The Delivery of Dissolved Organic Carbon from Forest Soils to a Head Water Stream

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INTRODUCTION

The temporal variation of the delivery of dissolved organic carbon (DOC) from hillslopes to the adjacent streams is determined by hydrological and biogeochemical processes that have not been completely quantified. In particular, processes involving differences in the fate and transport of the easily biodegradable fraction of dissolved organic carbon (BDOC) and the more recalcitrant fraction of DOC (NDOC) are of ecological importance.

Our research site is White Clay Creek (WCC) watershed, WCC watershed is a 725 ha, 3rd-order watershed located in southeastern Pennsylvania. The major goal of this research is to estimate the spatial DOC flux distribution within the watershed.

OBJECTIVES

➢**Objective I:** Estimate vertical annual DOC flux to groundwater. (*One dimensional treatment*)

➢ **Objective II:** Estimate the DOC flux to the stream during precipitation events along the hillslope. (*Two dimensional treatment*)

MODEL DESCRIPTION

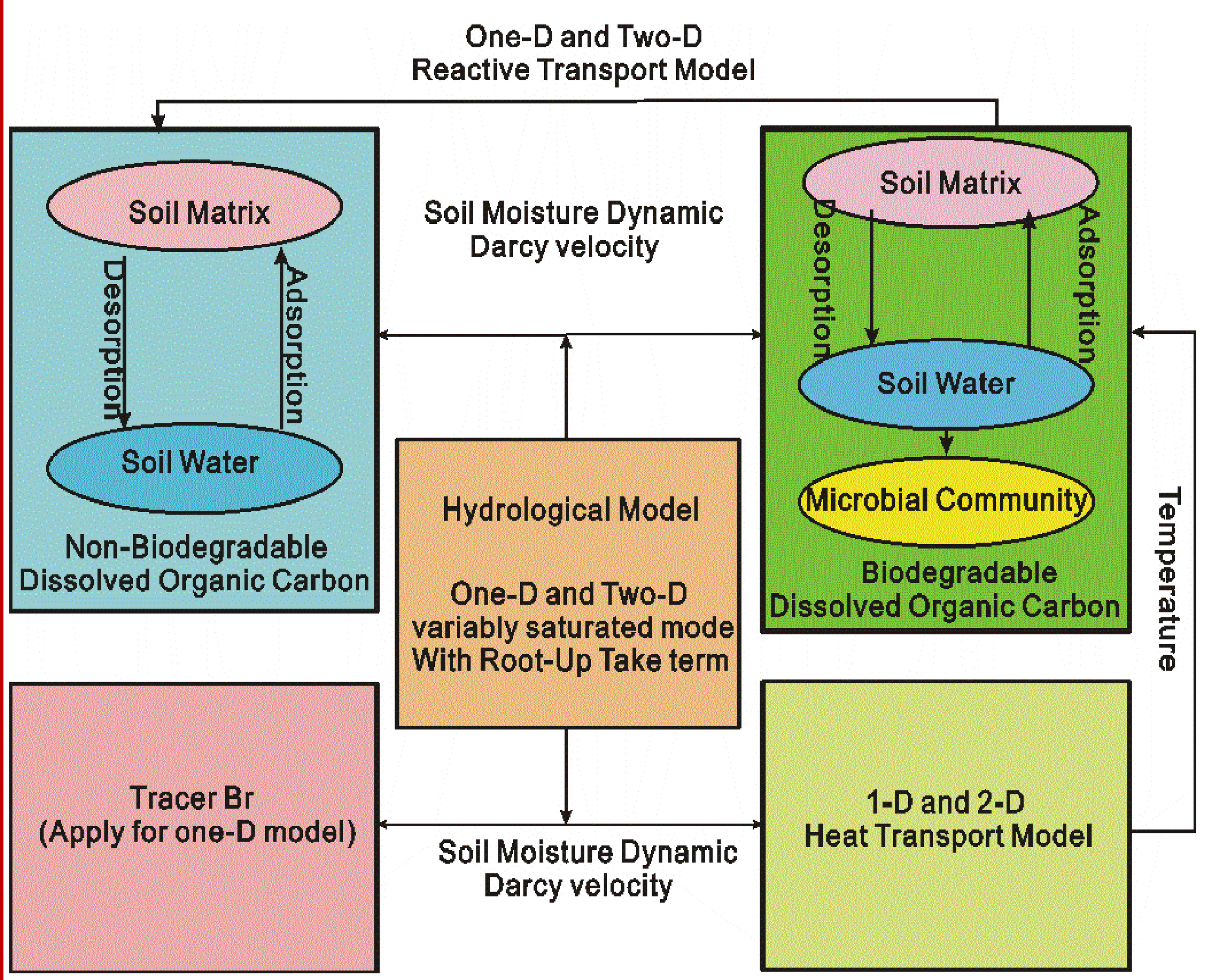


Fig 1. One Dimensional and Two Dimensional Model Structure

1-D dual-permeability unsaturated flow and transport model:

➢ The one dimensional model was used to estimate vertical flux through soil column.

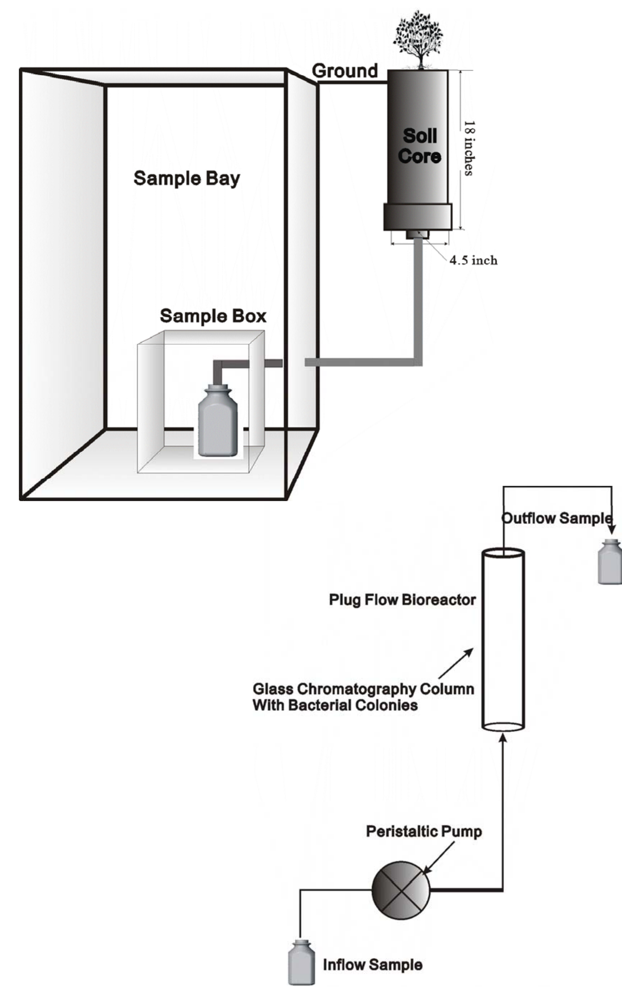
➢ The model was first calibrated using the experimental data (Fig 2), then 1997 meteorology data was used to run the calibrated model for the whole year.

2-D saturated and unsaturated flow and transport model:

➢ The two dimensional model was used to calculate DOC flux through the hillslope for a precipitation event.

***One Dimensional Model Equations are Available on Handout**

OBJECTIVE I



FIELD AND LAB METHODS

Soil Core Experiments:

➢Applied Bromide-amended solution on the top of in-situ soil core at a controlled speed.

➢Collected water samples at the bottom at fixed time intervals.

➢Kept track the temperature at the top of the soil core and 3 cm into the soil core.

Lab experiments:

➢Plug-flow bioreactor was used to separate BDOC and non-BDOC by running samples through it, DOC and BDOC concentrations were obtained by calculating the difference between the inflow and outflow samples of the bioreactor.

SIMULATIONS RESULTS

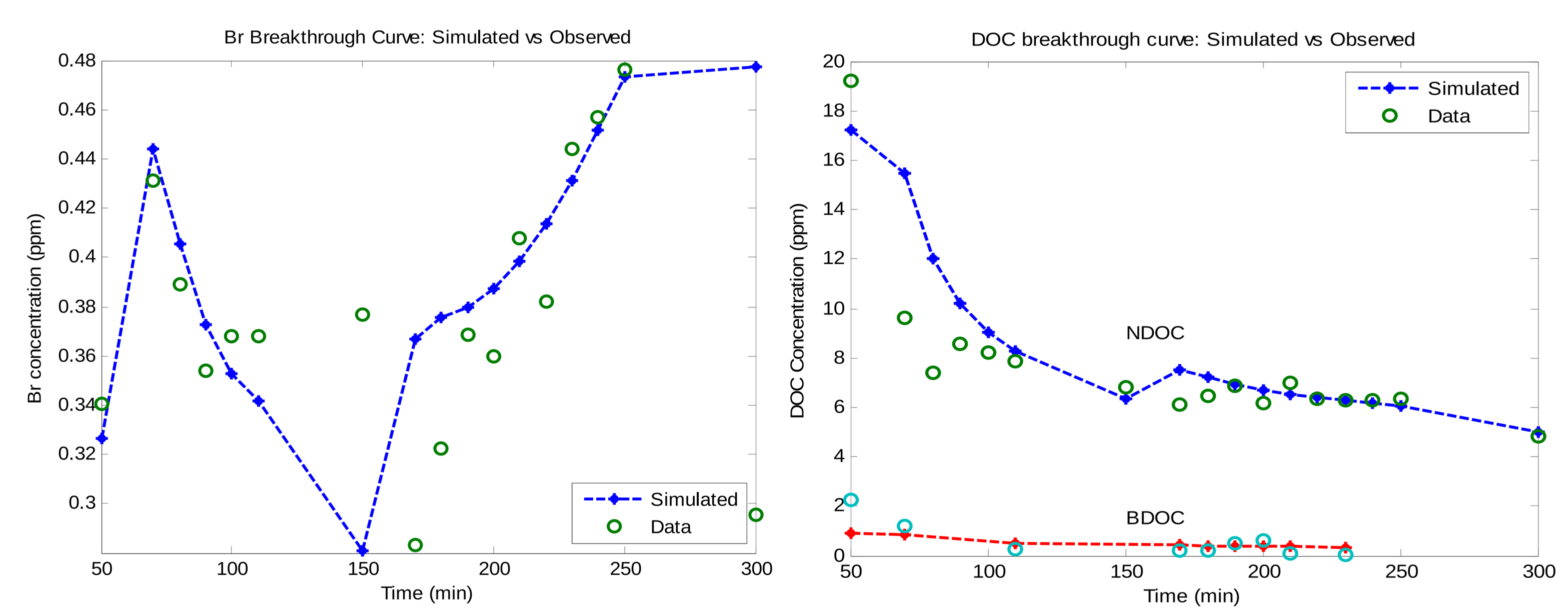


Fig 2. Calibration of one-D model from soil core experiments

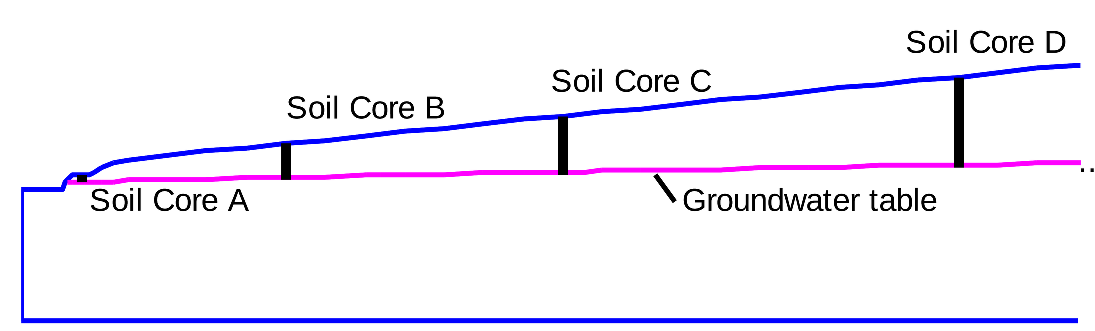


Fig 3: Extend one-D model to different lengths assuming each length represents a soil core above groundwater table.

➢ Simulation results show that the riparian zone (groundwater depth less or equal to 3m) contributes 98% DOC to the groundwater. and the rest of the area contributes less than 2% .

➢ The model output of total DOC recharge to groundwater in 1997 is about 4700 kg C/year.

➢ Baseflow contributed about 67% of the total DOC exported from WCC in 1997.(*Model estimation*)

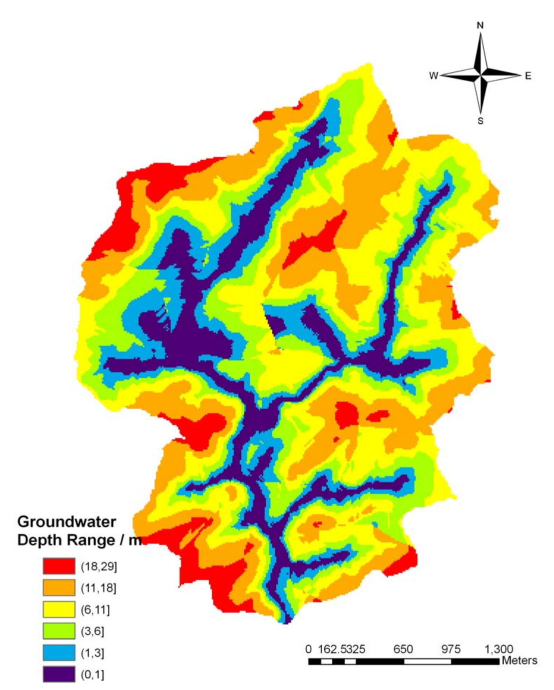


Fig 4. Groundwater depth distribution across the watershed

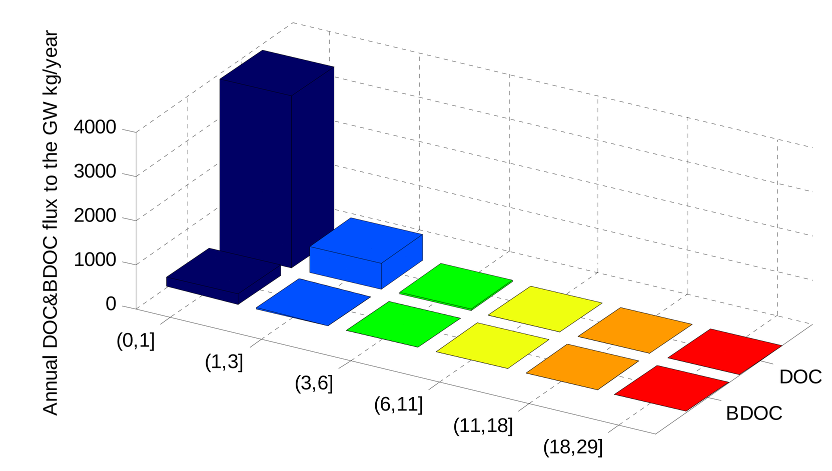


Fig 5. Calculation results of NDOC and BDOC flux to groundwater in each specific groundwater depth region
(Each region uses a representative soil core length)

OBJECTIVE II

2D HILLSLOP APPROACH

Fig 6 Riparian zone

Fig 7 Middle hillslope

➢ A hillslope transect located on the east bank of the third order stream of White Clay Creek was selected to explore horizontal DOC flux along groundwater flow path.

➢ This transect is nearly perpendicular to the stream and almost parallel to the flow direction of shallow phreatic groundwater (Fig 6 and Fig 7).

METHOD: NUMERICAL MODEL

Saturated-unsaturated flow

$$\nabla\cdot\left[\mathbf{K}_s k_r\cdot(\nabla h+\mathbf{k})\right]-R=\left(C+\frac{\theta}{n}S_s\right)\frac{\partial h}{\partial t}$$

DOC and BDOC transport

$$\frac{\partial}{\partial t}(\theta c_b+\rho s_b)=\frac{\partial}{\partial x_i}\left(\theta D_{ii}\frac{\partial c_b}{\partial x_i}+\theta D_{ij}\frac{\partial c_b}{\partial x_j}\right)-q_i\frac{\partial c_b}{\partial x_i}-S$$

➢ A 2-D vertical finite element model was used to solve for flow and DOC transport along this 120 m hillslope in WCC watershed.

SIMULATION RESULTS

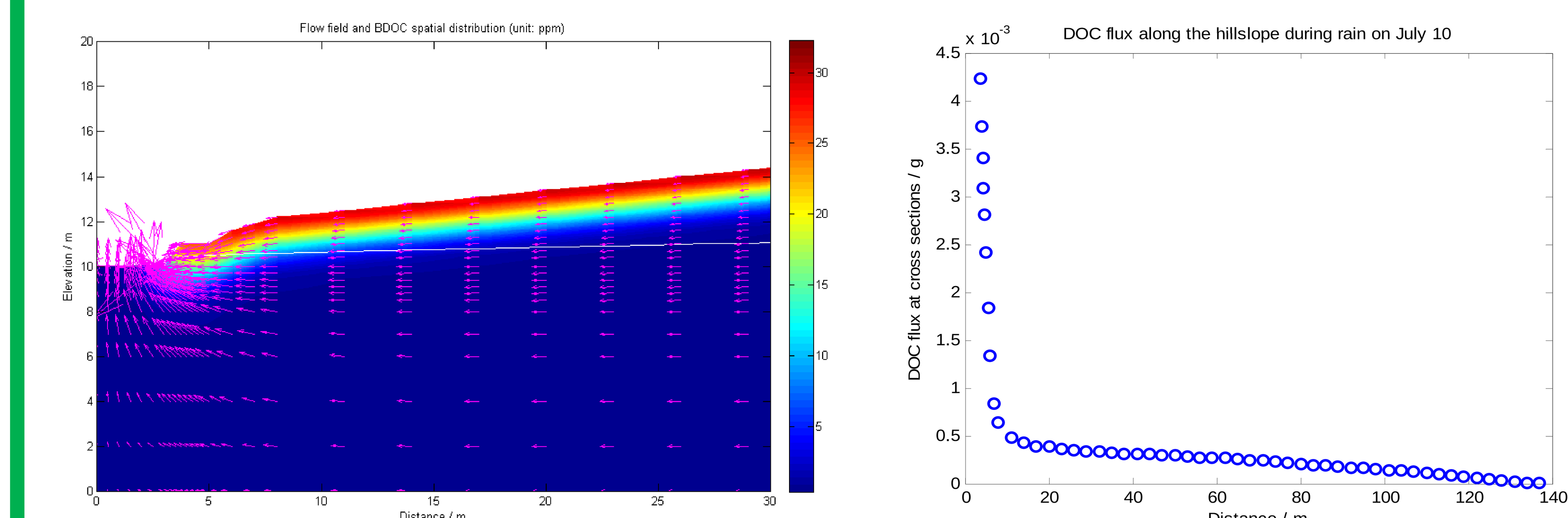


Fig 8. DOC concentration spatial distribution and DOC flux along the hilllslope

➢ The 2D model simulation results show that DOC flux is high near the stream and declines rapidly in the upland area (Fig 8).

DISCUSSION

As DOC is "flushed" from its terrestrial sources to the stream, the riparian zone has a much more significant effect on the DOC and BDOC concentrations in the adjacent stream than do sources from the upper hillslope. The groundwater level is very close to the top soil layer in the riparian zone, and when the stream stage rises rapidly during the rain, the ground water level in the riparian zone rises accordingly and reaches major DOC sources in the upper soil layers.

FUTURE RESEARCH

Collaboration with the PennState CZO group has been initiated. The PennState Integrated Hydrological Modeling System (PIHM), a physically-based fully distributed hydrology model, will be extended to simulate the DOC dynamics at a whole catchment scale. The Christina Basin will be the test bed for the model.

ACKNOWLEDGMENTS

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