Spatial data for:

Sarah V. Carter and Sarah J. Hart

May 21, 2025

# Overview

The following code will download nearly all publicly-available spatial 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.

# 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"))  
}

## Disturbance data

We acquired polygon data describing the extent and severity of the Cameron Peak fire from the Monitoring Trends in Burn Severity Project ([MTBS Project 2024a](#ref-mtbsproject2024MTBSDataAccess), [2024b](#ref-mtbsproject2024MTBSDataAccessa)) (<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"))  
}  
  
# MTBS burn severity  
dir.create(here("Data", "Spatial", "MTBS"), showWarnings = FALSE)  
temp <- here("Data", "Spatial", "MTBS", "mtbs\_CO\_2020.zip")  
if(!file.exists(temp)){  
 drive\_download(  
 file="https://drive.google.com/file/d/1uj9QeBrZjSdhlf4ILtTglvWXlK2tfTha/view?usp=sharing",  
 path = temp,  
 overwrite = TRUE  
 )  
 unzip(temp, exdir=here("Data", "Spatial", "MTBS"))  
   
}

We also obtained spatially data describing land ownership from the Colorado Natural Heritage Program ([2019](#X2da1eed41ddca3a7cf715e9d6203265a8ad97e8)).

dir.create(here("Data", "Spatial", "SUFS"), showWarnings = FALSE)  
temp <- here(paste0("Data", "Spatial", "USFS", "RangerDistricts.zip"))  
if(!file.exists(temp)){  
 download.file("https://data.fs.usda.gov/geodata/edw/edw\_resources/shp/S\_USA.RangerDistrict.zip", temp)  
 unzip(temp, exdir=here("Data", "Spatial", "USFS"))  
}

dir.create(here("Data", "Spatial", "CoMaP"), showWarnings = FALSE)  
temp <- here(paste0("Data", "Spatial", "CoMaP", "COMaP\_v20190306.gdb.zip"))  
if(!file.exists(temp)){  
 drive\_download(  
 file="https://drive.google.com/file/d/1lJVJlDVQmXX9n67mG1a4lTys9D8WPmBg/view?usp=sharing",  
 path = temp,  
 overwrite = TRUE  
 )  
 unzip(temp, exdir=here("Data", "Spatial", "CoMaP"))  
}

We obtained a 10-m resolution map of aspen cover in ca. 2019 from Cook et al. ([2024](#ref-cook2024MappingQuakingAspen)).

# Download spatial data describing the extent of aspen  
if(!dir.exists(here("Data", "Spatial", "Aspen"))){  
 dir.create(here("Data", "Spatial", "Aspen"), showWarnings = FALSE)  
 temp <- here("Data", "Spatial", "Aspen","srme\_skcv\_distribution\_binopt.tif")  
   
 drive\_download(  
 file="https://drive.google.com/file/d/1u45jPgRgieC84a7yhTswQfdUn\_--129B/view?usp=sharing",  
 path = temp,  
 overwrite = TRUE  
 )  
}

## 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 ([**terrainr?**](#ref-terrainr)).

if(!file.exists(here("Data", "Spatial", "DEM", "DEM30.tif"))){  
 # Read in perimeter data  
CameronPeak <- st\_read(here("Data", "Spatial", "MTBS", "mtbs\_perims\_DD.shp")) %>%   
 filter(Incid\_Name == "CAMERON PEAK") %>% st\_transform(crs=5071) %>% st\_buffer(20000)  
 dir.create(here("Data", "Spatial","DEM"), showWarnings = FALSE)  
  
 # 30 m   
 dem <- get\_tiles(data=CameronPeak, output\_prefix = here("Data", "Spatial", "DEM", "DEM30"), services="elevation", resolution=30)  
 dem.rast <- rast(dem$elevation)  
 writeRaster(dem.rast, here("Data", "Spatial", "DEM", "DEM30.tif"), overwrite=T)  
}

## PRISM

To characterize the study area’s climate, we obtained monthly precipitation totals, minimum temperatures, and maximum temperature 30-year normals (1980-2010) from PRISM ([PRISM Climate Group 2021](#Xc6a61ae9e57c85d16f010348d89f94dac75b6d1)) using the *prism* package ([Hart and Bell 2015](#ref-prism))

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("ppt", "4km", mon=3:5, keepZip = FALSE)  
 get\_prism\_normals("tmin", "800m", mon=1, keepZip = FALSE)  
 get\_prism\_normals("tmax", "800m", mon=7, keepZip = FALSE)  
   
 # Weather 2020, 2021 and 2022  
 get\_prism\_annual("ppt", years=2020:2022, keepZip = FALSE)  
 get\_prism\_monthlys("ppt", years=2020:2022, mon=1:12, keepZip = FALSE)  
 get\_prism\_monthlys("tmax", years=2020:2022, mon=1:12, keepZip = FALSE)  
}

# Generate study area map

dir.create(here("Data", "Spatial", "Processed"))  
  
# Read in aspen presence/absence data  
aspen <- rast(here("Data", "Spatial", "Aspen", "srme\_skcv\_distribution\_binopt.tif"))  
  
# Read in fire severity data  
severity <- rast(here('Data', 'Spatial', 'MTBS', 'mtbs\_CO\_2020.tif'))  
  
# Read in perimeter data  
CameronPeak <- st\_read(here("Data", "Spatial", "MTBS", "mtbs\_perims\_DD.shp")) %>%   
 filter(Incid\_Name == "CAMERON PEAK") %>% # pull out just Cameron Peak  
 st\_transform(st\_crs(severity)) # transform

## Reading layer `mtbs\_perims\_DD' from data source   
## `/Users/sarahhart/Library/CloudStorage/GoogleDrive-sarahjanehart13@gmail.com/My Drive/JOB/RESEARCH/Analyses/PostfireAspen/Data/Spatial/MTBS/mtbs\_perims\_DD.shp'   
## using driver `ESRI Shapefile'  
## Simple feature collection with 30331 features and 22 fields  
## Geometry type: MULTIPOLYGON  
## Dimension: XY  
## Bounding box: xmin: -166.1885 ymin: 17.94736 xmax: -65.33821 ymax: 70.15893  
## Geodetic CRS: NAD83

# Buffer fire by 5 km  
CameronPeak.buffer5000 <- CameronPeak %>%   
 st\_buffer(dist=5000)  
  
# Clip severity raster   
CameronPeak.severity <- crop(severity, st\_bbox(CameronPeak.buffer5000))  
  
# Convert to polygon  
CameronPeak.highseverity.p <- CameronPeak.severity %>%   
 st\_as\_stars() %>%   
 st\_as\_sf(as\_points = FALSE, merge =TRUE) %>%  
 filter(mtbs\_CO\_2020 %in% 4) %>% # select only high severity pixels  
 st\_union() # union  
st\_write(CameronPeak.highseverity.p, dsn=here("Data", "Spatial", "Processed", "CameronPeak-highseverity.shp"), append=F) # write to file

## Deleting layer `CameronPeak-highseverity' using driver `ESRI Shapefile'  
## Writing layer `CameronPeak-highseverity' to data source   
## `/Users/sarahhart/Library/CloudStorage/GoogleDrive-sarahjanehart13@gmail.com/My Drive/JOB/RESEARCH/Analyses/PostfireAspen/Data/Spatial/Processed/CameronPeak-highseverity.shp' using driver `ESRI Shapefile'  
## Writing 1 features with 0 fields and geometry type Multi Polygon.

CameronPeak.highmodseverity.p <- CameronPeak.severity %>%   
 st\_as\_stars() %>%   
 st\_as\_sf(as\_points = FALSE, merge =TRUE) %>%  
 filter(mtbs\_CO\_2020 %in% 3:4) %>% # select only moderate and high severity pixels  
 st\_union() # union  
st\_write(CameronPeak.highmodseverity.p, dsn=here("Data", "Spatial", "Processed", "CameronPeak-highmod.shp"), append=F) # write to file

## Deleting layer `CameronPeak-highmod' using driver `ESRI Shapefile'  
## Writing layer `CameronPeak-highmod' to data source   
## `/Users/sarahhart/Library/CloudStorage/GoogleDrive-sarahjanehart13@gmail.com/My Drive/JOB/RESEARCH/Analyses/PostfireAspen/Data/Spatial/Processed/CameronPeak-highmod.shp' using driver `ESRI Shapefile'  
## Writing 1 features with 0 fields and geometry type Multi Polygon.

# Convert aspen data from raster to polygon  
aspen <- aspen %>% crop(st\_bbox(st\_transform(CameronPeak.buffer5000, st\_crs(aspen)))) # crop aspen data to area in and surrounding Cameron Peak  
aspen.p <- aspen %>%   
 st\_as\_stars() %>%   
 st\_as\_sf(as\_points = FALSE, merge =TRUE) %>%  
 filter(Band\_1==1) %>%   
 st\_union(append=F) # union  
st\_write(aspen.p, dsn=here("Data", "Spatial", "Processed", "Aspen-CameronPeak.shp"),append=F)

## Deleting layer `Aspen-CameronPeak' using driver `ESRI Shapefile'  
## Writing layer `Aspen-CameronPeak' to data source   
## `/Users/sarahhart/Library/CloudStorage/GoogleDrive-sarahjanehart13@gmail.com/My Drive/JOB/RESEARCH/Analyses/PostfireAspen/Data/Spatial/Processed/Aspen-CameronPeak.shp' using driver `ESRI Shapefile'  
## Writing 1 features with 0 fields and geometry type Multi Polygon.

aspen.r <- rasterize(st\_as\_sf(aspen.p), aspen, filename=here("Data", "Spatial", "Processed", "Aspen-total.tif"), overwrite=T)  
  
# Get area of live aspen --> exclude aspen that burned at high severity  
CameronPeak.highseverity.p <- CameronPeak.highseverity.p %>% st\_transform(st\_crs(aspen.p))  
aspen.live.high <- st\_difference(aspen.p, CameronPeak.highseverity.p)  
st\_write(aspen.live.high, here("Data", "Spatial", "Processed", "aspen-live-high.shp"), append=F) # write to file

## Deleting layer `aspen-live-high' using driver `ESRI Shapefile'  
## Writing layer `aspen-live-high' to data source   
## `/Users/sarahhart/Library/CloudStorage/GoogleDrive-sarahjanehart13@gmail.com/My Drive/JOB/RESEARCH/Analyses/PostfireAspen/Data/Spatial/Processed/aspen-live-high.shp' using driver `ESRI Shapefile'  
## Writing 1 features with 0 fields and geometry type Multi Polygon.

aspen.live.high.r <- rasterize(st\_as\_sf(aspen.live.high), aspen, filename=here("Data", "Spatial", "Aspen", "Aspen-live-high.tif"), overwrite=T)  
  
# Get area of live aspen --> exclude aspen that burned at modeate or high severity  
CameronPeak.highmodseverity.p <- CameronPeak.highmodseverity.p %>% st\_transform(st\_crs(aspen.p))  
aspen.live.highmod <- st\_difference(aspen.p, CameronPeak.highmodseverity.p)  
st\_write(aspen.live.highmod, here("Data", "Spatial", "Processed", "aspen-live-highmod.shp"), append=F) # write to file

## Deleting layer `aspen-live-highmod' using driver `ESRI Shapefile'  
## Writing layer `aspen-live-highmod' to data source   
## `/Users/sarahhart/Library/CloudStorage/GoogleDrive-sarahjanehart13@gmail.com/My Drive/JOB/RESEARCH/Analyses/PostfireAspen/Data/Spatial/Processed/aspen-live-highmod.shp' using driver `ESRI Shapefile'  
## Writing 1 features with 0 fields and geometry type Multi Polygon.

aspen.live.highmod.r <- rasterize(st\_as\_sf(aspen.live.highmod), aspen, filename=here("Data", "Spatial", "Aspen", "Aspen-live-highmod.tif"), overwrite=T)  
  
# Calculate distance  
aspen.distance <- distance(aspen.r, filename=here("Data", "Spatial", "Processed", "aspen-dist.tif"), overwrite=T)  
aspen.live.high.distance <- distance(aspen.live.high.r, filename=here("Data", "Spatial","Processed", "aspen-live-high-dist.tif"), overwrite=T)  
aspen.live.highmod.distance <- distance(aspen.live.highmod.r, filename=here("Data", "Spatial","Processed", "aspen-live-highmod-dist.tif"), overwrite=T)

# Characterize study area

# Read in fire severity data  
severity <- rast(here('Data', 'Spatial', 'MTBS', 'mtbs\_CO\_2020.tif'))   
CameronPeak <- st\_read(here("Data", "Spatial", "MTBS", "mtbs\_perims\_DD.shp")) %>%   
 filter(Incid\_Name == "CAMERON PEAK") %>% # pull out just Cameron Peak  
 st\_transform(st\_crs(severity)) # transform

## Reading layer `mtbs\_perims\_DD' from data source   
## `/Users/sarahhart/Library/CloudStorage/GoogleDrive-sarahjanehart13@gmail.com/My Drive/JOB/RESEARCH/Analyses/PostfireAspen/Data/Spatial/MTBS/mtbs\_perims\_DD.shp'   
## using driver `ESRI Shapefile'  
## Simple feature collection with 30331 features and 22 fields  
## Geometry type: MULTIPOLYGON  
## Dimension: XY  
## Bounding box: xmin: -166.1885 ymin: 17.94736 xmax: -65.33821 ymax: 70.15893  
## Geodetic CRS: NAD83

CameronPeak.severity <- crop(severity, st\_bbox(CameronPeak ))  
CameronPeak.severity[CameronPeak.severity >=5] <-NA  
   
# Read in aspen data  
aspen <- rast(here("Data", "Spatial", "Aspen", "srme\_skcv\_distribution\_binopt.tif"))  
aspen.live.distance <- rast(here("Data", "Spatial","Processed", "aspen-live-highmod-dist.tif"))  
aspen.prefire.distance <- rast(here("Data", "Spatial", "Processed", "aspen-dist.tif"))  
  
# Read in elevation data  
dem <- rast(here("Data", "Spatial", "DEM", "DEM30.tif"))  
  
# Read in climate data  
prism\_set\_dl\_dir(here("Data", "Spatial", "PRISM"))  
  
#normals  
ppt.normal <- prism\_archive\_subset("ppt", "annual normals", resolution="800m") %>% pd\_to\_file() %>% rast()  
tmin1.normal <- prism\_archive\_subset("tmin", "monthly normals", mon=1, resolution="800m") %>% pd\_to\_file() %>% rast()  
tmax7.normal <- prism\_archive\_subset("tmax", "monthly normals", mon=7, resolution="800m") %>% pd\_to\_file() %>% rast()  
  
# weather 2020  
ppt.2020 <- prism\_archive\_subset("ppt", "annual", year=2020) %>% pd\_to\_file() %>% rast()  
ppt.2020.JJASO <- prism\_archive\_subset("ppt", "monthly", year=2020, mon=6:10) %>% pd\_to\_file() %>% rast()  
tmax.2020.JJASO <- prism\_archive\_subset("tmax", "monthly", year=2020, mon=6:10) %>% pd\_to\_file() %>% rast()  
  
# precip 2021  
ppt.2021 <- prism\_archive\_subset("ppt", "annual", year=2021) %>% pd\_to\_file() %>% rast()  
  
# precip 2022  
ppt.2022 <- prism\_archive\_subset("ppt", "annual",year=2022) %>% pd\_to\_file() %>% rast()  
  
# Sample and characterize patterns  
## Cameron Peak  
CameronPeak.sample.pts <- spatSample(CameronPeak.severity, 10000, method="random", replace=FALSE, na.rm=T, as.points=TRUE, values=TRUE, cells=FALSE)   
CameronPeak.sample.pts <- extract(aspen, CameronPeak.sample.pts, bind=T)  
CameronPeak.sample.pts <- extract(aspen.prefire.distance, CameronPeak.sample.pts, bind=T)  
CameronPeak.sample.pts <- extract(aspen.live.distance, CameronPeak.sample.pts, bind=T)  
CameronPeak.sample.pts <- extract(dem, CameronPeak.sample.pts, bind=T)  
CameronPeak.sample.pts <- extract(ppt.normal, CameronPeak.sample.pts, bind=T)  
CameronPeak.sample.pts <- extract(tmin1.normal, CameronPeak.sample.pts, bind=T)  
CameronPeak.sample.pts <- extract(tmax7.normal, CameronPeak.sample.pts, bind=T)  
CameronPeak.sample.pts <- extract(ppt.2021, CameronPeak.sample.pts, bind=T)  
CameronPeak.sample.pts <- extract(ppt.2022, CameronPeak.sample.pts, bind=T)  
  
CameronPeak.sample.df <- CameronPeak.sample.pts %>% as.data.frame()  
colnames(CameronPeak.sample.df) <- c("severity", "aspen", "distance.pre", "distance.post", "elevation", "ppt", "tmin", "tmax", "ppt.2021", "ppt.2022")  
write.csv(CameronPeak.sample.df, here("Results", "CameronPeak-attributes.csv"))  
  
## Study sites  
sites <- read\_excel(here("Data", "Postfire-Regen-Clean.xlsx"), sheet="Site") %>% dplyr::select("Site", "Easting", "Northing")  
sites.sf <- sites %>% st\_as\_sf(coords = c("Easting", "Northing"), crs = "EPSG:32613")   
sites.sf <- extract(severity, sites.sf, bind=T)  
sites.sf <- extract(aspen, sites.sf, bind=T)  
sites.sf <- extract(aspen.prefire.distance, sites.sf, bind=T)  
sites.sf <- extract(aspen.live.distance, sites.sf, bind=T)  
sites.sf <- extract(dem, sites.sf, bind=T)  
sites.sf <- extract(ppt.normal, sites.sf, bind=T)  
sites.sf <- extract(tmin1.normal, sites.sf, bind=T)  
sites.sf <- extract(tmax7.normal, sites.sf, bind=T)  
sites.sf<- extract(ppt.2021, sites.sf, bind=T)  
sites.sf <- extract(ppt.2022, sites.sf, bind=T)  
sites.df<- sites.sf %>% as.data.frame()  
colnames(sites.df) <- c("Site", "severity", "aspen", "distance.pre", "distance.post", "elevation", "ppt", "tmin", "tmax", "ppt.2021", "ppt.2022")  
write.csv(sites.df, here("Results", "sites-attributes.csv"))  
  
  
  
p1 <- CameronPeak.sample.df %>% ggplot(aes(x=elevation, y=distance.pre))+geom\_hex()+ylim(0,2100)+  
 scale\_fill\_viridis\_c(begin = 0, end = .9, option = "C", limit = range(c(0,250)))+ylab("distance to live\naspen pre-fire (m)")  
p2 <- CameronPeak.sample.df %>% ggplot(aes(x=elevation, y=distance.post))+geom\_hex()+ylim(0,2100)+  
 scale\_fill\_viridis\_c(begin = 0, end = .9, option = "C", limit = range(c(0,250)))+ylab("distance to live\naspen post-fire (m)")  
p3 <- CameronPeak.sample.df %>% mutate(aspen=factor(aspen, level=c(0,1), labels=c("absent", "present"))) %>% ggplot(aes(y=elevation, x=aspen))+geom\_boxplot()+xlab("aspen occurrence")+ylab("elevation (m)")  
p4 <- CameronPeak.sample.df %>% mutate(severity=factor(severity, level=c(1, 2, 3, 4), labels=c("unburned", "low", "moderate", "high"))) %>% ggplot(aes(y=elevation, x=factor(severity)))+geom\_boxplot()+xlab("fire severity")+ylab("elevation (m)")  
p1234 <- p1 + p2 + p3+ p4+plot\_layout(nrow=2, guides="collect") + plot\_annotation(tag\_levels = "A") &  
 theme(legend.position='bottom')  
  
ggsave(here("Results", "Figures", "CameronPeak-patterns.jpg"), width=5, height=4, units="in", p1234)

# References

Colorado Natural Heritage Program. 2019. [The colorado ownership, management and protection map (COMaP)](https://comap.cnhp.colostate.edu).

Cook, M., T. Chapman, S. Hart, A. Paudel, and J. Balch. 2024. [Mapping Quaking Aspen Using Seasonal Sentinel-1 and Sentinel-2 Composite Imagery across the Southern Rockies, USA](https://doi.org/10.3390/rs16091619). Remote Sensing 16:1619.

Hart, E. M., and K. Bell. 2015. [Prism: Download data from the oregon prism project](https://doi.org/10.5281/zenodo.33663).

MTBS Project. 2024a. [MTBS data access: Burned severity mosaics dataset](https://mtbs.gov/direct-download).

MTBS Project. 2024b. [MTBS data access: Burned area boundaries dataset](https://mtbs.gov/direct-download).

PRISM Climate Group. 2021. [Monthly 30-year climate normals (1981-2010)](https://prism.oregonstate.edu/normals/).