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Annual production of harvestable deadwood in semi-arid savannas, South Africa

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Abstract

The annual production of deadwood available for harvesting by hand was determined from 28 permanent plots over three years for three protected areas along a rainfall gradient. Annual production varied considerably for individual plots, but the mean production per woody standing biomass was relatively constant from year to year at approximately 17 kg/ha/year per ton live biomass, or 1.7% per annum. Annual production of harvestable deadwood was related more to stand biomass than rainfall zone. The relative consistency of production rates has positive implications for sustainable use and harvesting strategies. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

In Africa, and most other developing regions, fuelwood is the primary source of energy for rural communities (Eberhard, 1990; Hall, 1994). Deadwood is generally favoured over livewood for energy purposes (Shackleton and Prins, 1992; Clarke et al., 1996). It is also used for the manufacture of charcoal. Frequently, the high localised demand for deadwood in the immediate vicinity of settlements cannot be met, and rural communities resort to the harvesting of livewood to supply their energy needs (Grundy et al., 1993; Shackleton, 1994; Sundriyal et al., 1994).

Despite the high demand for and favoured status of deadwood over livewood, there is little understanding of the rate at which useful deadwood is produced. Its potential commercial value in unexploited areas is also not fully appreciated (Shackleton, 1996). Additionally, there is inadequate knowledge of the ecological role and value of deadwood as part of the biological system in most sub-tropical woodland areas, including semi-arid savannas, other than generalised statements regarding its significance in nutrient cycles and provision of nesting sites for hole-nesting bird species. These have been challenged in generalist terms by Shackleton (1994, 1996), but require detailed investigation. Mudekwe (1997) indicated that more than 77% (on a per tree basis) of the total deadwood standing crop was unavailable for

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harvesting by hand (without tools such as an axe or saw, or without machinery) because it was too big, too high or too small.

In areas of poor resource supply, formal multi-product agroforestry systems or intensified natural resource management systems are seen as possible approaches, within a broader suite of potential solutions, to over-exploitation of local resources. The production of fuelwood is frequently cited as a primary benefit accruing from such initiatives (e.g. Chidumayo, 1993). However, in the face of a scarcity of data pertaining to deadwood production, it is difficult to determine the true value of deadwood as part of the ecological system or its potential contribution to sustainable livelihoods. This hampers the opportunity to make objective recommendations concerning the circumstances and controls under which deadwood harvesting could be encouraged and managed. Consequently, this study sought to (1) estimate the annual production of harvestable deadwood, and (2) determine whether or not this was influenced by mean annual rainfall (MAR).

1.1. Study area

Three protected areas were selected along a rainfall gradient in the semi-arid lowveld, South Africa, straddling the boundary between Mpumalanga and Northern Province (24° 30′S; 31° 05′E). The north–south distance between the three areas is 62 km. The east–west displacement is 16 km. Altitude at all these sites is approximately 550 m above the sea level. All three sites are situated on weathered granites with isolated doleritic intrusions. Soils are generally sandy, although typical catenal sequences are evident at all three sites; upland soils are shallow, coarse-textured and dystrophic, whilst bottomland soils are deeper, finer-textured and more eutrophic.

Mean annual rainfall is the primary variable differentiating the three areas; arid area – ±500 mm p.a.; semi-arid area – ± 670 mm p.a.; mesic area – >850 mm p.a. Rainfall is concentrated in the summer season from October to April. The length of the rainy season increases with increasing MAR. Rain is received largely in the form of convectional thundershowers, although periods of prolonged cyclonic showers do occur.

The three areas fall into Acocks (1988) broad vegetation type of Tropical Bush and Savanna. More specifically, the arid area is classified as Arid Lowveld, and is dominated by species of the Mimosaceae family (especially *Acacia nigrescens*, *A. gerrardii*, *Albizia harveyii*, *Dichrostachys cinerea*), along with *Combretum apiculatum*, *Sclerocarya birrea*, *Ormocarpum trichcarpum* and *Grewia* species. Mean height of the canopy is 5–6 m (Shackleton, 1997). The semi-arid area is situated on the boundary between the Arid Lowveld and Lowveld Veldtypes. The woody stratum is dominated by Combretaceae species (including *Terminalia sericea*, *Combretum collinum*, *C. hereroense*), with *S. birrea* and *D. cinerea* also being significant contributors to the biomass. Mean canopy height is 6–7 m (Shackleton, 1997). The mesic area is situated on the boundary between the Lowveld and Lowveld Sour Bushveld Veldtypes (Acocks, 1988). It is dominated by taller (8–12 m), more broad-leafed species than the other two areas, namely *Pterocarpus angoloensis*, *Faurea saligna*, *T. sericea*, *C. collinum*, *Parinari curatellifolia* and *Dombeya rotundifolia*, along with *S. birrea* and *D. cinerea* (Shackleton, 1997).

All the three areas became protected areas sometime in 1950s and 1960s. Relics of human settlements (pot sherds, grinding stones, etc.) are to be found within each area indicating past human occupation, but there appear to be no macro-environmental disturbances resulting from these. Stumps of large trees of commercially valuable species such as *Pterocarpus angolensis* and *Combretum imberbe* are evident at the semi-arid area, and to a lesser extent, the mesic area. Informal comments by the local inhabitants suggest that at the semi-arid area these species were cut out to supply a local furniture factory. Low levels of timber extraction occur at the mesic area, as well as some selective removal of *Pterocarpus angolensis* by subsistence woodcarvers. Anthropogenic fires are common at the mesic area on an annual basis.

2. Methods

Twenty-eight plots of varying standing woody biomass were judgementally located within the three reserves of contrasting MAR. Twenty-four plots were 0.5 ha in area, two were 1.0 ha and two were 0.375 ha.

Local fuelwood harvesters were hired to clear all '*utilisable*' deadwood by hand from each plot at the end of winter (September) each year. Utilisable deadwood was all detached or attached deadwood occurring on the ground, or less than 2.5 m above the ground, with a stem circumference of greater than 5 cm, that could be broken off by hand and carried away. The initial clearance was in 1992 for the semi-arid area (10 plots), and in 1993 for the arid and mesic areas (nine plots each). After collection the wood was made into bundles that were weighed with a spring balance to the nearest 100 g. These values were totalled and the results expressed on a per hectare basis. Moisture content was not determined because (1) determinations were made at the end of the dry winter period, and (2) it was intended to carry the results through to consumption models that employed wet mass values (Griffin et al., 1992). Moisture content of deadwood under such conditions is 12% (South African Forestry Research Institute, 1976). The results are considered as underestimates of the actual annual production of deadwood because not all deadwood was considered as harvestable. Pieces that were too large to be removed by hand, too small to have any purpose, too high or to hard to break off were left in situ. General collecting height was 2.0–2.5 m.

In 1994 the circumference and height of all living stems within five transects (5 m wide) across the shortest axis of each plot were measured, and biomass calculated from the allometric equations of Rutherford (1979). Data were tested for normality and then differences between the rainfall zones were tested using ANOVA. Annual production of harvestable deadwood was related to standing biomass of each plot through linear regression.

3. Results

The mean annual production of harvestable deadwood was relatively constant from year to year across the different rainfall zones (Table 1). The semi-arid area had a lower production than the arid area in 1993/94, and was not significantly different in 1994/95. This is probably a result of the lower mean standing biomass at the semi-arid area. The two-way ANOVA indicated that neither differences between rainfall zones (($F=5.33$; d.f.=2; $p>0.05$) and years ($F=0.12$; d.f.=2; $p>0.05$) were significant, nor was the interaction between the two. Closer examination found that in the last year, mean yield was higher at the mesic area than either the arid or semi-arid areas ($F=3.91$; d.f.=2; $p<0.05$).

Annual production per plot was strongly related ($p<0.0001$) to the standing biomass at each plot across the entire sample (Fig. 1). Although, the yield for

Table 1
Annual yield of harvestable deadwood from three rainfall zones

Area		Mesic	Semi-arid	Arid
Mean annual rainfall (mm)		>850	670	500
No. of plots established		9	10	9
Wood harvesting history		Moderate	Negligible	Nil
Mean standing biomass (t/ha±SE)		25.3	14.4	17.7
		(5.3)	(3.1)	(2.5)
Mean mass of harvestable deadwood at initial collection (t/ha±SE)		895.5	303.5	994.9
		(116.7)	(61.2)	(139.3)
Annual harvestable deadwood production (kg/ha±SE)				
	1992/93	—	387.8	—
			(85.5)	
	1993/94	438.0^{a}	270.4^{a}	380.3^{a}
		(69.0)	(47.8)	(52.9)
	1994/95	455.8^{a}	353.6^{a}	343.7^{a}
		(62.3)	(55.4)	(63.2)
	1995/96	590.1^{b}	211.7^{a}	259.8^{a}
		(176.2)	(27.6)	(52.8)

Similar superscripts indicate no significant differences.

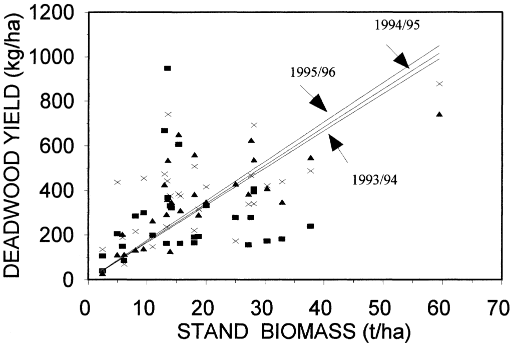

Fig. 1. Annual harvestable deadwood yield (wet mass) relative to stand biomass (▲ 1993/94; X - 1994/95; ■ - 1995/96)

individual plots varied by as much as 500% between years, the summary relationship across all plots was relatively constant from year to year, in the form:

$$\begin{aligned}&\text{Annual production of harvestable}\\&\quad = a \times \text{Standing biomass(t/ha)}\\&\quad\ \text{deadwood (1993/94)(kg/ha)}\end{aligned}$$

where

$$\begin{aligned}a &= 16.7(1993/94) \quad (r^2 = 0.87; p < 0.00001)\\&= 17.1(1994/95) \quad (r^2 = 0.81; p < 0.00001)\\&= 17.7(1995/96) \quad (r^2 = 0.56; p < 0.0001)\end{aligned}$$

The slope coefficient from the data set from the semi-arid area alone (n=10) for 1992/93 was 21.1 (r^2=0.65; p<0.005; n=10), not significantly different from the 17.2 derived for the data for all three areas in subsequent years. Adjusting for the 12% anticipated moisture content would decrease the value from 17.2 to 15.1.

4. Discussion

Deadwood is the result of mortality of individual stems or branches (Shugart, 1987; van der Meer and Bongers, 1996). Despite a variable environment, deadwood production was relatively constant from year to year. The same does not apply to live biomass production (Scholes and Walker, 1993; Shackleton, 1997). This suggests that the production of deadwood is controlled by factors other than those influencing productivity of living stems, for example fungal or microbial attack, insect infestation, wind damage or browser damage.

Deadwood production (wet mass) of 1.7% of standing biomass is less than the rate of production of living biomass in similar savannas (Scholes and Walker, 1993; Shackleton, 1997), leading to a net accumulation of standing woody biomass. However, the harvesting method, i.e. by hand, precluded a certain proportion of the annual production of deadwood from being collected. Pieces of wood that were too high to reach, too strong to break off, too big to carry or too small to be useful for fuelwood purposes were left in situ. Hence, the total annual production of deadwood is greater than that measured during this study. Additionally, a proportion has also been lost through comminution and decomposition between the sampling periods, although wood decays relatively slowly in these environments. Woody plant leaf litter lost 11–26% of its mass per year in a similar South African savanna, depending upon species (Scholes and Walker, 1993). Therefore, it can be assumed that losses from large pieces of deadwood would be in the order of 2–5% per annum, insufficient to alter the general findings of this study.

Comparative figures of harvestable deadwood production are not available. Litterfall studies concentrate on the smaller deadwood fraction, twigs and small branches. A few have included larger branches, but have not related production to stand structure or biomass. Moreover, the issue of harvestability is, by definition, not considered. Collins (1977) reported a wood fall rate for branches greater than 2 cm diameter of 682 kg/ha/year for a Nigerian savanna. This was 49% of the total wood fall. Malaisse et al. (1972) reported annual branch fall of 874 kg/ha in a Zairean miombo, but in another study reported a value of 4.4 t/ha/year (Malaisse et al., 1975). Alverez-Sanchez and Sada (1993) found 1.5 t/ha/year of branch fall in a Mexican lowland tropical forest. Deadwood production calculated as whole tree mortality from 51 permanent plots throughout the South African savanna biome was 1.2±0.32% in 1992/93, 2.2±0.6% in 1993/94 and 2.3±0.5% in 1994/95 (Shackleton, 1997). Extrapolation of the mortality data from Korning and Balslev (1994) from Amazonian tropical forests provides a figure of whole tree mortality of 1.9% of standing biomass per hectare. All these estimates include pieces of wood that would have been regarded as too big to remove in terms of this study. Therefore, it appears that an annual rate of deadwood production of 1.5–2.0% of standing biomass seems realistic from the data at hand.

A key implication of the apparent constant supply rate is the predicability for management purposes. More specifically, the possibility for sustainable harvesting of the deadwood component for a variety of purposes, such as fuelwood, curio pieces, florist decorations, charcoal production, and the like (Shackleton, 1996). The ecological consequences of deadwood harvesting are unknown. However, ensuring that harvesting is by hand would go a long way to ensure that some deadwood remains in situ to serve its broader ecological functions, such a nesting sites for certain bird species, micro-habitats for small vertebrates and invertebrates, nutrient recycling, micro-sites for seed germination, etc. Comparison of areas subject to unsustainable harvesting of wood (i.e. extraction of live and dead wood at rates greater than annual productivity so there is a declining standing woody biomass) relative to protected areas have detected little change in system attributes other than a declining above-ground biomass and stand structure (Chidumayo, 1993; Shackleton, 1993, 1994). However, du Plessis (1995) documented a possible decline in hole-nesting birds in areas subject to intense wood harvesting, which included removal live stems. In contrast, Johns (1996) recorded an increase in avifaunal species richness in logged forests relative to unlogged forests. Given that in these savannas (1) 50–80% of biomass is below ground (Scholes and Walker, 1993), (2) of the above-ground biomass, less than 10% is deadwood (Rutherford, 1979; Shackleton, 1993), and (3) less than 23% of deadwood is harvestable by hand (Mudekwe, 1997), the impact on ecosystem dynamics would probably be small, but requires further study, and would also be conditional upon the immediate management objectives for any specific area.

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