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INNOVATIVE RESEARCH FOR A SUSTAINABLE FUTURE

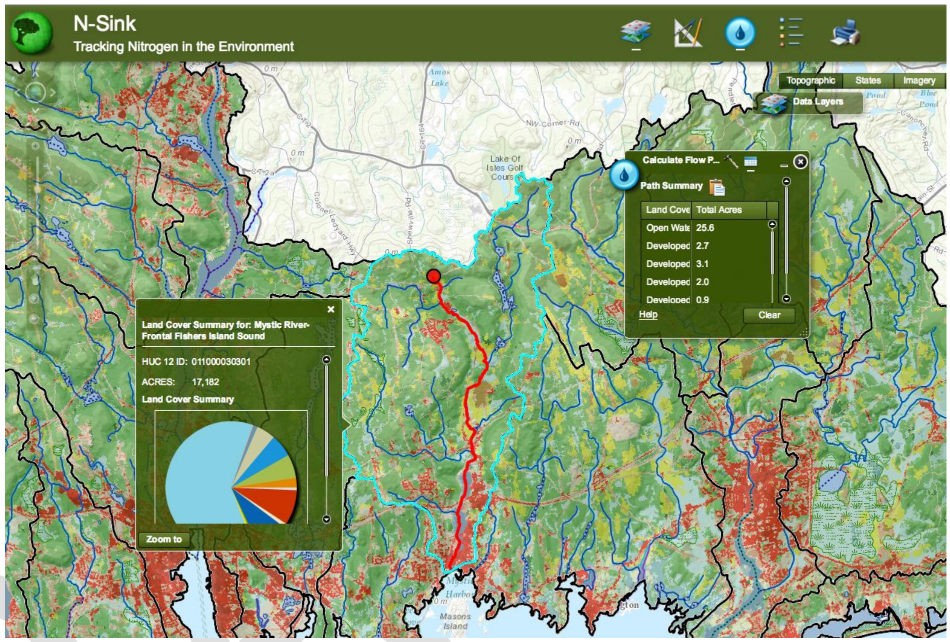
Development of a Tool to Identify Nitrogen Sources and Sinks within a Watershed Framework

The management of reactive nitrogen in watersheds requires sound scientific tools.

Although nitrogen fertilization is vital to maintain a productive and vigorous food supply, excess reactive nitrogen (N) released to the environment causes deleterious effects on human and ecosystem health. Excess N in aquatic systems brings about harmful algae and weeds, causes eutrophication induced hypoxia in coastal systems that leads to fish kills, and excess N contaminates many potable drinking water supplies.

In order to manage the widespread N pollution problem in watersheds it is requisite for decision makers to have a strong technical grasp of the factors that control N sources, sinks (regions or areas that can retain N), and pathways along which nitrogen is moved and transformed (U.S. EPA 2011). However, this scientific rigor should not serve to confuse the problem but communicate alternatives in such a way that management of land use is attainable for decision makers (U.S. EPA 2012). A fruitful approach to communicate the relationships between N processing and land use or land cover is through static and interactive maps supported by models of N processing (Kellogg et al. 2010). The N-Sink nitrogen management tool summarizes the complex biological, chemical, and physical conveyance of N to support watershed N management decisions with sound scientific information and a means by which to visualize alternative decisions.

Since the sources, sinks, and conveyance of N is highly landscape and hydrology dependent, the N-Sink tool helps decision makers summarize the influence of sources and sinks within a watershed. In terms of sources, N export from urban and suburban watersheds is much higher than from forested watersheds, although lower than from agricultural watersheds (Groffman et al. 2004). High concentrations of nitrate in shallow groundwater and streams are correlated with agricultural land use and unsewered residential developments (Nowicki and Gold, 2008). Sink areas include wetlands, hydric soils, reservoirs, small-order streams and impoundments (Groffman et al., 2003). In particular, riparian wetlands can be a significant sink for N due to the combination of surface filtering of sediments, plant and microbial uptake, and subsurface denitrification (Gold et al., 2001). Studies in both urbanizing (Kaushal et al. 2008) and agricultural (Clausen et al. 2000) watersheds have demonstrated that riparian restoration can reduce the delivery of nitrogen to streams. Given the complexity of N dynamics, there is a need to incorporate our understanding of land use and nitrogen cycling relationships into a tool that can guide land use decisions that support sustainable and healthy communities. In most areas local land use decision makers have little knowledge about N sources and sinks, and thus no way in which to factor N pollution into their land use policies and decisions. A relatively easy-to-use decision support tool that identifies N sources and sinks in a watershed, and estimates delivery efficiencies from particular locations in the watershed to the outlet is a valuable asset for communities to help reduce N pollution to their waters. This is the objective behind the development and testing of the N-Sink tool.



A web-based version of N-Sink is being worked on. This screen capture shows calculation of a flow path from source to watershed outlet (red line).

The N-Sink Tool

N-Sink is a customized ArcMap© program that provides maps of N sources and sinks within a watershed, and estimates the delivery efficiency of N movement from sources to the watershed outlet. The primary objective of N-Sink is to assist land use planners, watershed managers, and land conservation organizations to evaluate proposed development, prioritize restoration projects, and focus resources in areas that are most likely to yield reductions in N delivery to coastal waters.

Land cover and N movement relationships taken from the scientific literature are used to identify N source and sink areas, and to roughly quantify their impact on the N budget. This information, combined with modeling of water flow at the catchment scale using the *ArcHydro* extension to ArcGIS (Maidment, 2002) is used to estimate downstream delivery efficiencies. N-Sink is developed with widely available national databases in order to provide broad applicability. These data include:

- Topography (National Elevation Dataset, USGS)
- Hydrography (National Hydrography Dataset, USGS)
- Soils (Soil Survey Geographic Database, USDA/NRCS)
- Land cover (National Land Cover Dataset, multi-agency consortium)

N-Sink incorporates many complex biogeochemical and hydrologic relationships inaccessible to decision makers. However, the goals of broad applicability and ease of use dictate a trade-off in precision of the N delivery estimates. N-Sink works as a prioritization and visualization tool, which enables users to understand how N moves in a given watershed and investigate the relative N-related impacts of various land use scenarios. As such, the numeric outputs of the tool focus on percent removal of nitrogen from source to receiving water, rather than specific loading estimates.

The U.S. EPA's Nitrogen Management Group as part of the Sustainable and Healthy Communities program helps support the ongoing development of N-Sink. The early prototype base model for N-Sink created by the University of Rhode Island (URI), in partnership with Arizona State University and the University of Connecticut (UConn) (Kellogg et al., 2010) was funded by the USDA/NIFA Water Program. Together, these groups work to bring N-Sink to community decision makers.

Project Objectives

The objectives of the current project team from UConn, URI, and EPA are to:

(1) Develop a web-based version (figure). The original version, developed in 2010, requires significant reprogramming to take advantage of technological improvements and modern ability to bring the tool to the public. Geospatial experts at URI and UConn are testing the tool for the technical soundness of with the modern upgrades and works to ensure N-Sinks functionality in today's desktop and internet environment.

(2) Develop visual (map) outputs of the tool for their utility at the local level. UConn's Center for Land Use Education and Research, most notably the *Nonpoint Education for Municipal Officials* (NEMO) program, has a long and successful history of taking geospatial environmental information and folding it into educational programs and products that assist local land use decision makers (Arnold et al., 2000).

(3) Characterize N sources and sinks in two small (USGS Hydrologic Unit Code 12-digit) pilot watersheds in Connecticut and/or Rhode Island. The Niantic River watershed in Southeast Connecticut has already been selected as one of these pilots.

With a successful outcome to this project, the N-Sink team hopes to incorporate the N-Sink maps and information into educational outreach programs for local land use officials, watershed groups, and nonprofit organizations beyond the pilot watersheds.

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