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

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# Overview

The following code generates the study area map and characterizes the climate using data from PRISM ([PRISM Climate Group, 2021](#ref-prismclimategroup2021)).

# Generate study area map

host.meta <- read.csv(here("Data", "TreeRing", "Processed", "Host", "host-metadata.csv")) # import host metadata  
nonhost.meta <- read.csv(here("Data", "TreeRing", "Processed", "Nonhost", "nonhost-metadata.csv")) # import nonhost metadata  
  
hostXnonhost <- read.csv(here("Results", "hostXnonhost-subset.csv")) # import data describing the nonhost sites matched to each host site  
  
host.meta.sub <- host.meta %>% filter(SeriesCode %in% hostXnonhost$host) # select only host sites   
   
select.nonhost.sites <- hostXnonhost[,c('nonhost1', 'nonhost2','nonhost3')] %>% unlist() %>% unique()  
nonhost.meta.sub <- nonhost.meta[nonhost.meta$SeriesCode %in% select.nonhost.sites, ]  
   
nonhost.sites <- st\_as\_sf(x = nonhost.meta.sub, coords = c("Lon", "Lat"), crs = "+proj=longlat +ellps=WGS84 +datum=WGS84 +no\_defs") %>% st\_transform(proj.proj)  
  
host.sites.sub <- st\_as\_sf(x = host.meta.sub, coords = c("Lon", "Lat"), crs = "+proj=longlat +ellps=WGS84 +datum=WGS84 +no\_defs") %>% st\_transform(proj.proj)  
  
host.sites <- st\_as\_sf(x = host.meta, coords = c("Lon", "Lat"), crs = "+proj=longlat +ellps=WGS84 +datum=WGS84 +no\_defs") %>% st\_transform(proj.proj)

if(!file.exists(here("Results", "Figures", "FigStudyArea.jpg"))){  
 states <- st\_read(here("Data", "Spatial", "States", "cb\_2018\_us\_state\_20m.shp")) %>% st\_transform(proj.proj)  
  
 #Denver  
 denver <- st\_read(here("Data", "Spatial", "Cities", "Colorado\_City\_Point\_Locations.shp")) %>% filter(NAME=="DENVER") %>% st\_transform(proj.proj)  
  
 # Convert raster of Douglas fir occurrence to polygon  
   
 if(!file.exists(here("Data", "Spatial", "ITSPM","f202.shp"))){  
 df.rast <- rast(here("Data", "Spatial", "ITSPM","f202"))  
 srm <- st\_read(here("Data", "Spatial", "EcoRegions", "us\_eco\_l3", "us\_eco\_l3.shp"), quiet=T) %>% filter(US\_L3NAME=="Southern Rockies") %>% st\_transform(crs=st\_crs(df.rast)) %>% vect()  
 df.rast <- crop(df.rast, srm)  
 df.rast[df.rast<1] <- NA # set pixels were at least 1 of 64 pixels has Douglas fir  
 df.rast[df.rast>=1] <- 1  
  
 df.poly <- as.polygons(df.rast, aggregate=TRUE, values=TRUE, na.rm=TRUE)   
   
 writeVector(df.poly, here("Data", "Spatial", "ITSPM","f202.shp"), overwrite=T)  
 }  
  
 douglasfir <- vect(here("Data", "Spatial", "ITSPM","f202.shp")) %>% project(nonhost.sites) %>% st\_as\_sf()  
   
 x <- tmaptools::bb(nonhost.sites)  
 x[1] <- -107; x[2] <- 38.1; x[3] <- -104; x[4] <- 41.25  
 asp1 <- (x$ymax - x$ymin)/(x$xmax - x$xmin)  
 sg <- bb\_poly(nonhost.sites, projection = st\_crs(nonhost.sites))  
  
   
 studyarea <- tm\_shape(douglasfir, bbox=x) + tm\_fill(col="#5ab4ac") + tm\_shape(nonhost.sites) +tm\_symbols(size=0.25, shape=21,col="darkgray", alpha=1) + tm\_shape(host.sites.sub) +tm\_symbols(size=0.25, shape=17, col="black") + tm\_shape(denver) +tm\_symbols(shape=8, size=0.5, col="black") + tm\_text("NAME", just=c(-0.25,0), size=0.7, remove.overlap=T) + tm\_scale\_bar(position = c(0.95,0.005), text.size=0.75, just="right", breaks=c(0,50), bg.color="white", bg.alpha = 0.8)+tm\_compass(position=c("right", "top"), text.size=0.75, size=2, type="4star")+tm\_graticules(lines=F)  
  
 wus <- states %>% filter(STUSPS %in% c("WA", "OR", "CA", "ID", "NV", "AZ", "MT", "UT", "NM", "CO", "WY")) %>% st\_transform(st\_crs(douglasfir))  
 xy <- st\_bbox(wus)  
 asp2 <- (xy$xmax - xy$xmin)/(xy$ymax - xy$ymin)  
   
 insetmap = tm\_shape(wus) + tm\_fill(col="lightgrey") +  
 tm\_shape(wus) + tm\_borders(lwd = 1, col="grey") +  
 tm\_shape(sg) + tm\_borders(lw=2, col="black") +  
 tm\_layout(inner.margins = c(0.04,0.04,0.04,0.04), outer.margins=c(0,0,0,0))  
   
 w <- 0.3  
 h <- asp2 \* w  
 vp <- viewport(x=0.15, y=0.009, width = w, height=h, just=c("left", "bottom"))  
   
 tmap\_save(studyarea,filename=here("Results", "Figures", "FigStudyArea.jpg"),  
 dpi=300, insets\_tm=insetmap, insets\_vp=vp,  
 height=4.5, width=3.5, units="in")  
}

# Characterize climate

if(!file.exists(here("Results", "climate-norms-studyarea.csv"))){  
  
 df.poly <-vect(here("Data", "Spatial", "ITSPM","f202.shp"))  
 host.sites <- st\_as\_sf(x = host.meta, coords = c("Lon", "Lat"), crs = "+proj=longlat +ellps=WGS84 +datum=WGS84 +no\_defs") %>% st\_transform(st\_crs(df.poly)) %>% st\_buffer(1000)  
 df.poly <- crop(df.poly, host.sites)  
   
 prism\_set\_dl\_dir(here("Data", "Spatial", "PRISM"))  
   
 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()  
   
 AET <- rast(here('Data', 'Spatial', 'Rodman', 'AET and CWD', 'AET\_1981-2010.tif'))  
 CWD <- rast(here('Data', 'Spatial', 'Rodman', 'AET and CWD', 'CWD\_1981-2010.tif'))  
  
 dem <- rast(here("Data", "Spatial", "DEM", "DEM250.tif"))  
   
 df.poly <- df.poly %>% project(ppt.normal)  
 climate.normals <- data.frame(metric=c("mean", "min", "max"))  
   
 climate.normals$PPT <- NA  
 climate.normals[climate.normals$metric=="mean", ]$PPT <- terra::zonal(z=df.poly, x=ppt.normal, fun=mean)[1,1]  
 climate.normals[climate.normals$metric=="min", ]$PPT <- quantile(terra::extract(y=df.poly, x=tmin1.normal)[,2], 0.1)  
 climate.normals[climate.normals$metric=="max", ]$PPT <- quantile(terra::extract(y=df.poly, x=tmin1.normal)[,2], 0.9)  
   
 climate.normals$TMIN <- NA  
 climate.normals[climate.normals$metric=="mean", ]$TMIN <- terra::zonal(z=df.poly, x=tmin1.normal, fun=mean)[1,1]  
 climate.normals[climate.normals$metric=="min", ]$TMIN <- quantile(terra::extract(y=df.poly, x=tmin1.normal)[,2], 0.1)  
 climate.normals[climate.normals$metric=="max", ]$TMIN <- quantile(terra::extract(y=df.poly, x=tmin1.normal)[,2], 0.9)  
   
 climate.normals$TMAX <- NA  
 climate.normals[climate.normals$metric=="mean", ]$TMAX <- terra::zonal(z=df.poly, x=tmax7.normal, fun=mean)[1,1]  
 climate.normals[climate.normals$metric=="min", ]$TMAX <- quantile(terra::extract(y=df.poly, x=tmax7.normal)[,2], 0.1)  
 climate.normals[climate.normals$metric=="max", ]$TMAX <- quantile(terra::extract(y=df.poly, x=tmax7.normal)[,2], 0.9)  
   
 df.poly <- df.poly %>% project(AET)  
 climate.normals$AET <- NA  
 climate.normals[climate.normals$metric=="mean", ]$AET <- terra::zonal(z=df.poly, x=AET, fun=mean)[1,1]  
 climate.normals[climate.normals$metric=="min", ]$AET <- quantile(terra::extract(y=df.poly, x=AET)$`AET\_1981-2010`, 0.1)  
 climate.normals[climate.normals$metric=="max", ]$AET <- quantile(terra::extract(y=df.poly, x=AET)$`AET\_1981-2010`, 0.9)  
  
 df.poly <- df.poly %>% project(CWD)  
 climate.normals$CWD <- NA  
 climate.normals[climate.normals$metric=="mean", ]$CWD <- terra::zonal(z=df.poly, x=CWD, fun=mean)[1,1]  
 climate.normals[climate.normals$metric=="min", ]$CWD <- quantile(terra::extract(y=df.poly, x=CWD)$`CWD\_1981-2010`, 0.1)  
 climate.normals[climate.normals$metric=="max", ]$CWD <- quantile(terra::extract(y=df.poly, x=CWD)$`CWD\_1981-2010`, 0.9)  
  
   
   
 df.poly <- df.poly %>% project(dem)  
 climate.normals$Elev <- NA  
 climate.normals[climate.normals$metric=="mean", ]$Elev <- terra::zonal(z=df.poly, x=dem, fun=mean)[1,1]  
 climate.normals[climate.normals$metric=="min", ]$Elev <- quantile(terra::extract(y=df.poly, x=dem)$DEM250\_3DEPElevation\_1\_1, 0.1)  
 climate.normals[climate.normals$metric=="max", ]$Elev <- quantile(terra::extract(y=df.poly, x=dem)$DEM250\_3DEPElevation\_1\_1, 0.9)  
  
 write.csv(climate.normals, file=here("Results", "climate-norms-studyarea.csv"), row.names = F)  
}

# References

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