

# Formulation of a consistent multi-species canopy description for hydrodynamic models in mixed-forests

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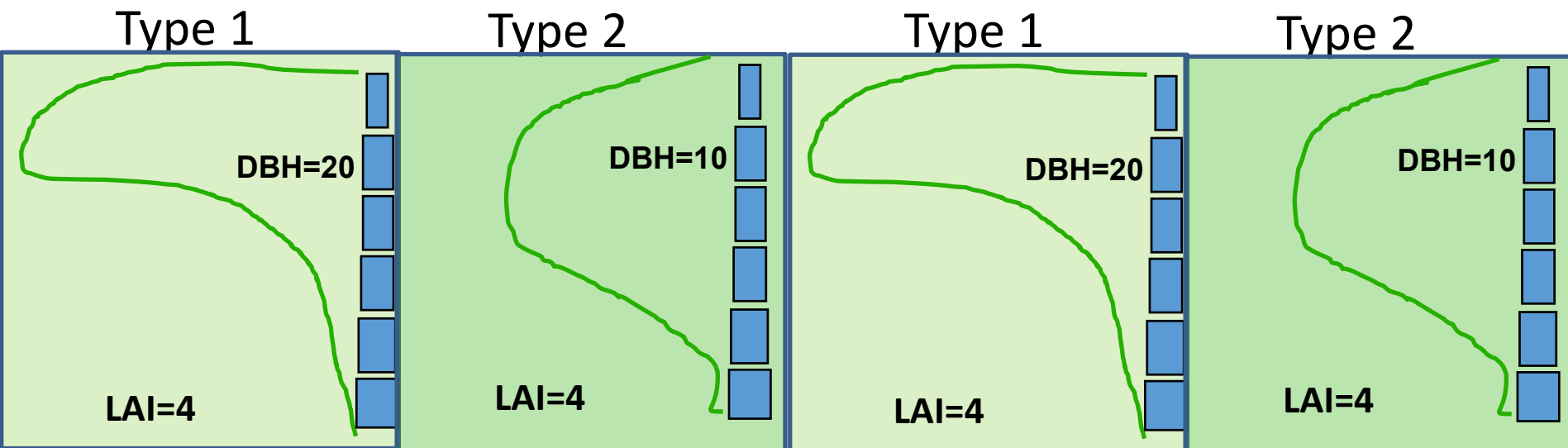
## Abstract

Representation of canopy and tree function in earth system models (ESMs) is going through rapid advancements in the last decade. The simplistic big-leaf representation of canopy in model is being expanded and replaced by more complex canopy representations that include multiple functional types, species and age/size stages, multiple patches with different canopy height and leaf area characteristics, and vertically detailed representations with between 2 (light and shade) to  $n$  canopy leaf layers. Recently, the hydrodynamic approach to modeling stomata conductance has advanced, and many ESMs include a hydrodynamic version. Under the hydrodynamic approach, stomata respond to water availability in the xylem, and not directly in the soil. The result is a model that include the stem, and xylem dimensions as canopy characteristics for determining the flow and storage of water in the xylem. However, pipe diameter, area and volume do not scale linearly, and thus, the simulations cannot resolve canopy-scale hydrodynamics by pulling all the stem conductive area and volume to a single virtual patch scale, but instead, need to consider the hydrodynamics of a single virtual tree and scale its resulting fluxes to the entire canopy. While that is trivial in a homogeneous canopy, the difference between the tree-level description of the hydrodynamic canopy and the horizontally pulled description of the canopy in the surface-flux and radiation-exchange modules leads to a conundrum. Imagine a mixed canopy: 50% oaks and 50% maples. Assume oaks have 20% more LAI and are 1 m taller than the maples. As far as hydrodynamics are concerned, the evaporative demands of maple follow from light attenuation and leaf area profiles of a maple-like canopy. However the roughness length and aerodynamic resistance, and the resulting wind profile inside the canopy is not characteristic of maple or oak but is a result of the mixed canopy. I will present formulation for a consistent scaling of tree-level canopies to patch-level for mixed forests with multiple species of different functional types. The formulation scales canopy characteristics and the resulting canopy fluxes from tree to forest in an energy and mass-conservative way, and allow a smooth and consistent multi-species canopy description for hydrodynamic models in mixed-forests.

# Formulation of a consistent multi-species canopy description for hydrodynamic models of mixed forests *Gil Bohrer, CEGE, OSU*

- Technological Convergence:
- Tree-level **observations** – remote sensing of crown shape, tree-level leaf density, species identification
- Mixed-vegetation in global vegetation **models** – PFT patches
- **Hydrodynamic** vegetation modeling – virtual tree-levels simulations

**Problem – tree-level species/trait heterogeneity within patch**

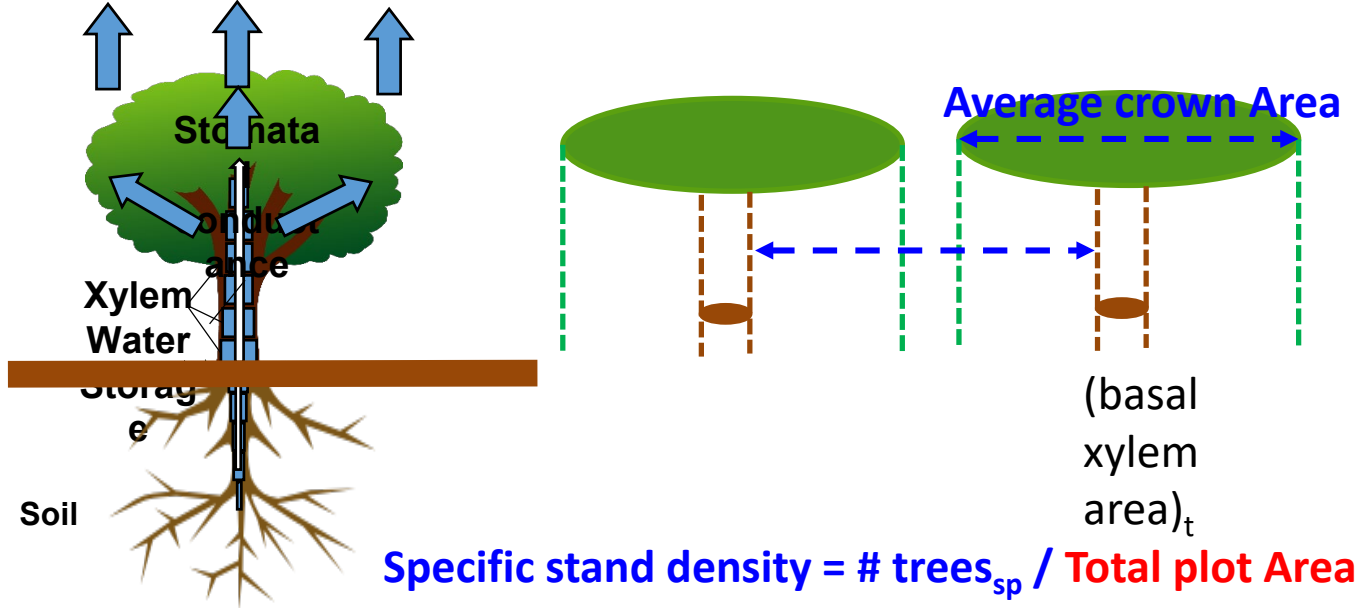


Plot-level, species-specific  $LAI_1=2$ ,  $LAI_2=2$

Plot area = 1, Species-specific coverage  $1/2+1/2$

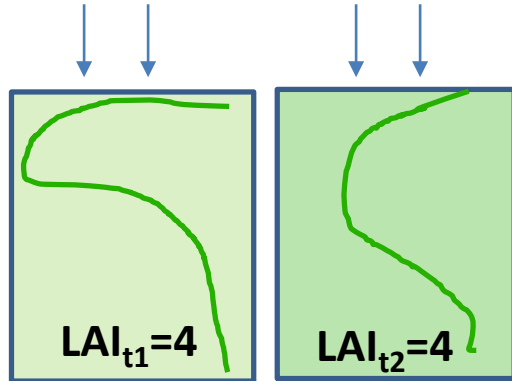
# Solution

Per ground area  $\neq$  Per xylem area  $\neq$  Per area under the tree



Split forcing: vertically attenuated vs. horizontally mixed

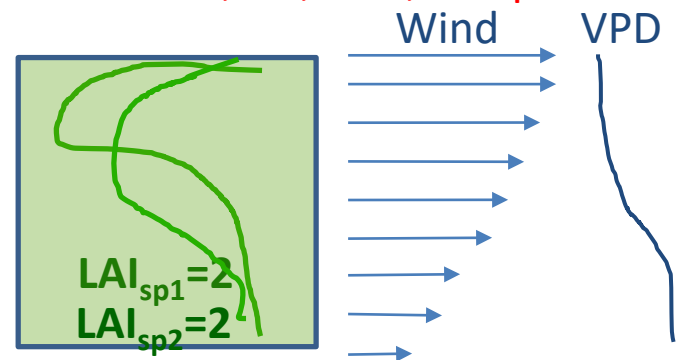
PAR; Net Shortwave; Precip.



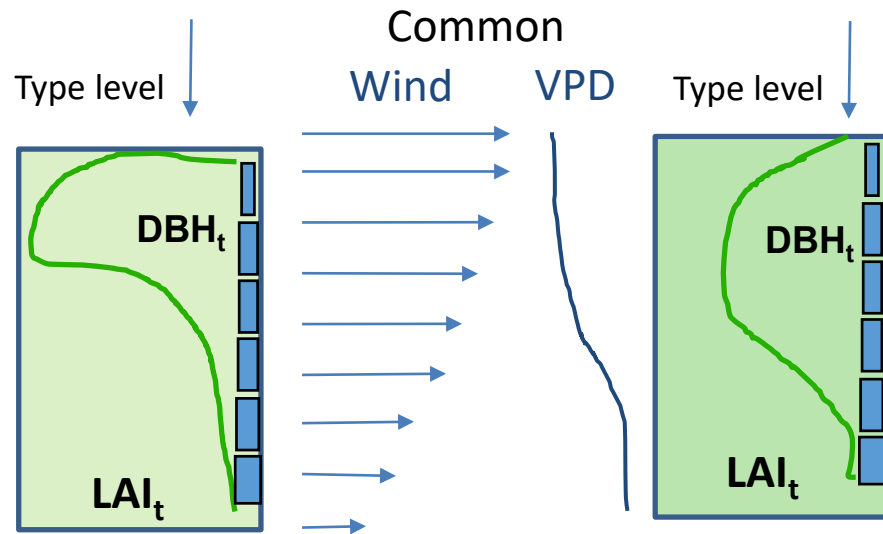
$LAI_p=4$

Alternative virtual canopy spaces

Wind; U\*; VPD; Temp



$LAI_p=4$



**Plot-level LAI** =  $\sum$  (Species specific LAI)  
 $LAI_p$   $LAI_{sp}$

**Species specific LAI** =  $Sd_{sp}$   $CA_{sp}$   $LAI_t$   
 Specific stand density x Average crown Area x Tree level LAI

$$Area_{sp} = Sd_{sp} \times CA_{sp} \times \text{Total Plot Area}$$

$FX_t$  = Tree level flux [flow/xylem area] =  $f(LAI_t)$       **What hydrodynamic models solve**

$$FX_{sp} = \text{Type level flux [flow/ground area under tree]} = FX_t \times (\text{basal xylem area})_t / CA_{sp}$$

$$FX_p = \text{Total plot flux [flow/ground area]} = \sum (FX_{sp} \times Area_{sp}) / \text{Total Plot Area}$$

**What we ultimately need!!**