

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 HUC 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 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:

```
# 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

Package	Task	Citation
sf	Spatial Data Handling and Analysis	E. Pebesma (2018); E. Pebesma (2021b)
raster	Spatial Data Handling and Analysis	Hijmans (2021)
stars	Spatial Data Handling and Analysis	E. Pebesma (2021c)
fasterize	Spatial Data Handling and Analysis	Ross (2020)
lwgeom	Spatial Data Handling and Analysis	E. Pebesma (2021a)
gstat	Spatial Data Handling and Analysis	E. J. Pebesma (2004); Gräler, Pebesma, and Heuvelink (2016); E. Pebesma and Graeler (2021)
sp	Spatial Data Handling and Analysis	E. J. Pebesma and Bivand (2005); Bivand, Pebesma, and Gomez-Rubio (2013); E. Pebesma and Bivand (2021)
units	Unit Transformations	E. Pebesma, Mailund, and Hiebert (2016); E. 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)

Package	Task	Citation
<code>igraph</code>	Data Management and Analysis	Csardi and Nepusz (2006); Csardi et al. (2020)
<code>readr</code>	Data Management and Analysis	Wickham and Hester (2020)
<code>foreign</code>	Data Management and Analysis	R Core Team (2020)
<code>rlang</code>	Data Management and Analysis	Henry and Wickham (2021)
<code>furrr</code>	Parallel Processing	Vaughan and Dancho (2021)
<code>future</code>	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 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")`.

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