Cotton2K Model

A. Marani

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Version history

The COTTON2K cotton simulation model has been originally derived from GOSSYM-COMAX. Its main purpose was to make the model more useful for conditions of cotton production under irrigation in the arid regions of the Western US. Since many changes have been made in the model, it has been given a new name: CALGOS (for CALifornia GOSsym). The present version, which is completely revised has been renamed COTTON2K.

The 1997 version of CALGOS had options both for Windows 3.1 and for Windows 95. The user interface had been compiled by Microsoft Visual C++ version 4, and the model itself by Microsoft PowerStation FORTRAN version 4.

The 1998 and 1999 versions could be run by Windows95, 98 and Windows NT4 only. The user interface had been compiled by Microsoft Visual C++ version 5 and the model itself was compiled by Digital Visual Fortran version 5.

The COTTON2K user interface has been compiled by Microsoft Visual C++ version 6, and it makes more use of Windows 9x/NT conventions for editing, opening and saving files, etc. The model itself now runs the simulations in the Windows environment.

Main characteristics of Cotton2K model

This is a process-level model. It simulates the processes occurring in the soil, plant, and in the microenvironment, and the interactions between these processes and the management inputs applied to the field.

The main modifications that make CALGOS and COTTON2K more suitable than GOSSYM for use in the irrigated arid regions may be summarized as follows:

1. Water Relationships.

Potential evapotranspiration is computed on an hourly basis, using equations derived from those adopted by CIMIS (California Irrigation Management Information Service). In order to enhance the accuracy of the computation of potential evapotranspiration, a procedure for estimating hourly values of weather parameters from the daily values has been implemented, and also dew-point temperatures are now required as input.

The root submodel has been modified, implementing the response of root growth and activity to differential soil moisture conditions. Average soil water potential is computed as an average of the root zone, weighted by root activity in each soil cell. This soil water potential is used for computing the actual transpiration by the plants.

Leaf water potential is computed on the basis of the average soil water potential, plant resistance to water transport, and potential transpiration, and it is used to compute empirical water-stress factors. These water-stress factors affect the growth rates of plant parts, aging rates of leaves and of bolls, photosynthesis, and abscission rates of leaves, squares and bolls.

2. Nitrogen relationships.

The processes of nitrogen mineralization and nitrification in the soil have been modified. Modules for denitrification, N immobilization under high C/N ratios, and urea hydrolysis have been added.

Uptake of N by the plants is assumed to be affected by their growth requirements and it is simulated as a Michaelis-Menten procedure. Nitrogen stress factors are computed, and their effects on plant growth rates, aging of leaves and bolls, and abscission of squares and bolls are simulated.

3. Plant Physiology.

Leaf growth is simulated separately for blades and petioles, and boll growth is simulated separately for seed-cotton and burrs, using improved growth functions. The routines for leaf, square and boll growth rates, aging and abscission have been completely revised.

Scientific principles on which the model is based

Cotton Plant physiology

Growth rates are related to temperature, using the concept of “heat units” also referred to as “degree days”. This is, however, modified as follows: calculations are based on hourly heat unit accumulation, using computed hourly temperature values. The threshold value is assumed to be 12 C. One “physiological day” is equivalent to a day with an average temperature of 26 C, and it is therefore equal to the sum of heat units per day divided by 14.

A linear relationship is assumed between temperature and heat unit accumulation in the range of 12 C to 33 C. The effect of temperatures higher than 33 C is assumed to be equivalent to that of 33 C.

In addition to temperature, carbon stress, water stress, and nitrogen stress have a strong effect on all simulated rates of growth and development.

Carbon stress: Potential growth of each organ is driven by its age and position, as well as by temperature. These “potential” growth rates computed for roots, stems, each leaf blade and petiole, each square, and for seedcotton and burs in each boll. The sum of these potential growth rates is the “carbon sink”.

Gross photosynthesis is computed from radiation, plant cover (radiation interception), temperature, CO_2 content in the air, water stress, and nitrogen content in the leaf blade. Subtracting photorespiration, maintenance respiration and growth respiration results in net photosynthesis. This, together with the supply from mobilized starch stored in the leaves and in the taproots, is the “carbon source”.

When the carbon source is less than the carbon sink, the potential growth can not be realized, resulting in a condition called “carbon stress”. This is numerically expressed as the ratio between source and sink (1 = no stress, and 0 = a most severe stress). There are usually two main periods of carbon stress in cotton: (1) 3 to 4 weeks after germination – caused by not enough leaf area; (2) from 2 to 4 weeks after start of flowering until boll opening – caused by the strong sink caused by boll growth.

When carbon stress occurs, growth is reallocated according to the priorities of the different plant organs. Highest priority is for square and boll growth, lowest priority for stem and roots. Carbon stress also reduces the rates of appearance of new nodes, rate of stem growth in height, and is considered to be the main cause of square and boll shedding.

Water stress: Potential transpiration is computed by the modified Penman equation (CIMIS version). Actual transpiration is modified by the light interception factor of the plant canopy, and by the average soil water potential (which is computed for soil cells containing active roots only, an average weighted by the amount of active roots in each soil cell).

Early morning (maximum) leaf water potential is derived directly from the average soil water potential. The minimum leaf water potential occurs when transpiration rate is maximal (usually in early afternoon). It is decreased by the product of the maximum transpiration rate and the total plant resistance to water transport. These leaf water potential values are the basis for computing empirical water stress factors (where 1 = no stress, 0 = most severe stress).

The water stress factors affect rates of photosynthesis, leaf aging, growth in height, shedding of bolls, rate of boll maturation, allocation of photosynthates, and relative root growth.

Nitrogen stress: Cotton2k handles urea hydrolization in the soil, mineralization of organic N, nitrification of ammonium N, denitrification of nitrate N, and movement of soluble N (nitrate and urea) in soil. It also computes the uptake of N by plant roots.

The nitrogen in plant organs is computed in the following way. The model first computes the N requirements for growth. Then it calculates the supply of N from uptake and from reserves. The model then computes the allocation of N to the plant organs, and the concentrations of N in plant dry matter. If supply of N does not cover the requirements for growth, the model computes nitrogen stress factors. There is a feedback of computed N requirements to the N uptake routine.

Nitrogen stress affects growth, new node production, leaf aging and abscission.

Cotton Phenology

The model simulates the development of vegetative branches, fruiting branches, their nodes and the associated appearance of leaves and squares in each node. This involves a number of processes and rates: production of new pre-fruiting nodes and leaves; appearance of first square; production of new fruiting branches and new nodes on fruiting branches. These rates are a function of temperature, stresses, and in some cases also of population density.

Soil processes

The model simulates the capillary flow and gravity flow of water and nitrate in the soil, redistribution of water and nitrate after irrigation (surface or drip), and evaporation of water from the soil surface.

Agrometeorology

Using daily weather data in the input files, hourly values of temperature, global radiation, etc., are estimated, and used to simulate evapotranspiration, soil temperatures and plant temperatures.

Input data needed

Although the model works in metric units, there are options for input and output in English units.

Climate data

For each day during the cotton season, the following weather data are needed:

- Radiation.
- Maximum temperature.
- Minimum temperature.
- Rainfall.
- Daily wind run (if not available – input seasonal average).

Dew point temperature (if not available – will be estimated by the model).

There are two types of weather files: (1) actual weather – can be used after the dates available; (2) predicted weather – based on previously recorded weather scenarios.

Agricultural input data

The Agricultural Input File contains information about the agricultural input for a simulation run.

Irrigation application. For each irrigation that has been applied, or is planned to be applied, the following data are required:

Date

Effective amount of water applied (in inches or mm)

Method of irrigation (sprinkler, furrow, or drip)

Location of the drip tubes (if it is a drip system) - the horizontal distance is measured from the mid-point between two plant rows, and the vertical distance is measured from the soil surface (inches or cm may be used).

Irrigation prediction. The model can be used to predict the optimal irrigation regime. The following data are required for using this option:

Dates of starting and stopping the predicted irrigation

Minimum number of days between successive irrigations

Maximum amount of water to apply in each irrigation

Method of irrigation (sprinkler, furrow, or drip)

Location of the drip tubes (if it is a drip system)

Required depth of soil to be wetted (if it is a furrow or a sprinkler system). The recommended wetting depth for cotton is usually 90 cm or 36 inches.

Nitrogen fertilizer application. For each application that has been applied, or is planned to be applied, the following data are required:

Date of application

Effective amount of nitrogen applied as NH4, NO3 or urea (in lbs. per acre or kg per hectare)

Method of application (broadcast, side dressing, foliar, or drip)

Location of the application (if the method is side dressing or drip)

Cultivation. For each cultivation the following data are required:

Date of cultivation

Depth cultivation

Defoliation. For each application of defoliation the following data are required:

Date of application

Method of application (broadcast, sprinkler, or banded)

Band width (in cm or inches), if it is a banded application

Rate of application

Units of application rate (lbs. per acre, gal per acre, oz per acre, acre per lb., or acre per gal).

Defoliation prediction. The model can be used to predict the optimal defoliation regime. The following data are required for using this option:

Percentage of boll opening at the first defoliation (usually between 65% and 90%)

The date to defoliate even if boll opening has not reached the defined level.

Pix application. For each application of Pix the following data are required:

Date of application

Method of application (broadcast, sprinkler, or banded)

Band width, if it is a banded application

Rate of application

Units of application rate (lbs. per acre, gal per acre, oz per acre, acre per lb., or acre per gal).

Prep application. For each application of Prep the following data are required:

Date of application

Method of application (broadcast, sprinkler, or banded)

Band width

Rate of application

Units of application rate

Water table data. For cases of shallow water table conditions (less than 2 m), the following data are required:

Date (of start of this water table condition)

Depth of water table

Soil characteristic data

General Soil Properties (common to all soil layers):

Soil Water potential at field capacity - The default value for this property is -0.3 bars, but it may vary in extreme sandy or clay soils. Use bar units.

Soil Water potential for free drainage - The default value for this property is -0.15 bars, but it may vary in extreme sandy or clay soils. Use bar units.

Properties specific for each soil profile layer:

Up to nine layers can be defined. If there is no detailed information about this soil, at least one layer should be defined.

Depth to the end of this soil layer.

Parameters for the 'van Genuchten' equation - This equation relates the soil water potential to the soil water content. There are four parameters:

Residual water content (by volume)

Saturated water content (by volume)

Alpha coefficient

Beta coefficient

Hydraulic conductivity - Input at least either the saturated conductivity, or the conductivity at field capacity. This will be the basis for computing the relationship of actual hydraulic conductivity with soil water content. Use cm per day units.

Soil Bulk density

Clay and Sand content - percent of dry soil

Soil initial data

Soil data at the start of a simulation run. The data are for eleven successive 6-inch (or 15 cm) deep layers of the soil, and a 12th layer which extends down to the bottom of the soil slab (80 inches, or 200 cm):

Water content, as percent of field capacity.

Soil nitrate and soil ammonium content, as kg per ha, or lbs. per acre of N for each layer.

Soil organic matter, as percent of soil dry weight.

Simulation Profile data

The profile file defines a single simulation run. It points to the other input files used for this simulation. Other data needed for this file:

Site location: Latitude and longitude (degrees), elevation above sea level.

Dates: Start and end of simulation, Planting or Emergence.

Crop Data - cultivar (six varieties, for which the model has been calibrated, are available now. If another variety is actually used, choose the calibrated variety that is most similar in its phenology and morphology).

- Site - Choose one of four sites from the list-box. (The climate functions have been calibrated for the California San Joaquin Valley, the Arizona Phoenix-Tucson area, and the Israel coastal plain and upper Galil. Choose the site closest to your actual climatic conditions).
- Row spacing
- Plants per Row Unit
- Skip-rows - Yes or No; if Yes - input skip row width (skip row width is the smaller distance between two adjacent rows. When skip rows are defined, "row spacing" will mean the larger distance between rows).

The profile file indicates the required optional outputs (some basic output will always be produced), and the units of the output (English or metric units). It also indicates if site numbers and weights of plant parts will be output on per plant or per unit area basis.

Understanding and using the output data

There are three types of output files:

1. Text files: Summary of results; summary of input; detailed daily output; plant maps; plant vigor data.
2. Charts: graphs of 18 output variables.
3. Soil maps: 2-dimensional graphs of the soil slab.

Problems of calibration for new cultivars or new areas

The model has been validated using extensive data sets from California, Arizona and Israel. It has presently been calibrated for the following cultivars: Acala SJ-2, GC-510, Maxxa, Deltapine 61, Deltapine 77, and Sivon.

Cotton cultivars differ in many of their properties. This is expressed in the model by the values of parameters used in equations describing the following:

Rates of leaf growth, stem growth, square and boll growth,
Rates of appearance of new nodes (prefruiting, main stem, fruiting branch),
Time to square, to flower, to open boll,
Susceptibility of abscission to stresses.

The weather related procedures have been tested and calibrated for the following regions: California San Joaquin Valley, Arizona (Phoenix - Tucson area), Israel Coastal Plain, and Israel Upper Galil (Hula valley area).

Differences between sites (geographical areas) are expressed in the model by the values of parameters used in equations describing the following:

Estimates of hourly wind speeds and hourly dew point temperatures,
Estimates of cloud type correction for computing hourly long wave radiation emitted from the sky,
Difference between time of daily maximum temperature and solar noon,
Estimates of daily deep soil temperatures (at 2 m),
Estimate of hourly relative humidities.

<u>Possible uses of the model by extension staff and growers</u>

Education: Use charts to show the response of cotton to different irrigation or nitrogen fertilizer regimes, or to different weather scenarios, etc.

Management: Use the ‘irrigation prediction’ option for planning irrigation regime for different weather scenarios. Try to eliminate Nitrogen stress by modifying the fertilizer regime (Note: disregard N-stress that coincides with C-stress). Use the ‘defoliation prediction’ option to get an idea when to defoliate.

Using plant mapping results: As a result of pests or diseases, or deficiencies in P or K or other nutrients, or incorrect input data – plant development in the field may be significantly different from model predictions. In this case, create a ‘*.MAP’ file from plant mapping results, and rerun the model using it in the input. Also, actual weather data will replace the predicted weather data for this rerun.