Enhancing CropSyst for intercropping modeling

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Intercropping

• **Definition** of intercropping: *Growing two (or more) plant species simultaneously overlapping in space and time.*

• **Benefits:**
  • better use of the acreage of land
  • better nutrient use (efficiency)
  • commensalism/allelopathy (e.g. Push-Pull systems)
  • diversification (improved diet, reduction of production risk, improved soil protection/health)

• **Costs:**
  • competition
  • increased complexity
  • allelopathy

• **Some definitions:**
  • (effective) land equivalent ratio (LER)
  • relative yield totals (RYT)
  • ...

"The whole is greater than the sum of its parts!"
The importance of intercropping in sub-Saharan Africa

- Intercropping dominates in smallholder farming systems of SSA!

Napier-Desmodium, Tanzania

Maize-Cowpea, Zambia

Maize-Pigeon pea, Tanzania

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The importance of intercropping in sub-Saharan Africa

Push-Pull System, Kenya

Maize-Bean, Kenya
Intercropping in CropSyst

"As simple as possible, but not any simpler."

- 1D
- 2 crops with now distinct row arrangement (no alley cropping or wide bed&furrow systems with distinct 2D pattern)
- different planting dates possible (relay cropping)
- dominance of one species over the other may change over time (e.g. maize cow pea system)
- simulate the growth of these two species and the influence of competition
  - light,
  - water,
  - nitrogen
Light interception \((I)\)

\[ I = f \times PAR \]

\[ f = 1 - e^{-k \cdot LAI} \]

Three cases to consider:

1. Interception by the taller (T) species above the shorter species
2. Interception by the taller species within/below the shorter species
3. Interception of the shorter (S) species
Light interception \((I)\)

The PAR fraction intercepted by the upper canopy is:

\[
f_U = 1 - e^{-k_T \cdot LAI_U}
\]  

\text{eq. 3}

The PAR fraction intercepted by the taller species at the lower canopy is:

\[
f_{L_T} = \frac{LAI_{L_T} \cdot k_T}{LAI_{L_T} \cdot k_T + LAI_{L_S} \cdot k_S} \left[ 1 - e^{-\left(-LAI_{L_T} \cdot k_T - LAI_{L_S} \cdot k_S\right)} \right]
\]  

\text{eq. 4}

and that of the shorter species:

\[
f_{L_S} = \frac{LAI_{L_S} \cdot k_S}{LAI_{L_T} \cdot k_T + LAI_{L_S} \cdot k_S} \left[ 1 - e^{-\left(-LAI_{L_T} \cdot k_T - LAI_{L_S} \cdot k_S\right)} \right]
\]  

\text{eq. 5}
Light interception \((I)\)

The PAR intercepted at the upper canopy is:

\[
I_U = f_U * PAR
\]  
\text{eq. 6}

The available PAR reaching the lower canopy must be reduced by this intercepted radiation.

Thus, the radiation intercepted by the two species at the lower canopy is:

\[
I_{L_T} = f_{L_T} * (PAR - I_U)
\]  
\text{eq. 7}

\[
I_{L_S} = f_{L_S} * (PAR - I_U)
\]  
\text{eq. 8}
Transpiration and evaporative demand

• Partitioning of evaporative demand between the upper and lower canopy and between species done using actual radiation interceptions as scaling factors.

Water and N-uptake

• Non limiting conditions:
  • uptake is calculated for each species as if it was growing alone using either the evaporative demand or crop-specific N-uptake boundaries as "sink".

• Limited conditions:
  • demand/uptake of each species is reduced based on a user-defined "competiveness factor", so as to allow the sum of both demands to be equal to the available water or N.
Maize-Bean intercropping trial – Wote, Kenya
Maize-Bean intercropping trial – Wote, Kenya

50 yr. annual average rainfall
sum: 600 mm
Maize-Bean intercropping trial – Wote, Kenya

• Planting
  • 20 October 2015
  • 60 cm row spacing

• Fertilizer application
  • 1.5 t/ha manure (maize and beans), incorporated before 5 day before planting
  • 25 kg/ha DAP at planting (maize only)
  • 50 kg/ha CAN topdressing of maize (16 Dec.)

• Maize phenology
  • 50% tasseling: 14 Dec.
  • 50% silking: 25 Dec.
  • maturity: 5 Feb. 2016
  • harvest: 16 Feb.

• Bean phenology
  • start flowering:
  • start grain filling:
  • maturity:
  • harvest:
Results – leaf area index and aboveground biomass

Maize

Bean

dots = observed (± SD); lines = simulations
Results – Aboveground biomass inter- vs. mono-cropping

![Graph showing aboveground biomass](image)

- **Maize**
  - Mono-cropping
  - Intercropping

- **Bean**
  - Mono-cropping
  - Intercropping
Results – Yield inter- vs. mono-cropping

Intercropping out-competes mono-cropping!
Outlooks

• some debugging
• implement simplified way of accommodating differences in plant density/spacing
• move from VBA to C++ version of CropSyst
Thank you!