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An Overview of APSIM, A Model Designed for Farming Systems Simulation

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Abstract
The Agricultural Production Systems Simulator (APSIM) is a modular modelling framework that has been developed by the Agricultural Production Systems Research Unit in Australia. APSIM was developed to simulate biophysical process in farming systems, in particular where there is interest in the economic and ecological outcomes of management practice in the face of climatic risk. The article outlines APSIM's structure and provides details of the concepts behind the different plant, soil and management modules. These modules include a diverse range of crops, pastures and trees, soil processes including water balance, N and P transformations, soil pH, erosion and a full range of management controls. Reports of APSIM testing in a diverse range of systems and environments are summarised. An example of model performance in a long-term cropping systems trial is provided. APSIM has been used in a broad range of applications, including support for on-farm decision making, farming systems design for production or resource management objectives, assessment of the value of seasonal climate forecasting, analysis of supply chain issues in agribusiness activities, development of waste management guidelines, risk assessment for government policy making and as a guide to research and education activity.

What is APSIM?
The **A**gricultural **P**roduction **S**ystems s**IM**ulator (APSIM) is a comprehensive model developed to simulate biophysical processes in agricultural systems, particularly as it relates to the economic and ecological outcomes of management practices in the face of climate risk. It is also being used to explore options and solutions for the food security, climate change adaptation and mitigation and carbon trading problem domains. From its inception twenty years ago, APSIM has evolved into a framework containing many of the key models required to explore changes in agricultural landscapes with capability ranging from simulation of gene expression through to multi-field farms and beyond.

APSIM is structured around plant, soil and management modules. These modules include a diverse range of crops, pastures and trees, soil processes including water balance, N and P transformations, soil pH, erosion and a full range of management controls. APSIM resulted from a need for tools that provided accurate predictions of crop production in relation to climate, genotype, soil and management factor while addressing the long-term resource management issues.

The APSIM modelling framework is made up of the following components:

- A set of biophysical modules that simulate biological and physical processes in farming systems.

- A set of management modules that allow the user to specify the intended management rules that characterise the scenario being simulated and that control the simulation.
- Various modules to facilitate data input and output to and from the simulation.
- A simulation engine that drives the simulation process and facilitates communication between the independent modules.

In addition to the science and infrastructure elements of the APSIM simulator, the framework also includes:

- Various user interfaces for model construction, testing and application
- Various interfaces and association database tools for visualisation and further analysis of output.
- Various model development, testing and documentation tools.
- A web based user and developer support facility that provides documentation, distribution and defect/change request tracking.

Purpose for building APSIM

At the outset, three key issues drove the development of a dynamic systems simulation capability to address the short and long-term consequences of crop management; quantifying the dynamics of genotype x management x environment interactions (GxMxE); and the use of modelling as a communication tool between disciplinary groups. Models have also been useful as a depository of accumulated knowledge about processes operating in agricultural ecosystems (eg. plant growth, soil physics etc). All three issues are still valid today and they are the key driving forces behind the on-going development of APSIM.

Overview of the APSIM system and its components

The APSIM modelling framework is made up of;

- a set of biophysical modules that simulate biological and physical processes in farming systems,
- a set of management modules that allow the user to specify the intended management rules that characterise the scenario being simulated and that control the conduct of the simulation
- various modules to facilitate data input and output to and from the simulation,
- a simulation engine that drives the simulation process and controls all messages passing between

Crops, pastures and forest

APSIM contains an array of modules for simulating growth, development and yield of crops, pastures and forests and their interactions with the soil. Currently crop modules are available for barley, canola, chickpea, cotton, cowpea, hemp, fababean, lupin, maize, millet, mucuna, mungbean, navybean, peanut, pigeonpea, sorghum, soybean, sunflower, wheat and sugarcane. In addition there are general modules for forest, pasture and weed as well as specific implementations for the pasture species.

Data requirements

An APSIM simulation is configured by specifying the modules to be used in the simulation and the data sets required by those modules. APSIM modules typically require initialisation data and temporal data as the simulation proceeds. Initialisation data is usually categorised into generic data (which defines the module for all simulations) and simulation specific parameter data such as site, cultivar and management characteristics. Typical site parameters are soil characteristics for soil modules.

APSIM software

APSIM modules implement a specific simulation process and communicate with other modules via a central simulation engine. Modules are completely self-contained 'black boxes', responsible for their own reading of parameters and internal configuration and can be written in any programming language. The user has the capability of plugging different combinations of modules together to configure APSIM for different simulations.

Model testing

The comparison of APSIM simulations with observed data has been conducted by many model users under a wide range of conditions. A recent inventory of papers and reports that contain some detail of APSIM predictions against observed data identified 55 items. This list has been loaded onto the APSIM help web site (www.apsim-help.tag.csiro.au) and is not repeated here for reasons of space.

Model application

A recent search for reports of APSIM applications identified 107 items published over the 1996–2001 period. This list of citations and where possible, the associated reports have been loaded onto the APSIM web site (www.apsim-help.tag.csiro.au). These applications can be classified into eight categories, namely crop management, water balance, climate impacts, cropping systems, species interactions, land use studies, soil impacts (erosion, acidity and nitrate leaching).

Closing the loop between development and application

Testing simulation models in realm of science has typically involved an assessment of how well they simulate measured experimental data and how plausibly they represent system behaviour in normative scenario applications targeted at exploring what land managers should do to improve system performance—the preceding sections provide numerous references to the scientific testing of APSIM. The question remains, however, as to how well simulation models perform in relation to real-world agriculture.

Distribution policy

APSIM distribution is managed via a licence system that protects the integrity of the product, meets the legal liability requirements of our institutions and enables an orderly development pathway. Many large modelling efforts in the agricultural research community have been devalued by uncontrolled model evolution that has led to multiple versions of unknown pedigree.

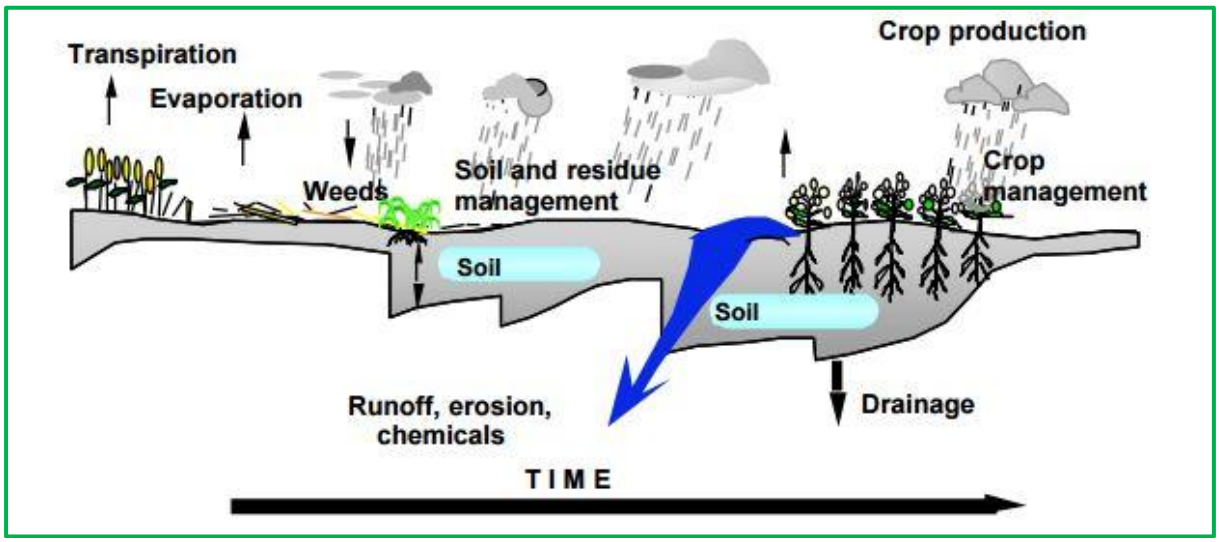

Figure 1: A diagrammatic view of the problem domain addressed by APSIM

Access and commercialisation

In recent years, APSRU has sought commercial partners to aid in delivery of model capabilities and tools to farmers and advisers. The Birchip Cropping Group (BCG) and NutrientMS, jointly with APSRU, are responsible for developing and deploying tools and outputs, based on APSIM, directly to consultants and growers. These companies are experienced in the distribution and marketing of agronomic products and services to the rural sector. As well as providing a revenue stream, this separation of model delivery from development frees up time of modellers and scientists for further research and development of APSIM. In addition to developing commercial licensing agreements, general access to APSIM has changed significantly in recent years. As APSRU moves into a more focussed delivery phase, APSIM's access policy has also changed to be more open and to make APSIM available to all interested users. For more information see www.apsru.gov.au. Whilst APSRU does charge a fee for APSIM to cover ongoing development, it does provide full source code for all modules on www.apsim.info. This provides a degree of transparency for APSIM modules that helps alleviate user's concerns that they are using a 'black box'. While APSRU has sought to deliver its technology predominantly by the commercial route, we also recognise the importance of contributing to the public good. This is achieved through developing good science, often in collaborative arrangements with other research groups, our contribution to education, and by ultimately delivering a product that will assist the operation of profitable farm and rural enterprises and contribute to a better environment.

Conclusion

While APSIM is primarily aimed at researchers, an increasing number of derived products have been developed. Adoption by commercial partners is also increasing and it is through these arrangements that consultants and growers who have no prior modelling experience can evaluate a large range of alternative crop and fallow management options. A large international breeding company is also using APSIM to evaluate alternative breeding strategies for maize. The fact that APSIM is in high demand today demonstrates that it is relevant, useful, and stable. These are all key indicators that APSRU's development strategy is sound. APSRU's experience in developing APSIM, like the process outlined in this paper, has been evolutionary. While APSIM has largely achieved the stated purposes, this has required a substantial investment in the underpinning, strategic infrastructure for model development (estimated costs so far exceed US $ 15 million) that was not without challenges. Not only was it necessary to secure the necessary funds on an on-going basis, it also caused frustration when development did not proceed at the desired speed. Although such tensions will always exist, the approach has evolved into a well designed, structured, and disciplined process. The APSRU group now numbers approximately 80 individuals, most of them contributors to APSIM in some way. It has become a core technology to investigate current and future issues in agricultural and environmental sciences and practice, while providing a vast depository of knowledge, bridging several disciplinary divides. APSIM applications have contributed demonstrably to change in farming practices, particularly in Australia. Given the rapid changes that are currently taking place in rural industries (driven by economic as well as environmental factors such as climate change), the importance of APSIM as a quantitative, predictive tool for scenario development and evaluation is likely to increase.

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