitutes a step forward in the understanding of how the baobab bark resource is currently used in the Save-Odzi Valley. It would be plausible to predict that the future scenario of both the baobab bark resource base and the livelihoods of inhabitants of the Save-Odzi valley would be jeopardized, if no management actions were taken.

Conservation based on NTFP use has constraints as well as opportunities. A clear-cut boundary of these constraints and opportunities is likely to contribute to an efficient management of the resource, for the benefit of the communities involved in the resource use, and of the resource base. Communities in the Save-Odzi valley do indeed get a significant income from marketing baobab bark products (Luckert *et al.*, (in prep). This fact represents an opportunity, and should entice local residents to actively participate (i.e. design, plan and implement) in management efforts. Additionally, it was noted that local inhabitants were aware of the increasing scarcity of the resource, which could be a source of motivation for their commitment to a management debate.

The constraints include the lack of sufficient ecological information on which to base firm management decisions (e.g. harvesting cycles, sustainable yields); and the potential unwillingness of governmental institutions to collaborate and share the responsibility with local institutions on the management of the resource.

Further ecological information is required so that the response of the system to different harvesting regimes can be modelled (i.e. 40% of annual harvest coming from virgin bark and 60% from regenerated bark, so optimising the % usable bark). It would also be feasible to find the most efficient combination of proportions between regenerated barks and their ages and virgin bark to distribute the annual yield into individual harvests.

It is important to start a collaborative monitoring activity with harvesters and researchers to help clarify the impacts that bark harvesting might be having on baobab trees. Because some trees have responded to elephant damage by failure to produce mature pods, there could be other or similar responses to harvesting. A phenological study would help clarify this issue.

Additionally, there is the need to improve on establishment of plots for yield studies and regeneration surveys as well as harvest assessments and concurrent adjustments (Avery, 1983).

There does not seem to be an explanation for the possible relationship between harvesting intensity and presence of sooty disease. An important eco-physiological tool that could assist in understanding the effects of the disease would be studies on photosynthesis and respiration of baobab trees. By evaluating carbon allocation capacities in infected and healthy trees it may be possible to comprehend the etiology of the disease.

The situation described in the quotation included at the beginning of this section (de Villiers, 1951) certainly does not apply to the baobabs of the Save-Odzi valley. In order to sustain the population of these baobabs in face of continuous utilization as a livelihood strategy, an active and adaptive management appears to be an imperative option.

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