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APSIM: a Novel Software System for Model Development, Model Testing and Simulation in Agricultural Systems Research

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Agricultural Systems 50 (1996) 255-271

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2015.3.13

Outline

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Abstract

- APSIM(Agricultural Production Systems Simulator) is a software system which allows **(a)** models of crop and pasture production, residue decomposition, soil water and nutrient flow, and erosion to be readily reconfigured to simulate various production systems and **(b)** soil and crop management to be dynamically simulated using conditional rules.

- A key innovation is change from a core concept of a crop responding to resource supplies to that of a soil responding to weather, management and crops.

- A shell of software tools has been developed within a WINDOWS environment which includes user-installed editor, linker, compiler, testbed generator,graphics, database and version control software. While the engine and modules are coded in FORTRAN, the Shell is in C++.

Introduction

- This era produced enormous progress in techniques for modelling the physical and physiological processes in crop production. But To meet the new needs and opportunities,new priorities are needed. One of these is better predictive performance;A second priority is to move from the performance of single crops to performance of cropping systems in terms of both crops and soil. A third priority is better software that reduces the over heads of simulation modelling in research, facilitates efficient convergence of modelling effort both within and among teams, and allows flexible and efficient reconfiguration for simulating different production systems.

- This paper deals primarily with these latter two priorities. We first address needs against the backdrop of current prominent software packages.We then describe the Agricultural Production Systems Simulator (APSIM) designed and developed to meet these needs.

The need for better software

- We begin definition of software needs with the general need for tools to aid the search for better farming strategies and development of aids to decision making. In many of the farming systems where this need is most pressing, rainfall is uncertain and often deficient, and soil degradation threatens the economic future of crop production. The required simulation package must deal credibly with both the season-to-season variability of production and the long-term trends in production in response to changes in the soil resource. To do this requires

  (1) crop models with sufficient sensitivity to extremes of environmental inputs to predict yield variation for analyses of economic risks;

  (2) models to simulate trends in soil productivity and erosion as influenced by management, including crop sequences, intercropping, and crop residue management;

  (3) software that enables efficient evolution of the modelling system by research teams.

- No existing cropping systems model of which we are aware provide all three features.

- Production of high quality software has rarely been a high priority in model development. In a research environment, code is generally written by scientists and it is efficient to use old code that suits (and works) in new programs, often with patched enhancements.

- APSIM results from a convergence of two previous efforts to achieve the combination of features 1 (high sensitivity of crop models), 2 (ability to simulate a wide range of configurations of crops, sequences, mixtures and management practices and effects on trends in soil productivity), and3 (software which is designed and tested).

- The efforts of the AUSIM and PERFECT development teams have been combined to produce APSIM, which goes beyond its predecessors in achieving all three features.

General design features of APSIM

- **Structure of the conceptual model**

The key concept is the central position in the model of the soil rather than the crop, in spite of the fact that the output generally of greatest interest is crop yield.

- **Structure of the program**

This model concept is implemented in the APSIM program using the structure shown in Fig. 1. Various high order processes, e.g. production of a crop, soil water balance etc.

structure of the program

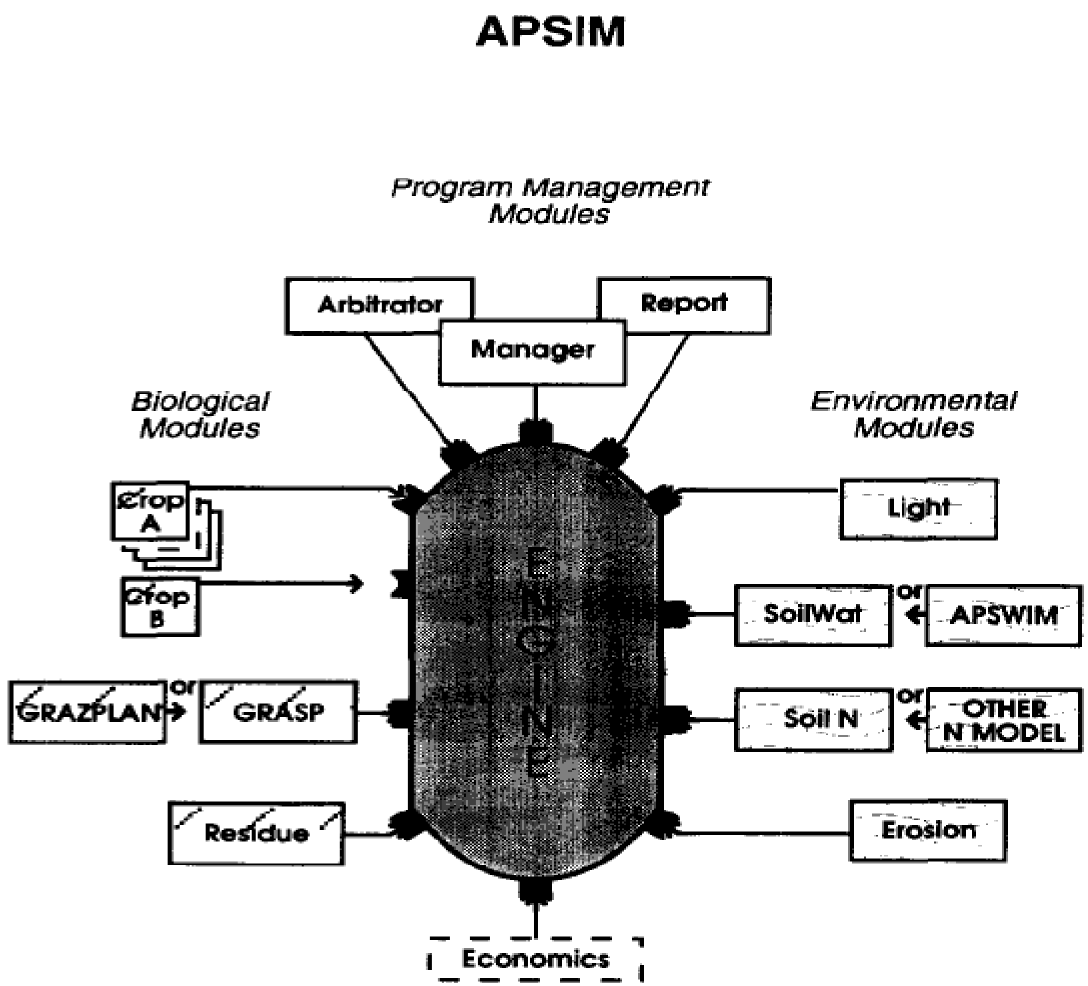

Fig. 1. The structure of the APSIM program. Modules are readily pulled out or plugged in. (See Table 1 for origin of modules; dashed box indicates module still under development.)

TABLE 1
List of Current APSIM Modules and Their Origins

Group	*APSIM module*	*Original model*	*Reference*
Crop	Cotton[a]	OZCOT	Hearn & Da Rosa, 1985
	Cowpea	ASPIM-Cowpea	Adiku *et al.*, 1993
	Maize	AUSIM-Maize	Carberry & Abrecht, 1991
	Peanut	QNUT	Hammer *et al.*, 1992
	Sorghum	QSORG	Hammer & Muchow, 1991
		AUSIM-Sorghum	Carberry & Abrecht, 1991
	Sunflower	QSUN	Chapman *et al.*, 1993
	Wheat1	Woodruff-Hammer	Hammer *et al.*, 1987
	Wheat2	CERES-Wheat	Ritchie *et al.*, 1988
Tropical grass pasture	GRASP[a]	GRASP	McKeon *et al.*, 1990
Temperate pasture	GRAZPLAN[a]	GRAZPLAN	Moore *et al.*, 1991
Soil water	SoilWat	CERES	Ritchie, 1985
		PERFECT	Littleboy *et al.*, 1992
	APSWIM[a]	SWIM	Ross, 1990*a*
Soil nitrogen	SoilN	CERES	Godwin & Jones, 1991
Soil erosion	Erosion	PERFECT	Littleboy *et al.*, 1989

[a]Intellectual property remains that of the original developer.

- **Manager module** (Fig. 1). Actions(e.g. choice of crop, planting, application of fertilizer, tillage or irrigation) can be either scheduled or controlled using conditional rules. The language for expressing rules is ‘If..... condition(s) satisfied., then... action(s) ‘. This form allows great flexibility and enables ready construction of complex rules.

- **The ‘Report’ module** implements the output of variables nominated in the control file.

- ‘**Arbitrator’ module** controls competition for resources among crops in mixtures (intercrops, weeds and crops, pasture components).

- A high degree of flexibility is achieved with ‘Biological and Environmental’ modules. Different versions of modules can be interchanged or a module can be absent without causing disruption (Fig. 1).

- **The Engine** has been designed to perform mainly one function. the passing of messages to modules from either itself or other modules.

Before a simulation run, the growth routine for the requiredcrops are selected from a library of crop models available and plugged in by selection in a screen menu (Fig. 2).

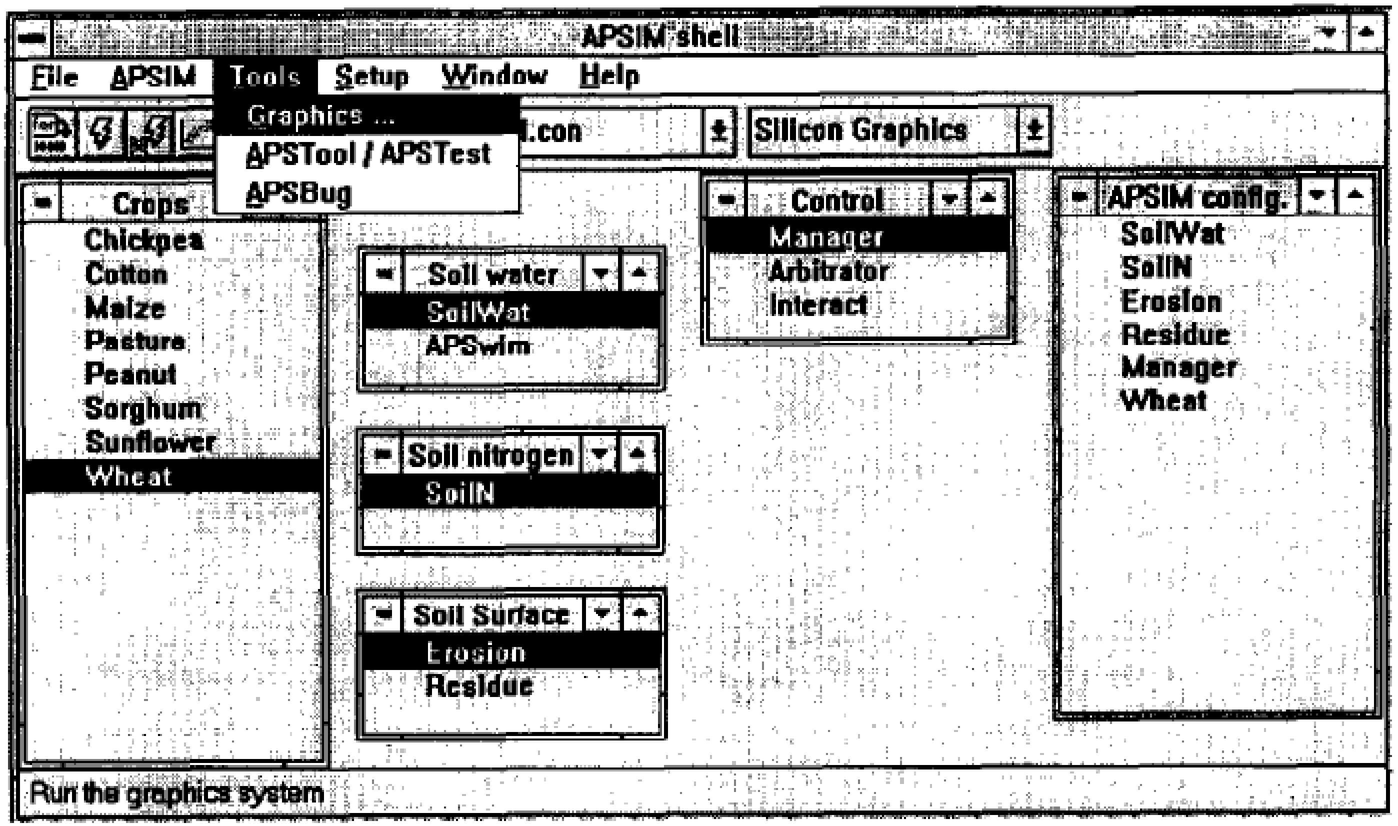

Fig. 2. The main screen of APSIM showing pull-down menus and modules available for a run configuration.

The user interface

- A user interface, developed in C++and Visual BASIC, provides a suite of tools for developing, testing and maintaining module code, running the model, and presenting and analysing output.
- The model is configured for a task from the main menu and shown in the Configuration window (Fig. 2).The several tools which are available are located on pull-down menus.

- Although seamless in practice, description of the user interface is simplified by considering separately the two major applications:

  (a) program development and maintenance and (b) simulation.

- **Simulation**

The environment for using APSIM for simulating production system performanceis shown in Fig. 3.

This is designed for ease in manipulating the configuration of the production system model, presenting appropriate input data, making simulation runs, presenting output, and making comparisons and analyses of both physical and economic outputs.

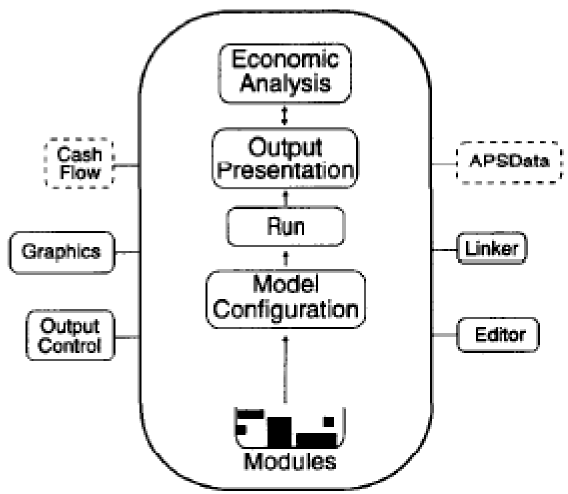

Fig. 3. The user environment for system simulation. Flow of operations are shown within the boundary and tools and resources outside. (Dashed lines indicate element still under development.)

➢Program development and maintenance

The environment for program developers is illustrated in Fig. 4.

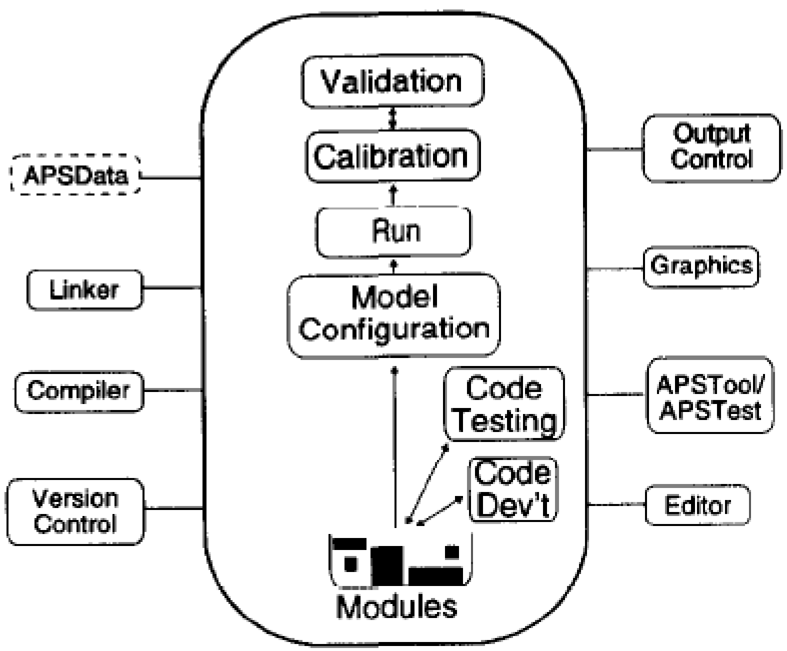

Fig. 4. The user environment for program development and maintenance.

The biological and environmental modules

Modules for two approaches to simulating soil water are available.

- **Soil-Wat (Fig. 1)** derives from the multiple store, cascading overflow, water balance routines in CERES Maize (Jones & Kiniry, 1986) and PERFECT (Littleboy et al., 1992). Changes include
  (1) transfer of solute leaching from the soil N routine;
  (2) inclusion of a surface residue effect on evaporation and runoff.

- **SoilN (Fig. 1)** derives from the nitrogen routine in the CERES models (Godwin & Jones, 1992). the main changes are the introduction of a labile soil organic matter pool and explicit carbon flows which govern nitrogen flows by C-N ratios.

- The surface residue dynamics are simulated in a **Residue module.** All above-ground material is considered as a single pool which can be burnt, incorporated into soil as FOM, or left to decompose on the surface.

- **The Erosion module** uses a modified event-based Universal Soil Loss Equation (Littleboy et al., 1992). Parameters are erodibility, slope and slope length. Inputs are daily runoff from the water balance module and daily soil cover from Residue.

Discussion

- APSIM contributes to better predictive modelling in a number of ways. **First,** improved representation of certain aspects of cropping systems enables important phenomena to be better simulated, **Second,**good routines in different models can be easily recombined to provide a superior configuration for a given task. **Third,** APSIM provides an infrastructure that can support convergent effort by teams in testing and improving models, with change taking place simultaneously on many fronts.

- Although designed for research on dry land cropping systems, APSIM is now being used for simulating other systems.

plant（maize） model

input：（1）Met--.met

（2）Soilwat2--.par

（3）Soiln2--.par

（4）SurfaceOM--.par

（5）Fertiliz--.par

（6）Irrigate--.par

（7）maize--.par

maize--.con

（clock、report、Met、manager、soilwat2、soiln2、SurfaceOM、Plant(maize)、fertiliz、irrigate）

Report

Thank you