Development of an Environmental Management System for Organic Farms and its Introduction into Practice

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Abstract

Increasing demands for documentation of farm activities as well as environment and quality assurance call for environment adapted management systems, also in organic farming. The model software REPRO is a tool for farm management and consultation. It is distinguished by a systemic depiction of farming systems and can be used in agricultural practice. The access to farm related data and site information is the basis for statements about matter cycles (C, N, P, K), humus budget, energy efficiency, erosion, soil structure and harmful soil compaction. Its application in rather differently structured farms under organic management discloses distinctly the relationships between the design of farming systems and their environmental effects. The possibility of scenario calculations allows the validation of optimisation strategies.

Introduction

Agricultural enterprises in the Federal Republic of Germany and the EU are confronted with increasing demands for documentation of environmental and quality assurance. This involves also farms under organic management. Researchers are challenged to develop suitable tools in cooperation with farmers and consulting services. The available methods and model software are preferably targeted at conventional farming and take only insufficient account of the conditions in organic farming. Therefore, their applicability is limited, and in single cases misinterpretations may occur.

This paper attempts

- to describe a system for environmental management which is suitable for organic farming (model structure and elements, scientific fundamentals) and to elucidate its special features vis-à-vis other programs,
- to identify relationships between the design of farming systems and environmental effects on the example of program results,
- to show fields for using the management system in practice,
- to outline the further development of the tool.

Methodology

Efforts towards the definition of environmental indicators and their integration into software tools are being made all over the world (e.g. Bockstaller et al. 1997, Lewis & Bardon 1998, Sands & Podmore 2000). Recent approaches differ in considered system level (cropping, livestock keeping, farm level, landscape), fields of application (administration, marketing, optimization), the degree of complexity, choice of indicators, analytical methods, definition of limits and the aggregation of indicators.

The model software REPRO (**Repro**duction of Soil Fertility, Hülsbergen 2003) considers the farm enterprise as a system. Indicators are not considered as isolated criteria but in their mutual relationship. The program approach allows for scenario calculations. On the basis of mass and energy fluxes, interactions between subsystems are examined (crop and animal production, arable land and grassland...). The software respects the complex character of farming systems. Great importance has been attributed to the consideration of actual farms in their complexity rather than on an exact covering of all details. This objective requires to survey natural site conditions, farm structure and design of production processes with just adequate accuracy – thus a „virtual farm“ is generated.

The REPRO program has a modular design and includes:

- databases for handling site and management information,
- balancing methods for disclosing mass and energy fluxes on farm level,
- links to simulation models (simulation of soil processes),
- interfaces to geographic information systems,
- evaluation tools (indicators, normalization and spin diagram techniques).

By use of DELPHI Professional, a PC version for WINDOWS 95/98/2000/NT/XP has been generated. The modular structure of REPRO allows its adaptation and extension to different target areas. Among others, the following agro-environmental sectors can now be analyzed: mass cycles (C, N, P, K) in the system soil – plant – animal – soil (Hülsbergen 2003), energy efficiency (Hülsbergen et al. 2001, 2002), humus budget (Leithold et al. 1997), erosion, soil structure/hazardous soil compaction. The basic data for the model were collected in long-term field experiments (Hülsbergen & Biermann 1997). The model has been validated both in field experiments and experimental farms (Hülsbergen & Diepenbrock 2001).

On the example of the Experimental Farm Scheyern located in the Tertiary Hills of Southern Germany (490 m a.s.l., mean annual temperature: 7.5 °C, mean annual precipitation: 833 mm; see Auerswald et al. 2000) it is demonstrated what results the model program can provide for N cycle and N management in farms. The N fluxes are closely related to the C fluxes, as has been described in the paper by Küstermann & Hülsbergen (2005). In order to bring the results of the investigations in Scheyern into the right context, a farm comparison is made on the basis of agro-environmental indicators.

Results and brief discussion

The structure of the farm in Scheyern (legume-based crop rotation: grass-clover mix – potatoes – winter wheat – sunflower – grass-clover mix – winter wheat – winter rye; catch crops on > 40 % of the arable land; stocking density: 1.4 LU ha^{-1}) and the high intensity and production level (dry matter yield: 7 to 8 t ha^{-1} a^{-1}) are reflected in an intensive N cycle (Fig. 1). Remarkable is the high N input with feedstuffs. They were produced on neighbouring fields under organic management. There is no purchase of conventional feed. With regard to the measured omissions (16 kg N ha^{-1} a^{-1}) and the recorded changes in soil-borne N owing to humus accumulation, the N surplus (= total of all N inputs into the soil and N removal by plants) amounts to 31 kg ha^{-1} a^{-1}.

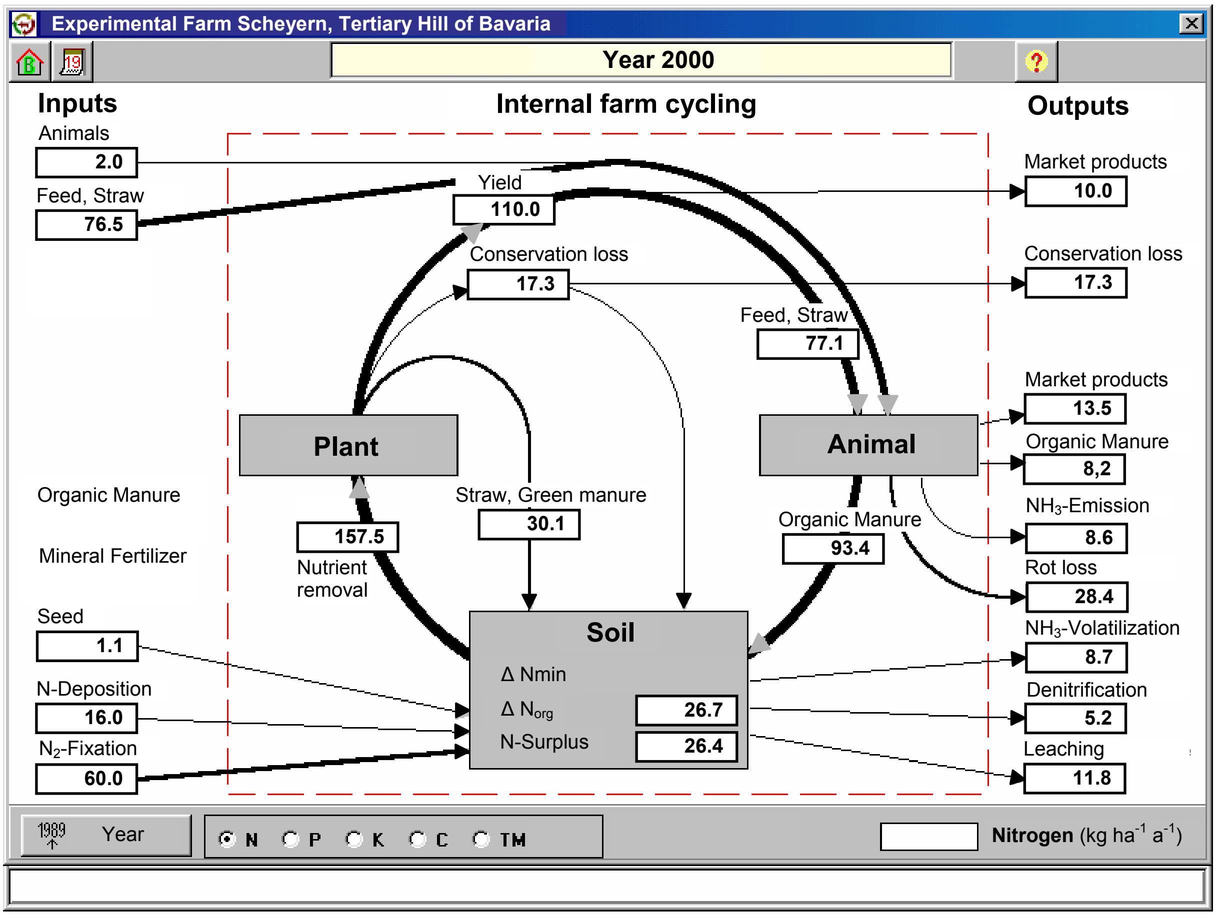

Fig. 1: REPRO screen shot: N cycle in the Experimental Farm Scheyern

This soil related N surplus characterizes the overall loss potential of reactive N compounds. The model allows to show the different loss paths. Nitrogen leaching reach 4 to 20 kg N ha^{-1} a^{-1}, which corresponds to potential nitrate concentrations of 6 to 40 mg NO_3^- l^{-1} below the root zone in case of annual percolation of up to 470 mm a^{-1}. The N losses entered into the model calculations dependent of local conditions corresponded well with the measured values (Matthes et al. 2001). The N accumulation in humus estimated by use of the model program has been confirmed in long-term samplings on a large number of grid points (Gutser & Reents 2001). The program approach allows to disclose, beside the described farm specific N cycles, also the spatial variability, for example subfield related N loss potentials. REPRO allows various partial aspects of the N budget to be integrated into an overall assessment. Scenario calculations make it possible to quantify the effect of modified farm structures and cropping technologies and to optimize farming systems.

In the Federal Republic of Germany, the model software has been used under differentiated site conditions in more than 200 agricultural enterprises of different structure, management intensity and design of production processes. Thus, a data pool has been generated that can be used also for inter-farm comparisons (Fig. 2).

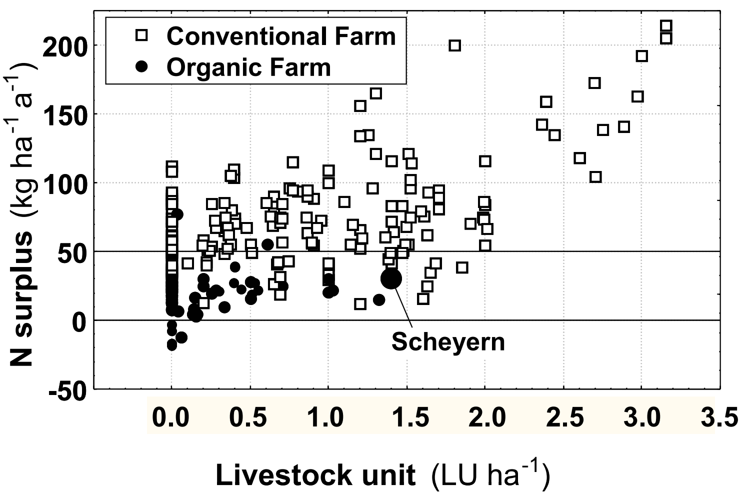

Fig. 2: Relationship between livestock unit and N surplus, n = 233 farms

In general, it can be estimated that in organic farming N losses are lower than in conventional systems. Farm-specific differences, however, may be considerable (see Fig. 2). The results obtained in the Experimental Farm Scheyern demonstrate that in organic farming the N surplus can be clearly limited to < 50 kg N ha^{-1} a^{-1}, even under intensive management and high livestock density (1.4 LSU ha^{-1} = admitted maximum acc. to the guidelines for growers associations). This requires optimal N management in a multicrop rotation with comprehensive catch crop growing.

Conclusion

REPRO represents a practice-oriented software program for analyzing, rating and optimizing farming systems and their environmental impact. The optimization of farming systems places high demands on software designers due to numerous interrelationships between technological and biological processes.

Since it is nearly impossible to assess the environmental effects of all agricultural activities, the approach used by REPRO emanates from the simplistic assumption that all environmental effects and ecological sustainability are dominated by the mass and energy regime as well as by the factors working on it (mainly site conditions, farm structure, input of operating resources and process design). Farm internal matter cycles play a key role in the functioning of agro-ecosystems (Edwards et al. 1993).

The model software has not only been used in scientific research but increasingly also in practical farming and consulting, so far preferably in ecologically sensitive areas (drinking water catchment zones, biosphere reserves). It is intended to closer adapt the program to the needs of practical farmers and to reduce the time for the software handling without impairing the results. Evaluations in graphic form as integrated into the software (for example the N cycle, Fig. 1) support the applicability of the software in farm consulting.

Currently it is checked whether the farm-related environmental management system REPRO can be coupled with product-related systems of quality management, because most agricultural processes are both environment and quality-related and require nearly identical management and process information. In the development stage are the modules “Nature Protection/Biodiversity” and “Emission Inventory” (see Küstermann & Hülsbergen 2005).

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