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Long-term Trends in Fertility of Soils under Continuous Cultivation and Cereal Cropping in Southern Queensland. VII* Dynamics of Nitrogen Mineralization Potentials and Microbial Biomass

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Abstract

The dynamics of nitrogen mineralization potential (N_0) and mineralization rate constant (k) were studied in six major soils which had been used for cereal cropping for up to 20–70 years. In the top 0·1 m layer of virgin soils, N_0 varied from 110 ± 22 mg kg^{-1} soil (Riverview) to 217 ± 55 mg kg^{-1} soil (Langlands–Logie), representing about 13% and 11%, respectively, of total N in these soils. Upon cultivation and cropping, N_0 declined by $1\cdot7\pm0\cdot5$ mg kg^{-1} yr^{-1} (Riverview) to $4\cdot8\pm2\cdot0$ mg kg^{-1} yr^{-1} (Billa Billa). This represented <20% of total N lost annually from the top layer (0–0·1 m depth) of these soils. The k values varied less than the N_0 values, both within and among soils, and were also less affected by cultivation than N_0. The mineralizable N in cultivated soil during cropping for periods up to 70 years can be estimated from N_0 and k values, taking N_0 as 5% of total N for soils of <40% clay and 15% of total N for soils of >40% clay and k as 0·066 week^{-1} at 40°C (0·027 week^{-1} and 0·054 week^{-1} at 25°C and 35°C, respectively).

Organic C and N contained in the 'stabilized' microbial biomass (determined after 30 weeks' pre-incubation) accounted for 1·7–3·8% of total organic C and 2·0–5·1% of total N in the six soils studied. The microbial biomass C and N declined with cultivation in most soils, biomass N representing 10–23% of the total annual loss of N_0. The microbial biomass, urease activity and total N, in addition to a number of other soil properties [e.g. light-fraction (<2 Mg m^{-3}) C, sand-size C, CEC and ESP], were significantly correlated with N_0 and k, thus indicating the existence of a myriad of environments for the activity, association and stability of microbial biomass and potentially mineralizable N in soil.

Introduction

Cultivation of a soil previously supporting native vegetation or pasture generally leads to a reduction in its organic C and N contents. Moreover, the loss of a 'labile' fraction could be proportionately greater than the loss of total soil organic matter (Dalal and Mayer 1986*c*, 1986*d*), with concomitant diminution of nutrient-supplying capacity, especially N. Factors influencing the ability of soil to supply N include the amount of mineralizable organic N, the mineralization rate and intensity factors such as moisture and temperature (Campbell *et al.* 1981).

There are a number of methods used to estimate the N supplying capacity of soil in the laboratory under constant temperature and moisture conditions (Bremner 1965). Since these methods are empirical in nature, an estimate of relative rather than absolute N supplying capacity of soil is obtained.

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Stanford and Smith (1972) used first-order kinetics to describe the net nitrogen mineralized during sequential incubations up to 30 weeks:

$$N_t = N_0\{1-\exp(-kt)\}, \qquad (1)$$

where N_t is the cumulative amount of organic N mineralized (mg kg^{-1} soil) at time t (weeks), N_0 is the nitrogen mineralization potential (mg kg^{-1} soil) and k is the mineralization rate constant ($week^{-1}$). They claimed that the nitrogen mineralization potential (N_0), that is, the quantity of soil organic N that is susceptible to mineralization in the long term according to first-order kinetics, provides an absolute value of N supplying capacity of soil. For 39 widely different soils, N_0 varied from 5 to 40% of total soil N (18–305 mg kg^{-1} soil). Campbell *et al.* (1981) considered N_0 as an 'active' nitrogen fraction in soil. Since light fraction (<2 Mg m^{-3} density) and coarse organic matter (mainly sand-size) constitute the labile fractions which are lost rapidly with cultivation (Dalal and Mayer 1986*c*, 1986*d*, 1987), the objective of this study was to examine the dynamics of N_0 and its relationship to the labile fractions and other soil properties in six major soils that have been cultivated continuously for cereal cropping for up to 20–70 years. The cultivation effects on the nitrogen mineralization rate constant (k), and the applicability of the model of Jones *et al.* (1982) to predict N_0 and k from soil properties were also examined.

Soil microbial biomass, a living part of soil organic matter, is an agent of transformation of the added and native organic matter and a small but labile source as well as a sink of N, P and S (Jenkinson and Ladd 1981). The size of the microbial biomass may, therefore, be related to the amount of potentially mineralizable N as well as the mineralization rates. This study examined the relationship between N_0 and k and microbial biomass. The effects of cultivation for periods up to 70 years on the amounts of C and N contained in microbial biomass in six soil series are also reported.

Materials and Methods

The study area (between 27° and 30°S. and 148° and 152°E.), description of soils, cultural practices, and soil sampling and analytical techniques were described by Dalal and Mayer (1986*a*, 1986*b*). The overall range in pH values, clay and organic C contents of the six soil series (0–0·1 m depth) from virgin sites were 6·5–8·1, 19–74% and 0·77–2·23%, respectively. Soil samples from the top layer (0–0·1 m depth) only were used in this study.

Mineralizable N in soil was measured by the procedure of Stanford and Smith (1972) except that twice the amount of quartz sand was used to increase the rate of leaching because of the high clay content of some of the soils (10 g soil : 20 g quartz sand). The samples were incubated at 40°C, assumed to be the optimum temperature for N mineralization in subtropical soils (Campbell *et al.* 1981).

Nitrogen mineralization potential (N_0, mg kg^{-1} soil), and mineralization rate constant (k, $week^{-1}$) were estimated from the measurement of the cumulative N mineralized (N_t) at time (t) periods of 2, 4, 8, 12, 16, 22 and 30 weeks by assuming that organic N was mineralized according to the first-order rate (equation 1). The parameters, N_0 and k and their standard errors were estimated by a Gauss–Newton iterative regression fitting procedure (Draper and Smith 1966).

The chloroform fumigation procedure of Jenkinson and Powlson (1976) was used to estimate C and N contained in microbial biomass. At the end of the incubation period (30 weeks) for measurement of mineralizable N, one set of duplicate samples was fumigated with chloroform for 24 h, then both sets were incubated for 10 days at 22°C, and CO_2-C evolved over the 10-day period was absorbed in 1 M NaOH and measured. After 10 days, mineral N ($NH_4^+ + NO_3^-$) in the samples was extracted with 2 M KCl and measured (see Dalal and Mayer 1986*a*). Further incubation for a 10–20 day period was unnecessary because pre-incubated samples were used. The proportion of biomass C mineralized during the 10-day period after $CHCl_3$ fumigation (k_C) was taken as 0·41 (Anderson and Domsch 1978), and a k_N value of 0·5 was taken for a rough estimation of biomass N, although the reported k_N values vary from 0·2–0·3 (Voroney and Paul 1984) to 0·68 (Shen *et al.* 1984).

All results were expressed on an oven-dry soil weight basis (105°C). Since the bulk density of soils changed due to cultivation, corrections in mineralizable N and microbial biomass C and N were made for equivalent soil depth among a soil series, similar to the proportionate changes in organic C and N (Dalal and Mayer 1986*b*, 1986*e*).

Table 1. Nitrogen mineralization potential (N_0), N_0/total N and mineralization rate constant (k)

Mean ± s.d. values from virgin sites

Soil series (No. of soils)	N_0 (mg kg^{-1} soil)	N_0/total N (%)	k (week^{-1})
Waco (5)[A]	203 ± 8	14 ± 1	0·050 ± 0·017
Langlands–Logie (6)[B]	217 ± 55	11 ± 3	0·075 ± 0·029
Cecilvale (7)[B]	197 ± 45	15 ± 3	0·078 ± 0·030
Billa Billa (7)[B]	180 ± 33	13 ± 2	0·063 ± 0·026
Thallon (6)[B]	151 ± 98	23 ± 15	0·052 ± 0·025
Riverview (5)[C]	110 ± 22	13 ± 3	0·051 ± 0·023

[A] Black earth (Typic Pellusterts).
[B] Grey, brown and red clays (brigalow, poplar box, belah and coolibah vegetation, respectively) (Typic Chromusterts).
[C] Red earth (Rhodic Paleustalfs).

Results and Discussion

Nitrogen Mineralization Potentials (N_0) and Mineralization Rate Constants (k) in Virgin Soils

The N_0 values varied from 110 mg kg^{-1} soil (range, 79–140 mg kg^{-1} soil) in Riverview soil to 217 mg kg^{-1} soil (146–290 mg kg^{-1} soil) in Langlands–Logie soil (Table 1). Campbell *et al.* (1981) estimated similar N_0 values for five Queensland soils. These values are also within the range of mean values (110–270 mg kg^{-1} soil) reported for seven soil orders (Jones *et al.* 1982). Although N_0 values for red earths (Riverview) were lower than the other five soil series (vertisols), N_0/total N per cent ('active' N) was not significantly different from other soils (Table 1). Similarly, k values did not differ significantly among the six soil series. The mean k value (0·066 ± 0·028 week^{-1} at 40°C) for all virgin soils (n = 36) was similar to those obtained by Campbell *et al.* (1981) and Stanford and Smith (1972) (0·070 and 0·066 week^{-1} at 40°C respectively). The N mineralization rate, therefore, is essentially similar in arable soils under similar temperature and moisture conditions.

The cumulative amounts of mineralized N (N_t) as proportions of N_0 at 2, 4, 8, 12, 16, 22 and 30 weeks' incubation were 0·39, 0·48, 0·58, 0·67, 0·74, 0·80 and 0·86, respectively; the relationship between N_t and N_0 became closer as the period of incubation increased. This was also observed by Stanford and Smith (1972). On this basis, Stanford *et al.* (1974) suggested that estimates of N_0 may be obtained from N mineralized during 2-week incubations following preliminary incubations of 1–2 weeks. From such a relationship, however, only poor estimates of N_0 would be obtained from short-term incubations in all soils, since in cultivated soils, the relationships between N_t and N_0 were much lower ($r < 0\cdot7$), even up to 16 weeks of incubation.

Soil properties that were significantly associated with N_0 (using stepwise multiple regression analysis) were oxalate-extractable iron (Fe_o) and total N (TN) in virgin soils ($R^2 = 0\cdot76$), that is,

$$N_0 = 45 + 168^{**}Fe_o(\%) + 735^{***}TN(\%). \qquad (2)$$

Total N accounted for most of the variation ($R^2 = 0\cdot70$) in N_0. Stanford and Smith (1972) also obtained a close relationship between N_0 and total N ($R^2 = 0\cdot66$). Fe_o in soil is involved in aggregation, probably through organic matter and clay bonding, and thus could affect N_0 by modifying the physical environment in which microorganisms function and have access to mineralizable N.

The mineralization rate constant (k) in virgin soils was significantly correlated with urease activity ($r = 0\cdot34$*) and microbial biomass C ($r = 0\cdot47$*), and hence may be regulated by microbial biomass and biochemical activity in soil.

Table 2. Microbial biomass C (MB-C) and microbial biomass N (MB-N)
Mean ± s.d. values from virgin sites

Soil series	MB-C ($mg\ kg^{-1}$ soil)	MB-C/organic C (%)	MB-N ($mg\ kg^{-1}$ soil)	MB-N/total N (%)
Waco	453±137	2·8±0·8	52±10	3·5±0·7
Langlands–Logie	508±253	2·3±1·1	47±16	2·3±0·8
Cecilvale	464±53	2·7±0·3	35±6	2·7±0·4
Billa Billa	361±91	2·4±0·6	29±4	2·0±0·3
Thallon	291±62	3·8±0·8	33±15	5·1±2·3
Riverview	213±52	1·7±0·4	22±7	2·5±0·8

Microbial Biomass C (MB-C) and Microbial Biomass N (MB-N) in Virgin Soils

The distribution of MB-C and MB-N was similar to N_0 among the soil series (Table 2). On soil volume basis (using bulk density values from Dalal and Mayer 1986*a*), Riverview soil contained the lowest amounts of MB-C and MB-N (264 and 27 $kg\ ha^{-1}\ dm^{-1}$) and Langlands–Logie soil contained the highest amounts of MB-C and MB-N (503 and 47 $kg\ ha^{-1}\ dm^{-1}$). The Langlands–Logie soil also contained the highest amounts of organic C and total N among the six soil series studied (Dalal and Mayer 1986*b*, 1986*e*).

The proportions of soil organic C contained in MB-C (1·7–3·8%) of these six soils from virgin sites are similar to those observed in South Australian soils carrying improved pastures (Oades and Jenkinson 1979) and fall within the range of MB-C values reported in soils from different climatic regions (Jenkinson and Ladd 1981; McGill *et al.* 1986). Also, MB-N values, which varied from 2·0 to 5·1% of the total soil N, are similar to those reported elsewhere (Jenkinson and Ladd 1981). However, the C:N ratio of the microbial biomass was almost twice that reported in many studies (8·7–13·2; mean, 10·6), and approached that of the whole soil, probably representing that of 'stabilized' microbial biomass. The C:N ratios of the microbial biomass reported in the literature are not always comparable because the proportion of microbial biomass N mineralized after fumigation and 10 days' incubation, k_N, varies from 0·2–0·3 (Voroney and Paul 1984) to 0·68 (Shen *et al.* 1984). Admittedly, some proportion of the microbial biomass may have been mineralized during the pre-incubation period before the soil was fumigated. The MB-C and MB-N values reported in this study may, therefore, be taken as relative values only, which are used for comparative purposes here.

The MB-C was negatively correlated with the mean annual temperature ($r = -0 \cdot 84^*$) of the six soil series, but positively with the rainfall ($r = 0 \cdot 71$ NS). Both MB-C and MB-N were significantly correlated with the urease activity (r values, $0 \cdot 77^{**}$ and $0 \cdot 68^{**}$, respectively) of the virgin soils ($n = 36$). Thus biological and biochemical activity of the soils are interrelated.

Dynamics of N_0 and k in Cultivated Soils

The relationships between mineralizable N measured from the cumulative net mineralized N over 2–30 weeks, the derived values of nitrogen mineralization potential (N_0) or mineralization rate (k) and period of cultivation (t) were described according to the exponential equation:

$$Y_t = Y_e + (Y_0 - Y_e)\exp(-rt), \qquad (3)$$

where Y represents mineralizable N, N_0 or k; Y_0, Y_t and Y_e represent values initially ($t = 0$), at time t (years) and at equilibrium ($t \to \infty$), respectively; r is the rate of loss (year^{-1}).

Table 3. Initial values (Y_0), equilibrium values (Y_e), rate of loss (r) and half-life of loss ($t_{1/2}$) of mineralizable N and nitrogen potential (N_0) after different incubation periods in Waco soil cultivated for 0–70 years

Y_0, Y_e and r were calculated according to equation (3); the half-life, $t_{1/2} = \ln 2 / r$

Period of incubation (weeks)	Y_0 mean ± s.e. (mg kg^{-1} soil)	Y_e mean ± s.e. (mg kg^{-1} soil)	r mean ± s.e. (year^{-1})	$t_{1/2}$ mean ± s.e. (year)	R^2
2	86±7	24±5	0·334±0·157	2±1	0·75
4	103±7	35±6	0·208±0·092	3±1	0·77
8	121±8	43±10	0·075±0·034	9±4	0·76
12	136±7	49±15	0·052±0·024	13±6	0·78
16	149±8	57±16	0·051±0·024	14±6	0·77
22	165±8	65±15	0·054±0·023	13±6	0·80
30	181±8	73±16	0·056±0·024	12±5	0·80
N_0[A]	208±9	90±10	0·090±0·029	8±3	0·85

[A] N_0 was calculated according to equation (1).

Where the rate of loss, r, was not significant (standard errors estimated according to Draper and Smith 1966) at $P < 0 \cdot 05$, a linear regression was used to describe the relationships between mineralizable N, N_0 or k (Y_t) and period of cultivation (t):

$$Y_t = Y_0 - a_1 t, \qquad (4)$$

where a_1 is the regression coefficient. The kinetic parameters (equation 3) of mineralizable N and N_0 in Waco soil (0–0·1 m depth) are given in Table 3 and the relationship between N_0 and period of cultivation is shown in Fig. 1.

The rate of loss of the mineralizable N decreased as the period of incubation increased, especially during the short 2–8 weeks' incubation periods (Table 3). Conversely, the half-life, $t_{1/2}$, of the mineralizable N increased from 2 years at 2 weeks' incubation to 13 years at 12 weeks' incubation. Obviously soil contains various forms of organic N that differ in the rates of mineralization, for example, N contained in different particle-size and density fractions (Dalal and Mayer 1987) and/or MB-N in various microflora and fauna in soil. It is for this reason that equation (1) represents an oversimplification of mineralization rates. However, an attempt to describe the mineralization rates with two fractions, such as the light fraction (<2 Mg m^{-3}) and the heavy fraction (>2 Mg m^{-3}) (Dalal and Mayer 1986*d*, 1987), was successful only in a few soil samples, although Deans *et al.* (1986) found that a double exponential equation provided a better fit than the single exponential equation (1).

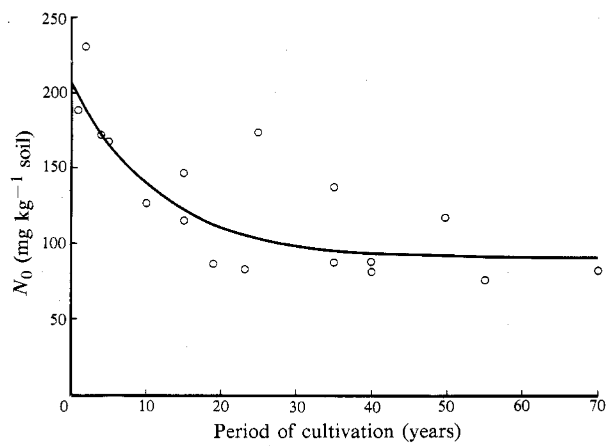

Fig. 1. Relationship between nitrogen mineralization potentials (N_0) and period of cultivation in Waco soil. The curve is fitted according to equation (3).

In the present study, the apparent failure of the double exponential equation

$$N_t = N_0 S\{1-\exp(-ht)\} + N_0(1-S)\{1-\exp(-kt)\},$$

where S and $(1-S)$ represent the labile and the resistant organic N fractions that mineralize at rate constants of h and k, respectively, may be because either insufficient mineralization data at short-incubation periods were available or there are more than two fractions of organic N that contribute to N_0 (Richter *et al.* 1982). The latter is supported by the r values obtained for the Waco soil (Table 3). For example, the rate of loss due to cultivation of mineralizable N measured after 2 weeks' incubation (0·33 yr^{-1}) was similar to that of organic C in the light fraction (0·37 yr^{-1}; Dalal and Mayer 1986*d*), and that after 4 weeks' incubation (0·21 yr^{-1}) was similar to that of organic N in the light fraction (0·19 yr^{-1}; Dalal and Mayer 1987), and that after 8 weeks' incubation (0·08 yr^{-1}) was similar to that of sand-size organic N (0·09 yr^{-1}; Dalal and Mayer 1986*d*). The rate loss of mineralizable N after 12–30 weeks' incubation (0·05–0·06 yr^{-1}) was similar to that of total N (0·06 yr^{-1}; Dalal and Mayer 1986*e*) in this soil. The N_0 in soil represents, therefore, a number of organic matter fractions of differing mineralization rates.

In the other five soils, rates of loss of mineralizable N after different periods of incubation and of nitrogen mineralization potentials (N_0) were linear with the period of cultivation (Table 4). The loss of N_0 accounted for less than 20% of the annual rate of loss of total N from the equivalent depth (0–0·1 m) of these six soils (R. C. Dalal, unpublished data). Since annual loss of total N from these soils was primarily accounted for in the crop removal (Dalal and Mayer 1986*e*), it is obvious that N supply to crops originated from other organic N fractions in addition to those contributing mineralizable N to N_0 under laboratory conditions. This was also reflected in the fact that, in five of the six soil series, N_0 declined with cultivation at a rate similar to that of total N. Only in Billa Billa soil, N_0 declined faster than the total N. In the majority of these soils, therefore, N_0 did not provide a significantly more sensitive index of soil fertility degradation due to cultivation than that shown by total soil N loss.

Table 4. Annual rate of loss (±s.e.) of mineralizable N (after 2 and 30 weeks' incubation) and nitrogen mineralization potential (N_0) from six soils

NS, not significant; all other values were significant at $P < 0{\cdot}05$

Soil series	Period of cultivation (years)	Rate of loss (mg N kg^{-1} soil yr^{-1})[A] Mineralizable N 2 weeks	30 weeks	N_0
Waco[B]	1–70	0·9±0·3	1·8±0·3	2·0±0·3
Langlands–Logie	0·5–45	1·3±0·3	4·0±0·7	4·2±0·8
Cecilvale	3–35	0·9±0·2	2·6±0·7	2·6±0·7[C]
Billa Billa	0·5–25	1·9±0·3	4·5±0·5	4·8±2·0[C]
Thallon	2–23	0·6±0·1	1·7±0·3	1·8±0·5[C]
Riverview	0·5–20	NS	NS	1·7±0·5[C]

[A] Calculated according to equation (4) where a_1 represents the rate of loss.
[B] For Waco soil, rates of loss of mineralizable N and N_0 were calculated according to equation (4) for comparative purposes only.
[C] Excluding 1–2 samples of large N_0 values (exceeding twice that of mineralizable N after 30 weeks' incubation).

The poor sensitivity of nitrogen mineralization potential (N_0) to soil fertility degradation may be due, at least, to two reasons. One reason is that during preliminary leaching, organic N, that may otherwise have been mineralized during incubation, was lost from the soil. Moreover, solutions leached through incubated soil samples contain organic N compounds which may be readily mineralizable (Legg *et al.* 1971). For example, Smith *et al.* (1980) found that amounts of organic N leached during 11 weeks' incubation in three soils ranged from 13% to 163% of total mineralized N. Another reason is that mineralizable N was measured under constant soil moisture and temperature conditions, whereas in the field, under semi-arid and subtropical conditions, wetting and drying of soil occur frequently. This would result in disruption of aggregates and exposure of new surfaces, thus making available additional mineralizable N which otherwise would have been inaccessible to microorganisms. Frequent wetting and drying and fluctuating temperatures also affect the activity, stability and mortality of microbial biomass and change the solubility of soil organic N.

The mineralization rate constant, k, was not significantly affected by the period of cultivation in Waco, Langlands–Logie, Thallon and Riverview soils, although in Cecilvale and Billa Billa soils it decreased with the period of cultivation. In these two soils, therefore, a greater loss of rapidly mineralizable organic N occurred, resulting in reduced k values with increasing period of cultivation.

The soil properties significantly associated with N_0 of both cultivated and virgin soils (using stepwise multiple linear regression analysis) were total N or organic C, clay content, electrical conductivity, light fraction (<2 Mg m^{-3}) C content, silt-size C, sand-size C, CEC, ESP and aggregate index, which together accounted for 74% of the variation in N_0. Of this, total N alone accounted for 60% of the variation in N_0. The relationship between N_0 and total N of six soil series is shown in Fig. 2.

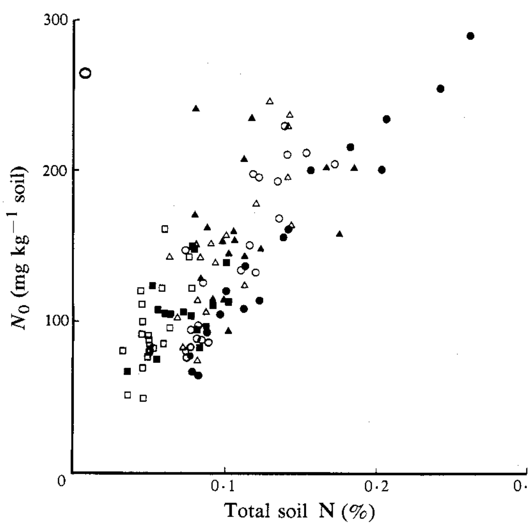

Fig. 2. Relationship between nitrogen mineralization potentials (N_0) and total soil N for Waco (○), Langlands–Logie (●), Cecilvale (△), Billa Billa (▲), Thallon (□) and Riverview (■) soils.

The equation between N_0 and total N,

$$N_0 = 43 + 970\mathrm{TN}(\%), \quad r = 0\cdot78^{**} \quad (n = 110), \tag{5}$$

shows that overall about 10% of total N is present as N_0 in these soils. However, there were significant differences among soils. The cultivated lighter-textured soils (<40% clay) contributed less than 10% to total N (Billa Billa, 5·20±2·31%; Riverview, 6·08±2·31%) and heavy-textured soils (>40% clay) contributed more than 10% to total N (Langlands–Logie, 11·62±0·65%; Cecilvale, 14·39±2·79%; Waco, 15·18±1·89%; and Thallon, 14·38±4·61%). Thus, although the lighter-textured soils in their virgin state contained proportions of total N as N_0 similar to the heavy-textured soils (Table 1), upon cultivation, lower values in the former reflect relatively less potentially mineralizable N in these soils.

Jones *et al.* (1982) used total N, organic C, pH and soil taxonomic criteria to estimate N_0 in soils. In these soils, however, the relationship between the experimental values of N_0 and the predicted N_0 values gave a lower correlation (r = 0·70**,

$n = 110$) than that provided by total soil N alone. Moreover, the mineralization rate constant, k, could not be predicted ($r^2 = 0 \cdot 05$) using the model of Jones *et al.* (1982). This is not surprising considering the fact that the k values were poorly, although significantly correlated with total N ($r = 0 \cdot 19$*), organic C ($r = 0 \cdot 22$*) and pH ($r = 0 \cdot 23$*), i.e. the soil properties used by Jones *et al.* (1982) to predict the k value.

The k values were significantly associated (using stepwise multiple linear regression analysis) with electrical conductivity, light fraction C concentration, cation exchange capacity, ESP, oxalate extractable aluminium, dispersion ratio, clay-size N, sand-size N and MB-C. The combination of these soil properties explained less than 40% of the variation in k, mainly because k varied much less than the other properties both within and among soils. Thus the k value of $0 \cdot 066$ week^{-1} at 40°C (present study) and $0 \cdot 054$ week^{-1} at 35°C (Stanford and Smith 1972) can be used, along with N_0 and the relationship between temperature and moisture contents and N_0 (Smith *et al.* 1977), to provide approximate mineralization rates under field conditions.

Table 5. Annual rate of loss (±s.e.) of C and N contained in microbial biomass (MB-C and MB-N) from six soils

NS, not significant; all other values were significant at $P < 0 \cdot 05$

Soil series	Rate of loss[A] MB-C (mg C kg^{-1} soil yr^{-1})	MB-N (mg N kg^{-1} soil yr^{-1})
Waco	4·4±1·5	0·21±0·08
Langlands–Logie	14·3±3·5	0·53±0·10
Cecilvale	7·5±1·7	0·32±0·07
Billa Billa	6·3±2·4	0·48±0·09[B]
Thallon	NS	NS
Riverview	NS	0·39±0·19

[A] Calculated according to equation (4); a_1 represents the rate of loss.
[B] MB-N and period of cultivation relationship in Billa Billa soil also followed equation (3), giving rates of loss of $0 \cdot 338 \pm 0 \cdot 143$ yr^{-1} and $t_{1/2}$, $2 \cdot 1 \pm 0 \cdot 8$ yr.

Dynamics of Microbial Biomass in Cultivated Soils

The organic C and N contained in microbial biomass declined linearly with the period of cultivation (20–70 years) in most soils. In Thallon soil, microbial biomass was not significantly related to the period of cultivation. Both MB-C and MB-N declined most in the Langlands–Logie soil and least in the Waco soil (Table 5). The proportion of MB-N lost due to cultivation represented 10–23% of annual N_0 loss, and less than 5% of total soil N loss. In Billa Billa soil, where MB-N was lost exponentially, MB-N showed a high rate of loss ($0 \cdot 338$ yr^{-1}), with a half-life of $2 \cdot 1$ years (Table 5), a rate of loss similar to that of the light fraction C ($0 \cdot 42$ week^{-1}) in this soil (Dalal and Mayer 1986*d*). Adams and Laughlin (1981) also found lower macroorganic matter and microbial biomass C and N in cultivated soil than in grassland or woodland soils. Similarly, Ladd *et al.* (1977) showed that the destruction of soil biomass was accompanied by significant decreases in the organic N of a light fraction from straw-amended soils. The half-life of $2 \cdot 1$ years for MB-N in Billa Billa soil is similar to the 'stabilized' microbial biomass in soil (Jenkinson and Ladd 1981; McGill *et al.* 1986).

A number of soil properties was associated with the microbial biomass (Table 6). The linear combination of urease activity, sand-size organic C, exchangeable Ca and Fe_o explained 52% variation in the MB-C. In the MB-N, 64% of the variation was accounted for by the linear combination of total N, clay-size organic C, exchangeable Mg, CEC, ESP, Fe_o and MB-C. The association of a number of soil properties, biochemical, physical as well as chemical, with the microbial biomass provide a myriad of environments for its activity, association and stability in soil.

Table 6. Coefficients of correlation between microbial biomass (MB-C and MB-N) and some soil properties

Only significant r values ($P < 0 \cdot 05$, $n = 110$) are given

Soil property	MB-C	MB-N	Soil property	MB-C	MB-N
Organic C (%)	0·55	0·51	Exch. Ca		0·46
Light fraction C (%)	0·28		Exch. Mg		0·56
Clay-C (%)		−0·22	Exch. Na		0·25
Silt-C (%)	0·28	0·39	Exch. K		0·38
Sand-C (%)	0·46	0·62	Oxalate-extractable Fe (Fe_o)	0·43	0·56
Total N (%)	0·53	0·47	Aggregate index	0·19	0·28
Light fraction N (%)	0·32		pH		0·23
Silt-N (%)		0·30	EC	0·21	0·23
Sand-N (%)	0·38	0·51	Nitrogen min. potential, N_0	0·43	0·38
Urease activity	0·58	0·47	Mineralization rate, k	0·36	0·21
Clay (%)		0·48	MB-C		0·51
CEC	0·22	0·56			

Conclusions

Mineralizable N, measured after 2–30 weeks' incubation, and nitrogen mineralization potential (N_0) decreased with cultivation in most soils. The shorter the period of incubation for measuring mineralizable N, the faster was its estimated rate of loss due to cultivation. Hence, the relative susceptibility to mineralization decreases as the period of incubation increases because less labile organic N is being used. The N_0 represents, therefore, soil organic N fractions which differ in their susceptibility to mineralization. The mineralization rate constant, k, appears to be less affected by cultivation and, for the purpose of predicting N mineralization rates in soil in the field, it can be taken as a constant (0·054 and 0·066 week^{-1} at 35°C and 40°C, respectively). The N_0, as a proportion of total N, in cultivated soils, which varies from 5% (light-textured soils, <40% clay) to 15% (heavy-textured soils, >40% clay) of total N, may improve estimates of mineralizable N in different soils, although 10% as N_0/total N may provide an approximate estimate of N_0 in southern Queensland soils.

Organic C and N contained in microbial biomass decreased with the period of cultivation in most soils. The size of the microbial biomass, urease activity and total N, among other soil properties, were associated with N_0 and k, thus demonstrating the biological and biochemical interactions in soil.

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