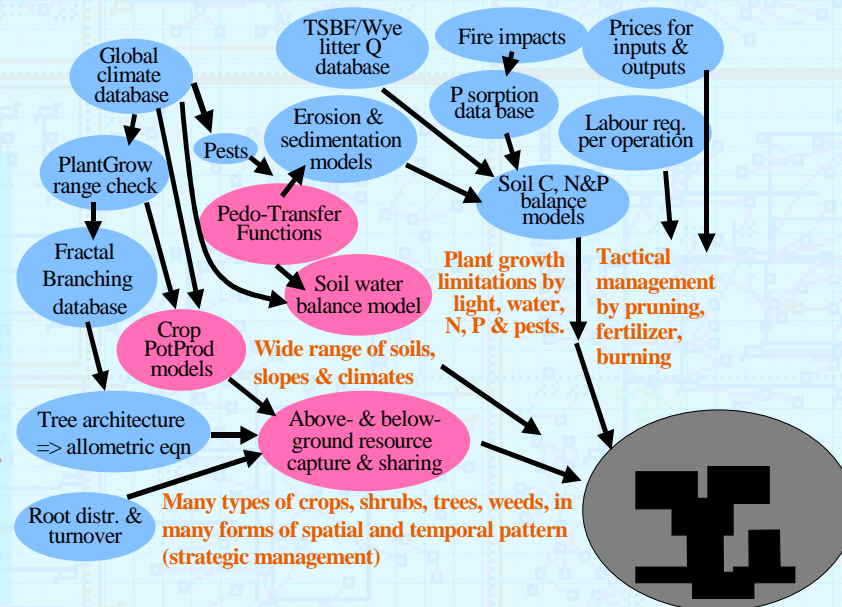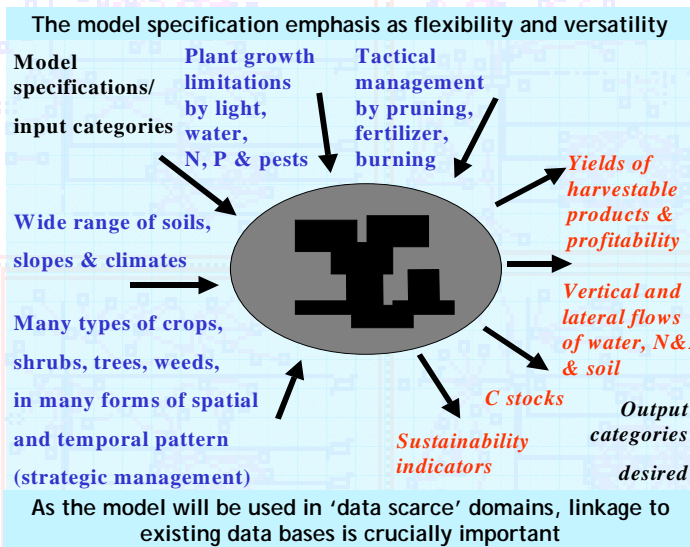# WaNuLCAS: a model of Water, Nutrient and Light Capture in Agroforestry Systems to evaluate Alternatives to Slash and Burn

M VAN NOORDWIJK, B LUSIANA and Q M KETTERINGS

ASB   ICRAF

Many forms of agroforestry, a single model?

WaNuLCAS was developed (using Stella) to represent tree-soil-crop interactions in a wide range of agroforestry systems where trees and crops overlap in space and/or time (simultaneous and sequential agroforestry). The model is based on above and below ground architecture of tree and crop, elementary tree and crop physiology and soil science (daily water, N, P and SOM balance for 4 soil layers and 4 horizontal zones). The model can provide a coherent way of evaluating sustainability indicators, C stocks and profitability for a range of land use systems, considered as 'alternatives to slash and burn'. A new module describes the effects of slash-and-burn land clearing on soil C, N and P transformations.

Slash and Burn

The model specification emphasis as flexibility and versatility

Model specifications/ input categories

Plant growth limitations by light, water, N, P & pests

Tactical management by pruning, fertilizer, burning

Wide range of soils, slopes & climates

Many types of crops, shrubs, trees, weeds, in many forms of spatial and temporal pattern (strategic management)

Yields of harvestable products & profitability

Vertical and lateral flows of water, N&P, & soil

C stocks

Sustainability indicators

Output categories desired

As the model will be used in 'data scarce' domains, linkage to existing data bases is crucially important

Global climate database — PlantGrow range check — Fractal Branching database — Crop PotProd models — Tree architecture => allometric eqn — Root distr. & turnover

TSBF/Wye litter Q database — Pests — Erosion & sedimentation models — Pedo-Transfer Functions — Soil water balance model — Above- & below-ground resource capture & sharing

Fire impacts — P sorption data base — Soil C, N&P balance models

Prices for inputs & outputs — Labour req. per operation

Plant growth limitations by light, water, N, P & pests.

Tactical management by pruning, fertilizer, burning

Wide range of soils, slopes & climates

Many types of crops, shrubs, trees, weeds, in many forms of spatial and temporal pattern (strategic management)
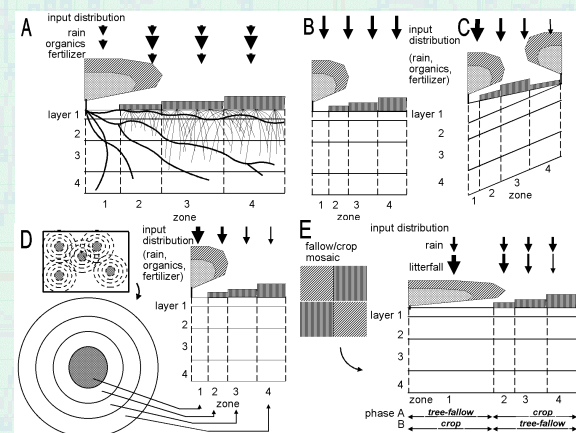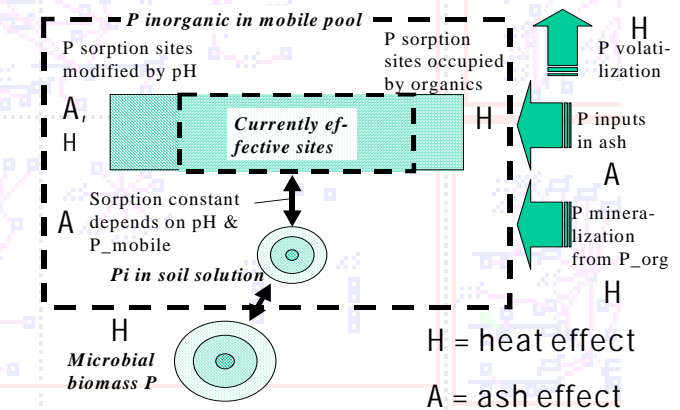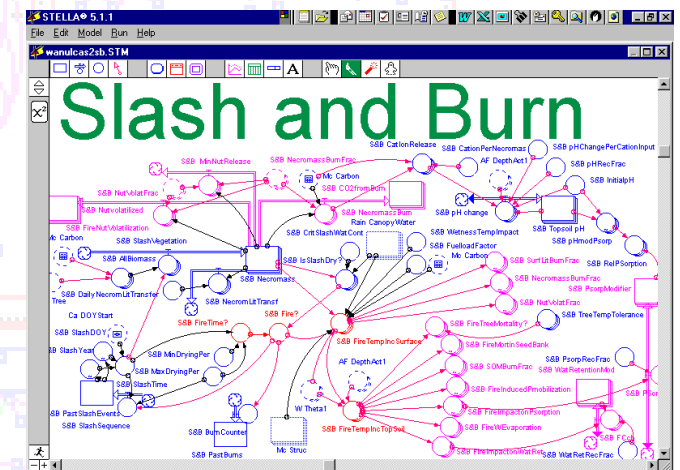
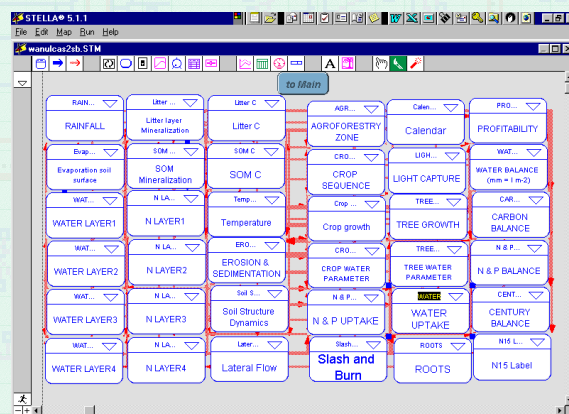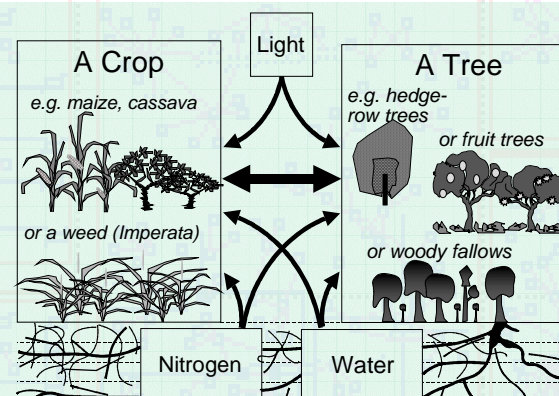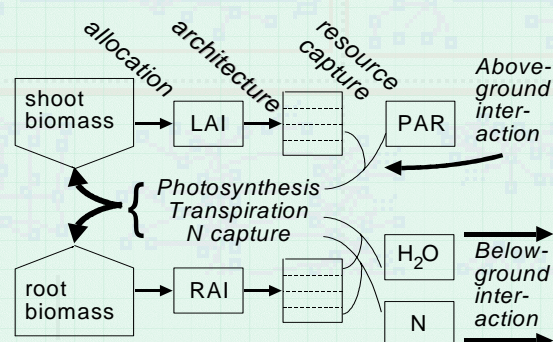### Representation of slash-and-burn events in WaNulcas

A number of 'Slash' events can be defined in the event calendar. Slash events transfer all current aboveground biomass in tree, weed or crop pools to the S&B_Necromass pool. From the S&B_Necromass a fraction can be transferred daily to the surface litter pool, where it will follow century-model based transformations of C, N and P pools. When the necromass has no intercepted water from rainfall the switch 'S&B_IsSlashDry?' will be turned on, allowing burn events to take place.

Burn events are defined by specifying a minimum number of days after the most recent 'slash' event. A fire event will be implemented on the first day in this period that the signal 'S&B_IsSlashDry?' is on. During a burn event, the temperature increase at the soil surface is calculated from the necromass + structural part of surface litter, with corrections for their respective moisture contents. The temperature increase in the topsoil is derived from the temperature increase at the soil surface, modified by soil water content of the topsoil. Burn events can have impacts on a number of pools in the model, either via the temperature at the soil surface or that in the top soil:

- reduction of surface necromass, surface litter and SOM pools,
- allocating all C of the burnt necromass to CO_2, and 1 - S&B_NutVolatFrac of its N and P content to mineral nutrients at the soil surface,
- induce a (one-off) transfer from the immobile P fraction in the topsoil
- induce a semi-permanent relative change of the effective P sorption with a gradual return to the original P sorption value,
- release cations into the topsoil from burnt necromass, leading to an increase of topsoil pH; this change of pH will modify the P sorption properties as well, with the overall effect obtained by multiplying the two factors,
- evaporate all soil water from the topsoil if the temperature exceeds $100^{o}C$
- modify soil water retention properties with a gradual return to the original values
- induce tree mortality if the temperature exceeds the temperature tolerance.

P inorganic in mobile pool

P sorption sites modified by pH

P sorption sites occupied by organics

Currently effective sites

Sorption constant depends on pH & P_mobile

Pi in soil solution

Microbial biomass P

H P volatilization
P inputs in ash
P mineralization from P_org

H = heat effect
A = ash effect

WaNuLCAS concepts of zones and layers

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

allocation — architecture — resource capture

shoot biomass — LAI — PAR

Above-ground inter-action

Photosynthesis Transpiration N capture

root biomass — RAI — H_2O — N

Below-ground inter-action

Sector map

Results for test runs of the Slash&Burn sector of the model show that different fuel load in different zones can lead to different effects on soil pH and contrasting net impacts on P sorption

Further parameterization of the model is obviously needed

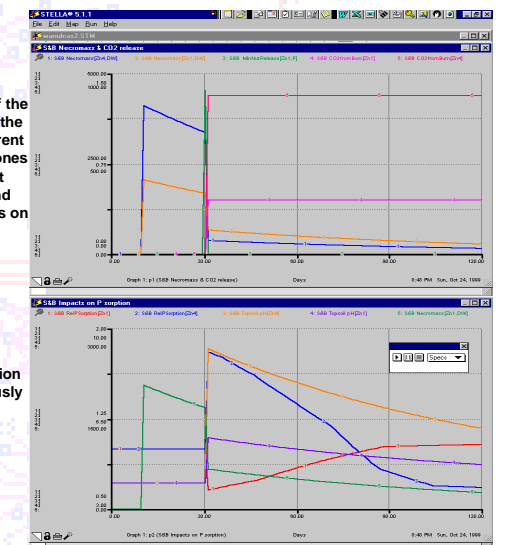| Concern	Global	Watershed functions	Sustainability	Profitability
Indicators	C stocks, GHG flux	Filter effects on H2O and soil flows	SOM, nutrient balance, weediness	Net present value, returns to labour
Land use system:				
tree crops in agroforestry arrangements				
contour hedge-row systems				
crop-fallow rotations (incl.S&B events)				

Can be simulated

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

For info on the WaNuLCAS model of water, nutrient and light capture in agroforestry system, please check: http://www.icsea.or.id/wanulcas/

For the 'crop down, fallow up' or CDFU model of fallow rotations at landscape scale: http://www.icsea.or.id/models/cdfu.htm.

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