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Soil fertility under *Calliandra calothyrsus* hedgerows and other land-use treatments following forest clearance in Jamaica

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Abstract

An experiment in the Blue Mountains of Jamaica investigated the consequences of three land-use treatments applied following forest clearance on soil fertility and resulting crop growth over a five year period. The treatments were: maintained weed-free without cultivation (bare); cultivated with herbaceous crops (agriculture); and cultivated with herbaceous crops and intercropped with *Calliandra calothyrsus* contour hedges (agroforestry) and compared with an uncleared secondary forest control (forest). Nitrogen mineralisation rates declined over time since forest clearance in the cleared treatments, but not in the forest. In the second and third years after clearance nitrogen mineralisation was higher under the hedgerows than all other treatments. However, by the fifth year this had reduced to net immobilization (both under and between hedgerows). Under controlled shade-house conditions bioassay plant growth was similar in soil from agricultural plots and from forest plots. In all the soils bioassay plant growth showed a slight (not significant) positive response to P addition. However, it did show a large positive response to N addition in all soils: most for agriculture soils, least for forest soils and intermediate for agroforestry. Crop plants growing in the agroforestry plots had significantly higher growth than those in the agriculture plots. This was sufficient to lead to grain yield per hectare being only 5% lower in agroforestry plots despite there being c. 20% fewer maize plants per hectare than in the agriculture plots. However, the results suggest that there was no clear positive effect of *C. calothyrsus* on soil fertility five years after establishment.

Introduction

The steeply sloping land of the Blue Mountains of Jamaica has been subject to extensive conversion from forest to agriculture which makes it vulnerable to soil erosion (McDonald et al. 2002). Incorporation of contour hedgerows of *Calliandra calothyrsus* Meissner (hereafter referred to as calliandra), a naturalized and locally favoured species, amongst agricultural crops reduced surface runoff and soil erosion losses, but had no overall significant effects on the measured soil physical and chemical properties (McDonald et al. 2002). A range of studies have reported varying effects of calliandra on soil properties and associated soil fertility. Mugendi et al. (2000) showed that, in the subhumid tropical highlands of Kenya, only a small fraction of the N contained in calliandra biomass applied to the soil was taken up by the crop, suggesting that a major benefit of the application may be in the build-up of soil N stocks. This is in keeping with the findings of Cadisch et al. (1998) who showed low rates (9%) of cumulative N recovery from calliandra prunings over three crop cycles. In Sri Lanka De Costa and Atapattu (2001) found calliandra to have the greatest biomass production, and the highest capacity for soil enrichment of nitrogen, phosphorus

and potassium out of a range of four leguminous trees and two other multipurpose species. They concluded that it was a suitable tree species for contour hedgerow systems on sloping tea lands. In the highlands of Burundi, Akyeampong (1999) found that calliandra hedgerows enhanced maize yield by 29–63%, and were effective in weed control in acid infertile soils. In the Rwandan highlands, Niang et al. (1998) found calliandra grown with *Setaria splendida* on contour lines to be an effective system producing high quality fodder, and showing low competition with crops. However, in their Kenyan study, Mugendi et al. (1999) found that the inclusion of calliandra hedges on cropland adversely affected maize yields.

The objective of the present study was to investigate the consequences of forest clearance, agriculture and agroforestry (agriculture incorporating calliandra hedgerows and the prunings used as a mulch on the farmed area between the hedges), on soil fertility and resulting crop growth. Specific hypotheses were that: (i) nitrogen mineralisation rates would be higher in agroforestry than agriculture plots; (ii) under controlled conditions plant growth would be lower in soil from agricultural plots than forest plots, but higher in soil from agroforestry than agricultural plots; (iii) the response of the plant growth to fertilizer additions of nutrients would be higher for those growing in soil from agricultural plots than forest plots, but the plants growing in soil from agroforestry plots would respond less to nitrogen addition than those growing in soil from agricultural plots; (iv) crop plants growing in the field would show higher growth and grain yield in agroforestry plots than agricultural plots and, within the agroforestry plots, higher growth with distance away from the calliandra hedgerows (reflecting higher N-inputs from calliandra mulch and reduced below-ground competition from the lower calliandra root length density (McDonald and Healey 2000)).

Materials and methods

The trial was carried out at c. 1300 m altitude in the Green River valley on the south-west slopes of the Blue Mountains, where the soils are eutric and chromic Cambisols and mean annual rainfall is 2685 mm, with marked but irregular variability between months and years, with an average maximum length of dry period (< 50 mm rainfall) per year of 1.4 months (as described in more detail by McDonald and Healey (2000) and McDonald et al. (2002)).

Experimental plots were established in:

1. Secondary forest (‘forest’)
2. Secondary forest cleared, burned and soil subsequently maintained weed-free (‘bare’)
3. Secondary forest cleared, burned and soil planted with annual vegetable crops (‘agriculture’)
4. Secondary forest cleared, burned and soil planted with agricultural crops and intercropped with calliandra contour hedges (‘agroforestry’)

Four blocks each containing one plot randomly assigned to each treatment were established in areas of secondary forest, that had previously been cleared for agriculture in the early 1970s (according to members of the local community) and abandoned soon after. Each plot was 10 m (across slope) × 20 m (down slope), with an inner assessment area of 8 m × 15 m. For the three cleared treatments, the secondary forest was cut, following local practice, in July 1992. These plots were subsequently left to dry until August 1992 and then broadcast burned. The plots were left for up to three weeks before planting in September, 1992. Various mixtures of escallion (*Allium ascalonicum* L.), thyme (*Thymus vulgaris* L.), carrot (*Daucus carota* L.), potato (*Solanum tuberosum* L.), beetroot (*Beta vulgaris* L. *subsp. vulgaris*), cabbage (*Brassica oleracea* L.), sweet pepper (*Capsicum annuum* L. var. *annuum*) and cucumber (*Cucumis sativus* L.) were planted in the plots of the agriculture and agroforestry treatments. The farmers followed their usual farming practice. In addition, each farmer kept their bare treatment plot weed-free by manual clearance with a cutlass.

The agroforestry system involved three hedgerows per plot. The hedgerows were 5 m apart and each comprised triple rows of trees at 1-m intra-row spacing and 0.5-m inter-row spacing. The trees were grown from seed collected from the naturalised population of calliandra in and around Cinchona Botanic Garden during February/March 1992 and were about 15 cm high when planted out. The hedgerows were cut back to a height of about 30 cm on a regular basis at approximately five-monthly intervals and were never allowed to grow more than about 1 m tall. During 1993 and 1994 the prunings were laid along the upper side of the hedgerows to help build up the barrier effect, but subsequently (from 1995) they were chopped up and used as mulch on the cropped area between the hedges. The biomass and N and P concentrations of the prunings were recorded at each cut:

on average the prunings resulted in recycling of 2916 kg ha^{-1} yr^{-1} of OM, 122 kg ha^{-1} yr^{-1} of N and 7 kg ha^{-1} yr^{-1} of P to the soil (McDonald et al. 2002).

Nitrogen mineralisation rates

In September each year from 1994 to 1997, six soil cores were collected from each plot from the surface 10 cm soil depth, using a corer of 10 cm diameter. In the agroforestry plots 12 cores were collected – six from under the hedgerows, and six from the cropped areas between the hedgerows. The samples were taken between 6 and 8 weeks after the application of the prunings (variation being due to the preference of the farmer as to when the pruning was required). Half of the cores from each plot were enclosed intact in gas permeable plastic bags and inserted back into the holes from which they had been taken (Marrs et al. 1988). The remaining cores were bulked by plot; 10 g (wet soil) sub-samples were used for inorganic-N extraction by shaking for one hour in 100 ml of 1 M KCl, and filtering through KCl pre-washed Whatman No. 44 filter papers and dry samples were retained for measurement of organic matter (OM) and total N concentrations. Inorganic-N concentrations were corrected to a per-gramme dry weight basis. The *in-situ* incubated cores were removed after 30 days, inorganic-N was extracted from wet soil sub-samples of each and dry samples retained for OM and total N measurement. The extracts were analysed for nitrate-N and ammonium-N colorimetrically by autoanalyser. The difference between the inorganic-N content after *in-situ* incubation and the inorganic-N content in the initial bulked sample is net mineralisation. Nitrate and ammonium contents were determined separately in both sets of extracts to assess rates of nitrification, as well as mineralisation, and expressed on the basis of oven-dried soil. OM was measured as loss on ignition at 550 °C for 2 hours and total-N was measured colorimetrically after sulphuric acid/hydrogen peroxide digestion.

Greenhouse bioassay

A bioassay was established five years after forest clearance, to elucidate any soil fertility limitations to crop growth. Soil was collected from 0–10 cm depth in all 16 experimental plots in July, 1997. One bulked sample was taken from each plot, except for the four agroforestry plots – in this case samples were collected separately from the cropped area between the hedgerows and from underneath the hedgerows. The soil was passed through a 2-mm sieve and transported to Cinchona Botanic Garden (1525 m altitude). Soils were mixed with acid-washed sand in the ratio 2:1 soil:sand to improve drainage and 500-ml pots filled with the mixture. Forty-five pots were filled with soil from each plot/position (i.e. there were 90 pots per agroforestry plot).

The test species used as a bioassay was *Melinis minutiflora* Beauv., locally known as Molasses, Wynne or Christmas Grass. In an earlier bioassay Healey (1989) found that this species showed significant differences in fertility between Blue Mountain forest soils. *M. minutiflora* was introduced to Jamaica in 1920 as a fodder grass and is now naturalized and fast growing. *M. minutiflora* is a perennial, stoloniferous grass that also spreads from seed. Single node stem sections with one leaf were collected from the Cinchona area and one placed in each pot. The stem sections were approximately 5 cm long, and roots were trimmed to 5 cm length. Plants that died within 14 days were replaced after which time no further replacements were made. The pots were placed at random on wooden benches under medium shade and watered daily.

Thirty six days after planting, the pots from each experimental plot/position were randomly divided into groups of 15; one group was left as an unfertilized control, one group was fertilized with phosphorus (equivalent to 25 kg P ha^{-1}) and the remaining group was fertilized with nitrate-nitrogen (equivalent to 50 kg N ha^{-1}). The nutrients were in the form of NaH_2PO_4 and $NaNO_3$ respectively. The position of the pots was rerandomised and left for 14 days, after which a repeat application of the fertilizers was administered, and the pot positions again rerandomised.

The bioassay plants were harvested 65 days after the first application of fertilizer. Soil was washed off the roots and the plants were dried at 105 °C for 2 hours. The dry weights of the root biomass, and above-ground biomass were determined, and the number of leaves. The replicate plants for each treatment were bulked for analyses of shoot nitrogen and phosphorus concentrations. Analyses for total N and P were conducted after sulphuric acid/hydrogen peroxide digestion. Nitrate-N concentrations were measured using a Dionex automated ion chromatograph, ammonium-N using an automated colorimetric system with indophenol blue, and P using an automated colorimetric system with molybdenum blue.

Field crop bioassay

In March, 1996, seeds of *Zea mays* L. were planted into the experimental agriculture and agroforestry plots. Planting lines were demarcated – in the agroforestry plots, the rows commenced adjacent to the calliandra hedgerows and thereafter every 50 cm until the next hedgerow. Intra-row plant spacing was also 50 cm. The same spacing was used in the agriculture plots. Two seeds were placed in each planting hole. Twenty days after planting, surplus plants were removed, and transplanted into empty holes where necessary to ensure full stocking. In September, 1996 randomly selected sub-samples of five plants per row per plot were harvested, and measurements made of: plant height, above-ground fresh biomass, cob length, cob weight and percentage cob fill. Sub-samples of leaf and cob were removed for dry weight determination after oven-drying at 105 °C for two and eight hours respectively to give a fresh to dry weight conversion factor.

Data analysis

The nitrogen mineralisation rates were analysed using a model determined by the design of the field experiment (McDonald et al. 2002). It had a randomised complete block design (with 15 df) and a split-plot structure for the agroforestry treatment (with a further 4 df). At the main-plot level differences amongst treatments were tested by three a priori planned contrasts (each with df 1,9): forest vs the others; agriculture vs bare; and agriculture vs agroforestry, as well as the split-plot level analysis of the difference in soil under and between agroforestry hedgerows (df 1,3). The greenhouse bioassay had the same design, with the additional fertilizer enrichment effect (df 2,33 main plot; df 2,15 within plot) and the enrichment × treatment interaction (df 6,33 main plot; df 2,15 within plot). Statistical analysis was carried out by analysis of variance using the General Linear Model of SPSS V. 9.0.0. All assumptions of ANOVA were checked by analysis of residuals. For the field crop bioassay, a weighted analysis of variance (df 4,12) was conducted in Genstat 5.4.1 (ed. 3) to overcome the problem of unequal variances, caused by the means being based on either 5 or 20 observations.

Results

Nitrogen mineralisation rates

There was a significantly higher rate of nitrification and total N-mineralisation under the hedgerows in the agroforestry plots than in the other treatments/locations in 1994 ($P < 0.001$) and 1995 ($P = 0.013$), the second and third years after the establishment of the hedges (Figure 1a and b). From 1995 to 1997 there was immobilisation of N (indicated by negative mean mineralisation values) between the hedgerows of the agroforestry plots; as a result N-mineralisation was significantly lower ($P = 0.04$) than in the forest plots (Figure 1b). In 1997, there was also net immobilisation under the agroforestry hedgerows and in the bare plots. This may be attributable to initially high organic matter concentrations which were subject to large reductions during the incubation period (Figure 1c). It is not attributable to high soil total nitrogen contents, which showed no appreciable changes during incubation (Figure 1d). In all the cleared treatments, there was a lower rate of mineralisation of NO_3-N, total N and N as a proportion of total soil N (P range < 0.001–0.026), compared to the forest plots, but not as a proportion of soil organic matter (Figure 1c).

Greenhouse bioassay

There were no significant differences amongst the main-plot treatments in shoot or root biomass of the unfertilized *M. minutiflora* plants, or in their root:shoot ratio or number of leaves. However there was a significant ($P < 0.001$) positive response to N-fertilization in root weight, shoot weight and number of leaves, and reduction in root:shoot ratio, and a significant plot-treatment × fertilizer interaction for shoot weight ($P = 0.039$). Total biomass was increased 234% by N-addition in the plants growing in soil from the agriculture plots, compared with 128% in the agroforestry plot soils, 103% in the bare plot soils and 61% in the forest plot soils. For the agroforestry plots, there was more *M. minutiflora* root production in the unfertilized soil from under the hedgerows than between ($P = 0.045$) and consequently a higher root:shoot ratio ($P = 0.005$). Again, there was a significant positive response to N fertilization in all growth variables ($P < 0.001$) of the bioassay plants growing in soil from both plot positions (Table 1).

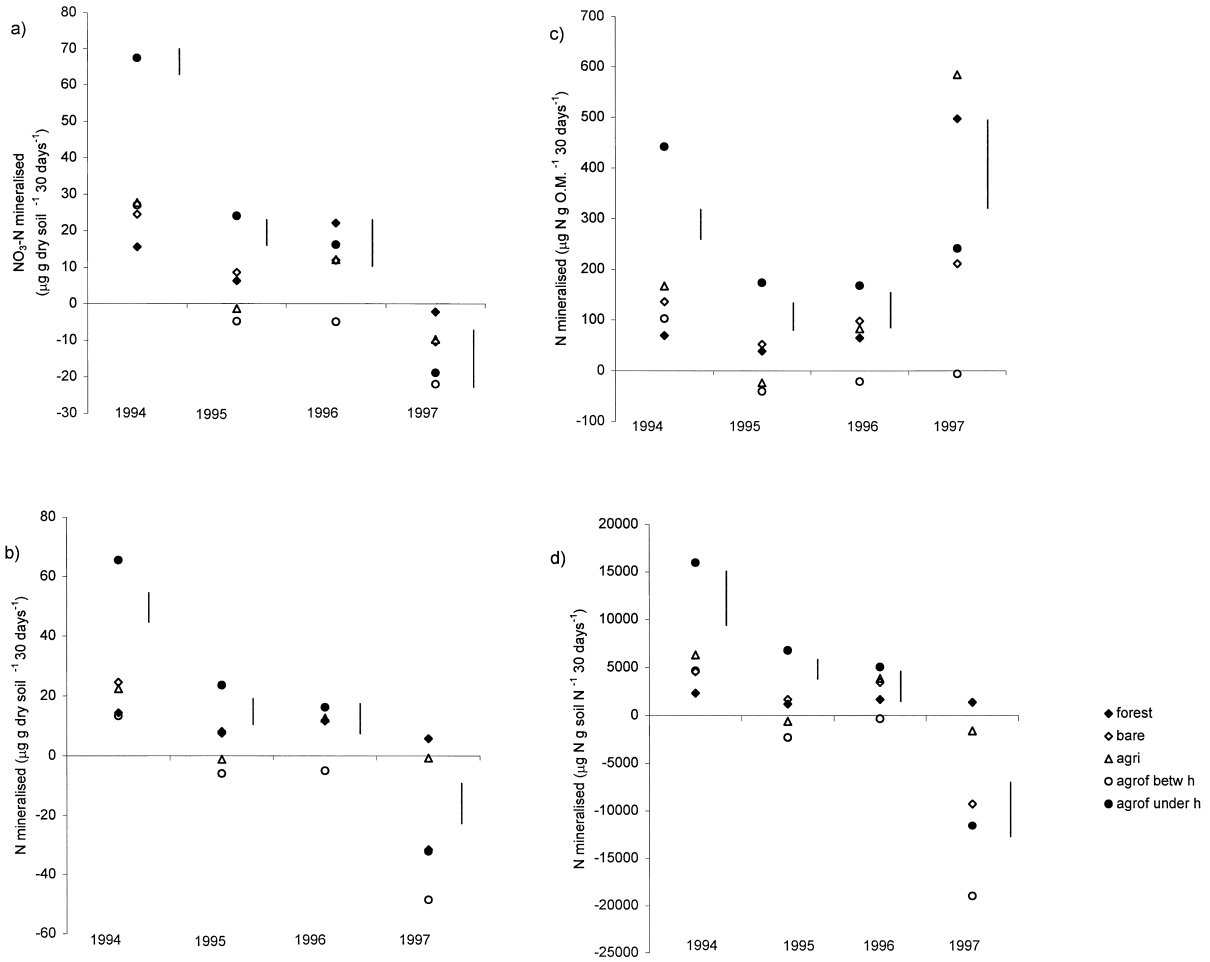

Figure 1. Nitrogen mineralisation rates over a 30 day period in land-use treatment plots in the Blue Mountains of Jamaica each year from 1994 to 1997: a) Nitrate-N mineralised, b) total nitrogen mineralised, c) total nitrogen mineralised, expressed as a proportion of organic matter, d) total nitrogen mineralised, expressed as a proportion of initial total nitrogen (mean values; vertical lines are the standard error of the difference between treatment means).

Shoot N-concentrations of the unfertilized plants grown in forest soil were higher than those grown in soil from the cleared treatments ($P < 0.001$). There was no significant difference in P concentration between the field-treatments, but it was significantly reduced by N-fertilization across all the treatments ($P < 0.001$), probably as the result of a 'dilution effect'. There was no difference in shoot N or P concentration between the plants grown in soils from under and between the hedgerows, and P concentration was significantly reduced by N-fertilization in both ($P < 0.001$).

Field crop bioassay

Mean above-ground biomass per maize plant was 15% higher in the agroforestry than the agriculture plots ($P = 0.014$) (Table 2). Within the agroforestry plots the differences between the four planting positions (distance from hedgerow) in all the measured variables were not significant. However, mean above-ground biomass of the plants 1.0 and 1.5 m from the hedgerows was 20% higher than those at 0 and 0.5 m. Despite the fact that there were c. 20% fewer plants per hectare in the agroforestry plots than the agriculture plots due to the presence of the hedgerows, the mean yield of maize grain produced in the agroforestry plots was only 5% lower than in the ag-

Table 1. Growth characteristics of *Melinis minutiflora* used as a soil-fertility bioassay plant, 100 days after planting, in the Blue Mountains of Jamaica in a) non-fertilised, b) N-fertilised and c) P-fertilised treatments.

a) Control	Root weight (mg per plant)	Shoot weight (mg per plant)	Number of leaves	Root:shoot ratio	P (%)	N (%)
Forest	423.3 (20.2)	770.0 (60.6)	8.8 (0.1)	0.56 (0.04)	0.26 (0.07)	1.33 (0.12)
Bare	446.7 (63.5)	810.0 (105.3)	8.9 (0.8)	0.55 (0.04)	0.41 (0.12)	1.09 (0.05)
Agriculture	435.0 (58.1)	735.0 (125.0)	9.1 (0.8)	0.60 (0.05)	0.38 (0.02)	0.95 (0.03)
Agroforestry (between hedgerows)	472.5 (67.8)	790.0 (108.9)	9.2 (0.9)	0.60 (0.01)	0.31 (0.06)	0.99 (0.09)
Agroforestry (under hedgerows)	577.8 (29.6)	860.0 (19.6)	9.4 (0.6)	0.67 (0.02)	0.33 (0.06)	1.01 (0.05)

b) + N	Root weight (mg per plant)	Shoot weight (mg per plant)	Number of leaves	Root:shoot ratio	P (%)	N (%)
Forest	583.3 (132.7)	1340.0 (285.5)	14.1 (2.6)	0.44 (0.02)	0.17 (0.02)	1.47 (0.23)
Bare	766.7 (59.6)	1786.7 (252.7)	16.7 (1.7)	0.44 (0.02)	0.21 (0.04)	1.09 (0.06)
Agriculture	1175.0 (130.4)	2730.0 (361.8)	22.2 (2.6)	0.44 (0.01)	0.15 (0.02)	0.87 (0.04)
Agroforestry (between hedgerows)	905.0 (147.1)	2030.0 (359.2)	18.4 (3.1)	0.45 (0.02)	0.16 (0.02)	0.99 (0.04)
Agroforestry (under hedgerows)	1107.5 (116.1)	2100.0 (213.3)	19.5 (1.0)	0.53 (0.01)	0.14 (0.01)	0.94 (0.03)

c) + P	Root weight (mg per plant)	Shoot weight (mg per plant)	Number of leaves	Root:shoot ratio	P (%)	N (%)
Forest	486.7 (46.5)	866.7 (80.9)	9.3 (0.1)	0.56 (0.03)	0.46 (0.03)	1.30 (0.05)
Bare	463.3 (52.5)	886.7 (66.6)	9.6 (0.4)	0.52 (0.02)	0.52 (0.11)	1.10 (0.05)
Agriculture	452.5 (49.9)	802.5 (88.0)	9.0 (0.7)	0.56 (0.01)	0.47 (0.03)	0.99 (0.04)
Agroforestry (between hedgerows)	512.5 (56.5)	897.5 (101.6)	9.8 (0.8)	0.58 (0.03)	0.45 (0.05)	0.99 (0.06)
Agroforestry (under hedgerows)	555.0 (30.7)	932.5 (50.7)	10.3 (1.0)	0.60 (0.01)	0.48 (0.04)	1.02 (0.02)

Means and standard errors.

Table 2. Production by *Zea mays* plants used as a soil-fertility bioassay plant in the Blue Mountains of Jamaica in agroforestry and agriculture plots.

	Agroforestry plots: distance from hedgerow (m)								Agriculture plots	
	0		0.5		1.0		1.5			
Height (m)	1.80	(0.08)	1.84	(0.08)	1.85	(0.08)	1.83	(0.07)	1.76	(0.03)
Above-ground biomass (g d wt plant^{-1})	114.27	(8.92)	114.97	(12.47)	147.70	(18.61)	126.60	(14.89)	109.55	(5.79)
Cob length (m)	0.155	(0.005)	0.151	(0.006)	0.157	(0.005)	0.158	(0.007)	0.148	(0.003)
Cob weight (g d wt plant^{-1})	88.54	(10.18)	89.88	(10.55)	104.28	(13.19)	84.41	(10.47)	71.79	(2.53)
Grain weight (g d wt cob^{-1})	54.73	(4.80)	64.59	(8.41)	76.54	(10.41)	57.75	(7.94)	46.83	(2.11)

Means and standard errors.

riculture plots and this difference was far from statistically significant ($P = 0.634$) (Table 3).

Table 3. Total production of a *Zea mays* crop used as a soil-fertility bioassay plant in the Blue Mountains of Jamaica in agroforestry and agriculture plots.

	Agroforestry		Agriculture	
Above ground biomass (kg ha^{-1})	3521.88	(284.96)	4382.89	(231.71)
Total cob weight (kg ha^{-1})	2599.21	(233.88)	2871.64	(100.91)
Total grain weight (kg ha^{-1})	1773.80	(158.87)	1873.10	(84.43)

Means and standard errors.

Discussion

The results from the bioassay under controlled greenhouse conditions indicate that plants grown in the secondary forest soil did not grow any faster than those in soil from the cleared-treatment plots, though they did accumulate a higher concentration of N. This was despite the concentrations of total N, available P, and exchangeable Mg, Ca, K and Na all being significantly higher in the forest than cleared-treatment soils (McDonald et al. 2002). The greenhouse bioassay does provide strong evidence that N was limiting plant growth in the secondary forest soils (N addition increased mean plant biomass by 61%). However, although mean plant biomass was elevated 13% by P addition, this was not significant. This is at variance with the findings of Healey (1989), who found P to be more limiting than N to bioassay plant growth in soils from primary/old secondary montane forests in the Blue Mountains. In the present study there was evidence of even higher N limitation to plant growth in the soils of the cleared-treatment plots, especially under agriculture. Under these circumstances, the two years of enhanced N-mineralisation rates observed under agroforestry hedgerows (after a period when hedgerow prunings were placed under the hedgerows) might assume significance for soil fertility. However, the results indicate that this was only a temporary phenomenon as two years' later net N-immobilization was observed in this zone. The observed changes in N-mineralisation were not in any way reflected in soil total N concentrations which showed similar levels in the agriculture plots and both positions in the agroforestry plots, and a steady decline both under and between the agroforestry hedgerows, over this period (McDonald et al. 2002).

The levels of N mineralized were generally low in all plots; however, the levels recorded were in keeping with other studies conducted at this altitude (Marrs et al. 1988). The rate of decomposition of organic matter is a function of environmental conditions, nutrient content resource quality and the decomposer community, which results in lower decomposition rates in the montane forest compared to the lowlands (Tanner et al. 1998). The decline over time in the cleared plots is unsurprising as SOM levels declined (McDonald et al. 2002), which can be attributed to reduced litter inputs, erosive losses and enhanced SOM decomposition (due to increased temperatures and tillage in the cultivated plots) (Palm et al. 2001; Tiessen et al. 2001). Total N concentrations (which were highly correlated with OM concentrations) declined over the same time period as a result of erosion (McDonald et al. 2002). Other factors contributing to observed differences between the forest and cleared plots were changes in bulk density (which increased in the cleared plots, McDonald et al. (2002)) and possibly changes in soil texture as a result of erosion and soil redistribution. SOM content (within a climatic zone) is determined largely by the silt+clay contents (Feller and Beare 1997; Van Noordwijk et al. 1997). However, it was not due to soil moisture content as there were no significant differences between treatments (except for 1995 when forest soil moisture content was higher than in the cleared treatments, but was not associated with higher rates of N-mineralisation). No attempt was made to normalize these factors as they were intrinsic to the treatments. It was also likely that the more labile, nutrient-supplying fractions of SOM were lost by erosion and decomposition in the early years after forest clearance. The current approach to SOM is to regard it as having fractions of different composition and turnover time (Palm et al. 2001). The most biologically active and labile fractions with rapid turnover are assumed to play a dominant role in soil nutrient dynamics (Phiri et al. 2001; Van Noordwijk et al. 1997). Lehmann et al. (1998) found the polyphenol:N ratio and the formation of stable organo-N-mineral complexes to be correlated following the addition to the soil of leaves and roots of three different tree species (*Gliricidia sepium, Calliandra calothyrsus*, and *Senna siamea*) in Central Togo, West Africa. In our study, the higher rates of N-mineralisation expressed

as a proportion of SOM in 1997 (Figure 1c) despite reduced rates of total N-mineralisation, and even immobilization, in that year (Figure 1b) indicate the persistence of a more recalcitrant SOM fraction. The integrated effects of erosion and cuiltivation on spatial variability was demonstrated by the rapid development of an 'armour' layer in the 'bare' plot after forest clearance (McDonald et al. 2002) which is a concentration of coarser soil particles on the soil surface as finer particles are selectively removed by erosion; cultivation cultivation of the agriculture and agroforestry plots distributed these coarser particles throughout the topsoil.

Other studies in the humid tropics report an increase in soil organic matter and nutrient concentrations after application of prunings (Tian et al. 1993). The light fraction of SOM can vary considerably in quantity and quality following the addition of organic inputs. Samples taken shortly after application will include a mixture of high and low quality materials that have not decomposed (Palm et al. 2001). The variability due to this was minimized by consistency of time elapsed after pruning application, and before initiation of the N-mineralisation studies. The biomass produced by the calliandra hedges and its nutrient content in the present study was within the range of production by hedgerow species in the humid tropics (Young 1997; McDonald et al. 2002). However, calliandra is known to have a slow decomposition rate and N-release rate because of its high concentrations of polyphenolics which bind with N (Chesson 1997). Potentially, this could have been beneficial in the study environment, resulting in a build-up of soil N store and minimising N-losses through leaching, volatilization and denitrification (Mugendi et al. 2000). However, the results of the present study and McDonald et al. (2002) provide no evidence that there is any accumulation in the soil of extra N inputs under or between the agroforestry hedgerows. Instead, after mineralisation they may be rapidly taken up again by the trees, or by the enhanced growth of crops.

The lack of a significant response of overall soil fertility to the incorporation of contour hedgerows in a cropping system after five years, as found by this study, is in accord with most previous studies (Young 1997; Agus et al. 1997, 1999; Samsuzzaman et al. 1999; McDonald et al. 2002). The greenhouse bioassay of the present study found evidence that redistribution of fertility within the agroforestry plots, leading to its elevation under the hedgerows, was a more significant phenomenon, matching the findings Garrity (1996) and Agus et al. (1997), Poudel et al. (1999) which has been attributed to a 'scouring' effect between the hedgerows in hillslope contour hedgerow systems. However, the field-crop bioassay did find evidence of significantly higher growth of *Z. mays* plants in the agroforestry plots than the crop-only agriculture ones. This is despite the lack of any marked differences in soil nutrient concentration between these two treatments revealed by conventional chemical analyses (McDonald et al. 2002). Mean above-ground biomass was 16% lower for the plants within 0.5 m of the pruned calliandra hedgerows than those 1–1.5 m distant. This is in accord with Mugendi et al. (1999) who found evidence that calliandra competes with alley crop plants. The net result was a 5% lower grain yield (per hectare) in agroforestry plots than crop-only agriculture ones. The lack of correspondence of the field bioassay of the present study and the soil nutrient concentrations reported by McDonald et al. (2002) with the patterns in N-mineralisation for 1996 and 1997 (between hedgerow N-mineralisation < agricultural N-mineralisation) is very likely to be accounted for by the spatial variability observed due to inter-hedgerow tillage patterns – resulting in variations in both nutrient status and soil texture.

The results suggest that there was no clear positive effect of calliandra on soil fertility five years after establishment. However, given its effectiveness in controlling erosion (McDonald et al. 2002), the calliandra contour hedgerow system may have potential to sustain hillslope agriculture in the future after a longer period of cultivation by which time soil fertility levels will have fallen further.

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