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Decision Support System for Agro-Technology Transfer (DSSAT)

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Introduction

The Decision Support System for Agro-technology Transfer (DSSAT) is a software application program that comprises crop simulation models for over 42 crops (as of Version 4.7.5) as well as tools to facilitate effective use of the models. The tools include database management programs for soil, weather, crop management and experimental data, utilities, and application programs. The crop simulation models simulate growth, development and yield as a function of the soil-plant-atmosphere dynamics. DSSAT and its crop simulation models have been used for a wide range of applications at different spatial and temporal scales. This includes on-farm and precision management, regional assessments of the impact of climate variability and climate change, gene-based modeling and breeding selection, water use, greenhouse gas emissions, and long-term sustainability through the soil organic carbon and nitrogen balances. DSSAT has been in used by more than 25,000 researchers, educators, consultants, extension agents, growers, and policy and decision makers in over 183 countries worldwide. The crop models require daily weather data, soil surface and profile information, and detailed crop management as input. Crop genetic information is defined in a crop species file that is provided by DSSAT and cultivar or variety information that should be provided by the user.

Simulations are initiated either at planting or prior to planting through the simulation of a bare fallow period. These simulations are conducted at a daily step or in some cases, at an hourly time step depending on the process and the crop model. At the end of each day, the plant and soil water, nitrogen, phosphorus, and carbon balances are updated, as well as the crop's vegetative and reproductive development stage. For applications, DSSAT combines

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crop, soil, and weather data bases with crop models and application programs to simulate multi-year outcomes of crop management strategies. DSSAT integrates the effects of soil, crop phenotype, weather and management options, and allows users to ask "what if" questions by conducting virtual simulation experiments on a desktop computer in minutes which would consume a significant part of an agronomist's career if conducted as real experiments. DSSAT also provides for evaluation of crop model outputs with experimental data, thus allowing users to compare simulated outcomes with observed results. This is critical prior to any application of a crop model, especially if real-world decisions or recommendations are based on modeled results. Crop model evaluation is accomplished by inputting the user's minimum data, running the model, and comparing outputs with observed data. By simulating probable outcomes of crop management strategies, DSSAT offers users information with which to rapidly appraise new crops, products, and practices for adoption.

- With the release of DSSAT v4.7, many changes have been incorporated-from both the structure of the crop models and the interface to the models and associated analysis and utility programs.
- The DSSAT package provides models of 42 crops with new tools that facilitate the creation and management of experimental, soil, and weather data files.
- DSSAT v4.7 also includes improved application programs for seasonal, spatial, sequence and crop rotation analyses that assess the economic risks and environmental impacts associated with irrigation, fertilizer and nutrient management, climate variability, climate change, soil carbon sequestration, and precision management.

Minimum Data

Each computer model requires a set of data as input. The Minimum Data Set (MDS) concept was first introduced during a workshop held at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Patancheru, India. MDS refers both to the minimum data required to run a crop model and the minimum data required to evaluate the crop model simulation outputs.

In order to run a crop, model the following data are required:

- Site weather data for the duration of the growing season, but preferably for the complete year
- Soil surface characteristics and soil profile data

- Crop management from the experiment that was conducted for model calibration

For crop model calibration and evaluation, the crop model inputs listed previously are required, as well one more or more observations, including yield, yield components, and the main phenological dates for grain cereals and legumes, including the first flowering date and maturity date.

Weather Data

The minimum required weather data include:

- Latitude and longitude of the weather station,
- Daily values of incoming solar radiation (MJ/m²-day),
- Maximum and minimum daily air temperature (ºC), and
- Daily total rainfall (mm).

You may also include dry and wet bulb temperatures and wind speed, which allow for simulating evapo transpiration with more robust methods. The length of weather records for evaluation must, at minimum, cover the duration of the experiment and preferably should begin a few weeks before planting and continue a few weeks after harvest so that “what-if” type analyses may be performed.

Soil Data

Desired soil surface data include soil classification according to NRCS, formerly referred to as SCS, surface slope, color, permeability, and drainage class. Soil profile data by soil horizons include:

- upper and lower horizon depths (cm),
- percentage sand, silt, and clay content,
- 1/3 bar bulk density,
- organic carbon,
- pH in water,
- aluminum saturation, and
- root abundance information.

Management and Experimental Data

Management data includes information on planting date, dates when soil conditions were measured prior to planting, planting density, row spacing, planting depth, crop variety, irrigation, and fertilizer practices. These data are needed for both model evaluation and strategy analysis.

In addition to site, soil, and weather data, experimental data include crop growth data, soil water and fertility measurements. These are the observed data that are needed for model evaluation.

Applications Overview

- Crop models calculate expected growth and development based on equations that describe how a crop, as community of plants, responds to soil and weather conditions.
- At their simplest level of interpretation, the equations used in a model are a set of differential equations representing rates of growth or development.
- Numerical integration over time, typically with daily or hourly time steps, allows estimation of growth, development, and water and nutrient levels. The equations are based on information from crop physiology, soil science, meteorology and other fields.
- The models provided in DSSAT deal primarily with annual crops including wheat, rice, maize and various grain legumes but also include herbaceous perennials such as forage legumes and grasses.
- Besides crop growth and development, the models simulate water and nutrient dynamics in the soil and crop, so processes such as leaching, organic matter decomposition, and runoff are also considered.
- The level of process details varies greatly, and in many cases, users may select among model options, allowing the user to assess how different assumptions affect simulations.
- Model applications range from real-time decision support for crop management to assessing the potential impact of climate change on global food security.
- Crop models are also invaluable as heuristic devices that help identify research problems where our current knowledge has limits and further research is needed.
- The ability of crop models to simulate how different weather years or soil conditions affect crop performance make models especially useful in research involving climatic uncertainty or geospatial variation.

- Recent advances in field phenomics and crop genomics are opening opportunities for crop models to support research in fundamental plant science.
- Because the quality of simulation results depends heavily on the data inputs, DSSAT includes tools to assist modelers in organizing input data for crop management, soils and weather.
- An especially challenging set of inputs are the genotype-specific parameters (GSPs) used to quantify how one cultivar differs from another. GSPs are most often estimated through calibration to measurements from field trials, and DSSAT provides tools both to organize data used for calibration and to estimate required GSPs.

Irrigation management

- The ability of DSSAT to simulate crop production under different levels of irrigation or other management conditions and for long-term (30-years or more) weather conditions, makes the model highly suitable for studying the impacts of irrigation management strategies.
- Particular note are simulation options allowing for automatic irrigation applications (i.e., varying dates or amounts) when the available soil moisture is depleted to a user-specified threshold.

Gene-based modeling

- With the rapidly increasing availability of data on DNA sequences of individual cultivars or breeding lines, there is growing interest in using this incredible data resource to improve crop model development and applications.
- Similarly, advances in understanding of the control of plant processes at the molecular level suggests opportunities to strengthen how mechanisms are represented in crop models. These interests have given rise to a broad area of activities termed "gene-based modeling."
- Topics of interest to DSSAT users and system modelers can pertain to four activities:
  - Estimation of genotype-specific model parameters (GSPs)
  - Improved representation of crop processes
  - Guiding genetic dissection of crop processes through analysis of GSPs as phenotypes
  - Use of genetic data for genetically realistic sensitivity analyses