Project Report

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11/19/2023

Questions of interest

- How is the growth of plants within the Sonoran Desert affected by different fertilization methods and nitrogen atmospheric deposition.
- Is there a difference in the impact of these fertilization methods and nitrogen deposition between the three zones studied? These zones are: with the urban core, west of the urban core, and east of the urban core.
- Is there a difference apparent between affect on growth of annual plants as compared to perennial plants? What is the impact on growth of Larrea Tridentata plants specifically?

Loading the required packages:

```
library(tidyverse) # For re-formatting data sets
```

```
## Warning: package 'tidyverse' was built under R version 4.1.3
## Warning: package 'ggplot2' was built under R version 4.1.3
## Warning: package 'tibble' was built under R version 4.1.3
## Warning: package 'tidyr' was built under R version 4.1.3
## Warning: package 'readr' was built under R version 4.1.3
## Warning: package 'purrr' was built under R version 4.1.3
## Warning: package 'dplyr' was built under R version 4.1.3
## Warning: package 'stringr' was built under R version 4.1.3
## Warning: package 'forcats' was built under R version 4.1.3
## Warning: package 'lubridate' was built under R version 4.1.3
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.2     v readr     2.1.4
## v forcats   1.0.0     v stringr   1.5.0
## v ggplot2   3.4.2     v tibble    3.2.1
## v lubridate 1.9.2     v tidyr     1.3.0
## v purrr     1.0.1
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
library(lubridate) # For manipulations of date columns
```

Read in data:

```
annuals_biomass <- read.csv("Data/632_annuals_biomass.csv")
annuals_composition <- read.csv("Data/632_annuals_composition.csv")
atmospheric_deposition <- read.csv("Data/632_atmospheric_deposition.csv")
fertilizer_application <- read.csv("Data/632_fertilizer_application.csv")
plant_root_simulator <- read.csv("Data/632_plant_root_simulator.csv")
stem_growth <- read.csv("Data/632_stem_growth.csv")
tissue_chn <- read.csv("Data/632_tissue_chn.csv")
tissue_icp <- read.csv("Data/632_tissue_icp.csv")
```

Prior to beginning analysis, the data should be cleaned to remove justifiable outlying observations. Additionally, variables which will not be used will be removed from each sub data set prior to combining data.

Begin by cleaning up `annuals_biomass` which contains the response variable of interest, biomass.

Appendix

Descriptions of Data Sets and Variables

Annuals_Biomass

Biomass (g) of annual plants harvested from subplots within Desert Fertilization study plots. One-meter subplots include locations around a Larrea tridentata plant and locations in the interplant space between shrubs. Material is harvested from 0.25 square meter quadrants within each subplot. All harvests occur during the spring.

- site_code - site name abbreviation
- plot_id - plot id number
- treatment_code - treatment name abbreviation
- location_within_plot - habitat within plot where probes were deployed
- subplot - subplot number (one of two replicates)
- subquad_orientation - direction of sub-quadrant from which biomass was harvested
- date - date of data collection
- year - year of data collection
- mass - mass of biomass harvested in 0.25 meter Square quadrant
- notes - field and processing notes

Annuals_Composition

Composition of annual plants and some other characteristics (e.g., bare soil, base or canopy of perennial plants) at subplots within Desert Fertilization study plots. One-meter subplots include locations around a Larrea tridentata plant and locations in the interplant space between shrubs. All measurements collected in the spring.

- site_code - site name abbreviation
- plot_id - plot id number
- treatment_code - treatment name abbreviation
- location_within_plot - habitat within plot where probes were deployed
- subplot - subplot number (one of two replicates)

- date - date of data collection
- year - year of data collection
- collector - initials of subplot surveyors
- cover_type - taxon of annual plant, plot characteristic, or logistical note
- cover_category - nature of the observation (taxonomic, general plot characteristic, logistical)
- cover_amount - proportion of subplot as a decimal fraction of this type

Atmospheric_Deposition

Ammonium-nitrogen and nitrate-nitrogen as measured by ion exchange resin (IER) collectors that are used to measure bulk (wet) deposition in interplant open spaces and throughfall (wet and dry) deposition under the dominant shrub.

- run_id - unique identifer of Lachat run provided primarily to allow users to associate blanks with samples
- field_id - sample identifer
- collection_date - date collectors are extracted from their deployment in the field
- notes - technician notes regarding conditions in the field or sample processing
- analyte_name - nitrogen species measured (ammonium-nitrogen or nitrate-nitrogen)
- concentation - concentration of nitrogen species measured as ammonium-nitrogen or nitrate-nitrogen
- site_code - site name abbreviation

Fertilizer_Application

Catalog of amounts and timing of nitrogen and phosphorus fertilizer applications to nitrogen (N), phosphorus (P), and nitrogen+phosphorus (N+P) treatment plots - applications are delivered to the respective plot at the site that receives either N, P, or an N+P addition, except control sites (n = 2) that do not receive a fertilizer amendment.

- site_code - site name abbreviation
- application_date - date of fertilizer application
- nitrogen - amount of ammonium-nitrate nitrogen fertilizer applied to 20mx20m nitrogen (N) and nitrogen+phosphorus (N+P) treatment plots
- phosphorus - amount of triple-super phosphate phosphorus fertilizer applied to 20mx20m phosphorus (P) and nitrogen+phosphorus (N+P) treatment plots

Plant_Root_Simulator

Soil ion concentrations as determined with Plant Root Simulator (PRS®) probes (ion exchange resin membranes). Probes for the analyses of soil anions have a positively-charged membrane to simultaneously attract and adsorb all negatively-charged anions, such as nitrate (NO3-), phosphate (H2PO4-, HPO42-), and sulphate (SO42-), whereas cation probes have a negatively-charged membrane to simultaneously attract and adsorb all positively-charged cations, such as ammonium (NH4+), potassium (K+), calcium (Ca2+), and magnesium (Mg2+).

- site_code - site name abbreviation
- plot_id - plot id number
- treatment_code - treatment name abbreviation

- start_date - date of probe deployment
- end_date - date of probe extraction
- analyte - analyte measured
- final_value - analyte concentration
- flag - data quality flag
- location_within_plot - habitat within plot where probes were deployed
- num_cation_probes - number of probes designated for analysis of cations recovered (of four)
- num_anion_probes - number of probes designated for analysis of anions recovered (of four)
- notes - notes pertaining to the deployment or analysis of the probes

Stem_Growth

Biannual measures of stem growth on five Larrea tridentata study plants in Desert Fertilization experiment treatment and control plots.

- site_code - site name abbreviation
- plot_id - plot id number
- treatment_code - treatment name abbreviation
- scientific_name - scientific name of plant measured
- shrub_code - study plant identifier
- direction - direction or quadrant of plant in which measured stem is positioned
- pre_date - date of initial or pre stem-length measurement
- post_date - date of final or post stem-length
- post_note - field note regarding final or post stem-length measurement
- post_measurement - boolean indicator denoting whether the measurement is a pre or initial stem-length measurement (FALSE), or a final or post stem-length measurement (TRUE)
- stem_length - length of stem
- stem_comment - field note(s) regarding particular shrub or measurement
- plot_comment - field note(s) regarding particular the plot or site

Tissue_Chn

CHN (Carbon, Hydrogen, and Nitrogen) elemental analysis of Larrea tridentata leaf tissue and Pectocarya recurvata (whole plant) tissue collected from control plots at Desert Fertilization study sites.

- site_code - site name abbreviation
- plot_id - plot id number
- treatment_code - treatment name abbreviation
- sample_date - date of leaf (Larrea) or plant (Pectocarya) collection
- season_year - season and year of collection (for easier sorting)
- tissue_type - source of tissue material
- analyte - element analyzed

- weight - weight of material used for analysis
- percent_compostition - percent composition of analyte
- comment - comment about analytical measurement

Tissue_Icp

Elemental composition of Larrea tridentata leaf tissue and Pectocarya recurvata (whole plant) tissue collected from control plots at Desert Fertilization study sites. Most analyses are by ICP-MS except Sulfur (S), which is typically analyzed by ICP-OES with the instrument type noted in the instrument field.

- site_code - site name abbreviation
- plot_id - plot id number
- treatment_code - treatment name abbreviation
- sample_date - date of leaf (Larrea) or plant (Pectocarya) collection
- season_year - season and year of collection (for easier sorting)
- tissue_type - source of tissue material
- instrument - instrument employed for tissue analysis
- isotope_element - isotope atomic mass and element symbol, except Sulfur (S; element symbol only)
- concentration - mass of isotope_element per mass of leaf material
- source_file - file name corresponding to raw data for the observation (raw data available as another entity in this data set)

Site Codes

- DBG - core region: Desert Botanical Garden
- EME - west region: Estrella Mountain Regional Park east
- EMW - west region: Estrella Mountain Regional Park west
- LDP - east region: Lost Dutchman State Park
- MCN - east region: McDowell Mountain Regional north
- MCS - east region: McDowell Mountain Regional south
- MVP - core region: North Mountain
- PWP - core region: Piestewa Peak
- SME - core region: South Mountain Park east
- SMW - core region: South Mountain Park west
- SNE - west region: Sonoran Desert National Monument east
- SNW - west region: Sonoran Desert National Monument west
- SRR - east region: Salt River Recreation Area (Tonto NF)
- UMP - east region: Usery Mountain Regional Park
- WTM - west region: White Tanks Mountain Regional Park

Treatment Codes

- C1 - control plot 1
- N - nitrogen amendment
- NP - nitrogen + phosphorus amendment
- P - phosphorus amendment

Location Within Plot (Biomass / Composition) Codes

- IP - subplot located in an interplant space
- P - subplot features a Larrea tridentata plant

Cover Category Codes

- annual - observation referring to a type of plant
- plot_characteristic - observation referring to characteristic of the plot other than cover of a specific type of annual plant
- record_keeping - entry for record keeping, typically whether the plot was survyed

Location Within Plot (Simulator) Codes

- between_plant - probes buried between plant canopies
- blank - field blank: probe stored in a clean container under refrigeration during the deployment period
- blk_washed - field blank (washed): probe stored in a clean container under refrigeration during the deployment period, and washed as per sample probes
- under_plant - probes buried beneath the canopy of Larrea tridentata

Analyte Codes

- Al - aluminum
- B - boron
- Ca - calcium
- Cd - cadmium
- Cu - copper
- Fe - iron
- K - potassium
- Mg - magnesium
- Mn - manganese
- NH4-N - ammonium-nitrogen
- NO3-N - nitrate-nitrogen
- P - phosphorus
- Pb - lead
- S - sulfur

- Total-N - sum of NO3-N and NH4-N
- Zn - zinc

Shrub Codes

- L1 - Larrea tridentata study plant #1
- L2 - Larrea tridentata study plant #2
- L3 - Larrea tridentata study plant #3
- L4 - Larrea tridentata study plant #4
- L5 - Larrea tridentata study plant #5

Tissue Type Codes

- Larrea tridentata - Larrea tridentata leaf tissue
- Pectocarya recurvata - Pectocarya recurvata whole-plant tissue

Analyte (Tissue_chn) Codes

- Carbon % - percent carbon
- Hydrogen % - percent hydrogen
- Nitrogen % - percent nitrogen

Instrument Codes

- ICP-MS - Inductively Coupled Plasma Mass Spectrometer
- ICP-OES - Inductively Coupled Plasma Optical Emission Spectrometer