Aspects of Applied Biology 79, 2006
What will organic farming deliver? COR 2006

The use of computer modelling to evaluate the agronomic, economic and environmental impacts of N management in contrasting organic rotations

By FRANCIS RAYNS[1], ULRICH SCHMUTZ[1], CHRIS FIRTH[1],
KRISTIAN THORUP-KRISTENSEN[2], KEFENG ZHANG[3] & CLIVE RAHN[3]

[1] *HDRA, Ryton Organic Gardens, Coventry, CV8 3LG, UK. E-mail:* frayns@hdra.org.uk
[2] *DIAS, Research Centre Aarslev, Kirstinebjergvej 10, Denmark*
[3] *Warwick HRI, Wellesbourne, Warwick, CV35 9EF, UK*

Summary

A new computer model (EU-ROTATE_N) has been developed with the aim of improving nitrogen management on all farms across Europe which include field vegetables in their rotations. It brings together aspects of many existing models and contains a number of features to make it applicable to organic producers (e.g. taking account of nitrogen fixation by legume containing leys, nitrogen conservation by winter cover crops and nitrogen supply by manures and composts). A key feature is the model's ability to simulate economic output and this enables it to be of value to policy makers when considering the impact of new measures to reduce environmental pollution. This paper describes the model and some initial work that has been conducted to evaluate it under UK organic field vegetable systems with contrasting fertility building strategies.

Key words: Organic farming, field vegetables, computer modelling, fertility building crops, rotational planning, farm economics

Introduction

EU-ROTATE-N is a new model that has been developed by a group of scientists in six European counties. It considers the agronomic, environmental and economic implications of different management practices on rotations rather than on single crops. It is intended that it will be of use both for farmers/advisors (to help with rotation design) and policy makers (to assess the implications of possible legislation). The project began in 2003; although the new model was based on N-ABLE, an established soil and plant nitrogen model for field vegetable rotations (Greenwood *et al.*, 1996), many new features have been added. It is suitable for both organic and conventional conditions and it is intended to be used across the climatic zones of Europe - all the necessary soil and meteorological information is included in databases. It is programmed using a modular approach so that in the future modifications will be relatively easy. An important part is the economic sub-model; this calculates appropriate marketable yields, financial outputs and crop or rotational gross margins. The information necessary for this (e.g. local size specifications and prices) can be provided by the user. A cost can also be attributed to nitrate leaching or gaseous emissions (Schmutz *et al.*, 2004; Schmutz & Firth, 2005).

The model currently contains parameters for 40 cash crops. Fertility building crops (short term green manures and green manures) are also included. Special routines have been written to deal with nitrogen fixation, species mixtures in leys, establishment by undersowing, management by mowing, litter loss and senescence of annual plants.

Final validation of EU-ROTATE-N and construction of the graphical user interface is currently being completed. It will be available on www.hri.ac.uk/eurotate by the end of 2006.

Methods

The performance of the model was assessed by comparing the simulations with measured values. Trials were conducted on the Hunts Mill site of Warwick HRI, located in central England. The soil is a sandy loam with a low organic matter content. Conversion to stockless organic management (vegetables and arable crops) began in 1995 and the site has been extensively monitored since 1995 (HDRA, 2005). The trials were conducted in adjacent areas having well established rotations with differing fertility building strategies i.e. either a 30 month grass/clover ley or a 7 month (overwintered) ley. Both leys were established by undersowing in a spring barley crop and were followed in 2003 by a crop of potatoes (to which 45 t ha^{-1} of farm yard manure was applied), in 2004 by a crop of carrots and in 2005 by a crop of spring barley. There were three replicate plots of each treatment. Regular samples were taken to determine soil mineral nitrogen and crop growth was assessed by harvesting by hand or using a plot combine as appropriate.

Results

Fig. 1 shows the simulation of plant dry matter. In the ley phase (up until spring 2003) the effect of mowing the long ley twice each summer is clear, as is the more gradual decline in biomass overwinter as litter loss is not replaced with fresh growth in the colder part of the year. Simulated nitrogen fixation is also shown and, as expected, the short ley fixes much less than the long ley. This extra input of nitrogen is reflected in the biomass production of the following cash crops.

Final biomass and marketable yields are given in Table 1. On average the simulations overestimated the biomass by 10% and the marketable yield by 20%. Simulated economic performance is shown in Table 2. The gross margins for individual crops were better in the crop sequence with the long ley (as a result of the better yields). The average yearly gross margin was higher for the shorter rotation with less time dedicated to fertility building.

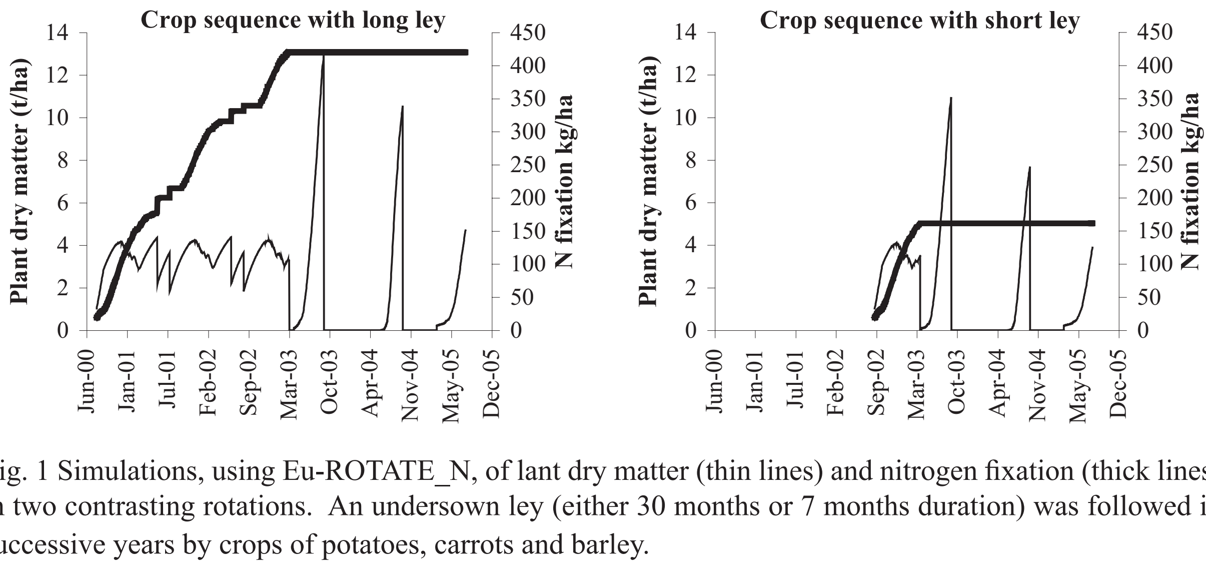

Fig. 1 Simulations, using Eu-ROTATE_N, of lant dry matter (thin lines) and nitrogen fixation (thick lines) in two contrasting rotations. An undersown ley (either 30 months or 7 months duration) was followed in successive years by crops of potatoes, carrots and barley.

There was a very close match between simulated and measured soil mineral nitrogen. As an example the 0-30cm depth results are shown in Fig. 2. Fig. 3 shows simulated nitrate leaching. As expected, most of this occurs in the cash crop phase of the rotation rather than from the ley.

Table 1. *Comparison of measured final plant biomass and marketable yield with simulated values using EU-ROTATE_N*

Crop	Biomass (t/ha)				Marketable yield (t/ha)			
	Simulated Long ley	Measured Long ley	Simulated Short ley	Measured Short ley	Simulated Long ley	Measured Long ley	Simulated Short ley	Measured Short ley
Potatoes	13.0	12.2	10.9	8.7	49	32	43	26
Carrots	10.5	10.0	7.7	7.4	57	45	46	37
Spring barley	4.7	--	3.9	--	2.9	4.0	2.4	2.6

Table 2. *Economic performance of two contrasting rotations simulated using EU-ROTATE_N*

Crop	Output (£/ha)		Variable Costs (£/ha)		Gross Margin (£/ha)	
	Long ley	Short ley	Long ley	Short ley	Long ley	Short ley
Ley	0	0	300	100	-300	-100
Potatoes	14700	12900	7386	6642	7314	6258
Carrots	14250	11500	8297	7054	5953	4446
Spring barley	479	396	149	149	330	247
Total	**29429**	**24796**	**16132**	**13945**	**13297**	**10851**
Yearly average					**2659**	**3617**

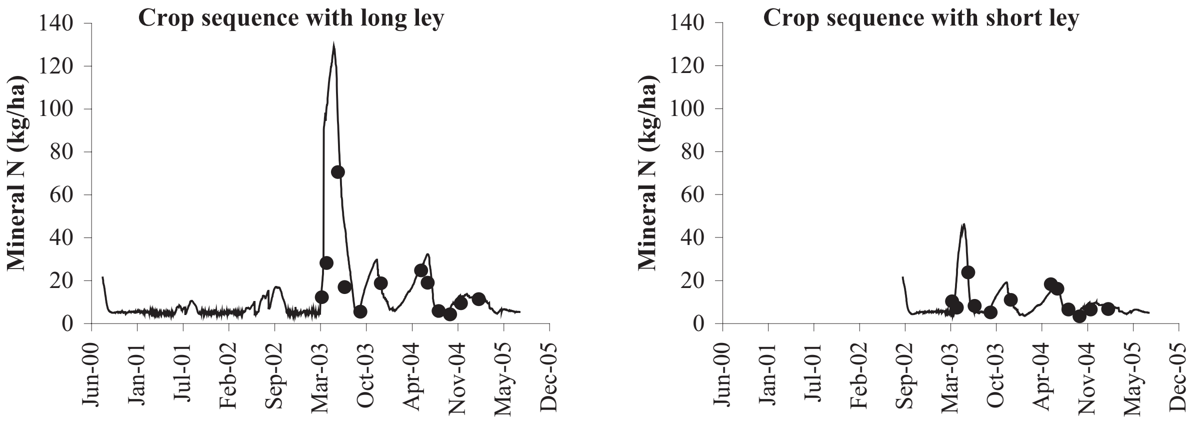

Fig. 2. Soil mineral nitrogen in the top 30 cm of soil; the lines show the simulations using EU-ROTATE_N; the points are measured values.

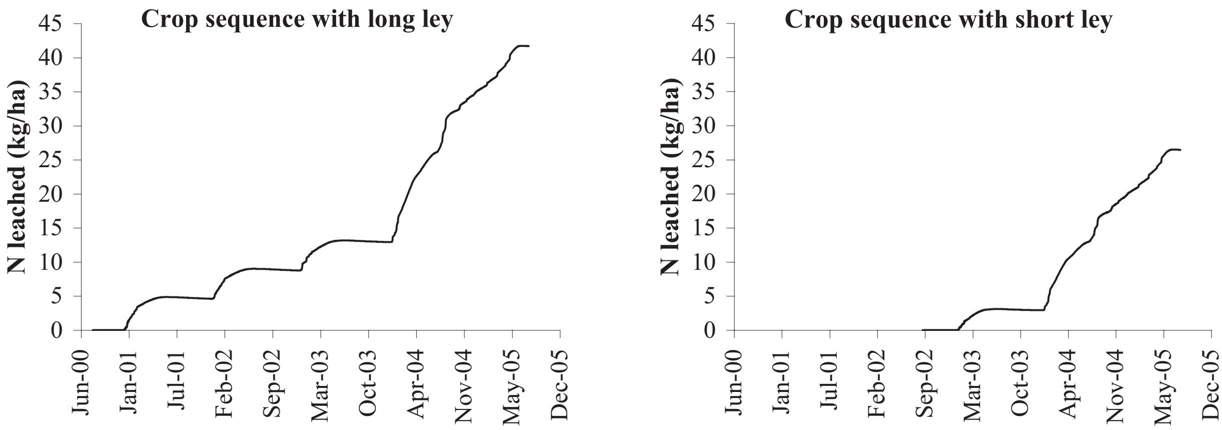

Fig. 3. Leaching below 90cm depth simulated using EU-ROTATE_N

Discussion and Conclusions

The results presented here show that there is a reasonably close match between measured and simulated values for two contrasting organic rotations. The main discrepancy is with overestimation of the marketable yield (as the model was initially parameterised for conventional production) and this can be addressed by alteration of the crop parameters rather than requiring reprogramming work. In the example shown the higher marketable yields of cash crops as a result of greater nitrogen availability did not compensate financially for the extra costs in rotations with longer fertility building periods.

In this paper only leaching below 90 cm depth is shown. The model also provides figures for leaching below 30 and 60 cm and for nitrate recovered below 90 cm by deep rooting crops. This is of importance for evaluating the significance of winter cover crops grown specifically for preventing nitrate leaching. Ascribing financial penalty of nitrate pollution then enables a comparison of the cost effectiveness of the various measures available to reduce it.

Work is ongoing to validate the model under a wider range of conditions and with more diverse rotations. In the future EU-ROTATE-N should prove to be a valuable tool that can be used by farmers, advisors, researchers and policy makers to support their decision making processes.

More information about the EU-ROTATE_N project can be found at www.hri.ac.uk/eurotate.

Acknowledgements

The authors are grateful to the EU for providing funding for Project QLK5-2002-01110.

References

Greenwood D J, Rahn C R, Draycott A, Vaidyanathan L V, Paterson C D. 1996. Modelling and measurement of the effects of fertilizer-N and crop residue incorporation on N- dynamics in vegetable cropping. *Soil Use and Management* **12**:13–24.

HDRA. 2005. Final report to DEFRA for Projects OF 0126T and OF 0191 Conversion to Organic *Field Vegetable Production*. Available on www.defra.gov.uk.

Schmutz U, Firth C, Rayns F, Rahn C. 2004. Can N use and farm income be optimized for organic field vegetable rotations in Europe? *Organic Farming: Science and Practice for Profitable Livestock and Cropping*. BGS/AAB/COR Conference 2004.

Schmutz U, Firth C. 2005. Optimising farm economics and nitrogen use – the economic module within the model EU-ROTATE_N. *NJF-Seminar, Malmo, 12–13 October 2005*, www.improvednp.com.