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A comparison of two models to predict nitrogen dynamics in organic agricultural systems

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Summary

Two publicly available crop/soil models were compared. These were the EU-Rotate_N model (www.warwick.ac.uk/go/eurotaten) and the NDICEA model (www.ndicea.nl). Each simulation was also compared to measured data from an organically managed site in the English Midlands. Results showed that, overall, EU-Rotate_N gave a better estimation of soil mineral nitrogen, particularly after the incorporation of a long-term fertility-building crop. This model has a lot of flexibility but is aimed at researchers and requires more work before it is ready to be used by farmers or advisors. The NDICEA model is much simpler to use with a user-friendly interface.

Key words: Modelling, nitrogen dynamics, organic, vegetables, leys, soil fertility

Introduction

Managing nitrogen (N) supply is important in any agricultural system but is particularly critical under organic management. In the absence of artificial fertilisers nitrogen is predominantly supplied through fixation by leguminous fertility building crops and it is difficult to match the mineralisation patterns of the fertility crop residues to the demands of cash crops in succeeding years. If this is not achieved there is a danger of both poor crop performance and nitrate leaching at different points in the rotation. Growing a fertility-building crop is expensive (mainly in terms of setting aside productive land) and so farmers want to ensure that they get the best return from them.

Computer modelling offers a way of helping with rotation design to optimise financial and environmental sustainability. Crop response models for conventional systems are well established. Although the laws of physical relationships are the same in conventional and organic agriculture, developing effective models for organic systems can be harder since, in the absence of conventional fertiliser inputs, it is particularly important to correctly predict the mineralisation from crop residues and fertility building crops. It is also essential that they are able to model full rotations. Two freely available models have been recently developed with the needs of the organic farmer in mind.

The EU-Rotate_N model (www.warwick.ac.uk/go/eurotaten) was developed by a consortium of European researchers (Rayns *et al*., 2006). It is particularly intended for vegetable production (although arable crops are also included). Modelling of a range of fertility building crops includes aspects such as nitrogen fixation, the effect of mowing, litter loss in long-term leys and establishment of crops by undersowing. The model in its present form is aimed at the researcher rather than the farmer. The NDICEA model (www.ndicea.nl) was developed by the Louis Bolk Institute to enable the assessment of organic fertilisation strategies and crop rotations using easily obtainable input values (Koopmans & van der Burgt, 2005). It is a simpler model and includes a user-friendly interface. In contrast to the EU- Rotate_N it does not estimate crop yield, so this must be entered manually. Additionally it requires ETo as an input, a figure which is not always easily available. In this paper we evaluate their strengths and weaknesses and compare simulated with measured values.

Materials and Methods

Data to test the models was obtained from a field (Hunts Mill) located at Warwick HRI in the UK midlands. The soil type is a sandy loam and the site has been managed organically, with a stockless vegetable/arable rotation, since 1995. The measurements used were made in a series of cash crops grown between 2003 and 2005. These were grown in two areas of the field, one (long ley) following a grass/clover ley that had been established in 2000 and the other (short ley) following a grass/clover ley that had been established in 2002. Both leys were established by undersowing in a preceding barley crop and were incorporated in spring 2003. Measurements were made of total and marketable yields and soil mineral N to 60 cm depth.

The EU-Rotate_N and NDICEA models were run using the above rotations and comparisons made with measured data. Locally obtained weather data was entered into each model. The NDICEA model required evapotranspiration figures to be entered. This was estimated using the method of Blaney-Criddle (Allen *et al*., 1998) which only requires temperature, date and location as inputs. This is the same method that EU-Rotate_N uses internally. The models were compared by visual assessments on a graph and also with quantitative statistical tests of the effectiveness of the models. The r-value and modelling efficiency are shown (Smith *et al*., 1996).

Results

Fig. 1 shows the measured and simulated soil mineral N values after incorporation of either a long or a short ley. During this period virtually identical cash crops were grown under both treatments, but crop yields were lower following the short ley. The numbers on the graphs indicate points of interest referred to in brackets in the text.

Both models correctly predicted a rapid rise in mineral N after the incorporation of the grass clover leys in March 03 [1]. The models also correctly predicted that the amount of N mineralised after the long ley was greater than that of the short ley. However the actual values generated were not always accurate. After the long ley, NDICEA overestimated the amount of N mineralised by *c*. 50% whereas EU-Rotate_N underestimated it by *c*. 50% [2]. After the short leys, both models predicted the amount of N mineralised fairly accurately [3].

EU-Rotate_N predicted the pattern of the N mineralisation (a rise in soil N when a ley or cash crop is incorporated and a gradual decrease in N when a crop is growing and taking up N) fairly well, although the actual values were not always accurate. For the first cash crop (potatoes) EU-Rotate_N predicted the levels of N in the soil very accurately [4]. For the second cash crop (carrots), EU-Rotate_N overestimated the amount of N available in both the short and the long ley [5].

NDICEA sometimes predicted that there was more N available in the soil than the crop needed for growth, resulting in a rise in soil N levels as it continued to be mineralised. In reality soil N levels were decreasing as the crop took it up [6]. However, when N levels in the soil were lower, i.e. during the second (carrot) crop after the short ley, NDICEA accurately predicted a fall in soil N levels as the crop took up N [7].

The r-value and modelling efficiency are shown in Table 1. For the long ley, the r-values were low, especially for the NDICEA model, suggesting that there was a poor association between the measured value and the modelled value. For the short ley, the r-values were better than for the long ley, as both the models predicted the shape of the curve more accurately, especially in EU-Rotate_N.

With the exception of the predictions for the long ley, modelling efficiencies (ME) were poor (less than zero). These poor values could be attributed to a few sampling occasions where the model's predictions differed widely from the measured values. One criticism of ME is that one or two outliers can have a large influence on its value (Smith *et al.*, 1986).

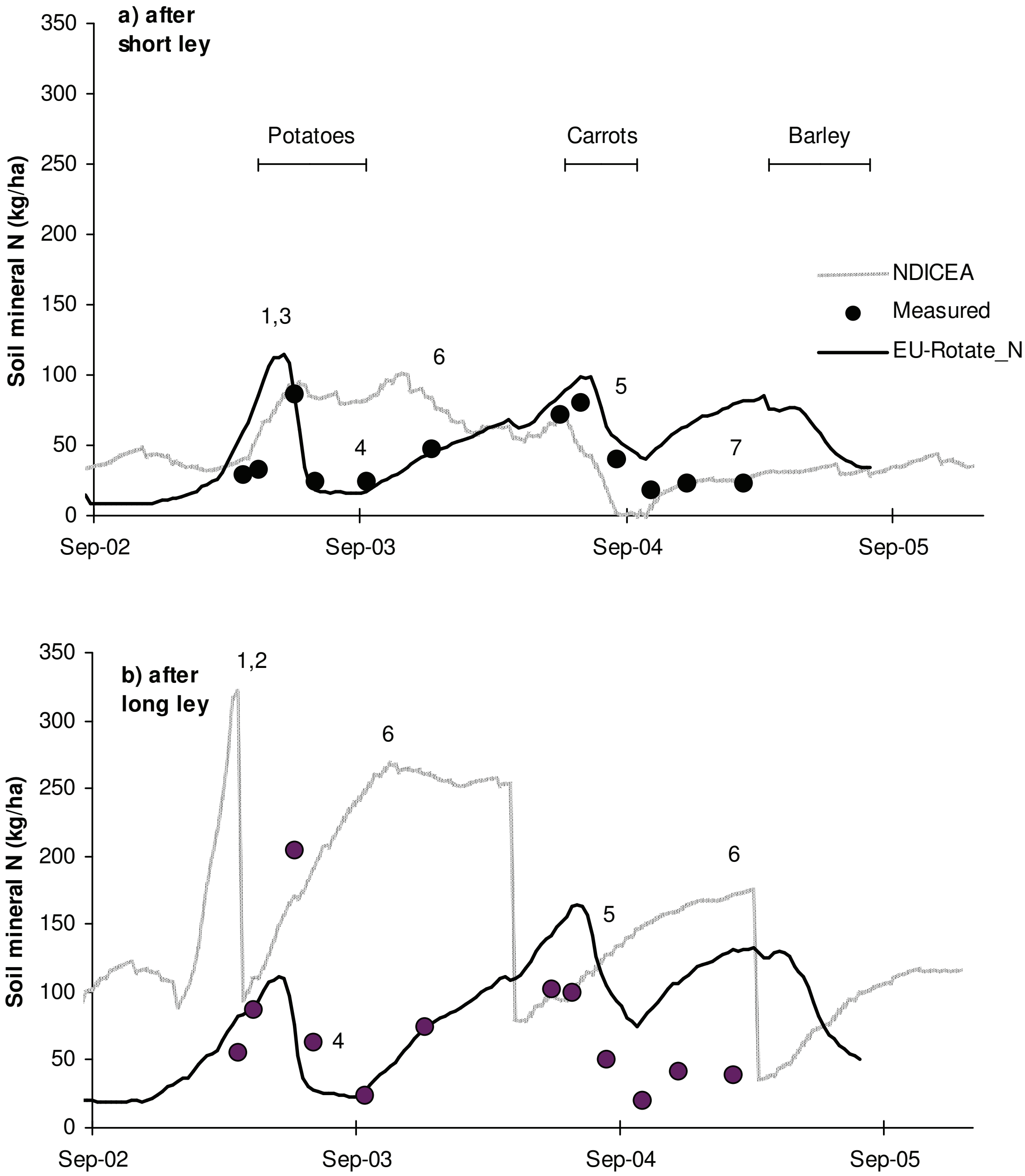

Fig. 1. Measured and simulated soil mineral nitrogen (N) values in the crop sequence following a long ley. The numbers refer to points of interest explained in the text.

Discussion and Conclusions

Both models provide useful information for the farmer but are contrasting in their approaches. In this study EU-Rotate_N provided a better estimation of soil mineral N levels than NDICEA. However, as only a limited set of data has been used, both the models should be compared under a wider range of conditions to provide a fair comparison. In another more extensive study, carried out in the Netherlands (Van der Burgt *et al.*, 2006), NDICEA predicted the available soil N within 20 kg ha^{-1} of the measured values for 60% of the fields without needing to further calibrate the model.

Table 1. *Modelling effectiveness parameters for the simulations shown in Fig. 1*

	Long ley		**Short ley**	
	NDICEA	**EU-Rotate_N**	**NDICEA**	**EU-Rotate_N**
r-value	-0.23	0.17	0.42	0.61
ME	-1.536	0.52	-0.59	-0.74

Conversely, in this work, NDICEA, often overestimated the amount of N available to the crop whilst it was growing, resulting in large inaccuracies for parts of the growing season. Further tests should be done on both models to identify the situations and reasons why they generate values that differ widely from those measured.

The quantitative statistical tests were of limited value for this data, especially the modelling efficiency which was heavily influenced by occasional outlying values. The approach employed by Van der Burgt *et al.* (2006) of calculating the percentage of predictions that are within 20 kg/ha of the measured value may be of more use practically, but this requires a larger number of measurements than were taken here.

In practice, the NDICEA model is currently much simpler to operate with a user-friendly interface, producing results that growers can use as a tool for growers or agronomists. It also provides outputs on other variables such as nutrient budgets for potassium and phosphorus. The EU-Rotate_N model is very flexible but, as a consequence, more difficult to use. It operates on a daily time-step (NDICEA has a weekly time-step) and so is able to model events such as the effects of heavy rain storms. The model also calculates gross margins for crops, fertility building crops and whole rotations and so is a good tool for comparing the economic impacts of various strategies.

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