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Enhancing CropSyst for intercropping modeling

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Bryan Carlson, Rolf Sommer*, Birthe Paul, Mirriam Muli and Claudio Stöckle

r.sommer@cgiar.org

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

The importance of intercropping in sub-Saharan Africa

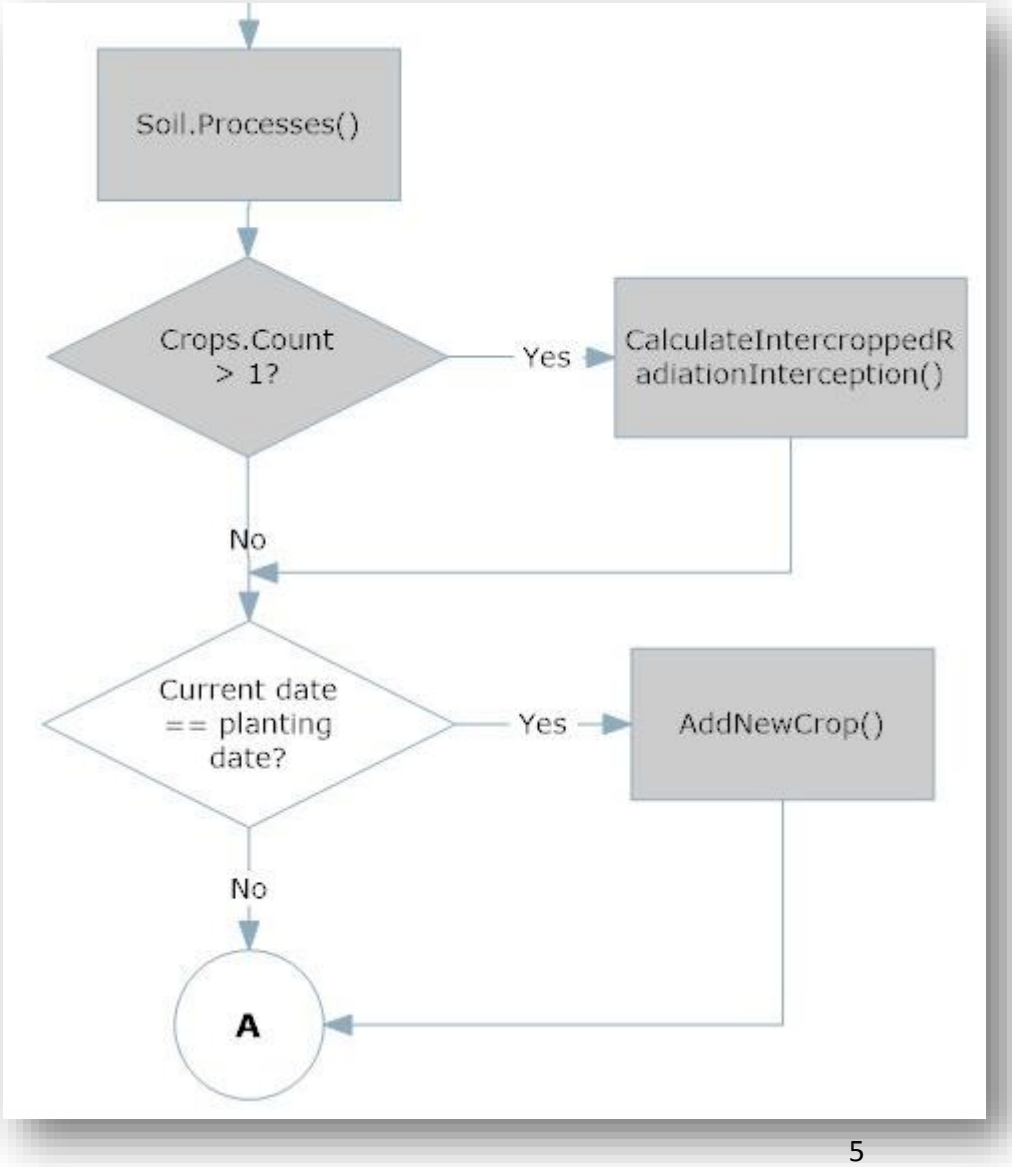
Push-Pull System, Kenya

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**



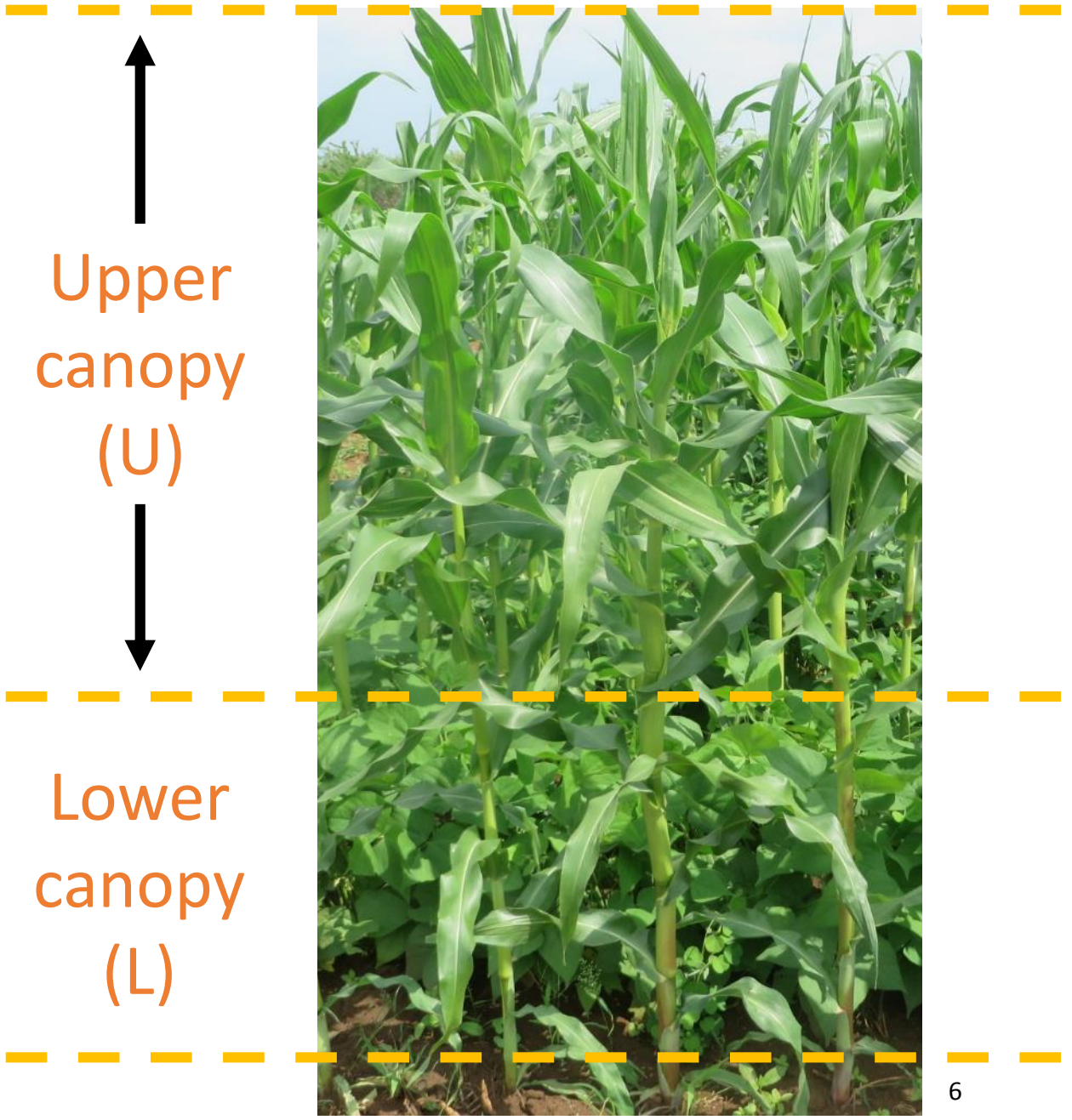
Light interception (I)

$$I = f * PAR$$

$$f = 1 - e^{-k*LAI}$$

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:

$$f_U = 1 - e^{-k_T * LAI_U} \quad \text{eq. 3}$$

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

$$f_{L\_T} = \frac{LAI_{L\_T} * k_T}{LAI_{L\_T} * k_T + LAI_{L\_S} * k_S} 1 - e^{\left[-LAI_{L\_T} * k_T - LAI_{L\_S} * k_S\right]} \quad \text{eq. 4}$$

and that of the shorter species:

$$f_{L\_S} = \frac{LAI_{L\_S} * k_S}{LAI_{L\_T} * k_T + LAI_{L\_S} * k_S} 1 - e^{\left[-LAI_{L\_T} * k_T - LAI_{L\_S} * k_S\right]} \quad \text{eq. 5}$$

Light interception (I)

The PAR intercepted at the upper canopy is:

$$I_U = f_U * PAR \qquad \text{eq. 6}$$

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:

$$I_{L\_T} = f_{L\_T} * (PAR - I_U) \qquad \text{eq. 7}$$

$$I_{L\_S} = f_{L\_S} * (PAR - I_U) \qquad \text{eq. 8}$$

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

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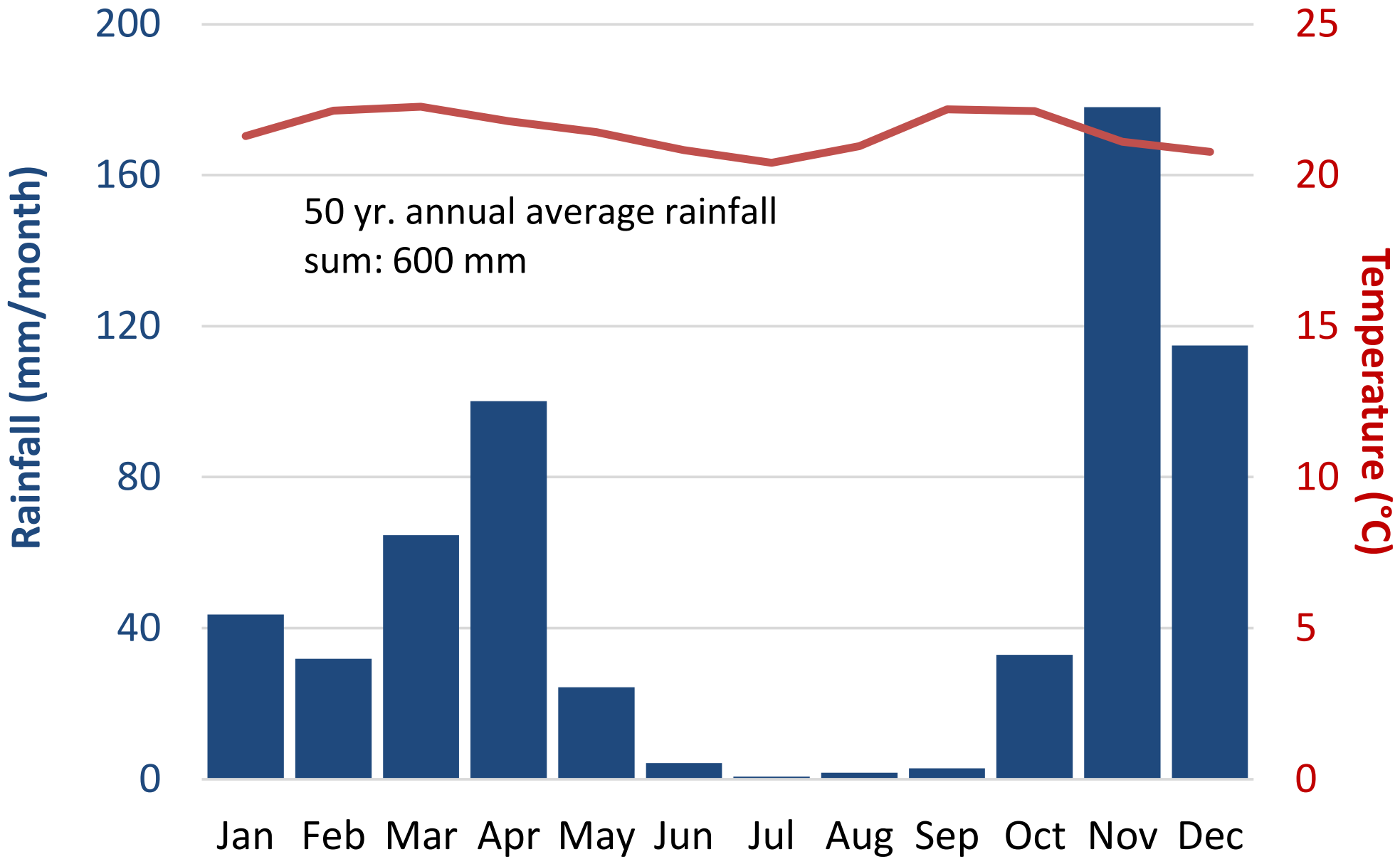


Maize-Bean intercropping trial – Wote, Kenya

- 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:

Maize-bean intercropping trial – Wote, Kenya

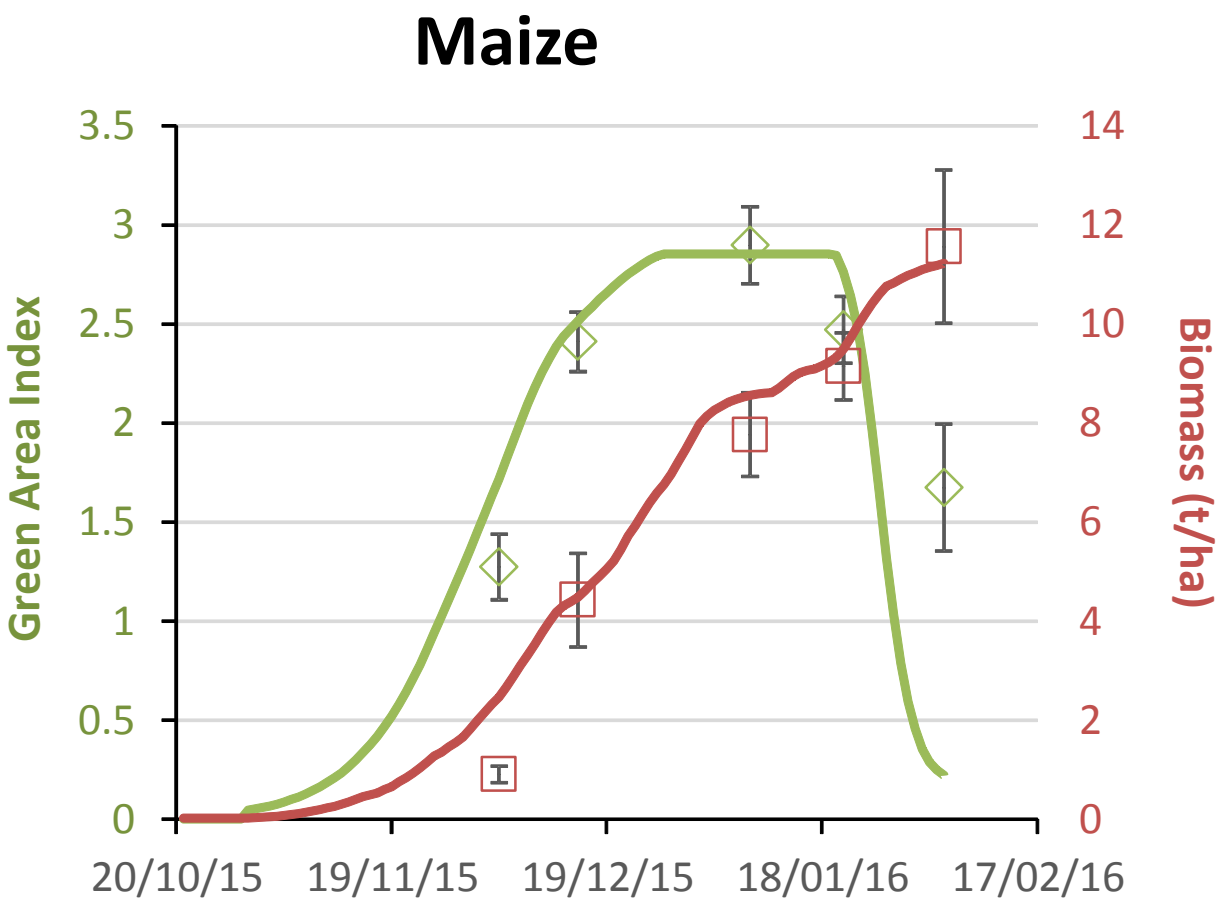
13 November

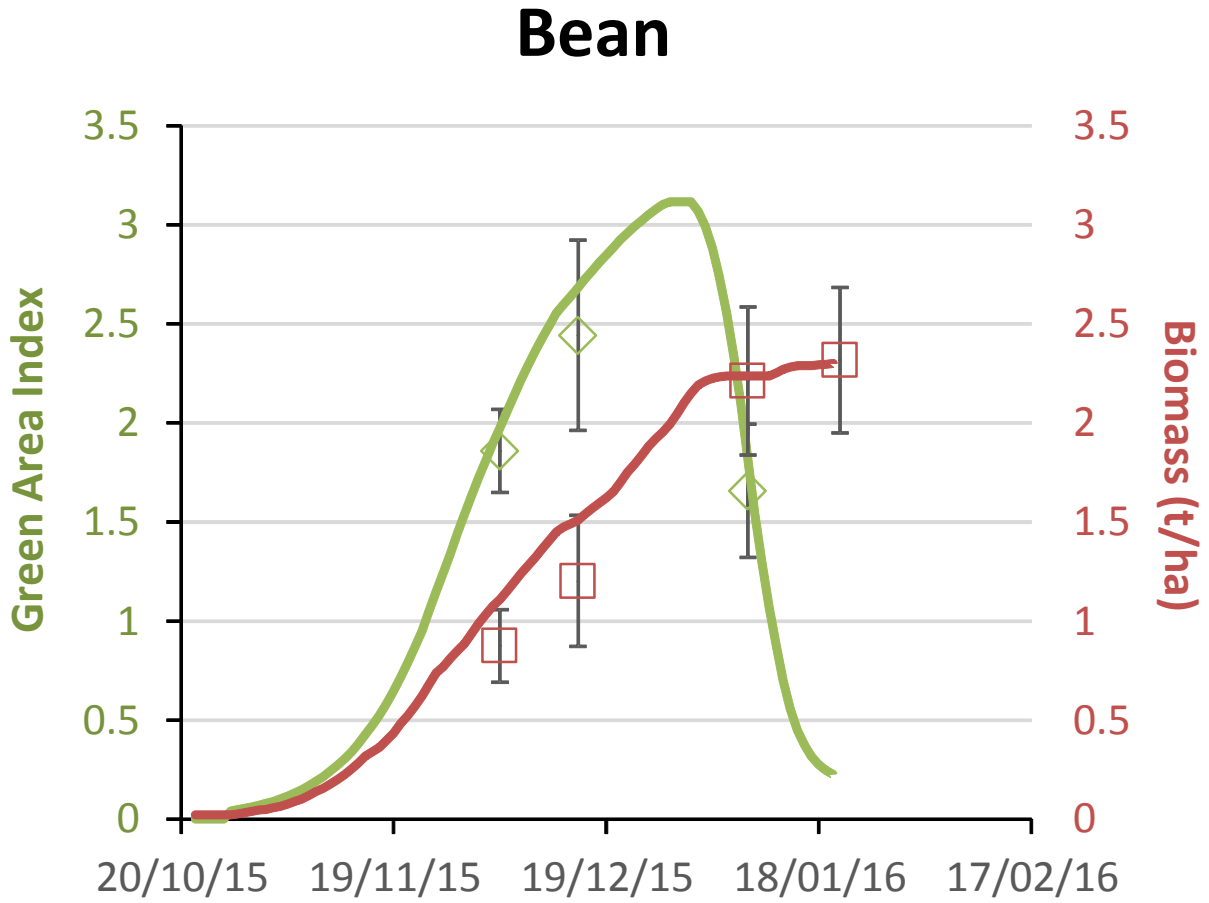
4 December

15 December

8 January

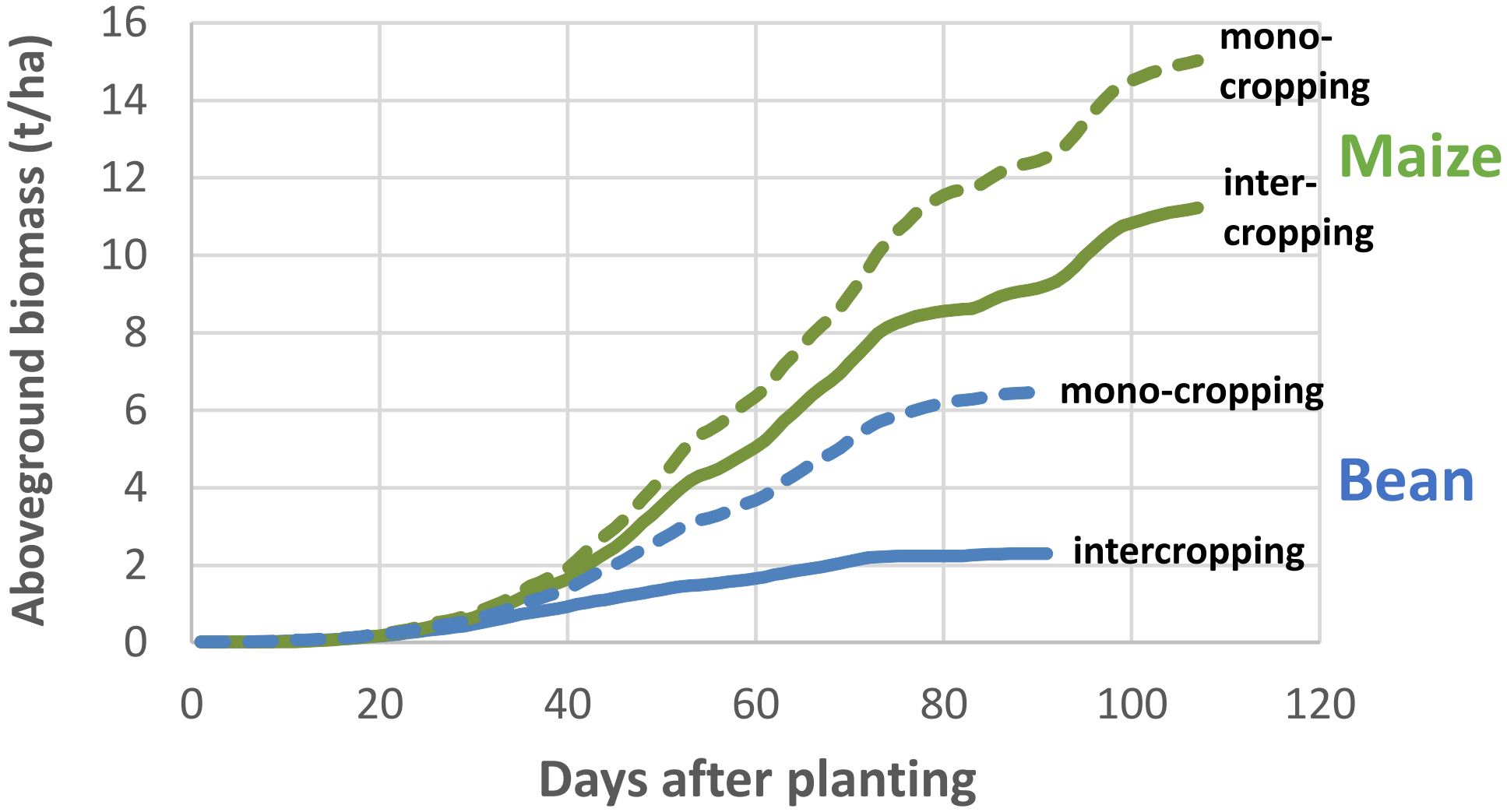
Results – leaf area index and aboveground biomass



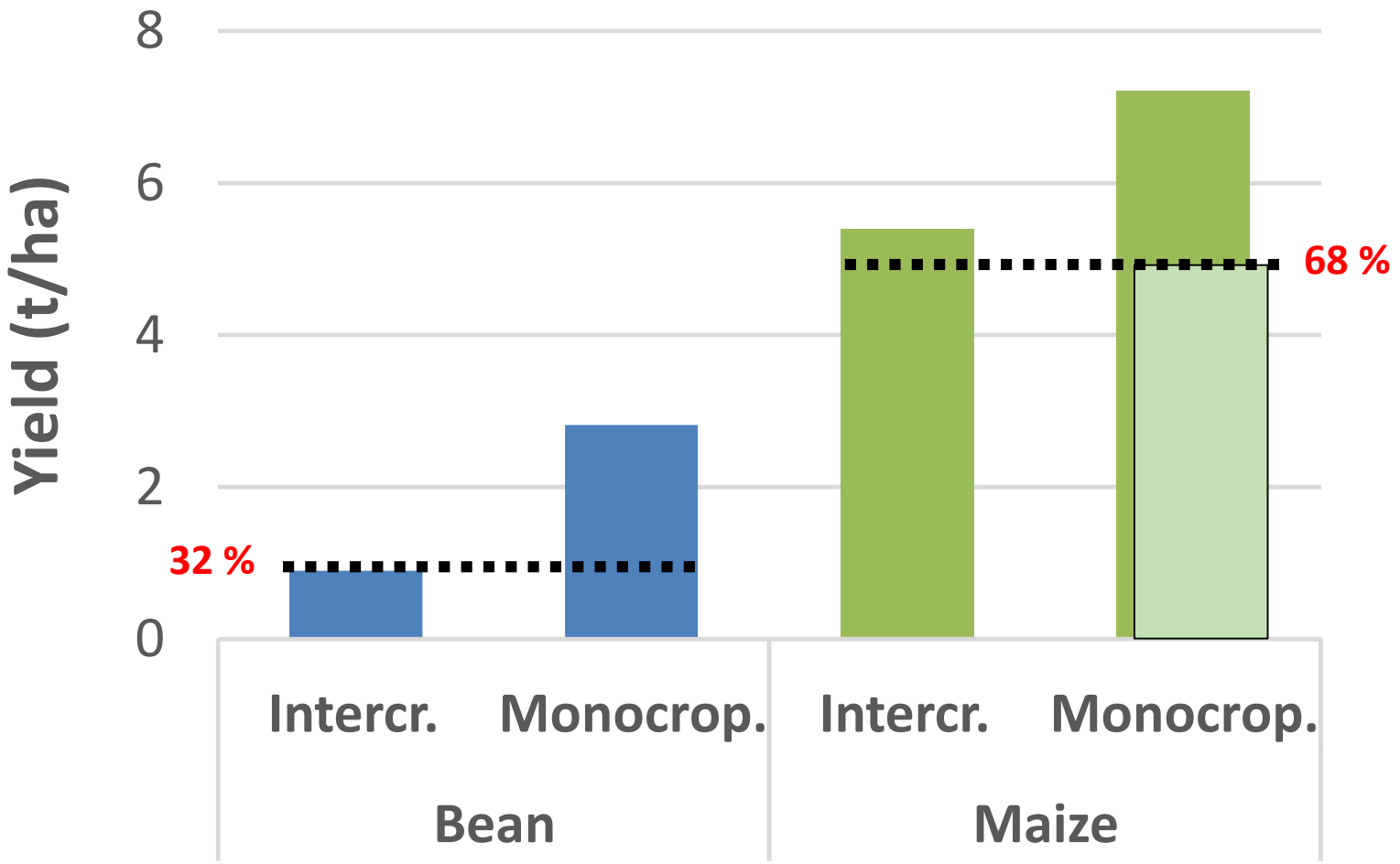


dots = observed (± SD); lines = simulations

Results – Aboveground biomass inter- vs. mono-cropping



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!