Modelling crop rotations for organic farms

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Introduction

Within the last few years, public interest in organic farming practices and products has been continually growing in response to increased environmental and health problems (e.g. BSE) linked to conventional farming methods. This level of awareness plays a significant role in the formulation of future agricultural policy (AGENDA 2000). Nevertheless, knowledge concerning optimal organic farming practices and their impacts on the environment is lacking. To support development and expansion of organic farming, research should focus on the optimisation of individual farm practices as well as assessments of the ecological effects of organic farming on a regional scale. Both issues rely on information obtained from modelling cropping methods and crop rotations. Sustainable organic crop rotations depend strongly on the management of (1) nitrogen budgets and fluxes within fields and farms, (2) weed control, (3) pest control through cropping methods and (4) farm fodder production. The aim of this approach was the development of a rule-based model for the identification of economically and ecologically optimal crop rotations as function of a variety of natural and socio-economic conditions. The developed modules are part of a linear programming farm optimisation model. Furthermore, a stand-alone crop rotation planning tool is also being developed.

Methods

The model development is based on a relational database consisting of extensive descriptions of so-called "standard cropping methods". These describe in detail all the practical, alternative cultivation techniques for various crops within a database, the corresponding periods of activity, machinery use and in/outputs are specified in different tables. The levels of inputs and outputs are site-specific and based on estimations for north-eastern Germany. Each crop may be produced by a variety of methods based on the following descriptors of the specific practice: preceding crop category, ploughing, stubble crop sowing, undersowing, manuring , cultural root-stock weed control (Tillage after harvest: 1 x cultivator, 2 x disk harrow, 1 x share plough with jointers) and harvesting of by-products. A number of estimation modules analyse these cropping methods with respect to the nitrogen balance, the risk of root-stock weedage, rotational restrictions and environmental effects. Additionally, the yield estimation module takes into account the preceding crop category and manuring.

Crop rotations are combined by the model as a sequence of standard cropping methods in the context of the following restrictions: (1) crop category of each preceding crop has to match the demand of each main crop

(2)..period of first cropping activity must occur after the last activity of the preceding crop

(3)..calculated total nitrogen balance of the crop rotation must be slightly positive

(4)..risk of root-stock weedage has to be under a reasonable threshold

(5)..phytosanitary restrictions for all crops must be fulfilled

With the help of these rule-based modules, a farm model has been constructed which generates an economic optimal combination of different crops and cropping methods for sustainable crop rotations. Crop rotations can be calculated for different soil qualities with consideration of total farm restrictions like fodder production, utilisation of the produced farmyard manure, availability of labour and so on.

The stand-alone crop rotation planning tool generates a large variety of valid crop rotations which can be prioritised according to the total gross margin of individual cropping methods. Both applications can be completed with abiotic and biotic indicators for ecological evaluation of all cropping methods included in the database.

Results and discussion

With the described holistic model approach it is possible to generate agronomically-suitable and detailed 3-8 year crop rotations for diluvial sites in north-eastern Germany under the special demands of organic farming systems with and without livestock production. The stand-alone version can be used for crop rotation planning at the farm level. In addition, this model version may be applied for studying the influence of the parameter and estimation algorithm ranges within the model on the complex interactions between site condition, cropping methods and the rotational cropping systems. Sensitivity analyses show those model parameters and estimation algorithms which have to be managed with special care and those for which further research is needed.

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