nsink: An R package for flow path nitrogen removal estimation

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Summary

The nsink package estimates cumulative nitrogen (N) removal along a specified flow path and is based on methodologies outlined in Kellogg et al. (2010). For a user-specified watershed (i.e., hydrologic unit code (HUC)), nsink downloads all required datasets from public datasets in the United States, prepares data for use, summarizes N removal along a flow path and creates several static maps. The results of an nsink analysis may be exported to standard geospatial files for use in other applications.

Statement of need

Excess N delivery via surface water to downstream aquatic resources contributes to impaired water quality and impacts ecosystem services including harmful algal blooms (HABs) and hypoxia (Rabalais et al., 2002). Identifying landscape N sinks (i.e., areas where N is effectively removed from the aquatic system) and analyzing N delivery at the watershed scale is helpful to watershed managers, land use planners and conservation organizations. The theoretical underpinnings for identifying N sinks rely on decades of research and are explained in Kellogg et al. (2010).

Prior N-sink implementations were done case-by-case. Data acquisition and manipulation were mostly manual and took weeks to months to complete for a single 12-digit HUC. The effort required for the analysis limited its application as scaling beyond a few pilot studies was not feasible. The goal of nsink was to address this limitation and provide an open source solution that could be run on a single small watershed (e.g., 12-digit HUC) in minutes to hours with minimal manual input.

The nsink package

Package Installation

The nsink package is available from https://github.com/usepa/nsink and may be installed in R with the following:

```r
# If not installed, install remotes
install.packages("remotes")
```

# Install nsink from GitHub

```r
remotes::install_github("USEPA/nsink", dependencies = TRUE, build_vignettes = TRUE)
```

## Package Details

The *nsink* package is designed around the major steps in running an N-Sink analysis and includes functions for the following tasks:

1. Prepare for analysis
   - Get data
   - Prepare data for analysis
   - Calculate relative N removal layer for hydric soils, lakes and streams.
2. Run a point-based analysis
   - Calculate a flow path
   - Summarize relative N removal along a flow path
3. Run a HUC-based analysis
   - Develop static maps
   - Generate output datasets

## Required Data

The ability to run an *nsink* analysis relies on several datasets for the conterminous United States. By limiting our approach to these national datasets we are ensuring scalability of *nsink* because the datasets will be available for most locations in the United States. The datasets that *nsink* uses are the National Hydrography Dataset Plus version 2 (NHDPlus), Soil Survey Geographic Database (SSURGO), the National Land Cover Dataset (NLCD) land cover, and the National Land Cover Dataset (NLCD) impervious surface (Jin et al., 2019; Moore et al., 2019; Soil Survey Staff, 2017). These datasets are all available via an Application Programming Interface (API) or via direct download.

## Dependencies

The *nsink* package depends on several existing R packages to facilitate spatial data handling, data acquisition, data management, data analysis and data processing. These are detailed in Table 1.

### Table 1. R package dependencies for the *nsink* package

<table>
<thead>
<tr>
<th>Package</th>
<th>Task</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>sf</td>
<td>Spatial Data Handling and Analysis</td>
<td>Pebesma (2018); Pebesma (2021b)</td>
</tr>
<tr>
<td>raster</td>
<td>Spatial Data Handling and Analysis</td>
<td>Hijmans (2021)</td>
</tr>
<tr>
<td>stars</td>
<td>Spatial Data Handling and Analysis</td>
<td>Pebesma (2021c)</td>
</tr>
<tr>
<td>fasterize</td>
<td>Spatial Data Handling and Analysis</td>
<td>Ross (2020)</td>
</tr>
<tr>
<td>lwgeom</td>
<td>Spatial Data Handling and Analysis</td>
<td>Pebesma (2021a)</td>
</tr>
</tbody>
</table>

Functionality

Currently, nsink provides 10 exported functions to facilitate a flow path analysis of relative N removal. The nsink repository (https://github.com/usepa/nsink) and R package documentation contain detailed documentation of each function. The package also has a vignette that outlines a typical workflow for running an N-Sink analysis with the nsink package. Upon install, the vignette is accessed in R with `vignette("intro", package = "nsink").`

Acknowledgements

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References


Pebesma, E. J. (2021b). *Simple features for r*. https://CRAN.R-project.org/package=sf


