National-scale modelling of N leaching in organic and conventional horticultural crop rotations - policy implications.

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Key words: Nitrogen leaching, modelling, crop rotations, vegetables, water framework directive

Abstract

A method is presented to model N leaching in crop rotations on a national scale. Representative crop rotations for different regions and soil types are used in the cross-disciplinary, plant, soil, environment & economics model EU-Rotate_N. By comparing contrasting farming systems (organic and conventional) in the UK, their strengths and weaknesses in delivering environmental and economic sustainability can be assessed. Modelling results show that the annual leaching in different horticultural rotations and UK regions, using median weather, is within the range of 13 - 88 kg N/ha/year for organic and 54 - 130 kg N /ha/year for conventional. The weighted annual average figures are 39 kg N/ha/year for organic and 81 kg N/ha/year for conventional, respectively. It is concluded that organic horticultural rotations, with a current share of 6.1% already contribute to lower overall N losses from agriculture. However, on a UK national scale, only a large share of organic land use (e.g. > 50%) has a large effect on reducing N losses. Similar reductions are also predicted by substantial cuts in conventional N inputs, giving a policy choice if pollution from agriculture steps up further on the political agenda.

Introduction

Many arable and vegetable crops across Europe are produced in intensive rotations, with large nitrogen (N) fertiliser inputs. Arable crops and especially field-scale vegetable crops use nitrogen often inefficiently and leave N residues in the soil after harvest. This can cause pollution to soil, water and aerial environments, economic losses and unnecessary recourse use. For policy planning, it is necessary to quantify these effects not only on a crop or farm rotation level but also on a national or county level with all its variations in soil type, climate, rotational design, management practise and marketing specifications. With the given constrains in computer power and data availability it is obviously currently not possible to model all rotations of a country and its differing farming systems. Therefore, the two main contrasting farming systems, conventional and organic production, in the United Kingdom were used. To simplify model inputs, statistic data were used to source representative rotations for each farming type.

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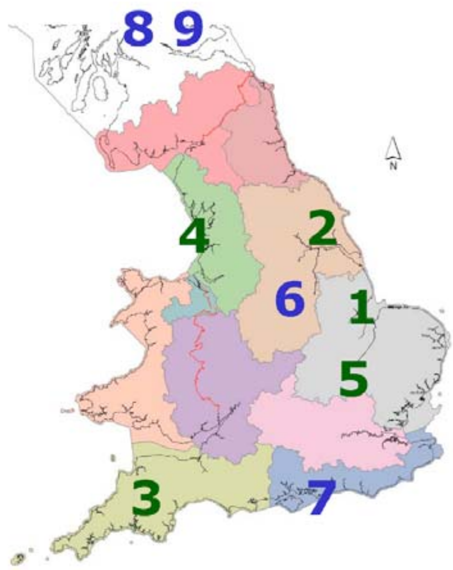
Materials and methods

The data were modelled using EU-Rotate_N a computer model developed over the last five years by a consortium of European researchers. It is a decision support system for soil-plant interactions based on N use in crop rotations. Up to 30 years of cropping can be simulated on a daily step in organic or conventional rotations. The model is written in Fortran and allows the experienced researcher great flexibility since all inputs can be modified to suit local conditions. The model includes routines for water use, water stress, mineralisation, snow and frost (Riley and Bonesmo 2005), root growth and distribution (Kristensen & Thorup-Kristensen 2006), N release from fertility building crops (Rayns et al. 2006) and economics including market channels, marketable yields, crop spacing and variable costs (Schmutz and Firth 2005). The model is available at www.warwick.ac.uk/go/eurotaten (Because of space constrains no further basic details about the model can be given here and reference may be consulted). The data and methods used to source representative 3 - 8 year crop rotations on a national scale are described elsewhere (Schmutz et al. 2006).

Based on these data, the following model runs have been selected (UK regions representing less then 5% of the national vegetable production e.g. Wales, North East England, Northern Ireland were excluded). The first five areas were also run with organic rotations. They represent main UK production areas for conventional and organic and are also scattered in the main river basins according to the water framework directive (WFD) as shown the England and Wales map Table 1.

Tab. 1: Represenative areas, regions, soil types and main crops used in the model runs. The first five areas are also done for organic rotations (run 1o-5o).

Run Nr	Area	Region	Soil Type	Main crops
1	South Lincolnshire	East Midlands	Heavy Silt	Brassicas
2	North Lincolnshire	East Midlands	Sandy Loam	Brassicas
3	Cornwall	South West	Sandy Loam	Brassicas
4	Lancashire	North West	Silt Loam	Brassicas
5	Bedfordshire	Eastern England	Light	Mixed vegetables
6	Nottinghamshire	East Midlands	Light sand	Onion, Carrot, Potatoes
7	Sussex	South East	Sandy Loam	Lettuces
8	Fife	Scotland	Sand	Root Crops
9	Fife	Scotland	Sandy Loam	Brassicas



Organic rotations were run with management data (not shown) representing current organic practices as defined by the Compendium of UK Organic Standards (Defra, 2006). Conventional rotations were run with management data (not shown) representing good agricultural practice (GAP) and N fertiliser inputs as defined by the Defra publication RB209 (Defra/MAFF, 2000). An example for current practice organic rotation is 2-year grass/clover, potatoes, broccoli, leeks, while the conventional has spring wheat, potatoes, broccoli leeks. In order to compare the land use patterns of organic and conventional rotations in a UK scenario they were statistically weighted according to their importance within UK vegetable regions (e.g. the current high representation of organic production in the high rainfall area of the South West (27.8% weight organic versus 5.8% weight conventional) is taken in account. The current dataset and method represents 86% of the UK conventional and 68% of the UK organic vegetable production. Because of limitations in statistically available data, potatoes and leguminous vegetable crops were excluded (Schmutz et al. 2006). The effects on N leaching, rotational gross margins and other parameters are shown for the current UK organic vegetable land use share of 6.1% and for scenarios with 0%, 2%, 20%, 50% and 100% organic management of the UK vegetable area.

Results

Given space constrains, the inputs and results of individual rotations and model runs are not discussed. Results are only presented on an aggregated level showing the weighted national UK average including all regions, rotations soil types and weather conditions. Data show (Table 2) that current good practice (GAP) horticultural land use has predicted looses of 39 kg N/ha/year under organic and 81 kg N/ha/year under conventional management, respectively.

Tab. 2: Average %-cropping in rotation, modelled N-fluxes and rotational gross margins of weighted organic and conventional horticultural rotations. Data are shown per ha and year, and for the UK horticultural sector assuming different land use percentages of horticultural crops.

Data per ha and year	Organic	Conventional	org%conv
% vegetables	56%	65%	
% cereals	4%	32%	
% fertility crops	40%	3%	
Modelled rotational N fluxes			
N input Mineral Fert (kg/ha/yr)	0	158	
N input Organic Fert (kg/ha/yr)	18	0	
N leach below 90cm (kg/ha/yr)	42	85	
N uptake below 90cm (kg/ha/yr)	3	3	
N system loss water (kg/ha/yr)	**39.2**	**81.4**	**48%**
N gaseous loss (kg/ha/yr)	54	28	191%
N fixed (kg/ha/yr)	30	0	
N system loss air (kg/ha/yr)	**24**	**28**	**86%**
N total loss (kg/ha/yr)	64	110	58%
Rotational gross margin (€/ha/yr)	**€ 3,466**	**€ 2,515**	**138%**
Data for UK horticultural sector			Combined
UK vegetable area (ha)	4720	72866	77586
N system loss water (kg/ha/yr)	39.2	81.4	78.8
Total UK kg N leached (t/year)	185	5929	6114
% organic land use	6.1%	93.9%	100%
Scenario with different % organic	% org	N (kg/ha/yr)	N (t/year)
	0%	81.4	6313
	2%	80.5	6247
current % organic land use	**6.1%**	**78.8**	**6114**
	20%	72.9	5658
	50%	60.3	4676

Gaseous losses of organic production are predicted to be higher than for conventional farming (54 kg versus 28 kg N/ha/year), however when N fixing by legumes is included, the system loss to air is slightly lower (24 kg versus 28 kg N/ha/year). With the current organic land use of 6.1%, the overall system loss for the horticultural sector of field scale vegetables (excluding potatoes and leguminous vegetables) is 79 kg N/kg/ha. Without organic land use (0%-scenario), the losses are predicted to be 81 kg N ha/yr or 6114 tonnes N per year for this sector. With 20% organic land use, the next realistic milestone in organic expansion of UK horticultural land use, the sector's losses are predicted to be 5658 tonnes N per year.

Conclusions and Discussion

For the organic rotations, it can be concluded that the annual leaching predicted for different UK regions and rotations, using median weather, is within the range of 13 - 88 kg N/ha/year. The weighted annual average figure for the UK with median weather is 39 kg N/ha/yr. The 25- and 75- rainfall percentiles give a range of the weighted average of 24 - 45 kg N/ha/year. Overall leaching losses in organic are predicted 48% of conventional. If individual rotations, not weighted, are compared a Student's t-test is possible showing significantly lower (5% error level) leaching losses in organic. For the conventional rotations it can be concluded that the annual leaching is within the range of 54 - 130 kg N /ha/year, with a weighted annual average of 81 kg N/ha/year. The 25- and 75- rainfall percentiles give a range of 50 - 93 kg N/ha/year. On a policy level, it can be concluded that organic production can play an important roll in reducing N losses from horticultural land use. However, on a UK national scale, only a large share of organic land use (e.g. > 50%) has a large effect on reducing N losses by 36% to 60 kg/ha/year. Similar reductions are also predicted by substantial cuts in conventional N inputs. Model runs where the current conventional average N input (based on GAP recommendations) was reduced from 158 kg/N/year to 111 kg/N/year resulted in leaching losses of 50 kg/ha/year on a national scale. However, these are only projections from today's land use and management practices, it is difficult if not impossible to predict the complex interactions of scale effects when organic production increases its critical mass, moves into more favourable low-rainfall areas and simultaneously conventional production becomes "greener". The conclusion is certainly different on a catchment scale, where 100% organic land use can be achieved or enforced by restricting management practices, and reductions more specifically modelled.

Acknowledgments

Research was funded by EU Quality of Life Programme (QLK5-2002-01100)

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