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Modelling orchard systems in APSIM

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Abstract:

Orchard systems comprising of a row of trees and an adjoining grass alley can be simulated in APSIM using newly released generic fruit tree and pasture sward models that were developed specifically for this purpose. The Simple Tree Resource Uptake Model (STRUM) and the Simple Pasture Resource Uptake Model (SPRUM) each have a user interface component requiring operators to set parameters to represent key fruit tree and pasture sward characteristics. APSIM infrastructure for configuring zones and arbitrating resource competition enables simulations where the tree canopy partially shades the alley understory and their roots compete with alley vegetation for water and nitrogen uptake.

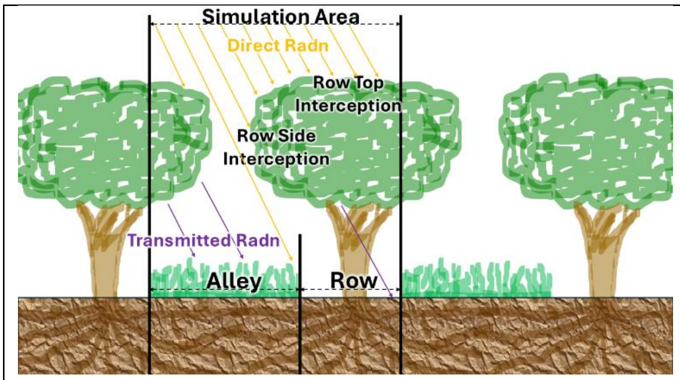
Keywords: *Perennial, Fruit, Row crops, APSIM, STRUM, SPRUM*

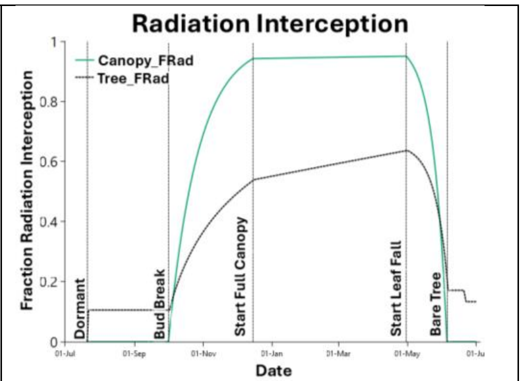
1. INTRODUCTION

APSIM is widely used globally for simulating annual cropping and pastoral farm systems. However, it has had limited application in the simulation of perennial fruit production systems. This is due to a lack of models for fruit tree species and challenges in representing the typical tree row and grass alley structure used in an orchard. A strip crop light interception model has been included in APSIM that accounts for the shading of shorter species in one strip by taller species in the adjoining strip. A model has also been added for simulating grape vines (Zhu et al. 2021) and this has been used with the strip crop light interception model to represent a row and alley vineyard system. To simulate other orchard systems we needed: more models for different kinds of fruit trees; a simple and reliable way to simulate the alley vegetation; and modifications to the strip crop light interception model to account for orchard systems where the tree canopy over-laps the grass alley in between. This abstract describes these additions.

2. THE STRUM MODEL

The Simple Tree Resource Uptake Model (STRUM) follows similar design principals as the Simple Crop Resource Uptake Model (Khaembah et al. 2023). Parameters that users must provide are demarked with bold italics. Canopy development is modelled between phenological stages (see figure): ***Bud Break Date*** when LAI expands as a linear function of time until reaching ***Start Full Canopy Date***. LAI remains at its maximum until ***Start Leaf Fall Date*** and then declines until ***Bare Tree Date***. ***Maximum LAI*** and ***Winter LAI*** can be set to represent both deciduous and evergreen trees.





A. Schematic representation of an orchard row and alley system.	B. Seasonal patterns of canopy development.

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Root depth increases with the age of the orchard until ***maximum root depth*** but presence of roots in the neighbouring zone is a user setting. Potential biomass production is predicted using a radiation use efficiency (***RUE***) model and ***temperature sensitivity*** parameters. Potential fruit growth is predicted from ***maximum fruit size***, ***fruit load*** and the ***timing of fruit development***. Fruit size may not reach potential if the crop encounters any stress (water or nitrogen) or if fruit demand exceeds the biomass production calculated by the RUE model. The ***age of the orchard at establishment*** and the ***number of years to reach mature size*** are used to determine annual increases in tree dimensions. Parameters for ***maximum*** and ***pruned height*** and ***width*** are used to predict seasonal changes in dimensions. ***Nitrogen content*** of each organ (leaf, trunk, fruit and root) are used to calculate N demands and ***canopy conductance*** parameters are used to calculate transpiration demand. This is a relatively simple plant model but is flexible and may be parameterised to be used for a range of different fruit tree crops in APSIM simulations.

3. THE SPRUM MODEL

The Simple Pasture Resource Uptake Model (SPRUM) also follows simple plant model design principles and was structured to represent the vegetation in an orchard alley with a minimum of user set up required. Its phenology consists of a regrowth phase (when cover is increasing from a ***post defoliation cover*** to a ***maximum cover***), a full canopy phase and a rewind phase which automatically returns the phenology to the start of the regrowth phase. Users set the ***thermal time duration of the first two phases*** to give sensible patterns of canopy development between defoliation events. Having the model rewind its phenology automatically means there is no need for manager modules to control defoliations. Potential productivity of the pasture is determined by the ***RUE*** and ***temperature sensitivities*** and potential nitrogen fixation is determined by the ***proportion legume*** parameter. The model consists of a leaf model that intercepts radiation and represents the part of the crop removed by defoliation; a residue organ that represents biomass not removed by defoliation, a root model that interfaces with the soil and a nodule organ that has no biomass but fixes nitrogen if the ***proportion legume*** parameter is greater than one. A biomass removal model must be included in simulations to specify what proportion of leaf is removed and added to surface organic matter each time the pasture defoliates. SPRUM was designed to provide a convenient way to model orchard alley biomass but is also useful in other applications where a simple representation of a pasture is required.

4. SIMULATING A ROW AND ALLEY SYSTEMS

The microclimate model arbitrates partitioning of light between multiple plant canopies. Radiation interception is modelled by treating the tree canopy as a cube. The proportion of radiation that would be intercepted by this cube is calculated, firstly assuming it is a black body and radiation is diffuse, then transmission through the cube is calculated based on the fractional radiation interception of the canopy (based on LAI and ***extinction coefficient***). Radiation that is not captured by the tree canopy is then partitioned between the row and alley understories. The STRUM canopy intercepts radiation with both green leaves (which drives photosynthesis and transpiration) and trunk area (which shades the understory). An example of a typical seasonal pattern of radiation interception is shown in figure B. When the tree has no green leaves it is intercepting a small proportion of the total radiation over the simulation area (Tree_FRad, as shown by the black line). At bud break, the leaf area starts expanding and the fractional radiation interception of the green canopy increases (Canopy_FRad as shown by the green line). Canopy_FRad remains constant from the start of full canopy until the start of leaf fall but Tree_FRad continues to increase during this time as the trees height and width increases and it captures more of the total radiation.

APSIM's soil arbitrator model deals with competition for water and nitrogen uptake. STRUM can be initialised with roots growing into the alley zone so it will access resources from both the row and alley zones. The amount of resources, available in each zone depends on the soil water and nitrogen content, and the size of each zone.

5. REFERENCES

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