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Crop modeling – a tool of risk assessment for climate change and adaptation strategies

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Introduction

Indian agriculture sector accounts to about 18 per cent of India's gross domestic product (GDP) and provides employment to 50% of the countries workforce (India economic survey, 2018). In general, weather plays an important role during growing season of the crop growth, development and yield. Projected changes in global climate on weather like increasing temperatures, variability in rainfall and changing atmospheric carbon dioxide concentration will have significant effects on crop plants (Erice *et al.*, 2011).. Further, they may also impair the effectiveness of externally applied inputs and thus food production. Crop simulation models are used over past 20 to 30 years by scientists to hypothesize ways to improve agricultural production under seasonal and daily variability in weather (Boote *et al.*, 2008). These models in connection with different General Circulation Models (GCM) predict the future agricultural practices that can adapt to different climate change scenarios. In this way it is more important for planning and policy of food security and national development strategies.

Causes for climate change:

- Burning coal, oil and gas produces carbon dioxide and nitrous oxide.
- Cutting down forests (deforestation). Trees help to regulate the climate by absorbing CO_2 from the atmosphere. So when they are cut down, that beneficial effect is lost and the carbon stored in the trees is released into the atmosphere, adding to the greenhouse effect.
- Increasing livestock farming. Cows and sheep produce large amounts of methane when they digest their food.
- Fertilisers containing nitrogen produce nitrous oxide emissions.
- Fluorinated gases from refrigerators and propellants produce a very strong warming effect, up to 23 000 times greater than CO_2.
- Increase in urbanization and industrialization

What is crop modeling?

Modeling is the use of equations or sets of equations to represent the behaviour of a system. In effect crop models are computer programmes that mimic the growth and development of crops (USDA, 2007). Model simulates or imitates the behaviour of a real crop by predicting the growth of its components, such as leaves, roots, stems and grains. Thus, a crop growth simulation model not only predicts the final state of crop production or harvestable yield, but also contains quantitative information about major processes involved in the growth and development of the crop.

Role of crop models in evaluating adaptation strategies:

Farmers can adapt to climate changes to some degree by

- Shifting planting dates.
- Choosing varieties with different duration.
- Irrigation options.
- Efficient fertilizer use.
- Resource conservation technologies
- Agroforestry practices.
- Greenhouse gas monitoring.

Types of models:

Depending upon the purpose for which it is designed, the models are classified into different groups or types. Of them a few are:

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, correlation, etc.
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 models: Time is not included as a variable. Dependent and independent variables having values remain constant over a given period of time.
7. Descriptive model: A descriptive model defines the behaviour of a system in a simple manner. 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.
8. Explanatory model: This consists of quantitative description of the mechanisms and processes that cause the behaviour of the system. It contains descriptions of distinct processes such as leaf area expansion, tiller production, etc. Crop growth is a consequence of these processes.
9. 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.

List of published simulation models for various crops

Cropsyst	Wheat and other crops
SIMCO	Corn
CERES	Rice, Rice, water
CERES	Series of crop simulation models
DSSAT	Framework of crop simulation models including modules of CERES, CROPGRO and CROPSIM
APSIM	Sugarcane, potential growth, water and nitrogen stress
SPICE	Whole plant water flow
REALSOY	Soyabean
MODVEX	Model development and validation system
IRRIGATE	Irrigation scheduling model
COTTAM	Cotton
APSIM	Modelling framework for a range of crops

Steps in model building:

1. Define Goals: Agricultural system
2. Define system and its boundaries: Crop model
3. Define key variables in system

a. State variables: Variables that can be measured. Eg. Soil moisture content.

b. Rate variables: Variables that measure the rate of various processes.

Eg. Photosysnthesis rate, Transpiration rate.

c. Driving variables: Variables that are not part of the system but are essential for analysis. Eg: Climate.

d. Auxiliary variables: Variables which are the intermediate products.

Eg: Drymatter partitioning.

4. Quantify relationships (evaluation)
5. Calibration
6. Validation
7. Sensitivity analysis

Advantages

In agro-meteorological research the crop models basically helps in

- Testing scientific hypothesis.
- Highlight where information is missing.
- Organizing data.
- Assist in genetic improvement.
- Evaluate optimum genetic traits for specific environments.
- Evaluate cultivar stability under long term weather.

Applications of crop-climate models in agriculture (Aggarwal *et al.,* 2006)

- Real-time
- Regional estimates of anticipated crop production
- Farm agro-advisories
- Strategic Planning
- Climatic risk assessment for crop insurance
- Impact assessment of climate change
- Strategic planning for development
- Hybrid seed production

References

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