Estimating carbon budgets of the Biscuit Brook watershed using RHESSys

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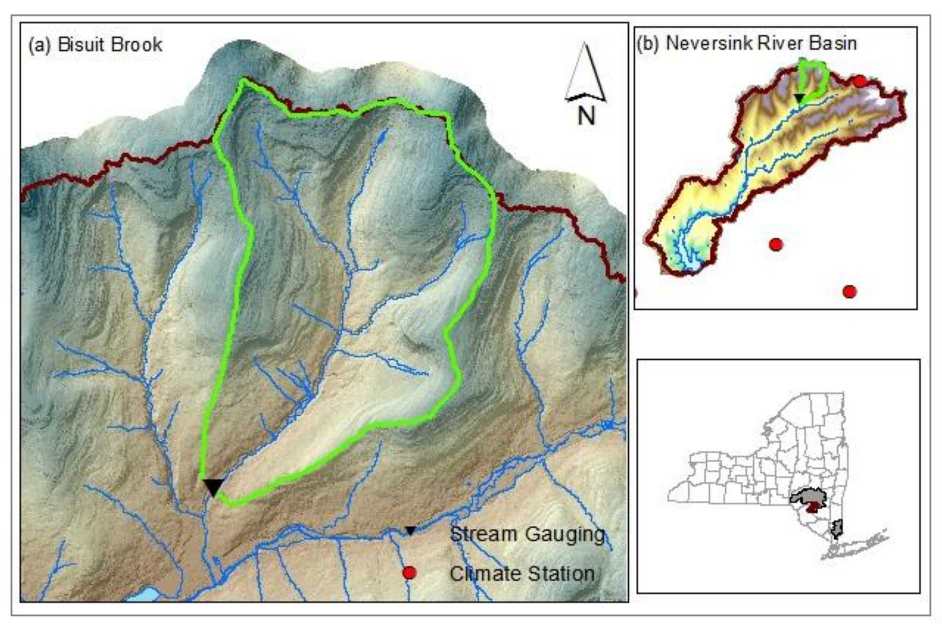
1.Research Background and Objective

Carbon inputs to New York City (NYC) reservoirs are potential precursors to disinfection by-products (DBPs) which are subject to regulatory limits in the NYC drinking water distribution system. As a first step towards increased understanding of the potential sources of watershed carbon, a forest ecosystem model (Regional Hydrologic Ecologic System Simulation, RHESSys) was applied to estimate the carbon pools and fluxes associated with soil, litter, coarse woody debris and live trees in selected NYC watersheds under historical climate conditions. As a case study, RHESSys was applied to Biscuit Brook, a headwater stream in the watershed of Neversink Reservoir that has a long record of streamflow, dissolved organic carbon (DOC) and other water chemistry data

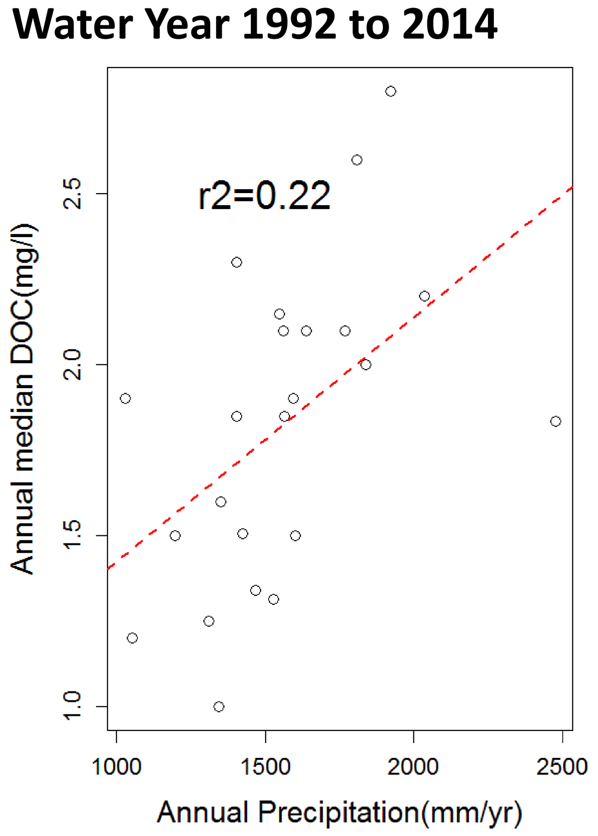
2. Study sites



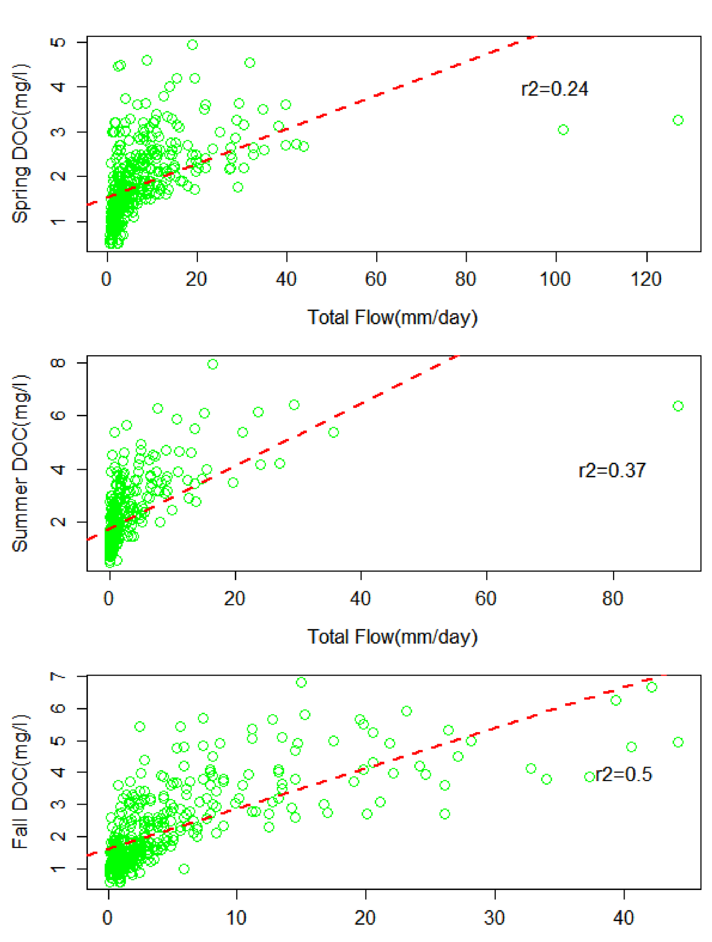
- The study site is located in the Neversink River basin, part of the New York City water supply watershed.
- Mean annual precipitation is 1590 mm, and 20-35% of total precipitation fall as snow. Peak discharge occurs in April.
- Major land use is forest (>98%), consisting of American beech, red maple, sugar maple and yellow birch.
- Steep slopes, quick-draining shallow till, and slowly weathering bedrock**.**

3. Observed DOC patterns

Water Year 1992 to 2014

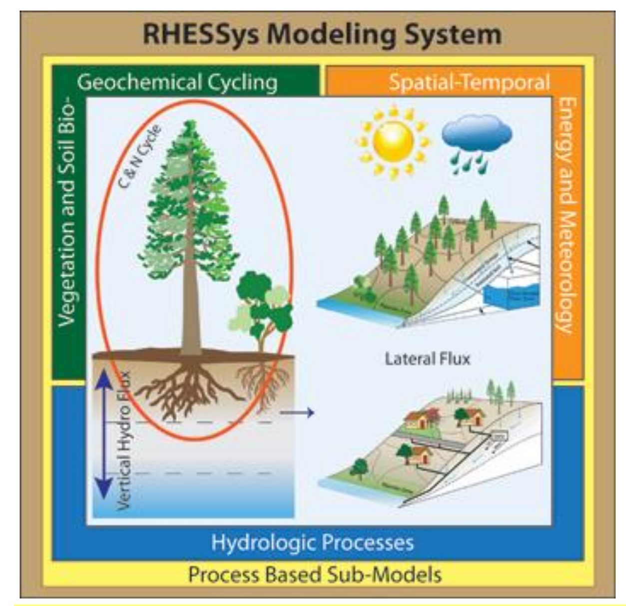


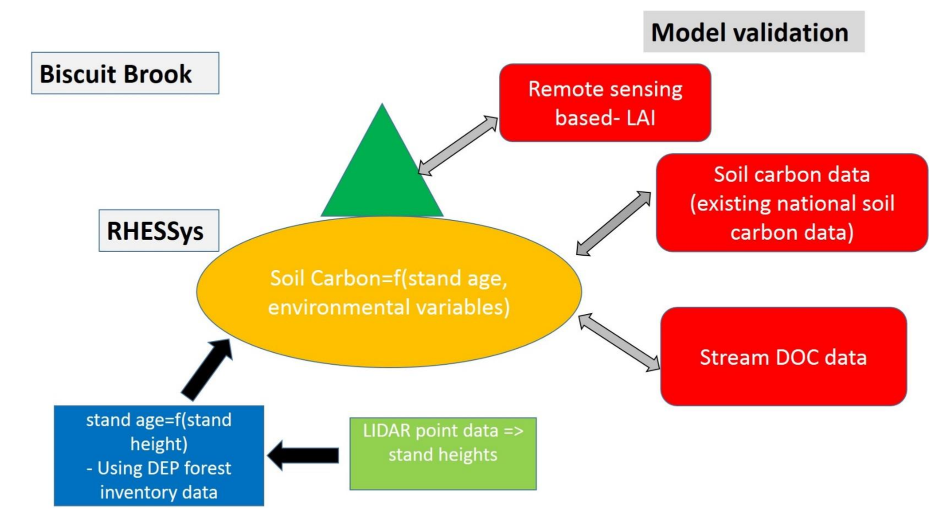
- Water year 1992 to 2014 data were used to analyze the relationship between annual precipitation and annual median DOC concentration.
- DOC concentrations at Biscuit Brook are positively correlated with the annual precipitation.
- Coefficient of determination (r^2) between annual precipitation and annual median DOC concentration at the Biscuit Brook is 0. 22.



- Flow is positively correlated with DOC concentration in spring, summer and fall seasons, and storm runoff has higher correlation with stream DOC concentration than baseflow.
- These results reflect that most of organic matters are transported to stream via surface and shallow subsurface runoff that are in contact with organic rich soil horizons.

4. RHESSys modeling Framework





- **Methodology**

1) RHESSys is calibrated to estimate soil parameters using measured streamflow.

2) To parameterize the soil carbon pools in RHESSys, we estimated forest stand ages for 30m grid cells within the NYC watersheds using LIDAR-based (Light Imaging, Detection, And Ranging) stand heights and an empirical age-height relationship.

3) Vegetation type for each grid is characterized from the Landsat Thematic Mapper (TM) based- vegetation map for the Catskill Mountains.

4) RHESSys is first run in spin-up mode to bring soil carbon pools in approximate equilibrium with local climate conditions.

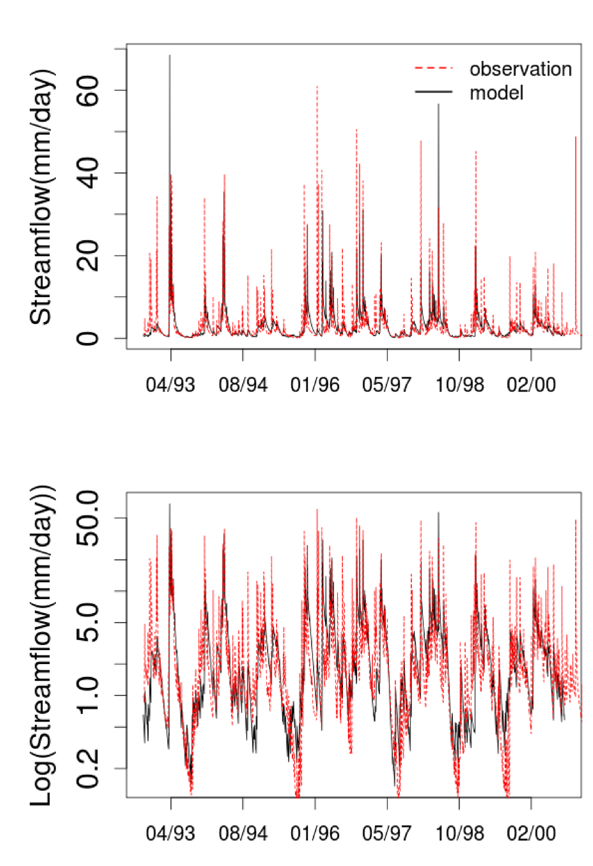
5) The spun-up model is then run for as many years as the oldest stand. For each model output variable of interest (carbon pools, including leaves, fine roots, coarse roots, coarse woody debris, litter, and soil), a composite map is constructed by extracting, for each grid cell, the value of the variable at the age in the model run that corresponds to the stand age previously derived from LIDAR.

6) The resultant spatial data are compared with existing national carbon database and the SSURGO (Soil Survey Geographic database) carbon database. In addition to soil carbon, simulated leaf area index (LAI) is compared with LAI based on Landsat TM imagery. Related parameters are calibrated to match the predicted LAI with the remote sensing-based LAI. The simulated DOC values at the outlet of a watershed are compared to measured values

5. Model implementation and assumptions

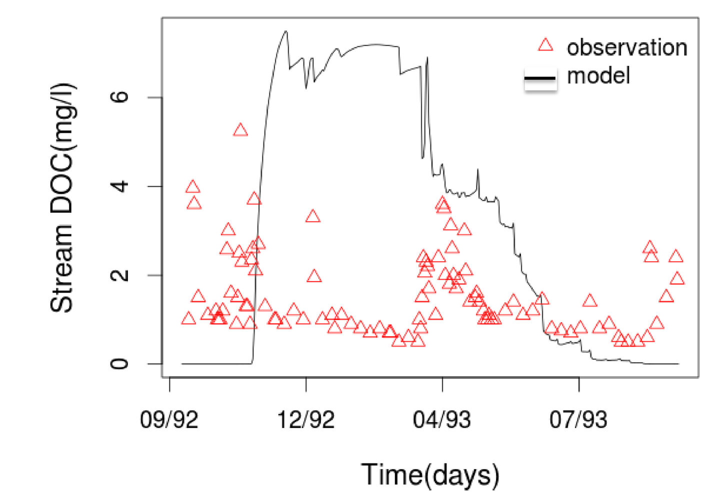
Parameters	Data source, assumptions
Topography	LIDAR 30M DEM
Vegetation	Two dominant species: evergreen tree, and deciduous tree
Soil parameters	SSURGO soil data
Tree age	Spatial uniform(65 – 73 yrs.)
Rooting depth	Spatial Uniform (1m)

6. Model calibration

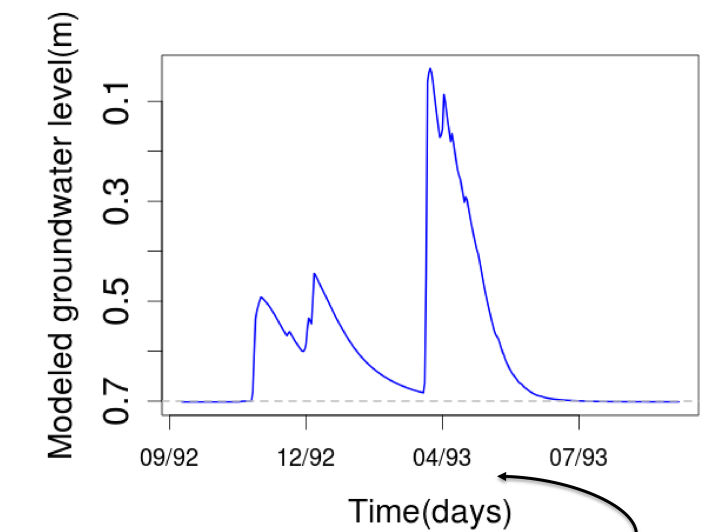


- Soil hydrologic parameters were calibrated with measured streamflow.
- RHESSys is able to capture the seasonal pattern of streamflow. Monthly stream flow accuracy is 0.76 (Nash–Sutcliffe efficiency).
- RHESSy has better prediction of low flows than high flow.
- Higher uncertainty in the climate input and simplified model assumptions have the potential to cause errors in streamflow predictions.

7. Stream DOC predictions

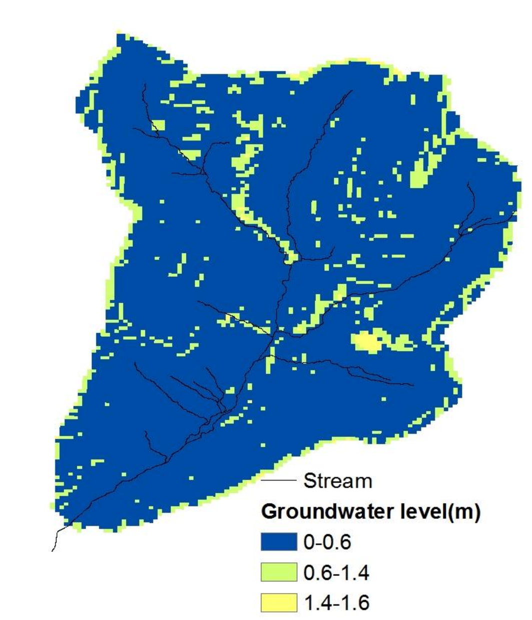


- RHESSys overestimates the stream DOC concentration in winter, spring and summer, but underestimates streamflow DOC in fall. These results may be related to error in groundwater level and streamflow predictions.
- In addition, leaf litter decomposition rate was not calibrated for local catchment conditions.



- Simulations indicate that DOC export occurs when the groundwater level is close to surface.
- This modeling result is supported by the correlation analysis.

Modeled spatial groundwater level(**04/1/1993**)



- Analysis of flow and DOC observation showed that most of organic matters are transported to the stream via surface and shallow subsurface runoff. Similarly, predictions showed that DOC export occurs when the groundwater level is close to surface.
- However, current model predictions of streamflow when observation is high and of DOC, need improvement
- Other available measurements (e.g. shown left) will be used to improve these predictions.
- This RHESSys application assumes: (i) spatially-uniform forest age, and (ii) simplified vegetation species (shown left) will be used to make more realistic assumptions. LIDAR-based stand heights and an empirical age-height relationship will be used to estimate spatially-varied forest ages. Spatial variation in specific vegetation species will be included.
- Model parameterization will be improved by using soil carbon and vegetation leaf area index (shown left).

8. Summary and Future research