Quantifying the Impact of Human Activities on Water Sustainability and Crop Yields Across the High Plains Aquifer

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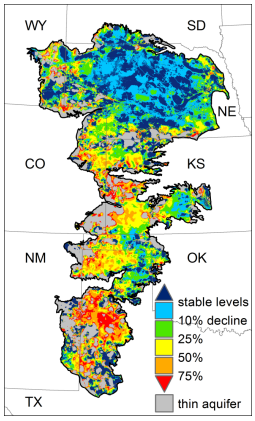
Outline

- Motivation
- Regional Climate Modeling with new Irrigation module
- Full energy and water balance simulations
- Synthesis of crop yield and production data
- Crop model → impacts of climate change and declining water levels on future crop production

Why Study the High Plains Aquifer?

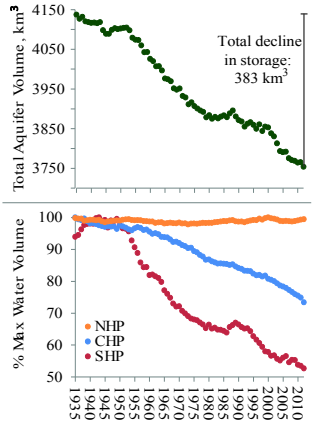


- It is an ideal region to study the effects of human activities
- Southern and Central HPA levels have been declining for decades

Haacker et al. (2015) Groundwater

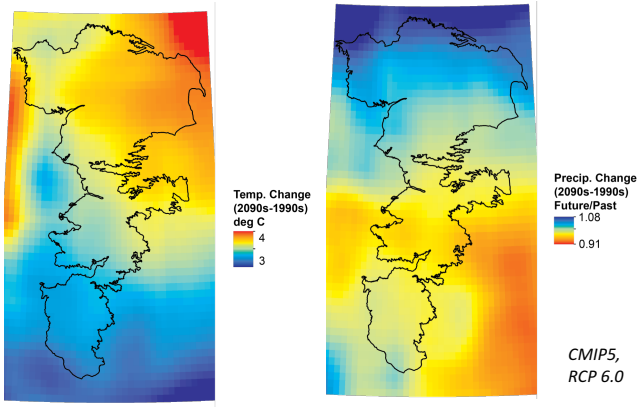
Changes in Water Storage (km^3)

- Loss of ~400 km^3 of water
- Storage Reduction
  - ~25% in CHP
  - ~50% in SHP

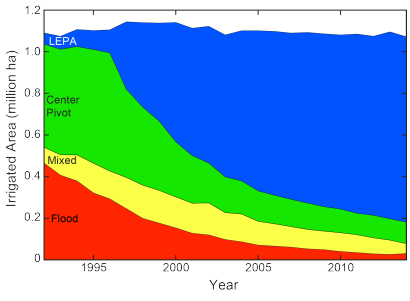


Haacker et al. (2015) - Groundwater

Climate is Projected to Become Warmer with More Variable Precipitation

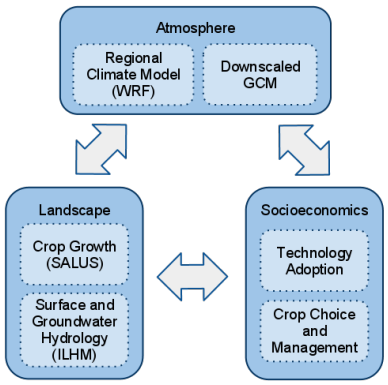


Irrigation Technologies are Changing



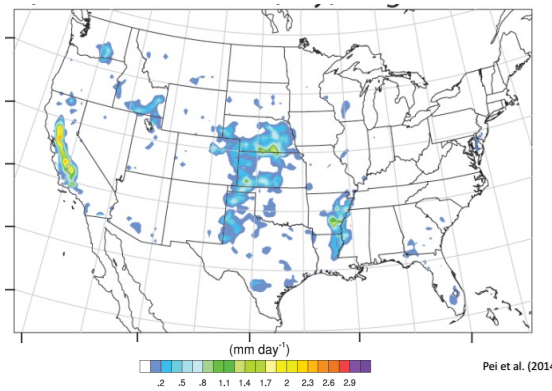
Coupled Systems Models

- Atmosphere
  - *WRF + Irrigation Module*
- Crop Growth
  - *SALUS*
- Landscape Hydrology
  - *LHM + Irrigation Module*
- Socioeconomics
  - *Irrigation Adoption*

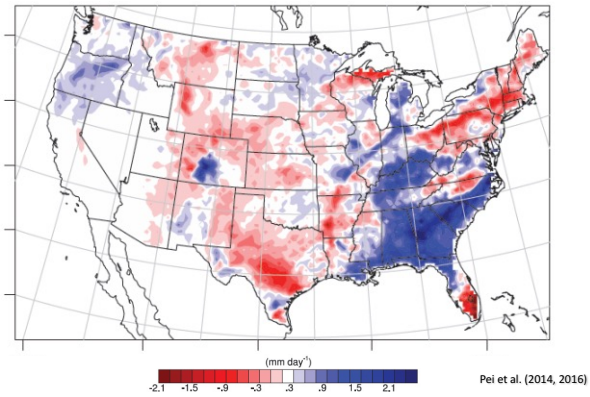


Climate Modeling: Simulated Irrigation

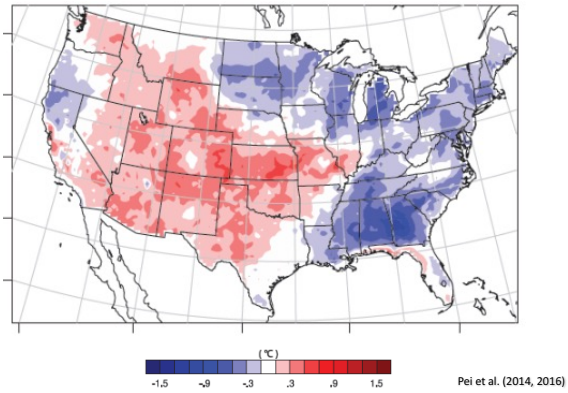
2012 (Dry year)



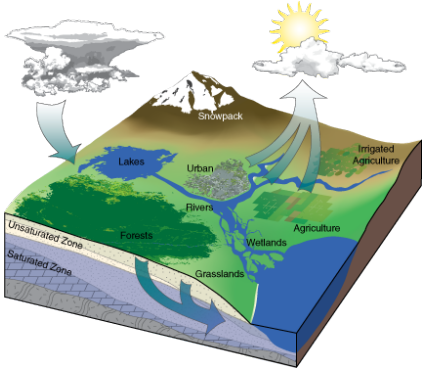
Changes in Summer Precipitation Due to Irrigation (2012)



Changes in Summer Temperature Due to Irrigation (2012)

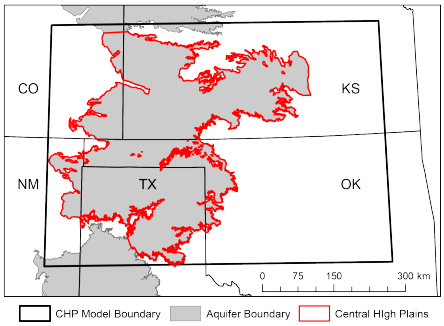


Landscape Hydrology Model (LHM)



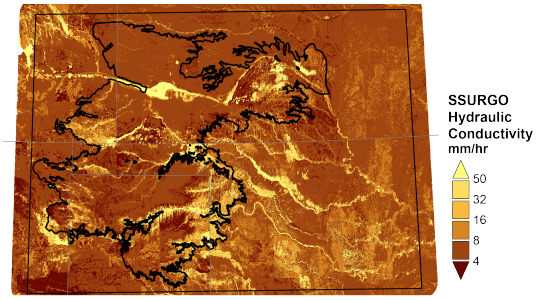
- LHM is: Process-based, fully-distributed, hourly
- LHM uses: Widely available climate, soils, GIS data

LHM Central High Plains Domain



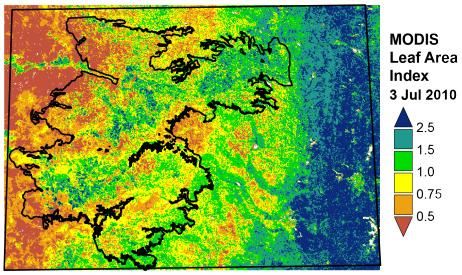
- ~385,000 km^2 with 1 km^2 cells

Select LHM Inputs: Soils



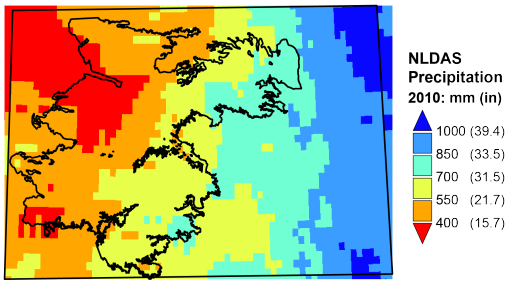
- Soils from SSURGO
  - Soil texture mapped to hydraulic properties

Select LHM Inputs: Leaf Area Index (LAI)



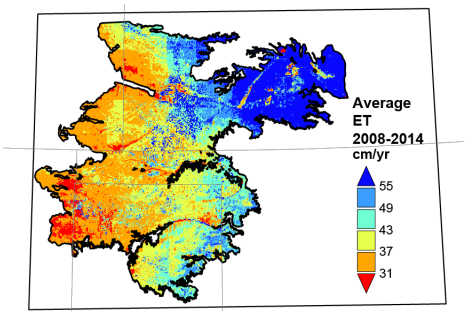
- LAI data from MODIS sensor
  - Every 8 days at 1 km resolution since 2000
- Irrigated agriculture clearly visible as higher LAI

Select LHM inputs: Precipitation



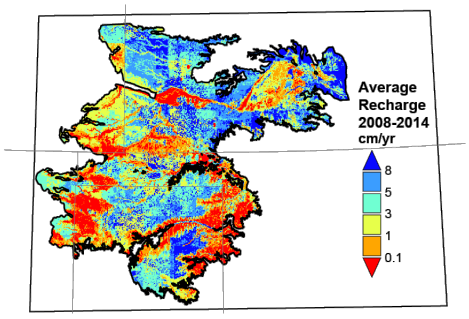
- Use data assimilation products such as NLDAS
  - consistent, hourly weather inputs since 1979
- Significant climate gradients across the domain

Simulated ET with Irrigation



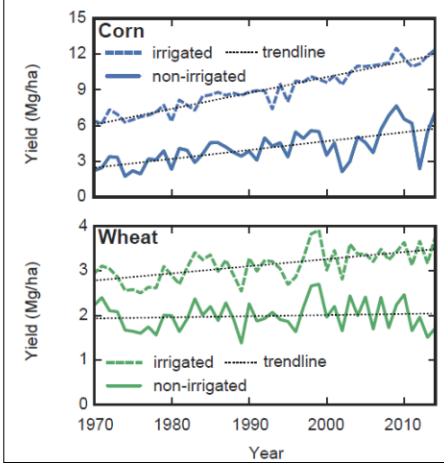
- Strong ET gradient from east (wetter) to west (dryer)
- Secondary patterns relate to land use and soil types

Simulated Recharge with Irrigation



- Quantify historical recharge and projected future changes based on management

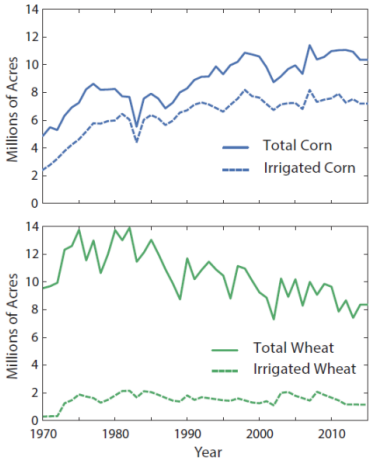
Data Synthesis: Irrigation ~Doubles Yield



- Yield increases through time
- New corn cultivars and management

Smidt et al. (2016) - SOTM

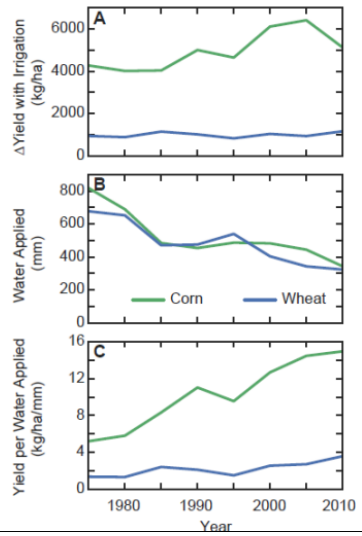
Changes in Acreage and Irrigation



- Corn acreage increases
  - Mostly irrigated
- Wheat acreage decreases
  - Mostly dryland

Smidt et al. (2016) - SOTM

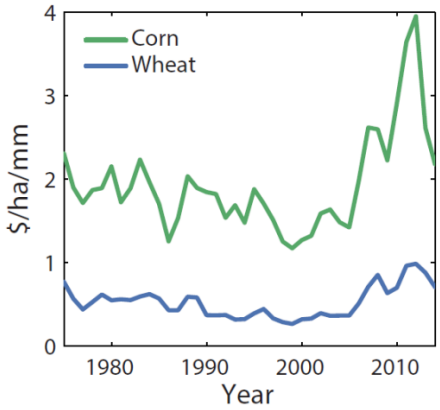
Crop per Drop



- More yield increase for corn
- Water application similar
- Yield per mm increasing

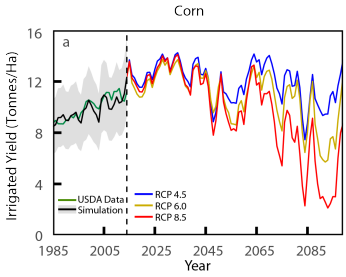
Smidt et al. (2016) - SOTM

Value of Applied Irrigation



Smidt et al. (2016) - SOTM

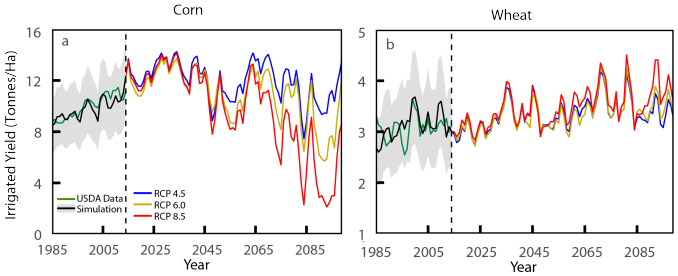
Crop Modeling: Irrigated Crop Yields (CHP)



- Accurately simulates historical yields without calibration
- Project yields for different climate change scenarios

Cotterman et al. (in prep.)

Simulated Irrigated Crop Yields (CHP)



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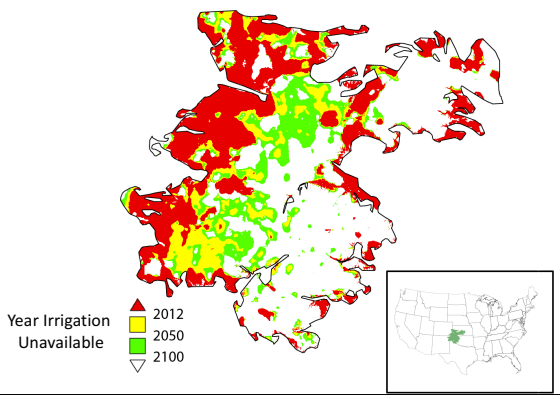
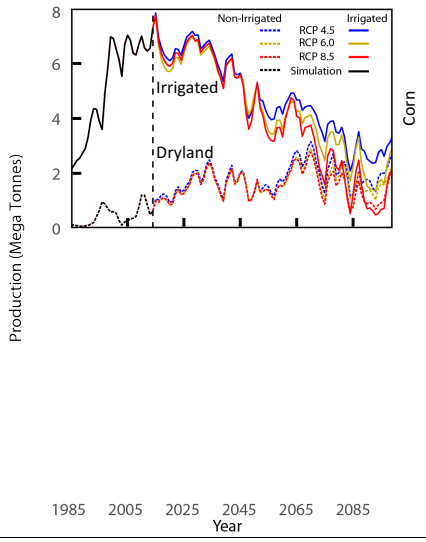
Declines in Water Level Increase Dryland Agriculture



Projected Crop Production

- Depends on **yield** and **water availability**
- Corn production mostly irrigated
- Wheat is mostly from dryland



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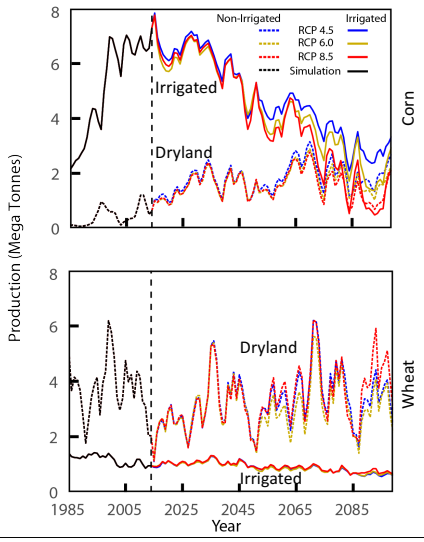
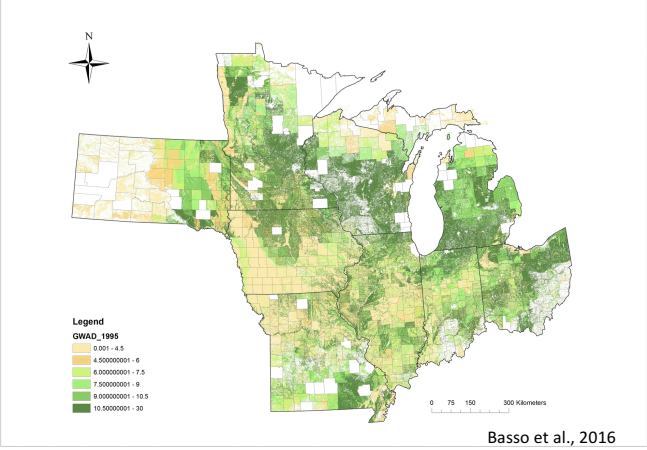
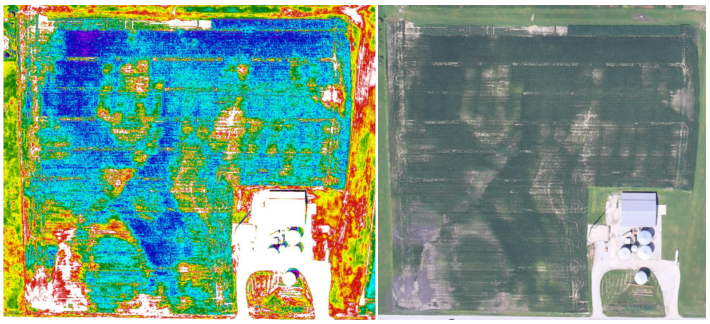


Regional Crop Modeling



Basso et al., 2016

High Resolution Remote Sensing →Precision Agriculture



Thermal imagery ➔ spatial variability due to water or nitrogen stress

Summary

- **The Central and Southern High Plains are far from Sustainable**
  - **Decline in storage of ~400 km^3**
- **Irrigation alters regional climate, and should be included in climate and hydrology models**
- **Climate change will exacerbate water and food production challenges**
  - **Irrigation across the CHP and SHP will decline**
  - **Crop production will decline due to limited water**
- ***Current work:* Help climate, nutrient and water smart technologies that couple remote sensing with process based models (NIFA).**

Thank you!

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