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MAPPING ECOSYSTEM SERVICES FOR THE SOUTHEAST UNITED STATES

Conservation and Restoration Priorities for Water Purification

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ECOSYSTEM SERVICE MAPPING SERIES OVERVIEW

Ecosystem services, the benefits that natural ecosystems provide to people, vary spatially. Mapping where they are abundant or in short supply is useful for a variety of purposes, including land-use planning, assessment of conservation and restoration priorities, identification of environmental equity issues, and communication with diverse stakeholders. The Nicholas Institute for Environmental Policy Solutions at Duke University, supported by the Southeast Climate Adaptation Science Center, has mapped the supply and demand of a variety of ecosystem services at the landscape level across the southeastern United States. The results for each ecosystem service can be used individually to identify target areas for conservation and restoration to support that service or can be overlaid with other ecosystem services to identify areas that can provide multiple benefits. Map products for each ecosystem service are available on ScienceBase, and more information about the project, including methods briefs for the other ecosystem services, can be found on the Nicholas Institute website.

SUMMARY OF THIS BRIEF

This methods brief focuses on water purification by natural land cover, which removes nonpoint-source pollutants from runoff water before they reach waterways. This analysis maps natural land cover within the likely flowpaths of water from agricultural areas to waterways. Regional priority areas for the restoration of additional natural land cover in the flowpaths and for the conservation of existing natural land cover in the flowpaths are identified based on the amount of agricultural land and the proportion of flowpaths that are made up of purifying natural land cover. Spatial datasets for these priority areas and associated metrics are available on ScienceBase.

INTRODUCTION

Clean water is important for a variety of uses, including drinking, recreation, and as habitat for aquatic species. Nonpoint-source pollution, such as nutrients, sediment, and pesticides from agricultural runoff, is a major cause of impaired water quality in the United States (Brown and Froemke 2012). Vegetation and soil in natural land cover help to remove pollutants from runoff water before it reaches streams and other waterways by slowing water flow and physically trapping sediment.

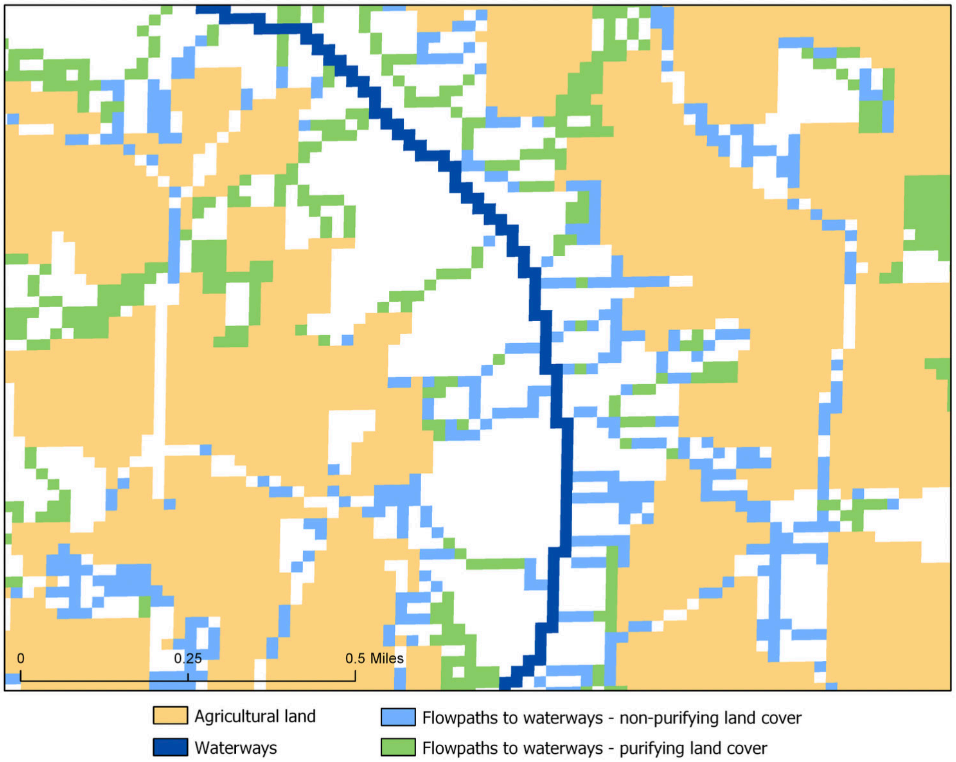
To assess the spatial distribution of water purification potential in the southeastern United States, we mapped the demand for purification as the total area of agricultural land and the supply of natural land cover in the flowpath over which water moves from agricultural land to waterways. We used this information to identify priority areas for restoration of natural land cover in the flowpath (areas with high demand for water purification and low supply of purifying land cover) and priority areas for conservation of purifying land cover (areas with high demand for water purification with moderate supply of purifying land cover). We identified priority areas at both the county and the subwatershed (12-digit hydrologic unit code, or HUC12) scales.

METHODS

We assessed the potential for water purification via natural land cover by identifying areas of natural land cover in the flowpath between agricultural sources of nonpoint-source pollution and waterways. This method is based on Olander et al. (2017), which was adapted from Baker et al. (2006) by John Fay.

First, we used a digital elevation model with sinks filled, resampled to 30-meters and aligned with the National Land Cover Dataset (NLCD), to create a flow direction raster and set the locations of streams to null values in the flow direction raster (USGS 2016b, ESRI et al. n.d.). We identified sources of nonpoint-source pollution from the NLCD; all agricultural areas (NLCD classes 81 and 82) were considered potential sources of nonpoint-source pollution. Developed and urban land are also sources of nonpoint-source pollutants, but runoff management in these areas (e.g., using stormwater drains) makes the topographic approach used in this analysis inaccurate for understanding how water moves from these areas. We also used the NLCD to identify areas of natural land cover that could remove pollutants from runoff water by slowing water flow (NLCD classes 41, 42, 43, 71, 90, and 95). To identify the paths over which water would flow from pollution sources to waterways, we ran a flow accumulation tool based on the flow direction raster and the raster of nonpoint-source pollution (this ensured that only flowpaths starting from pollution sources would be included) (Fig. 1). We extracted areas of purifying land cover coinciding with these flowpaths and calculated the percentage of the total flowpath area that was covered by purifying land cover types in each HUC12 and county.

Figure 1. Components of water purification analysis, including agricultural land (source of nonpoint-source pollutants), waterways, and flowpaths from agricultural land to waterways, classified by whether the flowpath is covered by purifying land cover (forests, wetlands, and natural grasslands) or not

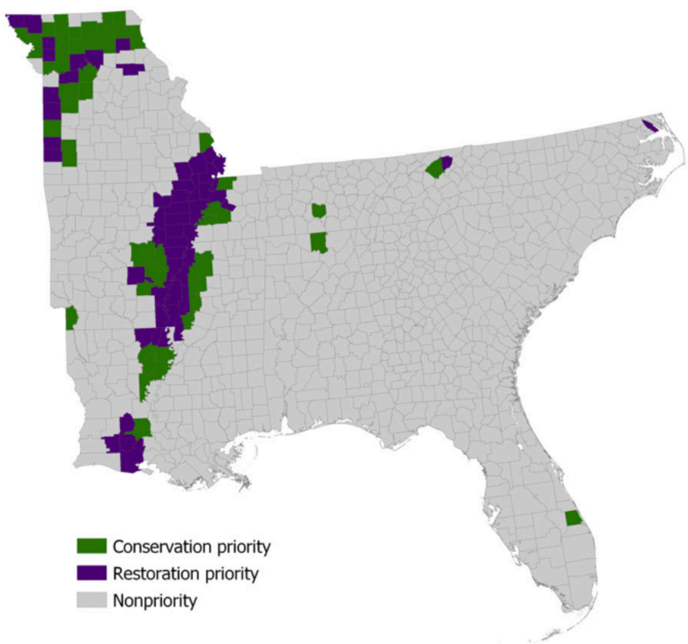


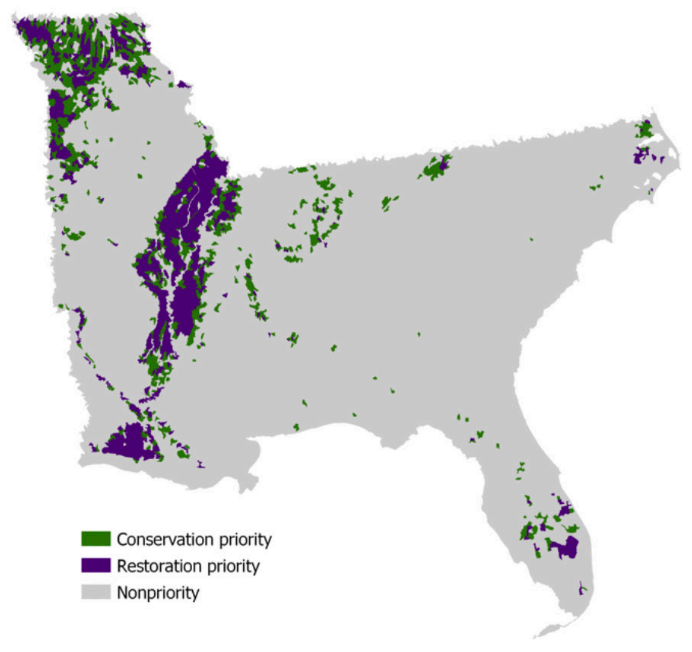
The area of agricultural land (as a percentage of the total area) and the percentage of the total flowpath area covered by purifying land cover were calculated for each HUC12 and county in the study area and used as the basis for identifying priority restoration and conservation areas. First, a threshold percentage of agricultural land was set to ensure that only areas with high demand for water purification, as indicated by the amount of nonpoint-source pollutant areas, were considered priorities. This threshold was set to include the top 25% of counties and HUC12 subwatersheds and was 37.2% for HUC12 and 35.8% for counties.

We attempted to distinguish between restoration priorities (areas where more purifying land cover is needed to remove pollutants and improve water quality) and conservation priorities (areas where existing purifying land cover should be protected to preserve water quality) by using data on impaired waterways to look for a relationship between the amount of purifying land cover in the flowpath and impaired waterway length in high-agricultural areas. Waterways can be impaired due to a variety of pollutants; the impairment metric we used was the percentage of total stream length impaired (included on the state's 303(d) list) due to three pollutants related to agriculture: nutrients, sediment, and pesticides, at the HUC12-level for HUC12 watersheds in the top 25% in terms of agricultural land coverage (EnviroAtlas). While there was a negative relationship between purifying land cover in the flowpath and percentage of waterways impaired, the stream impairment data was quite noisy with many zeroes, and the correlation was relatively weak. This is likely due to several factors: exclusion of impaired streams that are not on states' approved 303(d) lists from the EnviroAtlas data, differences in the methodologies and criteria that states use for listing and delisting waterways (Keller and Cavallaro 2008), and other influences on nonpoint-source pollution, such as groundwater movement, soil type, and temporal flow patterns. Differences among the states in terms of identifying impaired waterways are apparent; among the 703 HUC12s with at least 10% of their total stream length impaired due to the three agricultural pollutants, 67% of them are in Florida or Tennessee, even though there are extensive agricultural areas in Arkansas, Mississippi, and Missouri.

Since we were unable to identify a threshold amount of purifying land cover in the flowpath that indicates sufficient purification to protect water quality based on stream impairment data, we identified priority areas for restoration and conservation using the relative amount of purifying land cover in the flowpath. Restoration priorities were defined as high-agriculture areas (HUC12s or counties) below the 25th percentile (of all high-agricultural areas) in terms of the percentage of purifying land cover in the flowpath. These are places where there is high demand for removal of agricultural pollutants that is not likely being met by the low amount of purifying land cover. Conservation priorities were defined as high-agriculture areas (HUC12s or counties) in the 25th to 50th percentile (of all high-agricultural areas) in terms of the percentage of purifying land cover in the flowpath. These are places with high demand for removal of agricultural pollutants (high proportion of agricultural land cover) that are likely to be at risk of increased waterway impairment if the small amount of purifying land cover they currently have is lost (Fig. 2).

Figure 2. Regional conservation and restoration priorities at the county scale (left) and HUC12 subwatershed scale (right)





DATASETS AND USE

County-level and HUC12-level regional priority datasets for the southeastern U.S. are available on ScienceBase. The priority conservation counties or HUC12s can be used to identify where, at the regional level, the restoration of additional purifying land cover or the conservation of existing purifying land cover in the flowpath is most important for enhancing and protecting water quality from agricultural pollutants. These can also be overlaid with other data sources at the appropriate scale, including other ecosystem services maps, to find areas where conservation or restoration would provide multiple benefits.

The additional fields in the county- and HUC12-level datasets have the necessary information to make slight changes to the identification of priority conservation areas. For example, if you are working in a state with relatively little agricultural land compared to other parts of the southeast, you may want to decrease the threshold percentage of agricultural land used as an initial criteria for identifying priority areas.

If you wish to make more extensive changes to how priority areas are identified (e.g., a different boundary type), you will need to work with the underlying data used to calculate the metrics in the county- and HUC12-level priority datasets. These data are available on ScienceBase:

- Agricultural land (30-meter resolution)
- Flowpaths from agricultural land to waterways (30-meter resolution)
- Purifying land cover in flowpaths from agricultural land to waterways (30-meter resolution)

When using these data, please keep in mind that they are designed for landscape-level assessments. Due to inaccuracies in the national-scale input datasets, they should not be used to identify specific locations for restoration or conservation projects.

LIMITATIONS

This analysis assesses the potential for purification of runoff water by natural land cover based on topography and land cover. It assumes that water flow follows the surface topography and does not include groundwater movement or artificial drainage systems (such as stormwater management in urban areas). It does not consider other environmental and hydrologic factors relevant to water purification, including soil characteristics, slope, specific vegetation type, and temporal patterns of flow.

The distinction between restoration and conservation priority areas is based on the proportion of flowpaths from pollution sources to waterways that is covered by a purifying land cover type. While we were unable to use the EPA impaired waters information (as compiled in EnviroAtlas) to identify areas with high levels of stream impairment for the reasons discussed above, we include impairment information in the priority dataset attribute tables for reference. If you have access to better water quality information for your area of interest, it may be helpful to use that information to distinguish between restoration and conservation priority areas.

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Nicholas Institute for Environmental Policy Solutions
The Nicholas Institute for Environmental Policy Solutions at Duke University is a nonpartisan institute founded in 2005 to help decision makers in government, the private sector, and the nonprofit community address critical environmental challenges. The Nicholas Institute responds to the demand for high-quality and timely data and acts as an “honest broker” in policy debates by convening and fostering open, ongoing dialogue between stakeholders on all sides of the issues and providing policy-relevant analysis based on academic research. The Nicholas Institute’s leadership and staff leverage the broad expertise of Duke University as well as public and private partners worldwide. Since its inception, the Nicholas Institute has earned a distinguished reputation for its innovative approach to developing multilateral, nonpartisan, and economically viable solutions to pressing environmental challenges.

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The National Ecosystem Services Partnership (NESP) engages both public and private individuals and organizations to enhance collaboration within the ecosystem services community and to strengthen coordination of policy and market implementation and research at the national level. The partnership is an initiative of Duke University’s Nicholas Institute for Environmental Policy Solutions and was developed with support from the U.S. Environmental Protection Agency and with donations of expertise and time from many public and private institutions. The partnership is led by Lydia Olander, director of the Ecosystem Services Program at the Nicholas Institute, and draws on the expertise of federal agency staff, academics, NGO leaders, and ecosystem services management practitioners.

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