Trees now part of a global crop modeling framework (APSIM)

Authors:

Philip Smethurst[1], Neil Huth[1], Patricia Masikati[2], Justin Fainges[1], Catherine Muthuri[2] and Fergus Sinclair[2]
[1] CSIRO; [2] ICRAF

Until now global models of crop production have ignored trees, despite significant tree cover on much of the world's agricultural land. This is now changing thanks to a new tree-crop modeling initiative. ICRAF and partners in the ACIAR-funded project 'Trees-for-Food Security' have just published a landmark paper reviewing the modeling of tree-crop interactions at field scale (Luedeling et al 2016).

This evaluated well known agroforestry models, including ICRAF's WaNuLCAS (Water, Nutrient and Light Capture in Agroforestry Systems) and identified critical gaps in existing capabilities that compromise our ability to make accurate predictions of tree and crop growth and yield, and hence how trees impact food security.

The modelling framework of the Agricultural Production Systems Simulator (APSIM) already has these features, so adding agroforestry trees to it has allowed us to build on previous achievements. A new version of this Australian software (APSIM Next Generation) now includes an agroforestry model that can simulate crop and pasture production as affected by several important tree-crop interactions, including:

(1) Long-term effects of N-fixation by trees and herbaceous legumes in the soil,
(2) Effects of above-ground tree litter inputs for C and N cycling,
(3) Rain and light shading effects of trees
(4) Root competition for water and N
(5) Reduced population density of crops near trees

Maize under Cordia Africana. Bako, Ethiopia. Photo: Catherine Muthuri.

The model simulates crop or pasture production in zones at user-specified distances away from a tree. A simple sub-model is provided that allows the user to input some characteristics of trees that enables interactions with crops or pasture to be explored. A fully functional tree model that includes wood production, will be a focus in

2016 as the project works towards producing one or more active models for trees, like those currently available for crops, that will enable more dynamic modeling of tree-crop interactions as both trees and the crops grow. Already models of wheat, maize, and potatoes are available, and a teff model is also being developed for Ethiopia. These models will become freely available to anyone accessing APSIM, and the suite of crop, pasture and tree models is expected to expand significantly during the next few years.

Model development has drawn heavily on datasets developed by ICRAF over the past few decades, principally involving measurements of grevillea and gliricidia intercropped with maize at the Machakos experimental station in Kenya. This represents significant value-addition to earlier research. These datasets, supplemented by Australian experience and modeling expertise, have allowed us to model the interactions listed above and their net outcome on crop yields in particular settings. Net outcomes vary depending on soils and climate as well as tree and crop genetics and the management of the trees, crops and soil.

Australian Government
Australian Centre for International Agricultural Research

Initial simulations illustrating short-term effects of competition from fast growing trees for limited water or nutrients agree well with measurements. Model predictions of the effect of a eucalypt windbreak on wheat in Warra, Australia reflect observations of a 0-20 m zone of water competition (Fig. 1) in which wheat germination failed or water stress retarded crop development. Reduced crop germination and growth out to about 6 m from the shrubs in alley cropping practices involving grevillea and gliricidia observed at Machakos were also adequately simulated (Fig. 2). Longer term benefits from trees are evident where N-fixing gliricidia boosts maize yields after about two years in Machakos, and higher wheat yields occur under large trees because of reduced exposure to high-temperatures.

This project is funded by ACIAR and the CGIAR Forests, Trees and Agroforestry Research Programme, and led by the World Agroforestry Centre (ICRAF) in collaboration with CSIRO, World Vision, CIMMYT, and national agricultural research partners in Ethiopia, Rwanda, Burundi and Uganda. Model development is led by CSIRO.

(Photo: Neil Huth)

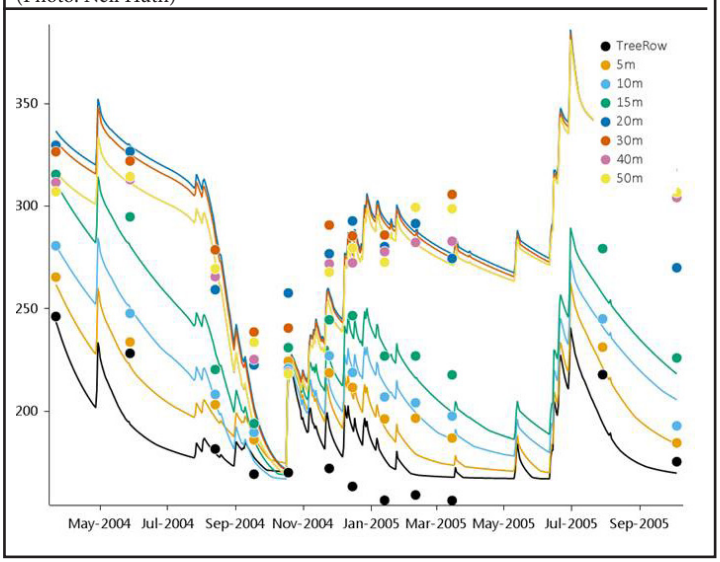

Figure 1. Top: experiment at Warra, Australia, showing a wheat-free competition zone due to failed germination or growth adjacent to a windbreak of eucalypt trees. Bottom: observed soil water content in relation to distance from the tree row (Huth 2010), compared to a screen-shot of APSIM-simulated values.

(Reproduced from Broadhead JS (2000) Ecophysiology of Indigenous Trees in Agroforestry Systems in the Semi-Arid Tropics. PhD Thesis, Univ. Nottingham, UK.)

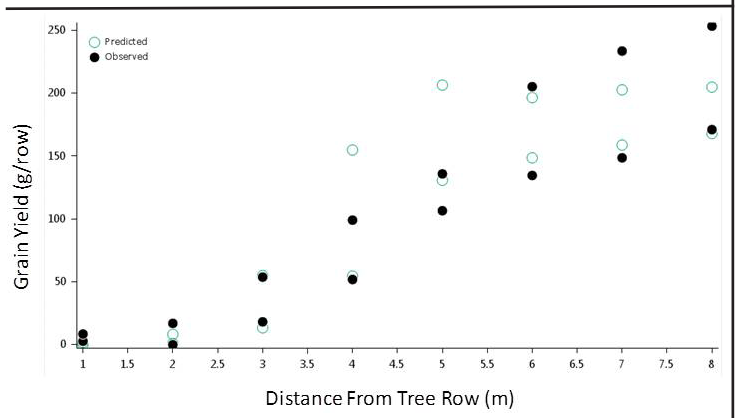

Figure 2. Top: Experiment at Machakos showing several plots of crop with or without trees (grevilliea and others) or gliricidia shrubs (foreground). Bottom: Observed maize grain yields in 1996 and 1997 in relation to distance from the a row of gliricidia shrubs (Odhiambo et al 2001), compared to a screen-shot of APSIM-simulated yields.

References:
Huth NI (2010) Measuring, modelling and managing tradeoffs in low rainfall agroforestry for Australia's subtropics. PhD Thesis, Univ. Queensland.
Odhiambo HO, Ong CK, Deans JD, Wilson J, Khan AAH, Sprent JI (2001) Roots, soil water and crop yield: tree crop interactions in a semi-arid agroforestry system in Kenya. Plant and Soil, 235(2), 221-233.
Eike Luedeling, Philip J. Smethurst, Frédéric Baudron, Jules Bayala, Neil I. Huth, Meine van Noordwijk, Chin K. Ong, Rachmat Mulia, Betha Lusiana, Catherine Muthuri, Fergus L. Sinclair (2016). Field-scale modeling of tree–crop interactions: Challenges and development needs: Agricultural Systems 142 (2016) 51-69.
http://www.sciencedirect.com/science/article/pii/S0308521X15300457