# Overview

# Methods

## Study area

## Data

### Phenology information

#### Leaf color change

1. Early color change
2. 50% Color change
3. All leaves changed color

#### Leaf dropping

1. Early dropping
2. 50% leaf drop
3. All leaves dropped

### Tree size

### Climate data

### PRISM

To characterize the climate conditions for each tree, we also obtained monthly precipitation totals, minimum temperatures, and maximum temperature 30-year normals from PRISM ([PRISM Climate Group 2021](#Xc6a61ae9e57c85d16f010348d89f94dac75b6d1)) using the *prism* package ([Hart and Bell 2015](#ref-prism)).

### This chunk of code downloads gridded PRISM data for CONUS. ###  
dir.create(here("Data", "Spatial"))  
dir.create(here("Data", "Spatial", "PRISM"), showWarnings = FALSE) # Create directory to hold data  
prism\_set\_dl\_dir(here("Data", "Spatial", "PRISM")) # tell program to download PRISM data to the directory we just created  
   
# download climate normals  
get\_prism\_normals("ppt", "800m", annual = TRUE, keepZip = FALSE) # annual precipitation

##   
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get\_prism\_normals("tmin", "800m", mon=1, keepZip = FALSE) # minimum temperature in January

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get\_prism\_normals("tmax", "800m", mon=7, keepZip = FALSE) # maximum temperature in July

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######### This code assigns the climate data to each unique location ###########  
  
### Read in data from budburst and create spatial object with latitude and longitude for each location id  
budburst.sf <- read.csv(here("Data", "budburst\_observations\_1739214151.csv")) %>%   
 # grab only location id, longitude, and latitude columns  
 select(location\_id,administrative\_area\_level\_1, longitude, latitude) %>%   
 # remove duplicates  
 unique() %>%  
 # create spatial object  
 st\_as\_sf(coords = c("longitude", "latitude"), crs = "+proj=longlat +ellps=WGS84 +datum=WGS84 +no\_defs")  
  
### Read in prism data  
prism\_set\_dl\_dir(here("Data", "Spatial", "PRISM")) # tell computer where PRISM data is stored  
  
#### ANNUAL PPT ####  
ppt.normal <- prism\_archive\_subset("ppt", "annual normals", resolution="800m") %>% # set what PRISM data we want to look at  
 pd\_to\_file() %>% # get path  
 rast() # read in data   
names(ppt.normal) <- "PPT"  
  
#### JANUARY TMIN ####  
tmin.normal <- prism\_archive\_subset("tmin", "monthly normals", mon=1, resolution="800m") %>% # set what PRISM data we want to look at  
 pd\_to\_file() %>% # get path  
 rast() # read in data   
names(tmin.normal) <- "TMIN01"  
  
#### JULY TMAX ####  
tmax.normal <- prism\_archive\_subset("tmax", "monthly normals", mon=7, resolution="800m") %>% # set what PRISM data we want to look at  
 pd\_to\_file() %>% # get path  
 rast() # read in data   
names(tmax.normal) <- "TMAX07"  
  
### Overlay budburst observations and extract climate normals  
budburst.sf <- extract(ppt.normal,budburst.sf, bind=T) # PPT  
budburst.sf <- extract(tmin.normal,budburst.sf, bind=T) # TMIN  
budburst.sf <- extract(tmax.normal,budburst.sf, bind=T) # TMAX  
budburst.climate <- budburst.sf %>% as.data.frame()

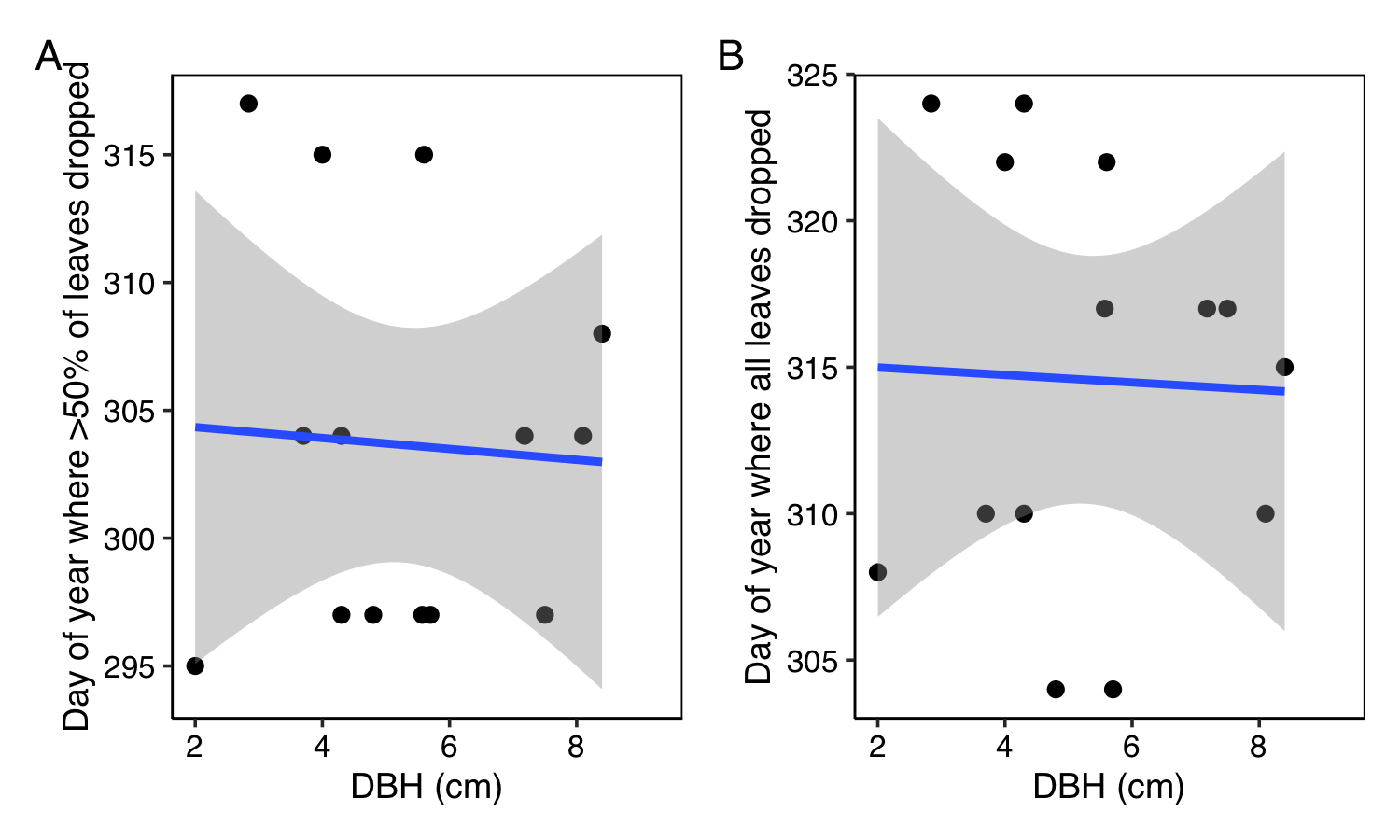
## Data preparation

### FIELD DATA ###  
  
#---- Read in excel file that links location\_id field from Budburst with the Locations assigned in the field ----#  
### Fort Collins ###  
FC <- read\_excel(here("Data", "Budburst-FortCollins-Beckett.xlsx")) # note I added the column name "Location" to column Z  
  
### Longmont ###  
Longmont <- read\_excel(here("Data", "Budburst-Longmont-Beckett.xlsx")) # note I added the column name "Location" to column Z  
### Clean this dataframe   
#### remove HOME location which is only this the datasheet once  
Longmont <- Longmont %>% filter(!Location=="HOME") # is this same tree as "Home"? They have different location ids  
#### fix formatting b/c location is listed as "Stacy’s Tree" in the DBH data but "Stacy's Tree" in this spreadsheet  
Longmont <- Longmont %>% mutate(Location = gsub("'", "’", Location))   
  
# Create data frame with information linking budburst location\_ids, Location, and Tree numbers  
## First pull out location\_id and Locations assigned in the field  
  
### Fort Collins ####  
Tree.key.FC <- FC %>%   
 dplyr::select(location\_i, Location) %>% # grab only location\_i column and Location column  
 na.omit() %>% # remove missing values / cells with out values  
 mutate(City="Fort Collins")# add column with city  
  
### Longmont ###  
Tree.key.Longmont <- Longmont %>%   
 dplyr::select(location\_i, Location) %>% # grab only location\_i column and Location column  
 na.omit() %>% # remove missing values / cells with out values  
 mutate(City="Longmont")# add column with city  
  
# Fort Collins and Longmont keys  
Tree.key <- bind\_rows(Tree.key.FC, Tree.key.Longmont) # combine two dataframes  
  
#---- Read in DBH data ----#  
# note this excel file had some permissions on it that only let me visualize the data in excel. I copied and pasted the data into a new excel file and tried to keep all of the formatting the same but some things may have changed slightly  
  
### Fort Collins ###  
DBH.FC <- read\_excel(here("Data", "DBH-Crown Excel.xlsx"), sheet="Fort Collins - Fort Collins", skip=2) %>%   
 # add column with name City and populate with Fort Collins  
 mutate(City="Fort Collins")  
  
### Longmont ###  
DBH.Longmont <- read\_excel(here("Data", "DBH-Crown Excel.xlsx"), sheet="Longmont - Longmont", skip=2) %>%   
 # add column with name City and populate with Longmont  
 mutate(City="Longmont")  
  
### Create data frame with information linking tree numbers from field data with Location ids ###  
### Fort Collins ###  
Tree.key2.FC <- DBH.FC %>%   
 select(Tree, Location) %>%   
 # add column with name City and populate with Fort Collins  
 mutate(City="Fort Collins")  
  
### Longmont ###  
Tree.key2.Longmont <- DBH.Longmont %>%   
 select(Tree, Location) %>%   
 # add column with name City and populate with Longmont  
 mutate(City="Longmont")  
  
# Fort Collins and Longmont keys  
Tree.key2 <- bind\_rows(Tree.key2.FC, Tree.key2.Longmont)   
  
#---- Combine Tree, Location, and location\_id information ----#  
Tree.key <- full\_join(Tree.key2, Tree.key, by=c("City", "Location"))  
  
#---- Add location id to DBH data ----#  
DBH.dat <- bind\_rows(DBH.FC, DBH.Longmont) # combine Fort Collins and Longmont data into one dataframe  
DBH.dat <- left\_join(DBH.dat, Tree.key, by=c("City", "Location", "Tree")) # Add location id  
colnames(DBH.dat) <- c("Tree", "DBH", "Canopy1", "Canopy2", "Size", "Location", "City", "location\_id") # rename columns so they are easier to worth with in R  
  
### BUDBURST DATA ###  
# read in budburst observation csv file  
budburst <- read.csv(here("Data", "budburst\_observations\_1739214151.csv")) %>%   
 # convert observation\_date to date object   
 mutate(date=as.Date(observation\_date, format="%m/%d/%Y")) %>%   
 # pull year and day of year (doy) into separate columns  
 mutate(year =lubridate::year(date), doy=lubridate::yday(date))

## Analyses

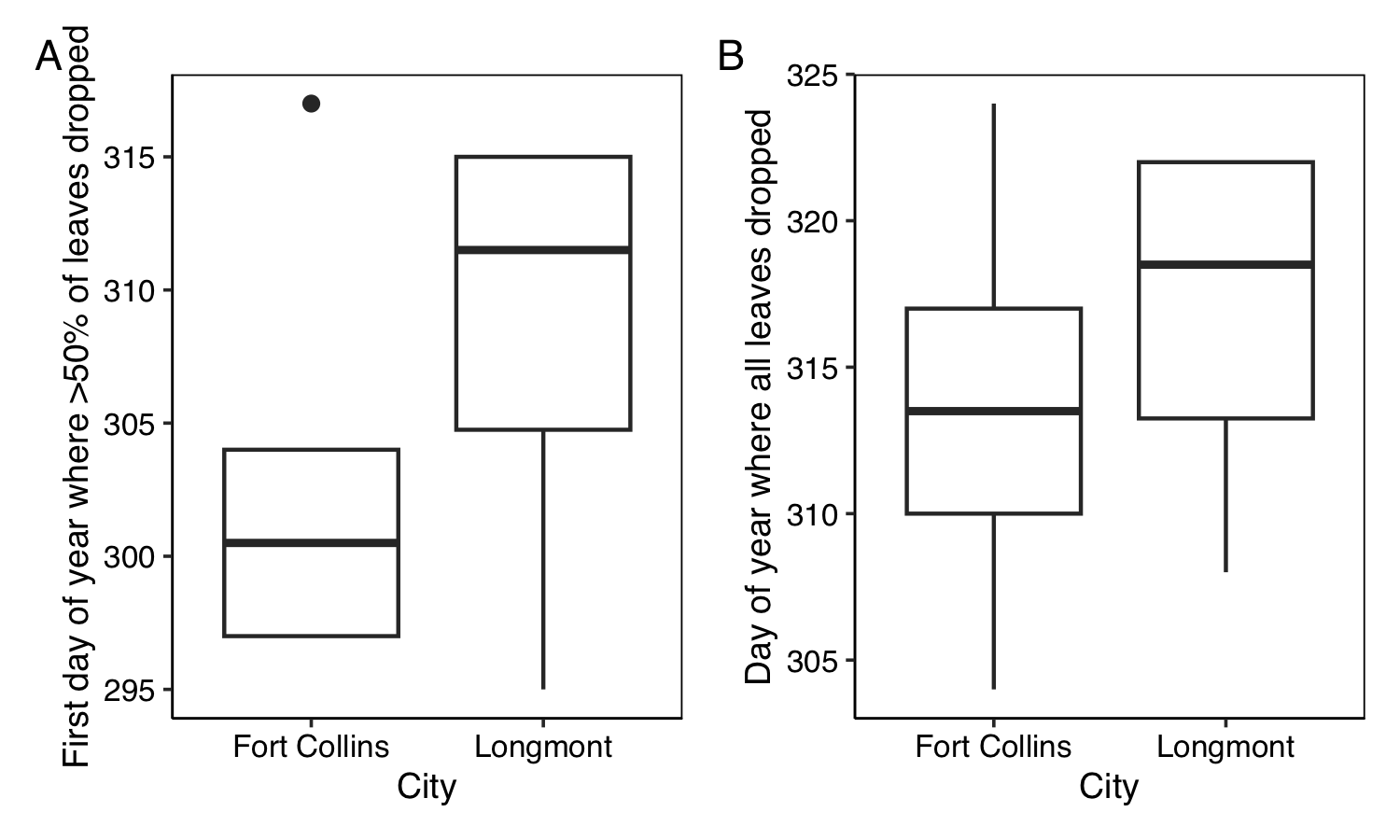
### Were small trees more likely to drop their leaves earlier?

#---- for each tree determine the first date when 50% of leaves had fallen ---#  
budburst.sub.drop50 <- budburst %>%   
 # limit dataset to just fall phenophase data describing leaf color  
 filter(phenophase\_plant\_structure %in% c("Autumn Leaves Dropping")) %>%   
 # limit dataset to just observations of 50% Leaf Drop  
 filter(phenophase\_title == "50% Leaf Drop") %>%   
 # group by location id   
 group\_by(location\_id) %>%   
 # for each location id calculate the minimum day  
 summarize(drop50=min(doy))  
  
#---- for each tree determine the first date when all leaves day had dropped ---#  
budburst.sub.dropall <- budburst %>%   
 # limit dataset to just fall phenophase data describing leaf color  
 filter(phenophase\_plant\_structure %in% c("Autumn Leaves Dropping")) %>%   
 # limit dataset to just observations of 50% Leaf Drop  
 filter(phenophase\_title == "All leaves dropped") %>%   
 # group by location id   
 group\_by(location\_id) %>%   
 # for each location id calculate the minimum day  
 summarize(dropall=min(doy))  
   
#---- combine data 50% and all leaves dropped data ---#  
dat.drop <- left\_join(budburst.sub.dropall, budburst.sub.drop50, by="location\_id")  
  
#---- combine Autumn Leaves Dropping data with DBH ---#  
dat.drop.FC <- left\_join(DBH.dat, dat.drop, by="location\_id")   
  
# Create scatter plot of dropall by DBH  
p1 <- ggplot(dat.drop.FC, aes(x=DBH, y=drop50))+geom\_point()+geom\_smooth(method='lm')+xlab("DBH (cm)")+ylab("Day of year where >50% of leaves dropped")  
p2 <-ggplot(dat.drop.FC, aes(x=DBH, y=dropall))+geom\_point()+geom\_smooth(method='lm')+xlab("DBH (cm)")+ylab("Day of year where all leaves dropped")  
p1 +p2+plot\_annotation(tag\_levels="A")



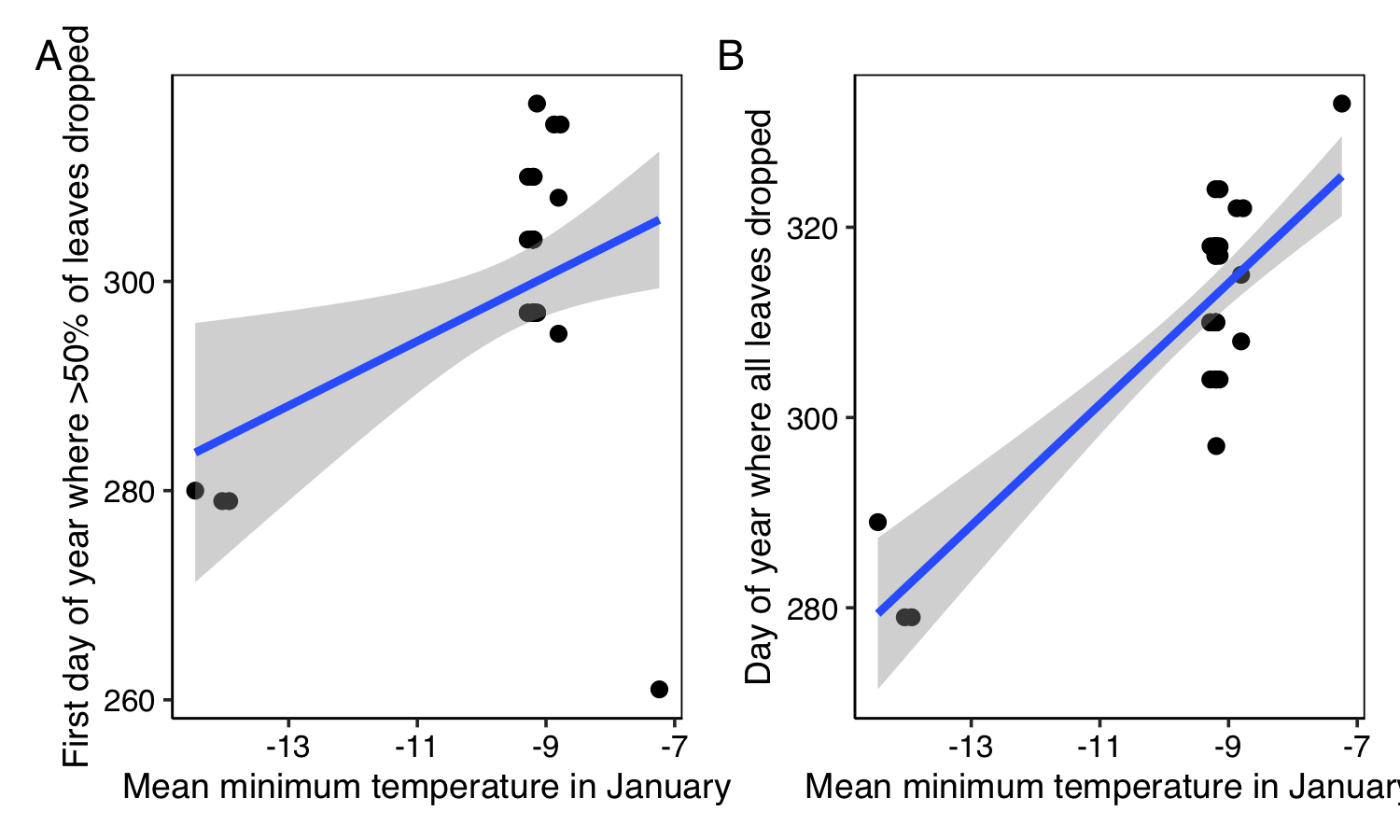
### Did trees in Fort Collins drop their leaves earlier?

# Create boxplot of dropall by city  
p1 <- ggplot(dat.drop.FC, aes(x=City, y=drop50))+geom\_boxplot()+xlab("City")+ylab("First day of year where >50% of leaves dropped")  
p2 <-ggplot(dat.drop.FC, aes(x=City, y=dropall))+geom\_boxplot()+xlab("City")+ylab("Day of year where all leaves dropped")  
p1 +p2+plot\_annotation(tag\_levels="A")



### Did trees from cooler climates drop their leaves earlier?

dat.drop.climate <- left\_join(dat.drop, budburst.climate, by="location\_id") %>%   
 # pull out just data from Colorado  
 filter(administrative\_area\_level\_1=="CO") %>%   
 # pull only dates in Sep to Dec  
 filter(drop50>243 & dropall>243)  
  
p1 <-dat.drop.climate %>%   
 select(TMIN01, drop50) %>% #  
 na.omit %>% # remove na values  
 # plot  
 ggplot( aes(x=TMIN01, y=drop50))+geom\_point()+geom\_smooth(method="lm")+xlab("Mean minimum temperature in January")+ylab("First day of year where >50% of leaves dropped")  
p2 <- dat.drop.climate %>%   
 select(TMIN01, dropall) %>% #  
 na.omit %>% # remove na values  
 # plot  
 ggplot( aes(x=TMIN01, y=dropall))+geom\_point()+geom\_smooth(method="lm")+xlab("Mean minimum temperature in January")+ylab("Day of year where all leaves dropped")  
  
p1 +p2+plot\_annotation(tag\_levels="A")



# References

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

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