Throughfall heterogeneity in forested landscapes as a focal mechanism for deep percolation: yes or no?

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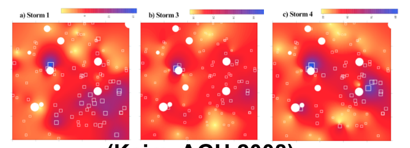
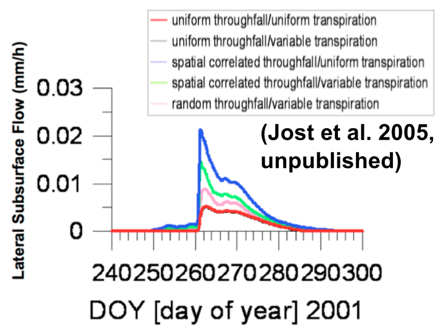
1: Background and motivation

Process knowledge



(Keim, AGU 2008)

-Distribution of throughfall is consistent over time (Raat et al. 2002, Keim et al. 2005)



(Jost et al. 2005, unpublished)

-Model simulations show focused throughfall and deep percolation will increase subsurface flow rates* (Jost et al. 2005, unpub.)

*Based on a strongly non-linear relationship between soil water content (SWC) and hydraulic conductivity (Van Genuchten 1980)

Does it really happen?
How does it work?
Can focused deep percolation be observed in the field?

Provision of ecosystem services

Payments for ecosystem services are a forest management policy in Costa Rica

Primary forest

conversion

Pasture

conversion

Secondary forest

Are the forests functionally the same in terms of the ecosystem services provided? Deep percolation and dry-season streamflow?

2: Objectives

Process-based questions:

1) Does forest structure that creates high spatial heterogeneity in canopy throughfall create rapid deep percolation pathways?
2) Alternatively, do roots simply homogenize any heterogeneity in these soil water inputs created by the overriding inputs from the canopy?

Ecosystem-level question:

1) Due to differences in structure, do primary and secondary forests differ in their rates of deep water percolation, thereby affecting their provision of ecosystem services such as groundwater recharge and dry-season streamflow?

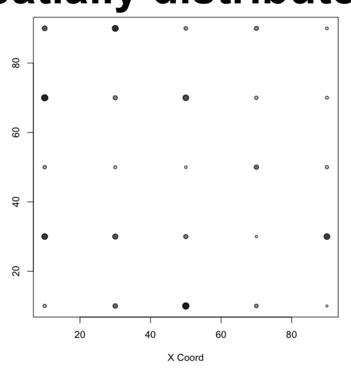
3: Methods

Throughfall

350 rain gauges
25 gauges per plot
14 plots
3 months
Spatially distributed

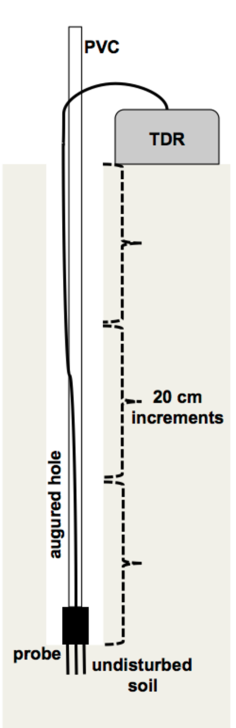
Secondary plot ages

Plot	Prior land use	Year of abandonment or timber extraction
Tirimbina	Pasture	1982
Cuatro Rios	Pasture	1972
El Bejuco	Pasture	1995
Juan Enriquez	Pasture	1995
Aceituno	Cleared but not used	1972
Manú	Cleared but not used	1962
Botarrama	Cleared but not used	1962



Manual weekly measurements

Soil Water Content (SWC) Profiles



In-situ methodology pairing:

-Frequency domain reflectometry (FDR) volumetric water content measurements

&

-Hand augering down to 3 m with field observation

Location:
Sarapiqui region, Costa Rica
Humid tropical climate
14 plots: 7 primary forest, 7 secondary forests

Timing:
July through September, 2009
(soil moisture July only)

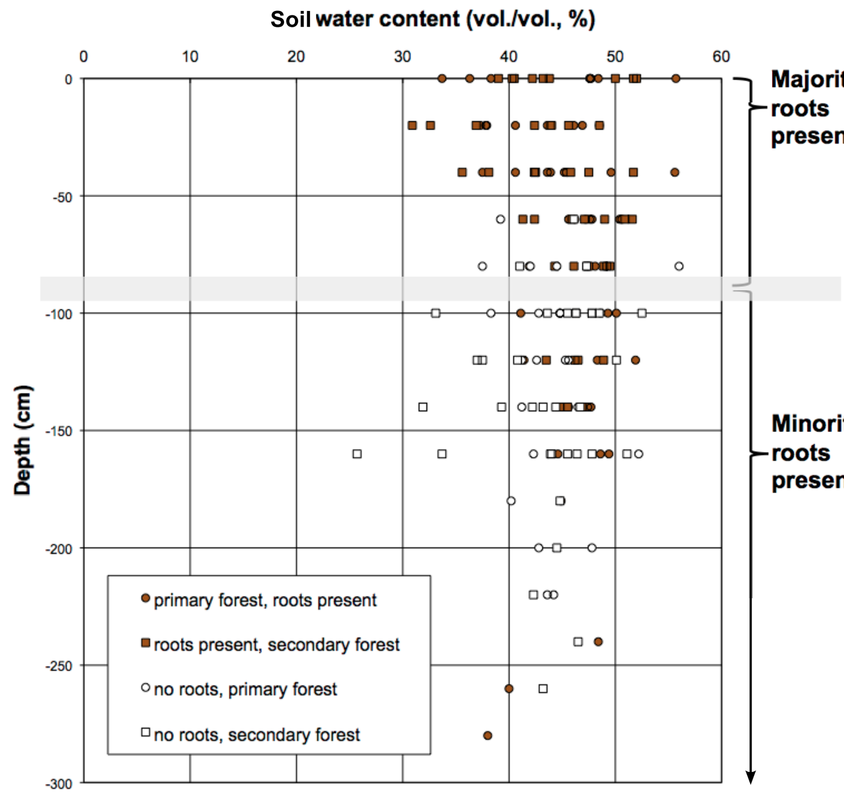
Neotropical deep clay-rich (>75%) soil, uniform across sites

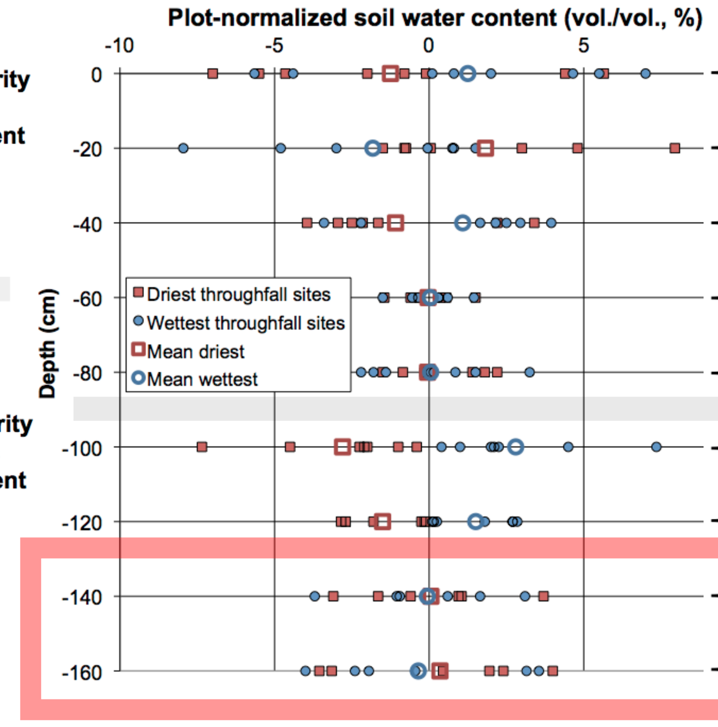
4: Results

Observational

Throughfall & rainfall

Forest Type	Primary	Secondary	All Types
Mean Throughfall	**67%**, sd 13%	**68%**, sd 16%	**68%**
Mean Maximum Throughfall	**140%**, sd 33%	**140%**, sd 26%	**140%**
Throughfall Heterogeneity (CV)	**0.45**, sd 0.12	**0.44**, sd 0.09	**0.45**
Mean Daily Rainfall (mm/day)			**11.0**





mean difference (wettest – driest)	p value*
2.5	0.27
-3.64	0.22
2.18	0.33
0.08	0.92
0.1	0.94
5.6	**0.02**
3.02	**0.02**
0.12	0.95
-0.7	0.79

*student's t-test
matched groups
2-tailed test

Majority root zone
difference: 0.28
p value*: 0.73

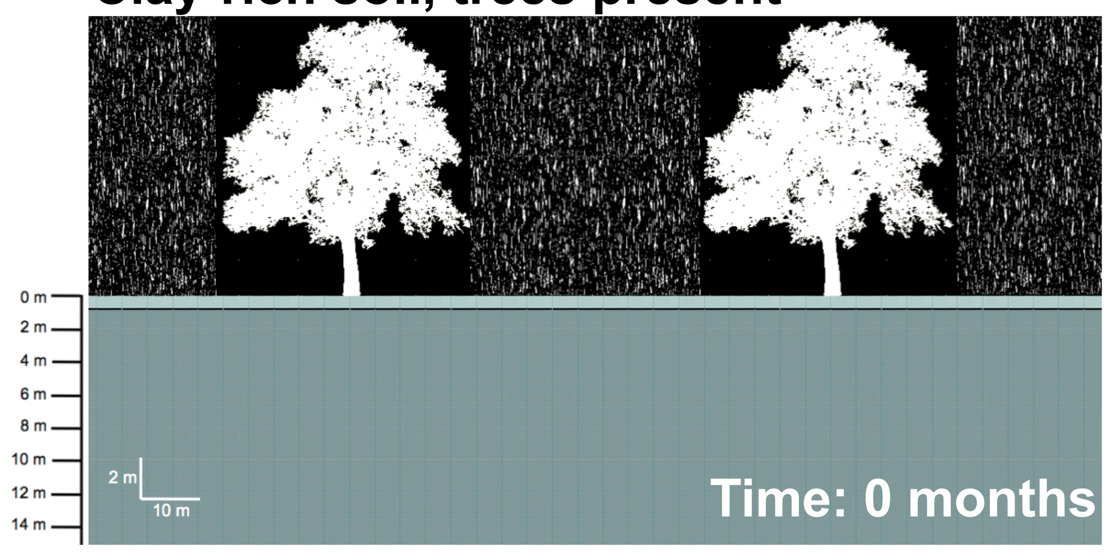
Minority root zone
difference: 1.56
p value*: 0.12

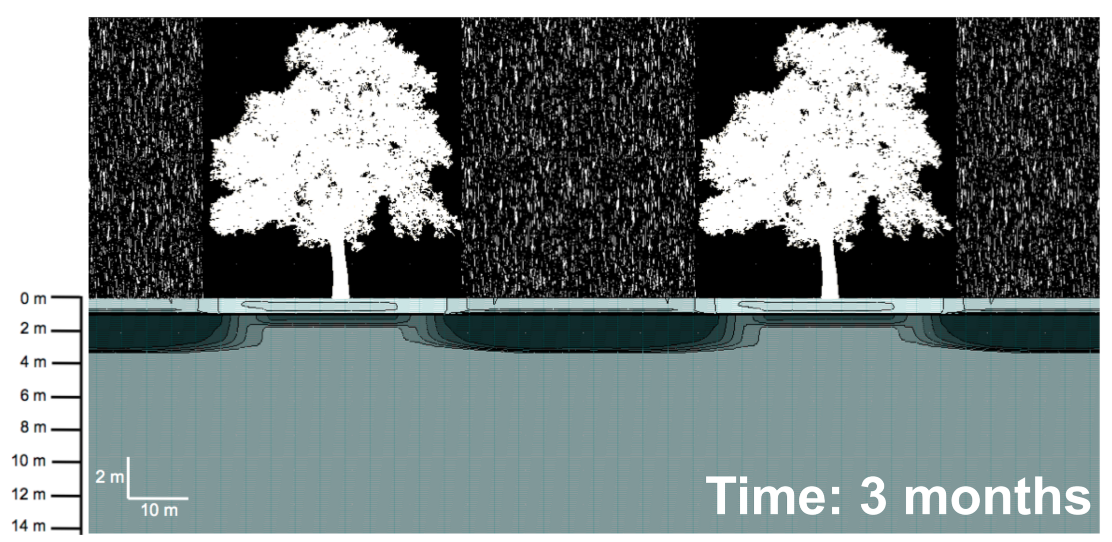
Forest type analysis

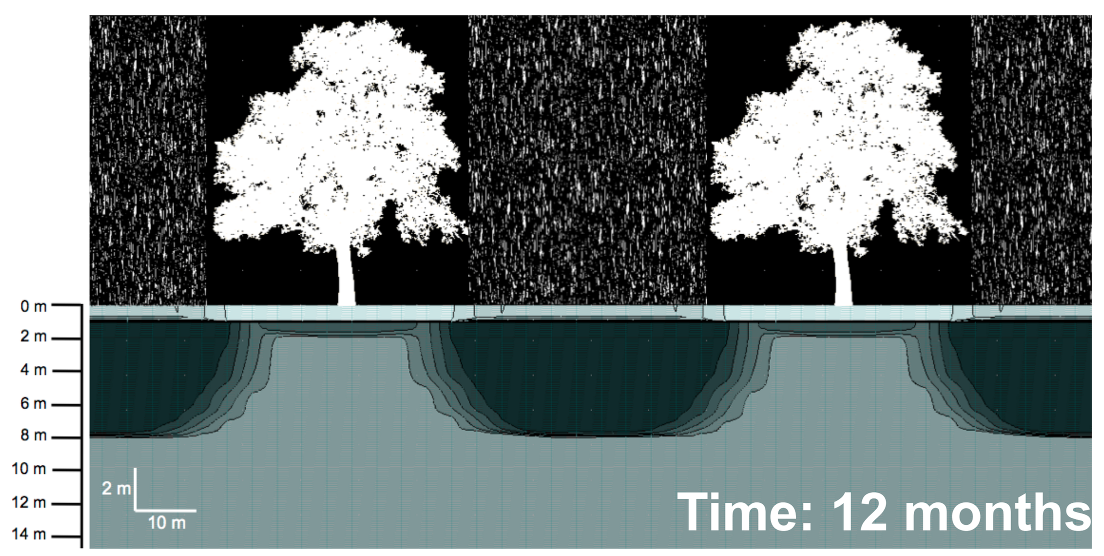
	PRIMARY FOREST		SECONDARY FOREST	
depth	difference	p value*	difference	p value*
all depths	0.92	0.41	0.86	0.38
0-80	0.56	0.75	0.14	0.92
100+	1.3	0.34	1.74	0.23

HYDRUS-2D simulations

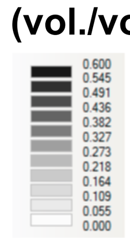
Clay-rich soil, trees present







LEGEND
Soil water content (vol./vol.)

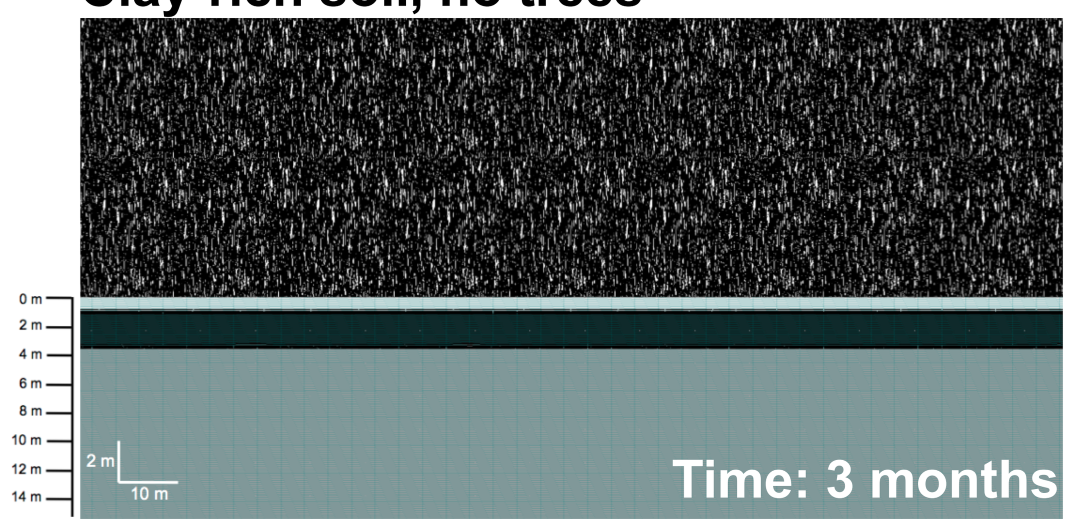


Parameters

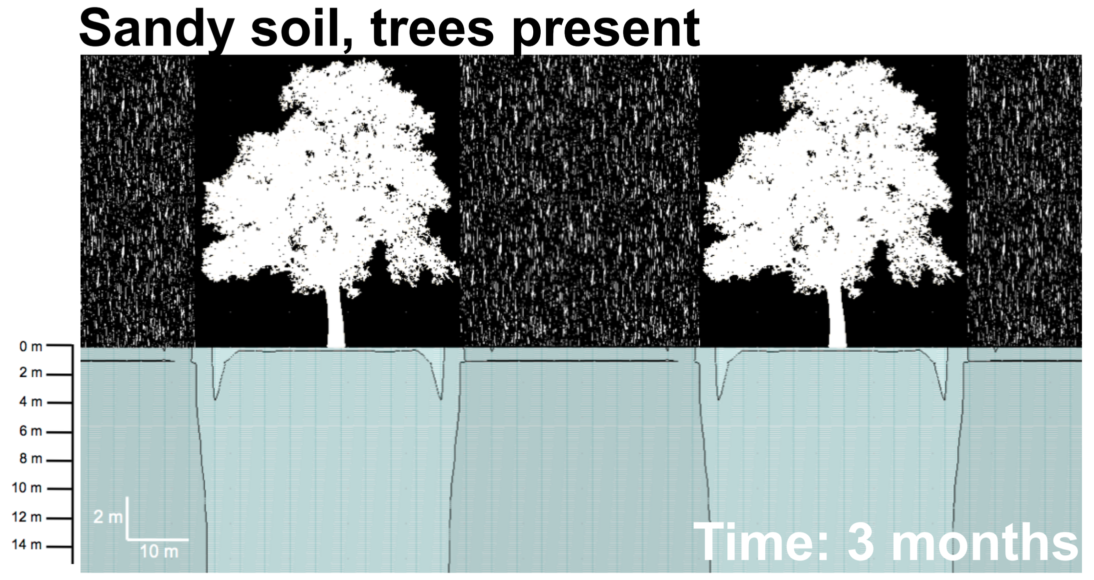
	Lower soil (0.9 to 20 m)			Upper root zone (0 to 0.9 m)					
Model Run	K_{sat} (m/hr)	SWC_{sat}	Particle Size	K_{sat} (m/hr)	SWC_{sat}	Particle Size	Gap Size (m)	Precipitation (mm/hr)	Time Step
Clay-rich soil, trees present	0.002	0.58	clay	2.0[1]	0.55**	sand*	43[2]	0.46****	1 hr
Clay-rich soil, no trees	0.002	0.58	clay	2.0[1]	0.55**	sand*	-	0.34***	1 hr
Sandy soil, trees present	0.297	0.43	sand	2.0[1]	0.55**	sand	43[2]	0.46****	1 hr

-All soil layers began model runs at field capacity, all parameters derived from HYDRUS presets unless otherwise noted
[1]Alaoui et al. 2011; [2]Loescher et al. 2002
*coarse particle size to simulate roots present
**maximum observed in field data
***rainy-season average observed from meteorological station at field base
****calculated using all-site mean throughfall (equivalent to a maximum throughfall of 135%)

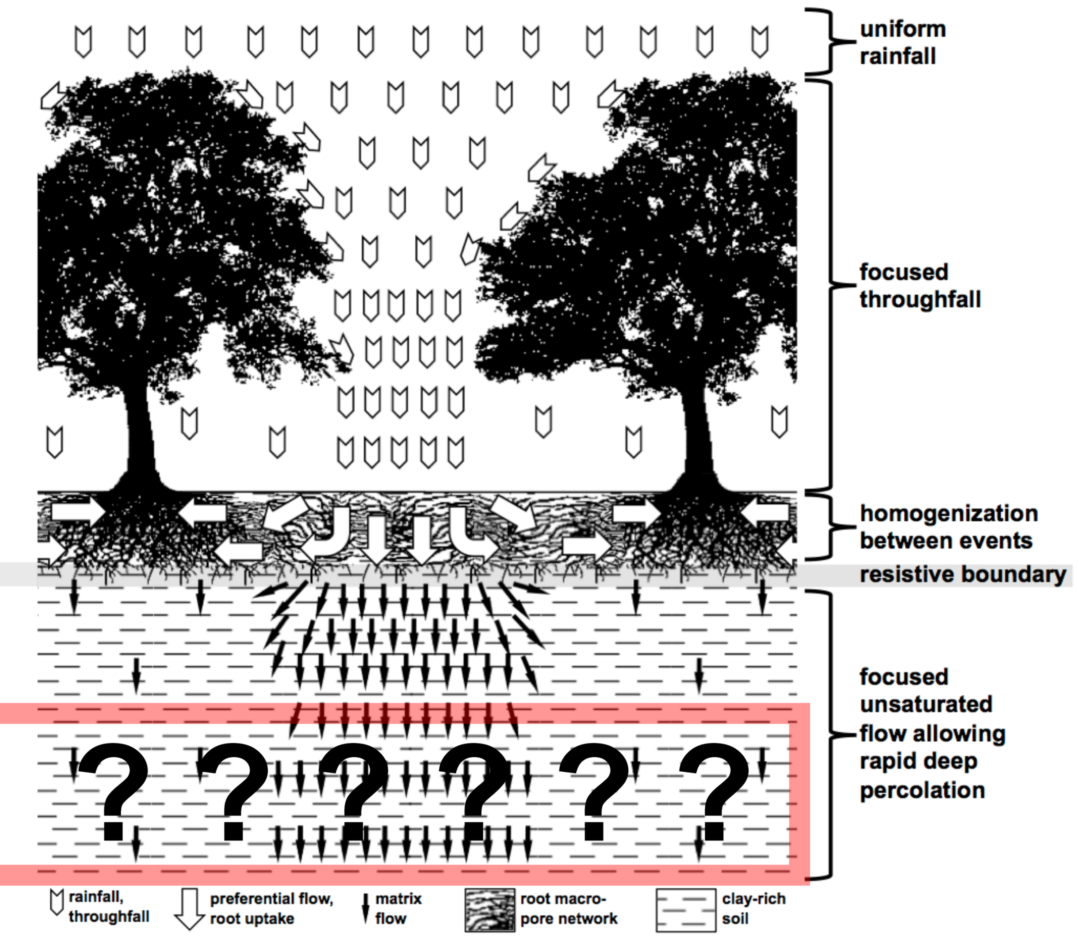
Clay-rich soil, no trees



Sandy soil, trees present



5: Discussion & conclusions



New process inference

-YES and NO, focused deep percolation does occur but its persistance at depth is uncertain
WHAT DO YOU THINK? Feedback encouraged!
-Preferential flow homogenizes SWC between events within the root zone
-ET not modeled, but large influence on transport and loss of water within root zone

Ecological and policy implications

-No observable difference between primary and secondary forests in their provision of deep percolation (small sample (n=7), one region only)

6: Future directions

-Sandy soils
-Snow-dominated environments
-Precipitation intensity thresholds
-Bedrock interactions
-Complex terrain

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