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Editorial

Advances in Modelling Cropping Systems to Improve Yield and Quality

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Additional food and bio-products are expected to be required to feed the growing world population under the changing climate. It is therefore increasingly important to maintain the sustainability of cropping systems, and to improve crop yield and quality with efficient resource use. Cropping systems consist of numerous complex and interacting biological processes, which can be influenced by human management. The quantification of these complex processes helps to increase our understanding of crop development and growth, and facilitates the design of new management strategies aimed at high yield and quality. Crop models are based on existing insights into the underlying chemistry, physics, physiology, and ecology of cropping systems. Information on weather, soil, and management practices is combined and processed to predict crop performance. Crop models increase insight into relevant processes, allow the study of the effects of crop management, and enable the exploration of possible consequences of management modifications. Modeling tools have been used in variety of areas, ranging in scale from functional genomics to regional natural resource management.

Recent studies showed that the existing crop models have variable success in simulating crop performance. It is necessary to upgrade crop models with newly developed knowledge to precisely project crop performances and explore mitigations under warming climate changes. The independent field experiment data are required to probe new principles of crop growth and to create confidence in modeling as an effective tool, because existing models have to be evaluated based on crop genetic characteristics and location-specific conditions before they can be successfully applied.

This Special Issue, entitled "Advances in Modeling Cropping System to Improve Yield and Quality", consists of ten papers on field experiments, model developments and improvements, and model applications confronting the emerging challenges in the crop production industry. These papers include a review paper on the modeling approach linking the genotype to the phenotype, two papers on crop performances under designed management practices, two papers on model developments and improvements, three papers on model applications to improve crop yield and resource use efficiency, and two papers developing new methods and models to predict crop production.

Since the pioneering work on plant modeling by C.T. de Wit [1] in the 1950s, crop models have been extensively developed and applied for different scales. For the micro scale of modeling, quantitative trait loci (QTL) information was incorporated into crop models to analyze genotype-by-environment interactions [2]. In the review paper in this Special Issue, Gu [3] introduced details on the development and applications of QTL-based modeling, outlining a genotype-to-phenotype approach that exploits the potential values of quantitative methods. Associated with crop modeling, the effects of QTL, typically at the single-organ level over a short time scale, were projected for their impact on crop growth during the whole growing season in the field. This quantitative approach can provide more markers for selection programmes in specific environments while also allowing for prioritization.

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The observations of field experiments are a basic requirement to provide knowledge of crop development and growth for developing and evaluating crop models. In most crop models, the emergence date is governed by temperature and soil moisture, and the impact of nitrogen (N) supply is usually ignored. In this Special Issue, Szabó et al. [4] reported an experiment on the emergence of maize hybrids in different age groups grown in a long-term experimental field under rainfed conditions. They observed the day of emergence, grain moisture, protein, oil, starch, and yields of the maize hybrids. They concluded that nitrogen fertilizer had a significant effect on the day of emergence by improving nutrient conditions for the germination of maize, which may be both considered by farmers and used by model developers for model improvement. It is another important topic for models to simulate crop rotations in a long-term pattern. To evaluate the models simulating crop rotations, collecting observed data from long-term experiments usually consumes much time and labor. Yuan et al. [5] conducted a long-term field experiment to investigate the effects of crop rotation and biochar-based fertilizer application on the crop yield, soil attribute, crop quality, and agronomic traits in 2014–2020. Their results show that the diversified corn and soybean rotations had a significant positive effect on average crop yield compared with their monocultures. A significant positive effect of biochar-based fertilization was observed for any crop in terms of both protein and oil content.

Crop producers usually use insecticides to protect crops from insects in order to achieve high yields; however, the impact of insects is considered in few current crop models. Crops are assumed to grow under no biotic stress in most crop models. To simulate the impact of insects and applying insecticide on crop production, Sulaiman et al. [6] provided a discretized system of a continuous dynamical model for enhancing crop production in the presence of insecticides and insects. The model was based on agricultural crop production with variable density of insect population, insecticide concentration, and some external efforts, which were given by a system of nonlinear differential equations. They used the Levenberg–Marquardt algorithm (LMA) based on artificial neural networks (NNs) to investigate the approximate solutions for different insecticide spraying rates. This study showed the feasibility of including the impact of insects on crop growth in most crop models in the future. Besides mimicking crop growth, improving the harvest method at maturity may yield additional benefits. With the innovation of technology, automatic harvest has become favorable for producers. To improve the accuracy of discrete element simulation parameters for the mechanized harvest of pears, Fan et al. [7] improved the simulation parameters of pear harvests by comparing physical experiments and simulations. Their study provided a basis for the design and parameter optimization of pear-harvesting machinery.

Three papers in this Special Issue highlighted the crop model as an important tool in designing management strategies to obtain high N use efficiency and crop yield. It was reported that an excessive nitrogen (N) application rate led to low N use efficiency and environmental risks in a potato production system in northwest China. Jiang et al. [8] applied two models, DNDC and WHCNS_Veg, to optimize management practices for improving potato yield and N use efficiency, after these two models were evaluated using measured tuber yield, above-ground biomass, N uptake, and soil inorganic N from a multiple-year field experiment in northwest China in 2017–2020. They concluded that the greatest tuber yield and N use efficiency were achieved at a N rate of 150–180 kg ha^{-1} with 2–3 splits, a fertilization depth of 15–25 cm, and a planting date of 25 April to 10 May. In the second published paper, Khan et al. [9] used the CSM-CERES-Wheat model to determine the influence of N fertilizer rates with different timings of application on wheat yield traits, i.e., tiller number, grain number, grain weight, grain yield, biomass, and grain N content. The simulation scenarios suggest that the application of 140 kg N ha^{-1} with triple-split timings, i.e., 25% at the sowing stage, 50% at the tillering stage, and 25% at the booting stage, resulted in the maximum yield and N recovery. Simulated N losses were determined by leaching for experimental conditions where a single N application of 100% or existing double-split timing was applied. Reducing the nitrate N ($NO3^{-}$-N) leaching is another important target to increase N use efficiency in a cropping system. Farmaha et al. [10]

linked SWAP (a water balance model) with ANIMO (a nitrate leaching model) and the Geographical Information System (GIS) to assess the spatial and temporal leaching of $NO3^-$-N from fields of a rice–wheat cropping system in the riparian wetlands in north-western India. The results reveal that $NO3^-$-N concentration in the groundwater exceeded the 10 mg $NO3^-$-N L^{-1} limit for drinking water only during December–January, and the SWAP–ANIMO model satisfactorily predicted $NO3^-$-N concentrations in the leachate in the vadose zone. Their study showed again that the modeling approach was satisfactory for an efficient quantitative assessment of $NO3^-$-N pollution in groundwater while accounting for the spatial and temporal variability.

Predicting crop growth and yield is an important issue for producers, stakeholders, and the global trade market. Mathematical models such as machine learning tools can be an addition to crop models in the prediction of crop yields. In this Special Issue, Rajković et al. [11] compared two machine learning tools, Artificial Neural Networks (ANNs) and Random Forest Regression (RFR), using them to unambiguously predict crop seed yield, oil, and protein content. The RFR model showed better prediction capabilities compared with the ANN model. Furthermore, monitoring crop leaf N content might help to adjust crop management to improve crop yield. Along these lines, Zhao et al. [12] elucidated the color changes in rice leaves after anthesis and created an algorithm for monitoring the N content of rice leaves, aiming to provide a theoretical basis for the precise management of rice nitrogen fertilizer and the development of digital image nutrition monitoring equipment. They measured rice leaf R, G, and B values, and analyzed the correlations between RGB-normalized values and leaf SPAD values. They concluded that it was accurate and efficient to use a scanner to obtain the RGB color index for deducing the N content of rice.

Conflicts of Interest: The author declares no conflict of interest.

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