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Integrated Approaches in Crop Simulation Modeling for Future Agriculture

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Abstract

Crop simulation models in general Crop Simulation Models (CSM) are the "dynamic simulation of crop growth by numerical integration of crop growth by numerical integration of constituent process with the aid of computers" Crop Simulation Models (CSM) integrate current scientific knowledge from many different disciplines, including crop physiology, plant breeding, agronomy, agro meteorology, soil physics, soil chemistry, pathology and entomology. CSM used in crop management, water balance, climate change and impacts, Cropping Systems, Intercropping and spacing interactions, Land use studies, Soil impacts (erosion, acidity, organic matter, leaching), Crop adaptations and breeding. CSM is widely used in different countries on various applications in agriculture. Precision farming and organic farming crop yield prediction, yield monitoring, farming system design and implementation, weather data collection, validation and utilization are being systematically used in crop modelling.

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Introduction

Crop simulation models in general Crop Simulation Models (CSM) are the "dynamic simulation of crop growth by numerical integration of crop growth by numerical integration of constituent process with the aid of computers" (Sinclair and Seligman, 1996). Crop simulation models integrate current scientific knowledge from many different disciplines, including crop physiology, plant breeding, agronomy, agro meteorology, soil physics, soil chemistry, pathology and entomology.

Calculate or predict *crop yield* as a function of:

a) Weather conditions,

b) Soil conditions,

c) Crop management scenarios reported by Piara singh *et al*. (2009).

Data Sets Required for Model

Daily Weather Data

Rainfall, maximum and minimum temperatures, solar radiation or sunshine hours. Soil profile characterization data (one time activity - data to be collected from soil survey reports): Soil texture by horizon, bulk density, fraction stones, organic carbon, soil pH (water), horizon thickness and depth, root growth distribution, surface characteristics such as soil colour, slope, permeability, drainage class, soil series name.

Management Data

Crop, cultivar, planting date, seedling rate, plant spacing, row spacing, planting depth, irrigation (dates, amounts, type and method of irrigation), fertilizer applied dates, amounts, type of material, method of application), chemical application (date, amount, type, method of application), tillage/inter culture operations (dates, depth, equipment used), organic fertilizer (date, amount, type and method of application), thinning and weeding (date and method).

Bio-Physical and Plant Characters on Crop Model Development

Physiological effects on crops, pastures, forests and livestock (quantity and quality), changes in land, soil and water resources (quantity and quality), altered hydrological cycle and precipitation variance, changes in length of growing period (LGP), Land degradation and desertification-increase in soil Salinity, Increased weed and pest challenges, Reduced crop yields. All these have implications for food production and livelihoods Crop development - various growth phases, Crop growth-photosynthesis, respiration and expansion processes, Partitioning to plant parts - Pod and seed growth etc., Nitrogen fixation - growth of nodules and N fixation, Root growth - depth and proliferation, Soil processes - nutrient transformations and balances, Hydrological processes - water balance, Direct and indirect effects - temperature and water stresses, Pests and diseases-growth and development.

DSSAT Applications

Diagnose problems (Yield Gap Analysis), Precision agriculture, Diagnose factors causing yield variations, Prescribe spatially variable management, Water and irrigation management, Soil fertility management, Plant breeding and Genotype* Environment interactions, Yield prediction for crop management, Adaptive management using climate forecasts, Climate variability and Climate change, Soil carbon sequestration, Land use change analysis, Targeting aid (Early Warning) - policy decisions, Bio fuel production, Risk insurance (rainfall).

Major DSSAT Users: Agricultural researchers, Educators, Extension service officials, Farmer advisors, Private sector, Policy makers and Students.

Advantages of DSSAT

DSSAT is a comprehensive decision support system ,which includes facilities to easily create input files, set up experiments for validation, It has ability to simulate sequence of cropping of more than one crop and to study the long-term effects of a particular combination of cropping system on soil organic matter and related issues, DSSAT offers convenient frame work validation of field experiments, DSSAT offers means to calculate the genetic coefficients by iterative process taking in to the observed values of a given experiment. It has provision for running crop models in a spatial mode by linking them to a GIS. It is capable of simulating the long-term consequences of potential climate change on crop production. Simulation results can be easily viewed as graphs and in the case of spatial simulations, as maps. It offers a simple means of comparing the observed and simulated results for validation. About 30 crops in different categories are available for simulation.

Info Crop

National Agricultural Technology Project (NATP) - ICAR mainly deals with the main features of Crop growth, water deficit, nitrogen management, temperature, crop-pest interactions, soil water and nitrogen balance & (soil) OC dynamics, GHG, Aerobic and anaerobic conditions.

Climatic change could contain either of the two values: (1) Same Change Everyday, (2) Variable Changes Overtime. No further development – lack of support (Aggarwal *et al*., 2008).

Advantages

Decision support system developed for simulation of annual, crops totalling 11 mainly using Indian experimental data and cultivars Scientists from CPCRI also used it for Coconut successfully. It simulates soil nitrogen, organic carbon and GHG emissions. It covers soils of 480 districts throughout India. 72 pests (insects, diseases & weeds) for 11 crops included. Common organic matter applied in India can be used. Different masters can be easily modified to include user required experimental data. Provision to make climate change studies using temperature, CO_2 and rainfall, provision to export results as graphs or in spread sheets, provision for converting weather from different format.

Climate Change and Variability Components Involved in DSSAT and INFOCROP

DSSAT and INFOCROP climate change and variability components describes climate change & contains treatment number, temperature change, input file, maximum change in ambient temperature, minimum change in ambient temperature, CO_2 concentration, change in average daily rainfall.

Climatic change could contain either of the two values: 1. Same Change Everyday 2. Variable Changes Overtime. No further development – lack of support.

WOFOST 7.1.3: Semi-deterministic crop simulation model of physiological processes, Simulation runs from sowing to maturity and is based on response of crop to weather (all Prod levels) and soil moisture conditions (Wat-lim). WOFOST Control Center version 1.8 (WCC).

WOFOST is designed to fit available regional data sets as input data: Crop, Soil, site Weather Farm management factors limited to crop cultivar choice and average sowing date.

Model Output

Crop Growth Curves: crop stage, biomass, LAI and harvestable part under potential, and water-limited conditions, soil moisture evolution, monitoring based on tracking differences with normal conditions, model output can be used as yield predictors, Crop (choice from 8 field crops), Standard crop file, 46 crop parameters including, 34 single parameters, 12 multiple parameter tables (crop age or temperature), Variety (regional cultivars), Crop calendar, start of season and end of season.

CropSyst Crop Simulation Model: Cropping Systems Simulation Model, Multi-year multi-crop daily time step simulation model, RS/GIS, C^{++}, Washington State University.

CropSyst Management Options: Cultivar selection, crop rotation (including fallow years), irrigation, nitrogen fertilization, tillage operations (over 80 options), and residue management. Simulates soil water budget, soil-plant nitrogen budget, crop canopy and root growth, dry matter production, yield, residue production and erosion.

Aquacrop: FAO Model

Aqua Crop v3.1 – 2011, specially -water limiting factors, planning purposes for use of economists, water administrators and Farm managers.

ORYZA 2000

Version 2.13 (2009), 1990 - Simulation and Systems Analysis for Rice Production (SARP), ORYZA1- potential production, ORYZAW - water limitations and ORYZAN - nitrogen limitations. To study the impact of climate change rice yields and to explore adaptive management options (fertilizer, cultivar, irrigation strategy, sowing date, etc.). This crop simulation model is only for rice and not dealing any other crops.

APSIM 7.3 February 2011TEAM: Commonwealth Scientific and Industrial Research Organization (CSIRO), The University of Queensland (UQ), Department of Employment, Economic Development and Innovation (DEEDI).

APSIM: Fallow Water Balance , Effect of residue cover on soil water storage during fallow, Nitrogen cycling, Single season crop simulations, Cropping sequence simulations (rotations), Evaluating a cropping system, Climate change projections***, APSIM South Asia manual 2011.***

APSIM application: Crop Management, Water Balance, Climate change and impacts, Cropping Systems, Intercropping and spacing interactions, Land use studies, Soil impacts(erosion, acidity, organic matter, leaching), Crop adaptations and breeding**.**

CERES CSM

CERES Rice and Maize to determine potential crop yields with and without constraints including water, nitrogen, capital, labour, farmers income and options to maximize food production and farmers and regional incomes for the state of Haryana, India. CERES model provides very little details on genetic coefficients and the values used in genetic coefficient data are not readily available. CERES Rice model used in tropical and sub tropical Asian environment where as CERES Wheat is used in temperate environment. MACROS, CERES Rice and RICESYS are used to study climate change impact on rice growing areas in Asia (MACROS for temperature, CERES for CO_2, and RICESYS for green house experiment data), MERES model is used to predict methane emissions in Rice, CERES Wheat application in India, relates to planting dates, planting methods, CERES Rice application in India, covers dry seeded rice (DSR) and transplanted rice (TPR) to improve rice production. CERES Rice and CERES Wheat models in India covers the crop parameters such as temperature, solar radiation, rain fall, wind, CO_2 concentration, pest and diseases, irrigation water.

Successful Agro Meteorological Models

A few successful models in Agro meteorology: The de Wit school models: the first model to attempt photosynthetic rates of crop canopies. Crop growth simulation (ELCROS) by de Wit *et al,* (1970). (BACROS) To improve the simulation of transpiration and involve into the Basic Crop growth simulator. IBSNAT and DSSAT Models: to sustain the yield levels, production of decision support systems, minimum amount of data required for running simulations, site specific yield simulations.

CSM Benefits to Students

Reduced time for experimentation, provision of safe learning environment, facilitates distance education, increased control over environmental variability and integration of different but associated topic areas.

Crop Model Prediction Challenges

• Build on existing research to identify or develop, and implement practical tools for downscaling climate forecasts tailored to needs of crop model users.

• Design and seek funding for the type of comparative study of potential and existing downscaling methods developments.

• Develop a mechanism for facilitating communication among researchers interested in pursuing this area further.

• Clarify and communicate a positive global policy for sharing climate model output with researchers working on downscaling and agricultural applications.

• Inadequate quantitative information about the skill and reliability of model-based.

• Forecasts difficulty in obtaining climate model hind casts, the mismatch of spatial and temporal scale between climate model output and crop model requirements.

Conclusion

Crop specific ICASA/ IBSANT crop specific models included in the DSSAT software (including all CERES and GRO models listed under each crop), Generic

WOFOST provides a family of generic models with specific parameters, for maize, wheat, sugar beet, and more (not listed under each crop since, are not crop specific), General model EPIC, Water irrigation requirements for all crops, CROPWAT, Alfalfa ALSIM, ALFALFA, Barley CERES-Barley, Cotton GOSSYM, COTCROP, COTTAM, Dry beans BEANGRO, Maize CERES-Maize, CORNF, SIMAIZ, CORNMOD, VT-Maize, GAPS, CUPID, Peanuts PNUTGRO, Pearl millet CERES-Millet, RESCAP Potatoes SUBSTOR, Rice CERES-Rice, RICEMOD, Sorghum CERES-Sorghum, SORGF, SORKAM, RESCAP, Soybeans SOYGRO, GLYCIM, REALSOY, SOYMOD, Sugarcane CANEMOD, Wheat CERES-Wheat, TAMW, SIMTAG, AFRCWHEAT, NWHEAT, SIRIUS, SOILN - Wheat. CSM application in agriculture has got wider scope for future developments, climate change studies and to meet the global food security in future.

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