The development of an integrated modelling system to support decisions on organic farms

C Julian N Smith, David Oglethorpe
Natural Resource Economics Dept., Scottish Agricultural College, West Mains Road, Edinburgh EH9 3JG, UK

J Wright
Institute of Ecology & Resource Management, University of Edinburgh, West Mains Road, Edinburgh EH9 3JG, UK

ABSTRACT

An Integrated Decision Support System (IDSS) is developed which synthesises current understanding of organic farming by means of a multiple objective framework incorporating GIS, biophysical models and socio-economic models of the farming goals. The IDSS uses a multi-tiered concept of a farming system as a collection of micro-enterprises at the field level, with individual resource endowments, objectives and activities. Farm-level decision drivers trickle down to affect the micro-level field enterprise selection. Biophysical models describe typical forage, cereal, root and legume output and a user-friendly interfaces permits easy access and output display via a GIS. A prototype of the IDSS framework, being developed as a part of the SAC organic research programme is presented.

Keywords: integrated modelling; GIS; socio-economics; farming systems; organic farming

INTRODUCTION

Organic food is fast becoming the most lucrative market in the UK (Which?, 2001). All major food retailers are increasing their range of organic products at an unprecedented rate. This demand is not currently being met by domestic production and around 70% of all organic products consumed in the UK are imported. However, the number of farmers seeking organic accreditation is increasing. In the European Union, organic farming continues to grow annually at an average of 25%, with more than 93,000 farms and 2.2 million hectares either certified as organic or in the conversion process (Lampkin & Measures, 1999). To aid this conversion process, there is a need to assist conventional farms who wish to convert to organic production, as well as the organic farms that are already operating, through decision-support.

The development of rational answers to decision making problems requires accurate information (Sharifi & Van Keulen, 1994). The issue of what motivates people to adopt organic techniques must be carefully considered. While many adopting organic practices are doing so for ethical reasons, price premiums for organic goods cannot be ignored (Rigby & Caceres, 2001). Farming places multiple and often conflicting demands upon natural resource use. In order to resolve these competing demands it is important that the decision maker has a variety of tools at his disposal (Sharifi & Van Keulen, 1994). To develop these tools, we need not only a clear understanding of the biophysical system but also how these link to the market (Sharifi & Van Keulen, 1994).

Key questions have been developed through focus groups with extension experts and organic farming researchers at SAC regarding: the optimal level of organic conversion support payments; the sustainability of organic systems in terms of accepted indicators; whether organic farming will remain a viable option after conversion support has finished; and, how organic rotations are designed to best optimise the nutrient building phase. Thus, target users are not only organic farmers themselves, but also policy-makers and those non-organic farmers considering conversion.

Farm modelling can support such decisions by providing an effective complement to research work (ten Berge *et al.*, 2000). This is because only a few selected farm prototypes can be tested experimentally in the field and models allow better specification of the trade-off between different objectives and goals. Also, commercial farms are not suitable test sites for evaluating risky new ideas and techniques and external conditions may change rapidly and can have profound impacts on the feasibility of field trials. Experimental prototypes are developed in a particular physical environment – the models can be used to extrapolate across space and time.

There are many examples of component models covering soil nutrient flows, biophysical growth of crops, and weed-crop interactions. These models predict how the system might react in the future. However, such knowledge is not always helpful in answering problems related to the rational allocation of scarce resources. To do this, resources need to be optimised across the whole planning horizon. It can be seen that optimisation techniques provide a very powerful tool for dealing with these problems across multiple time periods (Gupta *et al.*, 2000). With organic farming, such long-term planning is paramount. For example, the application of manure in one season may have positive benefits to the crops in future seasons and it may impact on the environment. Integrated models can provide support for this dynamic planning horizon.

PROTOTYPE MODEL

A case study farm was selected to calibrate a representative farm model. The farm is a mixed lowland arable unit producing cereals, roots and vegetables, beef and sheep, and one of several research sites currently being studied by SAC through their Organic Farming Centre. Input data for the model is derived from three sources: a GIS database, farm management records, and farm management handbooks [Lampkin and Measures, 1999; Chadwick, 1998] and other organic farming literature.

The model is mathematical in formulation, using a Linear Programming (LP) basis. The LP model was constructed to analyse the enterprise mix of the case study farm within the context of the whole farm system and prevailing constraints. The model has a profit maximising objective set within the constraints of the need for a crop rotation, which is modelled on the rotation used in the farm data. Livestock enterprises are incorporated, capturing the necessity of livestock in the recycling of nutrients. There are two types of activities in the model: those that take place at farm level (e.g. the hiring of labour) and those that take place at sub-farm level (e.g. cultivation). For the purposes of the prototype, sub-farm units consist of 3 blocks of fields, each having similar soil characteristics and historical land use records. Thus, it is the sub-farm level activities that use data from the GIS as inputs. Input data for farm-level activities are derived from sources such as farm management records and farm handbook figures for prices of agricultural produce.

The LP model is linked to a GIS which has two key roles: it is used to manage and integrate all of the geo-referenced information relating to the farm; and, it is used to visualise the output from the LP model.

Model Results

Tables 1 shows LP model output with and without variable quality arable land, against observed data. In the first case, the farm was simply divided into permanent pasture and arable land; in the second case, permanent pasture was retained and arable land was further divided into high and low yielding areas. Introducing variable quality arable land into the model had little impact on overall farm profitability and both model scenarios suggested that the optimal stocking of sheep is somewhat greater than current levels on the farm and the optimal number of cattle lower.

Table 1: Farm-level LP model output compared to actual case study farm records

Farm Information	Actual farm data	Without variable quality arable land (2 land classes)	With variable quality arable land (3 land classes)
Farm Size (ha)	57	57	57
Margin (£/farm ha)	753	632	624.2
Sheep (head/farm ha)	3.51	5.23	5.19
Cattle (head/farm ha)	0.79	0.10	0.10
Hired labour (hours/ farm ha)	Not known (labour not accounted for)	20.3	19.77

DEVELOPING AN INTEGRATED MODELLING SYSTEMS FRAMEWORK

This simple case study indicates three potential areas of difficulty in constructing a Linear Programming-GIS (LP-GIS) decision support tool for organic farming: technical feasibility, data availability, and current scientific understanding of organic techniques. Technical feasibility is not regarded as a major problem since organic farmers and advisors can easily acquire low-cost LP-GIS software. The availability of Geo-spatial and other data is limited by absence of detailed soils data but field boundaries are available for all farms in Scotland through the Field Information System and, when combined with Land-Line data depicting drainage, boundaries, building, roads, and other infrastructure, we can improve cartographic display. Finally, current scientific understanding of system linkages in organic farming is quite restricted since crop-soil interactions on organic farms are poorly understood at present. However, Shafari & Van Keulen (1994) were able to model the impact of climate and soil on yields within their GIS-LP for conventional farm enterprises and carry out some limited validation of predicted yields. However, in an organic farming context, far fewer studies of soil-yield relationships are available.

CONCLUSIONS

Many enhancements would need to be made to the prototype model presented here before it could be deployed as a decision support tool. In a fully functional model, a temporal dimension would also need to be introduced into the LP to represent all 6 years in the rotation cycle. Much could also be gained by explicitly modelling soil nutrients. In addition, the modelling of farmyard manure and lime application could be undertaken at field level, rather than farm level as in the present model. Further, a collection of constraints to test sustainability could be introduced. These could be based on an accepted set of sustainability indicators, measurable at the field level. For each indicator, aspiration levels can be set which drive the farm towards 'sustainability'.

However, if properly constructed, a temporal and spatial modelling system such as discussed here will help support decisions throughout the organic conversion process, allowing alternative decision paths to be simulated for more effective and viable operations.

ACKNOWLEDGEMENTS

Funding for the organic farming project is from the Scottish Executive Environment and Rural Affairs Department (SEERAD).

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From: Powell et al. (eds), ***UK Organic Research 2002: Proceedings of the COR Conference, 26-28th March 2002, Aberystwyth*****, pp. 161-164.**