Aust. J. Soil Res., 1987, **25**, 83–93

Long-term Trends in Fertility of Soils under Continuous Cultivation and Cereal Cropping in Southern Queensland. VI Loss of Total Nitrogen from Different Particle-size and Density Fractions

R. C. Dalal and R. J. Mayer

Queensland Wheat Research Institute,
Department of Primary Industries, Toowoomba, Qld 4350.

Abstract

The dynamics of total N in particle-size and density fractions of six major soils which have been used for cereal cropping for 20–70 years were studied in order to identify the labile organic matter fractions in soil. For virgin soils, no single particle-size was consistently enriched in N as compared with the whole soil. The clay fraction contained the largest proportion (53% overall) of total N. Silt-size and sand-size N fractions accounted for 26% and 21% of total N, respectively. Upon cultivation, the sand-size fraction lost most of its N (as much as 89% in Langlands–Logie soil). However, N losses also occurred from silt-size and clay-size fractions in most soils. Changes in C : N ratios of different particle-size fractions upon cultivation were not consistent in all soils, possibly because of the transfer of organic C and N among these fractions. Therefore, the separation of labile organic matter fractions from the whole soil based upon particle-size may not be successful in all soils.

On the other hand, the density fractionation of soil into a light fraction ($<2\ Mg\ m^{-3}$) containing relatively labile organic matter (76–96% lost upon cultivation) and a heavy fraction ($>2\ Mg\ m^{-3}$) containing less labile organic matter appears to be more successful in most soils. It is suggested that the cultural practices that enhance the amount of light fraction would increase the rate of nutrient cycling through microbial biomass and may increase the overall availability of nutrients in soil.

Introduction

Substantial losses of organic C and N occur upon cultivation of a soil previously supporting native vegetation (Dalal and Mayer 1986*a*). Furthermore, soils differ considerably in their rates of organic C and N loss (Dalal and Mayer 1986*b*, 1986*c*). Even within a soil, organic C fractions associated with different particle sizes differ in their rates of loss upon cultivation (Chichester 1969; Tiessen and Stewart 1983). For example, in a Langlands–Logie soil previously supporting brigalow vegetation (*Acacia harpophylla*), the rates of loss of organic C were 0·11, 0·08, 0·04 and 0·08 $year^{-1}$, from sand-, silt- and clay-size fractions and whole soil, respectively (Dalal and Mayer 1986*c*). The proportion of the sand-size organic fraction declined rapidly (from 31% to 13% overall) whereas that of the clay-size fraction increased from 48% to 61% overall over 45 years of cultivation (Dalal and Mayer 1986*c*). The association of organic C and N with clay may therefore be an important mechanism of organic matter protection in cultivated soil (Oades and Ladd 1977). The present study is concerned with the distribution and kinetics of total N associated with different particle sizes in six major soils of southern Queensland, which have been cultivated for 20 to 70 years.

It has been shown that the proportion of light fraction organic matter ($<2\ Mg\ m^{-3}$) to total organic matter provides an earlier indication of the

0004-9573/87/010083$02.00

consequences of different soil managements than the levels of total soil organic matter (Ford and Greenland 1968; Richter *et al.* 1975). This conclusion was supported by the density fractionation studies of five clay soils from southern Queensland, in which the loss of organic C from the light fraction was 2–11 times faster than that from the heavy fraction ($>2\ \mathrm{Mg\,m^{-3}}$) (Dalal and Mayer 1986*d*). This study was extended to investigate the dynamics of soil N in different density fractions so as to provide a better understanding of soil fertility changes under long-term cultivation. Changes in C : N ratios of soil organic matter associated with different particle size and density fractions are also reported. This should provide an indication of qualitative changes in organic matter and nitrogen supplying capability of the six major soils studied.

Materials and Methods

The study area (between 27° and 30° S. and 148° and 152° E.), soils, crop and soil management practices, and soil sampling and analytical techniques have been described previously (Dalal and Mayer 1986*a*). In virgin sites the overall ranges in pH values, clay contents and organic C contents of the six soil series (0–0·1 m depth) were 6·5–8·1, 19–74% and 0·77–2·23%, respectively.

The procedure used to obtain clay and clay + silt particles has been described previously (Dalal and Mayer 1986*c*). Densimetric fractionation of soil was done in a bromoform–ethanol mixture (Dalal and Mayer 1986*d*). The $<2\ \mathrm{Mg\,m^{-3}}$ fraction is referred to as the light fraction.

Total N was determined in clay, and clay + silt particles, and in light and heavy ($>2\ \mathrm{Mg\,m^{-3}}$) fractions by the micro-Kjeldahl method as described by Bremner and Mulvaney (1982).

The particle-size and density fractionations of soil were carried out in duplicate at 22±1°C. Total N in sand-size fractions was calculated by difference (Dalal and Mayer 1986*c*). Mean values calculated on oven-dry weight basis (105°C) are reported.

The first-order rate equation, $N_t = N_e + (N_0 - N_e)\exp(-kt)$, where N_0, N_e and N_t are total N concentrations in a given particle-size or density fraction initially ($t = 0$), at equilibrium ($t \to \infty$) and at time t, respectively, and k is the rate of loss (or gain) of total N from the soil fraction, was employed to describe the kinetics of total N loss from a particle-size or density fraction. Where the first-order equation was not applicable, trends in total N loss from different particle-size or density fractions at different periods of cultivation were discerned from linear and quadratic relationships. Trends in C : N ratios of different fractions were similarly discerned.

Table 1. Total N concentration of different particle-size fractions from six soil series (0–0·1 m depth): mean values from virgin sites

Soil series (No. of sites)		Total N concentration (%) Whole soil	Sand-size[A]	Silt-size[A]	Clay-size[A]
Waco	(5)	0·144	0·227 (21)	0·230 (22)	0·116 (58)
Langlands–Logie	(6)	0·203	0·165 (28)	0·331 (26)	0·184 (45)
Cecilvale	(7)	0·133	0·058 (19)	0·226 (26)	0·180 (55)
Billa Billa	(7)	0·139	0·070 (24)	0·217 (28)	0·194 (48)
Thallon	(6)	0·065	0·043 (12)	0·064 (22)	0·071 (65)
Riverview	(5)	0·084	0·025 (22)	0·279 (31)	0·212 (46)

[A] The proportion of soil total N in particle-size fractions is in parentheses. (Overall proportions of total N in sand-, silt- and clay-size fractions are 21%, 26% and 53%, respectively, for the 36 virgin sites.)

Results

Dynamics of Total N in Different Particle-size Fractions

Distribution

In all virgin soils, no single particle-size was consistently enriched in total N as compared with the whole soil (Table 1). The Thallon soil showed approximately equal N concentrations in the different particle-size fractions. In other soils, the silt-size fraction was generally the most enriched. Clay particles were also enriched in Cecilvale, Billa Billa, Thallon and Riverview soils, but only in the Waco soil did sand-size particles have a higher N concentration than the whole soil.

However, the largest proportion (53% overall) of total N was present in the clay-size fraction in all soils (Table 1). Silt-size and sand-size N fractions accounted for 26% and 21% of total N, respectively. Generally, total N concentration of the clay fraction decreased with increasing clay content ($r = -0 \cdot 73^{***}$).

Soil properties (Dalal and Mayer 1986*a*) which accounted for 90% variation (as determined by stepwise multiple regression analysis) in total N concentration in the clay-size fraction were clay content, oxalate-extractable iron (Fe_o), dithionite-extractable iron (Fe_d), $Al_o : Fe_o$ ratio and total N. Urease activity, exchangeable Ca, sand content and organic C concentration accounted for 78% of the variation in silt-size N concentration; total P, exchangeable Na, organic P and total N concentration accounted for 80% variation in sand-size N concentration. Active iron oxide (Fe_o and Fe_d) and clay are involved in aggregation, and thus, in the protection of clay size N.

Table 2. Distribution of total N into sand-, silt- and clay-size particles in virgin and cultivated soils (0–0·1 m depth)

Soil series (No. of sites)	Total N (kg ha^{-1}) Sand-size N Virgin	Cultivated	Silt-size N Virgin	Cultivated	Clay-size N Virgin	Cultivated
Waco (21)	255	77	267	254	705	491
Langlands–Logie (18)	560	64	520	276	900	802
Cecilvale (19)	257	123	351	156	743	554
Billa Billa (21)	309	127	360	222	618	530
Thallon (22)	74	51	135	122	400	290
Riverview (18)	227	61	319	188	474	470

In most soils there was a large reduction in sand-size N upon cultivation (Table 2); reductions ranged from 31% for Thallon soil to 89% for Langlands–Logie soil. Silt-size and clay-size fractions also lost N upon cultivation (Table 2). However, overall losses from these fractions were relatively smaller: for example, $\leqslant 10\%$ from the silt-size (Waco and Thallon) and the clay-size fractions (Langlands–Logie and Riverview).

Kinetics

The N present in various particle-size fractions in most soils declined linearly with the period of cultivation (Table 3). Loss of N from the sand-size fraction was low in Waco and Thallon soils (< 4 kg ha^{-1} yr^{-1}) but high in Langlands–Logie and Billa Billa soils (> 13 kg ha^{-1} yr^{-1}). Loss from the silt-size fraction was also high (> 10 kg ha^{-1} yr^{-1}) in the latter two soils. However, that from the clay-size fraction was similar (5–7 kg ha^{-1} yr^{-1}) in all five clay soils. No significant N losses were detected from the silt-size fraction and the clay-size fraction in Thallon and Riverview soils, respectively.

The proportion of sand-size N to that of the whole soil decreased with increasing period of cultivation in at least three soils (Waco, Billa Billa and Thallon) but that of the clay-size N increased linearly with period of cultivation in Waco, Langlands-Logie and Thallon soils.

Table 3. Regression coefficients of particle-size N and period of cultivation
NS, not significant. Correlation coefficients, significant at $P < 0\cdot05$, are in parentheses

Soil series	Regression coefficients (kg N ha^{-1} yr^{-1})[A] Sand-size N	Silt-size N	Clay-size N
Waco	2·59 (0·68)	1·85 (0·61)	5·26 (0·82)
Langlands-Logie	13·51 (0·68)	10·39 (0·80)	6·59 (0·65)
Cecilvale	5·82 (0·73)	Note[B]	6·14 (0·68)
Billa Billa	13·22 (0·79)	10·78 (0·85)	4·55 (0·47)
Thallon	3·99 (0·88)	NS	6·81 (0·69)
Riverview	8·51 (0·55)	Note[B]	NS

[A] Equation used: $N_t = N_0 - at$, where N_0 and N_t are the particle-size N concentrations (kg ha^{-1}) initially and after t years of cultivation, respectively, and a is the regression coefficient (kg N ha^{-1} yr^{-1}).
[B] For Cecilvale: $N_t = 342 - 23\cdot30^{*}t + 0\cdot56^{**}t^2$, $R^2 = 0\cdot61$;
for Riverview: $N_t = 296 - 30\cdot46^{*}t + 1\cdot46^{**}t^2$, $R^2 = 0\cdot55$.

The rates of N loss from the sand-size and silt-size fractions were significantly related to the amounts of C and total N contained in the light fractions of the virgin soils ($r = 0\cdot84^{*}$ and $0\cdot90^{*}$, respectively). These particle-size fractions, therefore, are a major source of labile organic matter in soil.

Table 4. C : N ratios of particle-size fractions from virgin and cultivated soils (0–0·1 m depth)

Soil series	C : N ratio Sand-size N Virgin	Cultivated	Silt-size N Virgin	Cultivated	Clay-size N Virgin	Cultivated
Waco	13·9	22·2[A]	16·1	11·9[A]	10·1	12·8[A]
Langlands-Logie	13·5	47·9[A]	10·0	14·7[A]	10·6	9·3
Cecilvale	20·6	21·4	14·9	20·4	11·1	12·3
Billa Billa	15·2	11·0	10·8	13·4[A]	10·6	10·9
Thallon	42·9	26·0	17·1	12·6[A]	10·1	11·9[A]
Riverview	29·3	17·2	9·7	17·1[A]	15·1	14·5

[A] Significantly different from virgin soil ($P < 0\cdot05$) according to paired 't' test.

C : N ratio

The C : N ratios of the sand-size fraction varied widely among soils (Table 4). Upon cultivation, C : N ratios of this fraction increased significantly in Waco and Langlands-Logie soils. The C : N ratios of the silt-size fraction varied less than those of the sand-size fraction but more than those of the clay-size fraction, among the six soil series, in both virgin and cultivated soils. Upon cultivation, C : N ratios of the silt-size fraction decreased in the heavy clay Waco and Thallon soils (>50% clay), but increased in Langlands-Logie, Billa Billa and Riverview soils (Table 4).

The C : N ratios of the clay-size fraction increased upon cultivation in Waco and Thallon soils. Changes in C : N ratios of the sand-size, silt-size and clay-size fractions with period of cultivation in Waco soil are shown in Fig. 1.

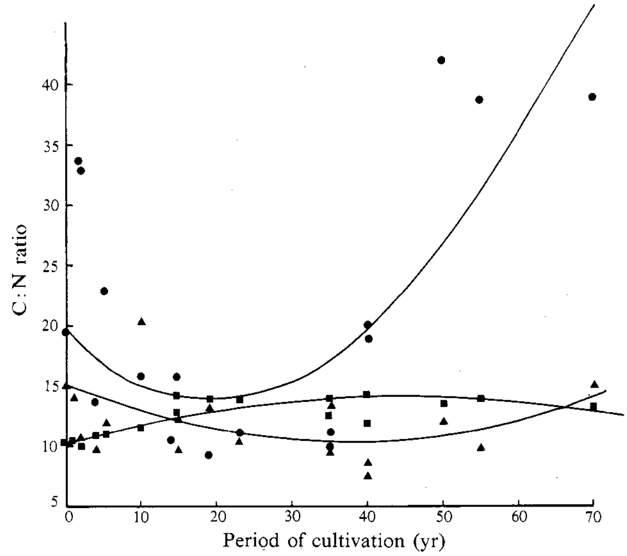

Fig. 1. Changes in C : N ratios (y) of particle-size fractions with period of cultivation (x) in Waco soil:

Sand-size N (●) $y = 19\cdot58 - 0\cdot53^{**}x + 0\cdot013^{*}x^2$, $R^2 = 0\cdot40$;
Silt-size N (▲) $y = 15\cdot12 - 0\cdot25x + 0\cdot003^{*}x^2$, $R^2 = 0\cdot25$;
Clay-size N (■) $y = 10\cdot41 + 0\cdot17^{*}x - 0\cdot019^{**}x^2$, $R^2 = 0\cdot61$.

As determined by stepwise regression analysis, the C : N ratio of the clay-size fraction of virgin soils ($n = 36$) was significantly correlated ($r = 0\cdot57^{**}$) with the bulk density, that of the silt-size fraction with clay content and DTPA-Zn ($R^2 = 0\cdot27$), and that of the sand-size fraction with silt content, $CaCO_3$, $Al_0 : Fe_0$ ratio, DTPA-Zn, organic C content and total N ($R^2 = 0\cdot69$). This implies that organic C and N from different particle-size fractions are lost, retained or re-utilized differently in these soils, depending upon the amounts of these soil constituents which are probably involved in aggregation, complexation and interaction with organic matter.

Dynamics of Total N in Density Fractions

Distribution

The distribution pattern of total N in different density fractions of virgin soil varied considerably among the six soil series (Fig. 2*a* and Table 5). However, the light fraction (<2 Mg m^{-3}) had highest N concentration in all soils. Generally the N concentration of the fractions decreased with the increase in their density.

Soils varied in total N distribution in different fractions. For example, more than 70% of total N was present in the 2·0–2·2 Mg m^{-3} fraction in Waco soil, but in Thallon and Riverview soils most was in the heavy fraction ($>2\cdot4$ Mg m^{-3}), reflecting thereby the differences in mineralogy of these soils (Dalal and Mayer 1986*a*). However, N in the light fraction declined most upon cultivation in all six soils. Therefore, fractionation of soil N into two density fractions, light (<2 Mg m^{-3}) and heavy (>2 Mg m^{-3}), may identify a light, labile N fraction, and thereby provide a more sensitive and early indicator of management effects on soil fertility.

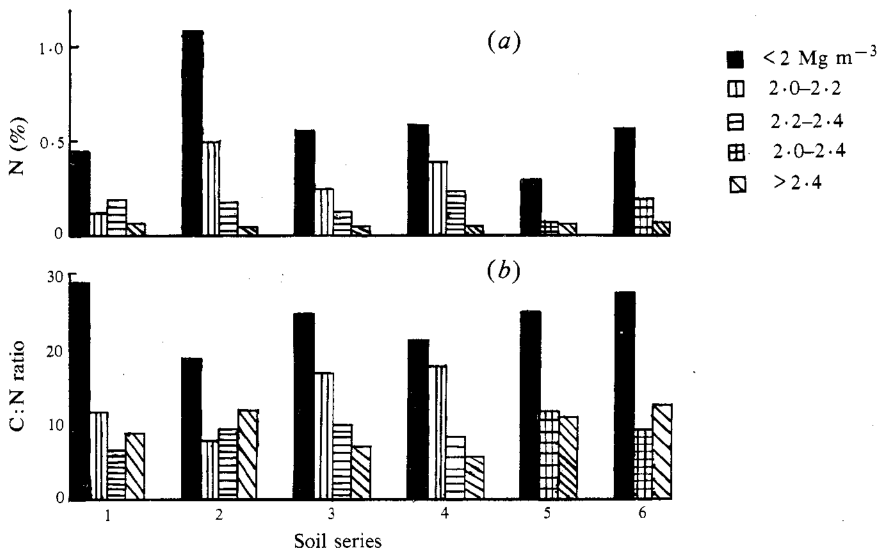

Fig. 2. N concentration (*a*) and C : N ratios (*b*) of different density fractions obtained from virgin sites of six soil series: 1, Waco; 2, Langlands-Logie; 3, Cecilvale; 4, Billa Billa; 5, Thallon; 6, Riverview.

Table 5. Distribution of total N into different density fractions in virgin soils (0–0·1 m depth)

Soil series	Proportion of soil total N (%) in density fractions[A] <2·0	2·0–2·2	2·0–2·4	2·2–2·4	>2·4 Mg m^{-3}
Waco	8 (−53)	72 (−26)		17 (−48)	2 (+35)[B]
Langlands-Logie	15 (−72)	22 (−44)		56 (−43)	7 (− 7)[B]
Cecilvale	10 (−72)	32 (−51)		31 (− 8)	22 (−34)
Billa Billa	15 (−53)	16 (− 9)		48 (−27)	18 (−20)
Thallon	8 (−45)		<1		90 (−23)
Riverview	14 (−35)		<1		81 (−18)

[A] In parentheses is the percentage change, i.e.

100 × (mean value in cultivated soils − mean value in corresponding virgin soils)/mean value in corresponding virgin soils.

Percentage reductions in total N in cultivated soils were 35%, 45%, 39%, 32%, 25% and 28% in Waco, Langlands-Logie, Cecilvale, Billa Billa, Thallon and Riverview soils, respectively (Dalal and Mayer 1986*e*).

[B] No significant change ($P < 0.05$).

Kinetics of N loss from the light (<2 Mg m^{-3}) and heavy (>2 Mg m^{-3}) fractions

The kinetic parameters of N loss from the light fraction are given in Table 6, and curves according to the first-order rate equation (see Table 6) are shown in Fig. 3. The rates of N loss from the light fraction (k_{Lf}) varied from 0·12 year^{-1} (Billa Billa) to 0·95 year^{-1} (Riverview), and were similar to the k_{Lf} values of organic C, except for Billa Billa and Waco soils with values for N less than half those for organic C (Dalal and Mayer 1986*d*). The k_{Lf} values for N loss were significantly correlated with the reciprocal of the clay content ($r = 0 \cdot 87^*$), the organic C/urease activity ratio ($r = 0 \cdot 93^{**}$), and frequency of the stubble retention ($r = -0 \cdot 84^*$). Also, k_{Lf} values were closely correlated with the soil C : N ratio ($r = 0 \cdot 98^{**}$), thus emphasizing the role of organic C substrates for microbial mineralization.

Table 6. Kinetic parameters of N loss from the light fraction (<2 Mg m^{-3}) of six soil series

Soil series	N_0[A] (kg ha^{-1} 0·1 m^{-1})	N_e[A] (kg ha^{-1} 0·1 m^{-1})	k_{Lf}[A] (year^{-1})	r[B]
Waco	101	24	0·188	0·98
Langlands-Logie	302	11	0·183	0·92
Cecilvale	133	20	0·482	0·99
Billa Billa	191	7	0·118	0·94
Thallon	48	9	0·174	0·94
Riverview	139	52	0·953	0·96

[A] Estimated from $N_t = N_e + (N_0 - N_e) \exp(-k_{Lf} t)$, where N_0, N_e and N_t are N concentrations (kg ha^{-1}) in the light fraction initially ($t = 0$), at equilibrium ($t \rightarrow \infty$), and after t years of cultivation, respectively, and k_{Lf} is the rate of loss of N from the light fraction (year^{-1}).

[B] Multiple correlation coefficient, significant at $P < 0 \cdot 01$.

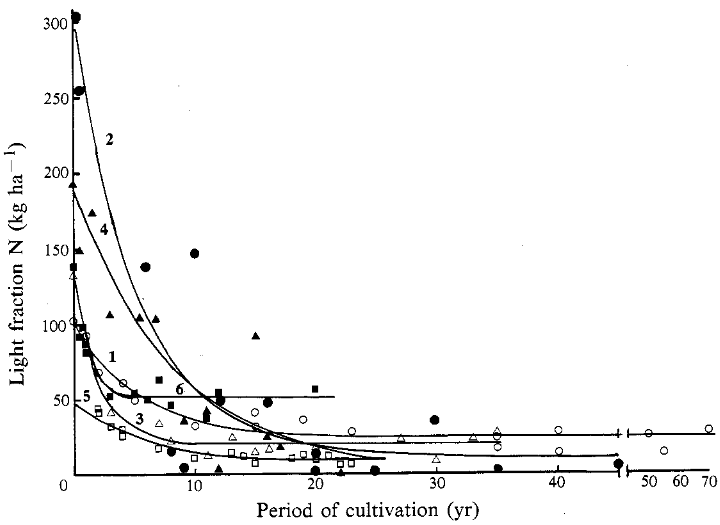

Fig. 3. Relationship between light fraction N and period of cultivation for soil series: 1, Waco (○); 2, Langlands-Logie (●); 3, Cecilvale (△); 4, Billa Billa (▲); 5, Thallon (□); 6, Riverview (■).

In all soils except Riverview, more than 75% (76–96%) of N from the light fraction would be lost at equilibrium $[(N_0 - N_e)/N_0]$. The N_0 values were closely correlated with the C_0 values of the light fraction ($r = 0 \cdot 97^{**}$), and thus similarly related to other soil properties (Dalal and Mayer 1986*d*). The N_e values were correlated with dithionite-extractable Fe ($r = 0 \cdot 98^{**}$) and the organic C/urease activity ratio ($r = 0 \cdot 92^{**}$), thereby reflecting the fact that N values at equilibrium depend upon the extent of protection provided by soil constituents against decomposition.

The rates of N loss from the heavy fraction (k_{Hf}) were 0·05, 0·10 and 0·24 year^{-1} in Waco, Langlands–Logie and Cecilvale soils, respectively. In Billa Billa and Thallon soils, N from the heavy fraction decreased linearly at the rate of 16 and 7 kg N ha^{-1} year^{-1} (1·5% and 1·2% of initial N in the heavy fraction) respectively. No significant loss of N occurred from the heavy fraction of Riverview soil, although this fraction lost significant amounts of organic C upon cultivation (Dalal and Mayer 1986*d*). The amount of N in the heavy fraction was closely correlated with the soil total N (r = 0·94**), and therefore similarly related to other soil properties (Dalal and Mayer 1986*e*).

C : N ratio

The C : N ratios generally decreased with increasing density of the fractions (Fig. 2*b*), as found also by Turchenek and Oades (1979). The C : N ratio of the light fraction (<2 Mg m^{-3}) was not significantly changed by cultivation in at least four soils and that of the heavy fraction (9–13) behaved similarly to that of the whole soil (Dalal and Mayer 1986*e*). The C : N ratio of the light fraction was significantly correlated with the dithionite-extractable Fe (r = 0·50**) and that of the heavy fraction with the bulk density (r = 0·49**) of virgin soils.

Discussion

Dynamics of Total N in Particle Size Fractions

Similarly to organic C (Dalal and Mayer 1986*c*), total N concentration in a particle-size fraction generally decreases as the fraction's total content in soil increases (Turchenek and Oades 1979; Young and Spycher 1979; Hinds and Lowe 1980). However, the clay fraction contains the largest proportion of total N in soils over a wide range of clay contents (Chichester 1969; Christensen 1985), although soils high in silt may also contain a high proportion of total N in that fraction (McKeague 1971). Moreover, the proportion of total N in the clay-size fraction increases upon cultivation (from 53% to 65% overall), indicating the protection afforded by the clay fraction to the soil organic matter (Mortland 1970; Sorensen 1981), although the mechanisms of clay-organic matter association to enhance or provide protection from decomposition are not well understood. This preferential protection of the clay-fraction N occurs in cultivated soils in spite of the fact that N in clay-size separates mineralizes more readily than in large particle-size separates (Chichester 1969). The relative inaccessibility of organic matter to microorganisms and proteolytic and other degradative enzymes within the soil matrix probably occurs through aggregate formation with the clay fraction. The association of N concentration in the clay-size fraction with Fe_0, Fe_d and clay content also indicates the role of these constituents in aggregation.

The clay fraction contains most of the microbial products and debris, the silt fraction contains most of the microbial biomass, and the sand fraction contains mostly plant debris (Ahmed and Oades 1984) and probably fungal hyphae (Oades and Ladd 1977) and faunal debris. Langlands–Logie and Billa Billa soils showed larger amounts of total N losses than the other soils (Dalal and Mayer 1986*e*); these excess N losses mostly occurred from the sand-size and silt-size fractions (Table 3), which comprise mostly the labile N fraction in soil.

Generally, C : N ratios of given particle-size fractions differ among soils (Table 4). The wide range of C : N ratio of the sand-size fraction shows the variable contribution of organic material from plant residues (C : N ratio, ⩾40) as well as from microbial sources (C : N ratio, $\leqslant 10$). In some soils at least, the latter is mineralized first, resulting in wider C : N ratio upon cultivation (Table 4). However, N mineralized from this source may be re-utilized to decompose plant residues, and thus lower the C : N ratio of the sand-size fraction, or else it is transferred to silt-size and clay-size fractions as microbial biomass and metabolites. These, if accessible to other microbes and to proteolytic and other degradative enzymes, in turn are mineralized as well and utilized by plants. This is clearly demonstrated by the changes in C : N ratio of the particle-size fractions with cultivation (Fig. 1). The processes of mineralization, immobilization and transfer of N from and among different particle-size fractions probably occur concurrently (Ladd and Amato 1980), and so affect each fraction. This is reflected in the significant relationships between C : N ratio of the sand-size fraction with silt content, and that of the silt-size fraction with the clay content of these soils. Physical fractionation alone, therefore, will not yield clean fractions containing distinctly different biological entities because of the complex association of organic matter with inorganic soil components (Ahmed and Oades 1984; Tiessen *et al.* 1984; Dalal and Mayer 1986*c*).

Dynamics of Total N in Density Fractions

Distribution of total N in different density fractions (Table 5, Fig. 2*a*) follows trends similar to that of organic C (Dalal and Mayer 1986*d*). However, the proportion of N in the light fraction (<2 Mg m^{-3}) is lower than that of organic C (8–15% for N, cf. 17–34% for organic C), resulting in wide C : N ratios (19–28) of the light fraction. Organic C and N of this fraction, however, decline most (35–72%) in all soils under cultivation (Ford and Greenland 1968; Dalal and Mayer 1986*d*). The light fraction contains most of the partly decomposed plant residues, microfloral and faunal debris and most of the microbial biomass (Oades and Ladd 1977). It is present in all particle-size fractions (Turchenek and Oades 1979), although a large proportion of it is derived from the sand-size and silt-size fractions. In fact, the enrichment ratio of organic matter in the light fraction [organic C or N (%) in the light fraction/organic C or N (%) in the whole soil] is directly proportional to the sand + silt content of the virgin soils (r = 0·94**), and hence, inversely correlated with the clay content of the soil (r = 0·93**). Similarly, the relationship between the k_{Lf} of organic C and N and the reciprocal of the clay content demonstrates that the light fraction is probably unassociated or only partly associated with the clay fraction. Unlike the heavy fraction (>2 Mg m^{-3}), in most soils it is poorly protected by clay, and, hence it is a relatively labile fraction in the soil.

Summary and Conclusions

Loss of N with cultivation occurred from all particle-size fractions in most soils. The magnitude of N loss from the sand-size and silt-size fractions varied among soils. The sand-size fraction lost the highest proportion of total N. Because the clay-size fraction lost relatively little N, especially from the Riverview (sandy loam) soil, the proportion of total N in this fraction increased with cultivation. The rates of loss of N from the sand-size and silt-size fractions were positively correlated with the amount of light fraction organic matter (organic C and N) present in these soils.

Although with cultivation N was lost from both the light and heavy fractions of most soils, the rates and proportion of N loss were much higher from the light fraction. Again, in Riverview soil, all the N loss occurred from the light fraction while the heavy fraction N appeared to be largely unaffected by cultivation. Nevertheless mineralization-immobilization of N possibly occurs in the heavy fraction of Riverview soil, because organic C was found to be lost from this fraction upon cultivation (Dalal and Mayer 1986*d*).

It is concluded that neither particle-size nor density fractionation provides a consistent and clear separation between labile and non-labile organic matter in all soils studied. The density fractionation of organic matter into the light fraction (labile) and the heavy fraction (non-labile) is probably useful in most soils. Soil and crop management practices that enhance the amount of light fraction should increase the rate of nutrient cycling through microbial biomass and increase the overall availability of nutrients in soil. Further improvements in density fractionation of soil, based upon distribution of natural aggregates which somehow measure the relative magnitude of accessibility of organic matter to microorganisms and degradative enzymes, may elucidate the dynamic nature of soil organic matter and thus provide a basis for sound management of organic matter and nutrient (N, P, S, etc.) supply to crops.

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Manuscript received 2 June 1986, accepted 12 September 1986