Characterizing neighborhood exchanges in disturbed landscapes using multi-scale routing in an ecohydrologic model

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Motivation

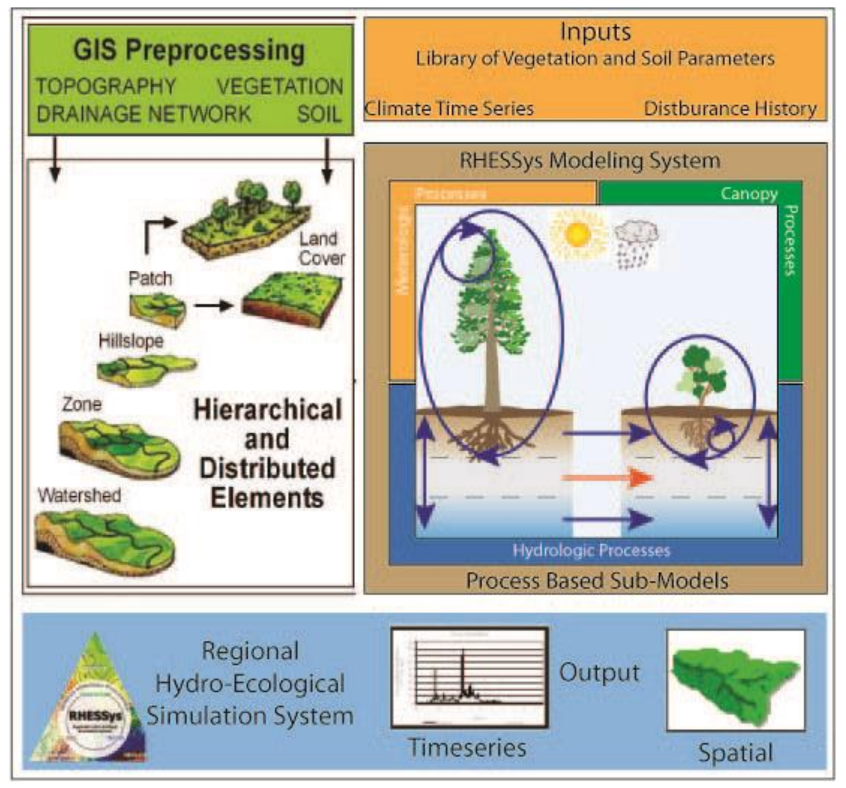
Spatially distributed ecohydrologic models are inherently constrained by the spatial resolution of their smallest units, below which land and processes are assumed to be homogenous. At coarse scales, heterogeneity is often accounted for by computing stores and fluxes of interest over a distribution of land cover types (or other sources of heterogeneity) within spatially explicit modeling units. However this approach ignores spatial organization and the lateral transfer of water and materials downslope. The challenge is to account both for the role of flow network topology and fine-scale heterogeneity. We present a new approach that defines two levels of spatial aggregation and that integrates spatially explicit network approach with a flexible representation of finer-scale aspatial heterogeneity.

The Problem

The RHESSys Model

Regional Hydro-Ecologic Simulation System (RHESSys) ver (e.g Tague and Band, 2004; Garcia & Tague, 2015)

- A process based ecohydrologic model
- The smallest spatial unit are patches ~ 30 to 90 m
- Standard topographically based routing between patches



Limitations

- Fine scale exchange may not be driven by topography (e.g exchange between open space and trees in a thinned forest)
- Highly heterogeneous/finely mixed landscapes sub patch/grid water redistribution ignored (e.g urban areas)

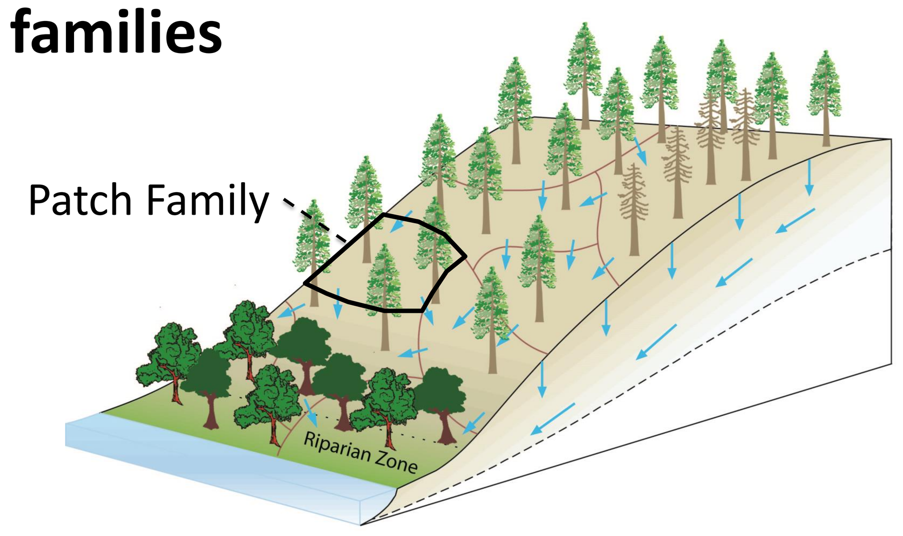
How do we model interactions that matter at scales too small to reasonably model?

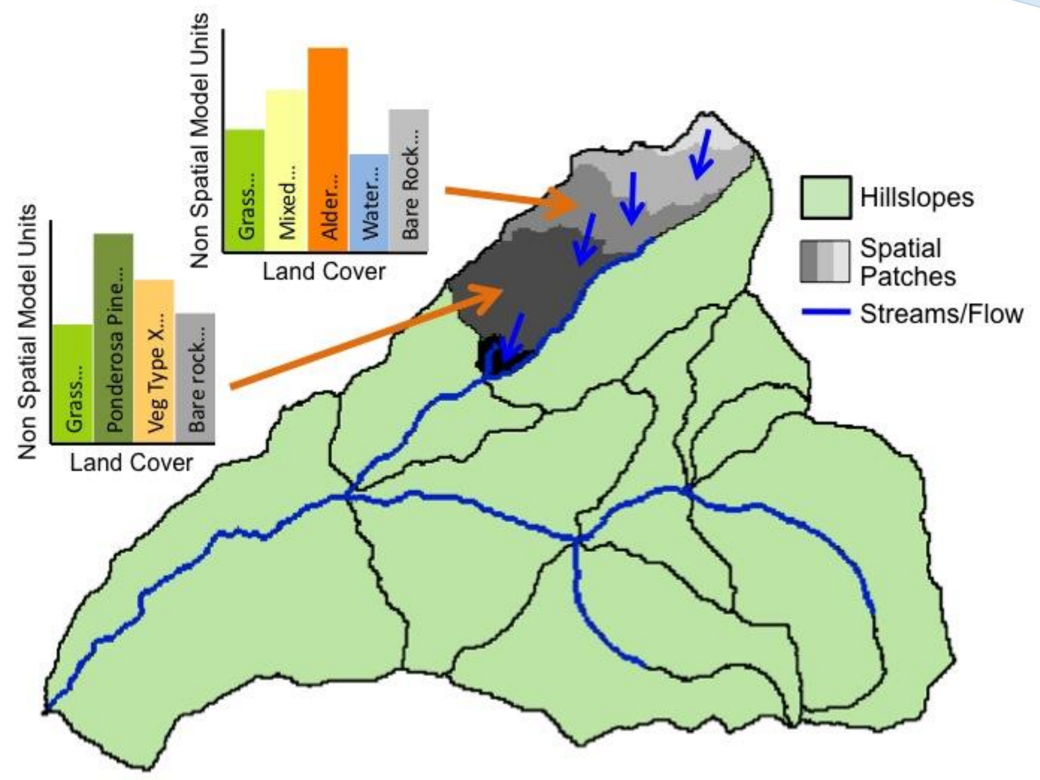
The Solution: Two scales of routing

Routing between patch families

- Spatially explicit
- Driven by topographic or water table gradients
- This is the standard routing approach (transmissivity or fill and spill connections between locations)

Between spatially explicit patch families





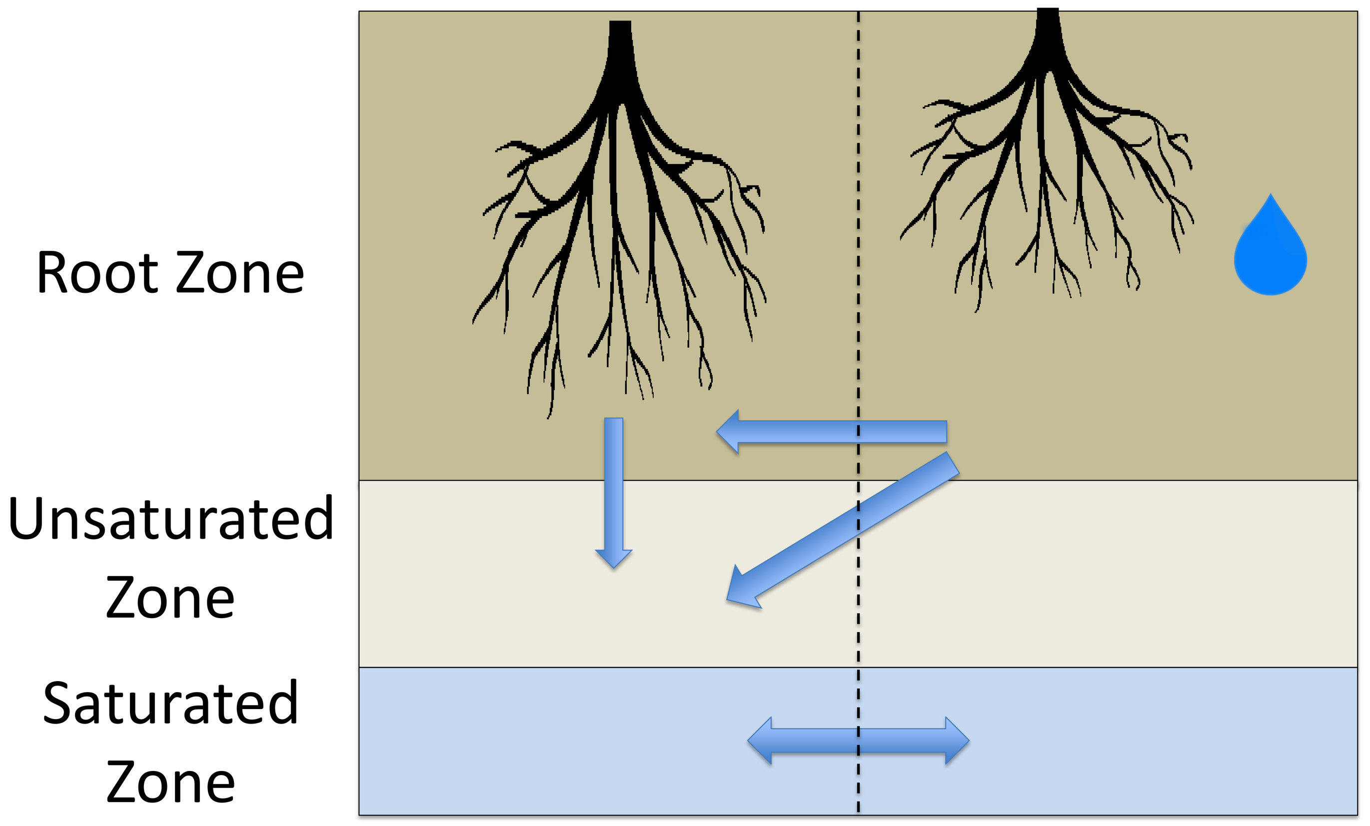
Routing within families of patches

- A-spatial – represented as a distribution of cover types
- Rule based routing between them

Aspatial Patch Functionality

- Simulates ecohydrologic processes (infiltration, evapotranspiration, etc.) in each aspatial patch separately
- Flow routing among aspatial patches determined by a scheme/set of rules – based on hypothesis about these lateral exchanges, for example:
  - Roof cover types drain to lawns (but not reverse)
  - Tree patches access water from open space patches as a function of root depth and time since clearing of open space area
- Redistribution scheme detailed here is broadly based on the TOPMODEL, which preserves water balance

Example aspatial routing



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Applications

Fuels Treatments

- The first application of multi-scale routing will be to simulate the impacts of thinning
- Thinning typically occurs at the scale of individual trees or small stands
- Characterization of tree size/carbon reduction and water transfers between neighboring trees
- But also capture watershed scale ecohydrologic impacts
- Fine scale effects can substantially alter model estimates, potentially shifting the impacts of thinning on downslope water availability from increases to decreases.

Rules for subsurface redistribution among aspatial patches (root-based)

RZ = Root Zone Store *Unsat = Unsaturated Store* *Sat = Saturated Store*
Δ = (RZ + Unsat) – mean(RZ + Unsat) *k = sharing coef (0-1)*
RZ_FC = field capacity for root zone

	Gaining Water (Δ > 0)	Losing Water (Δ < 0)
Root Zone Store (RZ)	RZ gain = Min(Δ * k * (RZ_z/(RZ_z + Unsat_z)) , RZ_FC)	RZ loss = Max(RZ_FC, RZ store – Δ * k)
Unsaturated Zone Store (Unsat)	Unsat gain = Δ * k * (RZ_z/(RZ_z + Unsat_z)) + Max ((RZ gain – RZ_FC) , 0)	Unsat loss = Max(Δ * k – RZ loss, 0)
Saturated Zone Store (Sat)	Sat store = k * (mean(Sat store) - Sat store)	

Urban Applications

Multi-scale routing well suited to applications in urban areas
* Lawn water routing
- Linking Storm water detention basins to hillslopes (see Bell et al., 2017)
- Small scale land cover heterogeneity

Next steps

Initial application: SERI Fire Project that uses RHESSys to estimate thinning and post-fire impacts on water and carbon cycling

Generalizable approach (two new inputs to RHESSys)

a) rules for defining patch types within spatially explicit areas (families)
b) rules for routing between patches within families

Our approach will provide a syntax for input files to RHESSys that allows users to specify a) and b)

Acknowledgements:

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