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, Turner, and Scavia 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 it’s 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:

# If not installed, install remotes  
install.packages("remotes")  
  
# Install nsink from GitHub  
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 (Moore et al. 2019; Soil Survey Staff 2017; Jin et al. 2019). 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

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| --- | --- | --- |
| Package | Task | Citation |
| sf | Spatial Data Handling and Analysis | Pebesma (2018); Pebesma (2021b) |
| raster | Spatial Data Handling and Analysis | Hijmans (2021) |
| stars | Spatial Data Handling and Analysis | Pebesma (2021c) |
| fasterize | Spatial Data Handling and Analysis | Ross (2020) |
| lwgeom | Spatial Data Handling and Analysis | Pebesma (2021a) |
| gstat | Spatial Data Handling and Analysis | Pebesma (2004); Gräler, Pebesma, and Heuvelink (2016); Pebesma and Graeler (2021) |
| sp | Spatial Data Handling and Analysis | Pebesma and Bivand (2005); Bivand, Pebesma, and Gomez-Rubio (2013); Pebesma and Bivand (2021) |
| units | Unit Transformations | Pebesma, Mailund, and Hiebert (2016); Pebesma et al. (2021) |
| FedData | Data Acquisition | Bocinsky (2020) |
| httr | Data Acquisition | Wickham (2020) |
| dplyr | Data Management and Analysis | Wickham et al. (2021) |
| zoo | Data Management and Analysis | Zeileis and Grothendieck (2005); Zeileis, Gorthendieck, and Ryan (2021) |
| igraph | Data Management and Analysis | Csardi and Nepusz (2006); Csardi et al. (2020) |
| readr | Data Management and Analysis | Wickham and Hester (2020) |
| foreign | Data Management and Analysis | R Core Team (2020) |
| rlang | Data Management and Analysis | Henry and Wickham (2021) |
| furrr | Parallel Processing | Vaughan and Dancho (2021) |
| future | Parallel Processing | Bengtsson (2021); Bengtsson (2020) |

### 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 pacakge 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").

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