ESM 232 - Homework 2

Kat Leigh, Alex Milward, David Segan and Mauricio Collado

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1. Objective

The goal is the estimation of the yield anomaly of almonds based on the average minimum temperature of February, and the average precipitation of January. We employ the following regression model proposed by Lobell et al. (2006):

$$Y = -0.015T_2n - 0.0046T_2n^2 - 0.07p_1 + 0.0043p_1, 2^2 + 0.28$$

- Y: yield anomaly (ton/acr).
- Tn: minimum temperature (Celsius).
- P: precipitation (mm).

The **Appendix** has the R source code for almond anomaly yield function.

2. Dataframe format

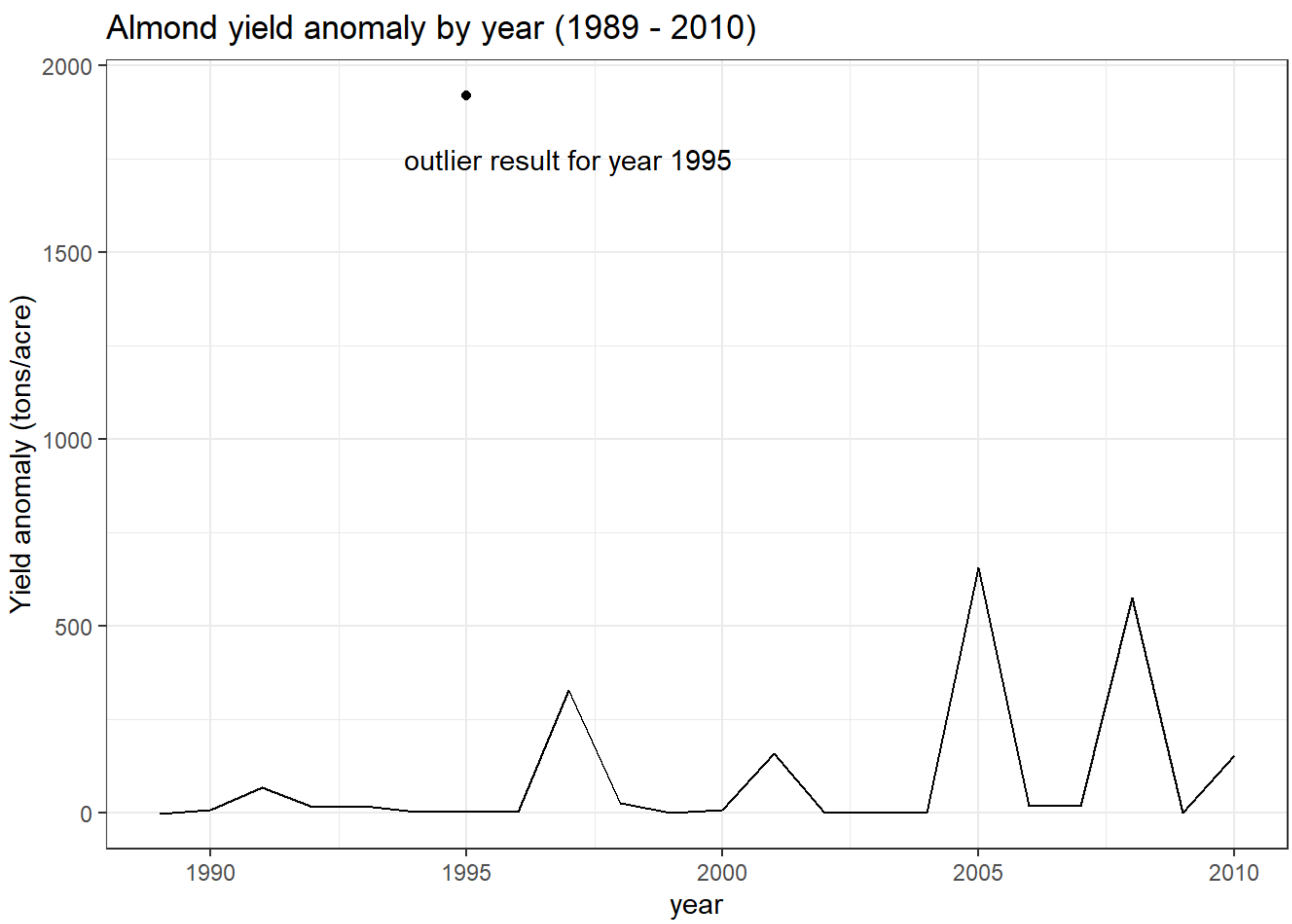
The dataframe requires daily data about minimum temperature (Celsius), and precipitations (mm). We display all the details for dataset management below:

```
# 1. We upload the packages
library(tidyverse) # basic tools
library(devtools)
library(here) # to locate the files easy

# 2. Dataframe format
#
#' Dataframe requires the following columns: date, day, month, year,
#' daily precipitations,and daily minimum temperature
#' The columns must be named exactly: day, month, year, tmin_c, and precip
#' The variable units are Celsius (tmin_c) and mm (precip)
#
# Read in data
climate_df <- read.delim(here('clim.txt'), sep = " ")
```

3. Results and analysis

We run the model for period 1988-2010, because the monthly data was available for those years.

```
# 3.1 We call our almond model (CHECK APPENDIX)
source(here("almond_anomaly.R"))

# 3.2We run for the specific dataset, named climate_df
# The parameters are the default ones
yield_anomalies <- almond_anomaly(climate_df)

# summarize yearly yield anomalies with line plot, address outlier
yield_anomalies_no_out <- yield_anomalies %>%
  filter(year != 1995)

yield_anomalies_1995 <-  yield_anomalies %>%
  filter(year == 1995)

# We construct our graph plot indicating the oulier
yield_plot <- ggplot(data = yield_anomalies_no_out, aes(x = year, y = yield)) +
  geom_line()+
  geom_point(data = yield_anomalies_1995)+ # outlier point
  annotate("text", label = "outlier result for year 1995", x = 1997, y = 1750)+
  theme_bw() +
  labs(x = "year",
       y = "Yield anomaly (tons/acre)",
       title = "Almond yield anomaly by year (1989 - 2010)")

yield_plot # graph
```



This graph depicts the estimated yield anomalies for almonds produced between the years 1989 to 2010 based on a simple regression model that uses the average precipitation in January and the minimum temperature in February for each year as inputs. The year 1995 indicated as an outlier since it differs considerably from the rest of the results. Notice that, generally, anomalies have become more extreme in recent years. We suspect the leading cause for the anomaly increase is climate change. We recommend implementing adaptative measures for this crop.

References

- Lobell, D., Field C., Cahill, K., & Bonfils, C. (2006). Impacts of future climate change on California perennial crop yields: Model projections with climate and crop uncertainties. *Agricultural and Forest Meteorology* 141, 208–218.

Appendix: Almond yield anomalies function

```
# Function to calculate the yield anomaly for almonds
# ESM 232
# Function developed by Kat Leigh, David Segan, Alex Milward and Mauricio Collado
######################################

# Model for yield anomaly for almonds
#
# Function uses a polynomic model with 2 climate variables
# to estimate the yield anomaly for almonds (tons acre)
#' @param climate_df name of the dataset with the climate variables over time
#' @param var1_mon month for minimum temperature Default is 2
#' @param var2_mon month for precipitation Default is 1
#' @param coef_t1 coefficient for min temperatue Default is -0.015
#' @param coef_t2 coefficient for squared min temperatue Default is -0.0046
#' @param coef_p1 coefficient for precipitation Default is -0.07
#' @param coef_p2 coefficient for squared precipitation Default is 0.0043
#' @param intercept Intercept of the relationship Default 0.28
#' Example (with defaults): yield_anomalies <- almond_anomaly(climate_df)
#' @references
#' Lobell et al. (2006).

almond_anomaly = function(climate_df, #dataframe
                          var1_mon=2, #month for variable 1
                          var2_mon=1, #month for variable 1
                          coef_t1=-0.015, #coeficient for tmin
                          coef_t2=-0.0046, #coeficient for squared tmin
                          coef_p1=-0.07, #coeficient for precip
                          coef_p2=0.0043, #coeficient for squared precip
                          intercept=0.28){ #contant

# We filter the dataframe for monthly average precipitation and minimun temp
filt_clim_df <- climate_df %>%
   group_by(year, month) %>% #we group by month and year
   summarize(mean_tmin = mean(tmin_c), #mean t_min within each month
             sum_p = sum(precip)) %>%  #sum of precip within each month
   filter(month %in% c(var1_mon,var2_mon)) # we keep the relevant months

# first and last year
firstyear=min(filt_clim_df$year) # first year of filtered dataset
lastyear=max(filt_clim_df$year) # last year of filtered dataset

# We filter the dataframe for the average minimum temperatures for February of each year
clim_var1_df <- filt_clim_df %>%
   filter(month == var1_mon) %>% #filter month for tmin
   select(mean_tmin)

# We filter the dataframe for total precipitation for January of each year
clim_var2_df <- filt_clim_df %>%
   filter(month == var2_mon) %>% #filter month for precip
   select(sum_p)

# We process the information and save it into a dataframe
yield_anom <- data.frame(year= seq(firstyear, lastyear, by = 1), # year
```

```
                         yield=coef_t1*clim_var1_df$mean_tmin # estimation
                            + coef_t2*(clim_var1_df$mean_tmin^2)
                            + coef_p1*clim_var2_df$sum_p
                            + coef_p2*(clim_var2_df$sum_p^2)
                            + intercept)
return(yield_anom) # result as dataset

}

######################################
# The end
```