Negotiation-support toolkit for learning landscapes

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15 Water, nutrient and light capture in agroforestry systems (WaNuLCAS): at the plot level

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Water, Nutrient and Light Capture in Agroforestry Systems (WaNuLCAS) is a tree–crop–soil interactions model at plot level with daily time steps. The model simulates interactions between crops and trees in sharing and competing for aboveground resource, that is, light, and belowground resources, that is, nitrogen, phosphorous and water. The model can be used to assess the performance (production and profitability) of agroforestry systems under different management regimes with different spatial and temporal configurations.

Introduction

A focal point in assessing the performance of agroforestry systems is how trees and crops use resources of light, water and nutrients and at what point their interaction becomes competitive or complementary. Tree–crop–soil interactions occur both in space and time. Thus, in modelling agroforestry systems a balance should be maintained between dynamic processes and spatial patterns, between temporal and spatial aspects.

The WaNuLCAS model (van Noordwijk and Lusiana 1999, van Noordwijk et al 2004) was developed to deal with a wide range ofagroforestry systems: hedgerow intercropping on flat or sloping land; fallow–crop mosaics or isolated trees in parklands; with minimal parameter adjustments. The model was developed using the STELLA platform and based on physiology and above- and belowground architecture of trees and crops. Trees and crops interact and share resources (light, water and nutrients) (Figure 15.1) in four soil layers and four horizontal zones (Figure 15.2A). Their interactions are interpreted in different modules (Figure 15.2B).

Assessment of tree–crop interaction in different systems and practices such as agroforestry can be tested and analyzed directly in the field by establishing experiments but this requires a lot of time, labour and cost. The assessment is needed to manage trees and crops in order to maximize production and to minimize negative competition. WaNuLCAS can be used to overcome these limitations.

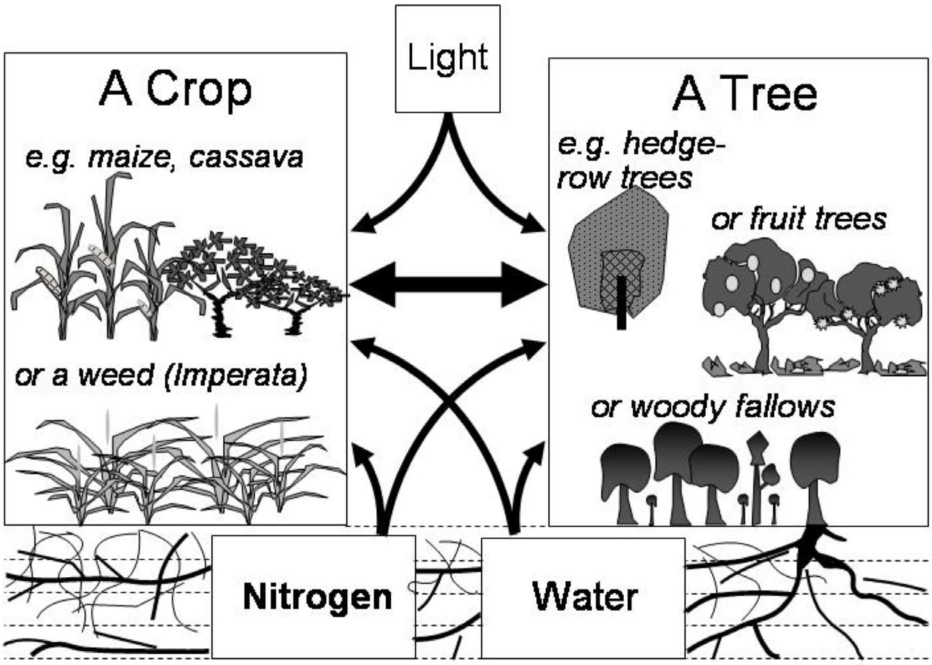

Figure 15.1. Components in WaNuLCAS

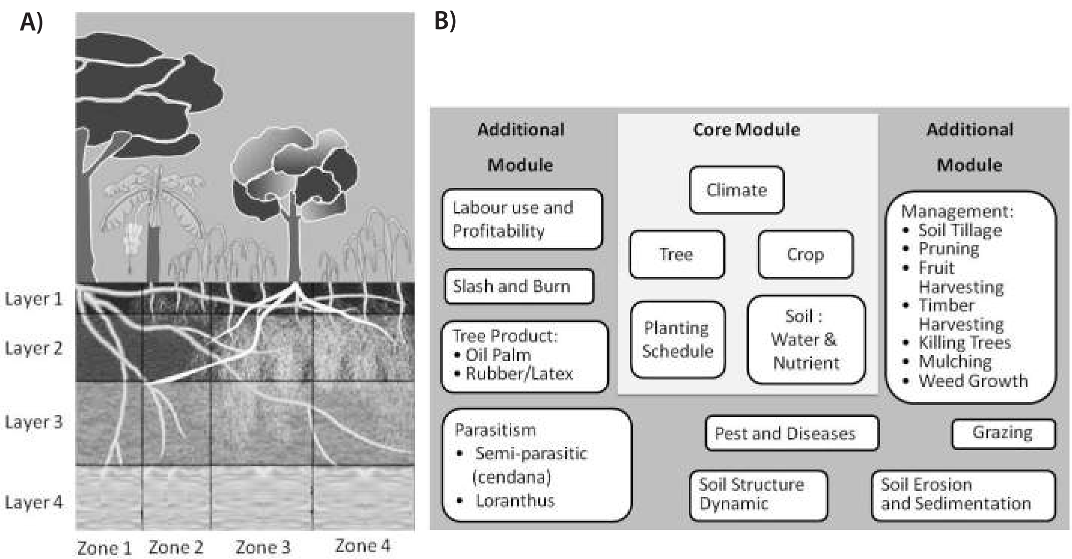

Figure 15.2. A) General layout of zones and soil layers in WaNuLCAS. B) Modules in WaNuLCAS that represent trees and crops sharing light, water and nutrient resources

Objectives

The objectives of WaNuLCAS are:

1. to explore new agroforestry practices before they are applied in the field;
2. to explore tree–crop interaction that cannot be done in the field.

Steps

Steps involved in WaNuLCAS application:

1. model parameterisation for calibration and validation test;
2. model calibration and validation;
3. model performance evaluation by comparing measured and simulated data; and
4. simulation of scenarios.

Example of application

In Indonesia, a decreasing forest area and a logging moratorium have seen timber production increasingly coming from smallholding systems. Inadaquate tree management in these systems has often led to low quality timber and hence low revenues for farmers. Researchers carried out ex-ante analysis with WaNuLCAS to explore the effect of different management practices on growth and production of intercropped teak and maize.

The study considered a three-treatment factorial: 1) initial teak density (1600 trees ha^{-1} (2.5 x 2.5 m), 1111 trees ha^{-1} (3 x 3 m) and 625 trees ha^{-1} (4 x 4 m)), 2) thinning (light (25%), moderate (50%) and heavy (75%) of tree density); and 3) pruning (40% and 60% of crown biomass). Researchers compared intercropping with both teak and maize monocultures to examine the trade-offs in different management options. An economic evaluation using profitability analysis was also carried out that took into account the cost of labour (for thinning and pruning) and its effect on additional timber revenue.

Result 1. Trade-off between trees and crops

Cumulative maize yield in the first years of teak growth was negatively correlated with tree density and 10–38% higher when tree density was reduced. All intercropping practices produced higher wood volume when compared with monoculture because the trees benefited from crop management and fertilization.

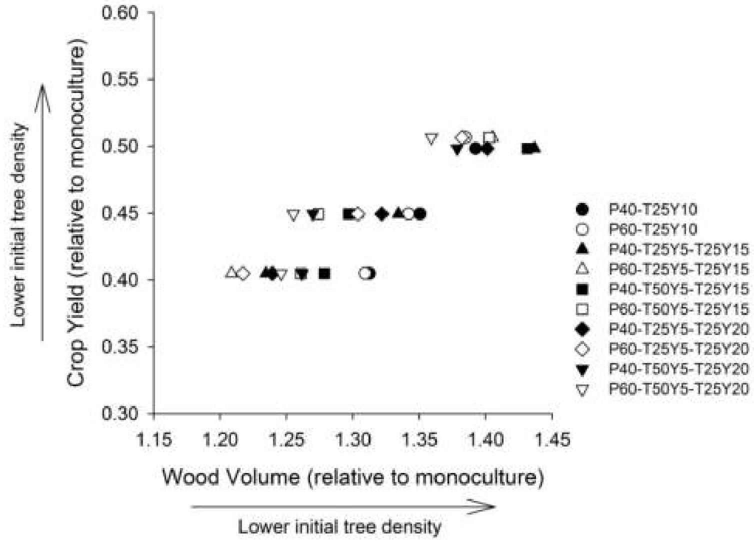

Figure 15.3. Trade-off analyses between tree and crop performance for various scenarios

Note: P: pruning, T: thinning, Y: Year; i.e P40-T25Y5-T25Y15: 40% crown pruned, thinning 25% at year 5 and 25% at year 15. Wood volume is the volume of remaining trees in field at year 30 (harvest time)

Result 2. Wood volume

Maximum wood volume (m^3 ha^{-1}) was provided by the system with initial tree density of 625 trees ha^{-1}: 25% of it was thinned at year 5 and another 25% at year 15; 40% of the crowns were pruned at years 4, 10 and 15. However, greater stem diameter per tree was provided by 50% of thinning at year 5 rather than 25% of thinning at year 5.

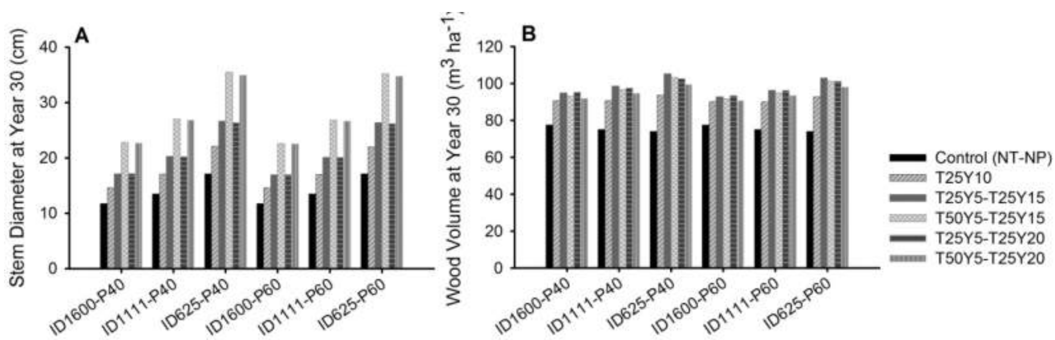

Figure 15.4. A) Wood volume, m3 ha^{-1}; and B) stem diameter, cm; presented at various treatments

Note: P: pruning, T: thinning, Y: Year, ID: initial tree density, i.e. T25Y5-T25Y15: thinning 25% at year 5 and 25% at year 15; ID1600-P40: initial density 1600 and 40% crown pruned. Wood volume is the volume of remaining trees in field at year 30 (harvest time)

Result 3. Economic analysis

The highest NPV and return to labour was provided by the system with initial tree density of 625 trees ha^{-1}: 50% of it was thinned at year 5 and another 25% at year 15; 40% of the crowns were pruned at years 4, 10 and 15.

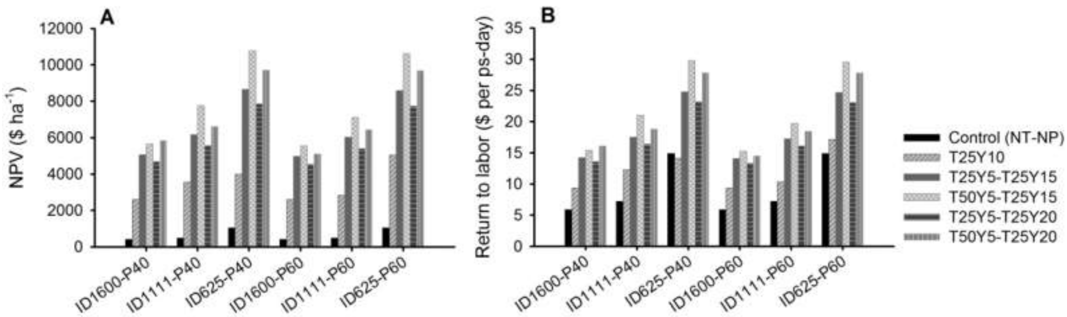

Figure 15.5. A) NPV; and B) return to labour; presented at various treatments

Note: P: pruning, T: thinning, Y: Year, ID: initial tree density, i.e. T25Y5-T25Y15: thinning 25% at year 5 and 25% at year 15; ID1600-P40: initial density 1600 and 40% crown pruned. Wood volume is the volume of remaining trees in field at year 30 (harvest time)

How to get WaNuLCAS?

WaNuLCAS can be downloaded from http://worldagroforestrycentre.org/regions/southeast_asia/resources/wanulcas.

Further reading

Khasanah N, Perdana A, Rahmanullah A, Manurung G, Roshetko J, van Noordwijk M, Lusiana B. 2013. *Trade-off analysis and economic valuation of intercropping teak (*Tectona grandis*)–maize under different silvicultural options in Gunung Kidul, West Java*. Paper presented at the Tropentag Conference 2013, 17–19 September 2013, Stuttgart-Hohenheim, Germany.

Van Noordwijk M, Lusiana B. 1999. WaNulCAS: a model of water, nutrient and light capture in agroforestry systems. *Agroforestry Systems* 43:217–242.

Van Noordwijk M, Lusiana B, Khasanah N, Mulia R. 2011. *WaNuLCAS version 4.0: Background on a model of water nutrient and light capture in agroforestry systems.* Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

The landscape scale is a meeting point for bottom–up local initiatives to secure and improve livelihoods from agriculture, agroforestry and forest management, and top–down concerns and incentives related to planetary boundaries to human resource use.

Sustainable development goals require a substantial change of direction from the past when economic growth was usually accompanied by environmental degradation, with the increase of atmospheric greenhouse gasses as a symptom, but also as an issue that needs to be managed as such.

In landscapes around the world, active learning takes place with experiments that involve changes in technology, farming systems, value chains, livelihoods' strategies and institutions. An overarching hypothesis that is being tested is:

> Investment in institutionalising rewards for the environmental services that are provided by multifunctional landscapes with trees is a cost-effective and fair way to reduce vulnerability of rural livelihoods to climate change and to avoid larger costs of specific 'adaptation' while enhancing carbon stocks in the landscape.

Such changes can't come overnight. A complex process of negotiations among stakeholders is usually needed. The divergence of knowledge and claims to knowledge is a major hurdle in the negotiation process.

The collection of tools—methods, approaches and computer models—presented here was shaped by over a decade of involvement in supporting such negotiations in landscapes where a lot is at stake. The tools are meant to support further learning and effectively sharing experience towards smarter landscape management.

World Agroforestry Centre
ASB Partnership for the Tropical Forest Margins
AARD
Federal Ministry for Economic Cooperation and Development
Norad
IFAD Enabling poor rural people to overcome poverty
CGIAR Research Program on Forests, Trees, and Agroforestry