A framework for assessing crop production from rotations

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ABSTRACT

Organic farming systems rely on the management of biological cycles for the provision of nutrients, which are crucial to maximising the production from the system. Rotations based on the use of grass-legume leys are central to the concept of organic farming systems, because they have the potential to support both animal production, and a subsequent, exploitative, arable cropping phase. A major challenge in organic farming is managing the supply of nitrogen, since it has a key role in governing both productivity and environmental impact. Hence, within a rotational system, there is a need to understand the complex interactions that are occurring between crop species and management, livestock production system and the impact of soil and climate on these processes. To understand these interactions, a framework is being developed for rotational farming systems that describes the soil nitrogen, crop growth and livestock production. The framework must address questions that are relevant to researchers and extensions workers. Typical questions relate to the management of nutrients in the short and long-term. Additionally, there are concerns over the impact of weeds, pests and diseases on productivity, as well as the impact of adopting new strategies or crops on the farming system.

Keywords: organic farming; biophysical models; nutrient flows

INTRODUCTION

Organic farming systems are production systems that rely on the management of biological cycles for the provision of nutrients. Hence, the management of the crop rotations to maximise the natural biological cycles is crucial to maximising the production from the system. Crop rotations based on the use of grass-legume leys are central to the concept of organic farming systems, because they have the potential to support both animal production, during the ley phase, and a subsequent, exploitative, arable cropping phase. One of the major challenges in organic farming is managing the supply of nitrogen, since it has a key role in governing both productivity and environmental impact. Hence, within a rotational system, there is a need to understand the complex interactions that are occurring between the selection and management of crop species, the livestock production system and the impact of soil and climate on these processes. To understand these interactions, a framework is being developed of rotational farming systems, which will link to an economic model to form an Integrated Decision Support

System (IDSS) (Smith *et al.*, 2002). This paper will discuss the broad outline of the framework and highlight the kind of questions relevant to researchers, policymakers and advisors/farmers that it will address.

THE FRAMEWORK STRUCTURE

A schematic diagram of the framework, which will be composed of a linked suite of biophysical models, is shown in Figure 1. The biophysical models will be run on a daily time-step, and will be dynamic and deterministic. They will describe the soil nitrogen processes, including nitrogen fixation by leguminous crops, representative crops typical of those grown in a rotational system, and animal production. The representative crops will include a typical forage, cereal, root and leguminous crop. The livestock types that will be modelled are dairy cows, 18-month beef systems and a lowground sheep system.

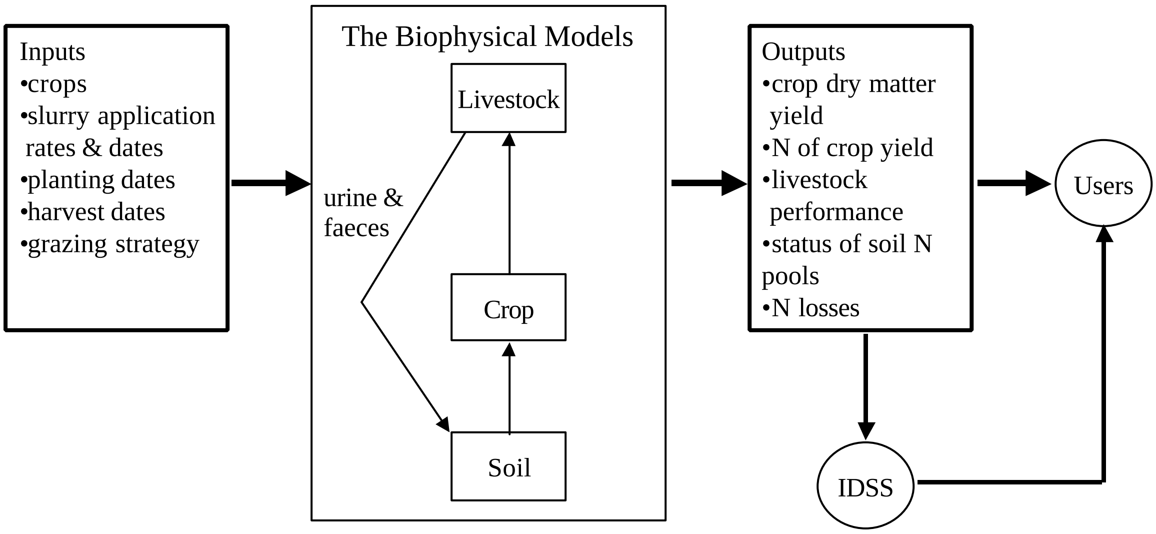

Figure 1. A schematic diagram of the framework

The biophysical soil and crop models to be used will be responsive to the effects of both environmental conditions (e.g. water availability, temperature and soil characteristics) and management practices (e.g. timing and level of organic slurries and manure applications and crop management). Essentially, the soil mineral nitrogen pools receive nitrogen by mineralisation, nitrification, fertilisation and deposition, and lose nitrogen by immobilisation, leaching, denitrification and plant uptake. The main processes and transformations of nitrogen and carbon represented will include decomposition of organic matter, mineralisation, nitrification, denitrification and plant uptake of nitrogen, which are modified by the soil temperature and water status. The model of nitrogen fixation (Doyle & Topp, 2001) assumes that fixation can be related to the above-ground legume mass, and that the rate of fixation is influenced by the soil mineral content, the soil water content and the soil temperature. In addition, it is assumed that the total nitrogen fixed by the legume exceeds the amount harvested, by the amount of fixed nitrogen embodied in the plant roots and stubble, transferred to the non-leguminous companion species and immobilised in the soil.

The crop models are physiologically based, and the processes of photosynthesis, respiration, translocation of resources and senescence are described. Crop production is calculated on a daily basis, and is presumed to be dependent on crop mass, air temperature, radiation, rainfall and atmospheric carbon dioxide concentration. The available soil water and nitrogen, which are outputs of the soil model, also affect the growth of the crop. The model describes the flows of carbon and nitrogen through the system, and hence the carbon and nitrogen concentrations of the leaf, stem and root structural material, and the shoot and root substrate pools. In the case of the grass-clover model, the grass and clover components are separately distinguished, and the sward will either be rotationally grazed or set-stocked by the dairy, beef or sheep systems.

The inputs to and the outputs from the model must be relevant to the farmer and relate to management practices. Hence, the inputs to the model are the fertiliser and slurry application rates and dates, the planting and harvesting dates, and grazing strategies that have been adopted by the farmer. In addition, the liveweight of the livestock and the date of parturition for the grazing dairy cows and sheep are required inputs to the model. As well as the management practices information describing the daily weather at the site is also required. The typical outputs include the harvested and residual dry-matter yields, the carbon to nitrogen ratio of the yields and the status of the soil nitrogen pools. The outputs from the livestock models include the yield of milk and meat. Hence, the model will allow the exploration of a range of management options. The inputs and the corresponding outputs will be used within the IDSS (Smith *et al.*, 2002).

QUESTION TO BE ADDRESSED

The potential end users for the framework are researchers, policy-makers, consultants and farmers. Each of these groups will be addressing the issue of organic farming from differing viewpoints, and the identification of the types of questions these different groups wish to address must be recognised in the design of the framework. Hence, using discussion groups with extension experts and organic farming researchers at SAC, some of the issues that this kind of framework should address have been identified.

The types of questions that researchers and extension workers would like the framework to address cover several broad categories. These include (i) the management of the crop at the field level; (ii) how does the management of the crop impact on the rotation and the farming system in the current year and over a longer time period; (iii) how does the management of the system impact on the environmental losses both at a field scale and a regional scale. Hence, the types of specific questions they see a need to address include:

- How do the crops grown within the rotation impact on the yield from crops grown in the subsequent periods?
- How does the performance of different management practices impact on the performance of the crops, and do they differ between localities?
- How does the environmental impact differ if the slurry is spread over a proportion of the farm instead of the whole farm?

- How do weeds, pests and diseases impact on the production?
- How does cultivation impact on the productivity of the farm?

DISCUSSION AND CONCLUSIONS

The framework that is being developed is based on biological principles, and hence the model will be applicable to a wide range of sites. Topp & Doyle (2002) have demonstrated the validity of this type of model for across Northern Europe for pure legume and grass-legume swards. The framework is being developed to address questions at the farm systems level as opposed to the regional level. At this stage of development, the impact of some issues, which are relevant to researchers and extension workers will not be addressed. These include pests and diseases, and although the impact of weeds will be included in the cereal model as part of an EU funded project (WECOF), the impact of weeds will not be incorporated into the overall biological framework. Nevertheless, the biophysical framework will be able to address a wide range of agronomic issues and because the framework links to a economic model, policy driven issues will be addressed within the IDSS (Smith *et al*., 2002).

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