**Crop Growth Modeling & Simulation**

**Crop** is defined as an “Aggregation of individual plant species grown in a unit area for economic purpose”.

**Growth** is defined as an “Irreversible increase in size and volume and is the consequence of differentiation and distribution occurring in the plant”.

**Simulation** is defined as “Reproducing the essence of a system without reproducing the system itself”. In simulation the essential characteristics of the system are reproduced in a model, which is then studied in an abbreviated time scale.

**A model** is a schematic representation of the conception of a system or an act of mimicry or a set of equations, which represents the behaviour of a system. Also, a model is “A representation of an object, system or idea in some form other than that of the entity itself”. Its purpose is usually to aid in explaining, understanding or improving performance of a system.

A model is, by definition “A simplified version of a part of reality, not a one to one copy”. This simplification makes models useful because it offers a comprehensive description of a problem situation. However, the simplification is, at the same time, the greatest drawback of the process. It is a difficult task to produce a comprehensible, operational representation of a part of reality, which grasps the essential elements and mechanisms of that real world system and even more demanding, when the complex systems encountered in environmental management.

**TYPES OF MODELS:** Depending upon the purpose for which it is designed the models are classified into different groups or types.

**1. Statistical models:** These models express the relationship between yield or yield components and weather parameters. In these models relationships are measured in a system using statistical techniques. Example: Step down regressions and correlation, etc (**Regression** is a measure of the relation between the mean value of one variable (e.g. output) and corresponding values of other variables (e.g. time and cost), and **stepwise regression** is a method of fitting [regression models](https://en.wikipedia.org/wiki/Regression_model) in which the choice of predictive variables is carried out by an automatic procedure In each step, a variable is considered for addition to or subtraction from the set of [explanatory variables](https://en.wikipedia.org/wiki/Explanatory_variable) based on some pre-specified criterion. Usually, this takes the form of a sequence of [*F*-tests](https://en.wikipedia.org/wiki/F-test) or [*t*-tests](https://en.wikipedia.org/wiki/T-test).

**2. Mechanistic models:** These models explain not only the relationship between weather parameters and yield, but also the mechanism of these models (explains the relationship of influencing dependent variables). These models are based on physical selection.

**3. Deterministic models:** These models estimate the exact value of the yield or dependent variable. These models also have defined coefficients.

**4. Stochastic models:** A probability element is attached to each output. For each set of inputs different outputs are given along with probabilities. These models define yield or state of dependent variable at a given rate.

**5. Dynamic models:** Time is included as a variable. Both dependent and independent variables are having values which remain constant over a given period of time.

**6. Static:** Time is not included as a variable. Dependent and independent variables having values remain constant over a given period of time.

**7. Simulation models:** Computer models, in general, are a mathematical representation of a real world system. One of the main goals of crop simulation models is to estimate agricultural production as a function of weather and soil conditions as well as crop management. These models use one or more sets of differential equations, and calculate both rate and state variables over time, normally from planting until harvest maturity or final harvest.

**8. Descriptive model:** A descriptive model defines the behaviour of a system in a simple manner. The model reflects little or none of the mechanisms that are the causes of phenomena. But, consists of one or more mathematical equations. An example of such an equation is the one derived from successively measured weights of a crop. The equation is helpful to determine quickly the weight of the crop where no observation was made.

**9. Explanatory model:** This consists of quantitative description of the mechanisms and processes that cause the behavior of the system. To create this model, a system is analyzed and its processes and mechanisms are quantified separately. The model is built by integrating these descriptions for the entire system. It contains descriptions of distinct processes such as leaf area expansion, tiller production, etc. Crop growth is a consequence of these processes.

**History and Need of Crop Modeling**

Models are useful tools for agricultural purposes. Several examples could be mentioned, in the areas of irrigation management, soil physics, plant nutrition, plant diseases, and related topics. There is even a model used in biology and agriculture for a longtime. The de Wit school of models (In the sixties) the first attempt to model photosynthetic rates of crop canopies was made (de Wit, 1965). The results obtained from this model were used among others, to estimate potential food production for some areas of the world and to provide indications for crop management and breeding (de Wit, 1967; Linneman et al., 1979). This was followed by the construction of an Elementary CROp growth Simulator (ELCROS) by de Wit et al. (1970). This model included the static photosynthesis model and crop respiration was taken as a fixed fraction per day of the biomass, plus an amount proportional to the growth rate. In addition, a functional equilibrium between root and shoot growth was added (Penning de Vries et al., 1974). The introduction of micrometeorology in the models (Goudriaan, 1977) and quantification of canopy resistance to gas exchanges allowed the models to improve the simulation of transpiration and evolve into the BAsic CROp growth Simulator (BACROS) (de Wit and Goudriaan, 1978).

To meet the requirements of resource poor farmers in the tropics and sub tropics IBSNAT (International Benchmark Sites Network for Agro-technology Transfer) began in 1982. This was under a contract from the U.S. Agency for International Development to the University of Hawaii at Manoa, USA. IBSNAT was an attempt to demonstrate the effectiveness of understanding options through systems analysis and simulation for ultimate benefit of farm households across the globe. The models developed by IBSNAT were simply the means by which the knowledge scientists have and could be placed in the hands of users. The major product of IBSNAT was a Decision Support System for Agro-Technology Transfer (DSSAT).

As agriculture becomes more intensive, the demand for a higher level of control of the environment in which the plants grow increases. This control ranges from better strategies of soil management to “closed” environments, where most, if not all, the atmospheric and soil variables can be adjusted. Based on this premise, plant growth and development models should be elaborated to supply a basis for planning and managing crop production. Crop modeling can also be useful as a means to help the scientist define research priorities. Using a model to estimate the importance and the effect of certain parameters, a researcher can observe which factors should be more studied in future research, thus increasing the understanding of the system. The model has also the potential of helping to understand the basic interactions in the soil-plant-atmosphere system.To simulate means to imitate, to reproduce, to appear similar. The art of simulating is as old as man. From the origin of the civilization, man had to struggle to survive, using, even if unconsciously, simulations of real future processes

to be ready for life. Simulation is, therefore, an analogy with the reality, being common in many areas. An athlete simulates during training the conditions that will prevail in the real competition; students make exercises and exams simulating their future work. In agriculture, the simulation is important to forecast the results of a certain system management or of a certain environmental condition.

Model is a word that admits several connotations, among which the following can be mentioned: (i) the representation of some entity, usually in smaller size than the original; (ii) a simple description of a system, used to explain it or to perform calculations. It can be noticed, based on the above definitions, that models can be a prototype, a simplified representation, as well as an abstraction of a reality.A model is as precise and reliable as the database used in its development, and a simulation is as accurate and reliable as the database used to feed the model.

The traditional experimentation is time consuming and costly. So, systems analysis and simulation have an important role to play in fostering this understanding of options. The information science is rapidly changing. The computer technology is blossoming. So, DSSAT has the potential to reduce substantially the time and cost of field experimentation necessary for adequate evaluation of new cultivars and new management systems.

Several crop growth and yield models built on a framework similar in structure were developed as part of DSSAT package. The package consists of : 1) data base management system for soil, weather, genetic coefficients, and management inputs, 2) models, 3) series of utility programs, 4) series of weather generation programs, 5) strategy evaluation program to evaluate options including choice of variety, planting date, plant population density, row spacing, soil type, irrigation, fertilizer application, initial conditions on yields, water stress in the vegetative or reproductive stages of development, and net returns.

One of the most important uses of models is to forecast the results produced by a given system in response to a given set of inputs. One very important future use of models in agriculture is to forecast the effects of certain environmental conditions and agricultural practices on crop performance.

Being useful tools for researchers, models have also been developed and applied to solve complex agricultural problems. Plant modeling has progressed clearly in the past 30 years, mainly due to the growing demand for models.

There was practically no demand for farm-level models a couple of decades ago, but nowadays, many farms are equipped with microcomputers and data-loggers, with access to mainframe computers through the Internet. The users are growing quickly in number and degree of sophistication. Another growing group of model users is the governmental agencies, concerned with developing agricultural and environmental policies. Another potential use of models comes from their ability in helping to set research priorities and guide fund allocations. Modeling can provide quantitative descriptions and the understanding of agricultural systems, helping to pinpoint areas where knowledge is lacking and helping in the design of more adequate and effective experiments.

A **Crop Simulation Model** (**CSM**) is a [simulation model](https://en.wikipedia.org/wiki/Computer_model) that describes processes of crop growth and development as a function of weather conditions, soil conditions, and crop management. Typically, such models estimate times that specific growth stages are attained, biomass of crop components (e.g., leaves, stems, roots and harvestable products) as they change over time, and similarly, changes in soil moisture and nutrient status.

**Commonly used crop simulation models**

**CropSyst:**  is a multi-year multi-crop daily time-step [crop simulation model](https://en.wikipedia.org/wiki/Crop_simulation_model) being developed by a team at [Washington State University](https://en.wikipedia.org/wiki/Washington_State_University)'s Department of Biological Systems Engineering. The model is used to study the effect of cropping systems management on productivity (budgeting).

The model has been parameterized for a wide range of crops such as [potatoes](https://en.wikipedia.org/wiki/Potato), [lentils](https://en.wikipedia.org/wiki/Lentil), [tea](https://en.wikipedia.org/wiki/Tea) and [grapes](https://en.wikipedia.org/wiki/Grape). The Management options include rotations, [irrigation](https://en.wikipedia.org/wiki/Irrigation), fertilization and [tillage](https://en.wikipedia.org/wiki/Tillage). It is widely used within research projects around the world including the [United States](https://en.wikipedia.org/wiki/United_States), [Italy](https://en.wikipedia.org/wiki/Italy) and the [United Kingdom](https://en.wikipedia.org/wiki/United_Kingdom) (e.g. [Land Allocation Decision Support System](https://en.wikipedia.org/wiki/Land_Allocation_Decision_Support_System)).

**APSIM:** The Agricultural Production Systems sIMulator is a highly advanced simulator of agricultural systems. APSIM was created by [CSIRO](https://en.wikipedia.org/wiki/CSIRO), the State of Queensland (through its Department of Agriculture Fisheries and Forestry) and [The University of Queensland](https://en.wikipedia.org/wiki/University_of_Queensland) in [Australia](https://en.wikipedia.org/wiki/Australia).