Identifying Hydrological Flowpaths and Land-Water Nutrient Transformations in Forested and Deforested Watersheds in the Southwestern Amazon: a Multivariate End-Member Mixing Analysis

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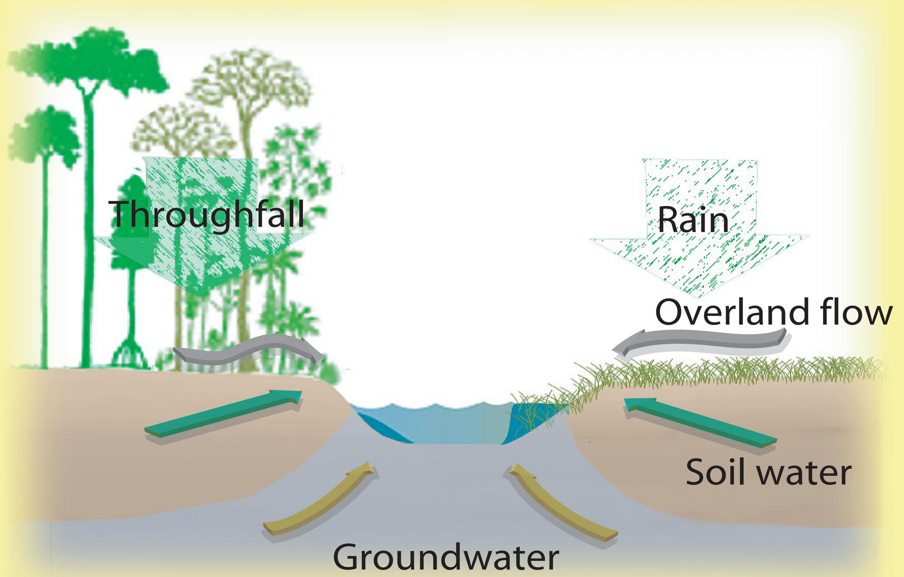
Background

The combined effects of water flow and biogeochemical processes determine nitrogen (N) and carbon (C) movement and transformation in watersheds. Water flowpaths (inset) are a key influence on N dynamics because they control the rate of water movement and the conditions capable of transforming N and C in moving water. Deforestation alters both hydrological flowpaths and the biogeochemical transformations that occur within flowpaths. We used a principal component-based analysis of storm-induced stream water flows to determine the contribution to storm flow by flowpaths in forest and pasture basins (1 ha) in Rondônia. Episodic streams that stop flowing during the dry season drain both basins. We are using this approach to quantify N & C transformations within individual hydrological flowpaths.



Questions

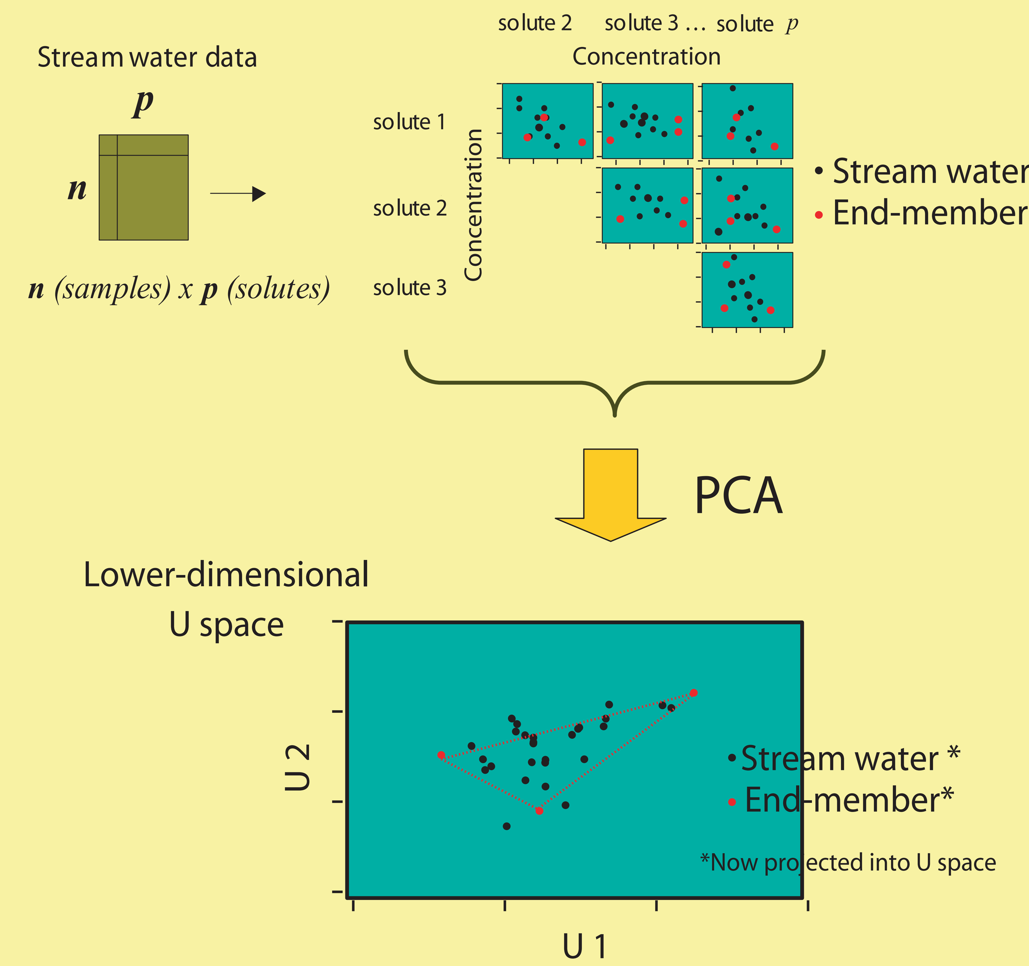
What are the hydrological flowpaths by which water moves from uplands to streams in tropical forest and pasture?

How are N & C transformed as it travels from uplands to streams within different flowpaths in forest and pasture?

How do flowpath hydrology and within-flowpath N & C transformations combine to influence movement at the watershed scale?

Method

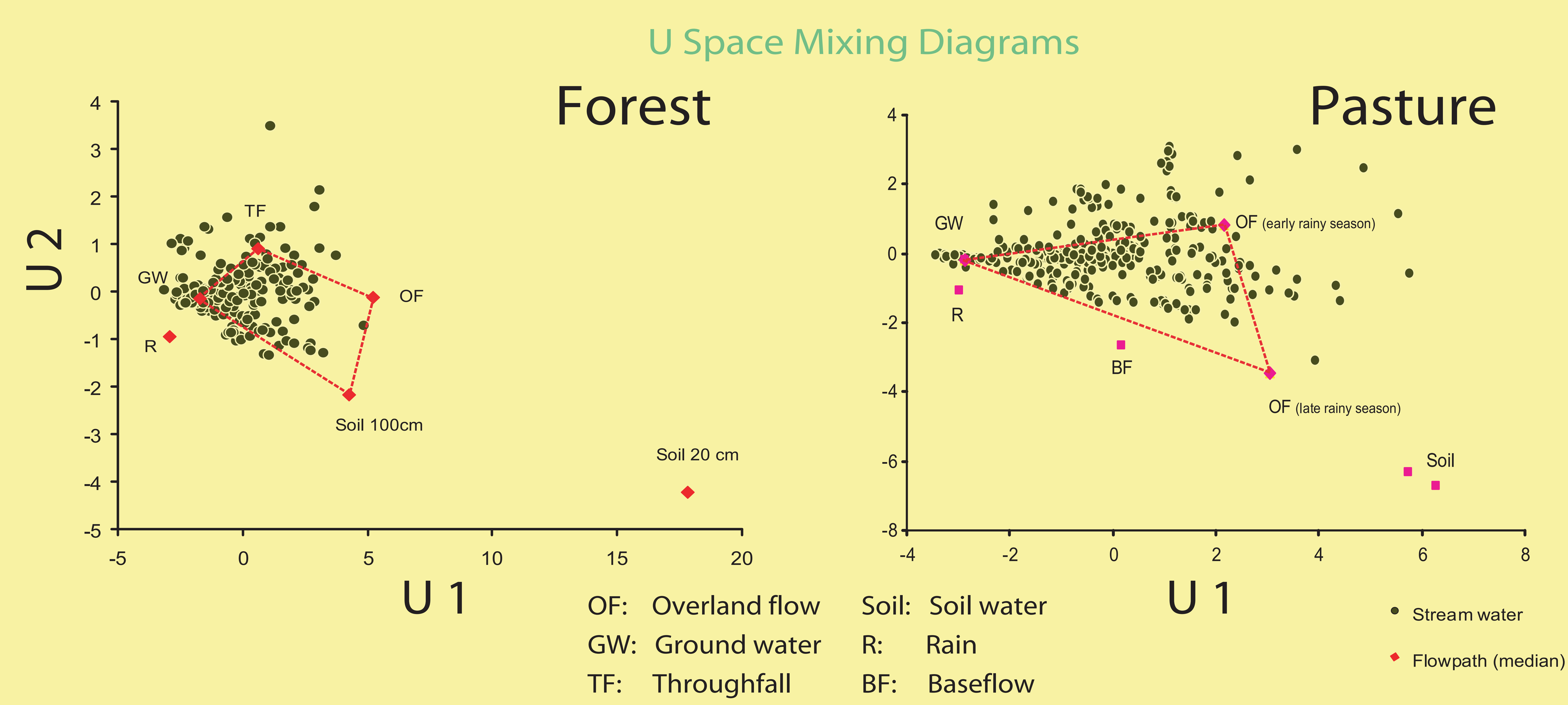
Multivariate data analysis techniques, such as principal component analysis (PCA), have been used in mixing problems from a variety of environmental sciences. The main purpose of PCA is to find a lower-dimensional space, U, where most of the observations can be assumed to lie within a specified accuracy (1). Once the data is projected into this lower-dimensional space (right), and a set of source solutions (end-members) that satisfactorily bound these data is found, a series of linear equations is constructed to calculate the proportion of each end-member for each stream water sample.



$$\begin{pmatrix} 1 & 1 & 1 \\ -1.96 & 7.37 & 1.36 \\ -1.15 & 2.76 & -0.88 \end{pmatrix}\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{matrix} 1 \\ -2.8 \\ 2.6 \end{matrix}$$

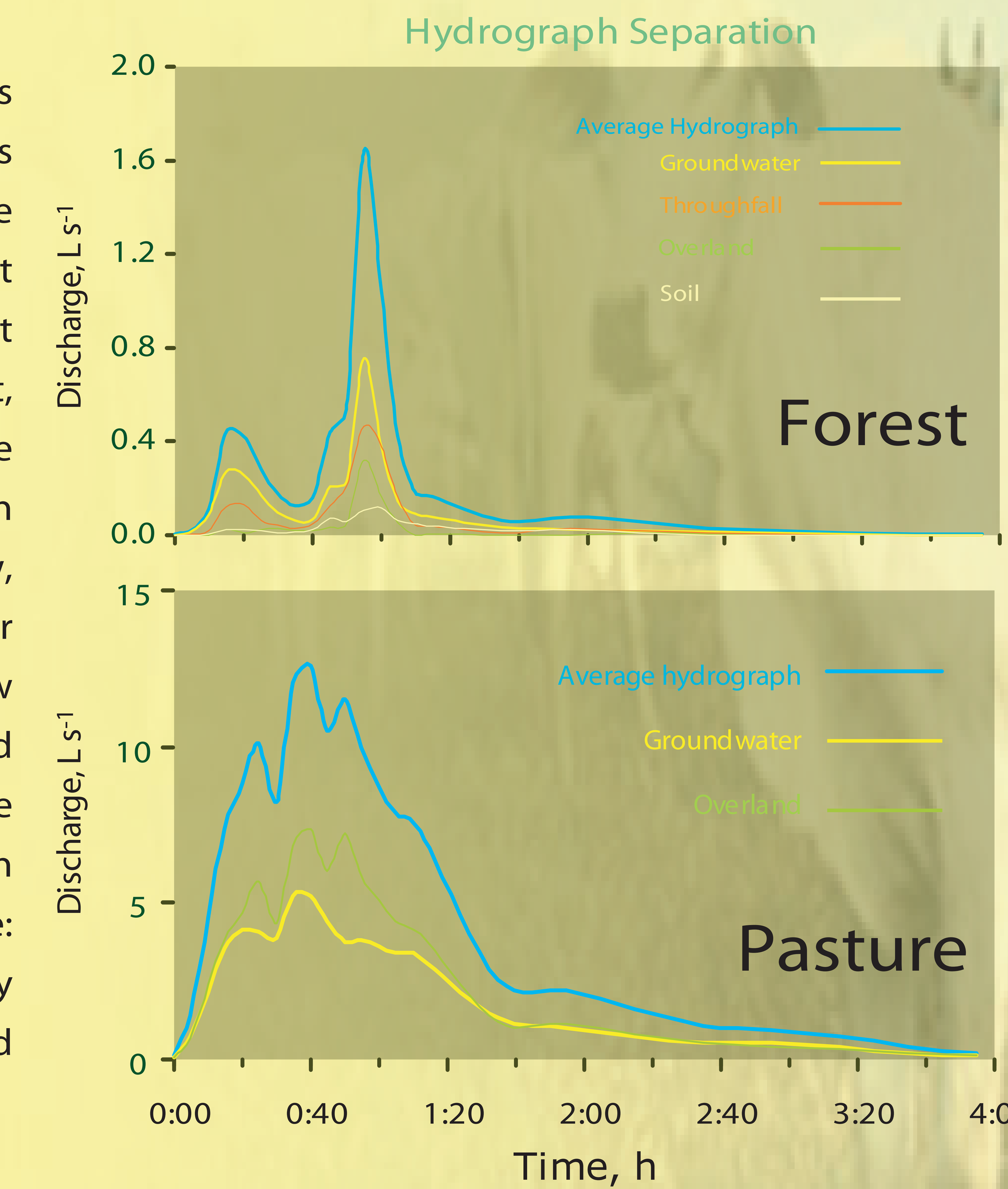
[1]Christophersen, N & Hooper RP Multivariate Analysis of Stream Water Chemical Data: The Use of Principal Components Analysis for the End-Member Mixing Problem. WATER RESOURCES RESEARCH, VOL. 28, NO. 1, PAGES 99–107,

Results



The U space mixing diagram for the forested watershed (top, left), shows that groundwater, throughfall, overland flow and soil water bound most of the stream water samples. For the pasture mixing diagram (top, right), most of the stream water falls between groundwater and overland flow. Although, overland flow was separated into two end-members due to the marked seasonal variation by this flowpath between the early and late rainy seasons. Soil water does not appear to contribute significantly to storm flow in the pasture. Neither direct rain input at both locations and base flow in the pasture appear to be source solutions during storm flow.

Water yields during storm events from pasture watersheds is about one order of magnitude greater than from forest dominated ones. Storm flow out of the pasture watershed (right, bottom) appears to be composed mainly by riparian groundwater and overland flow, with dominance by the latter during peak flow. Storm flow from our forested watershed (right, top) appears as a more complex mixture of, in decreasing order of importance: riparian groundwater, canopy throughfall, overland flow, and soil water.



Conclusions

We will use this technique in several important new ways:

1) We are testing the results of the hydrograph separation derived from the solute end member mixing analysis against concurrent measurements of overland flow, soil water storage and groundwater elevations made during the same storm events in the forest and pasture basins. This will provide a strong validation of the approach and allow us to apply it at a variety of scales. It already indicates the importance of overland flows even in intact forest.

2) We are using the information on flowpath hydrology and the behavior of conservative solutes as tracers to quantify the gains and losses of non-conservative solutes, such as ammonium, nitrate and phosphate, within individual hydrological flowpaths. This provides new insight into how hydrology interacts with biogeochemistry to alter sources and sinks of plant nutrients after deforestation.

3) We are coupling this information on the structure of hydrological flowpaths with measurements of dissolved carbon in each flowpath to quantify the sources of the large amount of dissolved carbon that is moving from Amazon terrestrial ecosystems into small streams and how those fluxes change with deforestation.

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