SHORT-TERM EFFECTS OF SOIL AMENDMENT WITH TREE LEGUME BIOMASS ON CARBON AND NITROGEN IN PARTICLE SIZE SEPARATES IN CENTRAL TOGO

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Summary—We examined the effects of adding different plant materials on short-term organic matter dynamics of a West African savanna soil. Leaves and roots from three alley-cropped tree legumes were added to soil and exposed in the field for 120 d using PVC cylinders. Particle size fractionation of the exposed soil separating particulate organic matter (POM, 20–2000 μm), silt (2–20 μm) and clay (<2 μm) demonstrated that most of the C was stored in the silt and most of the N in the clay size separates. Adding *Senna* leaves to the soil led to an increase of the organic C content in the silt and clay fractions, and to an increase of the N content in the silt fraction. In *Gliricida* amended soil, the N content increased in silt and clay size separates. Roots of all three species had no effect on C or N contents in particle size fractions. The lignin content and the polyphenol-to-nitrogen ratio (PP-to-N ratio) decreased from coarser to finer particle size separates, while the acid-to-aldehyde ratio (Ac-to-Al ratio) increased. The addition of *Senna* leaves decreased the polyphenol content and the PP-to-N ratio in all particle size fractions. The lignin content was not affected. In the silt fraction, the alkyl-C content was decreased, the carboxyl- and amide-C content increased by the addition of *Senna* leaves indicating that it was not unaltered plant material but microbial metabolites which were responsible for the increase of C. The PP-to-N ratio of the added plant material seems to control the effects of soil amendment with tree legume biomass through its influence on decomposition processes and on the formation of organo–mineral complexes for both C and N. © 1998 Elsevier Science Ltd. All rights reserved

INTRODUCTION

Soil fertility is closely related to soil organic matter (SOM) content (Tiessen *et al.*, 1994), especially under low input conditions as in tropical smallholder agriculture. Adding crop residues or prunings to the soil as mulch and green manure is believed to increase SOM (Young, 1989). Biologically fixed N may be bound in SOM and improve soil fertility through mineralisation of organic N compounds (Giller and Wilson, 1991).

Differences in bulk soil C and N contents due to changes in land use are difficult to detect even if yield differences are observed (Schroth *et al.*, 1995), because changes in C and N contents may be small in comparison to the total quantity of C and N present. Physical fractionation of SOM can help to identify more active variables. At the same time, it may allow to examine the process of stabilisation of SOM. Useful approaches to SOM fractionation are particle size, aggregate size and density fractionation (Christensen, 1992).

Not only physical protection but also chemical recalcitrance or inhibitory effects may influence the stability of SOM (Baldock *et al.*, 1992). In the course of decomposition and humification of above ground biomass, the O-alkyl and the lignin derived aryl-C content decreased, the alkyl-C compounds accumulated (Zech and Kögel-Knabner, 1994). Yet, in particle size classes the aromatic C content measured by solid-state ^{13}C NMR increased from coarse fractions to the silt and decreased in clay fractions; the O-alkyl-C content decreased and the alkyl-C content increased from coarser to finer particles size fractions (Baldock *et al.*, 1992). Wet chemical analyses of the carbohydrate content, however, revealed that carbohydrates accumulate in the clay fraction. This discrepancy may be caused by the formation of iron–O-alkyl complexes in the clay, which are not detected by the NMR technique (Guggenberger *et al.*, 1995a).

The chemical quality of the organic matter that is added to soil as crop residues or green manure may play an important role in organic matter dynamics but has not been the subject of specific research up to now (Anderson and Flanagan, 1989). In contrast, the influence of chemical quality on litter decomposition has been intensively studied both in

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temperate (e.g. Melillo *et al.*, 1982) and tropical conditions (Palm and Sanchez, 1991; Oglesby and Fownes, 1992; Lehmann *et al.*, 1995), but the link to SOM formation has not yet been evaluated.

We have compared C and N in particle size fractions following the addition of leaves and roots from three different tree species relevant in agroforestry during one vegetative period. In the fractions that showed a significant increase of C after adding a substrate, the polyphenol and lignin contents were analysed, and the distribution of C species was measured with CP MAS ^{13}C NMR.

MATERIALS AND METHODS

The experiment was carried out in Central Togo, West Africa. The rainy season is unimodal with a mean annual precipitation of 1156 mm. The soil at this site has been classified as plinthic Acrisol (FAO, 1990) associated with ferric Acrisols. The texture class at the soil surface layer is loamy sand with low C, N and P contents of 7.5 mg g^{-1}, 0.49 mg g^{-1} and 44.9 mg kg^{-1}, respectively. The effective cation exchange capacity is low with 3.7 cmol$_c$ kg^{-1} at a pH (H$_2$O) of 6.5 (for soil characterisation see Lehmann *et al.*, 1995). The plant material was taken from an alley cropping trial with *Gliricidia sepium* Steud., *Calliandra calothyrsus* Meissn. and *Senna siamea* (synonymous *Cassia siamea* Lam.). The experimental details are given in Schroth and Lehmann (1995). *Gliricidia* and *Calliandra* are able to fix atmospheric N in contrast to *Senna*. Leaves and roots of the tree species were collected 5 d before the first pruning of the hedges. Dead roots were discarded and living roots were carefully cleaned from adherent soil, washed and air-dried.

Sieved topsoil material (200 g) was mixed with either 2 g of leaves or 2 g of roots (dia < 1.5 mm) of all three species (six treatments and one control without the addition of plant material). Every treatment was replicated four times. The soil–plant mixture was contained in PVC cylinders (dia 10 cm), resulting in a soil amendment of 2.5 t DM ha^{-1} which is normal for hedgerow intercropping in subhumid regions (Young, 1989). The cylinders were closed at the bottom with a wire mesh (0.5 mm) to prevent loss of soil when removing from the site of incubation, and on the top with a plastic net (5 mm) to exclude larger insects and litter from the cylinders. On 28 May 1992, the cylinders were placed in the field using a randomised complete block design. They were inserted into the soil so that the soil surface inside the cylinders was level with the soil surface outside. After 120 d of field exposure, the cylinders were collected, the samples air-dried and transported to Germany for further processing.

For the particle size fractionation, 50 g of soil and 150 ml of water were shaken on an agitator for 24 h. Glass balls were added to ensure proper dispersion of the soil without risking a destruction of microbial cells (Cambardella and Elliott, 1994) and a redistribution of the organic matter between the fractions. The agitation was kept at a low number of revolutions so as not to destroy sand particles. This method was found to be adequate for the very sandy soils we studied, although it usually might provide only limited dispersion in other soils (Christensen, 1992). The sand fraction (20–2000 μm) was separated by sieving. The silt (2–20 m) and clay (<2 m) fractions were separated by sedimentation using Atterberg cylinders. In the sand fraction, the particulate organic matter (POM) was separated from the mineral soil material densiometrically with water using repeated extraction. Because of the sandy soil texture, this fractionation procedure was very effective, and our POM fraction is believed to resemble POM isolated by dispersing in sodium hexametaphosphate (Cambardella and Elliott, 1993). Only the POM fraction was further analysed chemically, not the mineral sand fraction since it contained less than 1% of the total soil C after fractionation (Table 2).

The soil fractions were oven-dried at 40°C for 24 h, weighed and ground. They were analysed for C and N with a C/N analyser. Polyphenols were determined colorimetrically (King and Heath, 1967) after extracting for 24 h on an agitator with 0.1 M NaOH. Lignin was digested by cupric oxide oxidation and analysed by gas chromatography (after Hedges and Ertel, 1982).

Carbon species were determined with CP MAS ^{13}C NMR spectroscopy. The four replications of the silt fraction of *Senna*-amended soil and the control were pooled; thus, no significant differences can be given for the C species distribution. The silt fraction of the soil with or without *Senna* leaves were treated with HCl–HF after Preston *et al.* (1989) in order to increase SOM concentration and remove the ferromagnetic iron. The CP MAS ^{13}C NMR spectra were obtained on a Bruker MSL 300 NMR instrument. Data acquisition conditions were: spectrometer frequency, 75.5 MHz; spectral width, 29,412 Hz; number of scans, 3000–30,000; spinning speed 4096 Hz. The spectra were divided into four chemical shift regions and integrated electronically (Table 4).

Statistical analysis of the data was carried out by analysis of variance computed with the ANOVA procedure from the Statistical Analysis System (SAS Institute, 1992). If main effects were significant at $P < 0.05$, a multiple comparison of the means was calculated using the least significant difference (LSD) test. Plotting the C and N contents, the data were calculated differently for the POM fraction than for the silt and clay size separ-

Table 1. Initial nitrogen and polyphenol (PP) concentrations in leaves and roots from three tree legumes ($n = 4$ for N, $n = 2$ for PP), residual C after 120 d and decomposition rates obtained from the litterbag study by Lehmann *et al.* (1995) ($n = 4$)

Species		N (%)	C-to-N	PP (%)	PP-to-N	Residual C (% of initial)	Dec. rate (% d^{-1})
Gliricidia sepium	leaves	3.18 a	14.0	4.1	1.31	0.2 a	8.3
	roots	2.14 b	20.5	1.0	0.49	30.5 b	1.8
Calliandra calothyrsus	leaves	3.36 a	13.6	13.0	3.89	4.3 c	3.1
	roots	1.13 c	40.1	18.7	16.41	80.6 d	0.3
Senna siamea	leaves	1.81 b	25.7	10.1	5.61	7.6 c	2.5
	roots	0.85 c	58.4	1.6	1.94	52.9 e	0.8

Means in each column followed by the same letter are not significantly different at $P < 0.05$.

ates: for the POM fraction, the content refers to the whole soil (mg g^{-1} bulk soil) in order to give the total amount bound in this fraction. For the silt and the clay fractions, the true concentrations (mg g^{-1} fraction) were chosen because treatment means varied less than for the amount of the total. This is in contrast to Cambardella and Elliott (1993) and Barrios *et al.* (1996) who found the concentrations less sensitive to land use changes; these authors were looking only at coarse size fractions. In both cases (values referring either to bulk soil or fraction), the amounts shown can be interpreted in the same way, since they describe the same process. The necessity to distinguish these lies in the fractionation procedure: concentrations (relative to fraction) do not reflect changes in C when the total amount of the fraction changes like in POM but not its C concentration. On the other hand, concentrations can satisfactorily reflect changes of C in a given fraction, when the size of the fraction does not change; in fact, the total amounts (relative to bulk soil) would be less helpful because particle size separation procedures may not be sufficiently exact and hence make it difficult to detect changes in C contents.

RESULTS

The polyphenol concentrations differed widely between plant materials and species and decreased in the order *Calliandra > Senna > Gliricidia* (Table 1). The N concentration was higher in the plant materials of the N-fixing species *Gliricidia* and *Calliandra* than in the non-N-fixing *Senna* and was higher in leaves than in roots.

The C concentration of the original soil material decreased in the order POM > silt > clay (Table 2). The N concentration, however, was lower in the silt

fraction than in the POM and clay fractions. Thus, the C-to-N ratio decreased in the order POM > silt > clay. The total amount of N increased in the order POM < silt < clay. C and N contents in the sand fraction after the separation of POM were below the detection limits (Table 2).

The effects of mixing leaves with soil are shown in Figs 1 and 2. Adding *Senna* leaves to the soil increased the C content in all three fractions, POM, silt and clay. In the POM fraction the addition of *Calliandra* leaves resulted in the highest C content. The N content could be increased in the POM fraction by *Calliandra* and *Senna* leaves, in the silt fraction by *Senna* and *Gliricidia* leaves and in the clay fraction by *Gliricidia* leaves only (Fig. 2). Adding roots to the soil did not increase the C or N content of any fraction (results not shown). The exposure time was probably too short to show any effect, because the major part of the incorporated C and N was still retained in the soil fraction > 2 mm.

Only the addition of *Senna* leaves showed a significant effect ($P < 0.05$) on the organic C content in all particle size separates; therefore, only those were analysed for organic compounds. The lignin compounds (vanillyl, syringyl and cinnamyl units: V + S + C) decreased from POM to clay (Table 3, shown as a particle size continuum). Adding *Senna* leaves had no effect on the lignin concentration in the particle size fractions. The acid-to-aldehyde ratio of the vanillyl and syringyl (Ac/Al$_{V + S}$) compounds increased from POM to silt and was lower in the silt and clay fraction when *Senna* leaves were added (Table 3). The polyphenol concentrations were higher in the POM and clay fraction than in the silt fraction (Table 3) and tended to decrease in all three particle size fractions when *Senna* leaves were added. Plotting the PP-to-N ratio against the fractions, a clear decline from POM to clay can be

Table 2. C and N content and C-to-N ratio of the particle size fractions in the unamended soil, calculated per fraction (mg g^{-1} fraction; concentrations) and per bulk soil (mg g^{-1} soil; contents)

Fraction	Particle size (µm)	Weight (%)	C (mg g^{-1} fraction)	N	C (mg g^{-1} soil)	N	C-to-N ratio	C (% total)
Sand	20–2000	75	< 0.1	< 0.01	n.d.	n.d.	n.d.	n.d.
POM	20–2000	1	221.5 a	11.8 a	0.76 a	0.031 a	18 a	22
Silt	2–20	12	39.6 b	2.85 b	1.39 b	0.090 b	14 b	39
Clay	< 2	12	34.6 b	3.65 b	1.35 b	0.140 b	10 c	39

Means in each column followed by the same letter are not significantly different at $P < 0.05$ ($n = 4$).
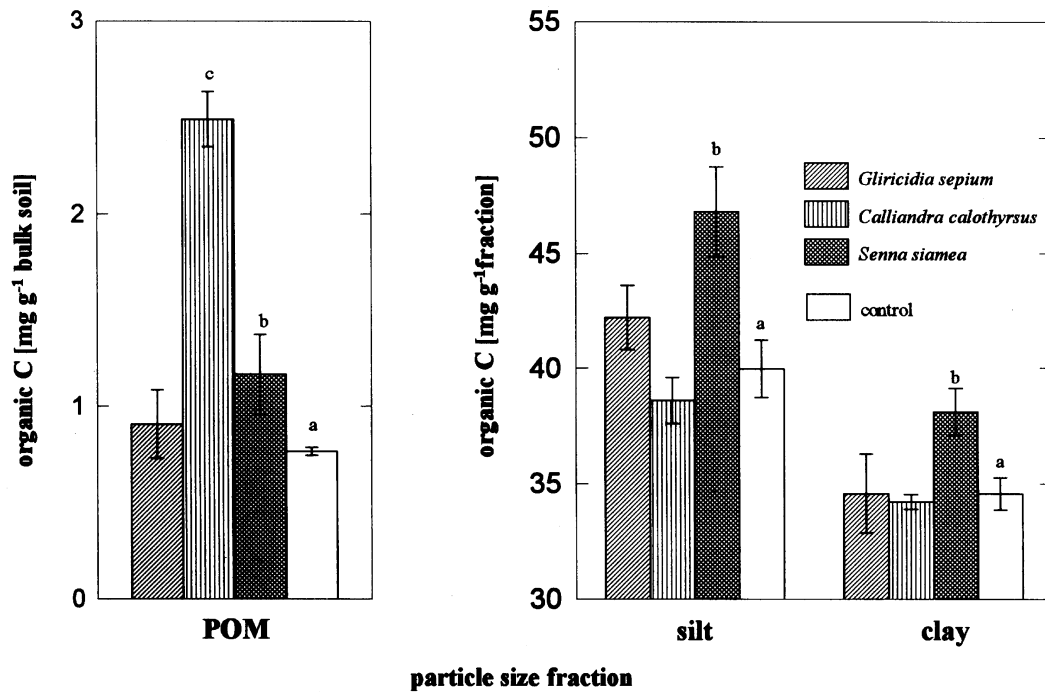
Fig. 1. Carbon concentrations in particle size fractions silt and clay and soil content of POM-C; bars with the same letters are not significantly different, bars without letters are not significantly different from the control ($P < 0.05$); means and standard errors.
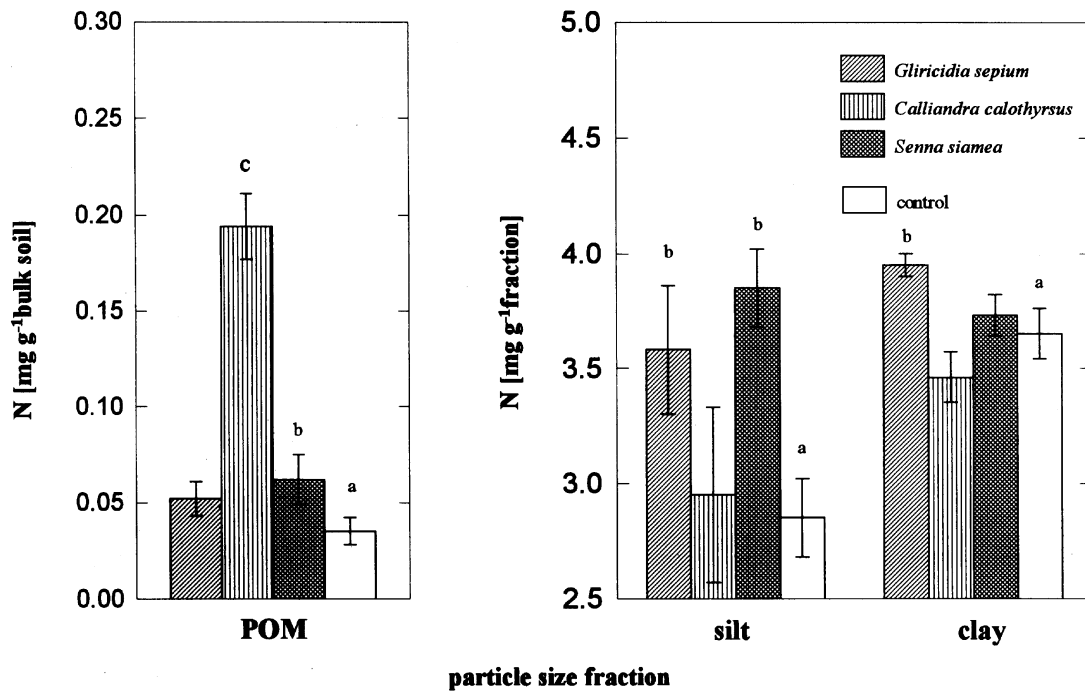
Fig. 2. Nitrogen concentrations in particle size fractions silt and clay and soil content of POM-N; bars with the same letters are not significantly different, bars without letters are not significantly different from the control ($P < 0.05$); means and standard errors.

Table 3. Organic compounds in the particle size fractions POM, silt and clay of the control, the soil amended with *Senna* leaves and the original leaf material

Treatment		V + S + C (mg g^{-1} C)	Ac-to-Al ratio	Polyphenols (mg g^{-1} C)	PP-to-N ratio
Senna leaves		27.7	0.22	217 a	5.61 a
Leaves added	POM	27.5	0.35	252 b	4.79 a
	silt	17.8	0.54	214 a	2.56 bc
	clay	8.1	0.68	227 a	2.24 b
Control	POM	30.0	0.34	277 b	5.21 a
	silt	16.6	0.65	226 a	3.09 c
	clay	7.3	0.82	286 b	2.71 bc

(a) lignin compounds V + S + C (vanillyl, syringyl and cumaryl compounds); (b) acid-to-aldehyde ratio of the vanillyl and syringyl compounds; (c) polyphenolic content; (d) polyphenol-to-nitrogen ratio; means in each column followed by the same letter are not significantly different at $P < 0.05$ ($n = 4$)

seen (Table 3). Again, the control showed higher values than the *Senna* amended soil.

The *Senna* leaves, the silt fraction of the *Senna* amended soil and the silt fraction without added plant material (= control) were analysed with CP MAS ^{13}C NMR spectroscopy to identify changes in the C-species distribution (Table 4). Adding *Senna* leaves to the soil did not influence C-species distribution. Only a very weak decrease of alkyl-C and an increase of carboxyl-C compounds can be observed. O-alkyl and aromatic C were not influenced by the treatment.

DISCUSSION

Carbon

Almost all the C and N of the sand fraction was contained in POM emphasizing the importance of this fraction (Table 2). The total C content was higher in the silt and clay fraction (39%, respectively) than in the POM (22%). This has been observed before (Baldock *et al.*, 1992). The organic matter in the silt and clay fractions seems to be a very important pool for the total SOM. It can be interpreted as organo–mineral complexes. These complexes are believed to form the stable organic matter (Christensen, 1992). This is especially important under warm and humid conditions (Duxbury *et al.*, 1989) and in sandy soils as in this study (75% sand), where potential binding sites are limited and aggregate protection is low.

The values of V + S + C in POM resembled those of the *Senna* leaf material. Thus, the particulate organic matter in the sand seemed to be composed mainly of unaltered plant material. POM seems to make up the light fraction organic matter with fast turnover times (Cambardella and Elliott,

1992). Even the addition of large amounts of fresh plant material did not change the Ac-to-Al ratio in POM (Table 3). A higher Ac-to-Al ratio shows a higher degree of microbial degradation of the lignin (Ertel and Hedges, 1984). The change in the Ac-to-Al and the PP-to-N ratio from leaf material to POM indicates at least a weak structural modification.

The lower lignin content in the clay than in the POM fraction agrees with results from Guggenberger *et al.* (1995b). Decomposition and humification progress from coarser to finer particle size fractions (Baldock *et al.*, 1992). This assumption is confirmed by the increasing acid-to-aldehyde ratios in the order POM, silt and clay and the decreasing CuO oxidation products and C-to-N ratios. The polyphenolic concentration did not show any consistent tendency comparing the particle size fractions (Table 3). Plotting the PP-to-N ratio instead of the polyphenolic concentration, a clear decrease is visible in the order POM > silt > clay (Table 3). Oglesby and Fownes (1992) and Lehmann *et al.* (1995) found a close relationship between decomposition and the PP-to-N ratio. This may also hold for the humification process.

The SOM of the West African savanna has not reached the advanced stage of humification of an oxisol under tropical pasture in Carimagua, where the lignin concentrations are lower and the Ac-to-Al ratios are higher (Guggenberger *et al.*, 1995b), but resemble the values of temperate soils (Zech *et al.*, 1992). Usually, the decomposition processes of soil organic matter are reported to be several times faster under tropical than temperate conditions (Duxbury *et al.*, 1989).

Table 4. Carbon compounds in the *Senna* leaves, the silt fraction of the *Senna* amended soil and the silt fraction without added *Senna* leaves (= control) from CP MAS ^{13}C NMR spectroscopy

Chemical shift (ppm)	Compounds	*Senna* leaves	*Senna* added (% of total C)	Control
0–50	alkyl-C	20	31	35
50–110	O-alkyl-C	55	28	29
110–160	aromatic-C	14	23	24
160–200	carboxyl/amide-C	11	18	11

Senna leaves were most effectively increasing the organic C content in all three particle size fractions after the 120 d of field exposure. At the same time, the decomposition rate of the *Senna* leaves obtained from a litterbag study (Table 1) were the lowest among the three species. Under our conditions, a slower decomposition may favour an increase of C in particle size fractions. This would indicate that recalcitrant C compounds are accumulating. The total lignin content, however, was not able to explain this increase. The Ac-to-Al ratio decreased in the silt and clay fraction (Table 3) indicating an import of less oxidised aromatic C compounds into these fractions. The polyphenolic concentration decreased through the addition of the *Senna* leaves (Table 3). If high polyphenolic concentrations and especially high PP-to-N ratios mean slower decomposition and N immobilisation (Lehmann *et al.*, 1995), lower values indicate the presence of more labile compounds from the added leaf material. Adding leaf material with higher PP-to-N ratios may in turn increase the organic C in particle size separates. One process of the observed C increase in particle size fractions may therefore be a selective preservation of specific C compounds, but not unaltered plant material.

The structural pattern of the silt fractions as revealed by CP MAS ^{13}C NMR spectroscopy resemble that of the two Oxisols examined by Baldock *et al.* (1992) with an unusually high amount of alkyl-C compared to other soils. This was interpreted with respect to high bioavailability of the plant residues, which allowed fast decomposition of the O-alkyl-C already at early stages of humification. The sandy soil texture in our experiment may also have resulted in low physical protection and rapid decomposition of the added *Senna* leaves. The similar amounts of aromatic C compounds in the silt of *Senna* amended soil and the control (Table 4) confirms the findings of the wet chemical analyses (Table 3). Also the O-alkyl-C content did not change after adding *Senna* leaves, although the leaves had more than half of its C in the O-alkyl range. Baldock *et al.* (1992) and Zech *et al.* (1992) found that only O-alkyl-C is mineralised during early stages of decomposition. The signal intensity weakly decreased in the alkyl-C range and increased in the carboxyl-C range when *Senna* leaves were added. This is probably caused by advanced humification, which is indicated by a breakdown of alkyl-C species and increased oxidation (see also Table 3). Again, the results make clear that the increase in organic C in the silt fraction by adding *Senna* leaves is not caused by unaltered plant material which would have resulted in an increasing carbohydrate content; it may rather be caused by selective preservation of polymethylene- and methyl-groups-containing organic acids (chemical shift at 160–200 ppm), which could be of microbial origin (Zech and Kögel-Knabner, 1994). Thus, the process leading to higher C contents in particle size fractions may be both an accumulation of specific plant compounds with high PP-to-N ratios and of microbial metabolites rich in organic acids.

Nitrogen

The total N content was 4.5 times higher in the clay than in the POM fraction, although the soil consisted of 75% sand and only 12% clay. The clay fraction is the most important N pool of the sandy savanna soil. Christensen (1992) reported that the bioavailability and mineralisation of N is highest in clay size separates.

The greater increase of the N concentration in the silt and clay fraction by adding *Gliricidia* leaves compared to the other two species reflects well the high N content of the *Gliricidia* leaves (Table 1) and their rapid N release (Lehmann *et al.*, 1995). The C concentration was not raised by the same species. Barrios *et al.* (1996) found significant differences between particle size separates of soils from maize and legume cropping systems only for the N but not for the C content. They concluded that for N-rich input materials the N content reacts more sensitively than the C content in particle size fractions to the input of N-rich materials. The addition of *Calliandra* leaves with a high polyphenol concentration, however, did not change the N concentration in silt or clay size separates in our study. More important than the pure N concentration seems to be the availability of N which is a function of the decomposition rate of the plant material (Table 1). Also, the C-to-N ratios of remaining *Gliricida* and *Senna* leaves were higher both throughout decomposition (2 times; calculated from Lehmann *et al.*, 1995) and after 120 d (1.5 times) compared to *Calliandra* indicating its lower relative N release.

The amount of N added to the soil by the leaves of *Senna* was only 54% of the amount added by the other two species; the N content in the silt fraction of the *Senna* amended soil, however, was higher than for the other two species. A higher N input can not entirely explain higher N contents in particle size separates. Palm and Sanchez (1991) demonstrated that polyphenols controlled the N mineralisation from ground leaf material of several tropical legumes. Oglesby and Fownes (1992) and Lehmann *et al.* (1995) found a close relationship between the PP-to-N ratio and the N release from leaves. Apart from the total N release, the formation of stable organo-N–mineral complexes may be responsible for the high N accumulation through the application of *Senna* leaves in our study. Thus, the efficiency of stabilising N in organo–mineral complexes may be controlled by the PP-to-N ratio of the original material in the same way as it was

shown for the decomposition (Lehmann et al., 1995).

The larger increase of both N and C in the silt than in the clay fraction is in contrast to results from temperate soils (Tiessen and Stewart, 1983; Christensen, 1992; Elliott et al., 1992). These authors state that the silt fraction is the least active. Using radiocarbon dating, Anderson and Paul (1984) found the oldest organic C in the fractions coarse clay (0.2 –2 μm), fine and coarse silt (2–5 μm and 5–20 μm, respectively); the fine clay was the most active fraction. Guggenberger et al. (1995b), however, found an increase of organic C in the silt fraction under legume pastures compared to native savanna in Columbia, as it was shown in our study. This result coincides also with the work of Bonde et al. (1992) in southeastern Brazil who found that the organic matter in the silt fraction is more labile than clay associated organic C.

Regarding both the C and N enrichment of the leaf added soil, the short exposure time and relatively small organic input must be born in mind. Several authors found the POM (Cambardella and Elliott, 1993) or the Ludox light fraction (Barrios et al., 1996) as the most active fractions after changes in land use. The enrichment effect in finer particle size fractions shown in our study may be temporary, consisting of easily mineralisable microbial metabolites. In the POM fraction of the Gliricidia amended soil, the N content was not significantly different from the control; obviously, the effect of adding the leaves to the soil had already decreased for the rapidly decomposing species. However, the higher N concentrations in the clay and silt fractions may lead to a greater N mineralisation at least for the next cropping season.

At the same experimental site, yield and foliar N concentration of alley-cropped maize with Gliricidia was higher than of the control at 3 m distance from the hedge (Schroth and Lehmann, 1995). This effect was not observed with Calliandra and to a lesser degree with Senna hedges. Gliricidia leaf mulch may have supplied the soil with more available N than the other two species. This result coincides well with the increase of N in the particle size separates when Gliricidia leaves were added in contrast to Calliandra, although they had similar N concentrations. The rapid N release of Gliricidia leaf mulch (Lehmann et al., 1995) and the binding of N in the organic matter as shown in our study may have been advantageous for the N nutrition of the maize. The results of this short-term experiment give no information about long-term SOM dynamics, but plant growth may benefit from the increased N content in the following cropping season.

CONCLUSIONS

Most of the soil C and N is contained in the silt and clay size separates compared to the fraction 20–2000 μm, where POM, consisting mainly of unaltered plant material, is the main fraction. The soil amendment with tree legume biomass increases C and N contents of POM for the slow decomposing leaves indicating that mainly recalcitrant C species are accumulated. In the silt and clay size fractions, Senna leaves are most efficiently increasing C and N concentrations. The chemical composition across the fractions suggests a combined effect of selective preservation of recalcitrant plant compounds and accumulation of microbial metabolites. The decomposition rates and N release patterns were able to explain the contrasting effect of the different plant residues. The combined findings of our study and the decomposition experiments by Lehmann et al. (1995) indicate a connection between the PP-to-N ratio and the formation of stable organo-N–mineral complexes.

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