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Title: Productivity and abundance of *Sclerocarya birrea* subsp. *caffra* in and around rural settlements and protected areas of the Bushbuckridge lowveld, South Africa

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Productivity and Abundance of *Sclerocarya birrea* subsp. *caffra* in and around Rural Settlements and Protected Areas of the Bushbuckridge Lowveld, South Africa

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ABSTRACT

Sclerocarya birrea (A. Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro is a common species throughout the semi-arid savannas of southern Africa, and is sought after by rural communities. It is frequently maintained in homesteads and fields in an agroforestry situation. It has also been identified by a number of international and national institutes as a key species for domestication and commercialisation. Yet, the sustainability of the resource and local user knowledge and practices have not been considered. This study reports on the abundance and productivity of *S. birrea* in four rural villages and neighbouring protected areas in the Bushbuckridge lowveld of the Limpopo Province, South Africa, where its English common name is marula.

The density of marula stems was measured in homestead plots, arable fields and the surrounding communal rangelands of each village. Fruit production was assessed by regular counting of fruit fall from marked trees of known size. Within the villages, fruit production was monitored via local community groups. Additional monitoring of fruiting was conducted on marked trees within local protected areas. The proportion of households planting or nurturing marula trees was determined through interviews with a stratified random sample of households.

The density of marula trees was significantly higher in protected areas than the neighbouring communal lands, fields or homesteads. However, the majority of trees in protected areas were small, while those in homesteads were large and mature. Density of adult fruit-bearing female trees, was similar between the protected areas and homesteads, but less in fields and communal lands. *S. birrea* tree were maintained in 79 % of homesteads and 58 % of fields. Mean fruit yield per tree was significantly higher from village trees (> 17 000 fruits) than protected area trees (< 3 500 fruits), even after accounting for differences in tree size. The fresh mass of individual fruits was also greater on village trees than on trees in protected areas. Both these characteristics suggest some degree of historical selection of the trees in the homesteads and fields. There was a positive relationship between tree size and number of fruits produced.

Key words: fruit size, fruit yield, tree density, tree size

INTRODUCTION

Rural communities in developing nations make extensive use of fruits from the local environment (e.g. Campbell 1987, Shackleton *et al*. 2000). This may include both indigenous and exotic species. In many instances people plant, nurture or maintain individuals of the most desirable indigenous fruit species within homestead plots and fields in a typical agroforestry situation (Campbell *et al*. 1991, Grundy *et al*. 1993, de Jong 2001). Consumption of the fruits makes an important contribution to local diets and culture and the sale of fruits sometimes generates income, thereby having a poverty reduction role, especially for poorer households (Leakey & Simons 1998, Chivaura-Mususa *et al*. 2000). Fruit trees also offer other secondary goods and services directly used or appreciated by rural households - such as shade, firewood, mulch, and a habitat for other useful species such as birds and edible caterpillars.

Sclerocarya birrea (A. Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro (marula) is a common and widespread fruit-bearing species throughout much of southern Africa (Peters 1988). It is frequently a community dominant and, hence, a keystone species in plant and animal community ecology and productivity. It is also widely used by rural populations in most countries where it grows (Palmer & Pitman 1972, Walker 1989, Shackleton *et al*. 2000, Shackleton *et al*. 2002). It has multiple uses, including the fruits that are eaten fresh or fermented to make a beer; the kernels are eaten or the oil extracted; the leaves are browsed by livestock and they and the bark have medicinal uses. The wood is carved into utilitarian items such as spoons and plates, as well as decorative animal figures. Several African cultures have specific beliefs and ceremonies associated with this species (Walker 1989).

S. birrea has frequently been identified as a key species in the development of rural enterprises using the fruit, beer, nuts or oil and, therefore, as a species for accelerated domestication (Holtzhausen *et al*. 1990, Nerd & Mizrahi 1993, Leakey & Simons 1998, Leakey 1999). Localised breeding and cultivation initiatives commenced in the 1970s and some continue. Interest in this species was renewed after the development of a highly successful liqueur using extracts from the fruit. This interest has developed further in southern Africa over the last decade, especially commercialisation initiatives orientated towards benefiting the rural poor - in Botswana, Malawi, Namibia and South Africa. Many of these are externally supported, and the project designs frequently contemplate domestication of the species and planting with superior cultivars already available (at a cost) in South Africa (Leakey 1999). Yet, a significant proportion of rural households already plant marula trees or nurture seedlings of *S. birrea* that germinate in their homesteads or arable fields, and maintain adult trees in an agroforestry regime (Grundy *et al*. 1993, High & Shackleton 2000, Shackleton *et al*. 2000). Others plant seedlings or propagate trees via stem cuttings. The extent of these activities, the productivity of the individual trees, and the effects of selection and planting of more trees to optimise the most desirable traits have not been considered in these commercialisation initiatives. Because of this, the agroforestry potential of *S. birrea* remains appreciated but undeveloped. Hence the objective of one component of a recent, large multi-institutional research project was to quantify the local use, abundance and productivity of *S. birrea* in an area where commercialisation is accelerating.

STUDY AREA

Four rural villages and two protected areas were selected in the Bushbuckridge lowveld (31^0 0' - 35' E; 24^0 30' - 25^0 0' S) in Limpopo Province, South Africa. The villages were Allandale, Edinburgh, Hokwe and Rolle A, situated towards the centre of the region. The size of each village and surrounding grazing lands is:-

- Allandale 2 698 ha,
- Edinburgh1 869 ha,
- Hokwe 3 536 ha, and
- Rolle A 598 ha.

The protected areas were Andover Nature Reserve and Wits Rural Facility.

The Bushbuckridge region ($\pm$ 2 600 km^2) is characterised by a west to east gradient in topography, climate, and former political boundaries, which have resulted in several distinct landuse zones. Against the Drakensberg escarpment in the west, the mean annual rainfall (MAR) is approximately 1 200 mm, decreasing to 550 mm in the east across a linear distance of 100 km. Mean annual temperature is 22^o C, and frost is rare. Except immediately adjacent to the Drakensberg escarpment, the terrain is flat to undulating, being underlain by potassic granites and grandiorite. The most extensive soil types are shallow sandy lithosols, except towards the base of the catena where deeper duplex soils are common. Parallelling the rainfall gradient, two broad vegetation types are evident; Lowveld Sour Bushveld in the wetter west, grading into Lowveld towards the east (Acocks 1988). The tree stratum is dominated by members of the Combretaceae (*Terminalia sericea*, *Combretum collinum*, *C. hereroense*, *C. zeyheri* and *C. apiculatum*) and Mimosaceae (*Acacia nilotica*, *A. gerrardii*, *A. ataxacantha*, *A. caffra*, *A. sieberana*, *Albizia harveyi*, *Albizia versicolor* and *Dichrostachys cinerea*), although local dominance varies considerably.

The central portion of the Bushbuckridge lowveld is characterised by relatively high-density, underdeveloped rural villages. It was part of the former Lebowa and Gazankulu homelands under the apartheid dispensation. The human population density in the eastern section is approximately 150 – 200 persons per km^2, and double this in the west. Approximately 60 - 70 % of the potentially economically active population are unemployed. Nearly all households cultivate small areas around the homestead during the rainy season, and 40 - 60 % of households also cultivate demarcated arable fields on the periphery of the village or further afield (Shackleton & Shackleton 2002). Approximately 14.7 % of the area is under residential land with an associated garden plot; 7.5 % is under demarcated arable fields, and the remainder (77.8 %) is zoned as communal grazing areas (Pollard *et al*. 1998). Most households harvest several different kinds of resources from these communal lands, including fruits, thatch grass, fuelwood, mushrooms, reeds and construction wood as an integral part of their livelihoods (Shackleton & Shackleton 2000). Fuelwood is the primary energy source of over 85 % of households (Banks *et al*. 1996), although a considerable mix of other fuel sources is used. Approximately one-third of households possess cattle, and the stocking rate is close to the zone's ecological carrying capacity (Parsons *et al*. 1997). Stocking rates of indigenous game in the two protected areas are negligible relative to the norm for the region.

METHODS

Planting and care of *S. birrea* stems

Structured interviews were conducted in the vernacular language (Tsonga), with 36 households, selected in a stratified (each village was divided into four segments to ensure spread throughout the village) random pattern per village, giving a total 144 interviews. The interview schedule covered a number of aspects relating to the use and processing of marula (summarised by Shackleton & Shackleton 2002), as well as planting activities and practices relating to the care of self seeded or planted trees. Additionally, two group workshops were held at Hokwe (27 participants) and Allandale (35 participants) to explore in a semi-structured fashion issues relating to tenure, access and controls over the use of *S. birrea*, and to follow up uncertainties raised during the structured household interviews.

Density of *S. birrea* stems

The density of all *S. birrea* trees, irrespective of size, was measured during December 2001 and January 2002 in homestead plots, arable fields, communal grazing lands, and, as a comparison, in the two local protected areas (i.e. at four land uses). A proportion of *S. birrea* trees (especially smaller ones, but not solely) are multi-stemmed thereby giving problems as to what comprises a single individual. Consequently, we counted and report upon stems per unit area, as opposed to individual trees.

Stem density in each homestead plot was determined in the same households per village used in the interview survey, except where tree measurement was not possible. The total sample of homestead plots was 99. The height and basal circumference (at 30 cm above ground level) of each stem were recorded, and whether or not it had fruit (or, if no fruit that season, did it sometimes bear fruit). Basal circumference was used in preference to girth at breast height since many stems were shorter than breast height, or divided below breast height. Homestead plot size was also measured in order to arrive at density of stems per hectare.

Thirty arable fields were randomly selected per village, giving a total sample size of 120. The size of each field was determined, as were the number and size of each tree. Only every second tree growing within the fence of the field was counted to ensure there was no double counting when adjacent fields sharing a common fence were enumerated. Stem dimensions and fruiting were measured as above.

The communal grazing lands around each village were sampled using four transects radiating out from the village to account for possible differences in stem density with decreasing levels of disturbance or harvesting (Shackleton *et al*. 1994). Each transect consisted of four 1 ha plots placed 300 to 500 m apart, resulting in 16 plots per village. At Rolle A the communal lands were so fragmented by houses and fields that only three transects were possible, and nor were the plots arranged in a linear transect. Thus, the total sample size for the four villages was 60 plots. The total area of land per village was determined from 1: 50 000 map sheets. Boundaries between settlements are not strict, but the high human population densities mean functional boundaries are more or less midway between adjacent settlements.

The density of stems in two protected areas was determined to provide a benchmark. In each protected area 25 plots of 0.2 ha were randomly located, providing 50 plots in all. A smaller plot size was used because of the greater overall density of trees and shrubs making sampling slower and more difficult than in the communal grazing lands.

Fruit yield

Fruit yield per adult female tree was determined within homestead plots, fields, and the two protected areas. It was not possible to monitor fruit yield in the communal lands since there was no tenure over specific trees, and thus harvesting of fruits from specific trees would have been difficult to monitor or control. The trees monitored at Wits Rural Facility were the same as those monitored by Shackleton (2002) in 1993, plus ten additional ones.

Fruit yield was determined by permanently marking a sample of trees, and counting fruit fall at each tree throughout the fruiting season. In villages, the monitoring was done at selected households by volunteers with support from the research team, after initial training. Researchers then met with each volunteer group on a weekly basis. The process went well except at Rolle A, where compliance with guidelines and attendance at meetings was poor, thereby introducing some element of doubt regarding the veracity of the results from Rolle A. In protected areas, monitoring was done by the research team with assistance from locally hired participants. Fruit yield was not determined at Edinburgh village because of a strong localised storm in late December that blew off much of the immature fruit, uprooted trees and damaged buildings. Trees were marked at Madile village instead. Up to twenty fruits were randomly selected from each tree and their fresh mass determined. The dimensions of each monitored tree (total height, height of canopy base, basal circumference, canopy spread as the diameter of both the long and short axes of the canopy) were determined. Canopy volume was calculated as the area of an ellipse (using the dimensions of the long and short axes of the canopy spread) multiplied by canopy height.

Most *S. birrea* products are derived from the fruit, and hence the density of adult female trees is of greater significance than total tree density. This requires definition of what is an adult tree (i.e. potentially could bear fruit), and what is female. In this study we defined a female tree as one that had fruit during the season of the study, or if no fruit was apparent, the tree was reported by local respondents to sometimes bear fruit, or had evidence of old kernels beneath the tree. Since juveniles do not bear fruit, we also had to differentiate adults from juveniles for data analysis. This was done by ranking all the trees on which fruit were recorded (582), and calculating a mean stem size for the smallest 5 % (29 stems) of these trees This gave a value of 42.8 ($\pm$ 2.5) cm basal circumference, which was then used to differentiate adults from juveniles. The smallest tree of all with fruits was 15 cm circumference, but the majority of the smallest 5 % were between 40 and 60 cm basal circumference.

Data analyses

Differences between villages or landuses were examined via ANOVA after testing for normality. The number of fruits per tree was log transformed, and the tree basal area or canopy volume attributes were square root transformed. Pair-wise comparisons of significant parameters in the ANOVA were examined via the Least Significant Difference. A T-test was used to test differences between protected areas and village areas (pooled data for homestead plots, fields and rangelands). The size class profiles of adult stems in the communal lands and protected areas were compared via means of a Smirnov test. The relationship between fruit yield per stem and stem circumference was examined via linear regression.

RESULTS

Stem density

The density of S. *birrea* stems varied with landuse, being greatest in the protected areas, and least in the agricultural fields (Table 1). The absolute density of female trees showed no difference between homestead plots and the wild populations in protected areas, with both having approximately 4.5 adult females per hectare. Only adult or female stems, presented a different picture. A greater proportion of the population of female adults was in the largely human modified environments, namely homestead plots and agricultural fields, with approximately 40 - 50 % lower density of adult female trees in fields and the surrounding communal grazing lands. This indicates reduced recruitment in these two environments, but a high proportion of potentially useful trees.

INSERT TABLE 1

Differences between villages were most marked in the fields and communal lands, especially in terms of the density of adult female trees, but the difference was only statistically significant so in the fields (Table 2). Edinburgh tended to have the greatest density of adult female trees. The total density of trees, and adult females increased with increasing distance from villages (Figure 1). Differences were not significant, but might be revealed so with a larger sample as the pattern was replicated across the three villages (Rolle A was not tested due to fragmentation of the communal lands).

INSERT TABLE 2

INSERT FIGURE 1

Fruit yield per tree

The average number of fruits per tree varied between trees, villages and landuses. Trees within the villages had significantly more fruits (>17 000 per tree) than those in the protected areas (<3 500 per tree) ($t = 12.5$; $p < 0.005$). There were also differences between the four villages, with the mean number of fruit per tree at Rolle A being almost three times that of the other villages (Table 3). In light of the data collection problems at Rolle A (see Methods), this result needs to be treated with caution. Omitting Rolle A from the analysis, still resulted in significant differences between landuses and between villages (Table 3).

INSERT TABLE 3

Although the trees in the villages were significantly larger than in the protected areas (mean circumference of monitored trees in villages and protected areas were 211.1 $\pm$ 5.7 cm and 141.7 $\pm$ 7.2. cm, respectively ($t=7.63$, $p < 0.001$); and corresponding values for tree height were 11.1 $\pm$ 0.3 m and 7.8 $\pm$ 0.3 m ($t= 8.36$; $p < 0.001$)), this difference was not solely accountable for the greater number of fruits per tree. Yield (in terms of number of fruits) was significantly higher in the villages than the protected areas on both a per unit basal area ($t = 9.8$; $P<0.001$) and canopy volume ($t = 6.4$; $p < 0.001$) basis. Thus, a cubic metre of canopy produced more fruits in the villages, than in the protected areas. This applied even if the data from Rolle A village were excluded (Table 4).

INSERT TABLE 4

There were significantly different size class profiles of adult stems in the communal lands relative to the random plots in the two protected areas, indicating a tendency towards larger trees in the communal lands (Table 5) (Smirnov statistic = 0.15; $p<0.001$). There was also a positive relationship between stem circumference and fruit yield from the marked stems, with different relationships derived for the trees monitored in protected areas and those monitored in homesteads and fields. The summarised form of these relationships were:

Village trees: *Log(No. of fruit) = 0.0039 (circum.) + 3.582* ($r^2 = 0.15$; $n=86$; $p<0.005$)

Protected areas: *Log(No. of fruit) = 0.0051 (circum.) + 2.359* ($r^2 = 0.16$; $n=62$; $p<0.001$)

The low r^2 values indicate a large degree of variation that is not explained by the stem circumference variable.

INSERT TABLE 5

Parallelling the differences in number of fruit per tree at the four villages and protected areas, so too were the significant differences in the mean fresh mass of individual fruits. In particular, fruits from trees at Hokwe were heavier than individual fruits at the other three villages ($F_{5, 2621} = 91.3$; $p<0.001$) (Table 6). In comparing fruit size on trees in the villages relative to the protected areas, they were approximately 20 % larger on the village trees (T = 15.2; p<0.001), except at Madile, where they were of a comparable mass. The mean fresh mass of a single fruit across all village trees was 24.9 $\pm$ 0.19 g, and only 20.9 $\pm$ 0.18 g for the protected area trees. There was no relationship between mean mass of individual fruits per tree and the total number of fruits produced per tree, for either the village trees (r^2 = 0.02; n = 74) or the protected area trees (r^2 = 0.04; n = 60).

INSERT TABLE 6

Tree planting and care

The higher density of adult female trees in homestead plots is probably a result of active planting of new trees, as well as passive protection and nurturing of self-seeded recruits (Table 7). Just less than one-third of respondents planted *S. birrea* in their yards, whereas approximately half the respondents nurtured new seedlings that they found growing in suitable positions in the home yard. When planting, most people used a seed that was harvested from trees in the wild or from neighbours' trees. Many also used either a truncheon harvested from a tree with desirable traits, or transplanted a seedling they had observed growing in the wild or elsewhere in the village.

INSERT TABLE 7

DISCUSSION

S. birrea products are widely used by rural households in the Bushbuckridge region (Shackleton *et al*. 2000, Shackleton & Shackleton 2002), supporting findings for this and other fruit species elsewhere (Campbell 1987, Cunningham 1988, Grundy *et al*. 1993). Over three-quarters of households use *S. birrea* trees for firewood, fruit and kernels. This region supplies *S. birrea* fruit and kernels to a number of externally mediated commercialisation initiatives, and growing small-scale, household-level commercialisation, especially of beer (Shackleton & Shackleton 2002). Thus, there is the potential for conflict if supply does not meet the already high local demand for *S. birrea* products. This is perhaps already apparent; 36.5 % of the interviewed households with adult female *S. birrea* trees in their yards or fields stated that theft of fruit from their trees was a growing phenomenon, but was unheard off until only a few years ago. Conflict is also apparent at an institutional level, with some local village headmen barring villagers under their jurisdiction from participating in commercialisation activities using *S. birrea* or *S. birrea* products. This is because, they argue, it undermines traditional norms and the cultural value of this species, and may reduce the availability of *S. birrea* products (especially beer) to local users. The felling and pollarding of live *S. birrea* trees and branches for firewood adds to the pressure on local resources and raises the possibility for conflict. Chopping of *S. birrea* trees is reasonably common, although many households would not admit to it, since traditional norms prohibit the felling of fruit trees. However, these norms are eroding in much of the communal management areas of South and southern Africa. In most instances it is the male *S. birrea* trees that are felled. If female trees are felled it is generally ones with undesirable fruit. This increases the proportion of trees with desirable traits, and is a form of selection. The cutting of male trees has been, until recently, actively encouraged by government extension officers, with little regard to the other agroforestry related benefits that large male trees offer to the environment as a whole, enhancement of agricultural production near the tree, nor the need for males to pollinate the female trees. A declining density of male trees has implications for pollination success, which according to Leakey *et al*. (2002) already seems less than optimal. A similar situation was reported in Zimbabwe with agricultural extension officers urging small-scale farmers to fell all indigenous trees within the fields and homestead plots (Campbell *et al*. 1991, Chivaura-Mususa *et al*. 2000). During the community workshops at Allandale and Hokwe many respondents stated, incorrectly, that there was no need for the male trees, and that the female trees will fruit even without male trees. Workshop participants also reported having seen locals cutting branches of trees while harvesting edible caterpillars. Overall, there was a perception at the workshops that the density of marula trees was declining, although the responses during the individual household interviews indicated little unanimity around this.

The local appreciation of *S. birrea* as a key species is also evident in the proportion of households that have *S. birrea* trees in their homesteads and/or fields, 78.9 % and 58.2 %, respectively. Most households in the region have at least one tree in their homestead, and *S.*

birrea is the most favoured indigenous species (High & Shackleton 2000, Paumgarten 2002). The presence of useful trees at most homesteads and fields is common throughout sub-Saharan Africa (e.g. Rugalema *et al*. 1994, Price & Campbell 1998, Gray 1999, Mortimore *et al*. 1999, Mbwambo 2000). The density of adult female trees in the intensively human-modified area around the house is no different from that in local protected areas. Conversely, there was a lower density of female *S. birrea* trees in fields and the surrounding communal lands. With increasing risk of theft of fruit, it is possible that people will channel most investment in *S. birrea* into the homestead plot, rather than the fields which are more distant and therefore harder to police. These results are comparable to those from unpublished data from Mozambique and KwaZulu-Natal Province in South Africa which also show that densities of *S. birrea* were not reduced, and in many areas were greater in anthropogenic landscapes than adjacent rangelands (A.B. Cunningham (WWF/People and Plants Initiative), Sept 2001, pers. communication). Many respondents stated that they would now plant more trees at home because of the new commercial opportunities offered by a local development project for raw fruit and kernels.

Over half the households reported nurturing self-seeded trees to increase the likelihood of survival to maturity. Almost one-third of the households indicated that they have actively planted *S. birrea* trees around their home, or in their fields. New plantings are also nurtured to maturity. Campbell *et al*. (1991) cite a number of studies in Zimbabwe reporting active tree planting by over 60 % of rural households. Such activities are common and have been reported from throughout the subcontinent, especially as human populations increase and rangelands decrease (e.g. Mbwambo 2000, Paumgaretn 2002), although elsewhere, historical contexts have been shown to be important, especially settlement and environmental history (Walters *et al*. 1999). Nurturing may take the form of watering the new plant, protecting it from browsers or being trampled by animals or humans, and clearing of weeds or climbers that may impair growth. Fertilisation was not mentioned. Using a seed from a female tree with desirable traits was the most common mechanism of direct planting. Traits considered desirable included productivity of the tree, and the size, hardness, juiciness, taste, and smell, of the fruit.

Given the amount of care and attention afforded *S. birrea* it was of little surprise to see that trees in the villages produced more fruit relative to their size than trees in protected areas. It may also be related to reduced plant competition for trees in homesteads as opposed to ones in the wild. This conclusion was unaffected by omitting the data from Rolle A village, where it is possible the results were erroneous. Additionally, the mean fruit size was significantly greater from trees in villages than the local protected areas. Both these traits suggest some level of domestication and selection of *S. birrea* by residents in the Bushbuckridge region (Leakey & Tomich 1999), as supported by preliminary examination of *S. birrea* fruit characteristics and variation within the Bushbuckridge populations (Leakey *et al*. 2002). This conclusion could be further supported through assessment of the proportion of trees with the desirable traits within the village populations relative to those within the protected areas. It would be consistent with the hypothesis for the protected area populations to have a greater proportion of female trees with undesirable fruit characteristics than village populations (and perhaps communal grazing land populations). Whilst sample trees from neither population were randomly selected, there is little reason to doubt the results. The patterns were consistent across all the villages and both protected areas. Local residents volunteered to help monitor fruit production without tree size of any other attribute being a criterion for participation.

The combination of heavier fruit mass and greater number of fruits per tree means that trees within the villages have a significantly greater mass of fruit than trees in protected areas. Shackleton (2002) recently reported a mean fruit production in the 1993/94 season of 37 $\pm$ 7.8 kg per tree from 64 trees from three protected areas in the same region, casting doubts on anecdotal reports of more than a ton of fruit per tree. Todd (2001) reported even lower yields, with a mean of 17.4 kg per tree across 122 trees. Within this new study, however, there were many trees within the villages that produced over one ton of fruit. The mean mass per tree was greater than one ton at both Allandale and Rolle A. In comparison, the mean mass of fruit per tree at the two protected areas was one or two orders of magnitude lower; 73 and 56 kg at Andover Nature Reserve and Wits Rural Facility, respectively.

From the above data, the total 2002 yield of fruits at Allandale, Edinburgh and Hokwe was over 500 tonnes of fruit per village. It was substantially less at Rolle A because of the smaller available area. However, this would meet only 55 - 70 % of the calculated demand based on respondent questionnaires and recall of amounts used for a range of purposes (Shackleton & Shackleton 2002). Yet, most respondents felt that there was sufficient fruit for all that wished to collect (Shackleton & Shackleton 2002), although sometimes respondents had to go out early in the morning. Thus, calculations reflecting a deficit do not adequately reflect current reality. The calculation of supply per village were most sensitive to inaccuracies in the area of land under communal grazing, and the yield per tree in the communal grazing lands. Despite the higher yields per tree in residential areas and fields, the small proportion of the total land area under these two lands uses meant that overall supply was most sensitive to communal grazing land attributes (area, density and fruit yield). Yet, yield per tree was not determined from this land use, and the proportion of land at each of the four sample villages was taken as composite figure for the region.

It is clear from the results of this study that trees in residential areas and fields have a significantly higher yield than wild population trees. The same may apply to a proportion of the communal grazing land trees as well. This initially seems unlikely, but is possible on the basis of two reasons. First is the significant resettlement of households in the region under government driven betterment planning of the 1960s and 1970s. Thus, "selected" trees growing in homesteads at that time were abandoned as homesteads were consolidated into betterment villages. These high yielding trees are now part of the communal landscape and have also provided a seed source for potentially higher yielding recruits around them. Second, is the finding that communal land trees are larger than the ones monitored in the two protected areas (due to decreased competition and increased resources as the density of woody biomass is reduced). Larger trees bear more fruit (Shackleton, 2002), thus, the use of fruit yield data from the protected area trees to represent 'wild' communal land trees results in underestimates of total production for the communal grazing lands. Thus, it is probable that the communal grazing land trees had a higher yield than that used in determining total supply per village, based solely on their larger size. This uncertainty needs to be addressed and appropriate monitoring done. The total yield also needs to be adjusted by the proportion of adult female trees that bear fruit with undesirable characteristics, such a being too dry, too hard, or of unpleasant taste. The workshop participants suggested that it was only 10 - 20 % of female trees.

This paper reflects yield data for the 2002 season alone. There are very limited data regarding the variability in fruit yield between seasons. Both Shackleton (2002) and Todd (2001) found marked differences in fruit yield between years, each based on a separate two year study. Respondents at the Hokwe workshop perceived a marked biennial fluctuation in fruit yields. Those at Allandale reported marked differences in yield from year to year, but that this did not follow a biennial pattern. The existing qualitative and quantitative data are of insufficient duration to make sound recommendations and populate descriptive spreadsheet models. A more long term study of fruit yield of marked trees is required, probably spanning five to ten years to allow for adequate variation in rainfall.

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CAPTIONS TO FIGURES

Figure 1: Density of all stems and adult females (x 10) in communal lands, relative to proximity to human settlement.

Table 1: Density of *S. birrea* under different landuses (Mean ± SE)

	Homestead yards	**Fields**	**Communal grazing lands**	**Protected areas**
Density (stems/ha)	10.8 ± 1.3	5.7 ± 0.5	61.3 ± 4.5	102.1 ± 10.2
% adults (≥ 43 cm circum.)	72.7 ± 3.6	73.9 ± 2.9	14.2 ± 2.1	13.1 ±5.9
% of adults that were female	58.1 ± 4.3	42.3 ± 3.0	34.1 ± 3.6	33.6 ± 5.9
Female density (trees/ha)	4.5 ± 0.7	2.0 ± 0.2	2.3 ± 0.3	4.5 ± 0.8

Table 2: Density of *S. birrea* within and around four villages (Mean ± SE)

Landuse	**Density**	**Allandale**	**Edinburgh**	**Hokwe**	**Rolle A**	**Signfic.**
Homestead yards	juveniles	7.3 ± 3.1	6.0 ± 1.7	3.2 ± 1.4	3.0 ± 1.1	F = 1.03
	adult males	1.6 ± 0.6	3.5 ± 0.8	2.2 ± 0.7	3.2 ± 1.3	F = 1.04
	adult females	2.9 ± 0.9	3.2 ± 0.9	3.2 ± 1.0	3.7 ± 1.5	F = 0.08
	all stems	11.9 ±4.0	12.7 ± 2.2	8.5 ± 1.8	9.4 ± 1.8	F = 0.57
Fields	juveniles	1.4 ± 0.4	1.5 ± 0.7	2.4 ± 0.8	2.1 ± 0.8	F = 0.42
	adult males	1.9 ± 0.4	3.1 ± 0.7	2.4 ± 0.3	2.0 ± 0.4	F = 1.35
	adult females	0.9 ± 0.3	2.5 ± 0.4	1.8 ± 0.3	1.9 ± 0.5	F = 3.28 *
	all stems	4.1 ± 0.8	7.1 ± 1.3	6.6 ± 0.9	5.9 ± 1.1	F = 1.50
Communal lands	juveniles	46.9 ± 9.0	47.8 ± 11.9	70.1 ± 15.8	57.2 ± 13.3	F = 0.76
	adult males	3.3 ± 0.6	5.6 ± 0.9	3.1 ± 0.7	3.4 ± 1.2	F = 2.14
	adult females	2.0 ± 0.6	3.8 ± 0.7	1.6 ± 0.5	1.9 ± 0.8	F = 1.50
	all stems	52.2 ± 9.4	56.7 ± 11.6	74.7 ± 16.1	62.5 ± 14.4	F = 0.59

* significantly different at 0.05 level

Table 3: Number of fruits per tree (Mean ± SE)

Village/protected area	No. of fruits	N	Significance
Allandale	44 200 ± 9 270	24	B
Hokwe	26 502 ± 3 961	18	B C
Madile	17 742 ± 3 251	23	C
Rolle A	115 399 ± 17 608	21	A
Andover	3 475 + 675	30	D
WRF	2 728 ± 842	32	D
Total	30 773 ± 4 265	148	($F_{5, 146}$ = 43.5; $p<0.001$)

Table 4: Number of fruits per cubic metre canopy volume (Mean ± SE)

Village/protected area	Fruit cubic metre of canopy volume	N	Significance
Allandale	59.6 ± 9.9	24	B
Hokwe	35.9 ± 5.3	18	B
Madile	34.2 ± 5.8	23	B
Rolle A	127.0 ± 25.2	21	A
Andover	9.2 ± 1.7	30	C
WRF	14.0 ± 3.6	32	C
Total	42.3 ± 4.1	148	($F_{5, 146} = 22.5$; $p<0.001$)

Table 5: Comparison of adult tree ($\geq$ 43 cm circumference) sizes in communal grazing lands and protected areas

	Communal grazing lands (n=342)	**Protected areas (n=113)**
Mean circumference (cm)	144.2	132.4
Median circumference (cm)	149	119
Mode circumference (cm)	48	43

Table 6: Fresh mass of individual fruits (Mean $\pm$ SE)

Village/protected area	**Fruit mass (g)**	**N**	**Significance**
Allandale	24.7 $\pm$ 0.32	443	B
Hokwe	28.9 $\pm$ 0.35	340	A
Madile	21.6 $\pm$ 0.34	360	C
Rolle A	24.8 $\pm$ 0.46	320	B
Andover	21.0 + 0.24	588	C D
WRF	20.7 $\pm$ 0.24	576	D
Total	23.6 $\pm$ 0.14	2627	($F_{5, 2621} = 91.3$; $p<0.001$)

Table 7: Proportion of households propagating *S. birrea* trees

	Allandale	**Edinburgh**	**Hokwe**	**Rolle A**	**Total**
% nurturing self seeded recruits	45.7	50.0	55.5	52.8	51.0
% planting new trees	37.1	22.2	27.8	33.3	30.1
Of those planting, Proportion using: - seed	42.9	50.0	50.0	33.3	44.1
- truncheons	28.6	25.0	30.0	16.7	25.1
- transplants	28.6	25.0	20.0	50.0	30.9
Proportion of households with at least one *S. birrea* tree in the homestead plot	68.6	77.8	86.1	82.9	78.9
Proportion of households with fields that have at least one *S. birrea* tree in the field	42.1	71.4	64.7	54.5	58.2