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LUCIA-Intercrop – A New Module for Simulating Competition for Light, Water, and Nutrients in Intercrop Systems

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The Land Use Change Impact Assessment tool (LUCIA)

<https://lucia.uni-hohenheim.de>

Scopes

- LUC impact on soil productivity & fertility, biomass production, watershed & ecosystem functions in small mountainous catchments
- Rubber plantations under climate change, Yunnan
- Tree-shrub-crop-livestock interactions in Savannahs



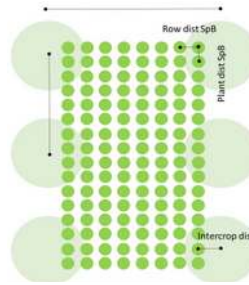
Characteristics

- Spatially explicit, distributed, landscape scale (PCRasterPython)
- Plants: Daily time step, multiple years (LUC)
- Evolved from WOFOST / CGMS (Supit 2003)
 - plant-related add-ons on canopies (Yang et al. 2019), source-sink and dormancy (Gutai et al. 2025), intercropping / agroforestry (Adam et al. 2026)



The Intercrop / Agroforestry module in LUCIA - Aboveground

Two species / pixel

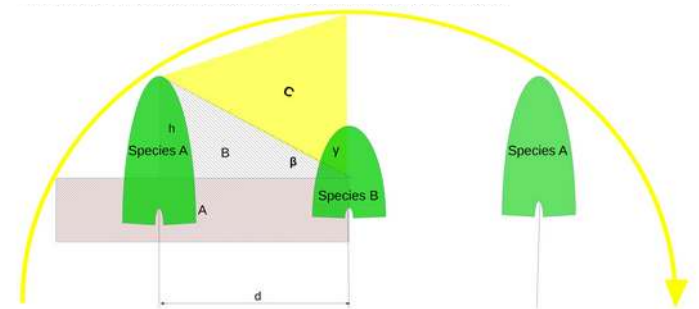
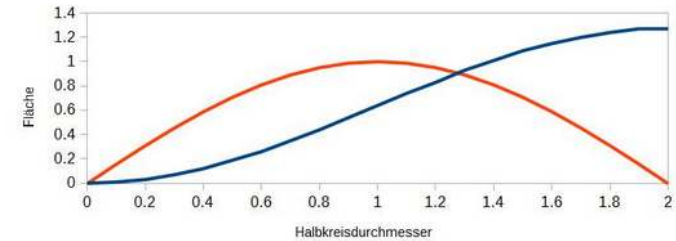


- Dynamic daily solar radiation
- Light transmission = $f(\text{LAI})$
- Canopy shape = $f(\text{shade tolerance})$
- Species can 'overtake' each other in height

Landscape scale

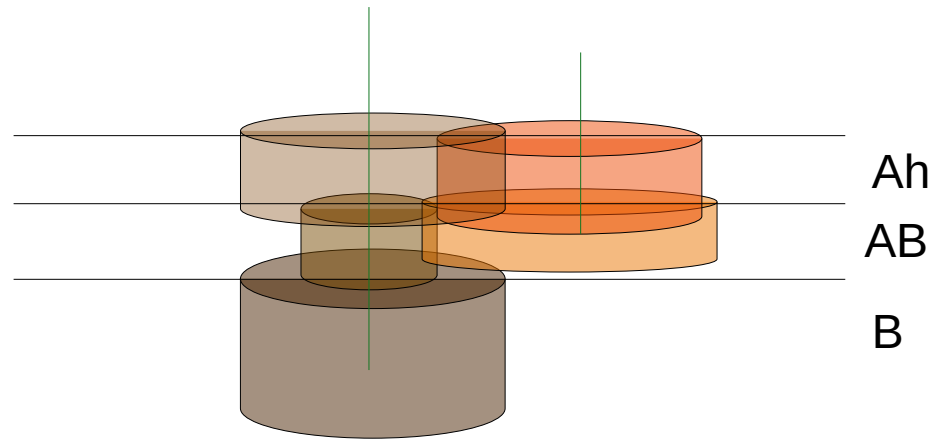
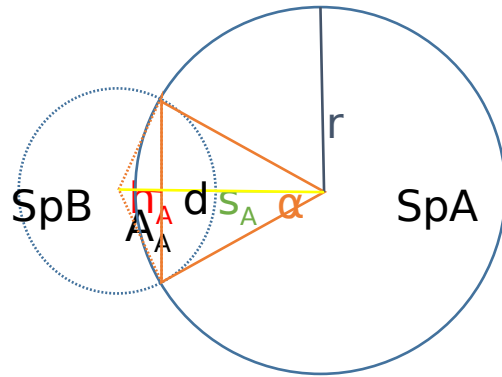
- Row orientation
- (Slope)

Daily solar radiation



The Intercrop / Agroforestry module in LUCIA – Belowground

- Roots are formed as root cylinder with species-specific RWD and rhizosphere radius
- Preferential root growth in horizon with highest concentration of the most limiting resource
- Resources in overlapping volume are shared

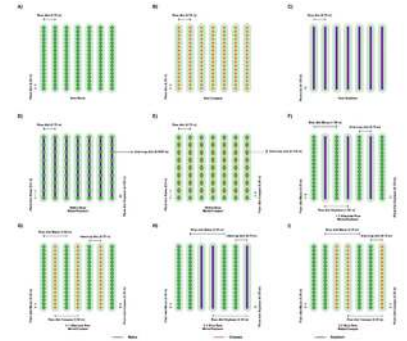


Details: Adam et al. 2026. The ongoing journey of modelling intercropping systems: A conceptual resource sharing intercomparison from model developers and expert users.

Case study

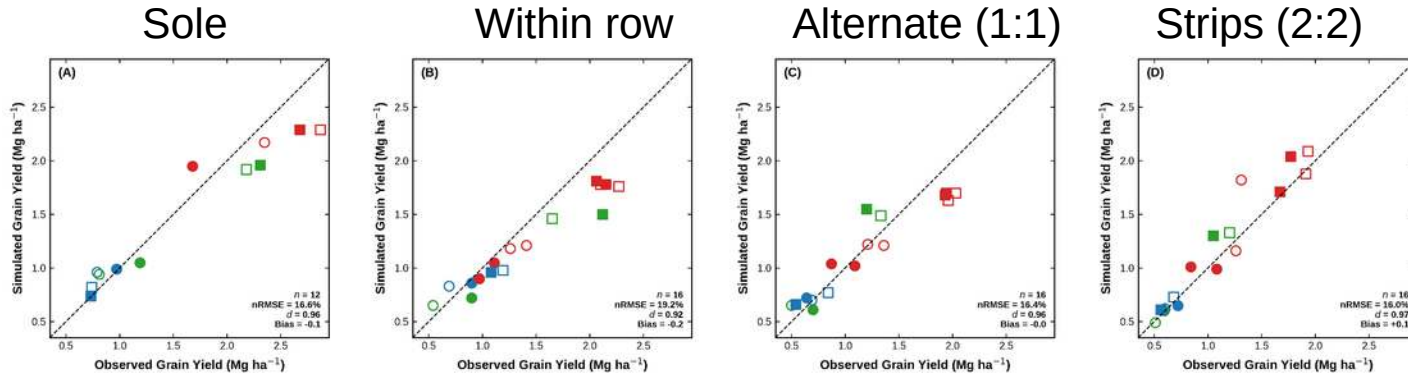
Adam et al. (submitted): Plot-level evaluation for maize-grain legume intercrops.

- Field data
 - Two contrasting agroecological zones in Northern Ghana
 - Maize-soybean and maize-cowpea
 - Spatial arrangements: within-row, alternate row (1:1) and strip (2:2)
 - Two growing seasons
- Calibration / validation
 - fPAR, aboveground biomass and grain yield
 - sole cropping → validation without further changes to intercrop systems
- Sensitivity: Row orientation, interplanted rows, distance SpA-SpB

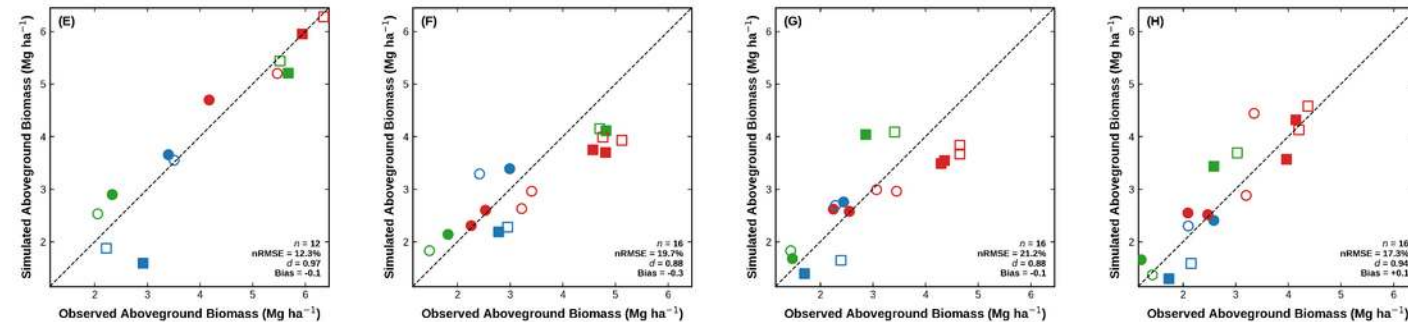


Case study – calibration / validation

Grain yield
[Mg ha⁻¹]



AGB
[Mg ha⁻¹]

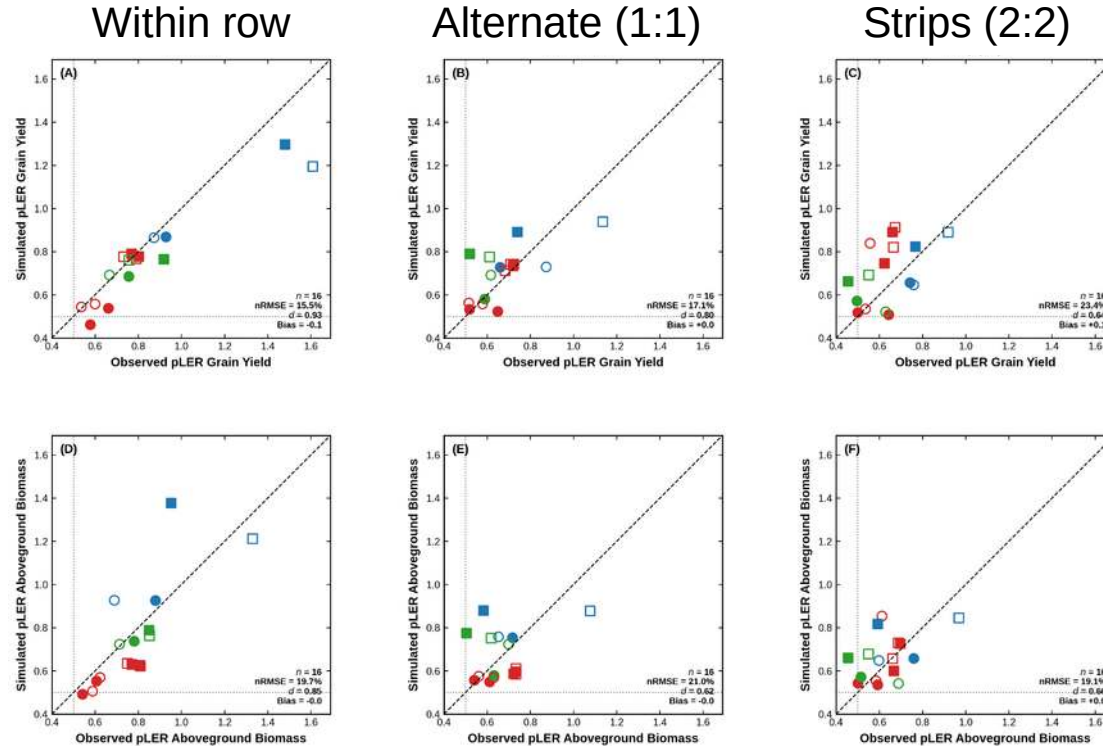


Maize Cowpea Soybean NGS SGS 2013 (filled) 2014 (open) ---- 1:1 line

Willmott's index of agreement []
Mean bias [Mg ha⁻¹]
Pooled yield / AGB

Partial Land Equivalent Ratio

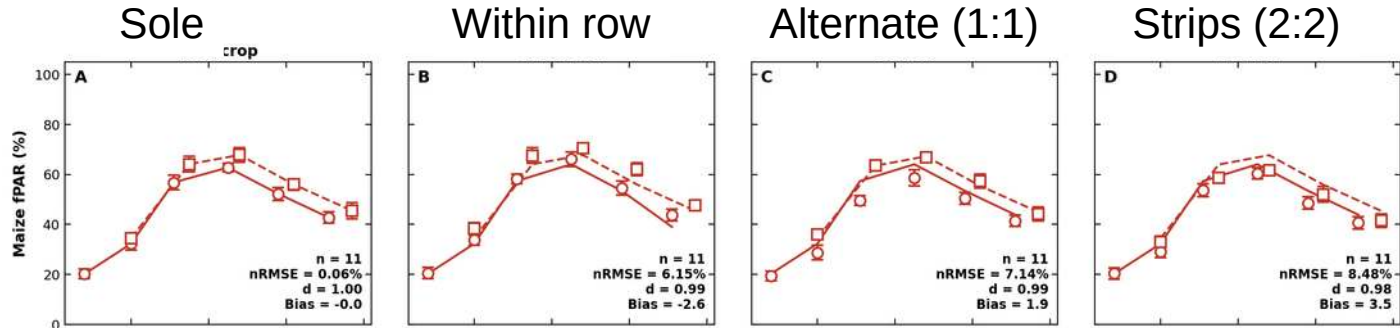
pLER
grain yield
[Mg ha⁻¹]



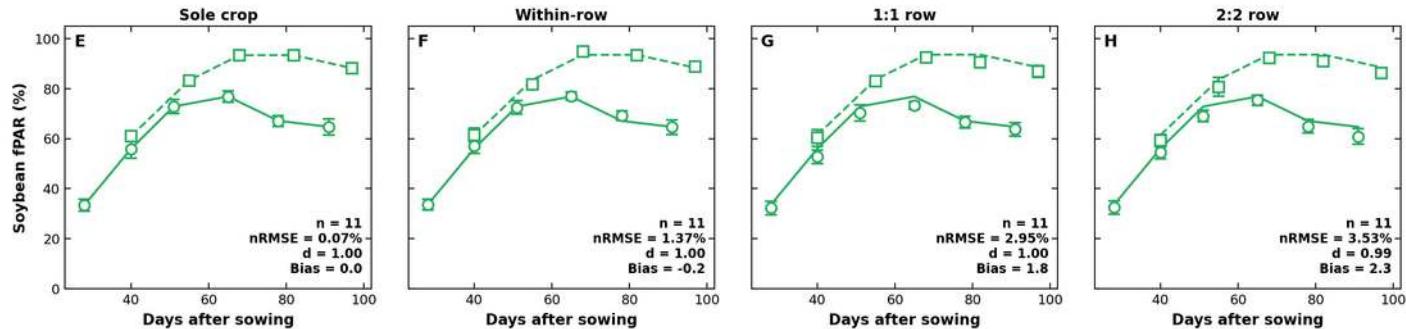
Maize Cowpea Soybean NGS SGS 2013 (filled) 2014 (open) --- 1:1 line — pLER = 0.5

Fraction of photosynthetically active radiation intercepted (fPAR)

fPAR
Maize
[%]



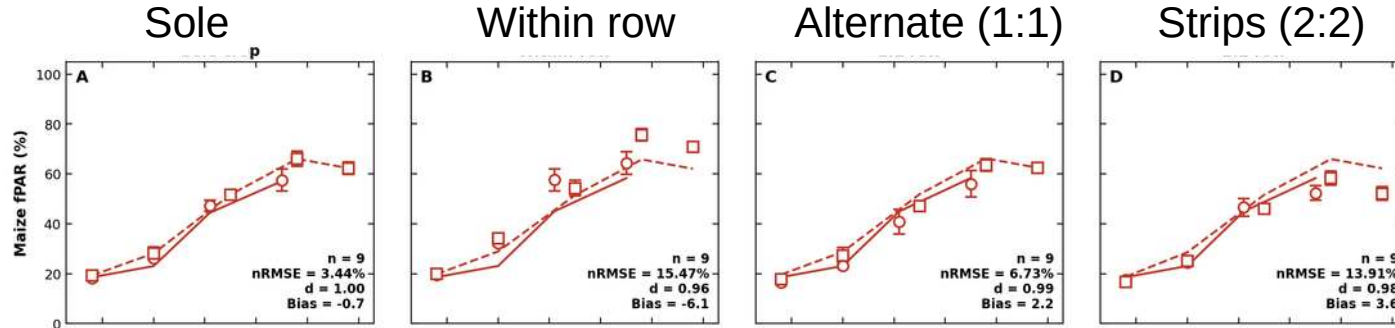
fPAR
Soybean
[%]



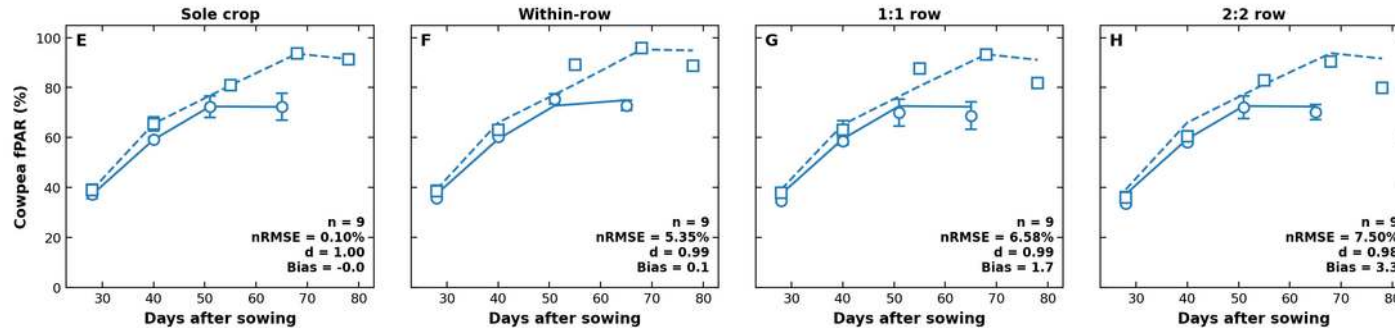
— Sim Maize NGS - - - Sim Maize SGS — Sim Soybean NGS - - - Sim Soybean SGS ○ Obs Maize NGS □ Obs Maize SGS ● Obs Soybean NGS □ Obs Soybean SGS

Fraction of photosynthetically active radiation intercepted (fPAR)

fPAR
Maize
[%]



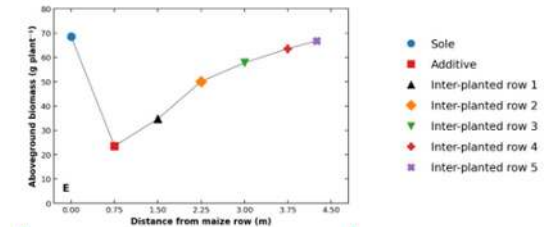
fPAR
Cowpea
[%]



— Sim Maize NGS - - - Sim Maize SGS — Sim Cowpea NGS - - - Sim Cowpea SGS ○ Obs Maize NGS □ Obs Maize SGS ○ Obs Cowpea NGS □ Obs Cowpea SGS

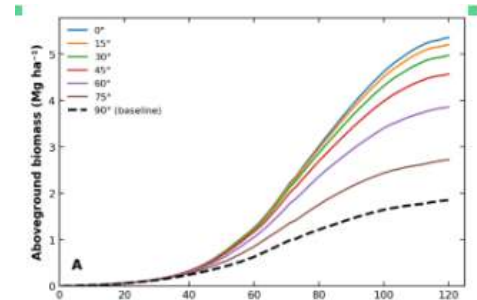
Conclusions & Outlook

- Light, water and nutrient competition captured reasonably well using sole crop calibration ONLY
- Soybean simulation less accurate than cowpea (light quality effects under shade?)
- Planting design matters



Next steps:

- Agroforestry applications (Faidherbia systems Sénégal)
- Landscape aspects (row orientation, slope)
- Light quality
- N sparing effects



Thank you for your attention!

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Am Lucia. Suffer me to take this man,
Who slumbers. Easier so his way shall speed.
— Dante, Divine Comedy

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