Predicting the fertilizer nitrogen value of farm manure applications to agricultural land.

Prévision de la valeur « azotée » de déjections animales épandues en agriculture.

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Abstract

A computer based decision support system to predict the fate of N following organic manure applications to land was developed, drawing together the latest research information on factors affecting manure N availability. The MANure Nitrogen Evaluation Routine (MANNER) accounts for manure N analysis, ammonia volatilisation, incorporation timing, nitrate leaching and mineralisation of manure organic N. Predictions from MANNER have been evaluated by comparison with independently collected experimental data. Good agreement was found between predicted and actual fertiliser N values for poultry manure, pig slurry and cattle slurry (p<0.001), confirming that MANNER provides a simple, quick and accurate estimate of the fertiliser N value of different farm manures spread under a range of circumstances.

Keywords *: organic manures, nitrogen, modelling, land application*

Résumé

Un système informatique d'aide à la décision destiné à prédire le devenir de l'azote consécutivement à l'épandage de déjections animales a été développé sur les bases des dernières connaissances disponibles.
Le système désigné par MANNER (MANure Nitrogen Evaluation Routine) prend en compte l'analyse de l'azote des déjections, la volatilisation de l'ammoniac, les conditions d'épandage (incorporation), la lixiviation des nitrates et la minéralisation de l'azote organique des déjections.
Les prévisions issues du système MANNER ont été comparées avec des données expérimentales indépendantes. Une bonne concordance a été établie entre les valeurs prédites et les valeurs fertilisantes obtenues pour du fumier de volailles, lisier de porc et lisier bovin (p < 0.001), confirmant l'intérêt du système qui permet une estimation simple, rapide et fiable de la valeur azotée des déjections animales.

Mots-clés : déjections animales, azote, modélisation, épandage.

1. Introduction

Land application represents the most cost effective outlet for organic manures and allows their nutrient and organic matter content to be utilised to supply crop nutrient demands and maintain soil fertility. However, it is clear from annual statistics on fertiliser use in the UK (Burnhill *et al*, 1994) that farmers make little or no allowance for the contribution of manures to crop fertiliser requirements, even where applied regularly and to a large proportion of the crop area. Whilst a number of factors contribute to the poor on-farm utilisation of manures, lack of confidence in accurately predicting the fertiliser N value of a manure dressing is an important issue (Smith and Chambers, 1995).

Recent UK research has contributed significantly to an improved understanding of the nitrogen supply characteristics of organic manures and this is now reflected in current advice (MAFF, 1994). However, a straightforward message is required for effective advice with simple decision support systems playing an increasingly important role in the practical application of research information.

2. Theoretical background

Nitrogen (N) transformations and losses following the land application of organic manures are many and complex. Comprehensive models which predict the fate of manure N should take account of each pathway in order to arrive at a robust estimate of the amount of crop available N. In addition, such models should be verifiable against independent experimental data and, if they are intended to have a practical application, should be easy to use and only require readily obtainable input data.

2.1 Rationale behind the current model

The ADAS 'MANNER' model (MANure Nitrogen Evaluation Routine) is a simple PC-based decision support system which has drawn together the latest information on factors affecting organic manure N availability and losses following land application. "MANNER" is designed to provide a quick estimate of the fate of manure N following land applications, for a range of agricultural situations. Currently not all N loss pathways and transformations are covered by the model. Although it is recognised that these may be of significance, on the basis of current UK knowledge, it has not been possible to include factors describing N immobilisation or denitrification.

In its present form, the model has 3 screens for data input : i) manure type/analysis, ii) incorporation and iii) leaching (eg. Figure 1). Comprehensive help screens and a User Guide are provided to assist the farmer/consultant with entering the information. A single screen, output (which can be saved to disk or printed) is produced which summarises both the data inputs and the fate of manure N, in terms of ammonia volatilised, nitrate leached, plant available N for current crop and organic N mineralised for next crop.

The calculations required to produce the model outputs are performed in the sequence as described below.

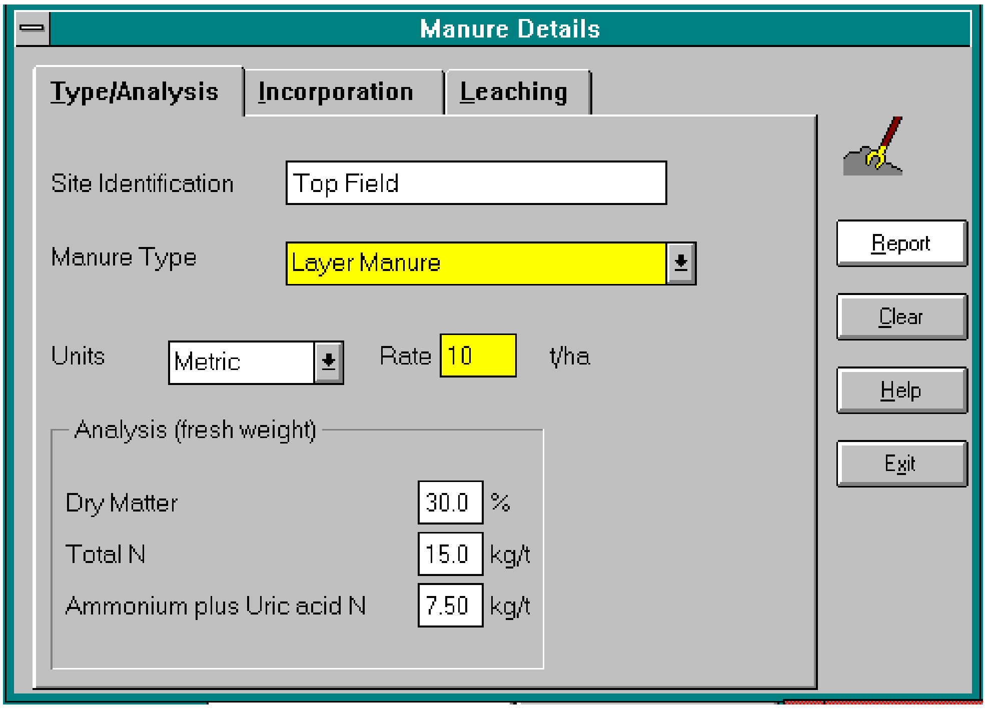

Figure 1
Example of a MANNER data input screen

2.2 Manure application rate and analysis.

The manure type and rate of application are required model inputs. A total of 17 organic manure types, including sewage sludges, can be selected from a drop-down menu (Figure 1). Information is required on the manure total N, ammonium N, uric acid N (poultry manures only) and dry matter (DM) content. Default values based on typical analyses are provided. However, as manure total N content and the relative proportions of the different N forms will vary according to animal diet, conditions of manure handling and storage, etc, it is important that actual analysis data, relating to the manure applied, are input where possible.

2.3 Ammonia volatilisation.

Ammonia volatilisation is generally the first major loss pathway for manure ammonium N following land application. Typically, 65% of the ammonium-N content of FYM and 35% of the ammonium+uric acid -N content of poultry manure can be lost through ammonia volatilisation (Chambers *et al.,* 1997).

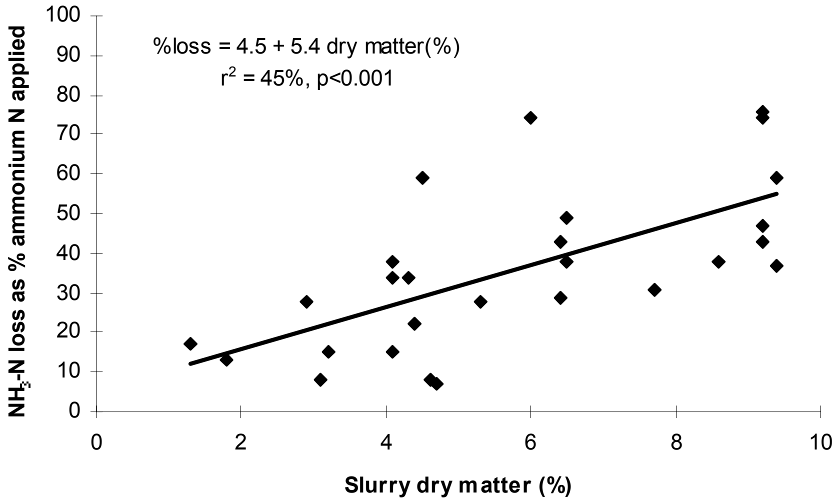

Figure 2
Relationship between slurry dry matter content and ammonia loss

Where slurries are surface applied, DM content has a large influence on ammonia loss (Sommer and Olesen, 1991). UK research measurements (Smith and Chambers, 1995) have shown an increase in ammonia-N loss of 5-6% of the ammonium-N applied per 1% increase in slurry DM, within a range of 1-9% DM (Figure 2). The speed of incorporation is also important - soil incorporation can be very effective in reducing losses, the more rapid the incorporation (particularly for slurries), the greater the impact in reducing losses. In recent field experiments, ammonia losses were measured following the surface application of cattle and pig slurries and a range of solid manures (broiler and turkey litter; layer manure; pig and cattle FYM). The ammonia loss curves were fitted with Michaelis-Menton type equations which have been sucessfully used by other researchers to describe ammonia emissions following land spreading (Sommer and Ersboll, 1994). MANNER estimates potential ammonia volatilisation from slurry depending on the dry matter content, before calculating actual ammonia loss in relation to soil incorporation practices using Michealis-Menton equations. Ammonia losses from surface spread separated slurries and liquid sewage sludges are calculated in the same way.

2.4 Crop uptake.

No allowance is made in the model for crop uptake of N overwinter or in early spring, because this is usually fully supported by background soil mineral N supplies, the manure N, at these early stages, being largely ‘surplus to requirements’.

2.5 Nitrate leaching.

The total water content in the soil profile at field capacity to 1m depth (volumetric moisture content - Vm) is defined by the soil texture and determines the soil's susceptibility to leaching. In the model, 15 different topsoil/subsoil textures are recognised. A simple piston flow model is used to describe water movement through the soil profile. This assumes that the volume of rainwater entering the soil displaces an equal volume of water through drainage, once the soil has reached field capacity.

However, not all of the rain which falls will drain into the soil as some will be lost through evapotranspiration. The 'effective' rainfall (ER) is thus the difference between actual rainfall (AR) and the amount lost through evapotranspiration. Data on evapotranspiration losses from fields with different crop cover types are available in the UK, however, it is unlikely that the farmer will have ready access to these. The model therefore uses a simple algorithm to calculate ER from AR. If no rainfall data is input, the model uses a typical value (if appropriate) for the period between manure application and the end of drainage.

The amount of N lost through leaching is then calculated based on the amount of readily 'available' N (ammonium+uric acid-N for poultry manures and ammonium-N for other manures) remaining after ammonia volatilisation, using the following relationship :

$$AN_l = AN_v \, (ER/Vm - 0.5) \qquad (1)$$

where AN_l is the amount of readily 'available' N remaining after leaching, AN_v is the amount of available N remaining after ammonia volatilisation and the value of (ER/Vm - 0.5) is constrained to lie between 0 and 1.

If the manure was ploughed down within 1 month of application, it is assumed to have 'by-passed' the topsoil (average incorporation depth is ca. 25 cm), with the Vm therefore accounting only for capacity of the subsoil, before being used in Equation 1.

2.6 Mineralisation.

Mineralisation of manure organic N additions will result in some N becoming available for crop uptake, even if all the readily 'available' N has been lost earlier through ammonia volatilisation or nitrate leaching. For MANNER, data from field experiments conducted in the UK using manures applied at normal agronomic rates (Smith *et al*, 1994; Chambers *et al*., 1996) were used to derive the following mineralisation equations:

$N_m = N_o \times 0.1$ (for FYM, slurry and spring applied poultry manure) (2)

$N_m = N_o \times 0.2$ (for autumn applied poultry manure) (3)

where N_o is the amount of organic N in the manure and N_m is the amount of mineralised organic N that will be utilised by the growing crop.

3. Model validation

One of the most important aspects of model development is testing the output against data collected independently from that use to assemble the actual model components. Comparisons of MANNER generated predictions of manure fertiliser N values for solid manures and slurries, with experimental data, are shown in Figures 2 and 3.

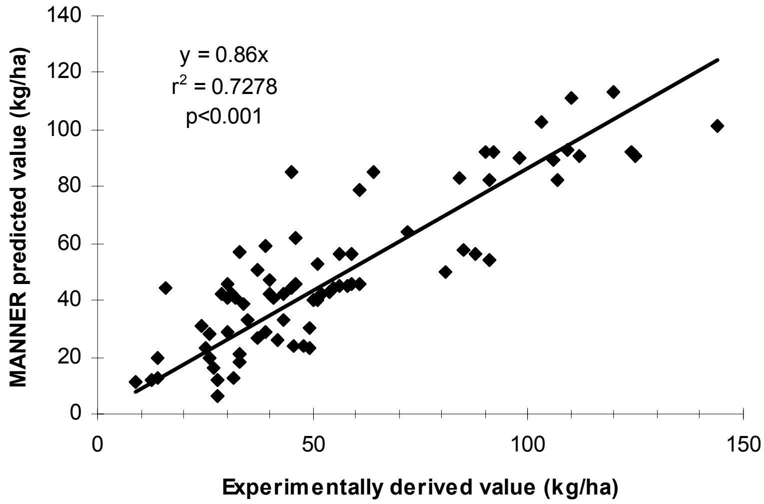

Figure 2.
Comparison of MANNER predicted and experimentally derived fertiliser N values for solid manures applied to cereals

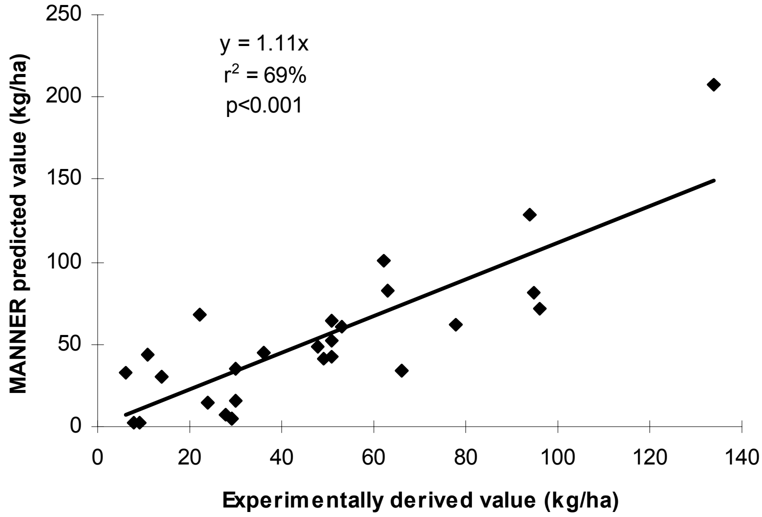

Figure 3
Comparison of MANNER predicted and experimentally derived fertiliser N values for slurries applied to cereals

Good agreements (r^2 ca. 70%; P<0.001) between the model predictions and experimentally derived data, confirm that MANNER can provide a simple, and accurate estimate of the fertiliser N value of different farm manures spread under a range of circumstances.

4. Acknowledgements

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