LONG-TERM IMPACT OF LEUCAENA-BASED GRAZING SYSTEMS ON SOIL ACIDITY

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ABSTRACT

Soil acidification and land degradation issues are assuming increasing importance in Australia and challenging the concept of sustainablity of current land management systems. In this study the impact of a 22 year old *Leucaena leucocephala* / *Urochloa mosambicensis* (Leucaena) pasture production system on soil acidification and selected soil chemical properties was compared to an adjacent *Urochloa mosambicensis* (Sabi) area. Significant acidification and cation depletion was observed to 70 cm under the Leucaena when compared to the Sabi system. The net acidification rate for the Leucaena system was estimated to be 2.73 kmol H^+ ha^{-1} yr^{-1} of which 0.17 kmol H^+ ha^{-1} yr^{-1} was estimated to have originated from animal product removal. These preliminary results bring into question the long-term sustainability of these legume based production systems.

INTRODUCTION

Unless nutrient removal by agricultural production systems are at the rate of natural biogeochemical weathering or supplemented by soil amendments, the net result is a depletion of nutrient reserves and soil acidification. The latter has developed over extensive areas of temperate southern Australia under what appeared to be stable ley pasture systems. In these production systems the decline in pH has been of the order of one unit over 50 years of pasture (Helyar and Porter, 1989).

Increased rates of acid input may not be confined to temperate pasture systems of southern Australia. Early evidence (M. E. Probert, cited by Williams and Chartres, 1991) indicated a significant decline in pH after 5 years under swards of *Stylosanthes* grown in the semi-arid tropics of northern Queensland on red and yellow earths (alfisols).

The objective of this study was to compare the impact of a long-term *Leucaena leucocephala* / *Urochloa mosambicensis* (Leucaena) pasture production system on net acid addition with that of an adjacent ungrazed *Urochloa mosambicensis* (Sabi) pasture.

MATERIALS AND METHODS

The study was conducted on a long-term Leucaena / Sabi grass grazing trial at the CSIRO Lansdown Research Station (19.5° S, 146.8° E), 50 km south of Townsville, Queensland, Australia. Lansdown has an annual mean rainfall of 836 mm which is highly summer dominant (November to April).

The Leucaena system was established in 1974 with cattle grazing treatments imposed in 1976. The trial has been grazed on a four-week-on/four-week-off basis for the past 20 years. Steers were put on to the pastures at between 180 - 200 kg and sold off when liveweights reached approximately 500 kg. On average over a 20 year period production has been estimated to have been 330 kg $ha^{-1}.yr^{-1}$. The adjacent Sabi system that was outside the trial had not been regularly grazed since the inception of the grazing trial and could therefore be assumed to have had little disturbance or grazing pressure.

Soil samples were collected on a transect across both treatments. In each of the treatments five sampling points were delineated approximately 10 m apart. At each sampling point three individual soil cores (diameter 50 mm) were taken to 70 cm depth and individual depth intervals bulked to form a composite sample for that point. Cores were sectioned, samples air dried and ground to pass a 2 mm sieve before being analysed for pH_{Ca} (1:5 soil :0.01 M $CaCl_2$). A subsample from each site and depth interval was bulked to produce a composite sample from which an estimate of exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) and cation exchange capacity (CEC) was undertaken using the compulsive exchange method of Gillman and Sumpter (1986). Soil organic carbon was measured using the modified Walkley Black method and pH buffering capacity (pHBC = mmol H^+ kg^{-1} soil pH^{-1} unit) was measured on composite samples for each depth interval using the methodology of (Aitken and Moody, 1994).

An estimate of the net acid addition rate was made based on the equation adapted from Helyar and Porter (1989). This was undertaken for each depth interval and the sum for the profile used as an estimate of net acidification rate.

The total quantity of bases (Ca^{2+}, Mg^{2+}, K^+, and Na^+) removed in animal products was estimated using published regression relationships (Agricultural Research Council, 1965). Ash alkalinity of animal products removed from the Leucaena system was estimated by calculation of the excess base, the difference between total cations and total anions.

RESULTS

The pH_{Ca} of the soil profile to 70 cm under the Sabi system adjacent to the trial area was significantly ($P<0.05$) less acid than that under the Leucaena system over all depth intervals (Figure 1). There was no evidence that the pH profiles of each of these systems were converging at 70 cm, suggesting that acidification had occurred to depths greater than that sampled. Concomitant with the decline in pH there was a corresponding decrease in exchangeable Ca^{2+} and K^+ down the entire sampling depth under the Leucaena system (Table 1). Exchangeable Mg^{2+} levels were lower under the Leucaena system over the 0 - 30 cm depth interval but then increased thereafter in comparison to the Sabi system.

Sabi grass had higher organic matter percentages in the 0 - 20 cm whilst organic matter percentage was higher under the Leucaena system in the 30 -70 cm depth interval (Table 1). The pHBC was higher under the Sabi system over all depth intervals other than the 50-70 cm depth (Table 1). The difference in pHBC is consistent with the higher organic carbon under the Sabi system.

An estimate of the net acid addition between the two production systems can be undertaken assuming that pH in the Sabi system has not declined substantially since initiation of the study. The net acid addition for the past 22 years for the Leucaena system was estimated to be 59.8 kmol H^+ ha^{-1} for the sampled profile depth. Over the entire length of the study it has been assumed that the annual turnoff from the Leucaena system averaged 330 kg ha^{-1} yr^{-1} thereby resulting in an estimated acid accumulation of 3.7 kmol H^+ ha^{-1}.

DISCUSSION

The net acid addition rate over the 22 year period since pasture establishment was estimated to be 2.7 kmol H^+ ha^{-1} yr^{-1} resulting in a significant reduction in soil pH. Agricultural and pasture ecosystems are characterised by having increased rates of acidification when compared to natural ecosystems due to product removal, the addition of acidifying nitrogenous fertilisers or nitrogen fixing legumes and the increased opportunity for nutrient leaching (Williams and Chartres, 1991). The rate of acidification in this study is considerably higher than that of natural ecosystems (0.5 kmol H^+ ha^{-1} yr^{-1}) in Australia but less than some exploitive intensively managed (20 kmol H^+ ha^{-1} yr^{-1}) production systems in southern Australia.

The effect of acidification on the chemical fertility status of the soil clearly indicates that there is a considerable draw down to depth in exchangeable bases under the Leucaena system indicating that there is exploitation by roots to greater than 70 cm. The long-term consequences of this soil degradation are permanent and bring into question the sustainability of the Leucaena system on this site.

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Table 1
Selected soil chemical properties of soils under a Sabi and Leuceana pasture production system.

Depth (cm)	Ca^{2+}	Mg^{2+} $cmol_c$ kg^{-1}	K^+	OC %	pHBC ($mmol_+$ H^+ kg^{-1} soil.pH^{-1} unit)
		Sabi system			
0 - 5	11.0	1.8	1.50	2.80	26.44
5 - 10	9.8	1.4	0.70	1.50	22.84
10 - 15	9.1	1.2	0.50	1.30	20.64
15 - 20	7.9	1.4	0.41	0.78	16.49
20 - 30	7.0	1.3	0.25	0.49	14.16
30 - 50	7.3	1.5	0.52	0.26	11.49
50 - 70	9.3	2.0	0.54	0.20	12.16
		Leucaena system			
0 - 5	4.1	0.81	0.73	1.70	12.73
5 - 10	3.7	0.88	0.47	1.00	10.32
10 - 15	3.3	1.10	0.42	0.97	10.46
15 - 20	3.3	0.79	0.17	0.73	9.47
20 - 30	3.4	1.10	0.11	0.63	9.17
30 - 50	4.6	1.80	0.15	0.42	9.74
50 - 70	7.3	3.10	0.19	0.58	12.93

Figure 1
Soil pH_{Ca} profiles for Leucaena and adjacent Sabi systems. Bars represent the $LSD_{0.05}$ between means at the same depth interval.