Exploration of tree management options to manipulate tree and crop interaction trade-off using WaNuLCAS model

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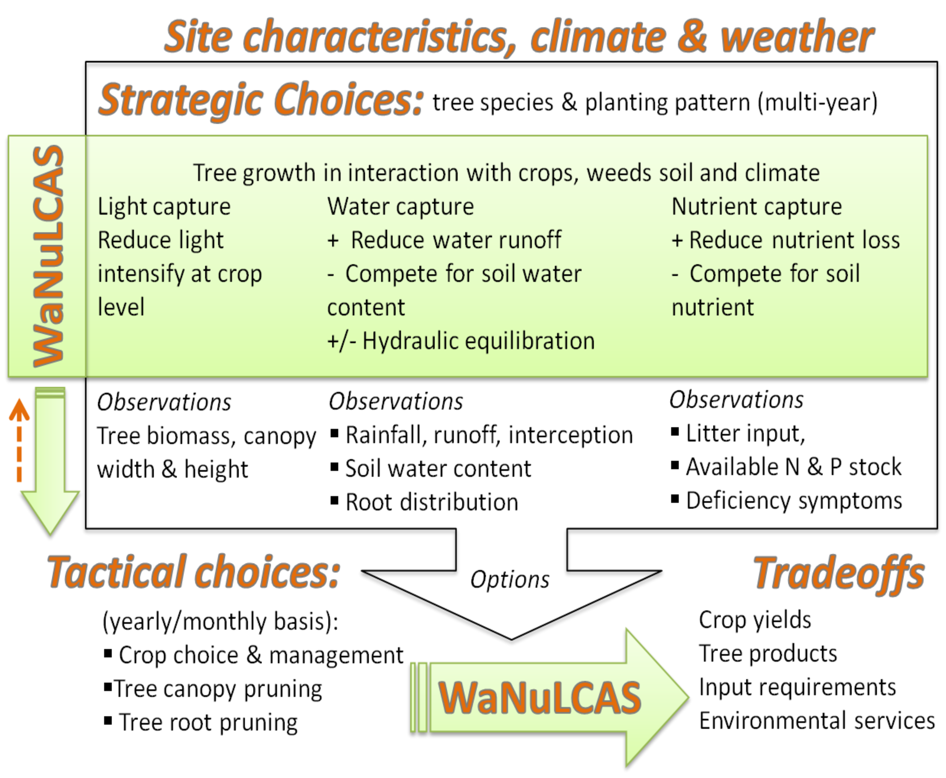
Background

The transformation from degraded soils to agroforestry can benefit from the complementarities between the early stages of tree-based production systems and crop growth.

Farmers managing such transitions must make strategic decisions (multi-year) on the choice of tree species, the number of trees per hectare and spacing; and tactical decisions (shorter term) on the choice of intercrops, tree canopy pruning and/or tree-root pruning.

We used a simulation model to explore these choices: the Water, Nutrient and Light Capture in Agroforestry Systems (WaNuLCAS) model (van Noordwijk and Lusiana 1999; van Noordwijk et al 2004). The study was conducted in Lampung, Sumatra, Indonesia.



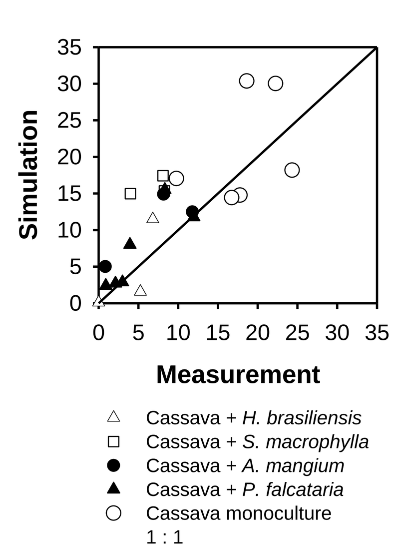
Model Validity Test

The model was validated prior to use by comparing simulation results to measurement results using statistical indicators proposed by Loague and Green (1999).

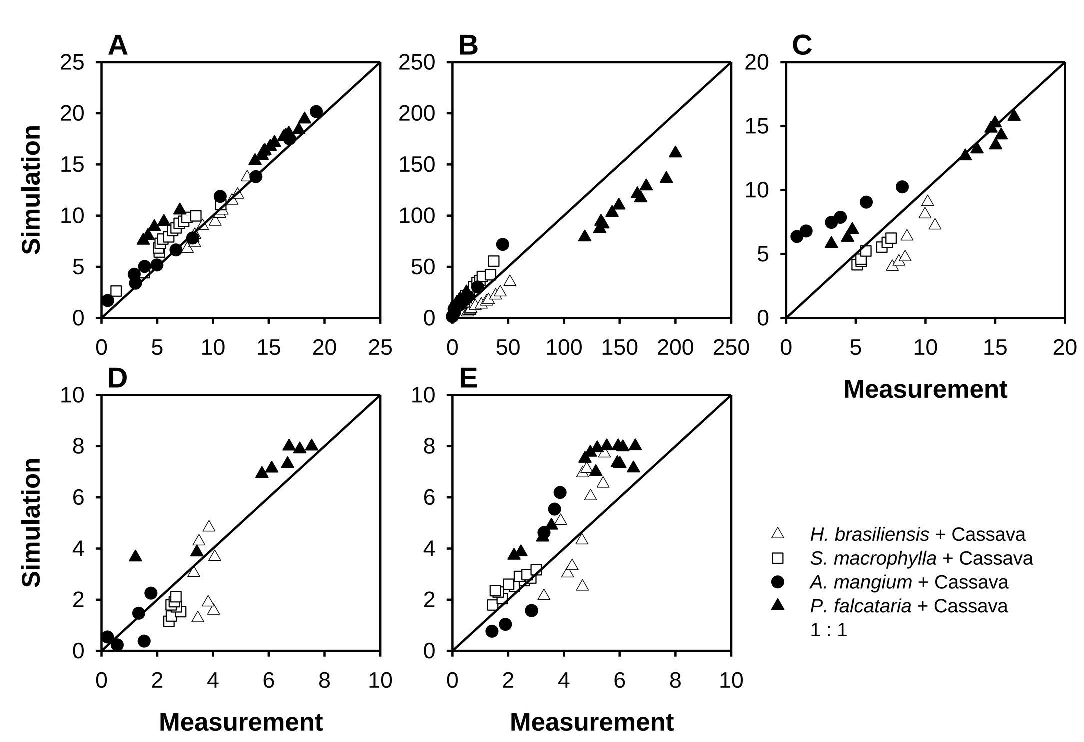
Simulation	Time (year)	Fertilizer (kg ha^{-1})	Crop	Tree	Spacing (m)	Tree density (tree ha^{-1})
Crop monoculture (weed-free)	10[1)]	100 N 60 P[3)]	Cassava	-	0.25 X 0.25	-
Tree intercropping (weed-free)	10[2)]	100 N 60 P[3)]	Cassava	Paraserianthes falcataria, Acacia mangium, Swietenia macrophylla	4 x 2	1250
				Hevea brasiliensis	6 x 3	556

1) The crop was simulated for ten cropping seasons, one per year
2) The trees were simulated for eight years, being planted after harvesting the crop for two years
3) Fertilizer was applied only for crop. N was applied twice: half at planting time and half a month after planting. P was applied once at planting time

The general agreement between simulated and measured crop yields may mask discrepancies, while the simulations for tree diameter and tree biomass provided the closest match, with some uncertainty remaining on tree height, tree canopy height and tree canopy width. However, the R^2 show high enough and closer match of all other indicators to their optimum value (0 for ME, RMSE, CRM, and 1 for EF and CD, respectively)



Cassava tuber yields (FW, Mg ha^{-1})



Tree growth : A. Tree Diameter (cm), B. Tree Biomass (Mg ha^{-1}), C. Tree Height (m), D. Canopy Height (m), and E. Canopy Width (m).

Criteria	Cassava Tuber (Mg ha^{-1})	Tree Diameter (cm)	Tree Biomass (Mg ha^{-1})	Tree Height (m)	Tree Canopy Height (m)	Tree Canopy Width (m)
ME, 0	12.50	9.38	65.02	7.71	4.64	3.79
R^2, 1	0.74	0.77	0.81	0.42	0.67	0.64
RMSE, 0	49.11	42.88	58.63	44.58	42.26	57.67
EF, 1	0.58	0.31	0.75	0.28	0.44	-1.22
CRM, 0	-0.13	-0.35	-0.25	-0.17	-0.13	-0.48
CD, 1	2.40	1.44	3.99	1.38	1.78	0.47

ME : maximum error, RMSE : root mean square error, EF : model efficiency, CRM : coefficient of residual mass, CD : coefficient of determination.

Reference

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

van Noordwijk M, Lusiana B, Khasanah N .2004. WaNuLCAS 3.01: background on a model of Water, Nutrient and Light Capture in Agroforestry Systems. Bogor, Indonesia. World Agroforestry Centre - ICRAF, SEA Regional Office. 246 p.

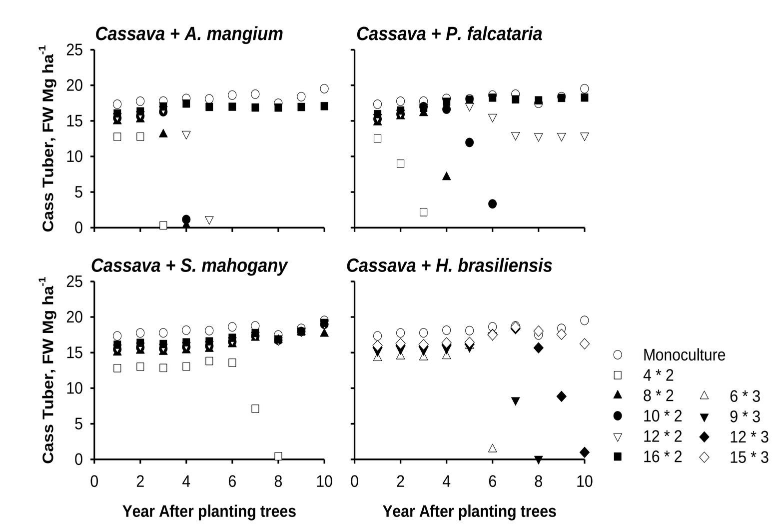
Model Scenarios

Simulation group	Time (year)	Fertilizer (kg ha^{-1})	Crop	Tree	Spacing (m)	Tree density (tree ha^{-1})
Crop monoculture (weed-free)	12[1)]	100 N 60 P[3)]	Cassava	-	0.25 x 0.25	-
Tree monoculture (weed-free)	12[2)]	-	-	P. falcataria, A. mangium, S. macrophylla	4 x 2, 8 x 2, 10 x 2, 12 x 2, 16 x 2, 3 x 3, 4 x 4, 8 x 4, 8 x 8	1250, 625, 500, 417, 313, 1111, 625, 313, 156
				H. brasiliensis	6 x 3, 9 x 3, 12 x 3, 15 x 3, 6 x 3, 5 x 3, 4 x 4, 6 x 6, 12 x 6	667, 370, 278, 222, 556, 667, 625, 278, 139
Tree intercropping : effect of widening tree row spacing on crop yield	12[2)]	100 N 60 P[3)]	Cassava	P. falcataria, A. mangium, S. macrophylla	4 x 2, 8 x 2, 10 x 2, 12 x 2, 16 x 2	1250, 625, 500, 417, 313
				H. brasiliensis	6 x 3, 9 x 3, 12 x 3, 15 x 3	667, 370, 278, 222
Tree intercropping: alternative spacing designs on tree – crop yield				P. falcataria, A. mangium, S. macrophylla	Narrow 4 x 2 3 x 3, 4 x 4 Wide 8 x 4, 8 x 8	1250, 1111, 625, 313, 156
				H. brasiliensis	Narrow 6 x 3, 5 x 3, 4 x 4 Wide 6 x 6, 12 x 6	556, 667, 625, 278, 139

1) The crop was simulated for twelve cropping seasons, one per year, as long as there was a net benefit (yield times price exceeds direct attributable costs and labour at minimum wage rate)
2) The trees were simulated for ten years, being planted after harvesting the crop for two years
3) Fertilizer was applied only for crop. N was applied twice, half at planting time and half a month after planting. P was applied once at planting time

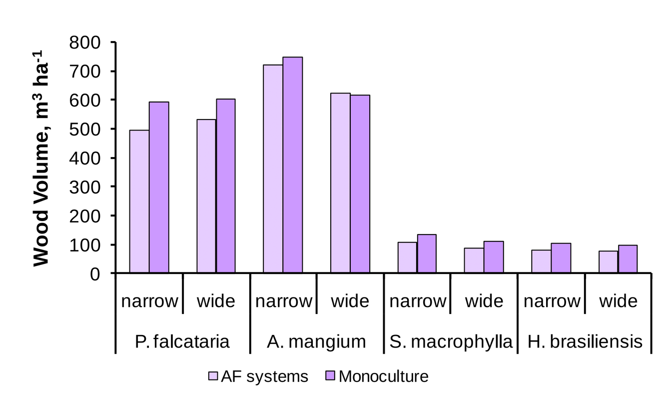
Strategic decision: length of cropping period

The four tree species tested have different growth rates and rates of canopy development, resulting in different opportunities for intercropping. For example, cassava tuber yield intercropped in *A. mangium* drops to a very low value in year 3, 4 or 5 for a tree spacing of 4 x 2, 8 x 2 or 12 x 2, respectively, and continuous intercropping is only feasible for 16 x 2.

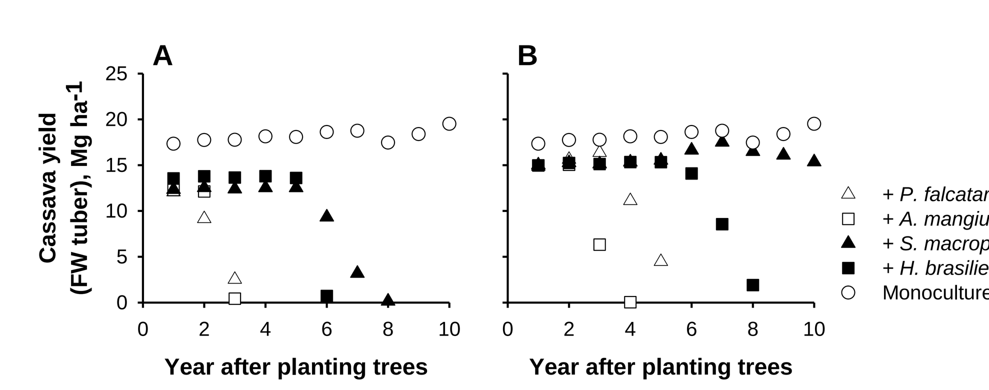


Strategic decision: alternative spacing designs

There was a small difference in wood volume between intercropped systems and monoculture trees, with monoculture trees slightly higher than trees in intercropped systems at the same density, except in *A. mangium*. The yield of cassava is significantly influenced by tree species grown in the systems and the wider the tree spacing, the longer time available for planting crop.



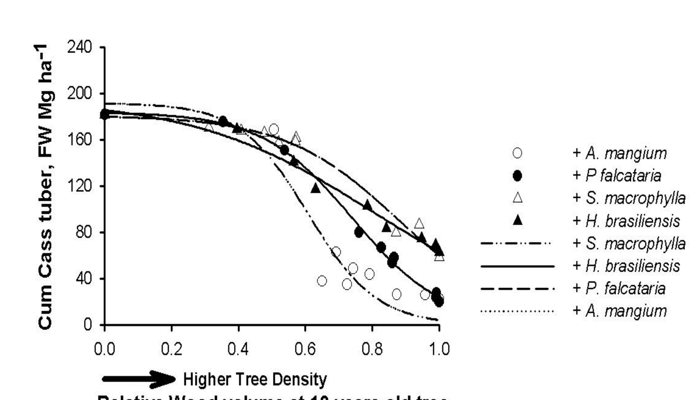
Wood volume at 10 years old



Cassava tuber yield (A. narrow spacing, B. wide spacing)

Trade-off between tree and crop yields

Increasing the space between tree rows makes longer intercropping possible but also reduces the expected yield from the trees. Most of the tree and crop combinations are substantially above the straight trade-off curve, suggesting that there is indeed a benefit to be obtained by the combination when compared to separate monocultures. However, the points for *A. mangium* suggest virtually no intercropping advantage.



Conclusions

- With the fast-growing *A. mangium* intercropping is feasible for two years at tree spacing normally used in monocultures; wider tree spacing will lead to a loss of wood volume that is proportional to the gain in crop growth. The final choice would depend on the economic feasibility of wood and crop production, with relatively little intercropping advantage other than in risk reduction.
- With the fast growing *P. falcataria* there is considerable scope for intercropping, with systems that yield about half of the maximum tree biomass still allowing for close to 90% of monoculture crop yield.
- With the slower growing *S. macrophylla* and *H. brasiliensis* there is more opportunity for intercropping, regardless of tree spacing selected, and there is still some scope for net benefits at wider tree spacing.

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