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Title: Quantifying demand sensitive drought risk and capturing the potential impacts across the United States.

Type of presentation: Oral

Abstract

Droughts have cascading effects on the environment, economy, and society. Seasonal water deficits resulting from natural variability in rainfall, coupled with increased demands have severe implications for the adequacy of water storage in both surface and groundwater stores. Historically, municipal water supply planning has focused on developing new resources as demands increased. Today, limitations on acceptable new reservoir sites, restrictions on groundwater sources, rising development costs, and growing concern for environmental impacts limit the ability to develop new resources. Furthermore, seasonal to multi-year water deficits resulting from natural variability in climate and changes in near to long-term demands also determine the reliability and resilience of water systems. Water managers need better tools to assist in water operations and decision-making. While global and national drought indicators exist, none directly connects existing or projected water demand to the potential deficit during the drought. They are essentially supply based. However, the temporal patterns of both demand and supply ultimately determine the stress or impact and provide essential elements of droughts that can be used for risk assessment, planning, and operations. Consequently, assessment of risk for various sectoral operations could be much better informed if appropriate stress indices were developed for drought conditions relative to current and projected demands, and their likelihood assessed through historical and future climate scenarios. This talk will present the development of demand sensitive droughts metrics for the conterminous United States (at the county scale) to emphasize the dimensions and spatial extents of the potential water scarcity relative to the historical and current water consumption patterns. The varying distribution of water supply and demand across the United States involves complex patterns and policies in space and time that directly influence water systems.

Quantifying demand sensitive drought risk and capturing the potential impacts across the United States

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CoRP symposium 2016 – Fort Collins, CO

[Intro]
Context

- Droughts have negative effects on the society and the economy; The cost of drought: $100+ billion since 1980
- We usually respond to droughts through a crisis management paradigm.
- Need to move to risk-based management practices.
- Preparing for droughts --> need to quantitatively estimate the phenomenon.
- The existing drought indices that provides estimates of drought conditions evolve from **simplistic measure of deficiency of rainfall** to more complex estimates based on water budget or satellites derived products.

[Intro]

Problem statements

- The existing drought indices are essentially **supply-based**
- They **do not consider water use** by sector or in aggregate
- They **can be misleading** {Example: two locations with same rainfall but different demands [coming up…]}
- They only indicate the **magnitude or the severity** of the drought, and duration sometimes.
- **Other important drought attributes**, such as recovery, resiliency, storage requirement to alleviate the impacts of droughts, **are not available to water users**

[Intro]
Proposed solution

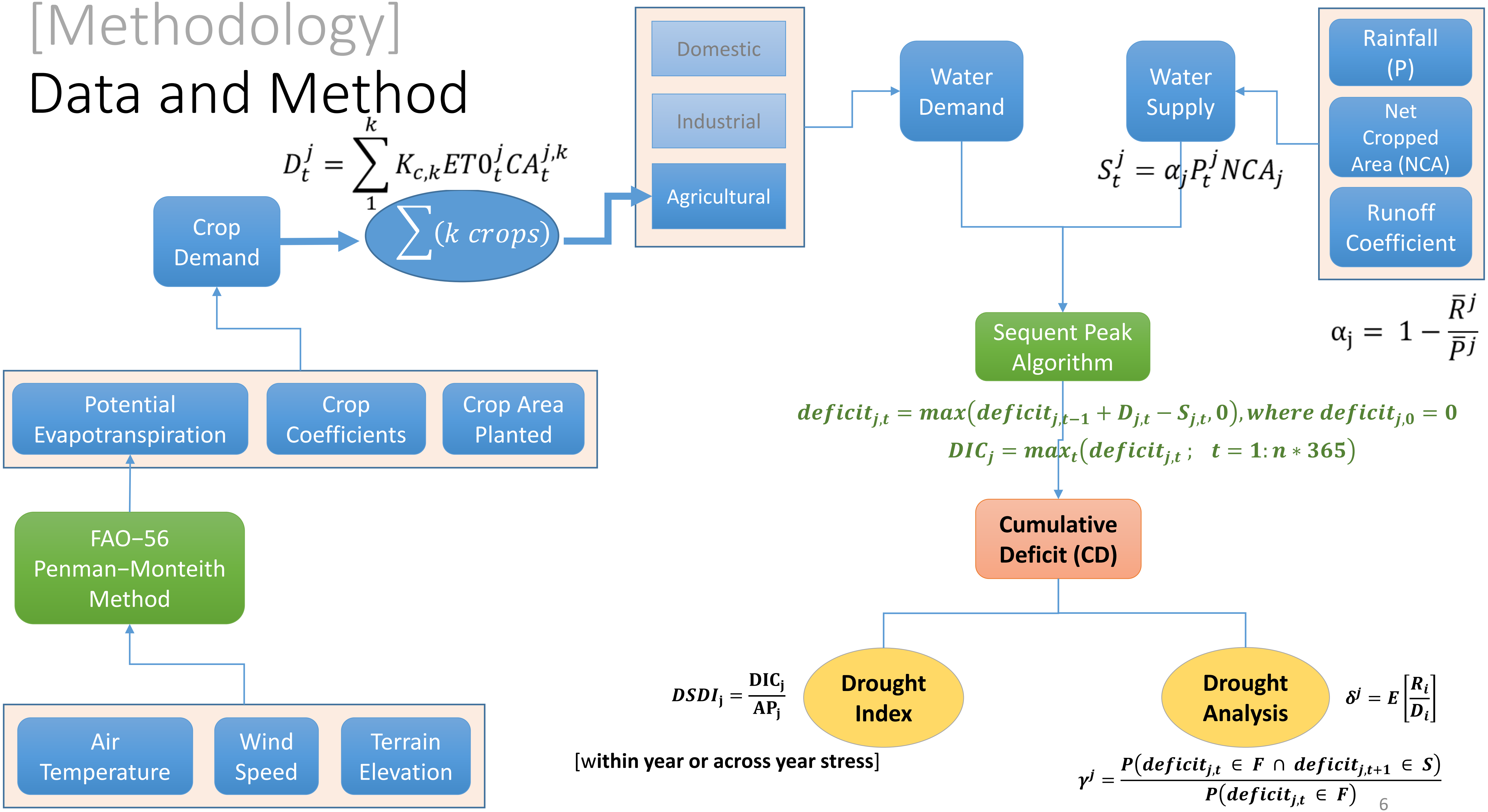
- The Demand Sensitive Drought Index:
  - Considers **daily supply and demand** to develop **aggregate or disaggregated indices**
  - Allows us to better understand the **causes of drought from an impact perspective**
  - The drought index is also **a measure of the storage required** to meet the time varying demand patterns in the region. Hence, one can design the system to meet the demands without failure.
  - Provides other important characteristics like the **duration, severity, recovery time** and the **resiliency** of a location to drought.
  - Can be **customized** to represent the drought of **a specific demand pattern**

Menu

- Methodology of developing DSDI
- Applications for different water use sectors
- Building simple models that can easily estimate the index
- Insights to drought forecasting – for future planning

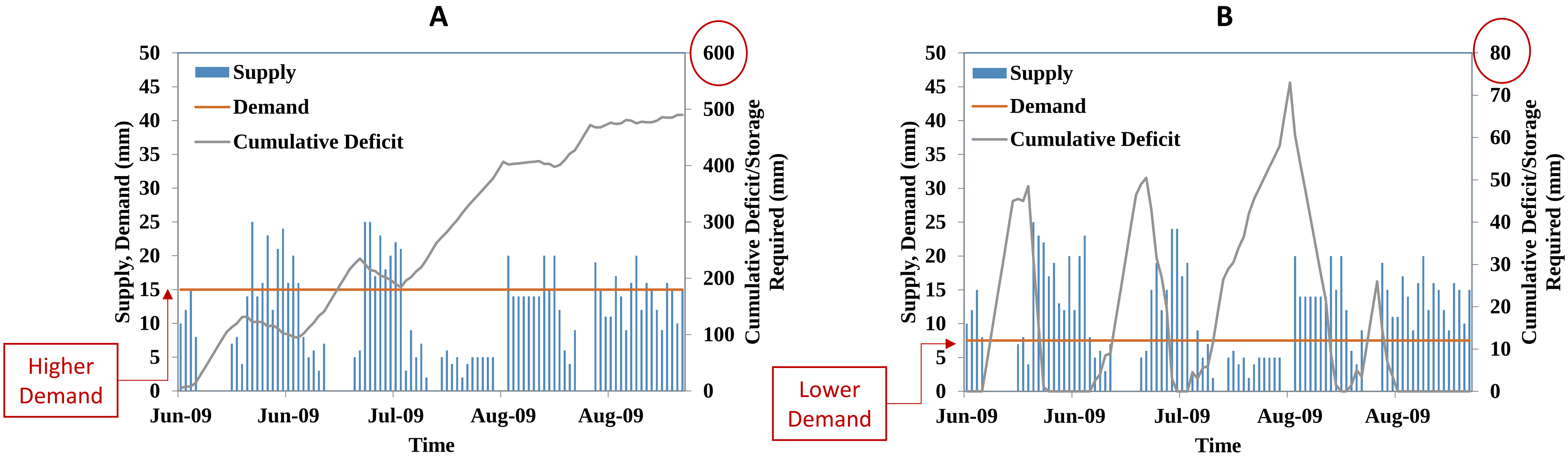
[Methodology]

Data and Method



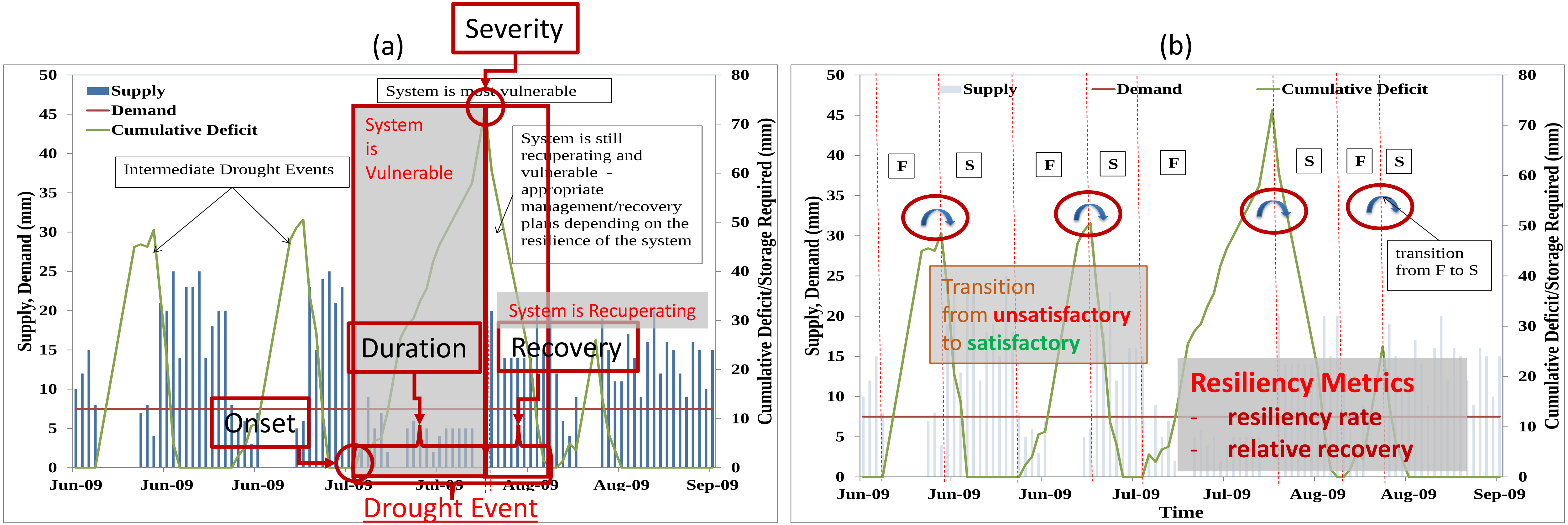
[Methodology]
The importance of Demand

- Two locations: same rainfall but different demand levels == > different droughts



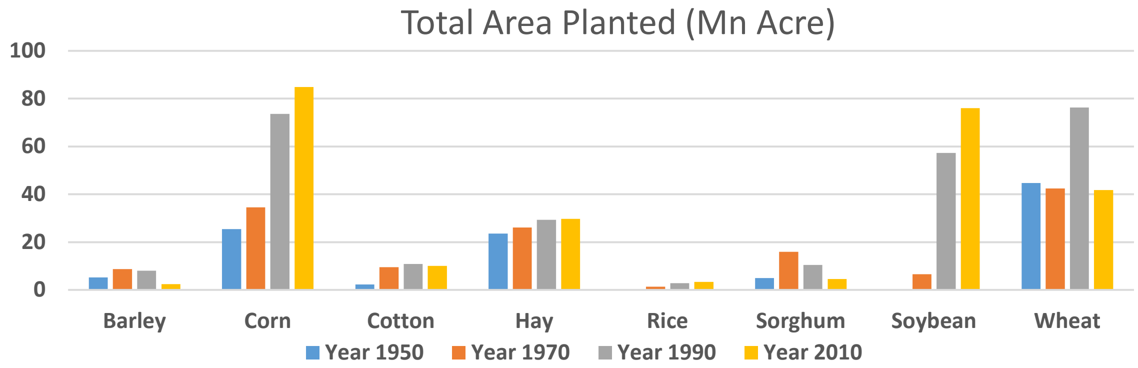
[Methodology]
Drought Attributes

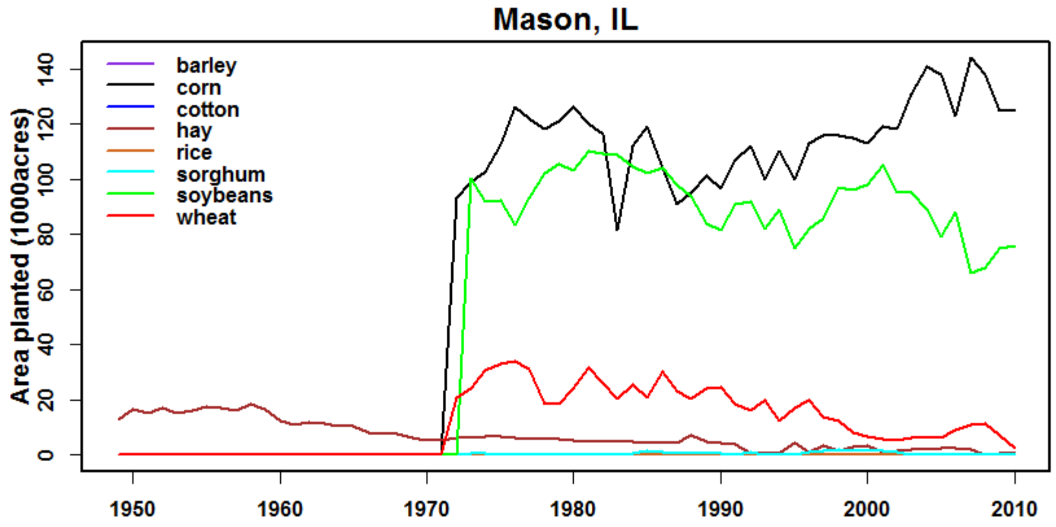
- Onset – Duration – Severity – Recovery - Resiliency

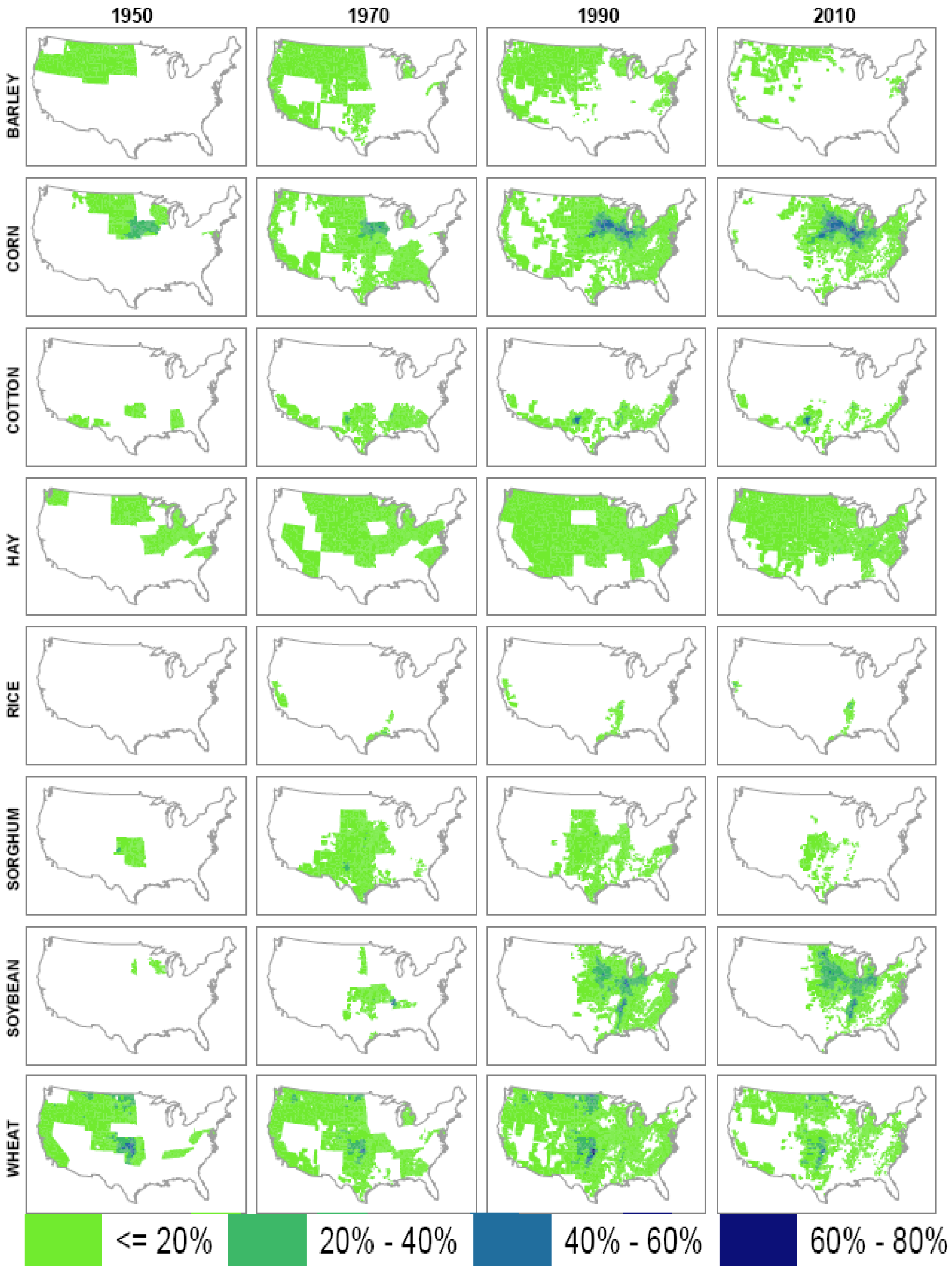


[Application - agri]

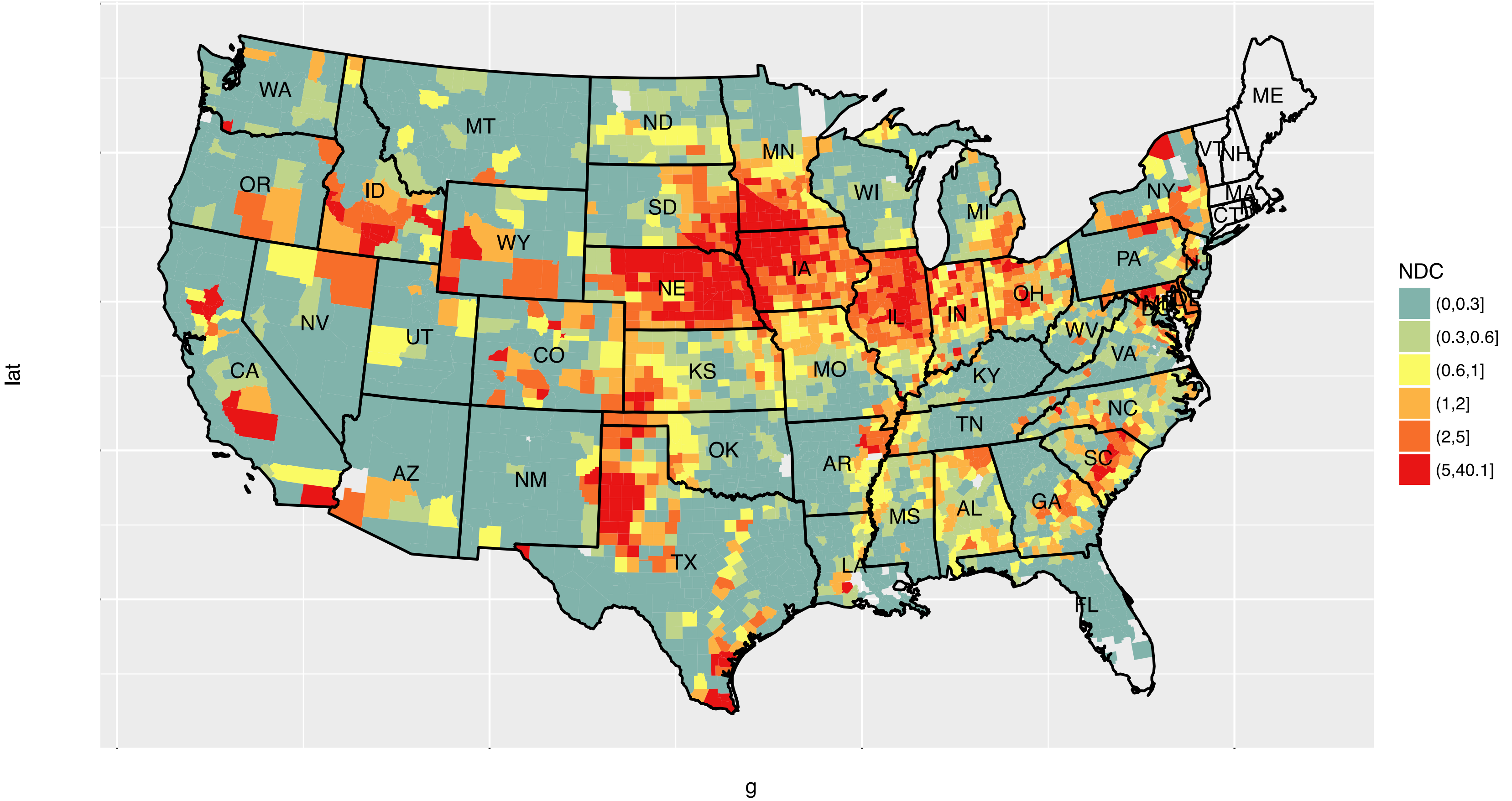
Aggregated crops demand





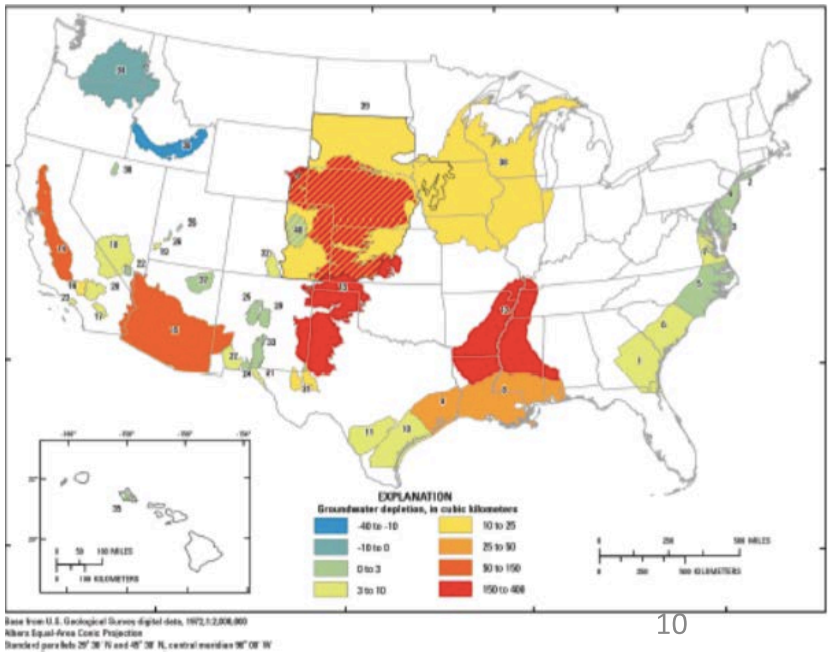


[Application - agri]
The drought index (DSDI)



- **DSDI < 1**: Endogenous water supply is enough to cover deficit
- **DSDI > 1**: External sources of water needed
- **DSDI> 5**: Chronic stress --> typically rely heavily on groundwater

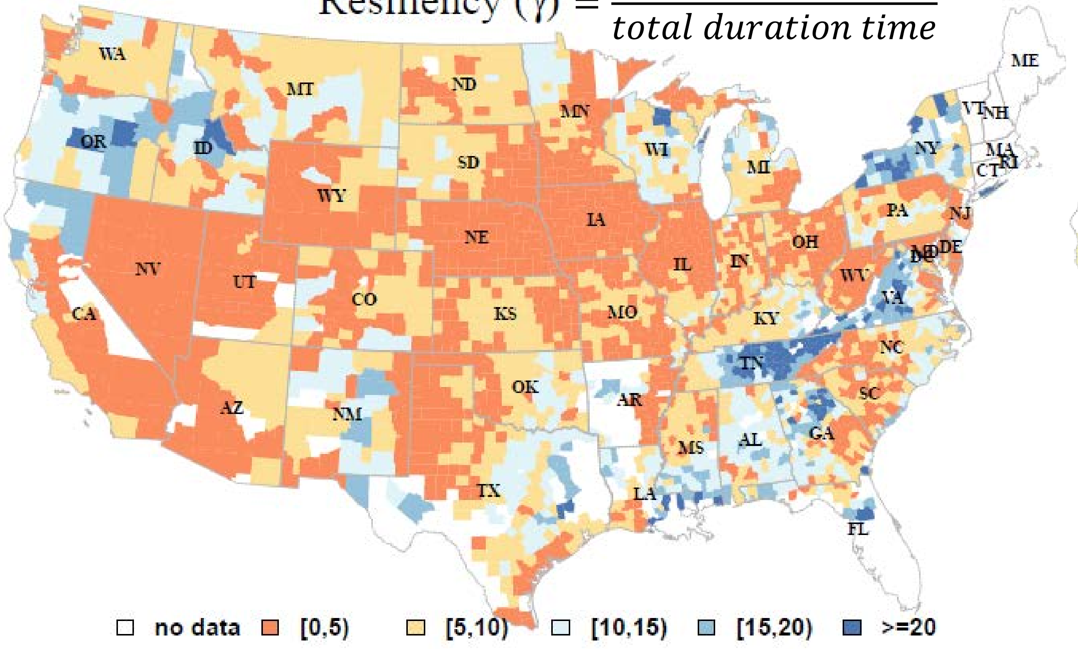
Groundwater Depletion Map



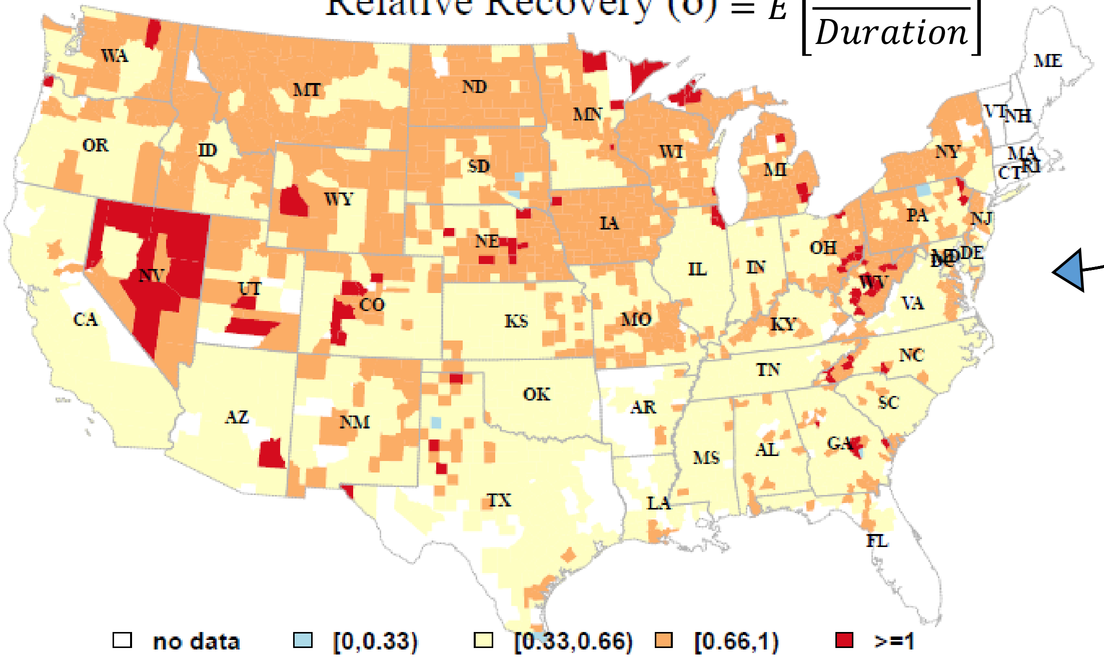
[Application - agri]
Resiliency metrics

- **Low resiliency rate => prolonged droughts with low probability of transitioning**
    - **High relative recovery => drought events take longer to recover**

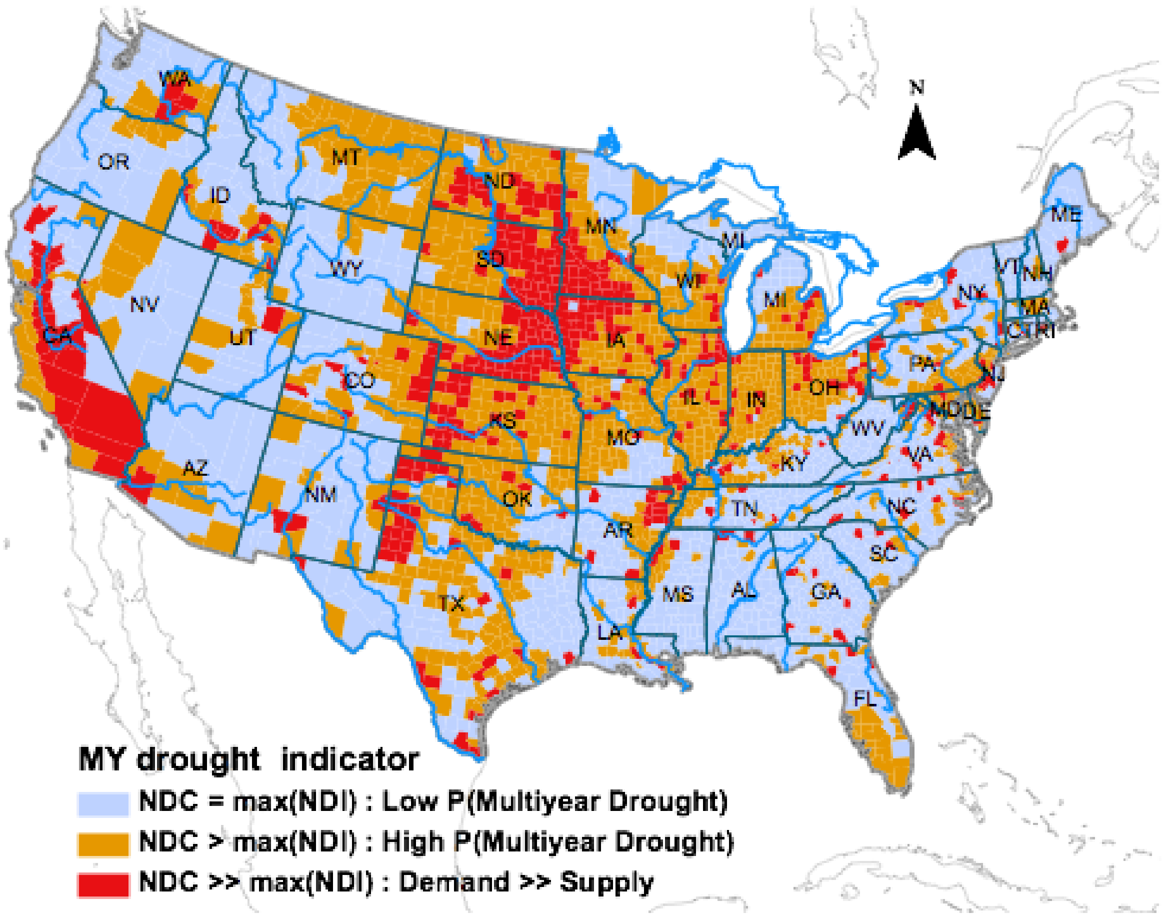
$$\text{Resiliency } (\gamma) = \frac{\#\ times\ recovery}{total\ duration\ time}$$

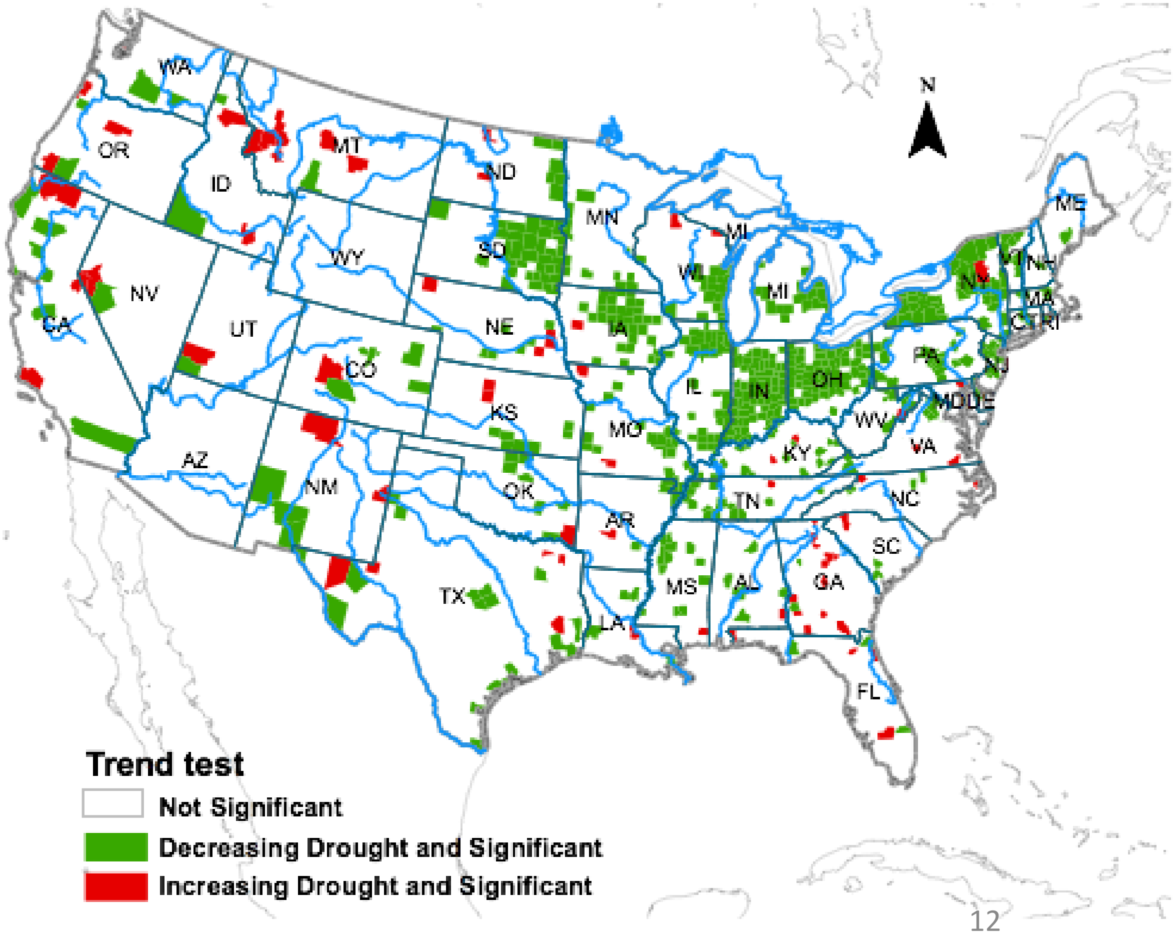


$$\text{Relative Recovery } (\delta) = E\left[\frac{Recovery}{Duration}\right]$$



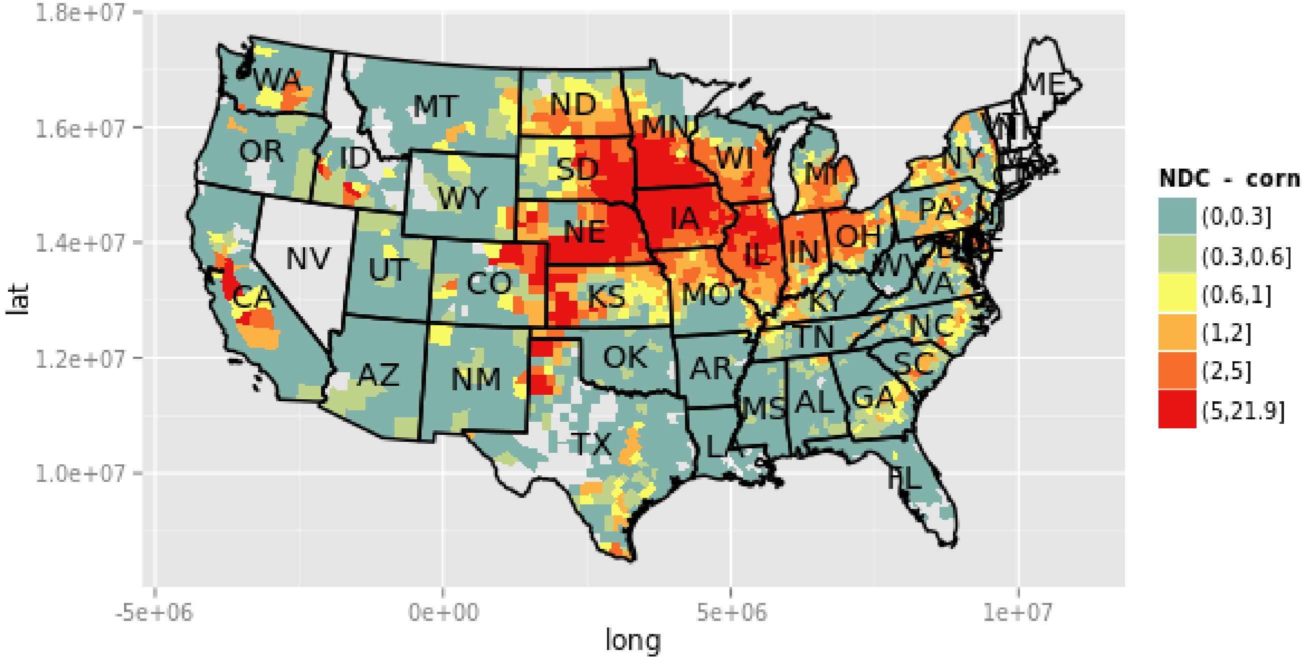
[Application – {Agri., Dom., Ind.}]
DSDI – overall total current (2010) demand



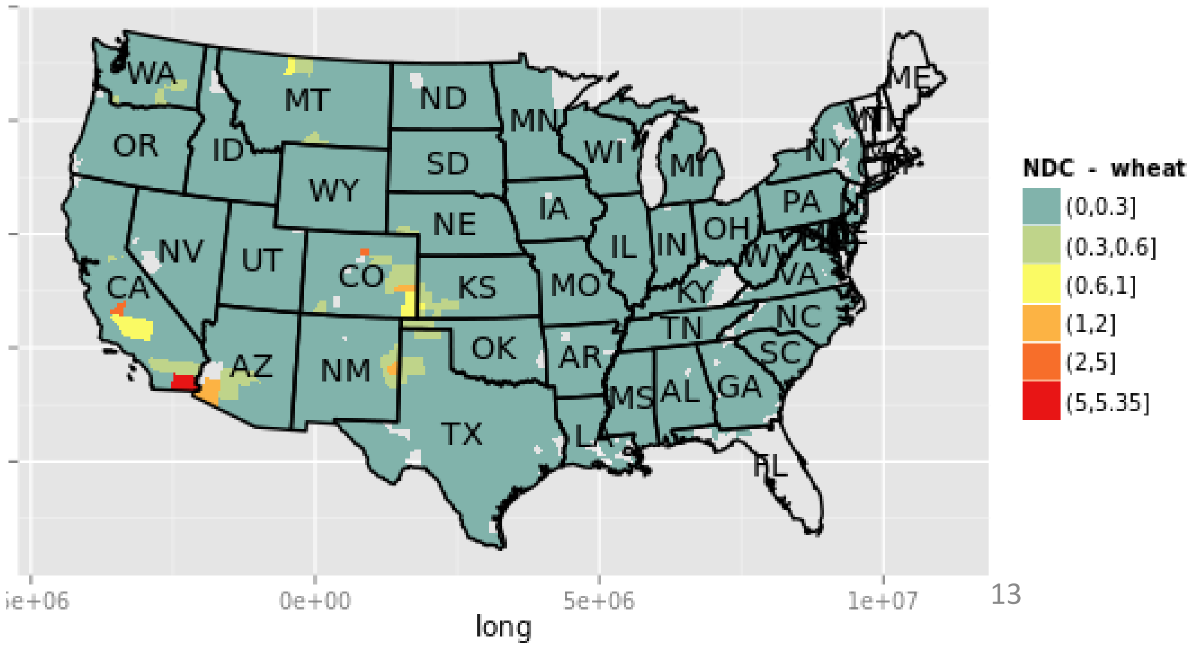


[Application – Single crop]
crop specific DSDI

Corn

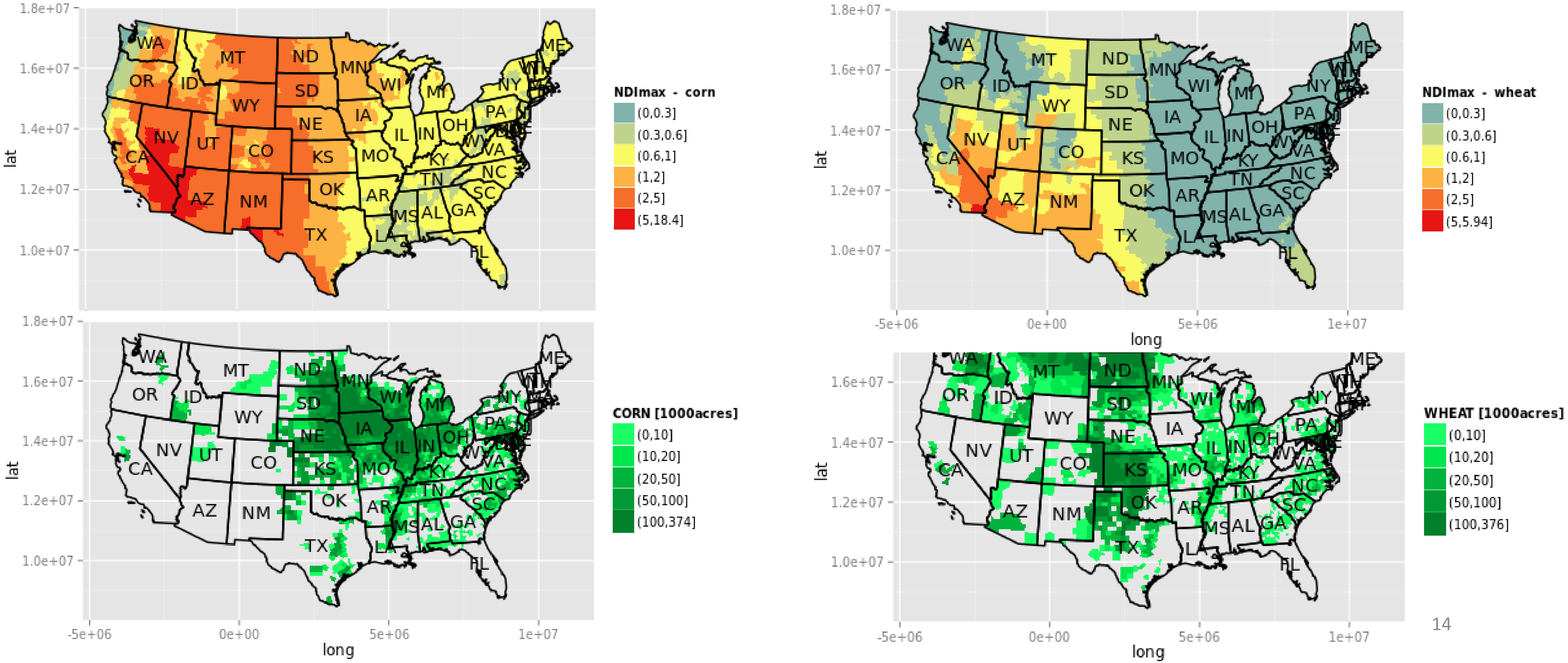


Wheat



[Application – Single crop]

Crop response to climate – #suitability



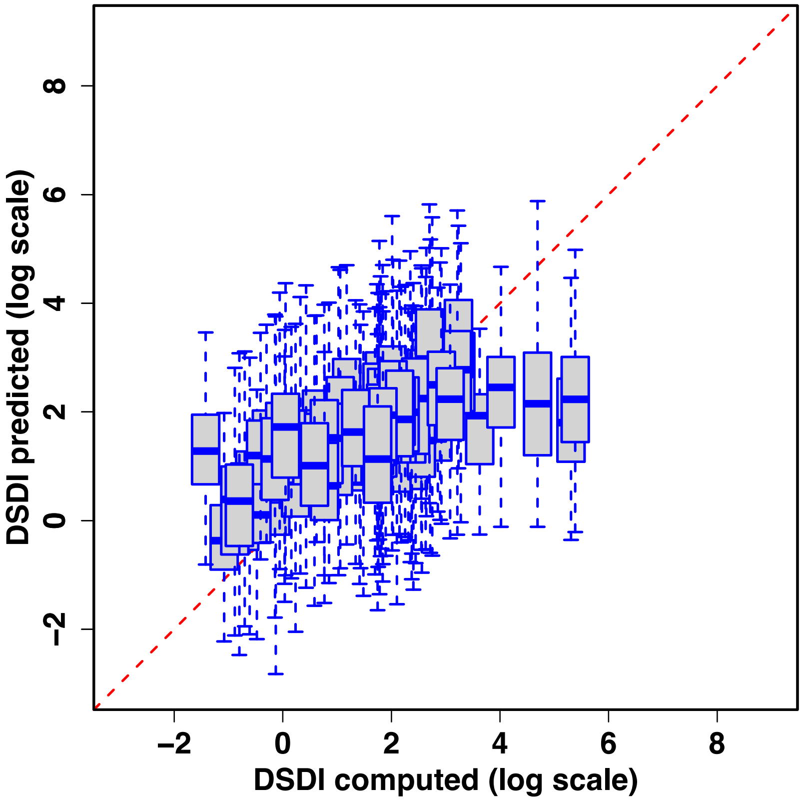
Estimate DSDI using parsimonious models

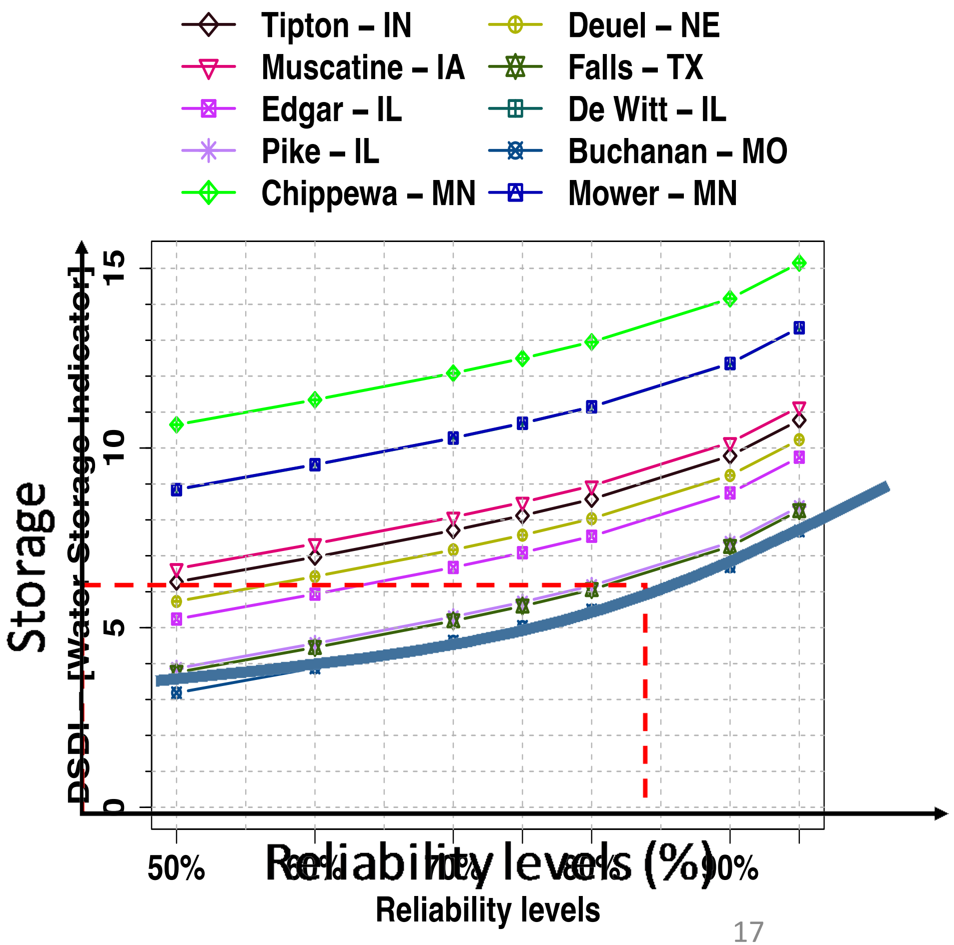
& obtaining probability distributions of the index

Simple models to estimate DSDI

Multi log-linear model

- $DSDI_i = (e^{\alpha})\left(X_{i,1}^{\beta_1}\right)\left(X_{i,2}^{\beta_2}\right)(\dots)\left(X_{i,n}^{\beta_n}\right)$
- $log(DSDI_i) = \alpha + \beta_1 log\left(X_{i,1}\right) + \beta_2 log\left(X_{i,2}\right) + \cdots + \beta_n log\left(X_{i,n}\right)$
- $\log(NDC_i) \sim N(\mu_i, \varepsilon)$
- $\mu_i = \alpha + \beta log(X_i)$



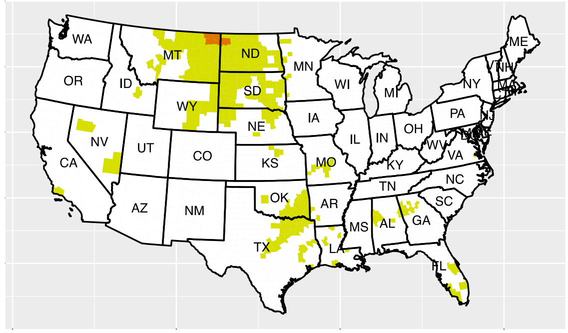


Future planning

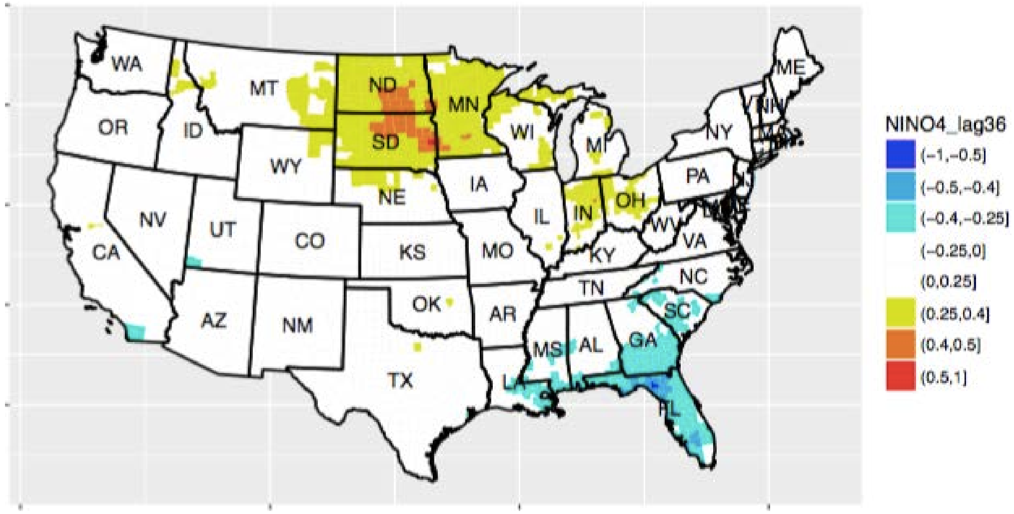
Ongoing analysis

Connection with Climate Indices

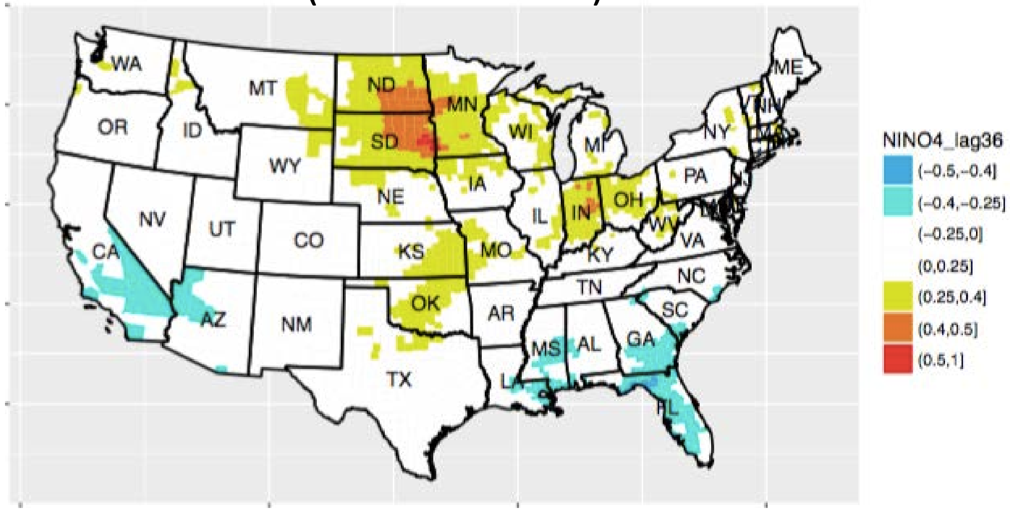
WHEAT - RK

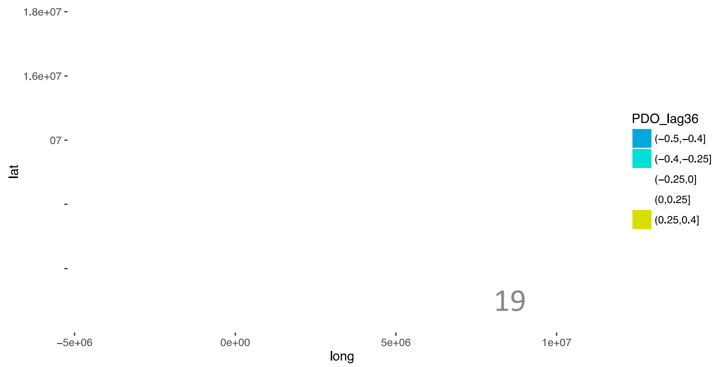


Barley – NINO4 (COR - LAG 3-6)



Corn – NINO4 (COR - LAG 3-6)





Summary

- ❖The drought index presented here focuses on water stress as defined through a temporal integration of **deficit at a daily resolution**.
- ❖The index is presented here for aggregate agriculture based on eight major field crops in the United States, but **can be disaggregated** into individual crop/demand indices
- ❖Furthermore the index can be derived for or integrated with **other water use sectors** such as industrial and domestic uses
- ❖The daily integration feature of the index makes it possible to be examined at **different levels of aggregation**, e.g., seasonal, annual or over the period of record
- ❖**The index directly informs storage requirements** needed to meet the supply-demand imbalance, and hence can be connected more directly to infrastructure planning, water conservation needs, or the size of trans-basin diversions.
- ❖Climate indices can serve to forecasting and projected risk per demand sector can be provided.

Thank you !