Plot-Scale Biophysical Modelling of Tree-Crop Interactions Using APSIM

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Background

- Demand for predictability of wood, food and livelihood outcomes of agroforestry options prompts a need to incorporate trees into plot-scale-biophysical and farm-scale livelihood models.
- The ICRAF project 'Scaling Trees for Food Security' aims to develop and apply this capability, and make it available for further use.
- The APSIM modelling framework was chosen for plot-scale-biophysical modelling because of its use in various contexts of food production around the world.
- However, this model lacked a two dimensional capability that could grow adjacent crops and trees interacting above- and below-ground.

Objectives

The project is developing, applying and making available this capability to provide:

- an agroforestry model using a proxy tree (user-defined shading, root distribution and density, water demand, and N demand)
- active tree models (i.e. tree counterpart to crop models in APSIM), and
- an agroforestry model using these active tree models.

Methods

- Develop these models within the APSIM Next Generation framework (www.apsim.info), which uses modern software technologies (Holzworth et al. 2018)
- Phase 1 involves a proxy tree model used in linear (tree row) or circular (single tree or parkland) configurations in which tree behaviour in relation to competition for light, water and N was highly user-defined.
- Phase 2 involves replacing the tree proxy with 'active' tree model options that respond to environment, management and genotype (as for any crop or pasture model in APSIM).
- Novel aspects for agroforestry modelling in APSIM includes light modelling for alley systems, nutrient uptake based on mass-flow and diffusion principles, arbitration of C and N allocation to plant components, version control, auto-validation checking, auto-documentation, and model development methods for non-coders.
- Genotype models of most interest to the project are:
    - Trees: *Gliricidia sepium*, tropical and subtropical *Eucalyptus* genotypes, *Alnus accuminata, Faidherbia albida, Grevillea robusta, and Cordia africana*
    - Crops: maize, wheat, teff, potato, bush bean, and climbing bean

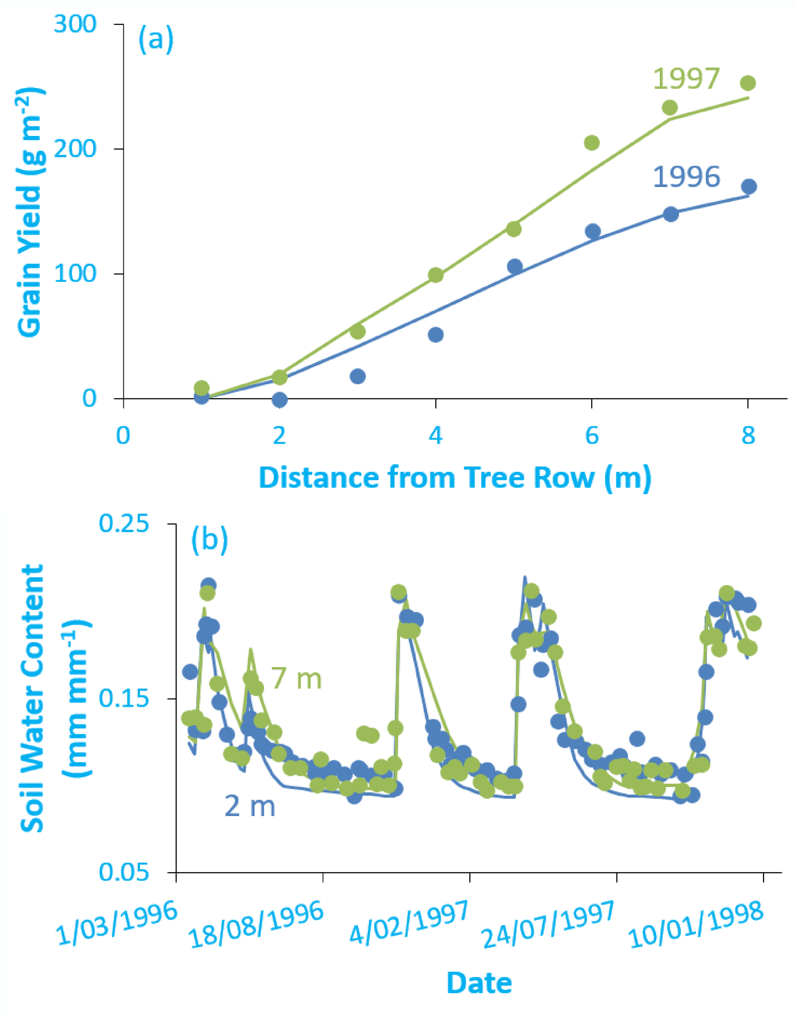


Fig. 1. (a) Observed and simulated maize grain yield and (b) soil water content (35 cm depth) in relation to distance from *Gliricidia* and date. Symbols = observations; lines = simulated.

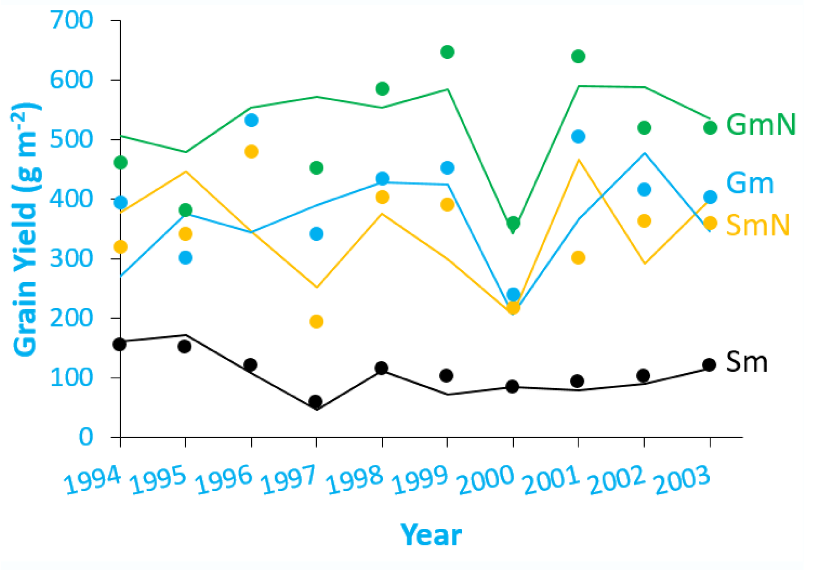
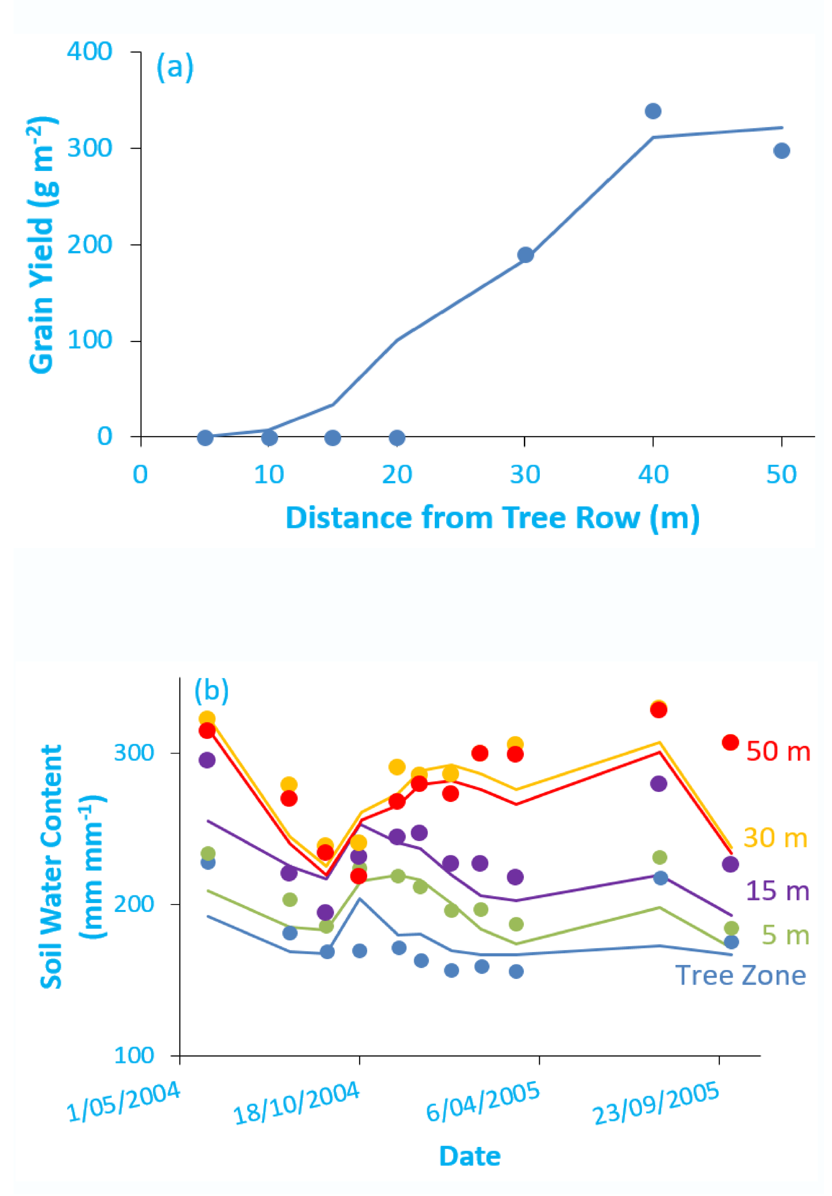


Fig. 2. Multi-year observed and simulated maize grain yield in factorial combinations of N fertiliser and *Gliricidia* (Sm = sole maize, Gm = *Gliricidia*-maize, N = N fertiliser; Symbols = observations; lines = simulated.)

Progress

- Eucalyptus, Gliricidia and oil palm are the tree models currently available within the project, along with wheat, maize, potato and several other crop or pasture models.
- During phase 1, adequate simulations in a range of contexts were achieved:
    - Gliricidia-Maize (Kenya and Malawi; row system; Smethurst et al. 2017, Figs. 1 and 2),
    - Eucalyptus-Wheat (Australia; row system; Fig. 3).
    - Faidherbia-Maize (Ethiopia; single-tree system; Dilla et al. 2018; Fig. 4)
- A current priority is to finalise (1) the tree proxy model (including release for public use) and to develop (2) the active tree capability, for which tree models have been developed for Eucalyptus (released), Gliricidia (prototype), and oil palm (released).
- Other useful capabilities envisaged for APSIM include sensitivity analysis, national or globally gridded simulations, other nutrients (e.g. P and K), livestock, and linkages to livelihood models.



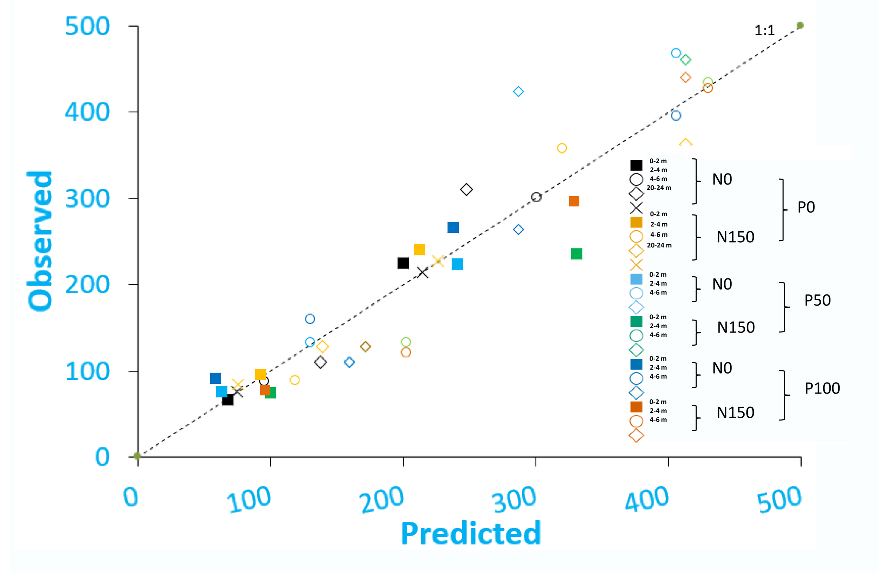


Fig. 3. (a) Observed and simulated wheat grain yield and (b) soil water content in relation to distance from *Eucalyptus* and date. Symbols = observations; lines = simulated.

Fig. 4. Two-year observed and simulated maize grain yield (g m^{-2}) in relation to distance from *Faidherbia*, N fertilisation (0 or 150 kg urea ha^{-1}), and pruning (P 0, 50 or 100%).

Conclusions

- Agroforestry tree-proxy modelling capabilities in APSIM are highly flexible and can be used to simulate many of the main effects of trees on food production in a wide range of contexts.
- Tree proxy models for row and single tree systems are available as prototypes.
- Development of the active-tree option will add the ability to simulate tree products.
- More tree models will be needed to fully utilise the active tree agroforestry model.

References

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