Mapping Tree Species Drought Sensitivity Under Climate Change

Technical Documentation

By:

Briana Barajas
Rosemary Juarez
Fletcher McConnell
Vanessa Salgado

Committee:
Dr. Joan Dudney
Dr. Carmen Galaz García

Client:
Dr. Joan Dudney

A Capstone Project submitted in partial satisfaction of the requirements for the degree of
Master of Environmental Data Science
for the
Bren School of Environmental Science & Management,
University of California, Santa Barbara

June 2024

Signature Page

Mapping Tree Species Drought Sensitivity Under Climate Change

As developers of this Capstone Project documentation, we archive this documentation on the Bren School's website, such that the results of this research are available for all to read. Team member signatures on the document signify joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

Briana Barajas

Rosemary Juarez

Fletcher McConnell

Vanessa Salgado

The Capstone Project is required of all students in the Master of Environmental Data Science (MEDS) Program. The project is a six-month-long activity in which small groups of students contribute to data science practices, products or analyses that address a challenge or need related to a specific environmental issue. This MEDS Capstone Project Technical Documentation is authored by MEDS students and has been reviewed and approved by:

Dr. Carmen Galaz García

Dr. Joan Dudney

DATE

Table of Contents

1. Abstract

Forests cover approximately 30% of Earth's land surface, absorb more carbon than all other terrestrial ecosystems, and provide trillions of dollars' worth of ecosystem services (Food and Agriculture Organization of the United Nations, 2005). However, climate change-induced droughts pose a significant threat to these vital ecosystems. As climate change intensifies, it is critical for our planning and management that we understand how and where trees will be the most threatened. Previous research has examined the effects of these droughts on forests at a global scale, but these large-scale analyses are not particularly helpful for land managers that often focus on specific regions and only a limited number of species. This project addresses this gap by assessing species-specific sensitivity to increasingly severe and frequent droughts, considering the variations within their ranges. This localized information is crucial for land managers to develop targeted conservation strategies. By analyzing species-specific data, we demonstrate that the impacts of drier conditions are not uniform across or within species. Our findings suggest that effective management strategies must adopt a multifaceted and area-specific approach. To make our findings easily usable, we developed an interactive dashboard for land managers and the public. Here, users can find species-specific sensitivity maps that highlight the areas of greatest concern within manageable spaces, providing a valuable tool for informed decision-making. Our project contributes to the understanding of the potential future drought impacts on forests and emphasizes the need for targeted conservation efforts to mitigate the consequences of climate change on these essential ecosystems.

2. Executive Summary

Forests encompass one third of the Earth's surface and provide habitat for more than 80 percent of all terrestrial animals, plants, and insects (Food and Agriculture Organization of the United Nations, 2005). They also supply trillions of dollars in ecosystem services and sequester more carbon than any other land ecosystem (Costanza, 1997, 2014). However, forests are increasingly threatened by climate change and hotter, more extreme droughts. Understanding how tree species cope with these stressors at the local level is critical for developing effective management strategies.

To identify species-level sensitivity to climate change, this project leverages data from the International Tree Ring Data Bank (ITRDB) and the Terra Climate (Climatology Lab) to estimate drought impacts on 26 tree species. The analysis consists of estimating tree sensitivity to climatic water deficit. The sensitivity estimates are then projected across species' range maps. Specifically, the sensitivity maps display variation in tree growth response to climatic water deficit (CWD)—where more negative values suggest higher drought sensitivity within a species' range.

The 26 tree species targeted for this analysis were selected based on two criteria: 1) a sufficient number of individual trees sampled, and 2) A select number of species that are of conservation concern. The maps produced for each species can be used to identify areas that are more sensitive to climate change and may need direct management intervention.

The combined sensitivity data for all species was gathered and exported into an interactive web dashboard created using the R-Shiny package. This combined data is available via the online data repository, as well as in the dashboard Data page. The tabular data was plotted as rasters with four different sensitivity levels: high, moderate, low and least concern. Dashboard users can view sensitivity predictions for each species by searching either the scientific name, common name, or species code. Providing these improved, accessible predictions will allow public or private organizations to make informed management decisions built around accurate data and predictions.

3. Problem Statement

Research suggests that trees vary in their response to drought. Although less common, trees in energy limited areas can benefit from drought that can lengthen their growing season (Dudney et al., 2023). Thus, the impact of drought on global forests can vary greatly between species, and even within an individual species' range. Ongoing research has examined the effect of droughts on a global scale, but the existing literature poses two contradictory hypotheses. The drought-naive hypothesis suggests species in the mesic portions of their range are most sensitive to water limitations, while the dry-range sensitive hypothesis suggests that trees in the drier portions of their range are most sensitive. To disentangle the complexity of this issue, our project provides a simple interactive tool for land managers to better understand how drought impacts sensitivity within different portions of a species' range. Identifying high-risk areas will allow public and private land managers to make more informed decisions regarding effective conservation and management strategies for key tree species.

4. Solution Design

A. Specific Objectives

This project will expand upon the existing research through completion of the following objectives:

1. Create 26 species-specific tables containing drought sensitivity data across a species range. The existing workflow will be integrated into a function that divides a global aggregate into species-level estimates and then automates the mathematical processes needed to calculate sensitivity across each species range.
2. Develop an interactive dashboard with maps of categorized tree sensitivity to drought across species ranges. Users will be able to efficiently view species and regions of interest and download the data required to recreate these maps.

B. Summary of Solution Design

1. About the data

The raw tree data was sourced from the International Tree Ring Data Bank (ITRDB). This data was used for accessing tree ring measurements for individual sampled trees from within multiple, specific sites in their species ranges.

The original ring width length measurements were sourced from the International Tree Ring Data Bank (ITRDB), which hosts data on over 125 tree species. Unfortunately, species with very few sites or tree cores could not be accurately estimated by the model. Therefore, we elected to create maps for the 26 tree species with the highest number of observations. This includes three species that were classified as species of high conservation concern.

This project builds off from scripts provided by the client, which calculates global estimates of sensitivity (Table 1). Team members reworked these scripts to better fit the scope of this project, producing new script files that calculate the species-specific estimates of sensitivity (Table 2). Scripts 1-4 calculate the sensitivity and RWI across individual species ranges, while script five converts this data into raster-type maps. This order is required, as the outputs from previous scripts often become inputs. Each script begins with a list of required inputs and final outputs. For a more rapid approach, main.R can be used instead. This file sources scripts 3-5 to rapidly produce maps without intermediate steps. This workflow was used on a select number of tree species to produce the final “combined_predictions.csv,” which contains sensitivity to climatic water deficit for 26 tree species. For more information, please visit this project’s dryad webpage or review Section 8 Archive Access of this documentation.

Predicted species growth (RWI) is calculated in the scripts, but not included in the final data. High climate variable correlation along with data processing limitations has resulted in select species having abnormal ranges for predicted growth. More processing is required to produce accurate RWI prediction.

2. Approach and Methods

The project is divided into two main phases, (1) creating Sensitivity maps and (2) developing the interactive dashboard.

1. Creating Sensitivity Maps
   a. Estimate sensitivity: To estimate tree-level sensitivity, we used a site-level model that predicted Ring Width Index (RWI) as a function of Climatic Water Deficit (CWD) and Potential Evapotranspiration (PET). Then we aggregated the coefficients of CWD and PET and ran a second regression with historic average CWD and PET as predictor variables. This created a single estimate of sensitivity to CWD across a species' range.

   b. Produce sensitivity rasters and maps: The end product of estimating sensitivity is "combined_predictions.csv," a data frame output for each species with columns representing latitude, longitudes, sensitivity, and species code ("x", "y", "cwd_sens", and "species_code"). Columns "x" and "y" represent latitude and longitude under the WGS 84 coordinate reference system used to plot rasters of sensitivity. The values for the sensitivity column were used to fill each pixel with the raster for the tree sensitivity map. To view major filenames used in this project, please refer to the appendix on table 3.

2) Developing the Interactive Dashboard

   The final table ("combined_predictions.csv") is then imported into the dashboard repository. The final table is then merged with species metadata ("species_metadata.csv"), which allows team members to separate data by species, convert to rasters, and map into interactive sensitivity maps. The interactive dashboard is then deployed and running for land managers and the public to access and use.

5. Product and Deliverables

   Land managers are often focused on a few key species in regions of interest, and drought responses can vary greatly by species and across landscapes. Thus, creating a species-specific product would provide the most value, allowing land managers to focus on species and areas of interest.

   There are two main deliverables for this project:

   A. Species' Sensitivity Maps

      Drought sensitivity estimates for 26 species from the International Tree Ring Data Bank, each stored as individual tables. Each data table row contains a numeric sensitivity value, as well as a sensitivity level that corresponds to a specific latitude and longitude within a species range. This tabular data was used to create raster maps of varying drought sensitivity levels across a species' range. The scripts for calculating and mapping sensitivity are stored in the project's GitHub repository. For more information on the structure of this table, see Appendix (table 2).

   B. Interactive Dashboard

      The second deliverable is an interactive dashboard created using R and R-Shiny. The dashboard will contain 26 maps and downloadable data tables for each species included. The code for creating this dashboard will be shared via the project's GitHub Repository. For more information, see User Documentation Section A, which outlines the creation of this dashboard, or User Documentation Section B which explains how users can navigate the dashboard and interpret values.

6. Summary of Testing
   Testing is divided into two groups:
   A. Code
      A majority of the project timespan was spent programming in R, using the Bren School online server, Tsosie. The mapping code and functions rely on the use of several R-packages, all housed within the same R script. To ensure the code is correct, team members have developed the following methods:
      1. Run unit tests on code to ensure accuracy
      2. Confirm match between outputs and metadata descriptions
      3. Clear R environment prior to running code

      These tests will ensure that the scripts are accurate and promote tidy structure within the mapping repository.
   B. Dashboard
      Dashboard testing consists of simple and effective ways to provide testing. The main way of testing the dashboard is implementing user testing. After consulting with the user tester on feedback, we will implement and add feedback to the dashboard. User testers will consist of team members, clients, and third-party testers. User testing will consist of setting a one to one meeting with a user. Users will then test the dashboard based on steps described below. The steps to implementing user feedback include:
      1. Limit explanation of dashboard to a minimum
      2. Ask user to click and explore variables
      3. Ask user to explain audibly their thought process and expectations
      4. When asking for feedback, make sure to ask open-ended questions.

      Dashboard explanation is minimized to allow users to approach the interface with a fresh perspective. This will provide valuable insights regarding user design in mind. By asking users to audibly express their thought process and expectations, helps team members identify areas where the user experience may be confusing or catch inconsistencies. Asking open-ended questions to users allows them to provide feedback not limited to closed-off questions.

      Once the user testing sessions are complete, team members will carefully review and analyze the feedback received. Post-analysis will include making adjustments to the dashboard's layout, functionality, or visual elements to improve the overall user experience. User testing phase will allow team members to create a dashboard that is user-friendly and efficient.

7. User Documentation

This section will provide user documentation providing guidance on our process. The User Documentation is split into two sections: Sensitivity Maps and a Dashboard Guide.

A. Sensitivity Maps

1. Raster Data Creation

Species' Sensitivity Maps for this project are the main deliverable and the process is as follows. This includes creating raster prediction sensitivity for 26 tree species. Using historic climatic data, tree ring data, and a regression model that inputs historic climatic variables such as potential evapotranspiration (PET) and climatic water deficit (CWD) and outputs a dataset describing species' standardized historic climate and their predicted sensitivity across species' full range.

2. Mapping Process

Within the dashboard, we used the R {leaflet} package to plot the interactive maps. The coordinate reference system is set to WGS84. The original sensitivity maps had a continuous scale of sensitivity. In order to increase interpretation of sensitivity maps, the categorical bins and orange-blue color palettes are created within the leaflet method "addRasterImage()" which takes in either three or four colors depending on the levels of sensitivity found in the dataset.

3. Dashboard Implementation

Our dashboard implementation can be found in Project Dashboard GitHub Repository. The dashboard can be found in the dashboard folder and further split into 5 main components: global.R, ui.R, server.R, /data, /text, and /www folder.

Loading necessary packages, data files and data cleaning are defined in the global.R script. The data used for the dashboard is species_metadata.csv and combined_prediction.csv. Note that the data necessary for only the dashboard is stored in the /data folder. Sensitivity level bins are created (High, Moderate, Low, Least Concern). The species that only have negative values have only three bins, with no "Least Concern" category. The data frame to raster conversion is done by creating a list of raster objects from a combined_pred data frame containing species distribution data. Each name identifier such as scientific_name, common_name, and spp_code follows the same code that creates a list of raster objects, where each raster corresponds to the sensitivity prediction of a single species. The key steps are filtering the data for each species, converting it to a raster, cleaning the species name for use as a list key, and then adding the raster to the list. This list is further used in server.R to extract each raster for a particular species in server.R

The user interface is defined in the ui.R script. The user interface layout follows the dashboard layout which consists of three containers: dashboardHeader, dashboardSidebar, and dashboardBody. Each container contains specific requirements and user interface boxes. The main purpose of the ui.R script is to allow users to filter data based on data variables using the selectInput or sliderInput functions. Each input method has a designated inputId element that is further used in server.R.

The server instructions on how to assemble user input values into outputs are defined in the server.R script. For each Leaflet map, our R code sets up an event listener using observeEvent to update a Leaflet map whenever the user selects a species from a UI input element. Each leaflet map is particular to each name identifier that selects the raster based on the selected identifier. The map rendering checks if the name identifier has three or four sensitivity levels.

For our additional directories, all markdown text files are found within the /text folder, css updates are found in /www folder in a file called fresh-themes.R, and /data contains pre-processed data used by the app. Please refer to our GitHub repository README.md file for further file structure information.

B. Interactive Dashboard
   1. Basic Functionality

      The home page provides a summary of the project approach as well as supporting research. An aggregated species range map provides an overview of locations covered by this analysis. For improved accessibility, the full list of species is available within the app as a searchable table, equivalent to Appendix Table 4. This allows users to check for species of interest more quickly, as there is a faster loading time than the map search. Simply type species code, common name, or scientific name into the search bar located in the upper right-hand corner of the table. Please note that this search cannot account for spelling errors and should only be one species only.

   2. Sensitivity Maps

      The "Sensitivity Maps" page contains the final 26 maps, which can be searched using one of three identifiers. An optional opacity slider is available, so users can lighten the sensitivity raster to better view the base map underneath. To begin, type a species name or select it from the drop-down menu. This will automatically produce a sensitivity raster that spans across the inputted species' range. For a closer view, users can zoom in on desired areas or drag to adjust the positioning.

   3. Map Interpretation

Sensitivity quantifies the relationship between a species' growth and changes in water availability, measured as climatic water deficit (CWD). More negative values of sensitivity represent areas with higher sensitivity, while positive values indicate trees that are growing more in drier conditions. The numerical values were converted into a categorical sensitivity level, which is easier to interpret. Any areas where a species experienced no change, or saw increased growth during drought, were grouped into the "Least Concern" category, which is the blue areas of the map. The remaining negative values are all sensitive, and were divided into High, Moderate, and Low sensitivity. "High" represents the 25% most sensitive areas, "Low" represents the bottom 25% negative values which are closer to zero. The remaining 50% center values were considered "Moderate" sensitivity.

4. Downloading Data
   Visit the "Data" page to access the final data used to produce the sensitivity maps. Scientific name, common name, and species codes are provided as filtering options. Using the drop-down menu, select all species or only species of interest. As selections are made, the interactive table below will automatically update. Once the desired species are selected, simply click the download button. This will produce a .csv file of the same table displayed on the page. This table includes both the numeric sensitivity estimate, and the mapped sensitivity level that is defined above.

5. Limitations

   Maps available on the web application are currently limited to the 26 species listed in the appendix. Due to data limitations and computational costs, not all species in the International Tree Ring Data Bank (ITRDB) could be included in this analysis. Tree species represented in the dashboard include the 26 most sampled species in the ITRDB.

   Raster resolution:

   The initial climate data had a resolution of 4km. This data was resampled to 30km resolution to pair historic climate data with predicted climate accurately. Resampling to a lower resolution is a result of fitting our Terra Climate data to fit the resolution of CMIP in script 3b. Therefore, the final prediction maps have a lower resolution, which limits the users' ability to distinguish unique values for sites of interest.

6. Searching Species of Interest

   Each species can be searched by scientific name (genus species), common name, or species code. Species codes are 4-letter abbreviations consisting of the first two letters of the genus and the first two letters of the species name. For example, *Pinus sylvestris* would have the species code PISY. Only one search term is required to produce the desired map or data frame. If the species of interest is not available, attempt a search other than the common name and check the conclusive species list available at Table 4.

8. Archive Access
   A. Raw Data
      The raw data for this project is available from several public repositories. Climate data were retrieved from TerraClimate, which is hosted by the Climatology Lab at the University of California, Merced. The tree-ring data is from the International Tree Ring Data Bank. Please see the final data repository for more information on versions and variables used. This project utilized processed versions of these data sets, provided by the client Dr. Joan Dudney. The processed data is not yet available publicly, as it is being used in ongoing research. For more information on the processing of the initial data, please contact Dr. Joan Dudney.
   B. Final Sensitivity Estimates and Scripts
      The final sensitivity estimates, and code scripts, are available on Data Dryad. The repository contains detailed information regarding the role each script, and data set played in producing the final drought sensitivity maps. All the scripts and sensitivity data within the data repository are publicly available under the creative commons license CC0 1.0. While it is available, species-specific data will also be available to download via the web dashboard.

9. References

1. Dudney, J., Latimer, A. M., van Mantgem, P., Zald, H., Willing, C. E., Nesmith, J. C. B., Cribbs, J., & Milano, E. (2023). The energy–water limitation threshold explains divergent drought responses in tree growth, needle length, and stable isotope ratios. *Global Change Biology.*, *29*(15), 4368–4382. https://doi.org/10.1111/gcb.16740
2. Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., ... & Van Den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *nature*, *387*(6630), 253-260.
3. Costanza, R., De Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S. J., Kubiszewski, I., ... & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global environmental change*, *26*, 152-158.
4. (2005). Global Forest Resources Assessment 2005: Progress Towards Sustainable Forest Management. *Food and Agriculture Organization of the United Nations, FAO Forestry Paper 147*. https://www.fao.org/3/a0400e/a0400e00.htm

2. Appendix

Table 1.

Original Client Scripts Structure

R Script Title	Description
3b. Species niche.R	1) Characterize climate niches for different species. 2) Standardize annual site data, baseline raster, and CMIP predictions for each species
4a. First stage.R	Run plot-level regressions of RWI sensitivity to annual weather variability
5a. Second stage.R	Run regressions to explore variation in drought sensitivity across species' ranges
6. Predictions.R**	Calculates predictions for future tree growth under CMIP5 climate predictions
7. Figure 2.R**	Species-level plots of sensitivity to CWD across species' ranges

Table 2.

Team Project Script Structure

Filename	Description
1_climate_niche.R	Extract and standardize climate data across species ranges
2_plot_level_regression.R	Estimate site-level sensitivity to variation in climatic water deficit
3_run_regressions.R	Estimate drought sensitivity across species' ranges
4_sens_predictions.R**	Predict species growth given estimates for

Filename	Description
	future variations in climatic water deficit through 2100
5_mapping.R**	Map species sensitivity and growth through 2100
6_mapping_levels.R	Creates the four-level sensitivity level binning for mapping.
main.R	Consolidation of R-scripts 3-5; create sensitivity maps without creation of intermediate data steps

Notes: Relationship between files:

1. The scripts with numerical indicators (1-5) must be run sequentially in order to reproduce the final results. The output for each script becomes the input for the following step.
2. The main.R file sources script 3-5 to generate species sensitivity maps in a single step, without the production of any intermediate steps. Running individual scripts instead of main.R will produce the same results, along with additional intermediate data.
3. **Predicted species growth (ΔRWI) is calculated in the scripts but not included in the final data. High climate variable correlation along with data processing limitations has resulted in select species having abnormal ranges for predicted growth. More processing is required to produce Δaccurate RWI values.

Table 3.

File Name and Descriptions

File Name	Description
TerraClimate19611990_def.nc	Raster of historic climatic water deficit (CWD), monthly averaged across 1961-1990

File Name	Description
TerraClimate19611990_pet.nc	Raster of historic potential transpiration (PET), average across 1961-1990
itrdbsites_pet.csv	Monthly potential transpiration (PET) for sites
itrdbsites_def.csv	Climatic water deficit (CWD) for sites
combined_predictions.csv	Final results, sensitivity values for 26 tree species
site_summary.csv	Attributes for sites within the International Tree Ring Data Bank (ITRDB)
merged_ranges_dissolve.shp	Species range maps
cmip5_cwdaet_start.Rdat	Climatic water deficit predictions using CMIP5
cmip5_cwdaet_end.Rdat	Climatic water deficit predictions using CMIP5
rwi_long.csv	Detrended tree ring data from the ITRDB
species_metadata.csv	Metadata for tree species included in the analysis

Table 4.

Tree Species List of 26

Species code	Scientific name	Common name
psme	Pseudotsuga menziesii	douglas-fir
pipo	Pinus ponderosa	ponderosa pine, western yellow pine
pcgl	Picea glauca	white spruce **
pisy	Pinus sylvestris L.	scots pine, scotch pine
pcab	Picea abies	norway spruce

Species code	Scientific name	Common name
pied	Pinus edulis	pinyon, colorado pinyon
pcen	Picea engelmannii	engelmann spruce
tsme	Tsuga mertensiana	mountain hemlock
abal	Abies alba	silver fir, european fir
quro	Quercus robur L.	english oak
fasy	Fagus sylvatica L.	european beech, common beech
lasi	Larix sibirica Ledeb.	siberian larch
pcma	Picea mariana	black spruce
quma	Quercus macrocarpa	bur oak
piec	Pinus echinata	shortleaf pine
pire	Pinus resinosa	red pine
pifl	Pinus flexilis	limber pine
laly	Larix lyallii	subalpine larch
pist	Pinus strobus L.	eastern white pine, weymouth pine
auch	Austrocedrus chilensis	chilean cedar, cipres de la cordillera, chilean incense cedar**
pial	Pinus albicaulis	whitebark pine **
psma	Pseudotsuga macrocarpa	bigcone douglas-fir
pilo	Pinus longaeva	intermountain bristlecone pine
pico	Pinus contorta	lodgepole pine
quve	Quercus velutina Lam.	black oak
pila	Pinus lambertiana	sugar pine

Notes:
**: Species of high ecological/conservation concern

Table 5.

R Package Versions

Package	Version	Objective	Purpose
tidyverse	2.0.0	Mapping	Load and manipulate tabular data
dbplyr	2.4.0	Mapping	
RSQLite	2.3.0	Mapping	
ggplot2	3.5.0	Mapping	
sf	1.0-9	Mapping	Read in species range files
rgeos	0.6-2	Mapping	
stringr	1.5.0	Mapping	
raster	3.6-20	Mapping	Load and process climate rasters
tmap	3.3-3	Mapping	Testing - Map climate rasters for species
tictoc	1.2	Mapping	Monitor function runtimes
terra	1.7-1.8	Mapping	Load and process climate rasters
data.table	1.14.8	Mapping	Improve aggregated data processing time
furrr	0.3.1	Mapping	Apply mapping functions in parallel
broom.mixed	0.2.9.4	Mapping	Create tidy tables for mixed models
broom	1.0.5	Mapping	Create tidy tables for statistical analyses
fixest	0.11.2	Mapping	Calculating species predictions
dtplyr	1.3.1	Mapping	Provides support for dplyr
MASS	7.3-58.1	Mapping	Calculating species predictions
margins	0.3.26	Mapping	Calculating species predictions
tidylog	1.0.2	Mapping	Testing - Return summary for tidy functions

Package	Version	Objective	Purpose
gstat	2.1-0	Mapping	Calculating species predictions
units	0.8-1	Mapping	
marginaleffects	0.18.0	Mapping	Calculating species predictions
sp	1.6-0	Mapping	
rnaturalearth	0.3.2	Mapping	
rnaturalearthdata	0.1.0	Mapping	
patchwork	1.1.3	Mapping	
prediction	0.3.14	Mapping	Calculating species predictions
snow	0.4-4	Mapping	Support parallel computing
profvis	0.3.8	Mapping	
rgdal	1.6-5	Mapping	
effects	4.2-2	Mapping	Calculating species predictions
dplR	1.7.6	Mapping	Tree-ring analyses
shiny	1.7.4	Dashboard	Shiny dashboard development
shinydashboard	0.7.2	Dashboard	Shiny dashboard development
shinycssloaders	1.0.0	Dashboard	Loading animations for Shiny
leaflet	2.1.1	Dashboard	Creating interactive rasters
markdown	1.5	Dashboard	Add text blocks to dashboard
shinyWidgets	0.8.6	Dashboard	Extension for widgets available in Shiny
DT	0.27	Dashboard	Create reactive data tables in Shiny
leaflet.extras	1.0.0	Dashboard	Additional functionality for Leaflet maps
googleway	2.7.8	Dashboard	Access Google Maps APIs
htmlwidgets	1.6.2	Dashboard	HTML Widgets for Shiny
htmltools	0.5.5	Dashboard	Tools for HTML generation and output

Package	Version	Objective	Purpose
fontawesome	0.5.1	Dashboard	Upload fonts
fresh	0.2.0	Dashboard	Aesthetics and themes
sass	0.4.6	Dashboard	Aesthetics and themes