Introduction to Agroforestry modeling

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ICRAF-SEA, Bogor, Indonesia

WaNuLCAS Model Training,
Hanoi – Vietnam, 9 – 13 July 2012
Do we need an agroforestry model?

If we would like to:

• Synthesize and integrate experimental and conceptual information as current understanding of how trees and crop component interact in complex systems – the model as a representation of the system - then YES

• Provide a reasonable null hypothesis about and extrapolate the results of tree-soil-crop-climate-management interaction that can be tested with field experiment – then YES

• Save money, energy, and time in looking for appropriate agroforestry design for our plots – then YES
Do we need an agroforestry model?

Examples of research questions that relate to tree-soil-crop interaction:

• What kind of tree and crop combination that should I cultivate in my agroforestry plots? Shallow-rooting crop and deep-rooting trees? Or any crop with less-shading tree?

• Will the growth in this mixed system better than in monoculture system? What about if I cultivate only crop without tree or tree without crop? Or should I combine the two with a certain distance or grouping?

• Can the growth and yield be increased through fertilization and/or irrigation? How much water and nutrient should I add to the plot to achieve good yield efficiently and effectively?

• Should I prune the tree canopy to obtain better crop yields? Should I do that before the start of each crop season?
Do we need an agroforestry model?

Research questions associated with **vulnerability** and **adaptation** and those associated with **climate change mitigation**
(http://www.worldagroforestrycentre.org/research/grp5_climate_change/research_questions)

A. **Vulnerability and adaptation to climate change**
   1. **The effect of climate change** - How will climate change affect water and nutrient availability and seasonal patterns, and how will these changes affect the productivity and stability of agroforestry systems at different scales (trees, farms, landscapes and river basins) – food security?
   2. **The affected location** - Where are the most vulnerable places and communities where agroforestry can be an effective strategy for climate change adaptation and mitigation?
   3. **The benefit of agroforestry** - How do agroforestry systems help farmers adapt to climate change, and how can the capacity of small farmers to adapt be improved? What tools and approaches are needed?
Climate change mitigation

1. **What are the costs and benefits of agroforestry carbon-sequestration projects** in different landscapes and what appropriate incentives can be applied to overcome constraints?

2. **What are the appropriate methods for measuring and attributing project impacts** including those affecting greenhouse gas sequestration, other environmental services, livelihoods and poverty?

3. What are the conditions regarding policies, institutions, communities and the private sector that enable the **wider application of pro-poor carbon-sequestration projects**? What models and standards can be employed?

4. **What are the trade-offs between different options?** What are the best combinations of trees and crops to maximize carbon sequestration and other benefits?
What agroforestry model do we need?

**Balance between ‘process’ and ‘pattern’. Generality. Accuracy**

- Balancing the complexity in modeling the soil-tree-crop interaction (‘*process*’) and spatial representation (‘*pattern*’)
- Spatial interaction (‘simultaneous’ agroforestry) and temporal interaction (‘sequential’)
- Spatial representation: simulation field 1D, 2D, or 3D
Specific or generic agroforestry model?

Many forms of agroforestry: a single model?
Specific or generic agroforestry model?

Looking for similarity between many forms of agroforestry systems

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Principal components in agroforestry systems

A Crop
- e.g. maize, cassava
- or a weed (Imperata)

A Tree
- e.g. hedge-row trees
- or fruit trees
- or woody fallows

Light

Nitrogen

Water

Soil
All plants are essentially the same..., but they differ in 2A & 2P

**Allometrics:**
Relationships between biomass, leaf & root area, stem diameter, etc.

**Architecture:**
Spatial distribution of leaf and root area, supported by stem and main roots

**Phenology:**
Response of development stage, litterfall and re-sprouting to environmental triggers and the internal biological clock

**Physiology:**
Response of allocation, architecture and/or phenology to internal stress factors and external triggers
All soils are essentially the same..., but they differ in:

**Soil properties:**
- Surface litter
- Soil structure
- Soil water
- Soil N
- Soil P
- Soil C

**Slope**

**Water capture**
- N capture
- P capture

**Initial stocks:**
- Water, N, P, C

**Soil physical properties:**
The way water is transported and redistributed after rainfall and the gradient required for getting it to the roots.

**Soil chemical properties:**
The way nutrients are adsorbed by and desorbed from the soil matrix and the gradient required for getting it to the roots.
All agricultural systems are essentially the same, but they differ in:

**Calendar of events:**
The timing of planting, pruning, weeding, harvesting, ploughing

**Use of external inputs:**
The amounts and types of organic and inorganic inputs

**Spatial complexity:**
The differentiation in zones with different components

**Management interventions:**
Rule-based interventions, triggered by conditions in the field
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Specific or generic agroforestry model?

All agricultural systems have the same outcomes, but they differ in:

- Sensitivity to: climatic and pest variability
- Sensitivity to: variability of prices
- Physical yields of useful products that can be obtained
- Labour and cash requirements for implementing the management interventions

Environmental impacts derived from (sub)surface flows of water, soil & nutrients, gaseous emissions and the C stocks on site
How good is our model?

Objective and Subjective judgment

Objective evaluation:
Statistical test of lack of fit to experimental dataset

Subjective evaluation:
• I think that the assumptions are reasonable
• I think that the structure represents the minimum complexity required for an ‘explanation’
• The results for a situation I know look plausible
• It can produce output in a form I like, on the basis of inputs which I understand and have available
• Generally, a model is sensitive to parameter setting and values
• A model is only a representation of a system that cannot include all factors affecting the output
• Due to these, we cannot use the model outputs as exact prediction as such, but rather using the model as an assistant to understand more about the components of and interaction in the system
• The outputs of a model can be used to design a new sensible hypothesis that is more feasible to test in the field – a model is a tool to design a sensible hypothesis
Examples of agroforestry models

Tree - soil – crop interactions

- SCUAF (Soil Changes Under Agro-Forestry)
- HYPAR (Hybrid forest model + Parch crop model)
- WaNuLCAS (Water, Nutrient & Light Capture in Agroforestry Systems)
- Hi-sAFe (Silvoarable Agroforestry For Europe)

Other interactions:

- Rubber AF - monkey model
- Tree/Imperata/Fire model - BEAM
- SEXI-FS (spatially explicit individual tree forest simulator)
- Tree-pasture-sheep (NZ)