Theory and description of the 3D Hi-sAFe agroforestry model

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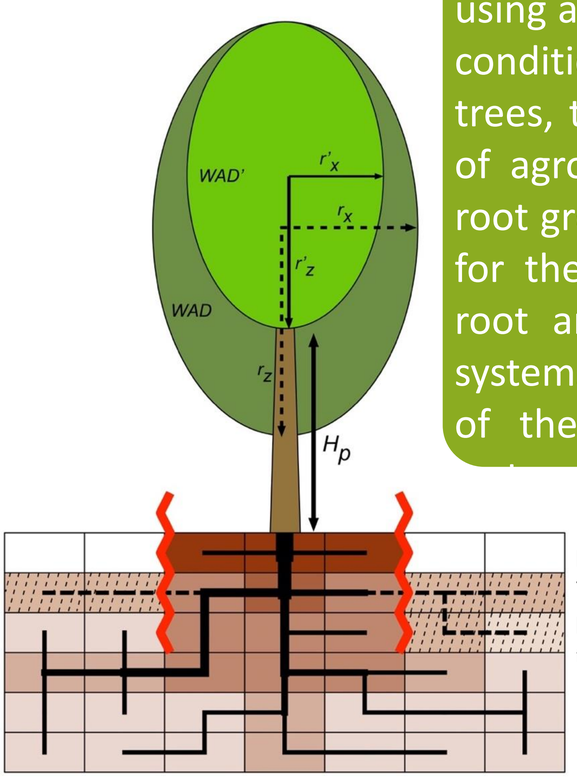
OBJECTIVES

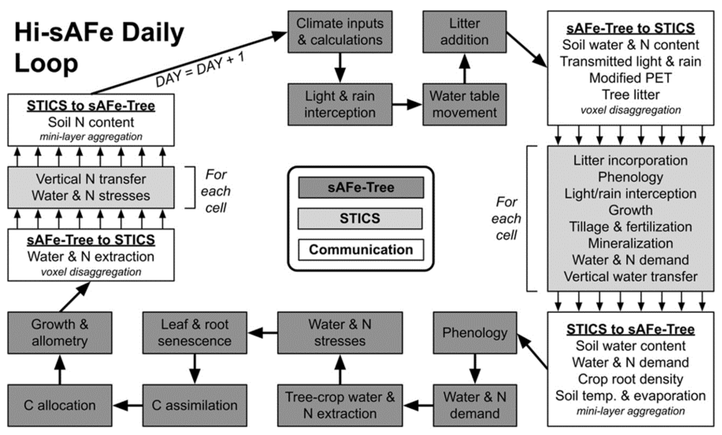
Hi-sAFe (Dupraz *et al*, 2019) is a mechanistic, biophysical model designed to explore the interactions within agroforestry systems that mix trees with crops. Hi-sAFe has been under development since 2002 since the Silvoarable Agroforestry for Europe (SAFE) project. The model couples the STICS crop model (Brisson *et al*. 1998) to a new tree model. **Trees and crops compete in 3D for light, water and nitrogen at a daily time step**.

MODEL FEATURES

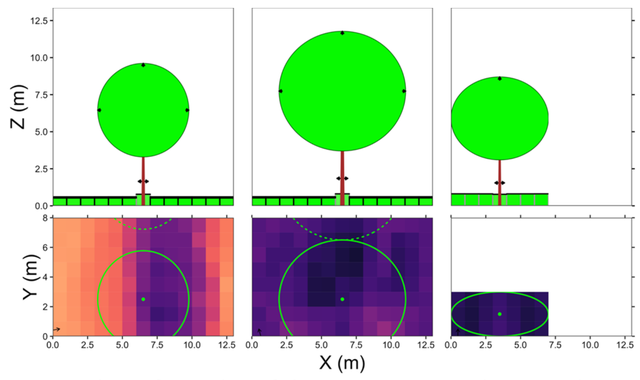
Modelled system geometry can be custom built using a grid of square cells and flexible boundary conditions, permitting the simulation of isolated trees, tree lines, stand edges, and a wide range of agroforestry patterns. An opportunistic tree root growth module (Mulia et al. 2010) accounts for the impact of resource availability on tree root architecture. Monoculture crop and tree systems are also simulated, enabling calculation of the land equivalent ratio of agroforestry



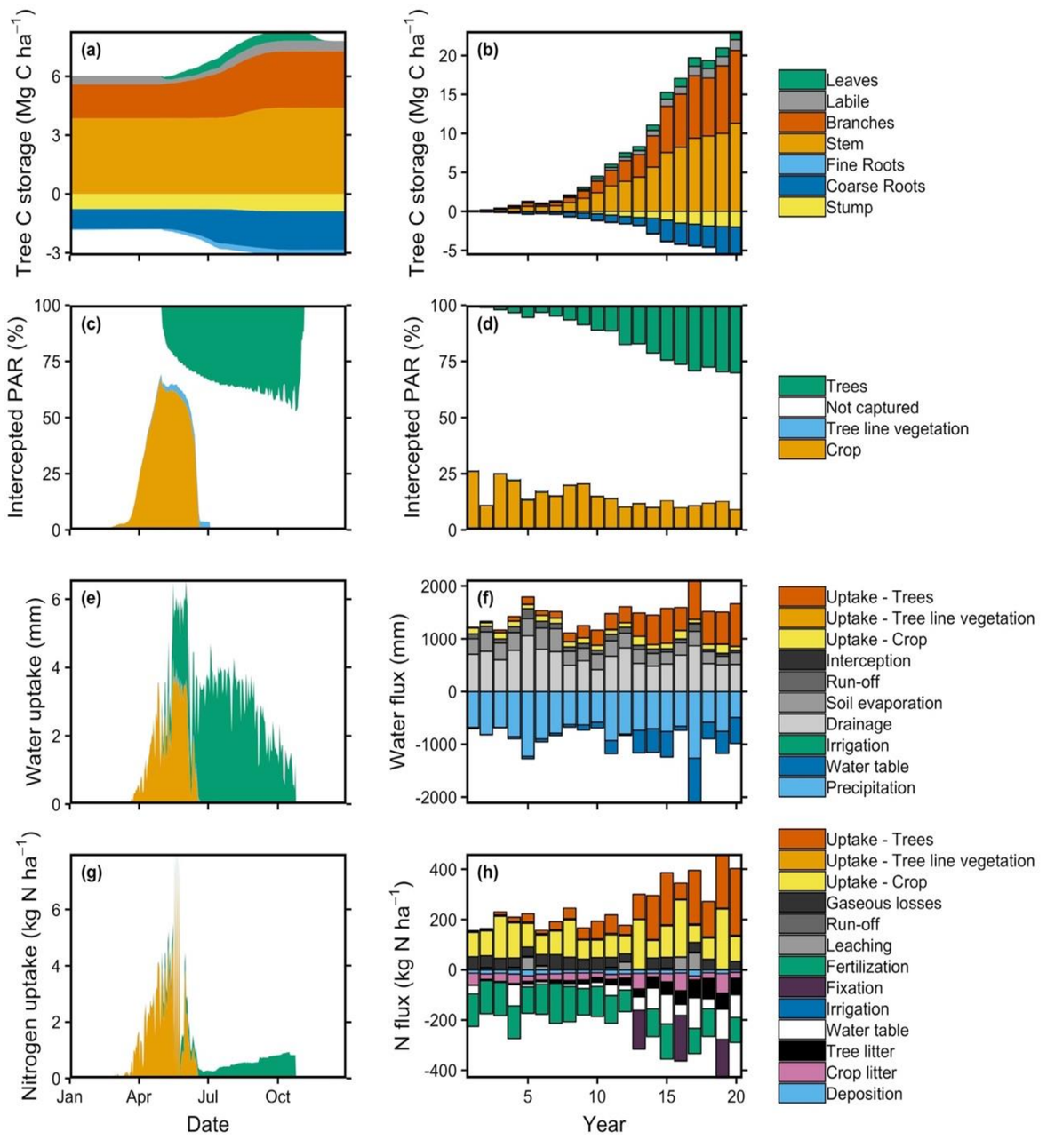
Branch and root pruning management interventions in sAFe-Tree. Coarse roots are represented by solid lines, with diameter proportional to line thickness. Fine root density is proportional to voxel shading, with darker colors indicating more fine roots.



Key simulated processes within the Hi-sAFe daily loop, as part of sAFe-Tree, STICS, and the communication between the two models.



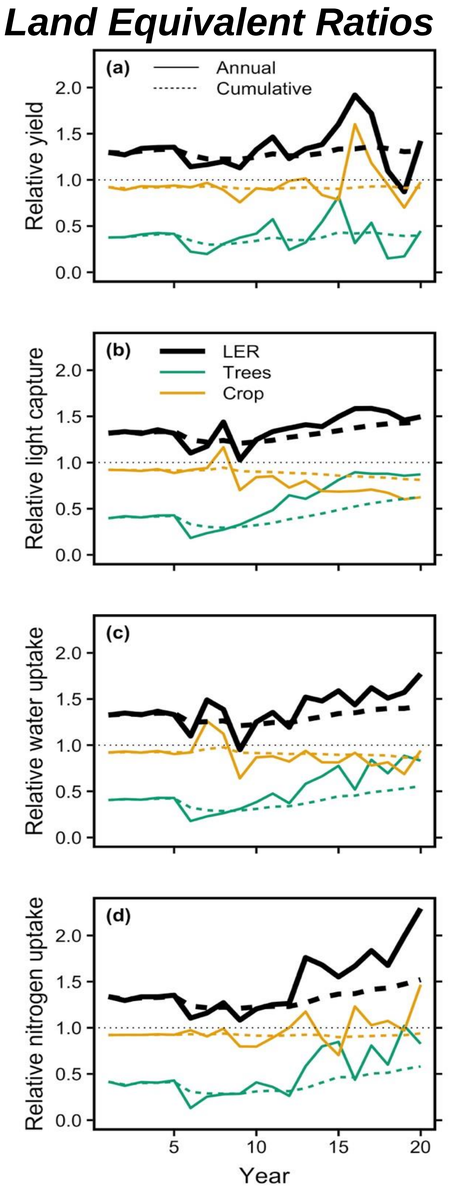
A snapshot of one day of three Hi-sAFe simulations. The top row illustrates a horizontal projection of the modelled scene. The bottom row shows a top-down view of the scene, with cell color proportional to shade by the tree on the crop (darker colors indicate more shade).



Simulations of tree carbon storage by compartment (a & b), intercepted PAR by plant component (c & d), water uptake and other fluxes (e & f), and nitrogen uptake and other fluxes (g & h). Left panels show daily values during the 12th year of tree growth. Right panels show annual values for each year of 20 years after tree planting. In panels (a) and (b), negative values indicate belowground carbon storage. Panels (f) and (h) show water and nitrogen balances of the soil, with positive values indicating export from the soil and negative values indicating input to the soil.

HisAFe allows to calculate tree and crop relative yield contributions and land equivalent ratio. Relative values are in respect to monoculture tree and crop control simulations. LER is the measure of the productivity, while similar coefficients can be calculated for light, water and nitrogen capture

Land Equivalent Ratios



PREDICTING PRODUCTIVITY AND ECOSYSTEM SERVICES

Hi-sAFe is a novel tool for elucidating daily interactions for light, water, and nitrogen in agroforestry systems. Its 3D and spatially explicit form is key for accurately representing many competition and facilitation processes. HisAFe can provide productivity assessments and quantify some ecosystem services such as C sequestration, Nitrogen lixiviation or resilience to climate change. Hi-sAFe is available online free of charge. A suite of tools for building, running, and analyzing Hi-sAFe simulations is also available via the hisafer R package (Wolz, 2018).

References

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Mulia R, et al, 2010, Plant Soil 337:77–92. doi: 10.1007/s11104-010-0502-3
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