Assessing the production impacts of a large-scale conversion to organic farming in England and Wales

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Key words: scaling of organic farming, optimisation, modelling

Abstract

This paper explores the implications for food production and land use of a 100% conversion to organic farming in England and Wales. The analysis uses a large-scale Linear Programming model of England and Wales agriculture, incorporating estimates of yield differentiated by soil and rainfall class, plus nitrogen supply/offtake and livestock feed demands. Results revealed a major reduction in arable crop outputs, milk and monogastric livestock under all organic scenarios. The results suggest that innovative approaches to nitrogen management on organic farms and changes in farm structure could help to improve the performance of organic agriculture at a national level, although this would require a major shift in current practices.

Acknowledgments

The material presented was produced within a PhD supported by the Organic Research Centre and the Engineering and Physical Sciences Research Council (EPSRC).

Introduction

With growing concerns over the capacity of modern farming to maintain current levels of production, in the face of environmental damage and increasingly costly inputs, there has been increasing interest in alternative low-input systems such as organic farming. Although such systems have the potential to produce food in an environmentally benign manner the broader impacts of a widespread conversion to organic practices are still unclear. This study aimed to provide a robust estimate of these impacts, e.g. on food production and land use, of a 100% organic conversion in England and Wales (E&W).

Material and methods

To answer the research question “how much food would be produced under a 100% organic agriculture in England and Wales?” a Linear Programming model was developed in the GAMS[i]programming language. The objective function of the model, which was maximised, was aggregate food output (Z) as metabolisable energy, i.e.:

$$\text{Maximise: Z} = \sum_{ij=0}^{n} C_{ij} \text{ x } X_{ij}$$

$$\text{subject to: } Ax_{(ij)} \leq b; \quad x_{(ij)} \geq 0$$

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Where C is the energy output of organic agricultural products (i) on each soil/rain class (j) and X is the activity scalar (crop areas or livestock numbers). A represents the input and resource requirements associated with diverse agricultural activities (x) and b is the resource endowment and input availability vector (e.g. manure-N, land by site class).

Data on typical organic crop yields and crop rotations were obtained from published sources providing technical information to the sector, structured interviews with farmers, recent meta-analyses (e.g. Seufert et al., 2012) and the Defra Farm Business Survey (FBS). Crop yields were adjusted for 16 soil/rainfall classes and 3 nitrogen-fixation rates through an application of the NDICEA model (Nitrogen Dynamics In Crop Rotations in Ecological Agriculture, Van der Burgt et al. 2006). Technical data on typical organic livestock systems were obtained from industry sources, the FBS and recent studies (e.g. Leinonen et al. 2012). A range of scenarios were assessed by adjusting key model parameters. Data from each scenario were compared to a 2010 baseline (Defra, 2011) and to results from the most recent study in this area (Jones and Crane, 2009). Upper limits on the production of individual crops and livestock products were set at 150% of production volumes in the non-organic baseline, under an assumption that further increases could not be absorbed by the market.

Results

The crop production volumes and livestock numbers under each organic scenario are presented in Figures 1 and 2 below, as a percentage of the non-organic baseline.

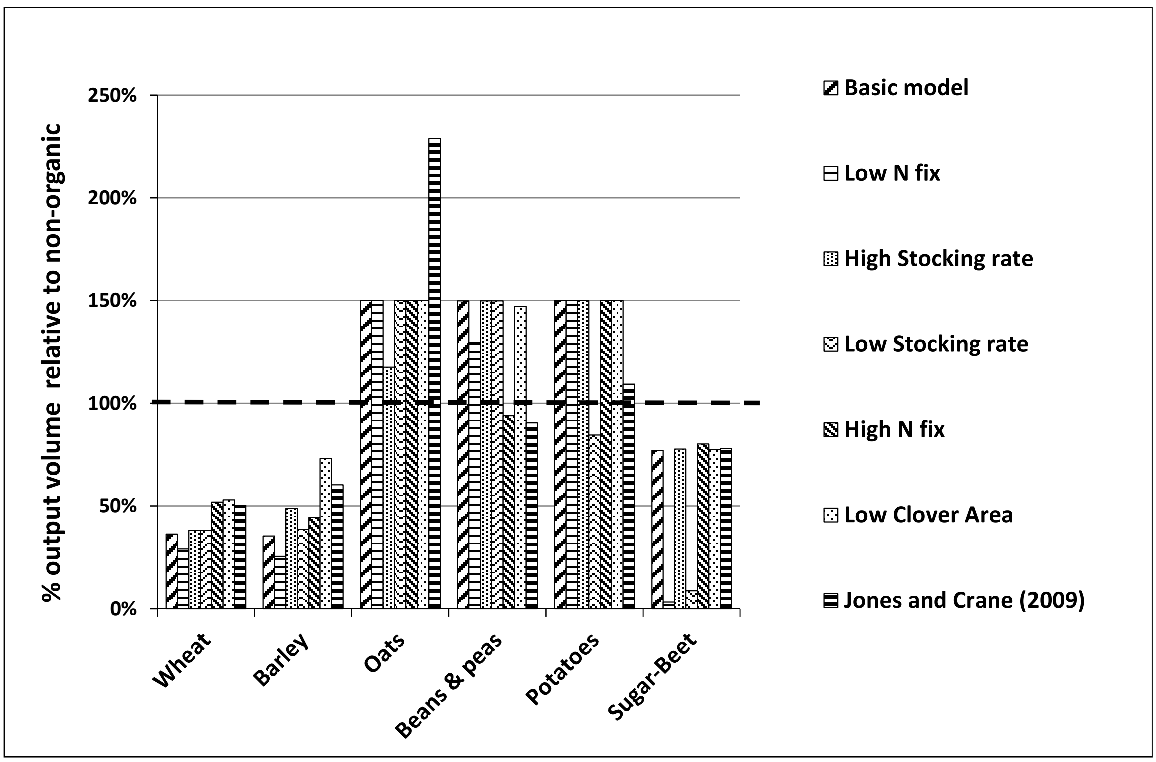

Figure 1. Production of arable crops in England and Wales under organic management scenarios as a percentage of a 2010 non-organic baseline

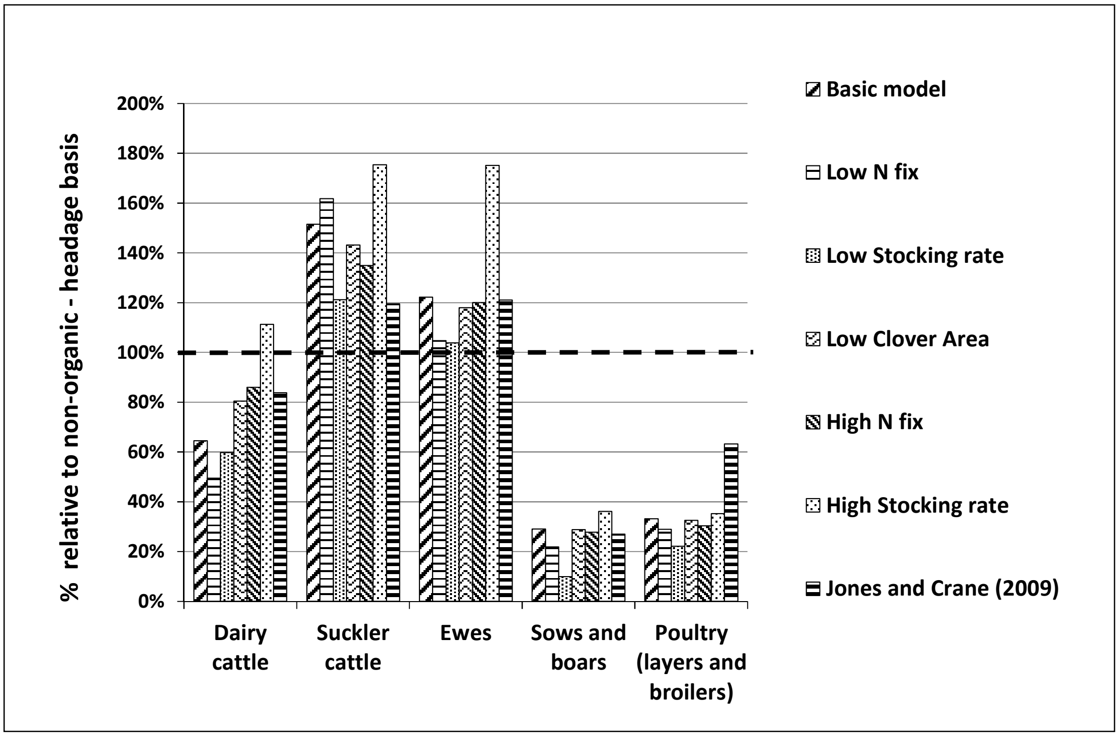

Figure 2. Livestock numbers in England and Wales under organic management scenarios as a percentage of a 2010 non-organic baseline

Despite increases for some crops such as oats and beans, total crop production was considerably lower than the non-organic baseline under all organic scenarios, in particular as a result of lower outputs of wheat, sugar-beet and barley. For livestock, beef and sheep numbers usually increased whereas monogastric livestock fell sharply. Dairy cattle numbers and milk production volumes were approximately three-quarters and two-thirds of the conventional baseline, with the greatest reductions seen in western areas of E & W. The greatest variation across scenarios was seen for the low and high nitrogen fixation rates. Reducing the area of fertility-building ley increased the outputs for cereals and reduced the production of high-N offtake crops (e.g. sugar-beet).

Discussion

The major decrease in crop production volumes under the organic scenarios highlights the importance of optimising the fertility building phase within organic arable systems in order to maintain yields. A switch from long-term leys of >12 months to targeted short-term green manures would help to increase outputs, through increasing land availability, although ensuring adequate nitrogen supply at times of peak-demand is likely to remain a challenge. Models such as NDICEA can help to improve nitrogen use efficiency in organic rotations through highlighting surpluses and deficits of N at key points. Increased use of imported composts (e.g. from household waste) and varietal (instead of species) diversity in rotations could also help to increase outputs.

For most scenarios, the total cereal production volumes were considerably lower than the estimates by Jones and Crane (2009). This illustrates the lower yield obtainable on wetter soils in western parts of the UK, something that could be improved through better cultivation practices and rotation design (e.g. reduced tillage and avoiding ploughing leys in the autumn to reduce leaching). The much lower production of wheat also highlights the importance of focusing organic breeding efforts on this staple crop.

In common with Jones and Crane (2009) an increase in ruminant livestock was found under organic management, with big increases occurring in arable-dominated eastern areas. Although beef and sheep livestock numbers increased the meat output was comparatively close to the non-organic baseline as a result of longer finishing periods. A sharp decline in the production of pigs and poultry was observed due to limits on feed availability, lower stocking rate limits and poorer feed conversion ratios. Developing suitable breeds for organic monogastric systems continues to present a challenge and more research on the efficient use of slower-growing breeds in organic systems would be valuable. Replacing some of the traditional small beef suckler herds on organic arable farms with poultry or pigs would also help to increase outputs for these livestock types, but would increase feed-crop needs.

Overall food-energy outputs fell to between 38% and 66% of the 2010 non-organic baseline, depending on scenario. Even if food waste were to be reduced the switch to organic methods would therefore result in a substantial decrease in domestic food production, requiring an increase in imports. Whether overseas land would be available for such an increase is questionable and a fundamental change in diets and/or farming systems could be required to avoid significant supply shortfalls.

Suggestions to tackle the future challenges of Organic 3.0

Similar rates of production for ruminant livestock highlight the potential benefits from a wider application of organic practices (e.g. clover in grassland to reduce dependence on manufactured N fertiliser) on organic and non-organic farms producing milk, beef or lamb.The much lower outputs for monogastric livestock also highlight a potential need to revisit organic standards in these areas to improve production efficiencies. Improved approaches to nitrogen management could also be explored to assist the development of the sector, with particular regard to rotation design.

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