Challenge 1: **Understanding key drivers of seasonal phenology in native tallgrass prairie.**

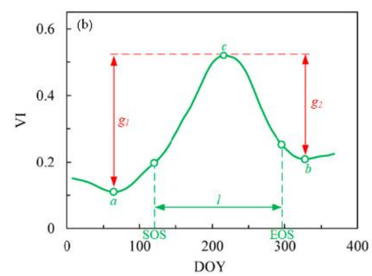
Understanding key growing conditions like duration of growing season, maximum vegetation, approximate start and end of the growing season at its dependance on the weather conditions can be very valuable to inform ranchers for better agricultural practices.

In this study, we will examine the key weather attributes that drive seasonal phenology and productivity of native tallgrass prairie. Firstly, conduct an exploratory analysis on several key interdependent environmental factors to examine their direct and indirect effects on vegetation phenology. Next, compute phenology parameters based on historical vegetation information. Then, perform correlation analysis between weather characteristics, vegetation and growing patterns at different scales including quarterly, seasonally, and annually to identify the key climate factors driving the seasonal phenology. Finally, develop predictive models to estimate phenology parameters.

Some definitions:

- **Vegetation** is represented using EVI: Enhanced Vegetation Index. Satellite remote sensing data.
- **Quarter**: Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec.
- **Season** (growing): Apr-Oct
- **Annual**: Jan – Dec

How to compute growing conditions: Start of season (SOS), End of season (EOS), Growing season length (GSL), Peak Growth Value (c: max EVI), Peak Day (c_{Day}: Day of the year with max EVI).



- c: maximum EVI value.
- a: minimum EVI value on the left side of c.
- b: minimum EVI value on the right side of c.
- g1: c-a; g2:c-b
- $SOS \geq a + 0.20 * g1$
- $BOS \leq b + 0.20 * g2$
- $GSL = EOS - SOS$. For example - GSL in days = DOY 300 - 100 = 200 days.

Weather Attributes:

- Tmax = maximum air temp (F)
- Tmin = minimum air temp (F)
- Tavg = average air temp (F)
- Havg = average relative humidity (%)
- Vdef = average daily vapor deficit (mb)
- Hdeg = heating degree-days (65 F standard)
- Cdeg = cooling degree-days (65 standard)
- Wcmn = minimum wind chill index temp (F)
- Wspd = average wind speed (mph)
- Atot = solar radiation (MJ/m2)
- Rain = daily rainfall (inch)
- Savg = average soil temperature 10 cm under sod (F)
- Bavg = average soil temp 10 cm under bare soil (F)
- TR05 = Soil Moisture Calibrated Delta-T at 5cm (degree Celsius)
- TR25 = Soil Moisture Calibrated Delta-T at 25cm (degree Celsius)
- TR60 = Soil Moisture Calibrated Delta-T at 60cm (degree Celsius)

Dataset:

Time period: 2000 – 2023, 23 years.

Remote Sensing data: EVI for six pastures A to F. *8-day measurements interpolate to daily observations*.

Weather: Same for all the Pastures A to F.

Study Objectives:

A. Initial Exploration: (20% effort)

1. Perform structural equation modeling (SEM) to examine the direct and indirect effects of main environmental factors on EVI using daily data weather.
2. Conduct SEM analysis on EVI separately for all 6 pastures using same weather data. Are the characteristics of drivers similar or different for each of the pasture data?

Note: EVI is given as an 8-day measurement, interpolate it to a daily value.

B. Computing Seasonal Phenology and its climatic drivers: (50% effort)

3. Plot EVI for each year to compute phenology terms: SOS, EOS, GSL, c, c_{Day}. w.r.to each pasture separately.
4. Identify/correlate them (SOS, EOS, GSL, c, c_{Day}.) with the main weather drivers such as average Tmin, Tmax, Tavg, Rain etc. for quarterly, seasonally, and annually.
5. Repeat steps 3 & 4 to compute SOS, EOS, GSL, c, c_{Day} for all pastures together, then identify weather drivers.

The key point here is to understand what weather variables at what period of the year control SOS, EOS, GSL, c (max EVI values)

C. Modeling: (30% effort): Use leave-one-out-CV approach to maximize the train and test split. Explore regression model using ML/DL/Ensemble approaches to improve the performance.
Combine all the pastures data together for the following analysis.

6. Leverage the findings from A & B to create custom annualized weather variables coupled with remote sensing data to create dataset for modeling.
7. Model growth factors one at a time using weather, remote sensing information.
8. Then, explore if adding other phenology parameters contributes to improved model performance using the below proposed approach: [weather, remote sensing information] + phenology parameters.
    a. For modeling EOS: explore using SOS, C, and C_{Day}.
    b. For modeling C: explore using SOS.
    c. For modeling C_{Day}: explore using SOS.
    d. For modeling GSL: explore using SOS, C, and C_{Day}.

For model evaluation, use standard metrics like MAE, MSE, RMSE, MAPE, R^2.

Note: For modeling, after the computing and annual transformation for growth factors, we will have 23 (years) * 6 (pastures): 138 observations.

The input weather attributes must be transformed into a meaningful representation based on quarters, seasonal or annual based on your exploratory analysis.

Ex: Temperature (T) can be transformed into $T(AVG)_Q, T(STD)_Q, T(MIN)_Q, T(MAX)_Q$etc. for quarters, for seasonal as well as annual measurements.

Grading:

25%: Extended abstract; 50%: presentation; 20%: coding.

The winner for each challenge will provide further support for code transfer, support in manuscript preparation and will be credited with co-authorship.