SIGMA PLUS: A COTTON CROP MODEL

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Abstract

This paper discusses the Sigma Plus crop model and gives a brief history of the use of on-farm cotton models.

Discussion

In 1986, the expert system Comax was introduced on cotton farms with the objective of advising growers on the timing and the application amounts of water and nitrogen, and of the optimum harvest date. Comax, written in Lisp, was coupled with Gossym, a cotton crop model written in Fortran. In time the system came to be known as Gossym/Comax. Since 1986 we have seen (1) an exponential increase in the speed and memory size of personal computers, (2) a broad acceptance of object oriented programming with the introduction of the C++ computer language, and (3) continuous improvements in the art and science of crop modeling. Sigma Plus continues the concept of on-farm cotton management advisory systems inaugurated by Gossym/Comax. The increase in computer capability has allowed a corresponding increase in the complexity and thoroughness of the model.

In the past four decades a succession of cotton models have been developed, each one superior and more complex than its predecessor. The primary objective of these models was research. However, in the early 1980s the field of expert systems received considerable publicity and attention. An expert system is a computer program that uses knowledge, heuristics and inference to solve a problem. The concept of applying expert systems to agriculture appeared promising, and the concept of coupling an expert system to a cotton crop model emerged. In 1986, the expert system Comax was completed (Lemmon 1986). The source of knowledge was the Gossym cotton crop model (Baker, et al., 1983). The heuristic and inference were programmed as a set of if-then rules which the Comax program applied. Comax operated Gossym to evaluate crop growth and utilization of water and nitrogen, then provided the grower with advice on when to irrigate, when to fertilize, and when to harvest. Comax was written in Lisp, Gossym was written in Fortran, and the system operated on IBM compatible PC computers.

In 1989 the U. S. Congress appropriated $500,000 per year for the establishment of the Gossym/Comax Information Unit in Starkville, MS for the purpose of distributing the Gossm/Comax system to growers and training them in its use. At the time of this writing (1994) the Congress is still providing this funding, and there are approximately 150 cotton growers using Gossym/Comax. This small number of growers is an anguishing bitter disappointment to those who saw, and still see, crop models coupled with expert systems as an important tool for agriculture. The reasons for the small number of users is debated. One reason put forth is that growers who have used it have found the Gossym/Comax decisions to be inconsistent. One perception is that Gossym, as good as it is, is perhaps not yet good enough to provide knowledge accurate enough to support the expert system's decision making process.

It is this presumption, that the current state of the art cotton crop model, w provided inconsistent knowledge that motivated the creation of Sigma Plus. This in no way invalidates the seminal work of Gossym or of its predecessors. Rather it reflects a continuous effort to develop the most precise and meticulous cotton model possible with the best crop and computer science available at the time.

Overview of the Crop Model

The model simulates stems, leaves, fruiting points, roots, movement of water and nitrate through the soil, evapotranspiration, and uptake of water and nitrogen. Growth of the modeled plant depends upon the plant variety, planting pattern and density, soil conditions, availability of nitrogen and water, solar radiation, air temperature, humidity, wind, rain and irrigation, and the application of fertilizer.

The program begins by reading a set of input files which describes the environment in which the cotton is growing and the parameters which characterize the growth characteristics of the cotton variety being simulated. The information includes cultural practices {such as distance between rows and plants per acre, dates and amounts of irrigation and nitrogen applied, the day the plant first emerges from the soil); climate data (rain, solar radiation, wind run, and temperature); soils data (hydraulic conductivity, residual and saturated water contents, bulk density, nitrate, ammonium, organic matter, and water content). In order to predict the crop growth into the future days of the growing season, future hypothesized weather files are also provided. Typically three hypothesized weather files are used, one specifying a season of normal weather, one of hot-dry weather, and one of cold-wet weather. This allows the grower to bracket the scheduling of future irrigation and fertilizer applications. As the season progresses, each day of hypothesized weather is substituted with actual weather.

The simulation begins with the day the shoot first emerges from the soil with its two cotyledons and progresses on a

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step by step basis (typically in one hour time intervals) to simulate the plants growth through the season. Photosynthate is manufactured according to the leaf area, radiation and temperature. Subsequent branches, leaves, fruit and roots appear as a function of temperature, and available carbohydrate, water, and nitrogen. Dry weight is lost when leaves and fruit abscise and when roots slough. Water evaporates from the soil surface, and as the plant transpires, water and nitrogen are taken up through the root system. Rain or irrigation is applied at the surface of the soil. Nitrogen is applied to the soil surface or subsurface or by foliar application. Organic matter mineralizes to ammonium and ammonium nitrifies to nitrate. The flow of water and nitrate through the soil is simulated as well.

Test Cases

The Sigma Plus crop model has been run on twenty-seven test cases over a wide range of conditions. The authors believe the model gives excellent results. However considerable care must be given to the preparation of the input data. In the presentation several examples were shown, but will not be given here.

Availability

The model is available for interested parties. Contact the first author for a copy of the model and a brief user's guide.