Spatial data for: Drought may initiate western spruce budworm outbreaks, but multi-year periods of increased moisture availability promote widespread defoliation

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February 04, 2025

# Overview

The following code will download nearly all publicly-available data used in this study. Where data is not publicly-available or easy to programmatically download, we provide more details about how to access the data.

# Tree ring data

## Host

Tree-ring data collected from Douglas fir trees for the purpose of reconstructing past western spruce budworm outbreaks are available on Dryad (<https://doi.org/10.5061/dryad.bnzs7h4n3>). In our analyses, we stored this data in the project subdirectory ~Data/TreeRing/Raw/Host/Veblen.

## Non-host

We obtained all raw ring width data collected from ponderosa pine trees collected in the state of Colorado from the International Tree Ring Databank (<https://www.ncei.noaa.gov/products/paleoclimatology/tree-ring>). In our analyses, we stored this data in the project subdirectory ~Data/TreeRing/Raw/NonHost/ITRDB.

# Spatial data

## Basic Geographic data

We obtained spatial data describing state boundaries from the US Census Bureau (<https://www.census.gov/geographies/mapping-files.html>).

# states  
dir.create(here("Data", "Spatial", "States"), showWarnings = FALSE)  
temp <- here("Data", "Spatial", "States", "cb\_2018\_us\_state\_20m.zip")  
if(!file.exists(temp)){  
 download.file("https://www2.census.gov/geo/tiger/GENZ2018/shp/cb\_2018\_us\_state\_20m.zip", temp, mode="wb")  
 unzip(temp, exdir=here("Data", "Spatial", "States"))  
}

We obtained point data describing the location of Colorado cities and towns from the Colorado Department of Health and Environment Open Data Portal (<https://data-cdphe.opendata.arcgis.com/>).

# Colorado cities  
dir.create(here("Data", "Spatial", "Cities"), showWarnings = FALSE)  
temp <- here("Data", "Spatial", "Cities", "Colorado\_City\_Point\_Locations.zip")  
if(!file.exists(temp)){  
 download.file("https://hub.arcgis.com/api/v3/datasets/b20b5c04576145be9428b4b4f28490c2\_0/downloads/data?format=shp&spatialRefId=4269&where=1%3D1", temp, mode="wb")  
 unzip(temp, exdir=here("Data", "Spatial", "Cities"))  
}

### Ecoregions

We obtained Level III Ecoregion data for the United States from the US Environmental Protection Agency (<https://www.epa.gov/eco-research/ecoregions-north-america>).

#EcoRegions  
dir.create(here("Data","Spatial", "EcoRegions"), showWarnings = FALSE)  
temp <- here("Data", "Spatial", "EcoRegions","us\_eco\_l3.zip")  
if(!file.exists(temp)){  
 download.file("https://gaftp.epa.gov/EPADataCommons/ORD/Ecoregions/us/us\_eco\_l3.zip", temp, mode="wb")  
 unzip(temp, exdir=here("Data", "Spatial", "EcoRegions"))  
}

### Digital Elevation Model

We obtained a 250 m resolution Digital Elevation Model (DEM) for the study area from the National Elevation Dataset (NED) using the *terrainr* package ([Mahoney et al., 2022](#ref-terrainr)).

if(!file.exists(here("Data", "Spatial", "DEM", "DEM250.tif"))){  
 # Southern Rockies  
 srm <- st\_read(here("Data", "Spatial", "EcoRegions", "us\_eco\_l3", "us\_eco\_l3.shp")) %>% filter(US\_L3NAME == 'Southern Rockies') %>% st\_transform(crs=5071) %>% st\_buffer(20000)  
 dir.create(here("Data", "Spatial","DEM"), showWarnings = FALSE)  
  
 # 250 m   
 dem <- get\_tiles(data=srm, output\_prefix = here("Data", "Spatial", "DEM", "DEM250"), services="elevation", resolution=250)  
 dem.rast <- rast(dem$elevation)  
 writeRaster(dem.rast, here("Data", "Spatial", "DEM", "DEM250.tif"), overwrite=T)  
}

## Douglas fir distribution

To characterize the distribution of Douglas fir across the study area, we acquired a 240 x 240 m raster describing tree presence intensity for Douglas fir in ca. 2002 from the USFS’s Individual Tree Species Parameter Maps ([Ellenwood et al., 2015](#ref-ellenwood2015)). Intensity was calculated by summing the number of a possible sixty four 30-meter pixels within a 240-meter pixel with presence of Douglas fir. The 2002 data is not available online, but can be obtained from the USFS (for more details see here <https://www.fs.usda.gov/science-technology/data-tools-products/fhp-mapping-reporting/individual-tree-species-parameter-maps>). In our analyses, we obtained this data in the form of an ArcInfo Gridstore and stored this data in the project subdirectory ~Data/Spatial/ITSPM/f202.

## Disturbance data

We acquired polygon data describing the extent of burned areas for the 1984-2023 period from the Monitoring Trends in Burn Severity Project ([2022](#ref-mtbsprojectMTBSDataAccess2022)) (<mtbs.gov>).

# MTBS   
dir.create(here("Data", "Spatial", "MTBS"), showWarnings = FALSE)  
temp <- here("Data", "Spatial", "MTBS", "mtbs\_perimeter\_data.zip")  
if(!file.exists(temp)){  
 download.file("https://edcintl.cr.usgs.gov/downloads/sciweb1/shared/MTBS\_Fire/data/composite\_data/burned\_area\_extent\_shapefile/mtbs\_perimeter\_data.zip", temp, mode="wb")  
 unzip(temp, exdir=here("Data", "Spatial", "MTBS"))  
}

### Aerial Detection Survey Data

To characterize recent history of WSB outbreaks across the study area, we acquired Aerial Detection Survey data for Region 2 from the USFS ([2020](#Xe07994a759a560b58250ecd1a6458592d9ea6d1)) (<https://www.fs.usda.gov/science-technology/data-tools-products/fhp-mapping-reporting/detection-surveys>).

dir.create(here("Data", "Spatial", "ADS"), showWarnings = FALSE)  
temp <- here("Data", "Spatial", "ADS", "CONUS\_Region2\_AllYears.gdb.zip")  
if(!file.exists(temp)){  
 download.file("https://www.fs.usda.gov/foresthealth/docs/IDS\_Data\_for\_Download/CONUS\_Region2\_AllYears.gdb.zip", temp)  
 unzip(temp, exdir=here("Data", "Spatial", "ADS"))  
}

## Climate data

### North American Drought Atlas

We obtained multi-century (i.e., AD 1650-2005) records of the self-calibrating Palmer Drought Severity Index (SC-PDSI) from the North American Drought Atlas (NADA), which provides tree-ring based reconstructions of June-August SC-PDSI on a 0.5° resolution grid ([Cook et al., 2010](#ref-cook2010)).

if(!dir.exists(here("Data", "Spatial", "NADA"))){  
 dir.create(here("Data", "Spatial", "NADA"), showWarnings = FALSE)  
 temp <- here("Data", "Spatial", "NADA", "nada\_hd2\_cl.nc")  
 download.file("https://www.ncei.noaa.gov/pub/data/paleo/drought/LBDA2010/nada\_hd2\_cl.nc", temp)  
}

### PRISM

To characterize the study area’s climate, we obtained monthly precipitation totals, minimum temperatures, and maximum temperature 30-year normals from PRISM ([PRISM Climate Group, 2021](#ref-prismclimategroup2021)) using the *prism* package ([Hart and Bell, 2015](#ref-prism)). We also obtained gridded June-August SC-PDSI data from the West Wide Drought Tracker ([Abatzoglou et al., 2017](#ref-abatzoglouWestWideDrought2017)).

if(!dir.exists(here("Data", "Spatial", "PRISM"))){  
 dir.create(here("Data", "Spatial", "PRISM"), showWarnings = FALSE)  
 prism\_set\_dl\_dir(here("Data", "Spatial", "PRISM"))  
   
 # Climate normals  
 get\_prism\_normals("ppt", "800m", annual = TRUE, keepZip = FALSE)  
 get\_prism\_normals("tmin", "800m", mon=1, keepZip = FALSE)  
 get\_prism\_normals("tmax", "800m", mon=7, keepZip = FALSE)  
   
 # Monthly climate data  
 temp <- here("Data", "Spatial", "PRISM", "scpdsi\_6\_PRISM.nc")  
 download.file("http://www.wrcc.dri.edu/wwdt/data/PRISM/scpdsi/scpdsi\_6\_PRISM.nc", temp)  
  
 temp <- here("Data", "Spatial", "PRISM", "scpdsi\_7\_PRISM.nc")  
 download.file("http://www.wrcc.dri.edu/wwdt/data/PRISM/scpdsi/scpdsi\_7\_PRISM.nc", temp)  
  
 temp <- here("Data", "Spatial", "PRISM", "scpdsi\_8\_PRISM.nc")  
 download.file("http://www.wrcc.dri.edu/wwdt/data/PRISM/scpdsi/scpdsi\_8\_PRISM.nc", temp)  
}

### Climatic Water Balance

We also downloaded actual evaportranspiration (AET) and climatic water deficit (CWD) normals (1981-2010) from Rodman et al. ([2020](#ref-rodman2020DataTraitbasedApproach); [2020](#X20380e1b959bd07d68b30ae6a2d2c1b8aed94e0)). Data is publicly available on Dryad (<https://datadryad.org/stash/dataset/doi:10.5061/dryad.cz8w9gj1b>). For our analyses, we downloaded the zipped data file and stored it in the project subdirectory ~Data/Spatial/Rodman.

# References

Abatzoglou, J.T., McEvoy, D.J., Redmond, K.T., 2017. The west wide drought tracker: Drought monitoring at fine spatial scales. Bulletin of the American Meteorological Society 98, 1815–1820. <https://doi.org/10.1175/BAMS-D-16-0193.1>

Cook, E.R., Seager, R., Heim, R.R., Vose, R.S., Herweijer, C., Woodhouse, C., 2010. Megadroughts in North America: Placing IPCC projections of hydroclimatic change in a long-term palaeoclimate context. Journal of Quaternary Science 25, 48–61. <https://doi.org/10.1002/jqs.1303>

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Mahoney, M.J., Beier, C.M., Ackerman, A.C., 2022. Terrainr: An r package for creating immersive virtual environments 7, 4060. <https://doi.org/10.21105/joss.04060>

MTBS Project, 2022. [MTBS data access: Burned area boundaries dataset](https://mtbs.gov/direct-download).

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Rodman, K.C., Veblen, T.T., Andrus, R.A., Enright, N.J., Fontaine, J.B., Gonzalez, A.D., Redmond, M.D., Wion, A.P., 2020. A trait-based approach to assessing resistance and resilience to wildfire in two iconic North American conifers. Journal of Ecology n/a. <https://doi.org/10.1111/1365-2745.13480>

Rodman, K., Veblen, T., Andrus, R., Enright, N., Fontaine, J., Gonzalez, A., Redmond, M., Wion, A., 2020. Data from: A trait-based approach to assessing resistance and resilience to wildfire in two iconic North American conifers. <https://doi.org/10.5061/DRYAD.CZ8W9GJ1B>

USFS, partners, its, 2020. [USDA forest service - aerial survey data download](https://www.fs.fed.us/foresthealth/applied-sciences/mapping-reporting/detection-surveys.shtml).