

Chapter 8

Modelling of N mineralization for improvement of N use efficiency

Abstract

Model calculations were made to improve our understanding of the experimental results, and to explore options for better N use efficiency. We used a modified version of MINIP, standing for **M**ineralization of **N**itrogen and **P**hosphorus. After explaining the principles of the model, calibrating some model parameters, and introducing corrections for temperature and rainfall, the model was applied to study rates of decomposition of organic materials and mineralization of N, as affected by time of application, weather conditions of the two seasons, availability of inorganic N, and composition of mixtures of high and low quality organic materials.

During the first 0.15 mineralization years (about 16 days) the decomposition rate of the organic materials was constant, and thereafter it decreased with time. For organic materials with a high C : N ratio, initial decomposition was sometimes retarded because of lack of immobilizable inorganic N. The time needed to mineralize the required amounts of N for the N uptakes found in the field was on average 51 days. Apparently N that is mineralized later is of less value to the crop. The simulated differences in rate of mineralization between 2000-2001 and 2001-2002 were smaller than was expected on the basis of N uptake in the field trials. Probably the effects brought about by temperature and rainfall were over- and underestimated, respectively. The effects of combinations of high and low quality materials were calculated for standard weather conditions of 25°C and no moisture stress, and three situations: (i) sufficient external N, (ii) no external N without interaction, and (iii) no external N with interaction between high and low quality materials. Interaction did not have much effect on the total N mineralization of sesbania and maize, but it had a clear effect on maize decomposition. For maize stover and pigeonpea roots, the immobilization period was 3 and 4 months, and maximum immobilization was 10 kg N per ton of materials, while 1.4 and 1.05 tons of gliricidia and sesbania prunings, respectively, were needed to neutralize this immobilization.

8.1 Introduction

Modelling offers an easy and cheap tool for extrapolating scientifically proven results to other areas without conducting experiments every time. In our study model calculations were made to improve our understanding of the experimental results described in Chapters 3, 4 and 5, and to give insight in the reasons behind some apparent inconsistencies in especially the interactions between low and high quality organic materials. Further, the aim was to explore options for optimum management of various organic materials so as to improve the N use efficiency. The model we applied is a modified version of the simple model MINIP, standing for **MI**neralization of **NI**trogen and **P**hosphorus. It forms part of the model DYNAMITE (DY namics of Nutrients And Moisture In Tropical Ecosystems), and is essentially described by Noij *et al.* (1993).

We have chosen the model MINIP because it is simple in nature, it does not require a huge set of input data for model parameters, and there is much experience with this model at the Department of Soil Quality of the Wageningen University. MINIP is able to deal with decomposition and mineralization within the course of a growing season, in contrast to a model like CENTURY that is meant primarily for long-term soil organic matter developments and not for daily supply of N from added organic materials (Paustian *et al.*, 1992; Rasmussen and Parton, 1994; Itimu, 1997).

In Section 8.2, the principles of the applied model are discussed. Section 8.3 deals with the calibration of some model parameters. The model is applied in Section 8.4 to study the effects of time of application of prunings (from Chapter 4), the differences in N mineralization between the two seasons 2000-2001 and 2001-2002 (from Chapter 5), the influence of availability of inorganic N on the rates of immobilization and remineralization of N, and of decomposition of the organic materials (also from Chapter 5). In Section 8.5, the model is used to calculate the optimum ratios of high and low quality organic materials in view of the lengths of the periods of immobilization, remineralization of immobilized N, and net mineralization of organic N from low quality organic materials. Section 8.6 presents conclusions and recommendations.

8.2 Principles of the applied model

8.2.1 Essentials

Basically the model calculations consist of two parts: (i) decomposition of the organic materials (ii) mineralization or immobilization of N as a result of the decomposition. Mineralization or immobilization of N requires microbial conversion of the organic matter. Part of the converted matter is used for assimilation in microbial tissue and part for oxidation to gain energy (dissimilation). The term organic-matter decomposition refers to dissimilation. The quantity of decomposed or dissimilated organic matter is thus the difference between the total amount of organic matter that is converted and the amount that is assimilated by the micro-organisms.

8.2.2 Decomposition

The decomposition (dissimilation) of organic matter is often described by first order equations of the type:

$$dY/dt = -k Y \quad \text{Eq. 8.1}$$

$$\text{or } Y = Y_0 e^{-kt} \quad \text{Eq. 8.2}$$

where Y stands for the organic material, t is time and k is the rate constant of decomposition.

It has been found, however, that the rate constant is not really a constant, but decreases over time. Also in our study (Section 5.4.1) decomposition rate constants tended to decline with time. The decrease in decomposition rate constant is usually ascribed to chemical changes in the substrate itself and the succession in microorganisms able to compete for substrate with a given chemical composition (Janssen, 1984; Yang, 1996; Yang and Janssen, 2000; Berg and Meentemeyer, 2002). In this study we applied the method of Yang and Janssen (2000) to describe the relation between decomposition rate and time. They found a linear relationship between $\log K$ and \log time, where K (dimension t^{-1}) is the average rate coefficient between times 0 and t:

$$\ln K = \ln R - S \cdot \ln t \quad \text{Eq. 8.3}$$

$$\text{or } K = R \cdot t^{-S} \quad \text{Eq. 8.4}$$

in which R and S are the regression constants. When t is 1, K (dimension t^{-1}) equals R, R (dimension t^{S-1}) is the K during the first unit of time. S is the slope of the line of Eq. 8.3, a measure of the rate at which K decreases over time, or the speed of ‘ageing’ of the substrate. Substitution of Eq. 8.4 in Eq. 8.2 results in:

$$Y_t = Y_0 * \exp(-K*t) \quad \text{Eq. 8.5}$$

and $Y_t = Y_0 * \exp(-R*t^{1-S}) \quad \text{Eq. 8.6}$

8.2.3 Mineralization

A part of the N that is present in the converted organic material is used in microbial tissue and the other part is set free (mineralized) as inorganic N. If the converted organic matter is low in N, the amount of N that is converted may be too low to satisfy the assimilation needs of the microbes. In such cases, microbes take up inorganic N from their environment, usually being the soil solution or the moisture in the organic material. The mineralization is then negative. This process, which is known as immobilization, results in an increase of organic N in the remaining organic material. After some time, the quantity of organic N that is converted is sufficient for the assimilation requirements of the microbes, and then mineralization turns from negative to positive.

The time step used in the model calculations is one day. In the equations below, subscripts b and e stand for beginning and end of the considered time step, the subscripts diss, ass, conv and min stand for dissimilation, assimilation, conversion and mineralization, DA means dissimilation:assimilation ratio, and CN means C:N ratio with the subscripts m and s for microbes and substrate. At the beginning of the time step, C/N_{sb} of the substrate equals C_b/N_b ; C_b and N_b are supposed to be known, and C_e follows from the calculation of decomposition (Eq. 8.5 or 8.6). The calculation of the mineralization is straight forward in the order:

$$C_{diss} = C_b - C_e \quad \text{Eq. 8.7}$$

$$C_{ass} = C_{diss}/DA \quad \text{Eq. 8.8}$$

$$C_{conv} = C_{diss} + C_{ass} = C_{diss} (1 + 1/DA) \quad \text{Eq. 8.9}$$

$$N_{conv} = C_{conv}/CN_{sb} = C_{diss} (1 + 1/DA)/ CN_{sb} \quad \text{Eq. 8.10}$$

$$N_{ass} = C_{ass}/CN_m = C_{diss}/(DA * CN_m) \quad \text{Eq. 8.11}$$

$$N_{\min} = N_{\text{conv}} - N_{\text{ass}} = C_{\text{diss}} (1 + 1/DA) / CN_{\text{sb}} - C_{\text{diss}} / (DA * CN_{\text{m}}) \text{ Eq. 8.12}$$

From these equations it follows that the mineralization of N is zero, if $CN_{\text{sb}} = (DA + 1) * CN_{\text{m}}$ = critical CN_{sb} . If CN_{sb} is larger than the critical CN_{sb} , the mineralization is negative, and if CN_{sb} is smaller the mineralization is positive. At the end of the time step it holds:

$$N_e = N_b - N_{\min} \text{ Eq. 8.13}$$

$$C_e / N_e = C_e / (N_b - N_{\min}) = CN_{\text{se}} \text{ Eq. 8.14}$$

The values of C_e , N_e and CN_{se} are used as the initial values in the second time step.

As a consequence the C:N ratio of the remaining organic material gradually decreases. Substrates of which the decomposition initially requires inorganic N turn into substrates of which the decomposition supplies inorganic N.

8.2.4 Retarded decomposition because of N shortage

So far it was assumed that sufficient inorganic N would be available for immobilization. If such is not the situation, the decomposition of the organic material is retarded. For the calculation some assumptions had to be made. It was supposed that the substrate consisted of two parts, one part with the critical CN_{sb} containing 99% of the nitrogen present in the substrate and another part containing 1% of the substrate N. The decomposition and mineralization of the first part followed the concept outlined above. The mineralised N from this part (N_{minI}), as calculated with Eq. 8.12, was set equal to the N assimilation of the second part (N_{assII}), and formed the starting point for the calculation of possible decomposition and mineralization of the second part.

$$N_{\text{assII}} = N_{\text{minI}} \text{ Eq. 8.15}$$

$$C_{\text{assII}} = N_{\text{assII}} * CN_{\text{m}} \text{ Eq. 8.16}$$

$$C_{\text{dissII}} = C_{\text{assII}} * DA \text{ Eq. 8.17}$$

$$C_{\text{convII}} = C_{\text{dissII}} + C_{\text{assII}} \text{ Eq. 8.18}$$

Eq. 8.18 is the same as Eq. 8.9.

In case there is a limited amount of external inorganic N available (N_e) for immobilization, Eq. 8.19 is used instead of Eq. 8.15, and after that Eq. 8.16 – 8.18, using N_{assII} as defined in Eq. 8.19:

$$N_{\text{assII}} = N_{\text{minI}} + N_e \quad \text{Eq. 8.19}$$

8.2.5 Influence of temperature and moisture

Temperature affects the rates of decomposition and mineralization. We used a correction factor f for the temperature range from 9 to 27 °C, as described earlier by Noij *et al.* (1993) and Yang and Janssen (2002):

$$f = 2^{(T-9)/9}, \quad \text{Eq. 8.20}$$

where T = temperature in °C. For temperature above 27 °C, f was set at 4.

Yang (1996) has used a standardized temperature of 9 °C; at that temperature the value of f is 1. The corresponding value of R is R_9 . In Eqs. 8.3 to 8.6, time is multiplied by f ; $f*t$ is called ‘mineralization time’. For example, Equation 8.6 can be rewritten as follows:

$$Y_t = Y_0 * \exp[-R_9 * (f*t)^{1-S}] \quad \text{Eq. 8.21}$$

Also moisture affects decomposition and mineralization. Too wet and too dry both limit the rates of decomposition and mineralization. Under wet conditions denitrification may occur and leaching, both resulting in losses of nitrate-N. Under the conditions of our experiments rainfall was erratic and has created irregularities in the decomposition and mineralization patterns, at the dry as well at the wet side. As a preliminary correction for decomposition we used the rainfall during the last 1, 5 and 10 days. If those values were 0, < 5 and < 10 mm, the soil was supposed to be too dry. Such a day was named a ‘moisture stress day’; the mineralization time of such a day was set at zero. We made some exercises with variations in the criteria for ‘moisture stress day’. It was found that the results were hardly affected when these criteria were 0, < 15 and < 30 mm rain during the last 1, 5 and 10 days, respectively. The consequence was that there was no decomposition and mineralization during that day.

8.3 Calibration of some model parameters

8.3.1 Required input variables

From Section 8.2 it follows that information is needed about the following parameters to run the model:

- Decomposability of the organic materials, *i.c.* the values of R_9 and S
- C : N of the organic materials
- Dissimilation : assimilation ratio (DA)
- C : N of micro-organisms (CN_m)
- Temperature
- Temperature correction
- Rainfall
- Drought correction

Temperature and rainfall were recorded at the experimental station. The way they were taken into account is explained in Section 8.2.5. In Tables 5.1 and 5.2, C : N of the organic materials were given; they are presented again in Table 8.1. The other required parameters are discussed in the following subsections.

Table 8.1. Rounded values of R_9 and S for the various organic materials, as calculated on the basis of the data of Table 5.3, and C : N derived from Table 5.2 and used in the modelling study.

| | R_9 , year ⁻¹ | S | C : N |
|-------------------------|----------------------------|------|-------|
| Gliricidia | 3.92 | 0.17 | 16 |
| Sesbania | 2.94 | 0.25 | 15 |
| Pea-Leaves/litter | 3.16 | 0.21 | 20 |
| Pea-Leaves/litter/Roots | 2.83 | 0.21 | 24 |
| Pea-Roots | 1.72 | 0.21 | 57 |
| Stover | 2.83 | 0.21 | 86 |

8.3.2 Decomposability: R_9 and S

In Section 5.4.1 it was shown that the decomposition rate constants decreased over time for gliricidia, and sesbania. The values for pigeonpea leaves remained about constant, and those for pigeonpea roots and maize stover were rather irregular, but

tended to increase, at least in the beginning of the incubation study. The increase of the decomposition rate constants was ascribed to initial shortage of inorganic N for immobilization; it is discussed in Section 8.4.3. From Appendix 5.5 (Chapter 5) it also appeared that the values of k were about the same during the first two time intervals. In his literature review, Yang (1966) has found such a lag phase in many experiments. That the values for 14 and 21 days did not differ much is also seen in Fig. 8.1, where $\ln K_9$ is plotted against $\ln(\text{mineralization time})$, following the procedure of Yang and Janssen (2000) to find R_9 and S of gliricidia and sesbania. Based on these considerations, we decided not to use the values obtained at 14 days for the calculation of R_9 and S . In the model calculations of this chapter, it was assumed that K was constant during the first 0.15 mineralization years; thereafter K was allowed to change with time, according to Eq. 8.3 and 8.4.

As Eq. 8.3 could not be used for the other organic materials than gliricidia and sesbania, values for R_9 and S could not directly be derived. We decided to allocate to these materials a value of 0.21 for S , being the average of values of S for gliricidia and sesbania. Next R_9 was calculated with Eq. 8.21 using for Y_t the value of the remaining organic matter at Day 84 (or 0.603 mineralization time), as given in Table 5.3. The results are presented in Table 8.1.

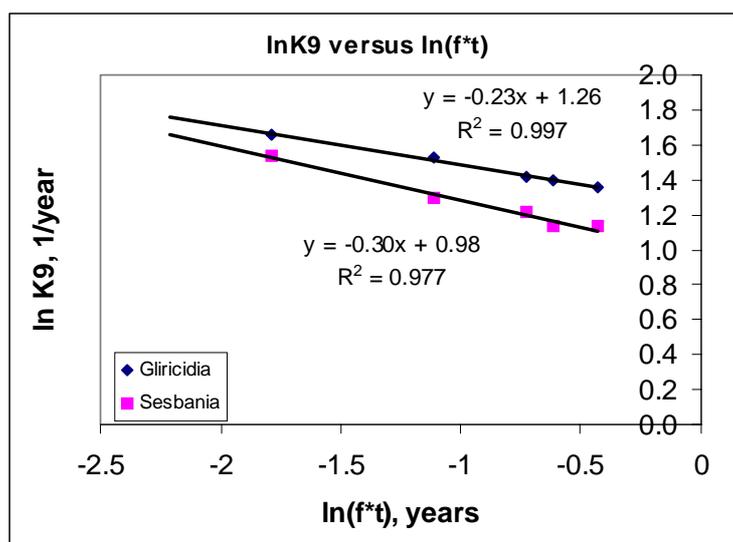


Fig. 8.1. Plot of $\ln K_9$ against \ln mineralization time, and corresponding regression equations. The values obtained at 14 days (0.11 mineralization years) were not included.

8.3.3 Dissimilation : assimilation ratio and C : N ratio of microorganisms

Results of the study with aluminum cores, described in Chapter 5, have been examined to find values for the dissimilation : assimilation ratio (DA) and C : N of micro-organisms (CN_m). Table 5.4 revealed that mineralized N hardly increased or even decreased after 21 or 42 days. In view of the heavy rainfall at 24, 69 and 71 days after the start of this experiment, it is likely that water-logging did occur in the cores which probably had resulted in denitrification. Hence, we had no reliable data for the calibration of DA and CN_m . Using only the experimental data obtained at 14 and 21 days in the aluminum core mineralization experiment, the best estimate for DA was 1.5 and for CN_m was 6. These values have been applied in the next subsections.

8.4 Model exercises

8.4.1 Time of application of organic materials

In Section 4.3.4, it was shown that time of application had a tremendous influence on the recovery of gliricidia N. This was ascribed to differences in the overlap of the periods of mineralization and uptake. We calculated the N mineralization from 3000 kg gliricidia for the period between 23rd October 2001 and 31st March 2002 for the various combinations of application times, taking into account the temperature and moisture corrections explained in Section 8.2.5, the values of R and S given in Table 8.1, a constant K during the first 0.15 years of mineralization time explained in Section 8.3.1, and the values of DA and CN_m explained in Section 8.3.2.

The advantage of application of prunings in October is obvious from the results of the model calculations presented in Fig. 8.2. When applied in October, mineralization of N started at about the time of planting in mid November. This rather slow start was caused by drought between mid November and mid December 2001. From Table 4.5 it was calculated that the amounts of N recovered from gliricidia were 13.9, 25.8, 30.3, 33.7 and 42.9 kg for the treatments DF, OF, OD, ODF and October, respectively. Considering a maximum recovery fraction of 0.75, as was found for CAN-N (Chapter 4), the required amounts of N for these uptakes had been mineralized at 32 to 73 days after planting on 19th November 2001, on average after 51 DAP, *i.e.* at 9th January 2002. N mineralized after 50 DAP, say 7 weeks, likely is of less value to the crop than N available in the beginning when the crop demand is highest.

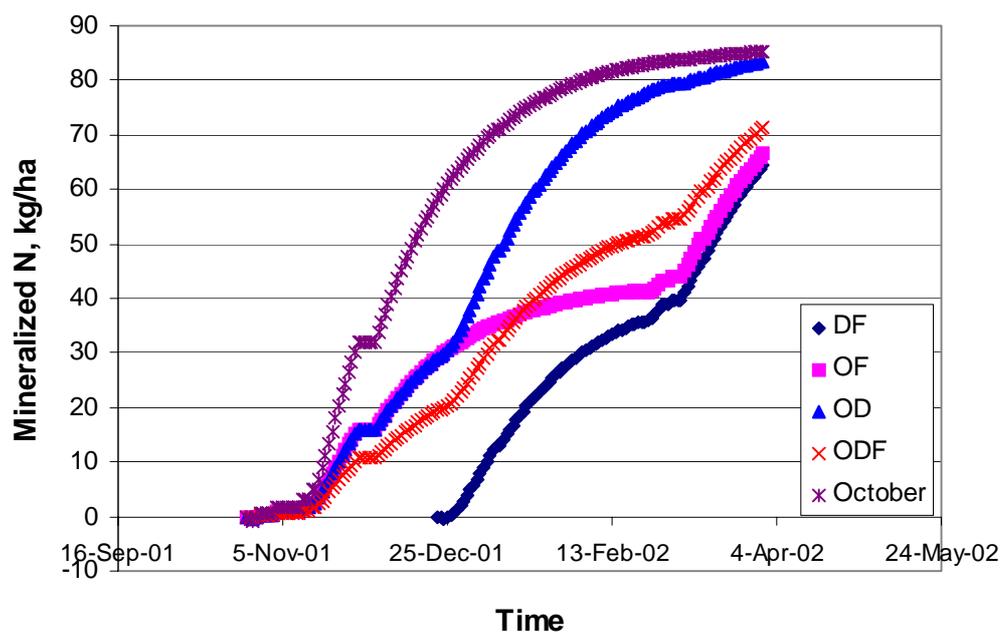


Fig. 8.2. Calculated N mineralization from 3000 kg gliricida between 23rd October 2001 and 31st March 2002 for the various combinations of application. Times of application were 23 October 2001, 22 December 2001, and 22 February 2002. Details of the trials are discussed in Chapter 4.

8.4.2 Differences between the seasons of 2000-2001 and 2001-2002

In Fig. 8.3 the calculated courses of N mineralization during 2000-2001 and 2001-2002 are compared for 1.5 t Sesbania and 3 t maize stover. For both materials the initial mineralization/immobilization is faster in 2000-2001 than in 2001-2002, which is likely caused by the drier conditions in the latter season. Total rainfall from October to March inclusive was 798 mm in 2001-2002 compared to 1179 in 2000-2001. After about 50 DAA, the situation is reversed, and the processes go faster in the second season. This must be ascribed to the higher temperatures in the second season (average from October to March inclusive was 28.3 °C compared to 22.6 °C in 2000-2001), which overcompensate the lower rainfall. The differences shown in Fig. 8.3 are not as big as expected from the differences in N uptake in the field trials described in Chapter 5. The points in Fig. 8.3 indicate the ranges between measured uptake (lower points) and required amount of available N (upper points) in case the recovery by the crop is 0.75. They are given for sesbania in both seasons and for stover-2 in 2000-

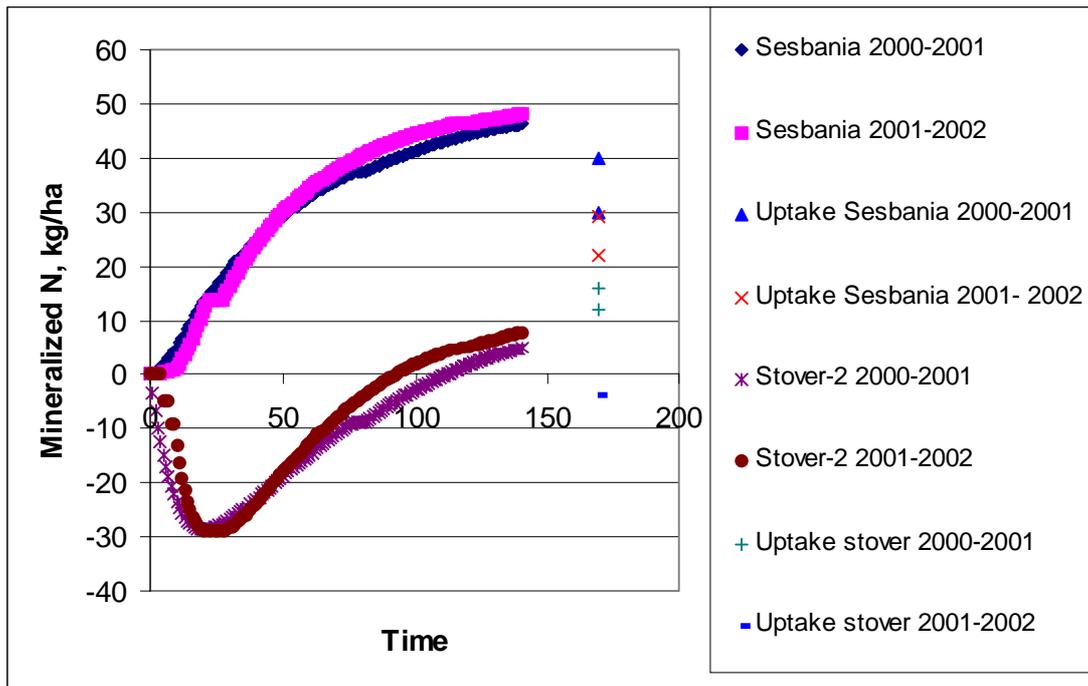


Fig. 8.3. Calculated courses of N mineralization during 140 days after application (DAA) in 2000-2001 and 2001-2002 for 1.5 t Sesbania and 3 t maize stover. Also indicated are the increases in N-uptake brought about by the applied organic materials, derived from Table 5.7. The lower point indicates the uptake, the upper point the required amount of mineralized N for that uptake in case the recovery fraction would be 0.75.

2001 only because there was immobilization in 2001-2002. The calculated amounts of mineralized N are high enough for sesbania, but too low for maize. Probably the temperature correction as expressed in Eq. 8.20 overestimates the differences between 22.6 and 28.3 while the procedure used to calculate too dry days was too mild. Further studies are needed to test these correction procedures.

Fig. 8.3 shows that maximum immobilization by maize stover was reached at 20-25 DAA, and that only at 90 DAA in 2001-2002, and 110 DAA in 2000-2001 the immobilized N was completely remineralized. We expected that it would take more time in the second season, because the measured mineralization by Stover was negative in 2001-2002. Between 20 and 50 DAA the immobilization was stronger in the second season and this period is more important for uptake by the plant than the period after 50 DAA.

8.4.3 Availability of inorganic N and rate of decomposition

It was suggested in Chapter 5 that the initial slow decomposition of crop residues could have been caused by N deficiency in the crop residues. To examine this hypothesis, we used the model to calculate the remaining fractions of pigeonpea roots (C:N 57) and maize stover (C:N 86) twice. Firstly it was assumed that there was sufficient inorganic N to be immobilized, secondly that there was no inorganic N at all to be immobilized. Fig. 8.4 shows that shortage of inorganic N indeed results in a retardation of decomposition. The measured values (from Table 5.4) are situated more or less in between the calculated lines for the two extreme situations, suggesting indeed that N deficiency may have slowed down the decomposition of crop residues in the litter bag experiments. These results provide sufficient confidence to the model to carry out the calculations described in the next sub-section.

8.5 Combinations of high and low quality materials.

When high and low quality materials are applied in combination, the courses of immobilization, remineralization and net mineralization may be different than when applied separately. The outcome of such a combination depends on the weather conditions. Another factor is the presence or absence of inorganic N that can be immobilized. If there is no external source of inorganic N, it could be important for the total result whether the micro-organisms decomposing the low quality material are able to utilize the N that is released from the high quality material; in that case there would be an interaction effect and not only additive effects.

The calculations were made for standard weather conditions with a temperature of 25°C and no moisture stress. (The average temperature during the rainy seasons of 2000-2001 and 2001-2002 was about 25°C). Three situations were distinguished: sufficient external N, no external N without interaction, no external N with interaction. Combinations of organic materials were 1 ton of sesbania prunings with 2

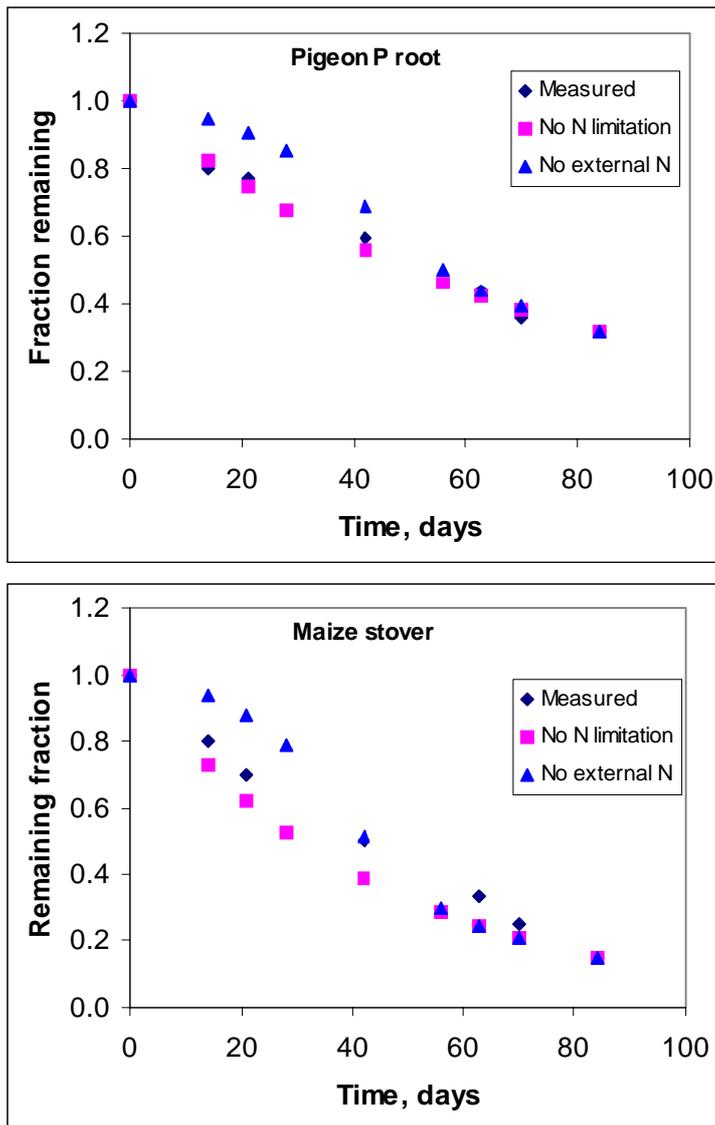


Fig. 8.4 Litter bag experiment. Remaining fractions of Pigeonpea roots (top) and Maize Stover (bottom) as measured and as calculated for the situation of no N limitation and No external N available.

tons of maize stover. For comparison, 1 ton of sesbania prunings alone and 2 tons of maize stover were also included in the calculations. Results presented in Fig. 8.5 indicated that in case of sufficient external N, lowest amounts of N mineralized by a combination of sesbania and maize were found at 10 DAA, and for maize stover alone maximum immobilization was reached after 17 days and amounted to 9.6 kg N per ton of maize stover. The period thereafter till 90 DAA was characterized by remineralization. After 90 DAA, there was net mineralization of maize stover N. For the case without external N without interaction, we calculated a very limited

mineralization of maize stover N, using Eq. 8.15 – 8.18. For the case without external N, but with interaction, we used Eq. 8.19 instead of Eq. 8.15; the N released by Sesbania prunings was then considered as a limited amount of external inorganic N available (N_e) for immobilization. Fig. 8.5 shows that the interaction did not have much effect on the total N mineralization of sesbania and maize together. The effect on the decomposition of maize, however, was clear; the remaining fractions of maize at 140 DAA were 3% in case of unlimited quantities of external N, 74% in case of no external N, and 21% in the case of interaction between 1 ton sesbania prunings and 2 ton maize stover. Because of the high C : N ratio of maize stover, not much difference in N release is found when in stead of 74% only 21% of the original substrate is remaining.

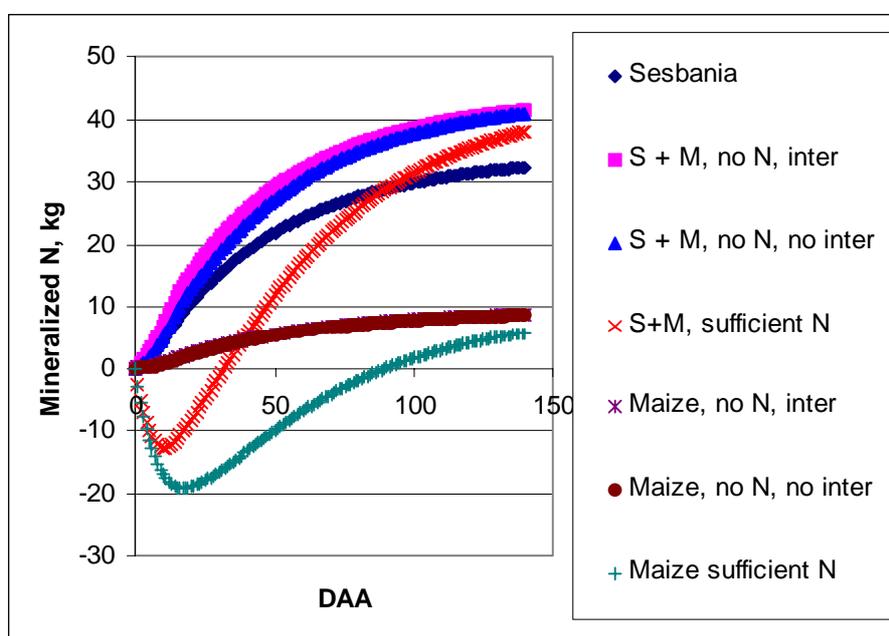


Fig.8.5. Course of N mineralization for 1 ton of Sesbania prunings alone, for 1 ton of Sesbania prunings in combination with 2 tons of maize stover, and for 2 tons of maize stover. Cases: no external inorganic N with interaction (inter) between Sesbania and maize stover; no external N with only additive effects (no inter); sufficient external N for immobilization. The difference between Maize, noN inter and Maize, noN, no inter is not visible. The maximum difference is 0.184 kg N, obtained at 16 DAA.

It is obvious that the initial period after application of the mixtures shows the biggest differences among the various situations. Especially the presence of sufficient external inorganic N has a large effect on the total result of sesbania prunings and maize stover. This makes it understandable that in practical situations available N for crop uptake may vary strongly, and that recommendations can only be of restricted relevance when no accurate data about soil mineral N (external N) are available.

Table 8.2 summarizes relevant characteristics of the low and high quality organic materials, as follows from the model calculations. Calculations were made for standard conditions (average temperature of 25 °C, no moisture stress). The following characteristics are indicated:

- Points in time at which the maximum N immobilization and the end of N immobilization are reached; they can be seen also in Figs. 8.4 and 8.5.
- Maximum N immobilization in kg N per ton of low quality organic materials (LQOM).
- Compensation ratios; the quantity of gliricidia or sesbania prunings needed to mineralize a same amount of N as is immobilized by the LQOM at the time of maximum immobilization.
- Fraction remaining; the fraction of LQOM that is still present at the points in time at which the maximum N immobilization and end of N immobilization are reached.
- C/N is the C : N ratio of LQOM at the end of the immobilization period.

The maximum and end of immobilization are reached later in the order: pigeonpea leaves + roots < maize stover < pigeonpea roots; the difference between the first two are related to their C : N ratio, the difference between the last two to their R₉ values (Table 8.1). The immobilization period is quite long, about 1, 3 and 4 months for these LQOMs, respectively. In general, more gliricidia than sesbania prunings are needed to compensate for the immobilization by the LQOM. The amounts of and the differences between the two types of prunings become smaller as the time of maximum immobilization is reached later. The reasons are that in the course of time more N is mineralized and that initially gliricidia immobilizes some inorganic N while sesbania prunings do not. The fractions remaining at maximum and end of immobilization decrease in the order pigeonpea leaves + roots < pigeonpea roots <

maize stover; this is the order of their C : N ratios (Table 8.1). Considering maize stover and pigeonpea leaves + roots as the most important LQOMs in practice, one may conclude that 1.4 and 1.05 tons of gliricidia and sesbania prunings, respectively, are needed per ton of LQOM to neutralize initial immobilization.

Table 8.2 Immobilization characteristics of combinations of high quality (Gliricida and Sesbania prunings) with low quality organic materials (LQOM). Maximum N immobilization in kg N per ton LQOM, points of time at which maximum and end immobilization are reached, and fraction of LQOM still remaining at that time. Compensation ratios and C/N, see text. DAA stands for days after application.

| Characteristic | Quantity | Unit | LQOM | | |
|------------------------|-----------------------|------|------------------|--------------|-----------------|
| | | | Pigeonpea leaves | Maize stover | Pigeonpea roots |
| Maximum immobilization | Point of time | DAA | 11 | 17 | 28 |
| | Immobilized N | kg | 4.7 | 9.6 | 9.5 |
| | Fraction remaining | | 0.65 | 0.51 | 0.55 |
| Compensation ratio | Gliricidia | t/t | 1.41 | 1.32 | 0.74 |
| | Sesbania | t/t | 0.93 | 1.05 | 0.66 |
| End of immobilization | Point of time | DAA | 33 | 90 | 128 |
| | Fraction CR remaining | | 0.43 | 0.20 | 0.06 |
| | C/N | g/g | 9.48 | 7.24 | 7.83 |

8.7 Conclusions and recommendations

The calculations were made for the climatic conditions (temperature and rainfall) of the experiments described in this thesis. Some of the experimental data (litter bag and aluminum core studies) were used to calibrate some of the input requirements (R_9 , S , DA , CN_m) of the model. The model was run to better understand the experimental outcomes and to examine whether the experimental results of organic matter decomposition, N mineralization and immobilization could be simulated. Further, the model was used to explore management options to improve the N use efficiency of combinations of low and high quality organic materials.

The major conclusions are:

- The decomposition rates found for crop residues with high C : N may have been lower than corresponds with the chemical decomposability of the materials because the quantities of inorganic N in the soil may have been too small for smooth decomposition.
- As a consequence, addition of prunings with low C : N results in N immobilization of mineralized pruning N; this promotes the decomposition of low quality crop residues, but has not much effect on the total N mineralization.
- Maximum immobilization of N was about 9 to 10 kg N per ton of maize stover or pigeonpea roots.
- The total period of immobilization and remineralization may last three to four months for maize stover and pigeonpea roots.
- It is recommended to apply 1.4 and 1.05 tons of gliricidia and sesbania prunings, respectively, per ton of maize stover to neutralize initial N immobilization.
- To take optimum advantage of added prunings, mineralized N should become available before 50 days after planting of the crop; this gives the highest N use efficiency
- Further calibration and testing of the model is needed, especially with regards to input parameters DA and C/N_m , and temperature and drought corrections.



Farmers admiring the maize in agroforestry systems



Contrast between maize in Sole-Maize and Gs-Maize (far left)