CROP GROWTH AND YIELD MODELING

ACROSS DIFFERENT SCALES

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Models are powerful tools for investigating the effects of different land use options and/or climate changes on crop growth and water and matter cycles as well as for bridging the gap between different temporal and spatial scales; they are urgently needed to support ecological and economic conflict solutions.

Crop growth modeling and crop yield estimation methods for arable and grassland farming at different spatial scales are very effective instruments for providing solutions to scientific, practical or impact assessment-oriented biomass and crop yield questions. The most popular utilization for both model developers and practitioners would be to have highly resilient and robust universal crop growth models applicable to different questions and spatial scales that are controlled by a defined and widely available set of parameters, and based on available model inputs. However, experiences show that such a solution is hardly ever or never achieved in practice. The reality of crop growth modeling is that there is a close interaction between model type, spatial scale and input data availability.

Crop growth models and crop yield models require meteorological values (D_j, $j = 1, 2, ... n_j$); management values (M_k, $k = 1, 2,...n_k$); site values (S_l, $l = 1, 2, ... n_l$) and parameters (P_m, $m = 1, 2,... n_m$). The model states (X_i, $i = 1,2,...n_i$) of crop growth and crop yield models are calculated on the basis of dynamic or static model approaches. The model states are described by

$$X_i = f\,[D_j(t), M_k(t), S_l, P_m].$$

At plot level where all site conditions are well known, a detailed plant physiologic process-based crop growth or agro-ecosystem model describing all important processes can certainly be expected to produce more satisfying scientific answers than similar simple crop growth approaches.

With increasing areas (from plot to region) considered, an obvious conflict appears between spatial heterogeneity of the area, the heterogeneity in plant reaction patterns (local environmental conditions), the considered process details, and the input and parameter availability and uncertainty. The selection of an appropriate approach for the context depends on the modeling goal as well as realistic input and parameter demands so that accurate and resilient results can be achieved.

This paper exemplarily for agro-ecosystem models focuses on the AGROSIM models developed in the Institute of Landscape Systems Analysis of the Leibniz-Centre for Agricultural Landscape Research (ZALF) Müncheberg, Germany, and demonstrates the effectiveness of plant physiologic process-based crop growth approaches developed and parameterized for specific locations relating to their applicability to other European sites (including different sites in Russia) and to larger regions. Additionally, a generic crop growth model approach for use at agro-landscape level, including a yield estimation model, will be presented.

As with ecological and environmental modeling, in crop growth modeling, there is not one single approach that can be applied to all spatial scales to address model crop biomass or crop yield. The spatial heterogeneity, the natural variability and the limited availability of data underline this hypothesis. Therefore it is unwise to search for an optimum modeling approach that can be used across all scales. Instead, it is advisable to find the best suitable modeling approach according to the scale of the project.

Determining the influence of spatial scale data on the selection of the modeling methods, however, is more difficult and warrants additional research in the future. The choice of modeling approach should be based on the problem being tackled and should be dependent on the spatial scale for which crop growth modeling is realized. It is better not to recycle an existing model, but to clearly express the model demands around the task in hand and to develop a modeling approach that is appropriate for the spatial scale of interest.

If the accuracy of the description of the final biomass accumulation or yield at harvest is the only criterion for choosing a certain approach, simple tried and tested models can be used.

In cases where diversity in the data for model development is significant and the relationships between variables are only vaguely understood, artificial neural network models are a suitable approach for finding appropriate nonlinear model structures for crop growth processes.

The advantages of complex plant physiological-based algorithmic models do not lie in more accurate forecasts, but in their ability to evaluate processes and interactions between different system parts more effectively and to express side effects.

If it is possible to regionalize model driving forces, inputs and parameters with a reasonable effort and to restrict model modifications to a minimum, for the most important agricultural crops it is possible to use originally field-related, physiologically based models as AGROSIM, MONICA or AGROTOOL also for practically oriented applications on higher spatial scales, but these are not appropriate for the landscape scale.

Because of the wide range of different arable crops and grassland types, limited data sources and the absence of specific management and cultivar information from agro-landscapes, on this scale, generic crop growth models are more successful options for biomass and yield modeling.

Nevertheless, in the science of crop growth modeling, various problems remain unsolved and others have only been partially resolved. Three examples of these problems are (1) the degree of generalization depending on spatial scale; (2) the long-term reliability of certain model approaches; and (3) the robustness of using models for large-scale projects, i.e. whole landscapes.

The special challenge in crop growth modeling, i.e. modeling biomass growth and yield formation, is to find a balance between the modeling goal, input data availability (quantity and quality), spatial scale, and the model’s approach for obtaining resilient and robust results.