5 Soil Quality In Alley Cropping

5.1 Introduction

Leucaena leucocephala (leucaena), a multi-purpose fodder tree, has been studied extensively with regard to its use as an animal feed, source of fuel wood, green manure or mulch and ameliorating effect on soil in topical climates. Widely used in alley cropping systems because of its nitrogen fixing ability, prunings of leucaena are reported to provide nitrogen and organic matter when used as a mulch or green manure between the alley crops (Wilson & Kang, 1981; Yamoah, Agboola, Wilson & Mulongoy, 1986; Balasubramanian & Sekayange, 1991; Xu, Saffigna, Myers & Chapman, 1993; Matta-Machado, Neely & Cabrera, 1994).

Kang, Grimme and Lawson (1985) concluded that although large amounts of N were obtained from prunings, supplementary rates of fertiliser N were still needed to obtain high maize yields. Application of only leucaena prunings could sustain the main season maize yield for up to five years. Repeated application of leucaena prunings also maintained higher soil organic matter levels.

Larbi, Jabbar, Atta-Krah, & Cobbina (1993) reported that available phosphorus tended to increase with increasing proportion of prunings applied as mulch, whereas Atta-Krah (1990) and Haggar (1994) found that soil P was lower than with conventional cropping. Organic carbon accumulation is higher under NFT's – a reflection of continuous addition of leaf litter and dead roots below tree cover. Soil pH was also higher under NFT's than in control plots (Dalland, Våje, Matthews, & Singh, 1993; Leal, Pavan, Chavez, Inoue & Koheler, 1996; Mishra & Bhola, 1996). Atta-Krah (1990) reported no changes in soil pH after fours years of alley cropping.

Apart from soil chemical properties, bulk density, mean aggregate diameters and water holding capacity were also improved in alley cropped sites (Kang *et al.*, 1985; Yamoah *et al.*, 1986; Hulugalle & Kang, 1990). It was concluded that hedgerow species that frequently produce large quantities of prunings, which decompose slowly, might be the more desirable for alley cropping systems.

Hagger (1994) noted that there is now substantial evidence that alley cropping maintains soil fertility above levels found in pure annual cropping systems. The question, however, remained regarding the origin of increased availability of N to the crop. The author came to the conclusion that the soil contains considerable reserves of organic N that becomes available to plants slowly. The loss of N by leaching might also be reduced, due to the presence of a deeper and perennially active tree root system. Finally, the fixation of atmospheric N by leguminous trees is the most obvious source of N (Hagger, 1994).

In order to understand the various reported results, it is necessary to be reminded of the basic principles behind soil chemistry as summarised by Arnon (1992):

Most of the N in soil is in an organic form (OM has about 5% N). The amount of N in soil is not an indication of amounts of this nutrient which are immediately available to the crop, but constitutes a reserve from which nitrogen may become available to the plants - and not necessarily at a rate commensurate with the requirements of an actively growing crop. The fraction of N in the soil tends to remain constant at a level, which depends on the nature of the parent material, the leaching characteristics of the soil (mainly determined by its texture), and on the management system adopted.

P is present in mineral and organic forms. At low concentrations of soil phosphorus, the supply of P is insufficient for the requirements of plants and soil micro-organisms and competition occurs. Bacteria in the rhizosphere assimilate labile inorganic P and P uptake by plants is thereby restricted. Where intensive cropping, including P fertilisation, has been practised for a number of years, the phosphorus content of the soil has generally been built up, frequently to a level at which farmers can stop using P fertilisers for a number of seasons.

Even when there is adequate P in the soil, it may not be all available to the plants. Deep roots may be able to absorb P from deep soil horizons and release it to the surface soil during organic matter decomposition. K is brought to the surface in a similar manner, BUT, soil K is highly susceptible to leaching. This may be the reason for lack of change in soil K levels before and after NFTs'.

K is usually an abundant element in soils. Semi-arid soils may become depleted of K by the cropping and removal of crop residues. K occurs in a number of forms in the soil:

a) water soluble - in the soil solution. It constitutes a very small fraction and even in very fertile soils is not enough to meet crop requirements.
b) exchangeable - held by the exchange fraction of the soil. A small part of the total K.
c) non-exchangeable - slowly available. Native soil K from partly weathered minerals forms the reserve from which water-soluble K is gradually replaced. The higher the temperature, the greater the rate of release.
d) in unweathered K-bearing parent minerals, the element is released at an extremely slow rate.

Ca content varies more than any other element. It produces several specific effects, which result in the improvement of soil structure and increased crop production.

Large amounts of Na may accumulate in the soils of arid and semi-arid regions.

The availability of soil plant nutrients may be influenced by certain soil conditions, e.g. microbial N-fixation when C:N ratios are high. The amount of organic matter in arid and semi-arid soils is generally very low, being limited to mere traces in certain instances. This is due mainly to a sparse plant cover. The little organic matter that is not rapidly mineralised, is quickly dispersed by wind. Animal manure makes a small contribution and in many instances organic residues are used for fuel.

Blair, Catchpoole & Horne (1990) estimated that only 7,6 % of the N_2 fixed by *Leucaena leucocephala* shrubs are transferred to the herbage layer. The availability of N for annual plant growth may be increased by applying prunings of Leucaena as a green manure, leading to increased crop production.

At the University of Pretoria, alley cropping with leucaena was evaluated under semi-arid conditions. As part of the evaluation, soil fertility was also monitored. In 1996 the trial was converted into an alley cropping trial, during which leucaena was pruned and the prunings placed in the alleys as a mulch. Soil fertility was determined once a year. The objective was to determine if leucaena mulching would have any effect on soil fertility under lower rainfall conditions.

5.2 Materials and Methods

An alley cropping field experiment was conducted on the Hatfield Experimental Farm of the University of Pretoria (Table 1).

Table 1 Site Description on Hatfield Experimental Farm

Locality	28°16'E, 25°45'S
Altitude	1360 m
Annual rainfall	650 mm
Mean min. & max. temperature	2°C (June) - 26°C (June
Soil type	Sandy clay (37 % clay), Hutton, homogenous to a depth of 0.66 m after which it becomes gravelly (MacVicar, Loxton, Lamprechts, Le Roux, De Villiers, Verster, Merryweather, Van Rooyen & Von M. Harmse, 1977).

The study was laid out in a 2x3x3 factorial randomised complete block design with five replications, involving two alley widths (3m and 6m), three pruning treatments (Table 2), and a split plot for three alley crops (maize, grain sorghum, fodder sorghum). Within-row spacing was 1 m. Blocking was done across the length of the plot, on an east-west axis, based on previously observed differences in growth (Lindeque, 1997).

Table 2 Pruning treatments applied to *L.leucocephala* in the alley cropping trial

S1	Control - no pruning
S2	Pruning to a single stemmed tree (± every 6 weeks), clearing the undergrowth up to 1 m. In 1998 the interval was changed to 8 weeks.
S3	Hedgerow (± every 4 weeks), cut back to 1m height and ±0.75 m width

An existing leucaena stand, planted at a tree density of 3 333 trees per ha, was used. No fertiliser had been applied for the previous five years. Before the start of the 1996/1997 growing season, the trial was converted to an alley cropping trial by removing selected alternate rows. The plant populations of the 3m and 6m treatments were 3333 and 1667 trees per ha respectively. Pruning of the trees started in November 1996 and was repeated at fixed intervals thereafter, until April 1998. Except for the first harvest, yields of the different pruning treatments were applied as a mulch between the alley crops. The amount and nitrogen content of this mulch is illustrated in Table 3. No irrigation or fertiliser was applied. Soil samples were previously taken in 1993. Samples were again taken at the onset of the trial, and after each growing season from 1996, in the S3 treatment (hedgerow pruning) and 3m alley, at a depth of 0-20 cm (topsoil) and 20-40 cm (subsoil). Soil parameters included pH, Ca, P, K, Mg and total N.

Table 3 Total yield and quality of leucaena prunings in hedgerow treatment

	Pruning yields (t/ha)	Prunings Nitrogen Content (%)
1997	18.148	3.64
1998	38.593	4.69

5.3 Results and discussion

Results of the soil analyses are represented in Figures 1 – 5.

A steady decline in macro-nutrient content was noted from the first analysis in 1993 until 1996. During this time, crop removal predominated, with little or no recycling. The only organic matter returned to the soil was due to leaf drop from the trees. The sharper decline of nutrients in the subsoil represented "mining" from the subsoil (at least up to a depth of 1.5m), resulting in relatively higher values in the topsoil. After 1996, the macro-nutrient content increased once mulching commenced. The values declined again towards the end of the 1998 season, after two years of cropping between the leucaena trees. Phosphorus in the subsoil was depleted, similar to observations by Attah-Krah (1990) and Haggar(1994). The decrease after 1996 could be attributed to usage by fodder sorghum. N-fixation was not as good as would be expected from leguminous species. The C:N ratio of 14:1 was representative of cultivated conditions. The pH initially increased after the addition of mulch to the soil, confirming results cited in most literature, but then declined to an even lower level than before, when sampled after the 1998 mulch application.

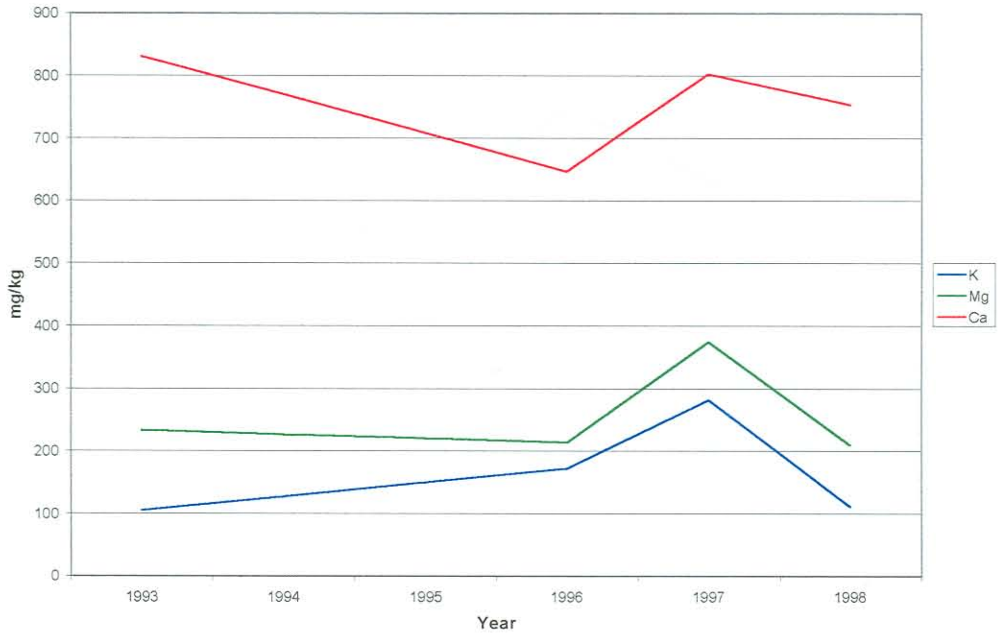

Fig. 1 Macro-nutrients in topsoil

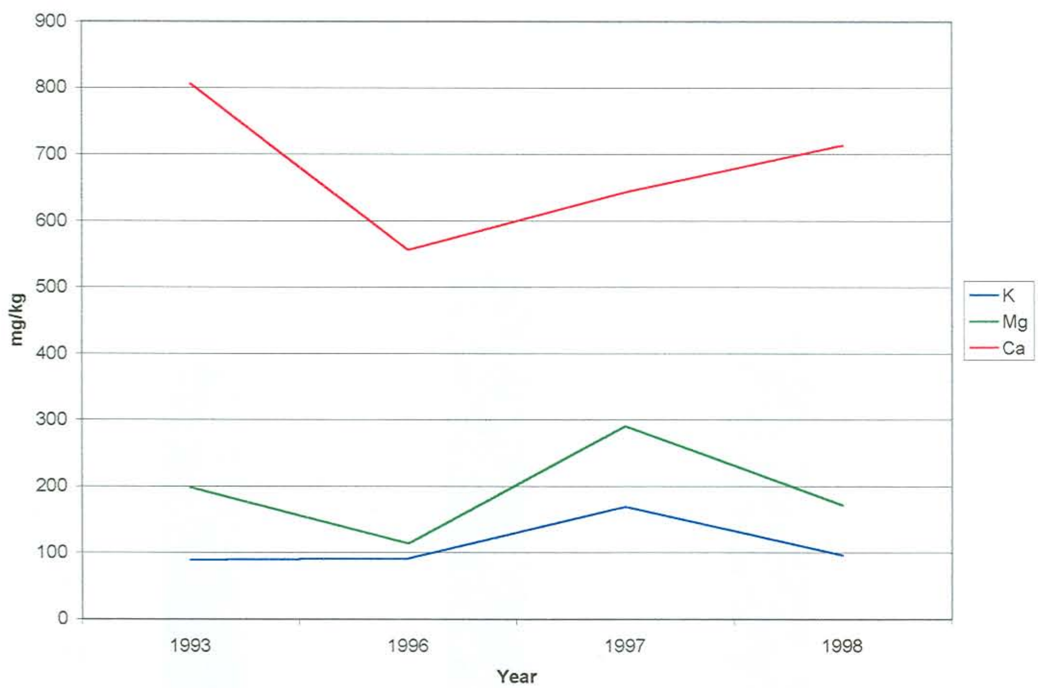

Fig.2 Macro-nutrients in subsoil

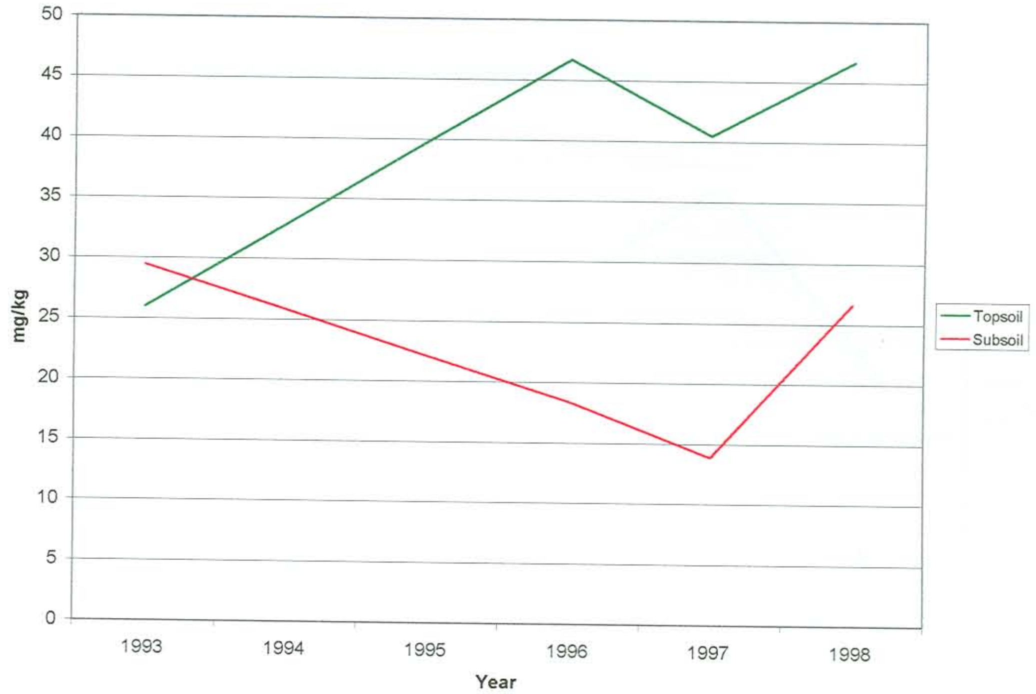

Fig. 3 Concentration of phosphorus

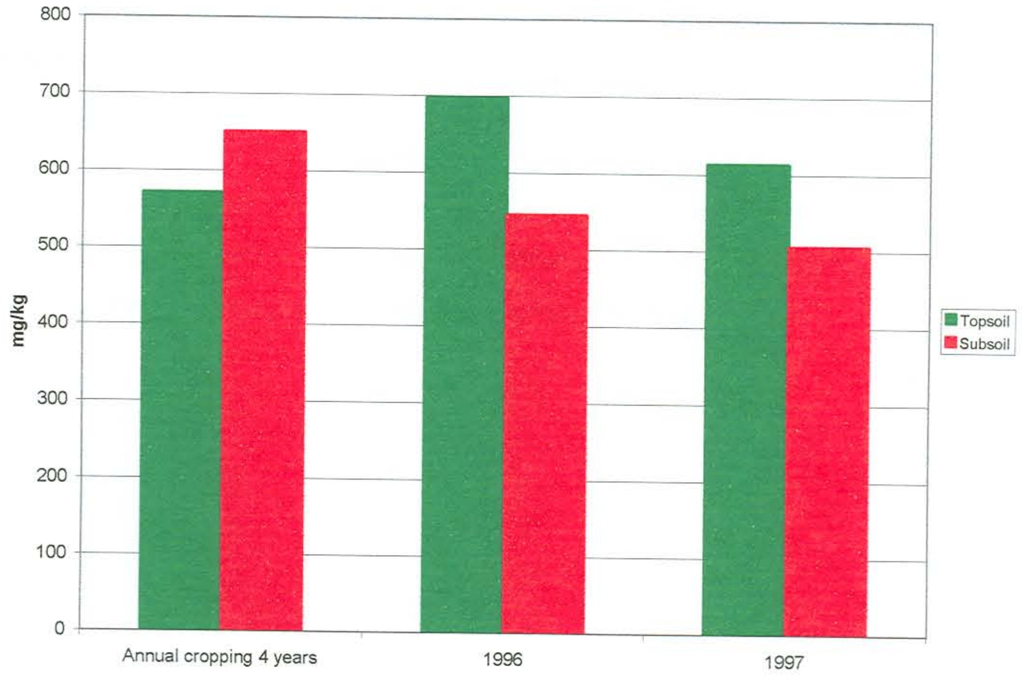

Fig. 4 Total nitrogen

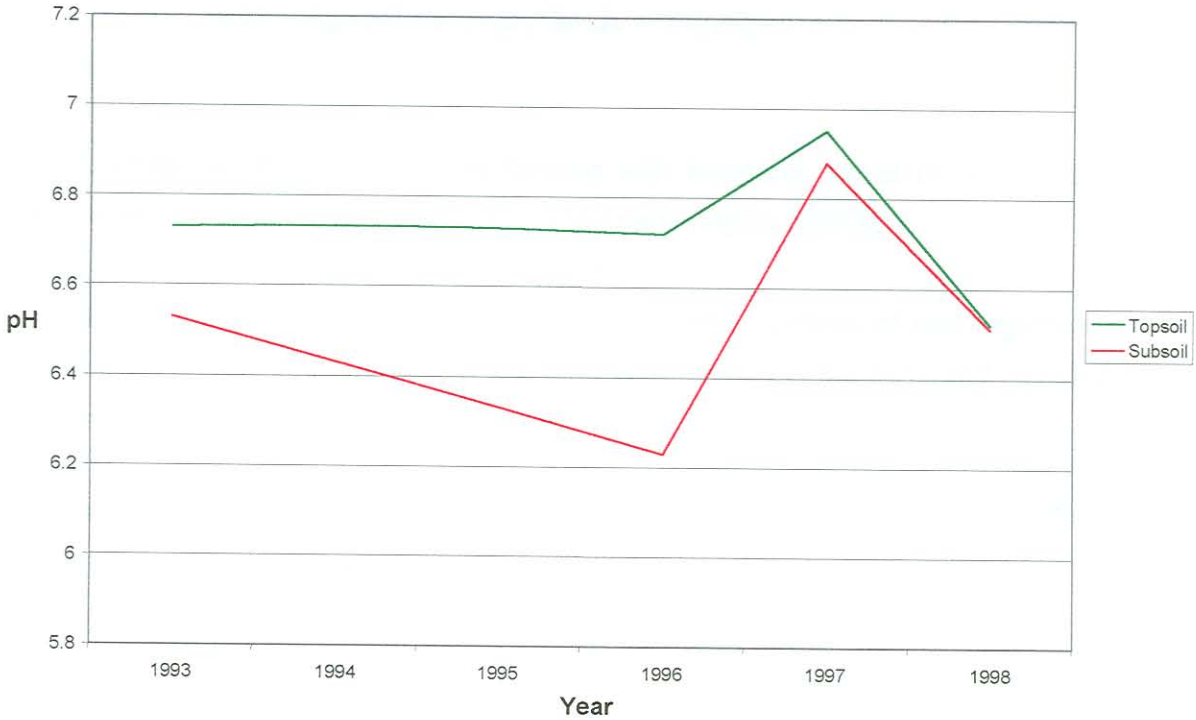

Fig. 5 pH levels

5.4 Conclusions

The addition of prunings had a definite effect on the soil fertility status, as had the crops planted in the alleys. The ideal would be to monitor soil quality over a much longer period, with and without the effect of nutrient removal by cropping, in order to make more accurate estimates of changes in soil chemical properties.

5.5 References

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