Assigment 2 - ESM 232 Climate Modeling

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Background

Almond conceptual model

The almond model derived from Lobell et al. (2006) is a statistical model calculating annual yield anomaly of almonds in California, which is based on February minimum temperature (Celsius degree) and January accumulated precipitation (mm).

Load function(s)

Load the almond model function!

The function will process:

- Turn the daily minimum temperature and daily precipitation into monthly results
- Calculate annual almond yield conceptual model

Read input data

Read the climate data in a txt format.

- There is a column containing time information
- It includes two variables: minimum temperature and precipitation

Calculate almond yearly yield anomaly

Use the defined function to calculate almond yield of each year in California (units: ton/acre).

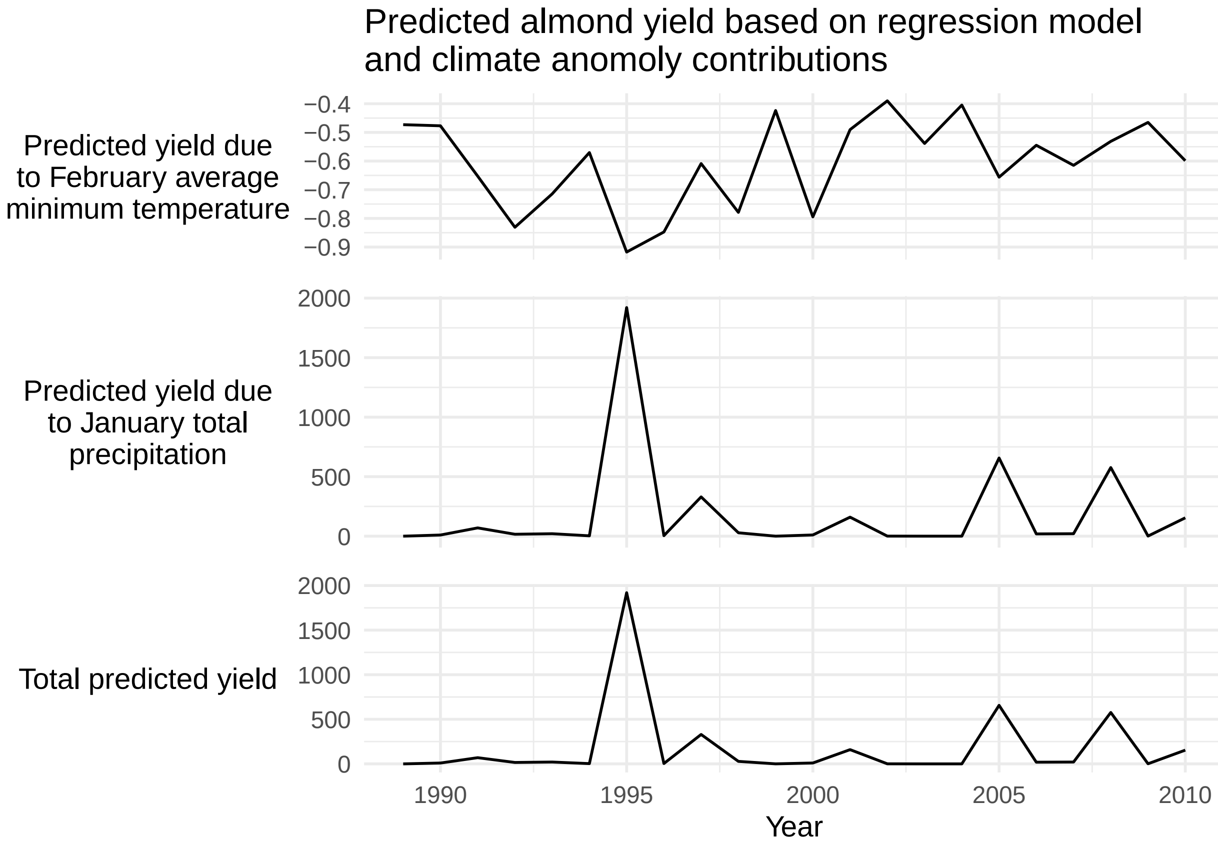
The almond yield equation (Lobell et al. 2006) is:

Y = -0.015* (Tn,2) - 0.0046* (Tn,2)^2 - 0.07* (P1) + 0.0043* (P1)^2 + 0.28

where Y is almond yield anomaly (ton/acre); Tn,2 is February minimum temperature (C); P1 is January precipitation (mm)

The yearly yield results will be returned to **yeild_outcomes**

Results



Discussion

A multiple linear regression model based on February minimum temperature and January total precipitation was used to predict annual almond yield anomalies and the contribution of each variable from 1988 to 2010. The figures show that the February minimum temperature reduces almond yield in the range of -0.4 to -0.9, with a relatively strong negative contribution until 2000, but diminishes after 2000. However, for the January precipitation, it produced positive apricot yield anomalies ranging from 0 to 2,000 tons/acre. Considering the effects of each variable and interceptions together, we obtain total annual almond yield anomalies. Total yields were highly correlated with precipitation predictions, with a similar magnitude and variation. Several peaks in the total yield prediction are also identified in the precipitation prediction, such as in 1995, 2005 and 2008. February minimum temperature accounts for only 0.05% of the magnitude of January precipitation. Therefore, total apricot production was dominated by January precipitation rather than the average minimum temperature in February.

References

Lobell D B, Field C B, Cahill K N, et al. Impacts of future climate change on California perennial crop yields: Model projections with climate and crop uncertainties[J]. *Agricultural and Forest Meteorology*, 2006, **141(2-4)**: 208-218.

Appendix - `almond_model.R`

```
#' Almond Model
#'
#' This function computes the annual yield of almonds in California
#’ based on monthly minimum temperature in February and
#' accumulated precipitation in January (Lobell et al. 2006)
#' @param clim_data file path to climate data that includes fields for
#'   row_number, D, day, month, year, wy, tmax_C, tmin_c, precip, wyd
#' @param k1 coefficient for February minimum temperature changes
#' @param k2 quadratic term coefficient for February minimum temperature changes
#' @param k3 coefficient for January Precipitation changes
#' @param k4 quadratic term coefficient for January Precipitation changes
#' @param intercept the intercept of the fitted line
#' @author Anthony Luna, Chen Xing, Atefeh Mohseni
#' @examples almond_model(["1" 1991-06-01 1 6 1991 1992 21.232 14.234 1.56 1])
#' @return Almonds yield anomaly (ton acre-1)
#' @references
#' Lobell D B, Field C B, Cahill K N, et al. Impacts of future climate change on
#' California perennial crop yields: Model projections with climate and crop
#' uncertainties[J]. Agricultural and Forest Meteorology, 2006, 141(2-4): 208-218.

almond_model <- function(clim_data,
                         k1=-0.015 ,
                         k2=-0.0046 ,
                         k3=-0.07 ,
                         k4= 0.0043,
                         intercept = 0.28 ) {
  ## Error checking
  ## You can use the library checkmate to
  ## make this easier, or just do it with ifelse statements

  # check clim_data dimensions
  no_col <- max(count.fields(clim_data, sep = " "))
  if (no_col < 10)
  {
    print("The input climate data file should have 10 columns")
  } else {
    # check clim_data column names
    file_header <- read.delim(clim_data, header=TRUE, sep = " ", dec = ".")
    file_headers = colnames(file_header)

    expected_header = c(
      "row_number",
      "D",
      "day",
      "month",
      "year",
      "wy",
      "tmax_c",
      "tmin_c",
      "precip",
      "wyd"
    )
```

```
  check_res <- isTRUE(all.equal(file_headers, expected_header))

  if (check_res) {
    # check clim_data column datatypes
    summary <- summary.default(file_header)
    numeric_types = length(summary[which(summary=="numeric")])
    date_types = length(summary[which(summary=="character")])

    if (numeric_types != 9 | date_types!= 1){
      print("There should have 9 numeric data type and 1 date type in the input file!")
    }
  }
  else{
    print("The format of the input file header is not as expected!")
  }
}

clim_data <- read_delim(file = clim_data, delim=" ")

# check coefficients and intercept value

## End error checking

# Turn the daily minimum temperature into monthly data through monthly average
# and calculate monthly accumulated precipitation from daily station
# precipitation data

df_summarized <- clim_data %>%
  select(year,month,day,tmin_c,precip) %>%
  group_by(year,month) %>%
  summarize(avg_tmin_c=mean(tmin_c),tot_precip = sum(precip)) %>%
  ungroup()

# Extract the February minimum temperature from the data summary

df_temp <- df_summarized %>%
  filter(month==2) %>%
  select(-tot_precip,-month)

# Extract the January precipitation from the data summary

df_precip <- df_summarized %>%
  filter(month==1) %>%
  select(-avg_tmin_c,-month)

# Calculate the almond annual yield from the statistical relationship:
# Y = k1*(Tn,2) + k2*(Tn,2)^2 + k3*(P1) + k4*(P1)^2 + intercept
# Y: almond yield anomaly (ton/acre); Tn,2: February minimum temperature (C);
# P1: January precipitation (mm)

df_out <- full_join(df_temp,df_precip) %>%
  mutate(yeild = k1*avg_tmin_c+k2*(avg_tmin_c^2)+k3*tot_precip+k4*(tot_precip^2)+intercept) %>%
  mutate(yeild_temp = k1*avg_tmin_c+k2*(avg_tmin_c^2)) %>%
```

```
    mutate(yeild_precip = k3*tot_precip+k4*(tot_precip^2)) %>%
    mutate(intercept = intercept)

  # return the yield to the main function

  return(df_out)
}
```