A New Generation of APSIM

Dean Holzworth[1], Neil Huth[1] and Drew Holzworth[2]

[1] CSIRO, PO Box 102, Toowoomba, QLD 4350, Email: www.apsim.info, Dean.Holzworth@csiro.au
[2] APSIM Initiative, PO Box 102, Toowoomba, QLD 4350, Email:www.apsim.info

Abstract
From its inception in 1990, the Agricultural Production Systems sIMulator (APSIM) has grown from a small, field focused framework used by a small number of users into a framework used by many to simulate a farming system at various scales (plant, gene expression, field, farm, region, continent, global). During this time, computer hardware, software and the rise of the internet and smart phones have fundamentally changed the software development landscape. APSIM's software needed to meet these evolving requirements so in 2014, development began on modernising the framework and the associated software development processes, to better meet the needs of users and developers. This talk presents the current status of APSIM Next Generation.

Keywords
Agricultural model, farming system model, simulation.

Introduction

APSIM (Holzworth et al., 2014) is a farming systems modelling framework capable of simulating a diverse range of farming systems. At its inception in the early 1990s, APSIM was a point-based model with a small number of crop and soil models that were used to explore land management decisions at the field level. Since this time, it has greatly expanded its scope to contain biophysical models that allow a broad range of simulation studies (Holzworth et al., 2018):

- investigate agricultural soil sustainability processes,
- model horticultural cropping systems,
- model agroforestry systems,
- evaluate resource use and efficiency,
- evaluate environmental characterisation,
- provide farmer advice,
- perform yield gap assessments,
- inform plant breeding programs,
- conduct hypothetical trait modification,
- conduct climate change and adaptation analyses,
- understand the drivers of production and environmental effects of grazing systems,
- understand the interactions between livestock and mixed crop-livestock enterprises,
- conduct whole farm modelling analyses,
- investigate biotic and abiotic system constraints,
- conduct global, continental and sub-continental scale analyses.

At the scope of APSIM was broadening, the computing landscape underwent significant changes. Programming languages and tools changed and became much more capable, mobile smart phones were invented, the internet was invented and became a way of life. By 2014 it was clear that APSIM needed to pivot to meet these new demands. A new generation of APSIM was created to provide tools to let users more effectively conduct their simulations studies, provide a Plant Modelling Framework (PMF) (Brown et al., 2014) to make it easier to build plant models and provide a modern software environment that makes it easier to maintain the APSIM source code.

Description of APSIM Next Generation

To improve the user experience and model reliability of APSIM, many existing capabilities were enhanced.

- Model documentation is automatically generated by merging the source code with the model description and validations. This produces a PDF document that is somewhat similar to a journal or conference article. This documentation is updated every time a change is made to APSIM. The documentation can be found here: https://apsimnextgeneration.netlify.app/modeldocumentation
- All models are validated against observed data and their validations are published as part of their documentation at the above link.
- All source code is open source and available on GitHub for non-commercial use (https://github.com/APSIMInitiative/ApsimX). GitHub is also used as a collaboration platform allowing users to ask questions and post defects.
- The development team use continuous integration where a change to source or configuration files automatically triggers a rebuild of APSIM and a rerun of the testing system. The criteria for acceptance of a change is an improvement in RMSE, NSE and RSR. Should one or more of these statistics be adversely impacted by the change then the onus is on the developer to provide an explanation on why the change should be incorporated into the release. This process protects against unwanted and unexpected changes in model performance / output.
- Execution speed has always been an issue for users running APSIM on large numbers of points (global, continent scale). APSIM Next Generation is approximately 10 times quicker than APSIM 7.10. A continuous wheat simulation running for 100 years takes 4 seconds in APSIM Next Generation vs 40 seconds in APSIM 7.10.
- The user interface is cross platform and will run natively on Windows, Linux and Mac OS.
- Manager scripts are written by users in C# which provides much greater flexibility (e.g. classes, methods, properties, looping etc).

Plant Modelling Framework (PMF)

To improve the transparency of model development and reduce development time, the PMF was created to allow developers to construct a plant model visually using drag and drop, from the user interface. Developers can define the processes to use and their parameterisation by changing the shape of functions and how the functions combine to make up larger process. Figure 1 shows the developer modifying the XY pairs of an RUE temperature modifier in the wheat photosynthesis process.

Figure 1. This figure shows the temperature factor (FT) of the wheat photosynthesis model in the GUI.

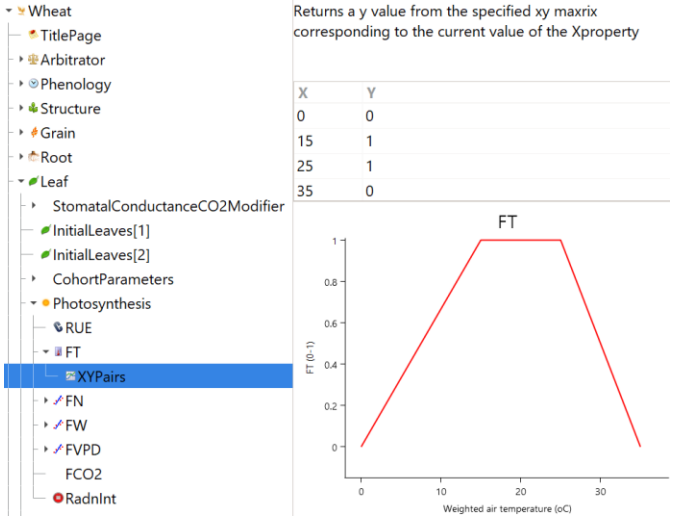

Table 1. Current list of models in APSIM Next Generation (as at August 2021).

Model name	Model Description
AgPasture	Simulates Ryegrass and White Clover. Prototypes: Browntop, Cocksfoot, Kikuyu, Lucerne, Paspalum, Phalaris, Red clover, Rhodes grass, Tall fescue.
Agroforestry	Simulates tree-crop and silvopastoral systems. This model does not simulate tree production. Instead it calculates tree-crop interactions (microclimate/soil effects).
Barley	Built using the PMF.
Chicory	Built using the PMF, this model simulates the perennial herb Chicory (*Cichorium intybus* L.).
Chickpea	Built using the PMF.
Eucalyptus	The Eucalyptus model was calibrated on datasets of three species (*E. globulus, E. saligna, E. grandis*), one hybrid (*E. grandis x E. urophylla*), and two clones of this hybrid.
Fodderbeet	Built using the PMF.
Maize	Built using the PMF.
MicroClimate	Allows the calculation of potential transpiration for multiple, competing canopies that can be either layered or intermingled
Nutrient	This model simulates pools of organic matter and mineral nitrogen.
Oats	Built using the PMF, this model builds upon an earlier APSIM Oats model that was constructed in 2007.
OilPalm	This model is configured to match commercial dura x pisifera. Other varieties are specified in terms of how they differ from this base variety.
Plantain	Built using the PMF, this model simulates Plantain (*Plantago lanceolata*), also known as English plantain, ribgrass or ribwort.
Potato	Built using the PMF.
RedClover	Built using the PMF, this model simulates Red Clover (*Trifolium pratense*), an herbaceous perennial herb in the Fabaceae family.
SCRUM	The Simple Crop Resource Uptake Model simulates a range of crops where water and nitrogen are of interest, but a fully mechanistic model is not needed.
Slurp	Built using the PMF, this model provides a simple representation of crops. The model does not predict growth, development or yield. It takes up water / nitrogen.
SoilArbitrator	This model arbitrates the below ground resources of water and nitrogen.
SoilWater	This model is a cascading water balance model.
Soybean	Built using the PMF.
Stock	The Stock model is an implementation of the CSIRO's Australian Feeding Standards as expressed in the Grazplan (https://grazplan.csiro.au) model.
Sugarcane	A direct port of the sugarcane model in APSIM 7.10.
Wheat	Built using the PMF.
WhiteClover	Built using the PMF, this model simulates White Clover (*Trifolium repens*).

Discussion

APSIM Next Generation has been released for several years and is being used in many projects. Almost all development effort is in APSIM Next Generation and not APSIM 7.10.

The PMF has allowed 6 non-software developers to create models for APSIM Next Generation without a need to write source code. This has the benefit of distributing the work of building models beyond the software team. In our experience, the model builders still need support and guidance but once they understand the design paradigm, they can readily construct a model. A word of caution though. Building a plant model requires a particular skill set including a good agronomic background, an understanding of how model processes work together and the level of detail that is required. A good experimental data set is also a fundamental requirement for building a model and often this is limiting factor. While we have solved the software challenges of building a model, there is still a steep learning curve for how to 'become a model builder'. The tools provide almost infinite flexibility to describe and parameterise model processes and this leads to a tendency to over-specify a model, incorporating unneeded complexity and over parameterisation. Graeme Hammer has produced a YouTube video that discusses these issues. It is titled "The nature of crop models (and modellers) needed to advance crop adaptation and improvement" - https://www.youtube.com/watch?v=6yfqUOCrUCk.

Currently there is no timeframe or roadmap on when new models will be added to APSIM Next Generation. They are typically added on an as needed basis or when a model builder is contracted to build a model. For this reason, some models in APSIM 7.10 may never be migrated, particularly the models that get very little use.

Conclusion

APSIM Next Generation is recommended for use where APSIM has the required models - see Table 1 for a list of released models. New models are being continuously added, for example, in the next 6 to 12 months, models for peanut, sorghum, pinus, canola, and SWIM will be released. Our recommendation is that if a project can use APSIM Next Generation then it should do so. We also suggest that the model documentation page (https://apsimnextgeneration.netlify.app/modeldocumentation) be visited from time to time to determine the current list of released models.

Acknowledgements

Acknowledgment is made to the APSIM Initiative which takes responsibility for quality assurance and a structured innovation programme for APSIM's modelling software, which is provided free for research and development use (see www.apsim.info for details).

References

Brown, H.E., N.I. Huth, D.P. Holzworth, E.I. Teixeira, R.F. Zyskowski, et al. 2014. Plant Modelling Framework: Software for building and running crop models on the APSIM platform. Environ. Model. Softw. 62: 385–398. doi: 10.1016/j.envsoft.2014.09.005.

Holzworth, D.P., N.I. Huth, P.G. deVoil, E.J. Zurcher, N.I. Herrmann, et al. 2014. APSIM - Evolution towards a new generation of agricultural systems simulation. Environ. Model. Softw. 62: 327–350. doi: 10.1016/j.envsoft.2014.07.009.

Holzworth, D., N.I. Huth, J. Fainges, H. Brown, E. Zurcher, et al. 2018. APSIM Next Generation: Overcoming challenges in modernising a farming systems model. Environ. Model. Softw. 103: 43–51. doi: 10.1016/j.envsoft.2018.02.002.