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Effect of Land-Use, Soils, and Human Populations on Export of Water, C, N, and P from the Mid-Atlantic Coastal Plain

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Abstract

During the last four centuries, the Atlantic coastal plain of North America has been largely transformed from undisturbed forest to anthropogenic land uses. Initial forest clearing by European settlers in the first 200 years was primarily for agriculture, but urbanization has increasingly claimed more area in the last 100 years. The disturbance and intensive use of the region, both by agriculture and increasing urban populations, has led to greater export of N and P in stream discharges. The result has been declining water quality of lakes and estuaries which receive these stream waters, and watershed management is an important ecological and political issue in the region.

Under previous funding, we investigated the history of these land use changes and their impacts over the previous 350 years in the Choptank River basin on the Delmarva Peninsula. To assess the environmental impacts of these changes, we used the hydrochemical model GWLF to estimate fluxes of water, N, and P from subbasins of the watershed using the local land use, soil characteristics, and human populations. Under current conditions, we found that well-drained soils with large amounts of agriculture or large human populations had the greatest N fluxes due to the efficient passage of highly soluble nitrate via groundwater. In contrast, more poorly drained soils combined with large proportions of anthropogenic land uses promoted greater losses of P due to greater overland flow routing and erosion. Historically, land use changes resulted in relatively small increases in export of P, increasing fluxes by a factor of ~2, whereas N fluxes increased by a factor of ~10 after 1950 when both human populations and fertilizer applications to agricultural lands increased.

Under our current funding, we are extending the spatial domaine of this approach. We will use the history of land cover in the Choptank basin for perspective, and we will apply the hydrochemical model GWLF to data on land cover, human populations, and soils for 15-20 small basins (400-4000 km^2) on the Atlantic coastal plain. To date, we have selected 2 additional basins and we are considering 15 others from NY to SC. We have identified some empirical relationships useful for increasing the spatial domaine of our modeling, expanded the capabilities of GWLF to include a C export module, and integrated GWLF into GIS software platforms. This report is a summary of the first 10 months of a 3 year program.

keywords: research fields = historical landuse, nutrients, runoff/streamflow
geographic area/biome = North America, coastal zone
remote sensing = aerial photography, Landsat
methods/scales = GIS, in-situ data, local scale

Scientific Questions

This research project touches on all three of the NASA ESE scientific questions that are central to the LCLUC program. Under our previous funding we made a detailed case study of land cover and land use changes in the Mid-Atlantic region over 1660-2000 in the Choptank basin; we examined some of the causes of LCLUC; and, we modeled the hydrochemical consequences of the LCLUC in terms of export and N and P from land (see final report submitted for previous funding in Mar. 2002).

Under our current funding beginning Aug. 2001, we are expanding our case study results from the Choptank basin to 15-20 other Atlantic coastal plain watersheds (see Fig. 1). We will use the history of land cover obtained in the Choptank as perspective, and we will use current land cover data to examine the consequences of LCLUC by modeling fluxes of water, C, N, and P from these watersheds. To date, in addition to the Choptank, we have selected the Patuxent and Chester watersheds (within the Chesapeake Bay watershed), and we are considering 3 others in DE (2 in the Delaware Bay watershed, 1 draining to Rehobeth Bay), 4 in NJ (1 draining to Delaware Bay, 3 to NJ coastal bays), 4 in NC (1 draining to Albemarle Sound, 1 to Pamlico Sound, 2 into coastal estuaries), and 3 in SC (all draining to coastal estuaries). These basins vary in size from ~400 to ~4000 km^2, and all except one lie entirely on the Coastal Plain geological province. Only the Patuxent spans the fall line and partially lies on the Piedmont geological province. We will select the final set of 15-20 coastal plain watersheds on the basis of number and history of USGS gaging stations, availability of water quality data to calibrate the hydrochemical model, and collaboration with local scientific groups working in or near these basins. Of the LCLUC themes, our current project covers the following: Carbon (25%), water (25%), nutrients (50%), and GOFC (0%). The proportion of social science in our previous funding was 25%, but approaches 0% under the current funding.

Goals

There are three major goals of this project:

1- investigation of the relationships between current land use and export of sediment, C, N, and P over the Atlantic coastal plain from New York to South Carolina,

2 - modeling of the export of water, sediment, C, N, and P from ungauged areas within defined basins of the coastal plain using the hydrochemical model GWLF, and

3- dissemination of this information from the project web site for validation by other investigators, local watershed management, and educational purposes.

The **first goal** represents the expansion of my previous research to a larger area of the coastal plain. To achieve this goal, I have been looking for empirical relationships which would be useful for modeling purposes (e.g., see Fig. 2). To achieve the **second goal**, it was necessary to make adjustments in GWLF. The broader ranges of environmental variables in our current research influences watershed behavior (e.g., Fig. 2), and we have expanded the model capabilities by adding C parameters in a C module for GWLF. In addition, we have integrated

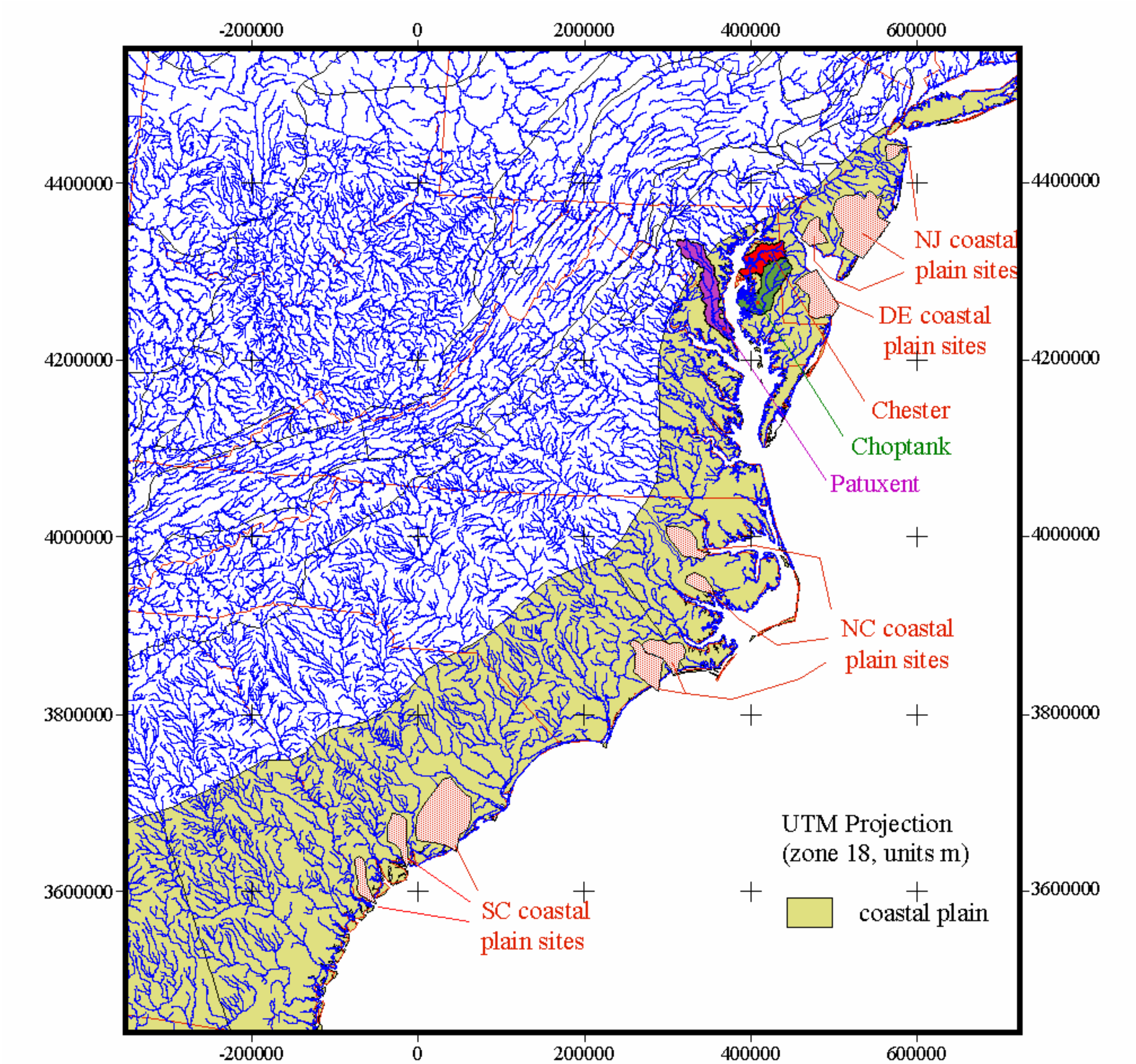
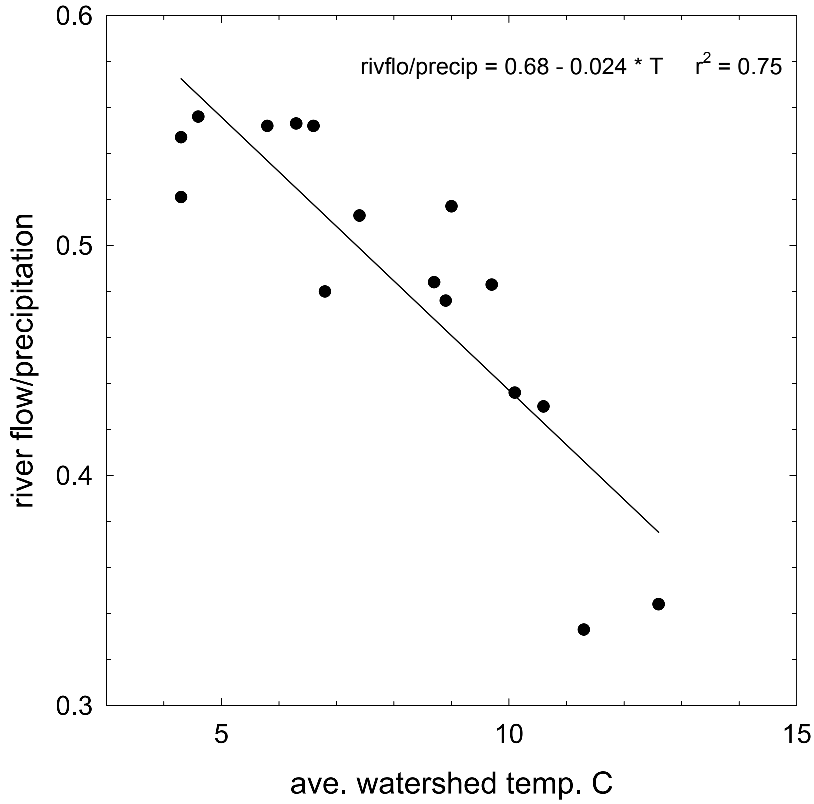


Fig. 1. Locations of selected and potential Atlantic Coastal Plain basins for hydrochemical modeling of water, C, N, and P export.

the model with both the ArcView and ArcGIS software platforms (Liboni et al. sub.). The **third goal** involves local and educational outreach. In addition to our original web site (http://www.hpl.umces.edu/GIS_group/timescale1), we have created a second one (http://www.hpl.umces.edu/gis_group/Pages/index) to provide data, graphics, coverages, and maps as they become available, with the intent of making data available to other investigators for independent validation or testing, to teachers wishing to use GIS in classroom settings, and to watershed managers for evaluating watershed issues.

Approach/Method

Our primary approach is GIS, remote sensing, and modeling. We use GIS for our spatial databases (e.g., land use/land cover derived from 2000 satellite imagery), and we calibrate GWLF, a hydrochemical model (Lee et al. 2000, 2001), within the relatively small gauged areas of the coastal plain basins in order to estimate fluxes of water, C, N, and P from ungauged areas (typically >80% of the total basin and >50% in all basins in Fig. 1).



data source: Van Breemen et al. 2002. Biogeochem. 57/58: 267-293

Fig. 2. Water yields from Atlantic basins of varying latitude, expressed as ave. annual temperature. Water yields decline at lower latitudes due to greater evapotranspiration.

Progress

We have completed the first 10 months of a 3 year project. To date we have made a preliminary selection of watersheds (Fig. 1), identified some empirical relationships which may be used to expand the capabilities of GWLF (e.g., Fig. 2), developed a C module to enable GWLF to predict C as well as N and P fluxes, and integrated GWLF into two GIS software packages (Liboni et al. sub.).

In addition, there are still project activities which have continued from our previous funding. My former student, J. Benitez, will be returning for one month this summer to convert three chapters from his recent PhD thesis into manuscripts for submission to journals, and two other former students, K.-Y. Lee and A. Liboni, have continued to expand the capabilities of our hydrochemical model (Liboni et al. sub.). A local high school teacher, A. Goodyear, is employed in my lab as a summer intern, and he will finish the development of a 1938 land cover map of the Choptank basin mosaiced from >2000 aerial photos (1:20,000 scale). When completed, we will distribute poster-sized printouts of this mosaic to local schools, NRCS offices, and town offices, and jpg and geotif files will be made available on our web site and sent to NASA HQ.

Conclusions

We have just begun this new phase of our project, expanding the spatial domaine from the Delmarva Peninsula to the Atlantic Coastal Plain from SC to NY. We are still assembling spatial and water quality data sets, and no conclusions beyond those in the final report from our previous funding can be given at this time.

List of peer-reviewed publications resulting from NASA funding:

Fisher, T. R., K.-Y. Lee, H. Berndt, J. A. Benitez, and M. M. Norton. 1998. Hydrology and chemistry of the Choptank River basin in the Chesapeake Bay drainage. Water Air Soil Poll. 105: 387-397

Fisher, T. R., J. D. Hagy, and E. J. Rochelle-Newall. 1998. Dissolved and particulate organic carbon in Chesapeake Bay. Estuaries 21: 215-229

Rochelle-Newall, E. J., T. R. Fisher, C. Fan, and P. M. Glibert. 1999. Dynamics of chromophoric dissolved organic matter and dissolved organic carbon in experimental mesocosms. Int. J. Rem. Sens. 20: 627-641

Lee, K.-Y., T. R. Fisher, T. E. Jordan, D. L. Correll, and D. E. Weller. 2000. Modeling the hydrochemistry of the Choptank River basin using GWLF and Arc/Info: 1. Model calibration and validation. Biogeochem. 49: 143-173

Norton, M. G. M. and T. R. Fisher. 2000. The effects of forest on stream water quality in two coastal plain watersheds of the Chesapeake Bay. Ecol. Engin. 14: 337-362

Fisher, T. R., D. Correll, R. Costanza, J. T. Hollibaugh, C. S. Hopkinson, R. W. Howarth, N. Rabalais, J. E. Richey, C. Vorosmarty, R. Wiegert. 2000. Synthesizing Drainage Basin Inputs to Coastal Systems, pps. 81-101 IN: J. E. Hobbie (ed.) Estuarine Science: A Synthetic Approach to Research and Practice, Island Press, Washington, DC, 539 pps.

Lee, K.-Y., T. R. Fisher, and E. Rochelle-Newall. 2001. Modeling the hydrochemistry of the Choptank River basin using GWLF and Arc/Info: 2. Model Application. Biogeochem. 56: 311-348

Rochelle-Newall, E. J. and T. R. Fisher. 2002. Chromophoric dissolved organic matter and dissolved organic carbon in Chesapeake Bay. Mar. Chem. 77: 23-41

Rochelle-Newall, E. J. and T. R. Fisher. 2002. Production of chromophoric dissolved organic matter (CDOM) fluorescence: an investigation into the role of phytoplankton. Mar. Chem. 77: 7-21

Liboni, A. R., K.-Y. Lee, and T. R. Fisher. Integration of the hydrochemical model GWLF (Generalized Watershed Loading Functions) in GIS Environments. submitted to ACM-GIS Conference for publication in Proceedings.