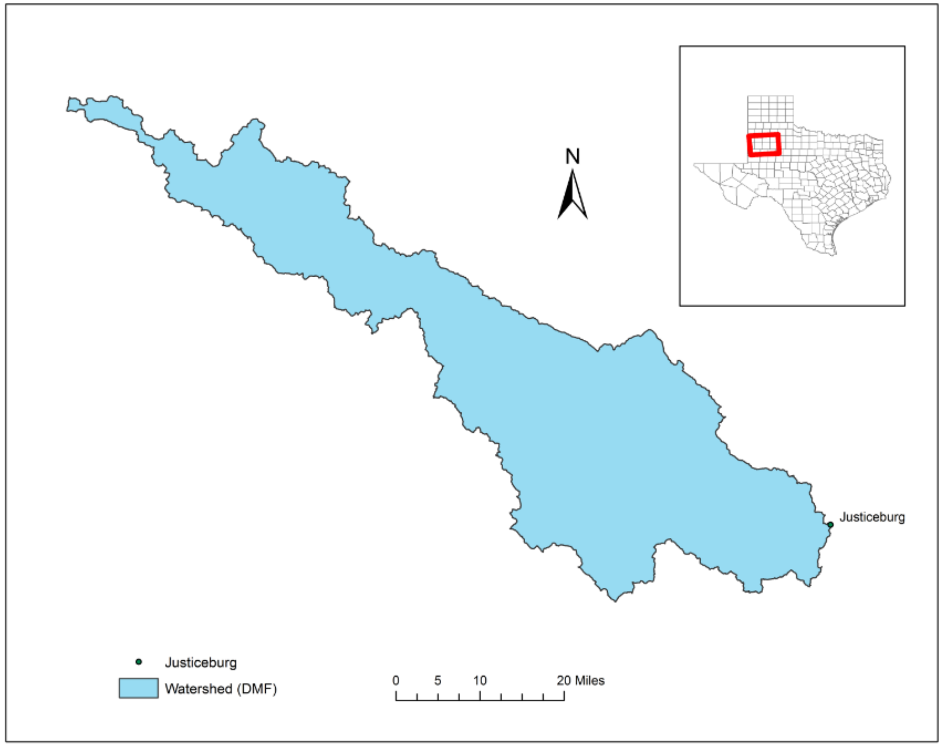
Modeling Sustainable Adaptation Strategies towards a Climate-Smart-Agriculture in the Southern High Plains of Texas, USA



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PROBLEM

- Groundwater Depletion
  - Pumping rate > Recharge rate
- Climate Change
  - Increasing temperature
  - Change in precipitation patterns

TARGET

- Maximize yield
- Optimize available water resources

SOLUTION

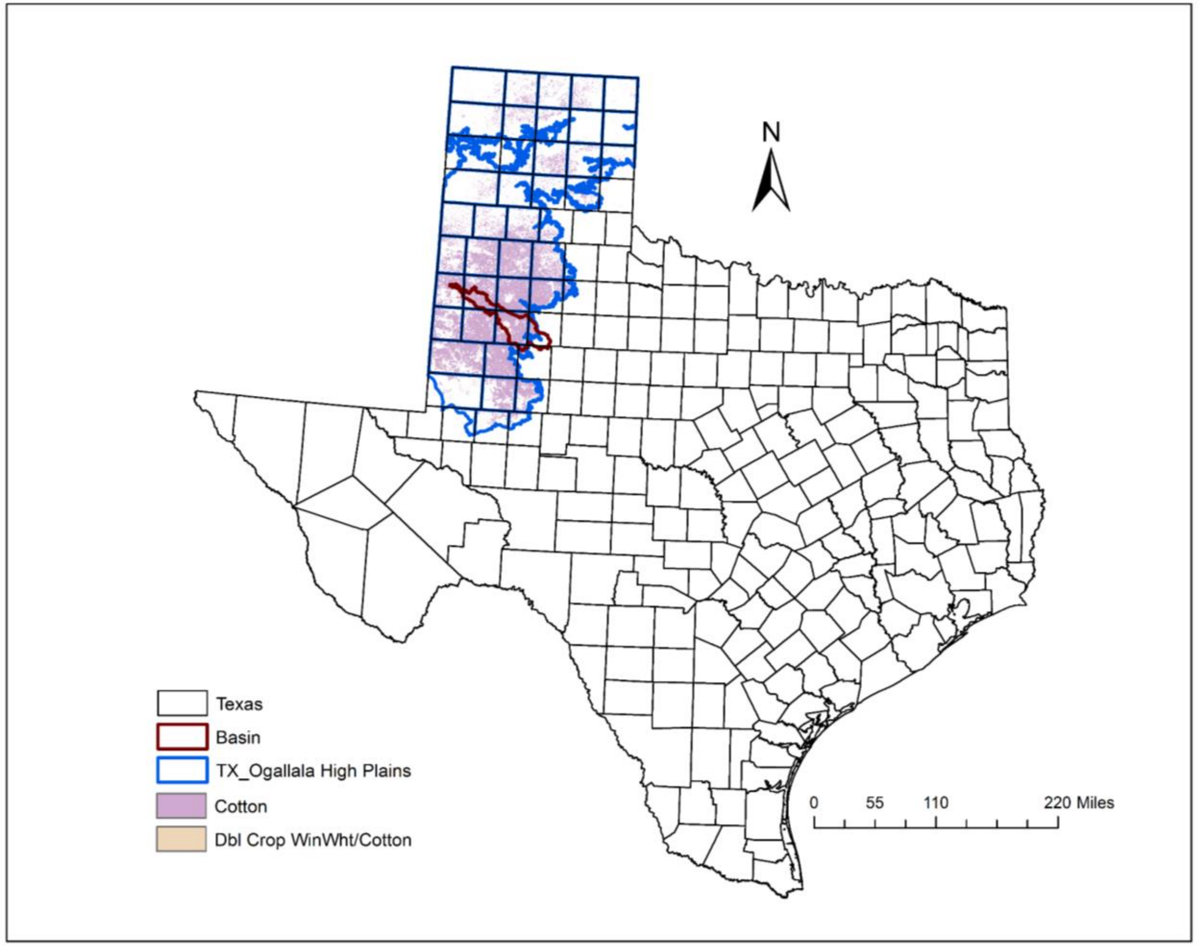
- Climate - Smart - Agriculture
  - Sustainable adaptation strategy

OBJECTIVES

- Develop a Watershed Model for the Double Mountain Fork (DMF) watershed.
  - Soil Water Assessment Tool (SWAT) adopted here
- Assess the impacts of future climate change on crop productivity.
  - Cotton response to future climate and adaptability study of dryland cotton production.

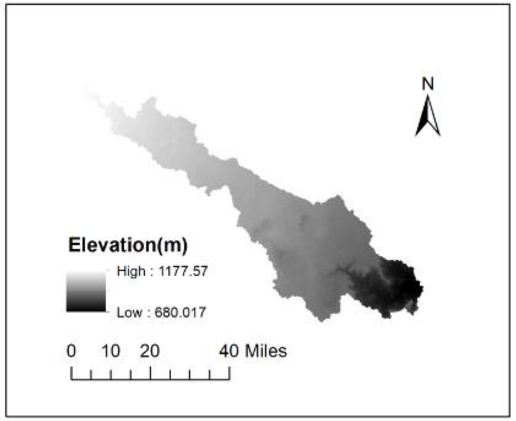
Cotton (*Gossypium hirsutum*)

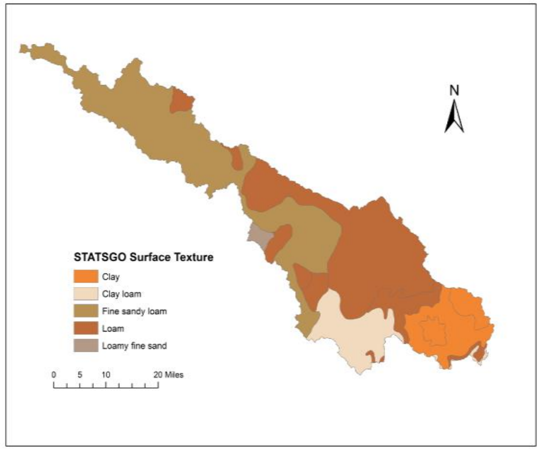
- Texas – Nation's No.1 cotton producing state.
  - High Plains contributes two-thirds of Texas cotton.
  - Cotton generates 9% of the state's total agricultural receipts and 29% of the nation's cotton revenues.
- Cotton is a drought resistant crop
  - Water requirement of around 640 mm (less as compared to other major crops grown in the region)
  - Viable crop for regions with depleting groundwater.
  - Helps sustain groundwater from the Ogallala aquifer.
- Cotton growth is controlled largely by temperature.
  - Very little growth takes place below 60°F (~16°C) or above 100°F (~37°C).
  - Air temperatures in the 90°–95°F (~30°C) is considered optimum for growth.

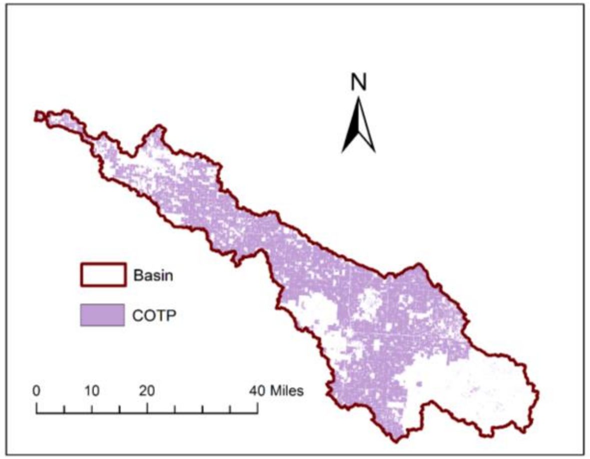


Double Mountain Fork Watershed

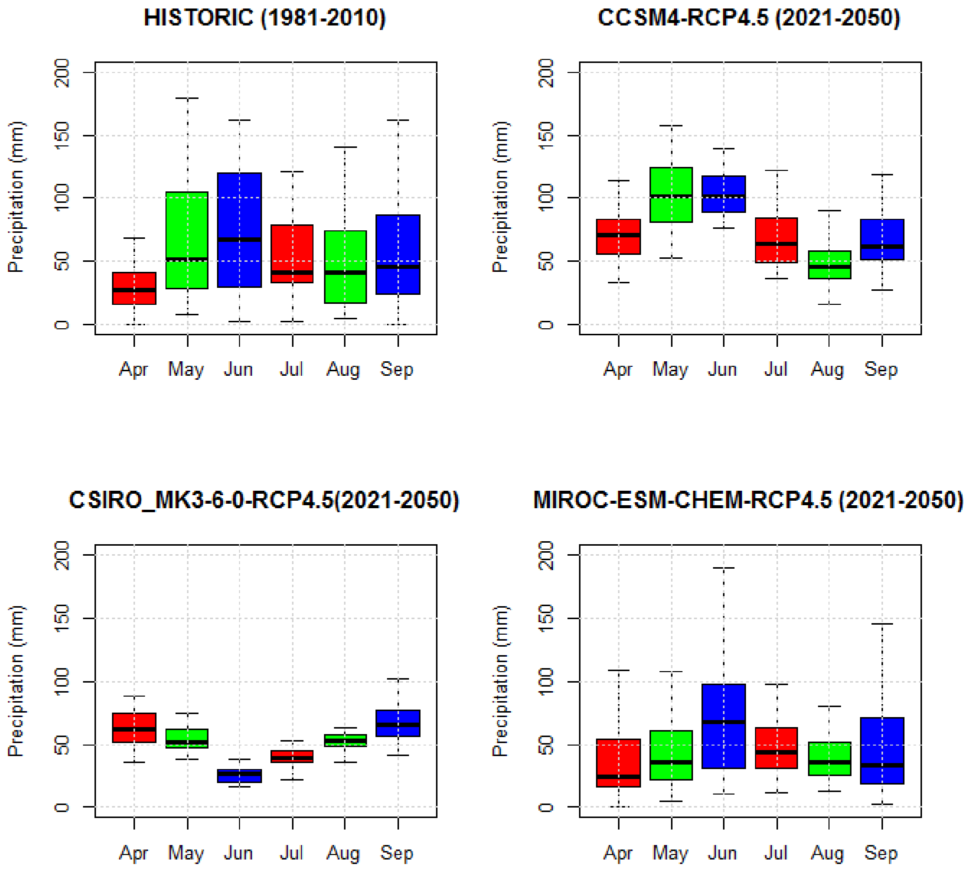
- Tributary of the Brazos River (HUC 12050004).
- Drainage area of 1466 sq. mi.
  - USGS streamflow-gaging station 08079600 DMF Brazos Rv at Justiceburg, TX
- A significant portion of the watershed overlies the Ogallala Aquifer.
  - Downstream area lies over Dockum Outcrop below the caprock.
  - Extend in the counties of Hockley, Lynn, and Garza.
  - Elevation in the watershed ranges from about 680 to 1180 meters
  - Mostly agricultural area
    - Cotton dominant (53% of watershed area) with loam and fine sandy loam soil type.

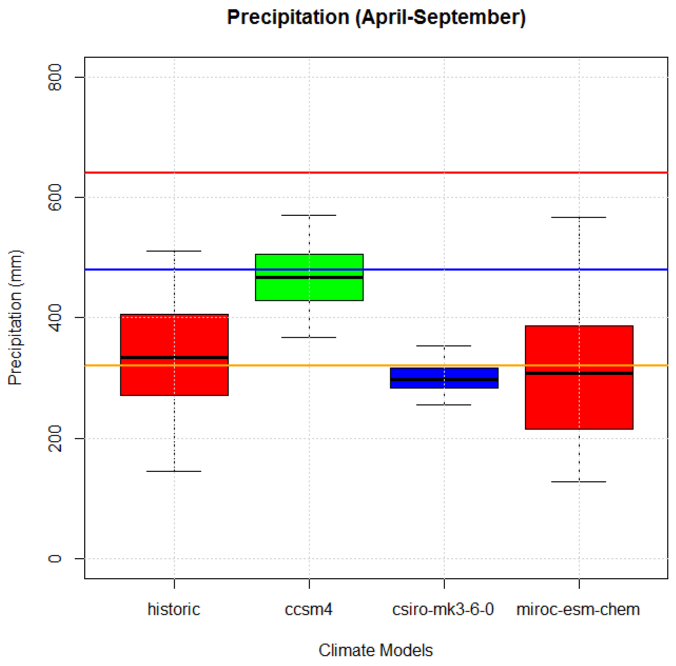






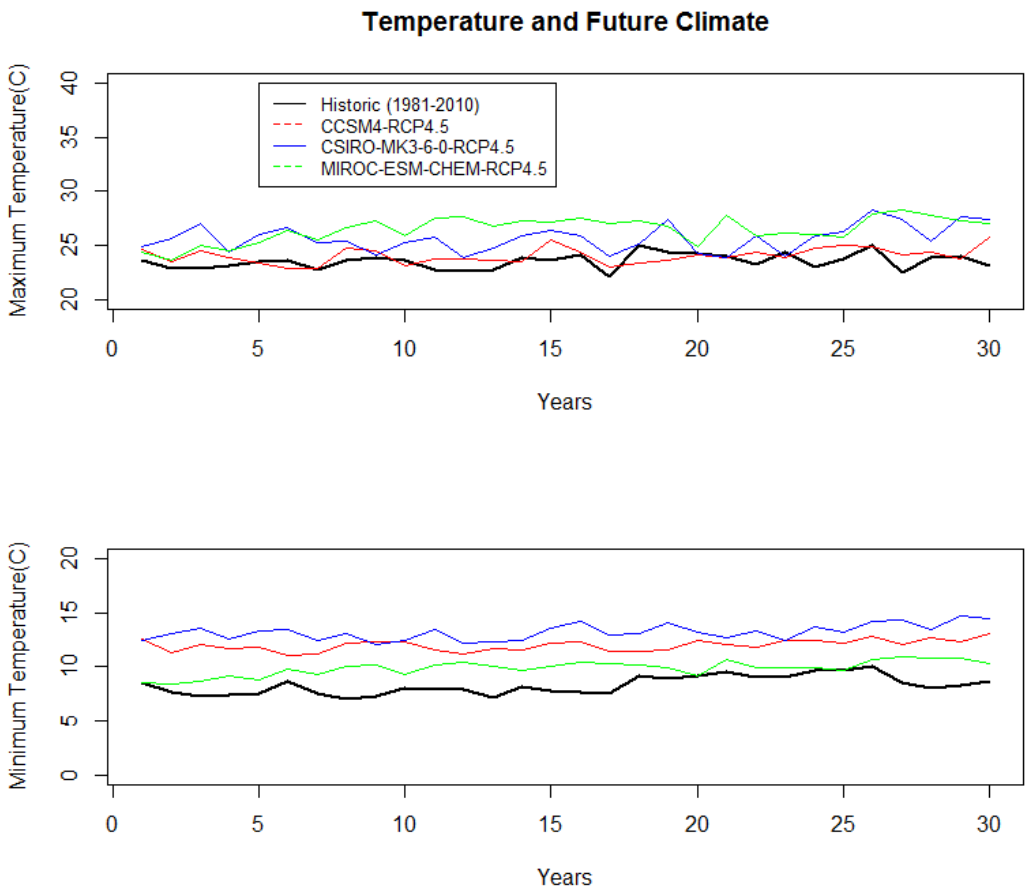
Precipitation

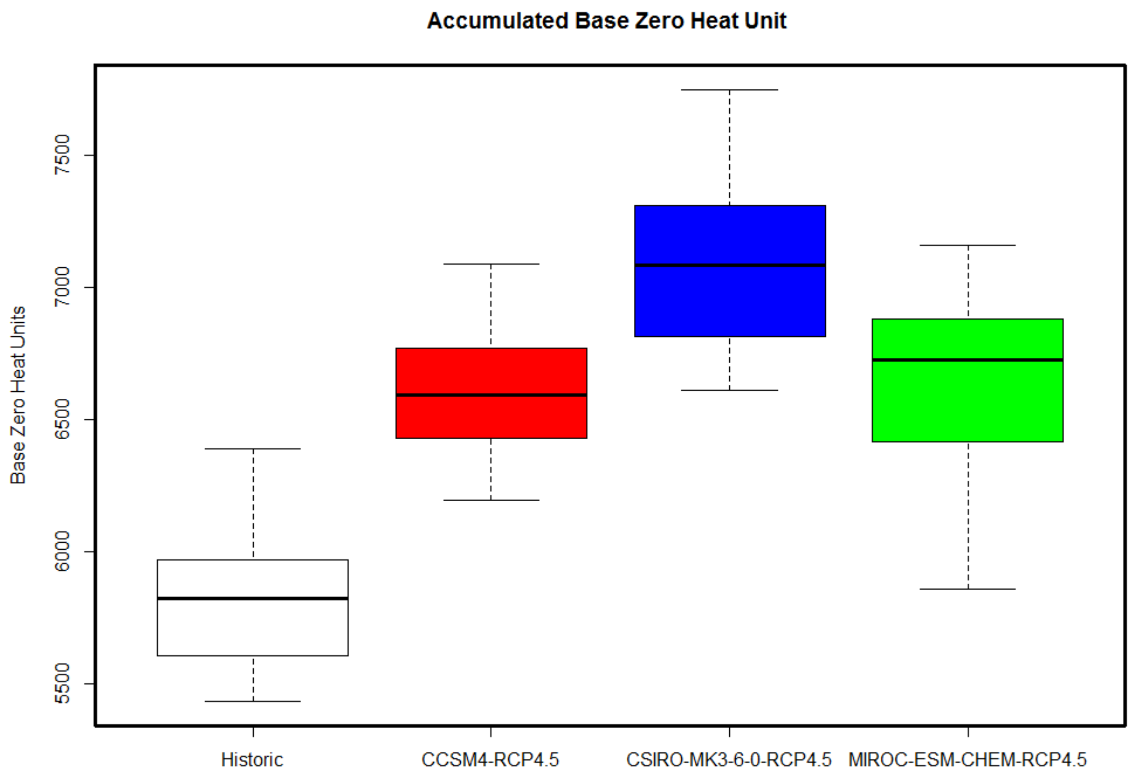




- Most of the annual precipitation is observed during the growing season.
- On average, more than 50 percent of the water requirement during the growing season is supplied through precipitation (varies with climate projections)
  - Indicates possibility of dryland cotton production

Temperature



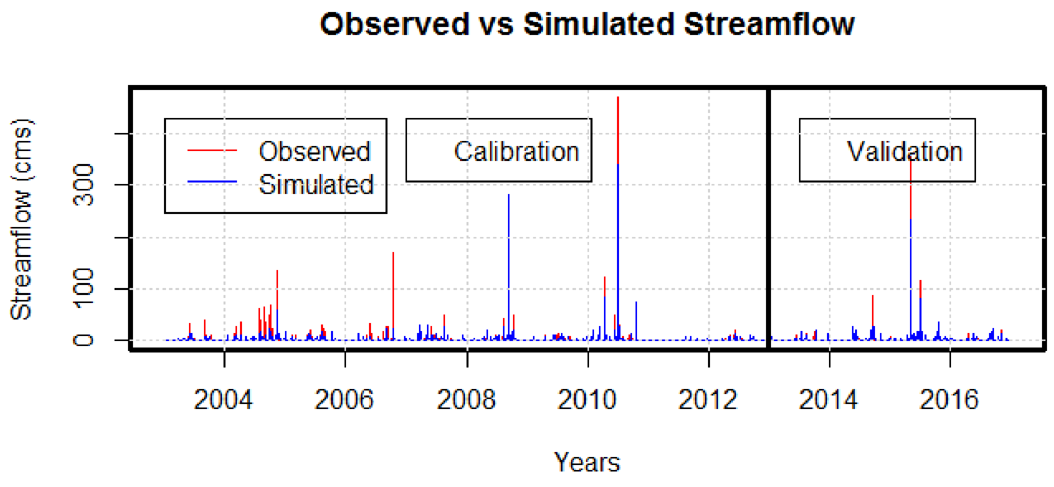


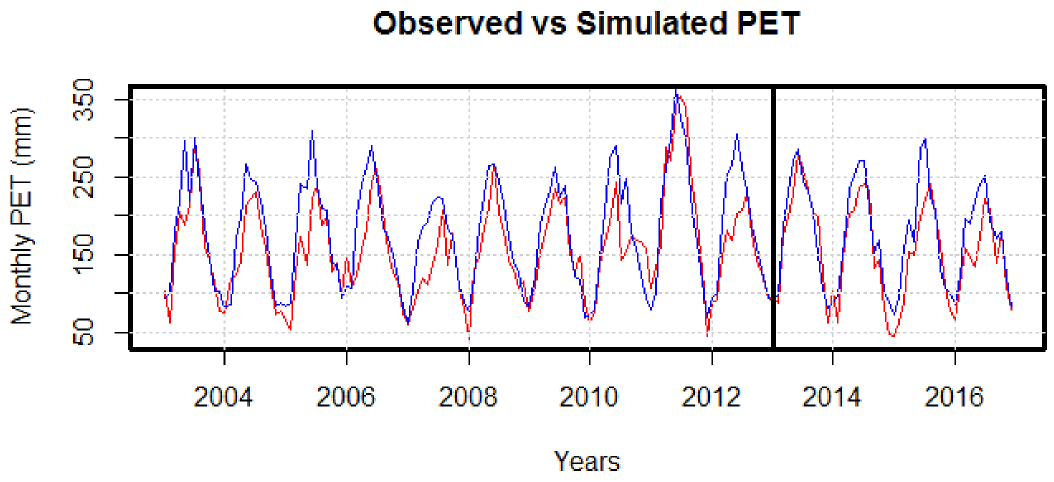
- Increase in the minimum and maximum temperatures.
- Annual averages are higher as compared to historic.
- Increase in accumulated base zero heat units.
  - Plants can accumulate required heat units for growth earlier than the historic.

SWAT Calibration and Validation

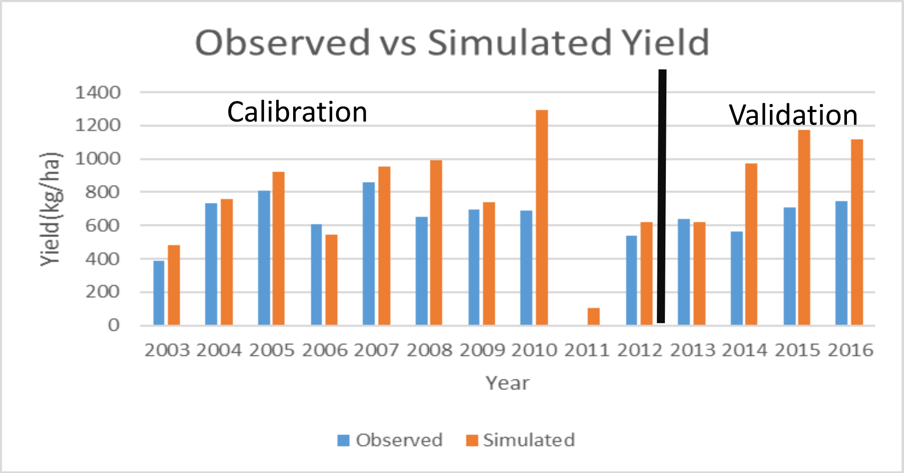
- Multi-criteria calibration
  - Streamflow comparison with observed flows from USGS gaging station at Justiceburg, TX
  - ET comparison with lake ET data from TWDB
  - Crop Yield data USDA-NASS
- Evaluation using multiple metrics (Moriasi et al., 2007)
  - Nash-Sutclife Criterion (NSE)
  - Percent Bias (PBIAS)
  - Root Mean Square Error / Standard Deviation (RSR)

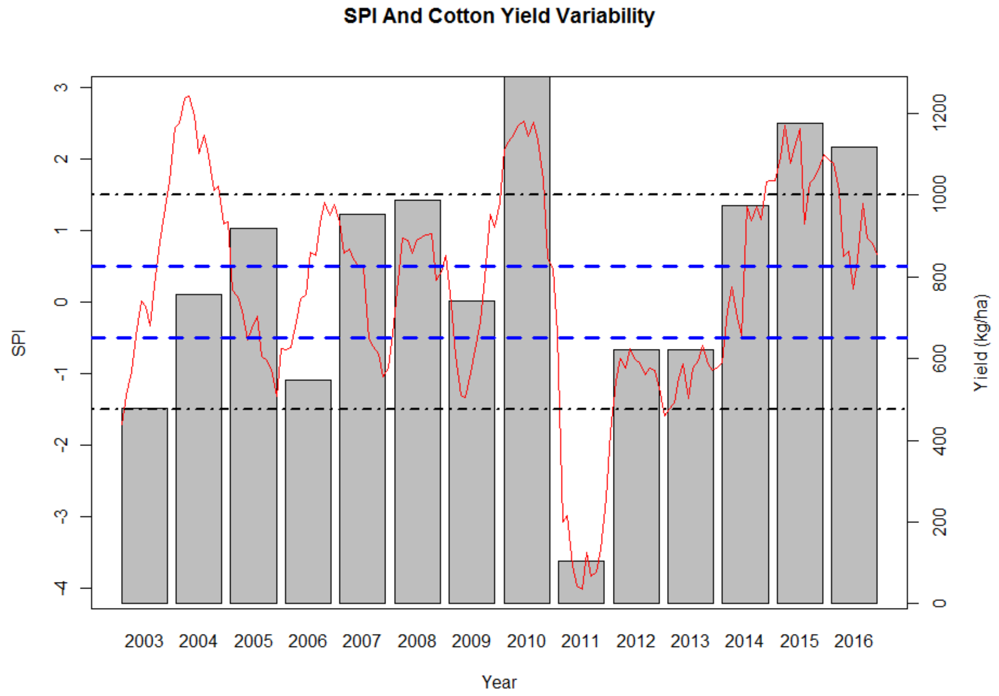
Metrics	Target	Streamflow (Validation)	Evapotranspiration (Validation)
NSE	≥ 0.5	0.75 (0.76)	0.58 (0.69)
PBIAS	± 25%	1.23 (-41.98)	-13.33 (-12.49)
RSR	≤ 0.7	0.49 (0.48)	0.64 (0.55)

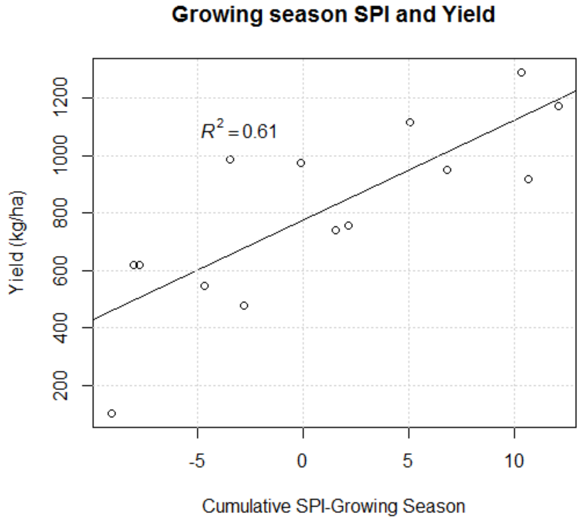




Yield Calibration and Validation



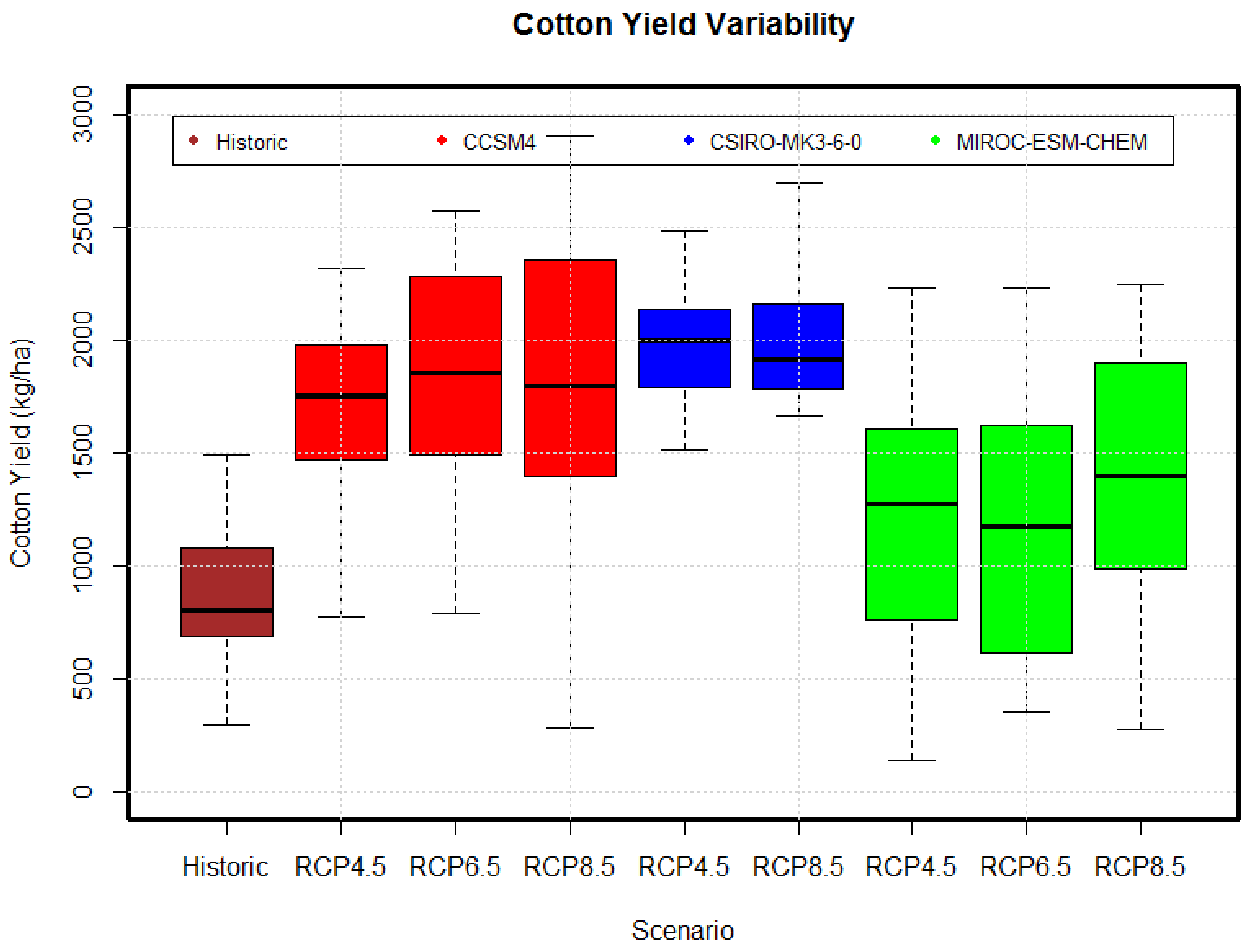




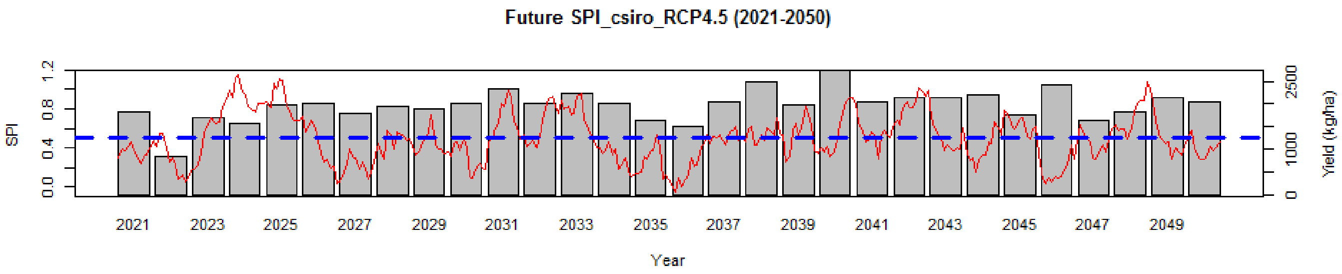
- 2011 drought has significant reduction in the yield.
- 2010 observed as the wettest year during the study period with maximum yield.
- The drought duration and severity has huge impacts on drought.

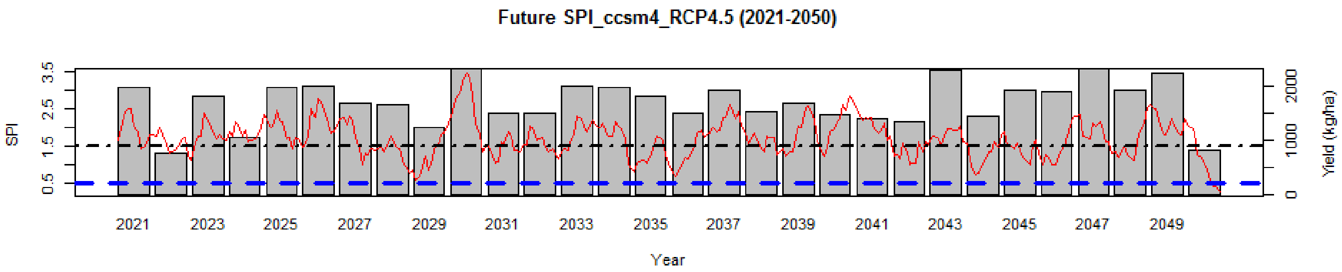
Future Climate and Cotton Yield

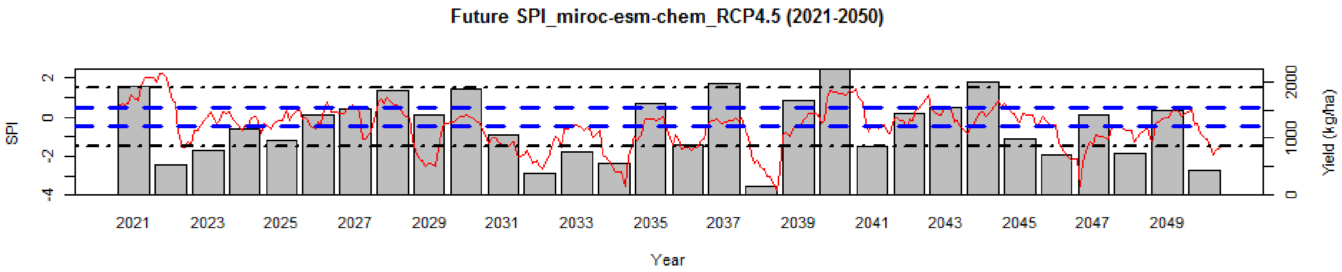
- Increased average annual yield.
  - Effects of increased temperature during the growing season and increased CO2 levels
- Higher variability associated with the yield values.
  - Unusual climate events
  - Reduced yields during droughts
  - The variability increase with increasing levels of CO2.

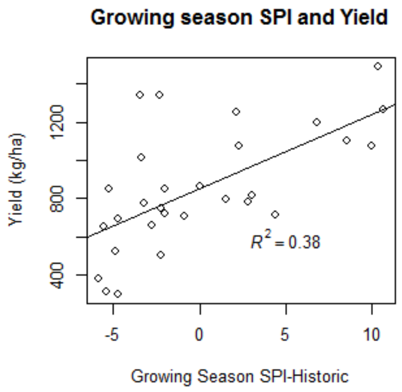


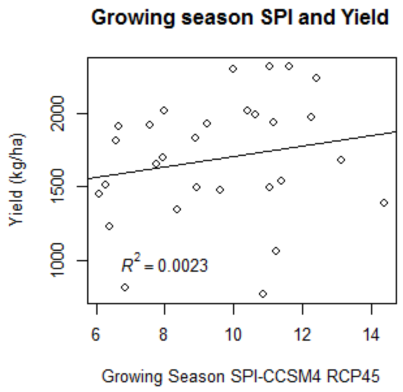
Future SPI and Cotton Yield

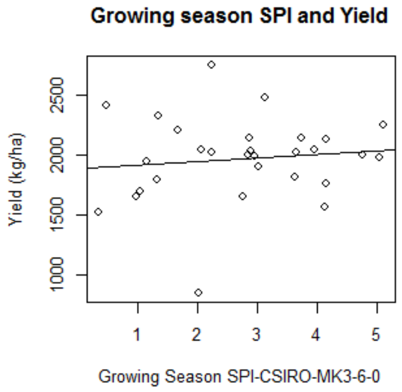


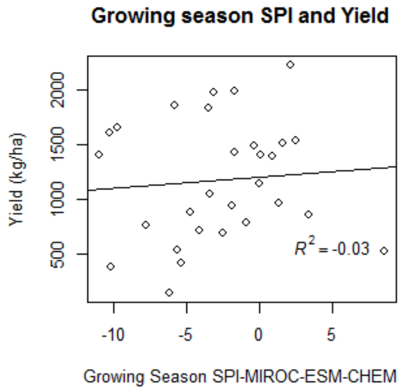






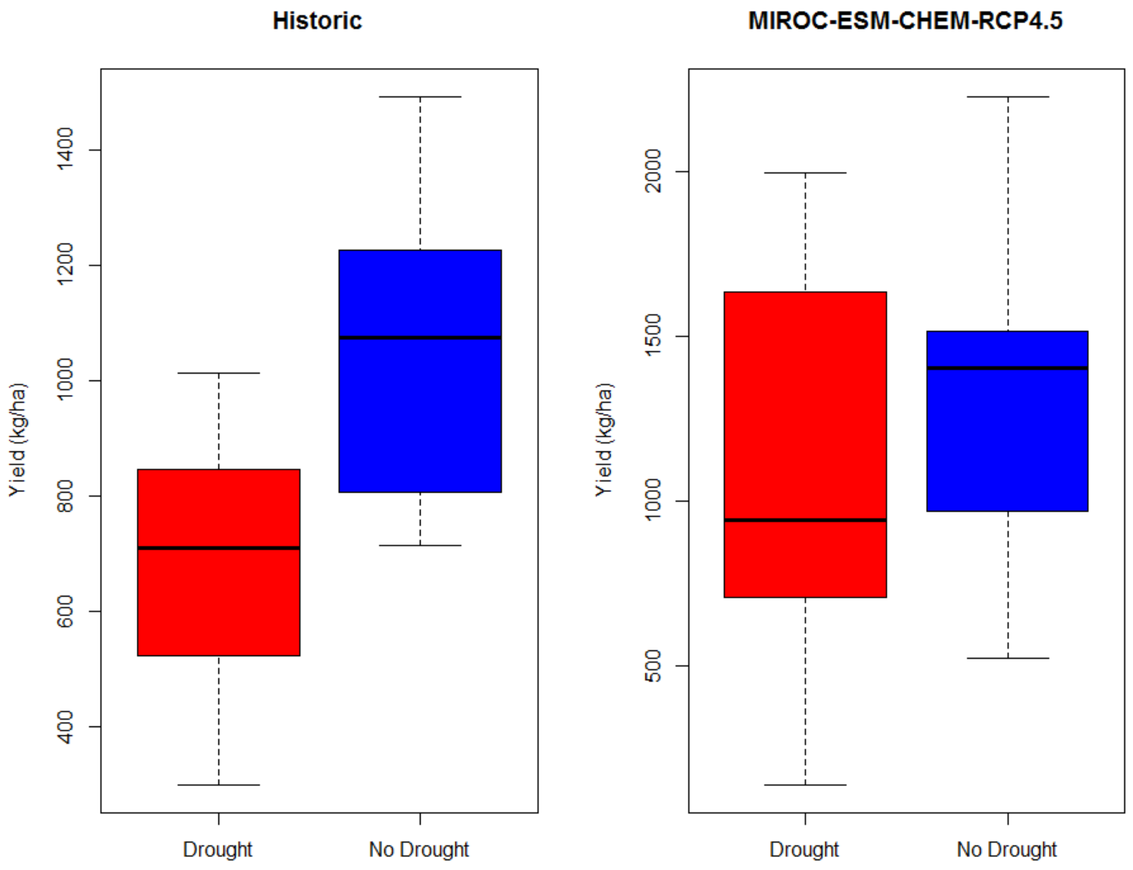




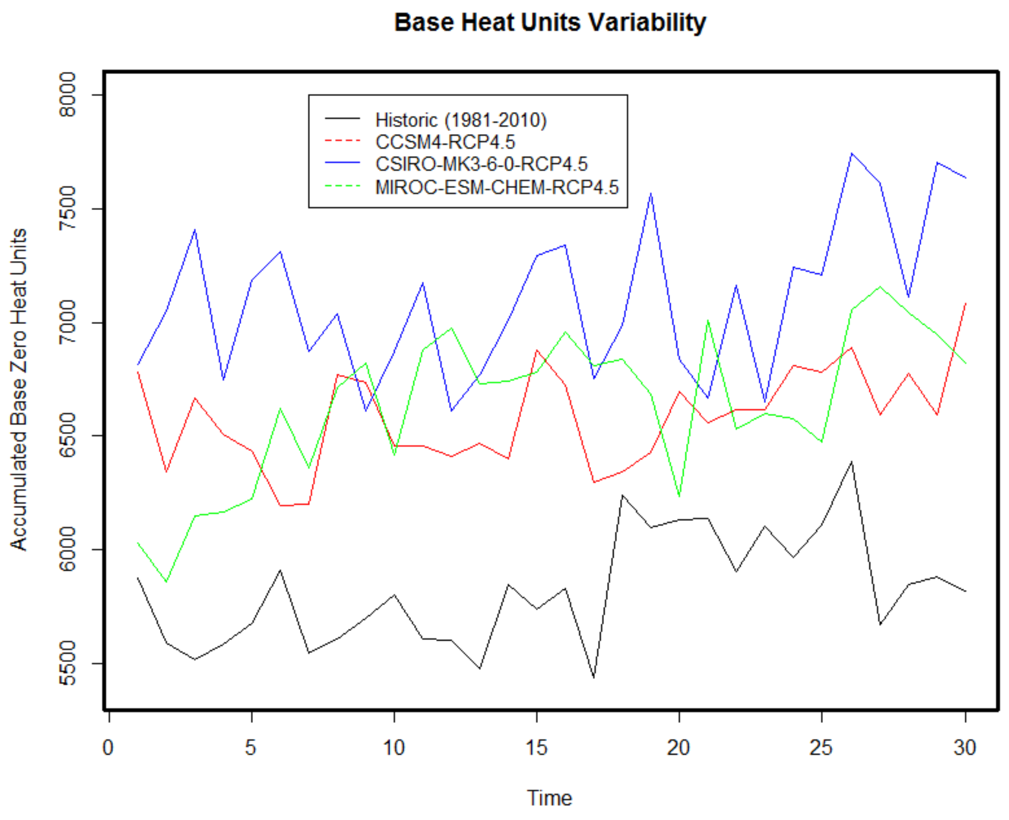


Yield Variability and Drought

- Drought years are expected to have much lower average yield as compared to the normal/wet years.
- Variability observed during both the periods.
    - Effects of antecedent soil moisture
    - Timing of rainfall.

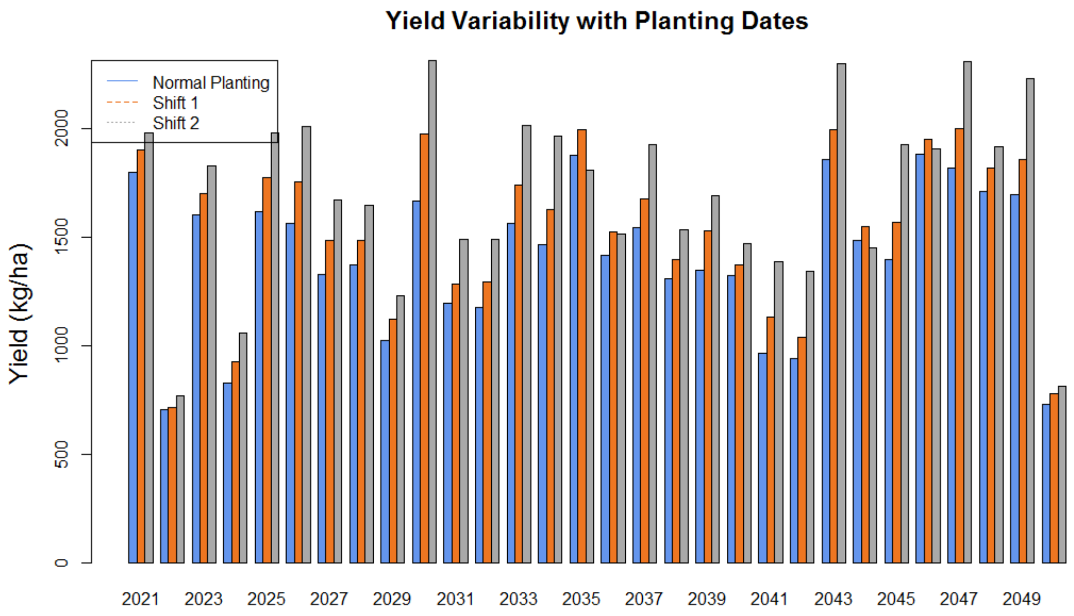


Adaptation Strategy



- Earlier shift in planting dates leads to relatively higher yields.
  - Projected increase in minimum and maximum temperature.
  - Plants can accumulate required heat units for growth earlier as compared to historic climatic conditions.
  - Projected increase in precipitation during the months of April to September
- Deficit irrigation could be applied during severe droughts.

Normal Planting	Shift 1	Shift 2
Mid-May	End-April	Mid-April



Summary and Future Prospects

- Calibrated SWAT model developed for the Double Mountain Fork watershed.
  - Model simulate the physical process occurring in the system.
- Possibility of dryland cotton production under future climate.
  - More than 50 percentage of water requirement is supplied through precipitation.
  - Reduced yields projected for periods of drought.
  - Dryland production helps to sustain the life of Ogallala Aquifer.
- Early planting has higher yield values.
  - Effects of increased temperature (heat units).
  - Most of the annual rain observed during the months starting from April.
- ***Optimal dates for planting based on heat units.***
- ***Use of multiple climate projections.***
- ***Dryland vs irrigated cotton production under future climate.***

Thank You!