**Applications and Uses of Crop Growth Models in Agricultural Sciences**

Crop models have long been powerful tools in unraveling physiological mechanisms that determine crop yield in relation to the environment. For example, nitrogen management was a key limiting factor for high-yielding rice varieties, using a model that explained yield differences reasonably well in terms of radiation, temperature, leaf N content and variety phenology types.

In the context of a global need to improve productivity, yield gap analysis is critical to identify the most important crop, soil and management factors; to effectively prioritize research and interventions; to evaluate the impact of changing circumstances such as climate change or disease; and to provide an agronomic basis to models assessing food security and land use at different spatial scales (Van Ittersum et al. 2013).

**Who uses the Models (DSSAT) tools?**

The crop growth models are being developed to meet the demands under the following situations in agricultural Sciences.

1. When the farmers have the difficult task of managing their crops on poor soils in harsh and risky climates.

2. When scientists and research managers need tools that can assist them in taking an integrated approach to finding solutions in the complex problem of weather, soil and crop management.

3. When policy makers and administrators need simple tools that can assist them in policy management in agricultural meteorology. The potential uses of crop growth models for practical applications are as follows;

 **On farm decision-making and agronomic management**

The models allow evaluation of one or more options that are available with respect to one or more agronomic management decisions like:

* Determine optimum planting date.
* Determine best choice of cultivars.
* Evaluate weather risk.
* Investment decisions.
* The crop growth models can be used to predict crop performance in regions where the crop has not been grown before or not grown under optimal conditions. Such applications are of value for regional development and agricultural planning in developing countries. A model can calculate probabilities of grain yield levels for a given soil type based on rainfall. Investment decisions like purchase of irrigation systems can be taken with an eye on long term usage of the equipment thus acquired.

**Understanding of research**

In agro-meteorological research the crop models basically help in:

* Testing scientific hypothesis.
* Highlight where information is missing.
* Organizing data.
* Integrating across disciplines.
* Assist in genetic improvement;

 Evaluate optimum genetic traits for specific environments.

 Evaluate cultivar stability under long term weather.

**Policy management**

The policy management is one very useful application of crop simulation models. The issues range from global (impacts of climate change on crops) to field level (effect of crop rotation on soil quality) issues. crop simulation modeling using satellite and ground-based data could be used to estimate crop production for famine early warning which can allow policy makers the time they need to take appropriate steps to ameliorate the effects of global food shortages on vulnerable urban and rural populations. Crop models can be used to understand the effects of climate change such as:

a) Consequences of elevated carbon-dioxide, and

b) Changes in temperature and rainfall on crop development, growth and yield. Ultimately, the breeders can anticipate future requirements based on the climate change.

Crop modeling is of great utility in examining hypothetical or projected scenarios, helping build the case for investment in agricultural research and rational policymaking, especially in combination with economic analysis. This is one example of the multidisciplinary collaborations that crop modeling can ultimately facilitate.

**Uses of crop models:**

1. A mechanistic model of vegetative growth is used to describes the plant performance based on the knowledge of the processes that are taking place in its growth and development
2. An empirical model is used to describes the plant behavior based directly on observations at the plant level.
3. A model can simulate the crop yield.
4. It is used to represent the relations between all plant processes.
5. It sure be empirical at some lower level, such as the variation in gross photosynthetic rate according to the temperature.
6. It helps us to understand the interactions of its main components.
7. Crop model at the prediction level can be found in Waggoner (1984), in which wheat yield in a given year and place is calculated in function of meteorological variables, such as temperature, precipitation and number of days warmer than 32°C, in a simple equation, without representing the plant processes, by just varying the constants of the equation (weights of each variable) according to the location.
8. Model have excellent forecast mechanisms.
9. At the organ level model can be found in Teruel (1995), in which the sugar-cane leaf area index is calculated by an exponential-potential equation, the only variable being the Growing Degree Days (GDD) accumulated from planting, varying the constants in function of the cultivation cycle.
10. Some models try to represent processes in the system up to two organization levels below the forecast level.
11. A model is also used to forecast crop yield will represent the processes at organ level
12. At organ level model is used to provide the forecast of photosynthesis, respiration, and foliar expansion and abscission, only being empirical down to this level.
13. They help us better understand the operation of a real system.
14. The software GLYCIM (Acock et al., 1985) is an example of a mechanistic model which is used to predict the soybean growth and yield.
15. Model consists of thousands of equations which is used for describing the atmospheric and soil environments, light interception by the leaves, photosynthesis, carbon partition between different organs, respiration, and water and nutrient uptake.
16. At the photosynthesis organization level, the model used to represent the photosynthesis for leaf area.
17. Models have a much larger potential to allow extrapolation in the forecasts outside the boundaries in which they were generated (Chanter, 1981).
18. Model gives information about facts regarding a phenomenon.
19. Crop models can be indicated the analysis of observed responses in plant growth as a function of certain factors, to increase our understanding of the crop growth and to provide direction in our research.
20. It also helps in simulation of plant growth by models consisting of many interacting components and levels, as an aid for teaching and learning.
21. They give forecast of the plants response of to certain climatic or management condition, as a tool for management and decision-making.
22. Model can supply the knowledge one does not have about a system.
23. The model is a simplified version of the system and it will be as good as the available knowledge of the system.
24. Modeling is to produce a tool that can be used to test hypotheses, to generate alternative hypotheses, to suggest experiments, to refute them, and furthermore, to predict the behavior of the system in unknown situations.
25. A model used to help to detect areas where the knowledge and data are scarce.
26. The modeling process stimulates new ideas
27. When data compared with traditional methods, the models make, usually, a better use of data.
28. Models allow interpolation and prediction
29. A model summarizes large amounts of information
30. A good model can be used to suggest priorities in the application of resources for research
31. The mathematical basis for the hypothesis allows progress in better understanding the behavior of the system and discerning among alternative hypotheses.
32. The elaboration of a model follows exactly the basic rules of the Scientific Method
33. The sensing is commonly addressed as a very technical discipline, the match between the information currently collected with sensors and those required for site-specific application of different inputs, and crop growth and development.
34. Sensing also highlighting the most accurate method to measure a soil property for a given application.
35. The simulation model of plant yield has practical application in the management of cropping systems.
36. Crop simulation models gives the formation of stocks
37. It also used in the commercialization
38. It is used in the making of agricultural policies and zoning, and in many other branches of agricultural activity.
39. Models used in each one of those contexts will have a different form and will be used in different ways.
40. In a context of resource management, the models can serve as a learning aid in predicting the results of a given usual practice compared to alternative actions in the agricultural system.
41. The model to be used in management is a summarized form of the detailed simulation model obtained through research, in which several intermediate state variables are removed and some parameters are maintained constant for the particular case.
42. Before the model is applied for resource management, its accuracy needs to be tested within a given range of variables.
43. The model is used to simulate the effects of different management techniques or environmental variations on the crop performance.
44. The model, should necessarily be used within its tested boundaries (Rimmington & Charles-Edwards, 1987).
45. Crop models have many current and potential uses for answering questions in research, crop management, and policy.
46. Models can assist in synthesis of research understanding about the interactions of genetics, physiology, and the environment, integration across disciplines, and organization of data.
47. They can assist in preseason and in-season management decisions on cultural practices, fertilization, irrigation, and pesticide use.
48. Crop models can assist policy makers by predicting soil erosion, leaching of agrichemicals, effects of climatic change, and large-area yield forecasts.
49. Simulation models can be used to predict appropriate trait phenotypes and selection protocols in breeding programmes to achieve [ideotypes](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/ideotypes%22%20%5Co%20%22Learn%20more%20about%20Ideotypes%20from%20ScienceDirect%27s%20AI-generated%20Topic%20Pages) (Boote *et al.*, 1996), for a true integration of crop models and breeding, the inheritance of model parameters is required (Yin *et al.*, 2003).
50. Crop models, such as the DSSAT-CSM group (Jones *et al.*, 2003) and APSIM (Keating *et al.*, 2003), are extensively used in the analysis, evaluation, and prediction of crop growth and production, on in-field scale up to regional or country levels.
51. The information that can potentially be delivered by soil sensors for use in these models is on water and nutrients (mainly N, in relation with organic matter dynamics).
52. The WOFOST model (van Diepen *et al.*, 1989) addresses the macro nutrients NPK.
53. Few models addressing the interaction between the main nutrients.
54. Sensors provides Site-specific information as would allow estimations of spatial crop yield differences,
55. Crop models can also be used as a guide for breeding programmes or as a means to envision a crop [ideotype](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/ideotype%22%20%5Co%20%22Learn%20more%20about%20Ideotype%20from%20ScienceDirect%27s%20AI-generated%20Topic%20Pages) (Boote *et al.*, 1996).
56. In a breeding programme model is used to optimize plant carbon allocation among plant components (i.e. leaf, stem, [rhizome](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/rhizome) and root).
57. Model can be used to study the effects of genotypes with different [biomass partitioning](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/biomass-partitioning) schemes.
58. Crop model application in irrigated watersheds must simulate accurately the growth of crops because it determines N uptake, which is a relevant component of the N cycle.
59. Models are used to in simulating different [irrigation systems](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/irrigation-systems) and scheduling strategies and different N fertilizer management (N rates, application methods, and N splitting) if different strategies are to be assessed to reduce N loads.
60. APEX simulations properly identify the main soil and crop N polluters within the studied watersheds

**Issues related to weather on crop modeling**

For any application of a crop model weather data is an essential input and it continues to play a key role. So:

1. There is an urgent need to develop standards for weather station equipment and sensors installation and maintenance.

 2. It is also important that a uniform file format is defined for storage and distribution of weather data, so that they can easily be exchanged among agro-meteorologists, crop modelers and others working in climate and weather aspects across the globe.

3. Easy access to weather data, preferably through the internet and the World Wide Web, will be critical for the application of crop models for yield forecasting and tactical decision making.

4. Previously one of the limitations of the current crop simulation models was that they can only simulate crop yield for a particular site. At this site weather (soil and management) data also must be available. It is a known fact that the weather data (and all these other details) are not available at all locations where crops are grown. To solve these problems, the Geographical Information System (GIS) approach has opened up a whole field of crop modeling applications at spatial scale. From the field level for site-specific management to the regional level for productivity analysis and food security the role of GIS is going to be tremendous.

**Limitations of Modeling**

Cautions and limitations in model uses are suggested, because appropriate use for a particular purpose depends on whether the model complexity is appropriate to the question being asked and whether the model has been tested in diverse environments. One problem with these models, already empirical at the forecast level, is that they cannot be extrapolated. In some cases, simple models are not appropriate because they are not programmed to address a particular phenomenon. Complex models are not appropriate because they may require inputs that are not practical to obtain in a field situation.

Corp models required large amount of input data, which may not be available with the user along with it, required skilled manpower, good knowledge of computers and computer language. Crop modeling needs multidisciplinary knowledge. No model can take into account all the existing complexity of biological systems. Hence simulation results have errors. A model is a tool for improving critical thought, not a substitute for it. Models can help formulate hypotheses and improve efficiency of field experiments, but they do not eliminate the need for continued experimentation. Models developed for a specific region cannot be used as such in another region. Proper parameterization and calibration is needed before using a model.

**Conclusions**

Models are holistic, knowledge-based international tools for worldwide and local applications. Crop model help us in assimilating knowledge gained from experimentation. It helps to understand or foresee the behavior of biological systems on the basis of fundamental level of incorporation. It offers dynamic, quantitative tools for analyzing the complexity of agricultural systems. Promote inter-disciplinary research. Increase the efficiency of agricultural research and management and improve agronomic efficiency and environmental

**Needs / Future Thrust / Final consideration:**

There is no such thing as a right or wrong model, but models with variable degrees of suitability for a certain circumstance. There is no universal model that provides a solution for all problems; however models should continue to be developed and adapted to several particular situations. They must only be used in conditions similar to those in which they were generated.  There is a need for both complex and simple models. Modelers need to be forthright in model description and promotion. The professionals working with modeling should define their objectives prior to constructing their models, and the model users should choose one that has been developed to solve their particular needs.

More advanced models are needed to better understand and more precisely represent plant physiology and reactions to abiotic and biotic stresses. Broadly used varieties representing all crop mega environments need to be calibrated and shared with the global community, as well as the definition of virtual varieties to evaluate the value of certain traits to mitigate impact of climate change or biotic stresses.

A robust calculation of yield potential requires data-intensive field trials to calibrate the crop model for each field/year. For yield gap analysis, around 10 to 20 years of daily weather data is needed, along with 10 years of current yield or at least 5 where data is poor (Grassini et al. 2015), preferably sub-national. The lack of reliable yield data, along access to timely climate, soil and other relevant data is a major obstacle.

Given the clear benefits of enhanced use of crop modeling and integration in other research and policy activities, much more investment in modeling approaches and data sets is needed. Such investment would be soon repaid in terms of targeted research for development, increased breeding efficiency, and rational pre-emptive policies.