The Office of Cyber and Infrastructure Analysis

National Protection and Programs Directorate
Department of Homeland Security

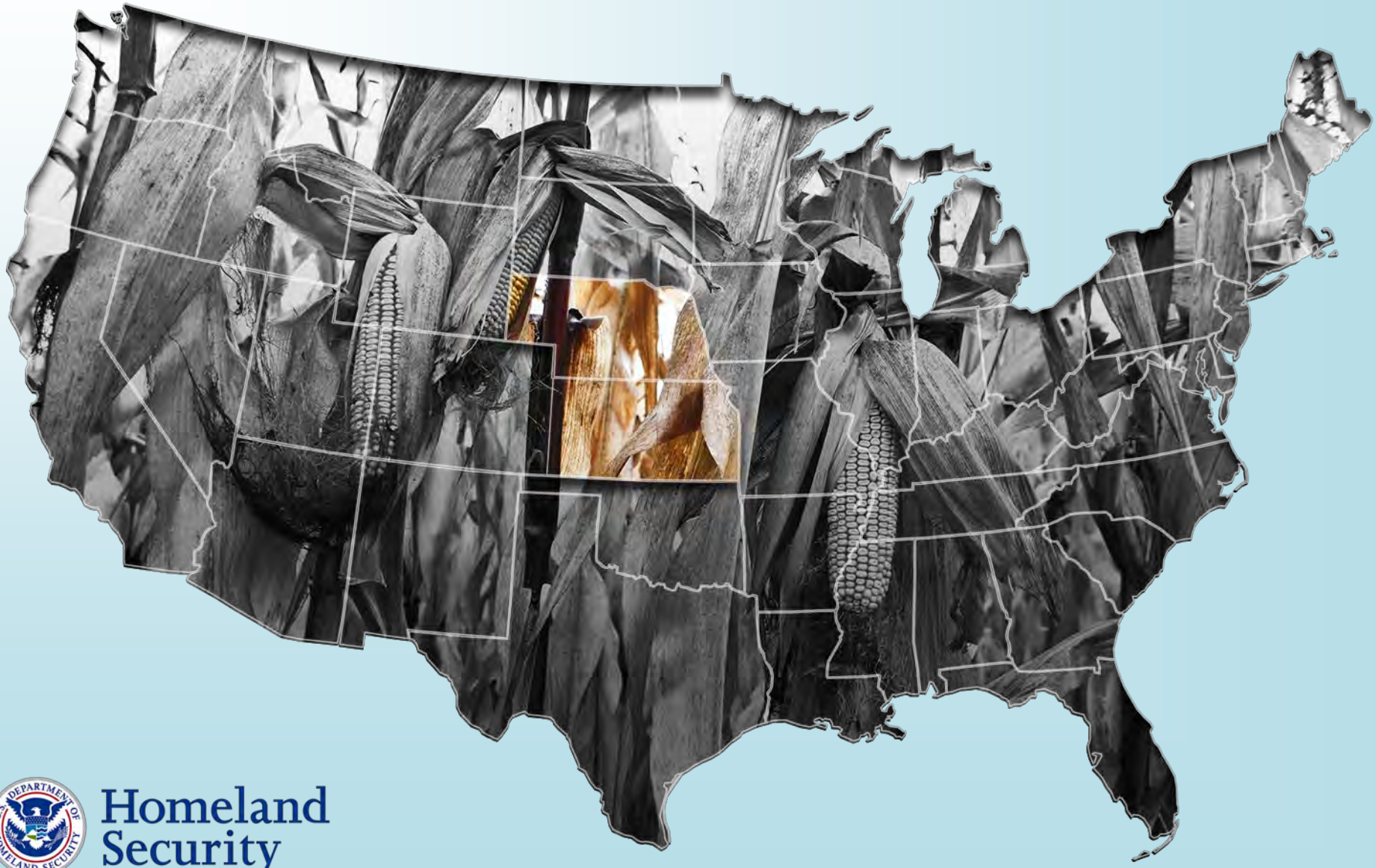
National Infrastructure Simulation and Analysis Center

High Plains Resource Risk and Economic Impacts in Nebraska and Kansas

Nebraska Infrastructure Protection Conference

August 31, 2015

High Plains Resource Risk and Economic Impacts in Nebraska and Kansas



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High Plain Resource Risk Topics

Key Analytical Questions

Key Findings

High Plains Model → Crop Model → Economic Model

Summary

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Key Analytical Questions

How will climate variability and groundwater depletion impact agricultural production in the High Plains?

- *Reduced yields*
- *More dryland farming*

What are the affected Critical Infrastructures?

- *Food and Agriculture*
- *Water and Wastewater*
- *Chemical (Ethanol)*
- *Energy (Ethanol)*

How do current water practices affect groundwater depletion?

- *Changes in groundwater level and supply*

What are the local, regional, & national economic impacts of ground water depletion?

- *Farm exit*
- *Loss of irrigated acreage*

Which economic activities are vulnerable to groundwater depletion?

- *Farming and livestock*
- *Agriculture support*
- *Food manufacturing*
- *Animal processing*

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Key Findings

- Climate projections impose a small downward trend on dryland crop yields – ***Innovations could offset the decline in crop yields.***

- If current water use practices are continued**,** ***7 counties in Nebraska and 60 in Kansas are projected to face exhaustion of groundwater supplies in 100 years or less.***

- ***Declining water levels mean increased farm operations costs.*** A $1,000 increase in utility expenditures corresponds to a 2.62 percent increase in the probability of a farm operation exiting the industry.

- Gradual changes in operating costs and conversion from irrigated to dryland farming due to declining groundwater levels have ***small impacts on State GDP growth.***

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High Plain Resource Risk Topics

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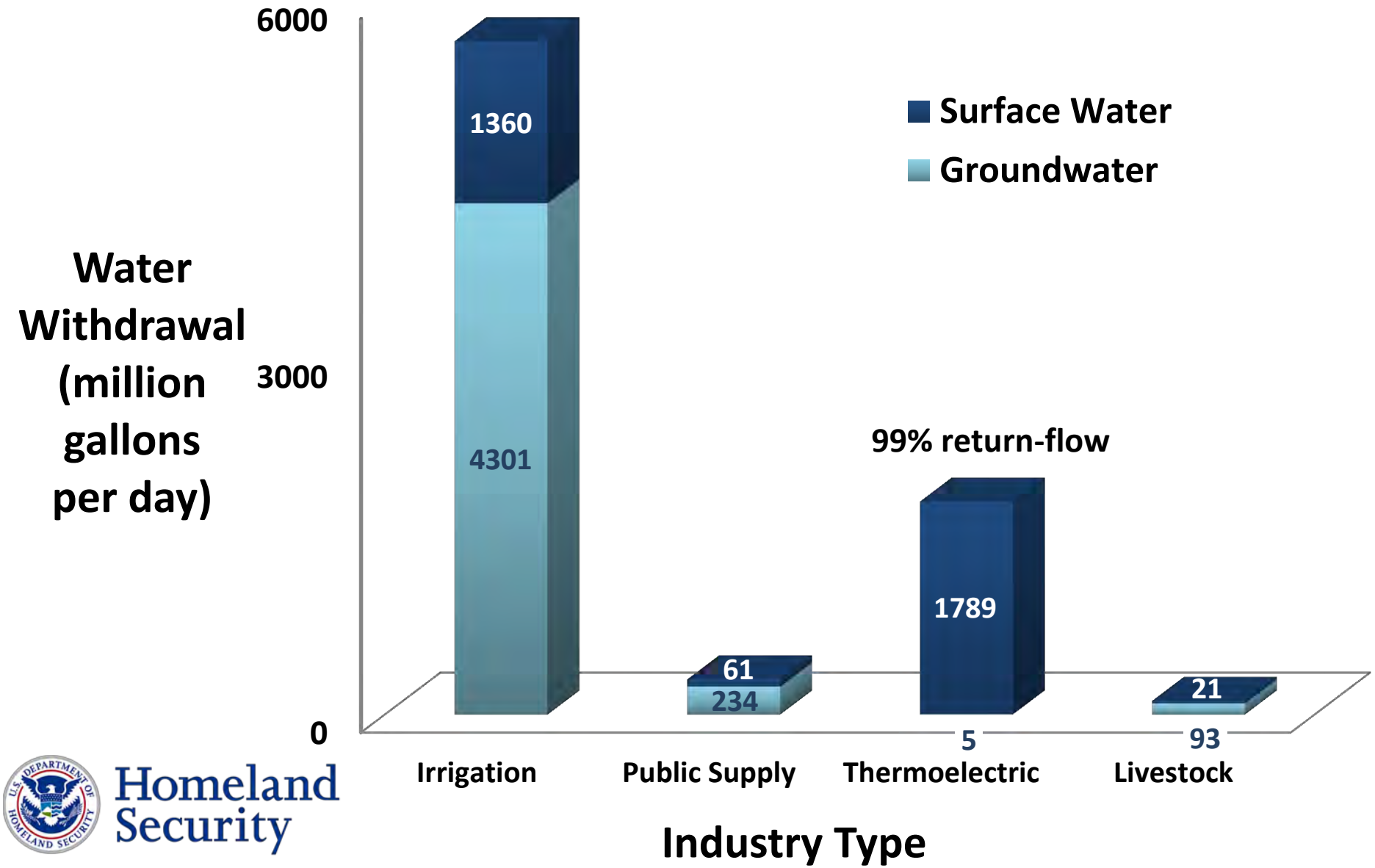
Nebraska: Agriculture is the Largest Water User



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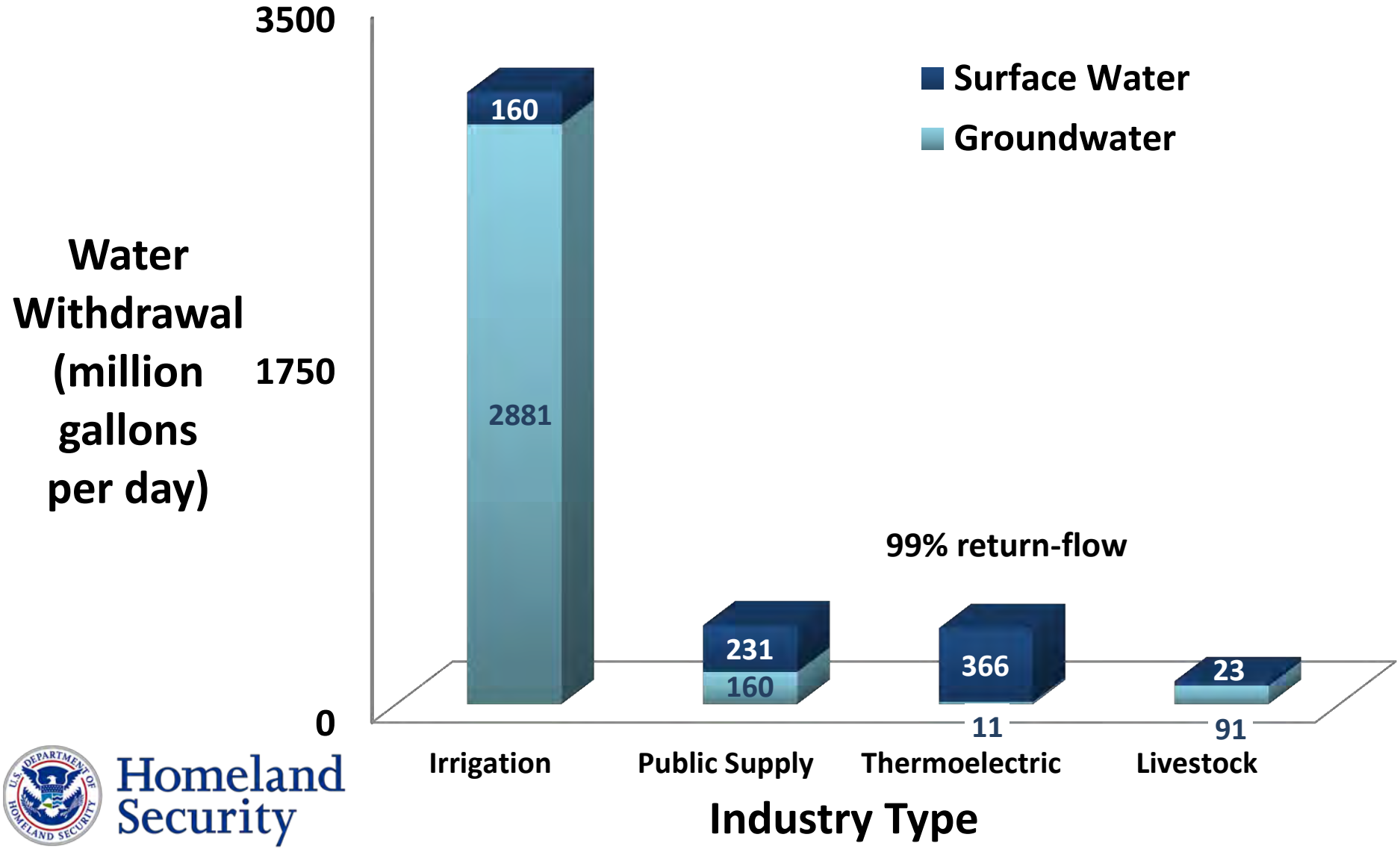
Kansas: Agriculture is the Largest Water User



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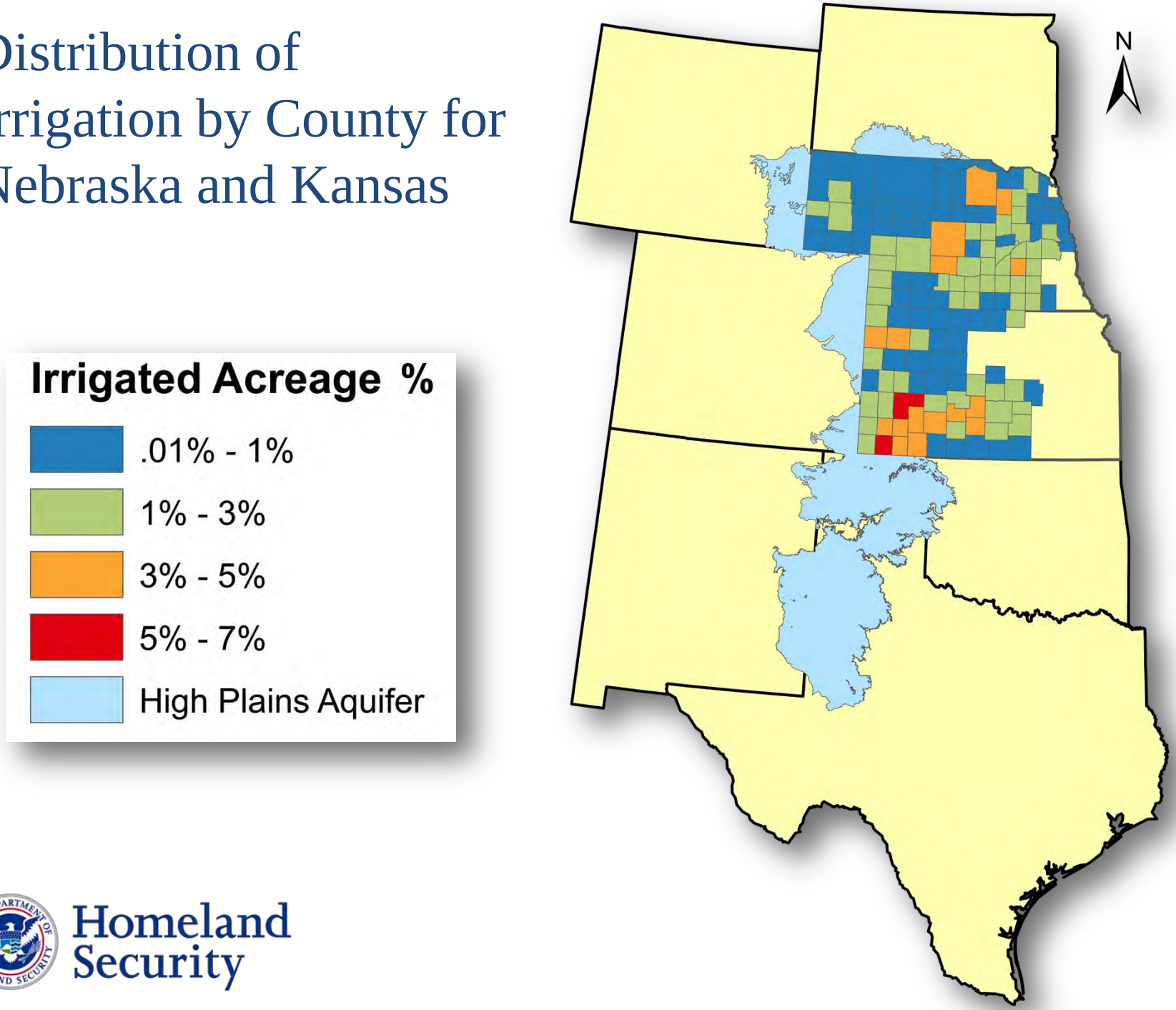
Distribution of Irrigation by County for Nebraska and Kansas



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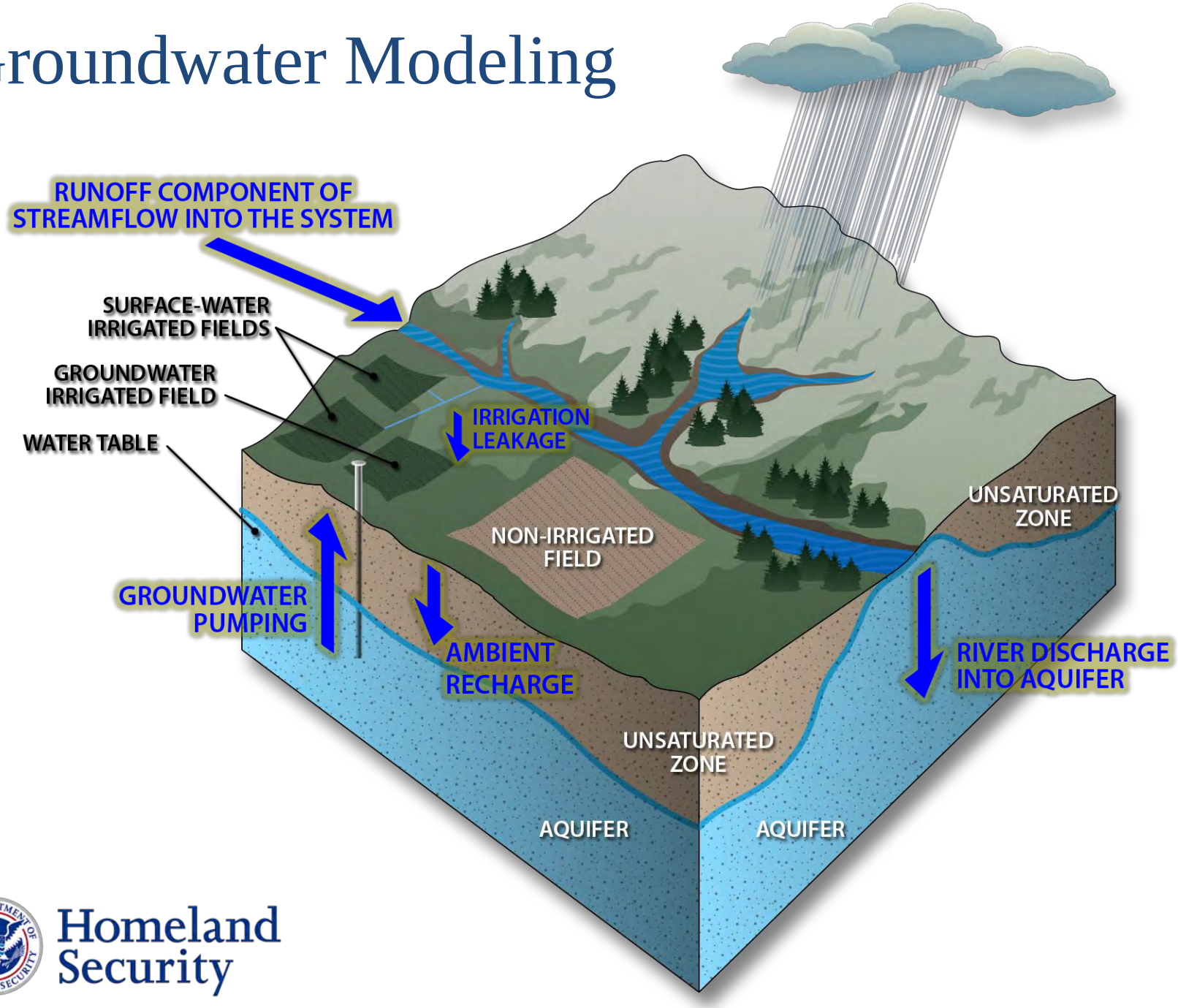
Groundwater Modeling



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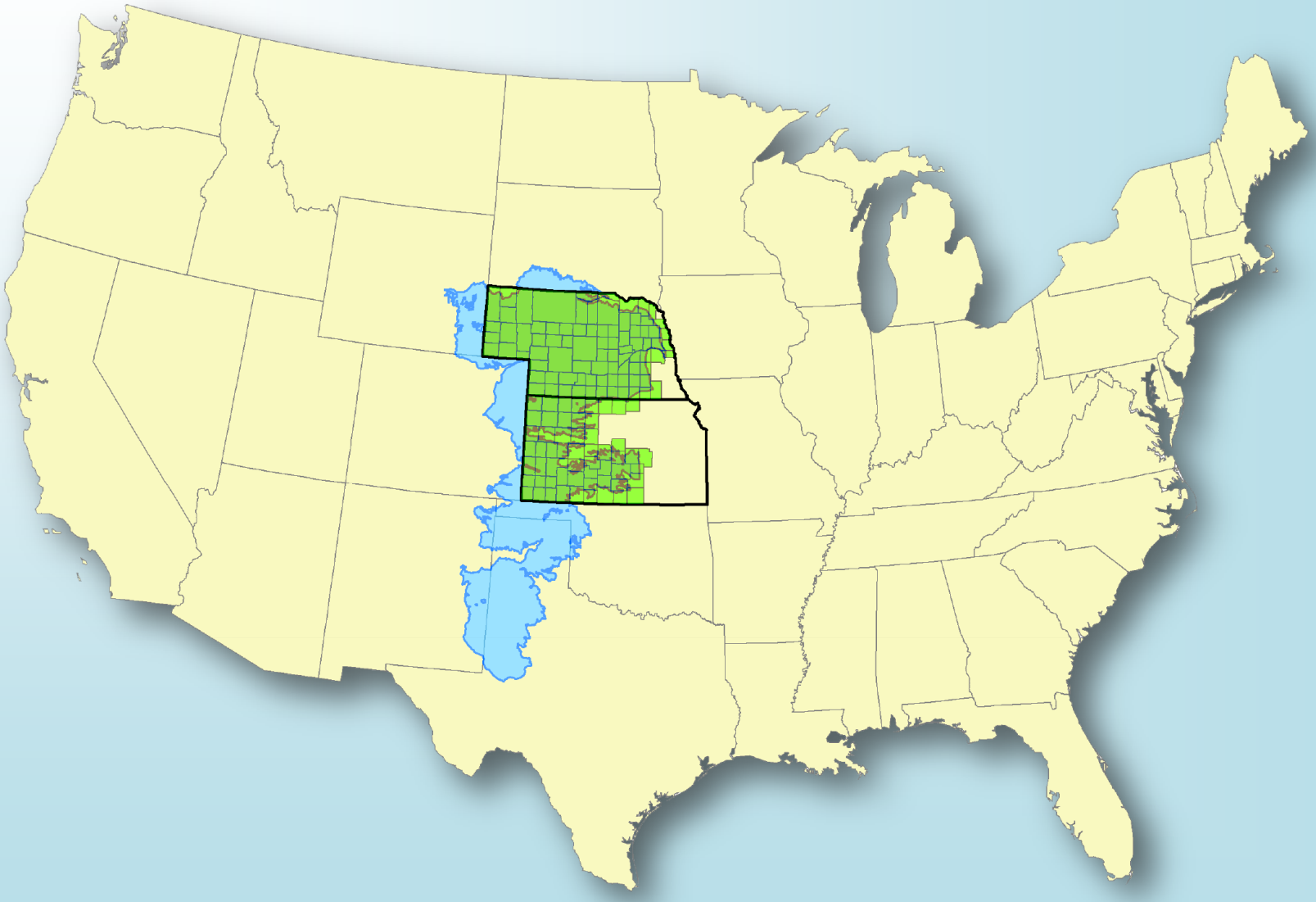
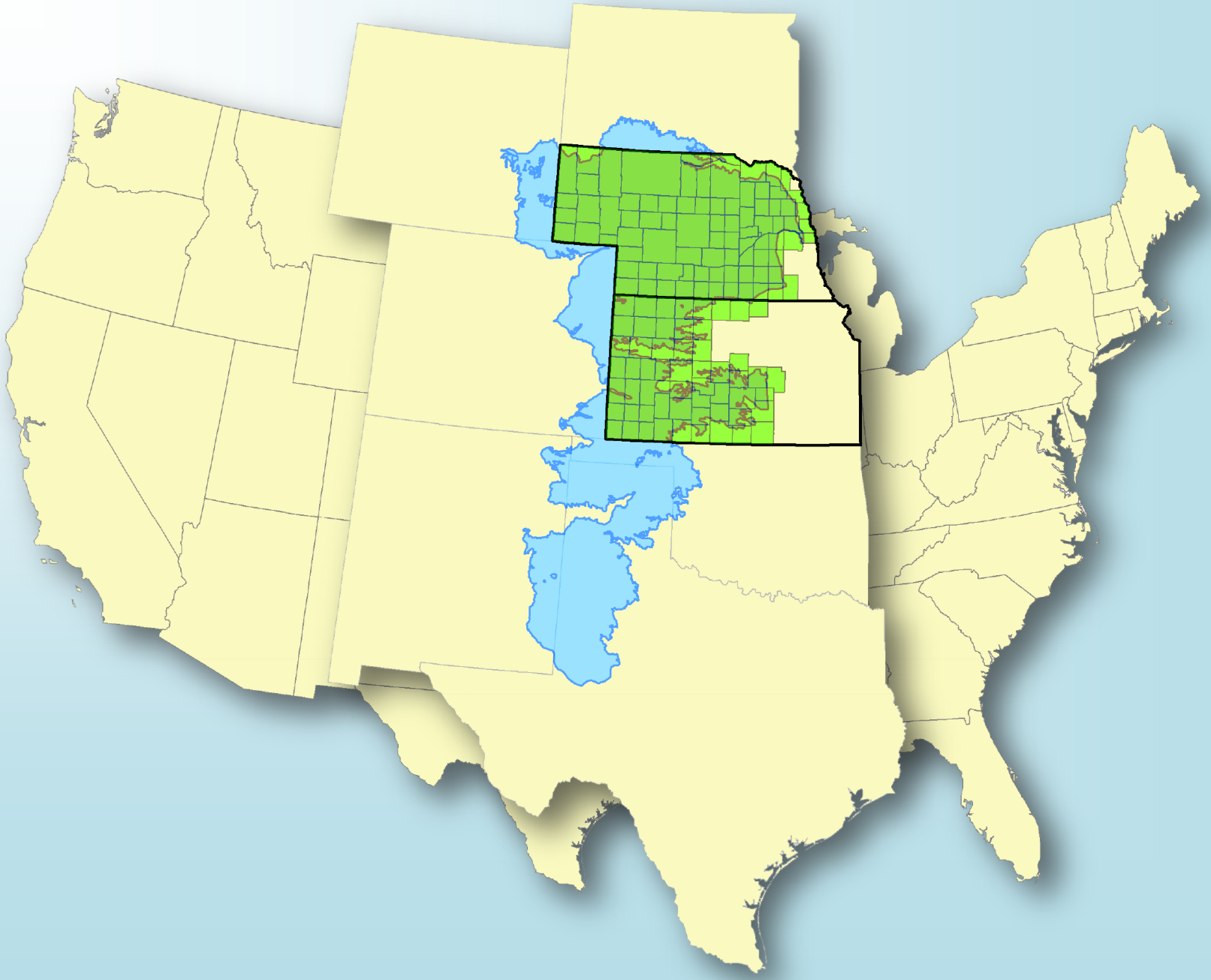
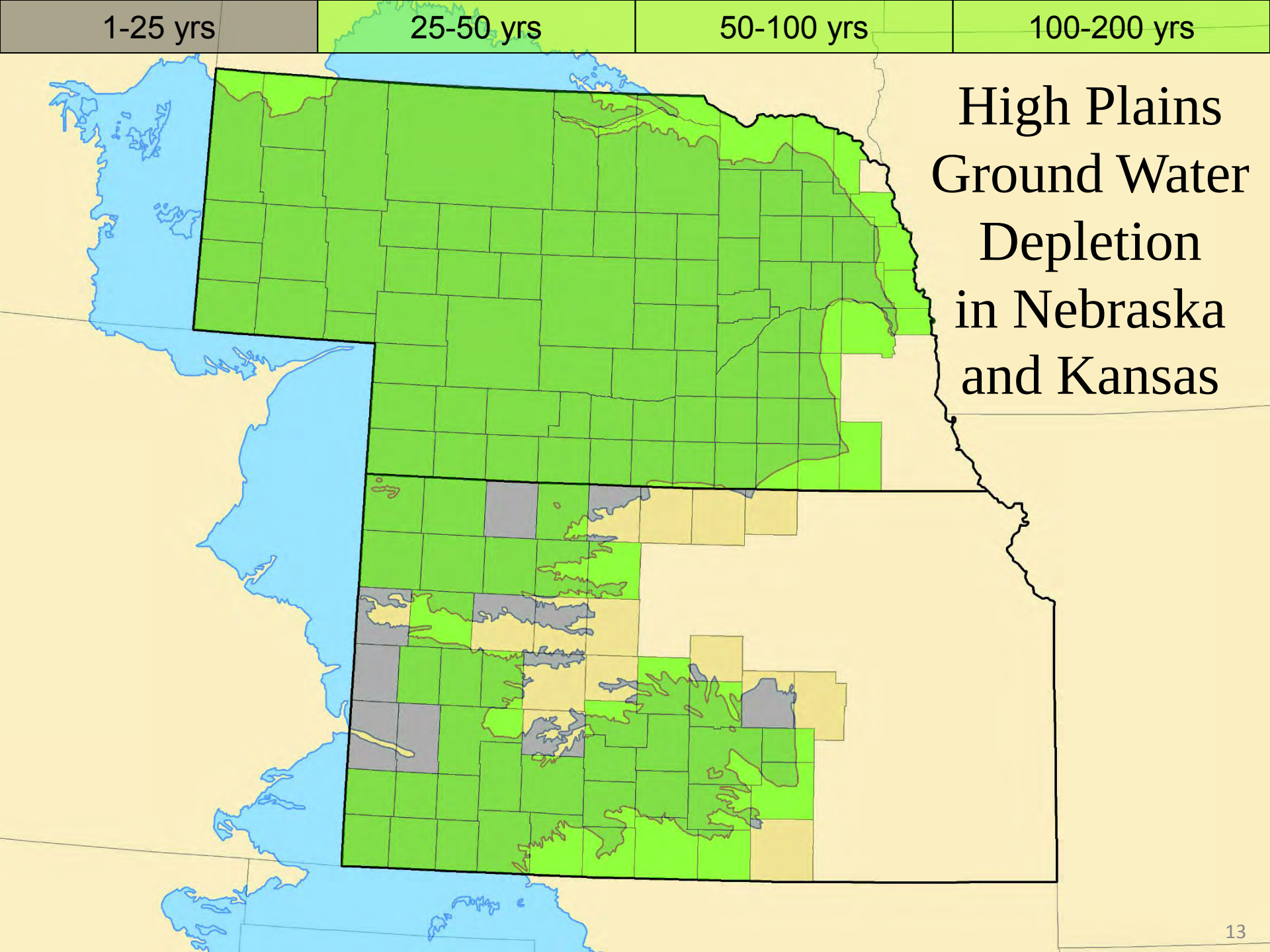
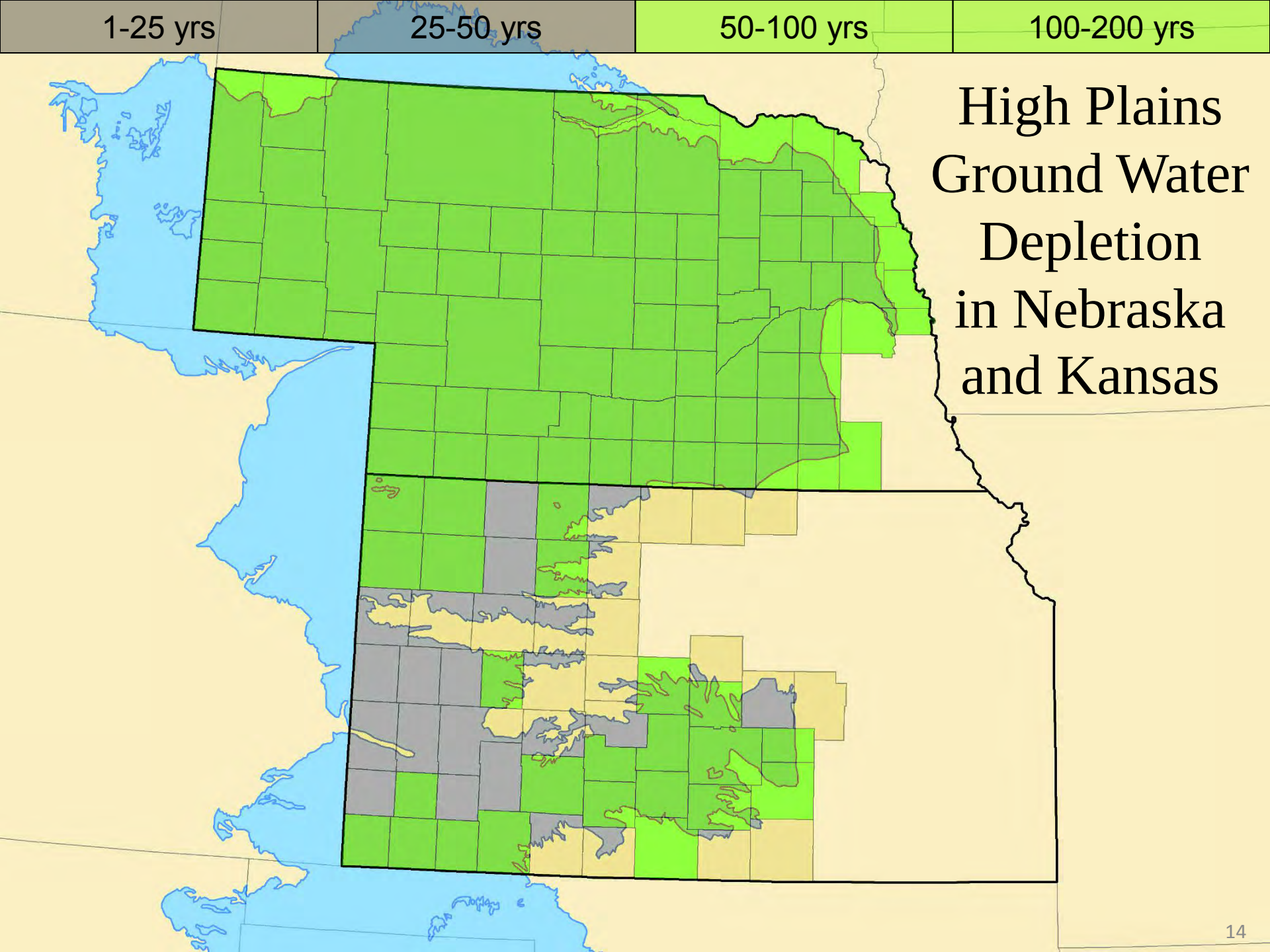
High Plains Ground Water Depletion



High Plains Ground Water Depletion




1-25 yrs
25-50 yrs
50-100 yrs
100-200 yrs
High Plains Ground Water Depletion in Nebraska and Kansas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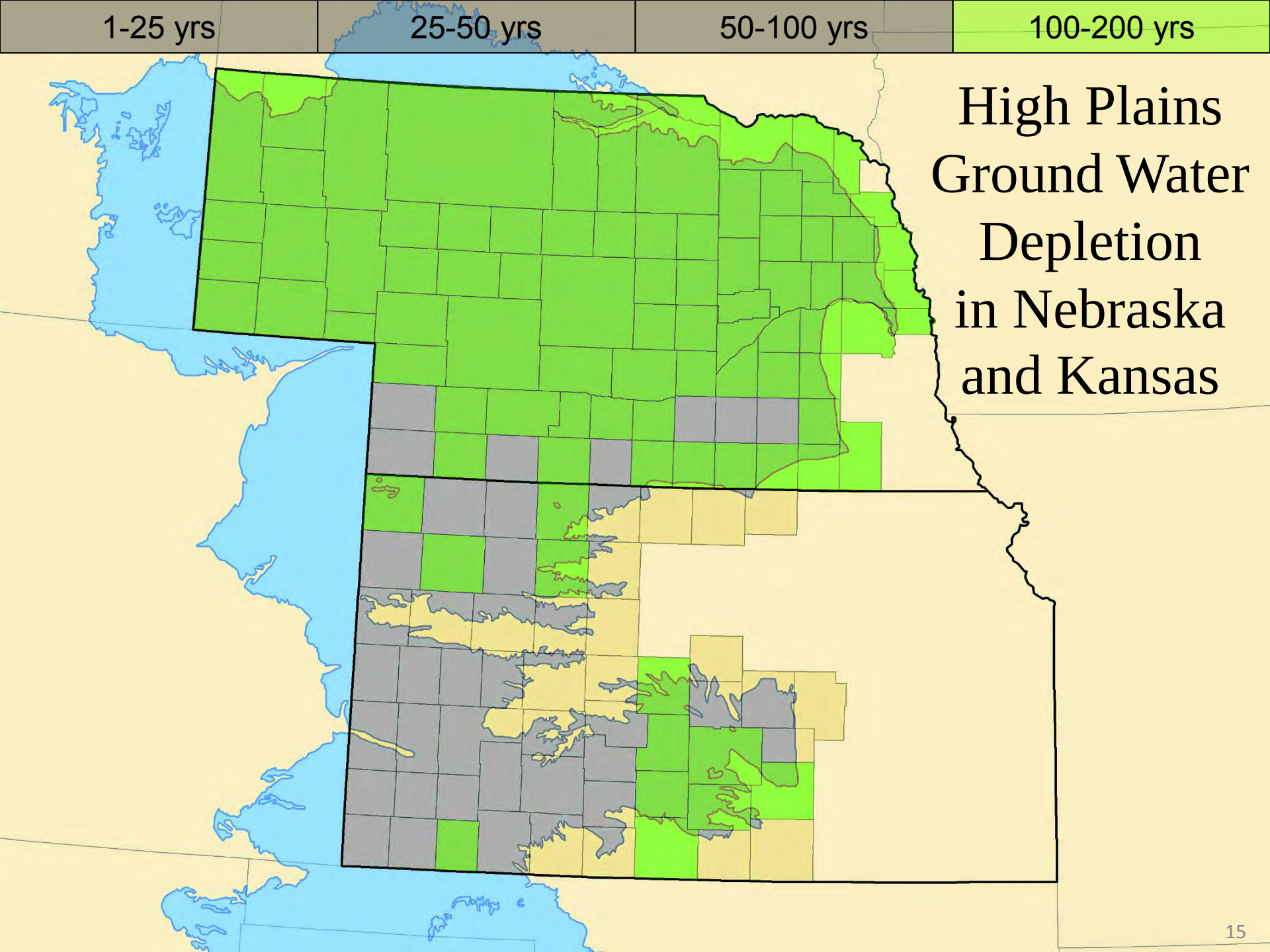
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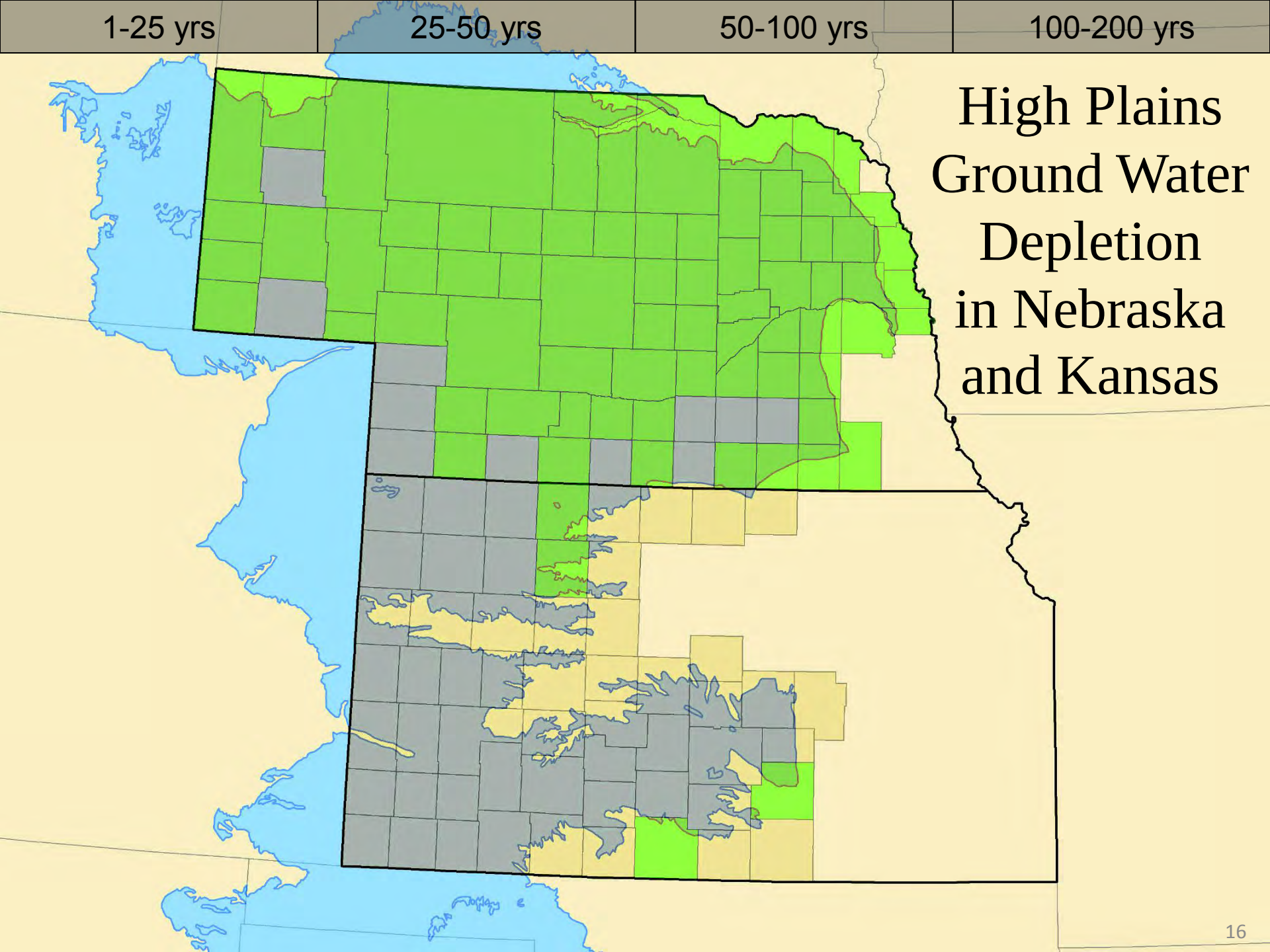
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High Plains Ground Water Depletion in Nebraska and Kansas

High Plain Resource Risk Topics

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Key Findings

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Economic Model

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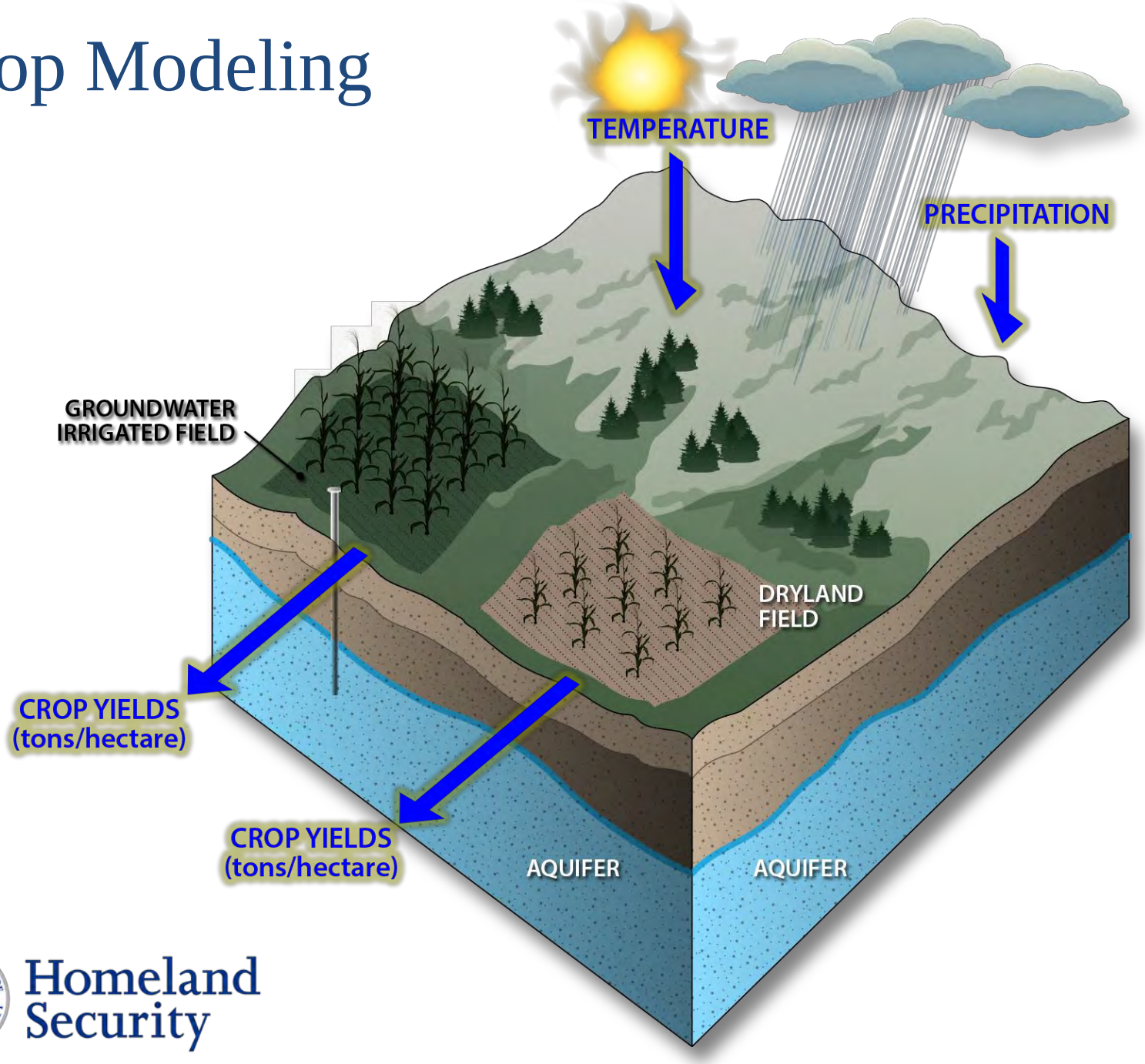
Crop Modeling



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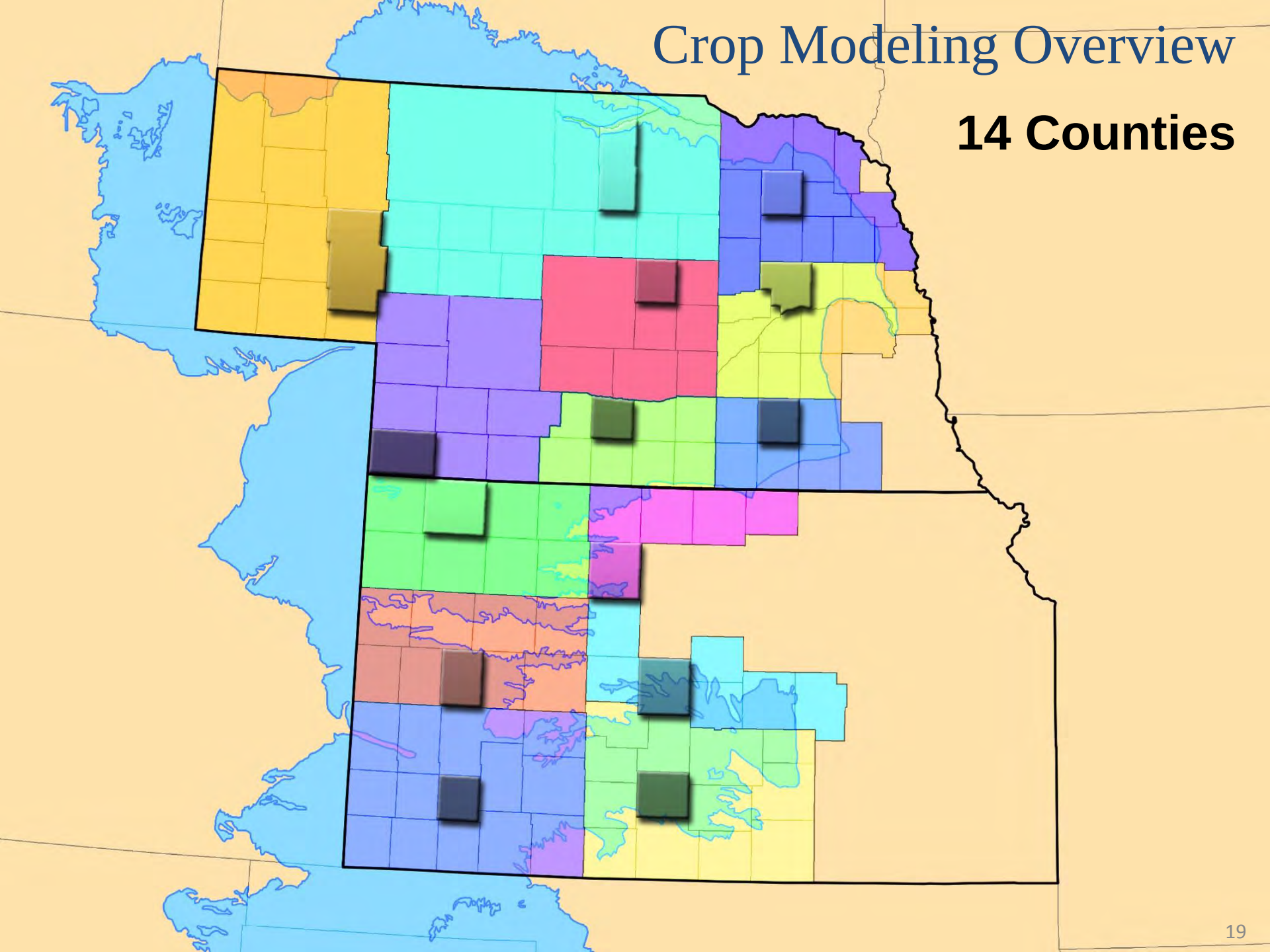
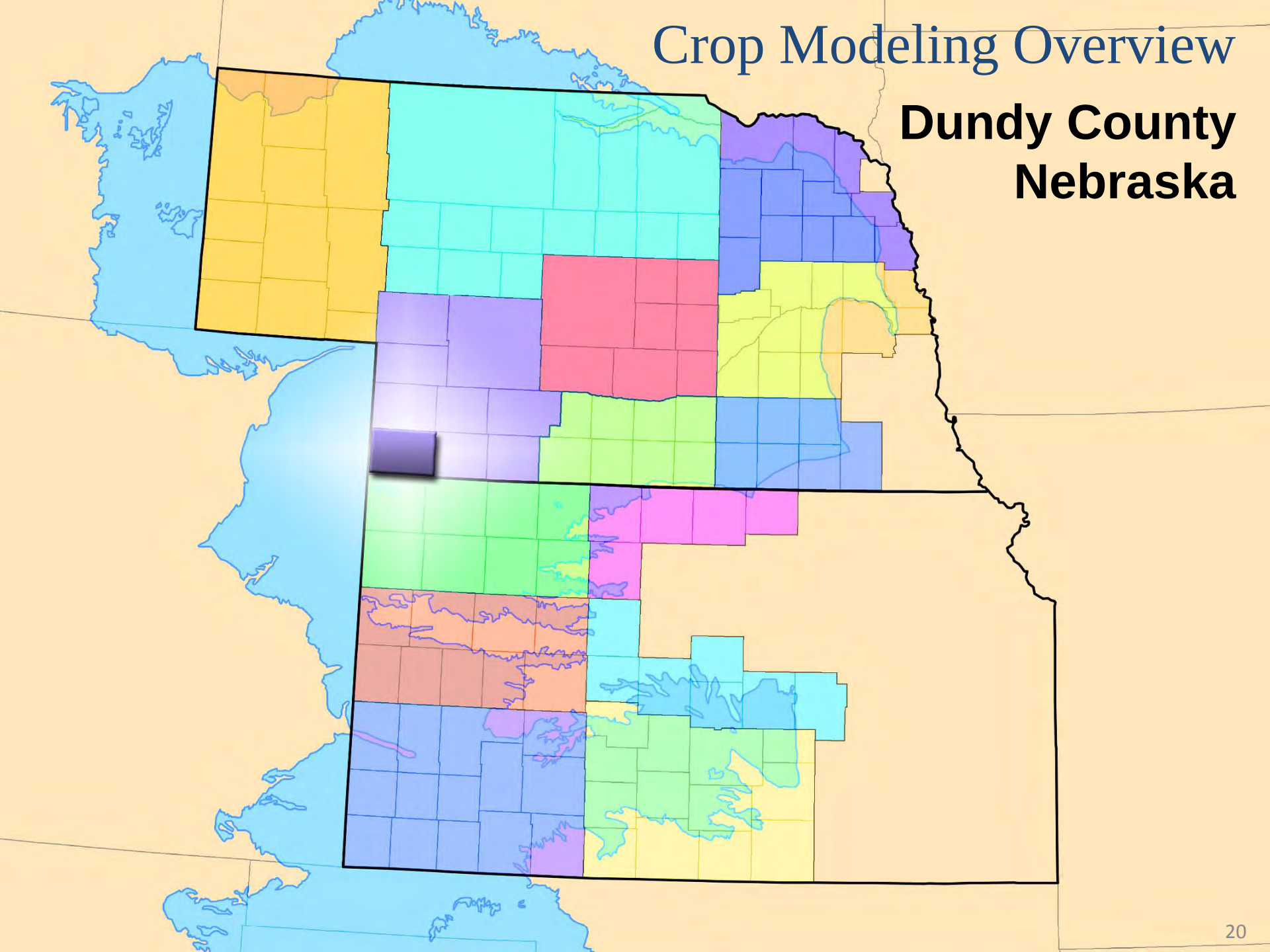
Crop Modeling Overview

14 Counties



Crop Modeling Overview

Dundy County Nebraska



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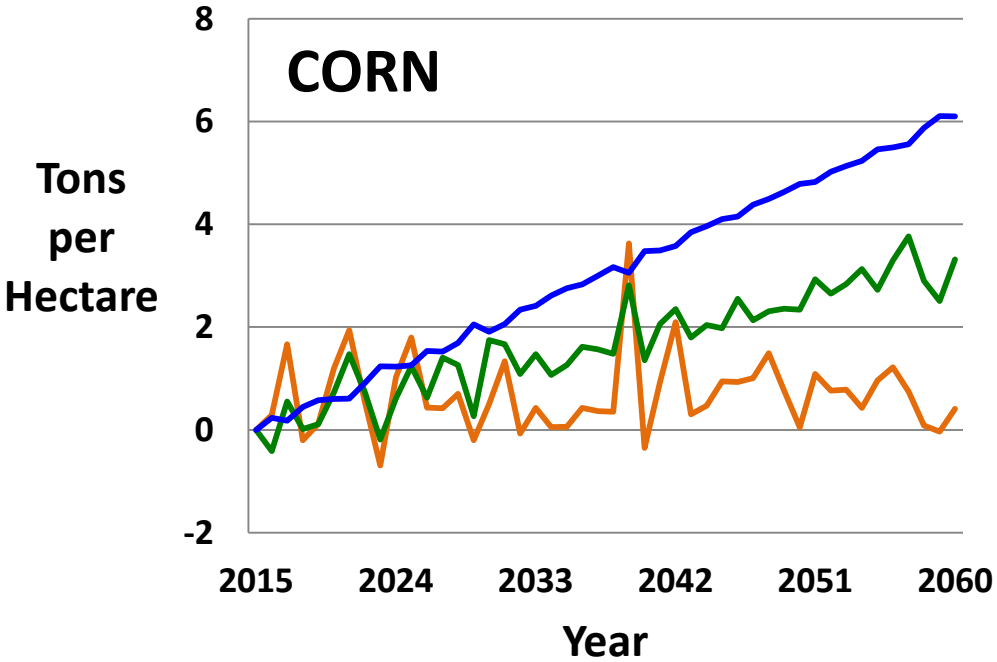

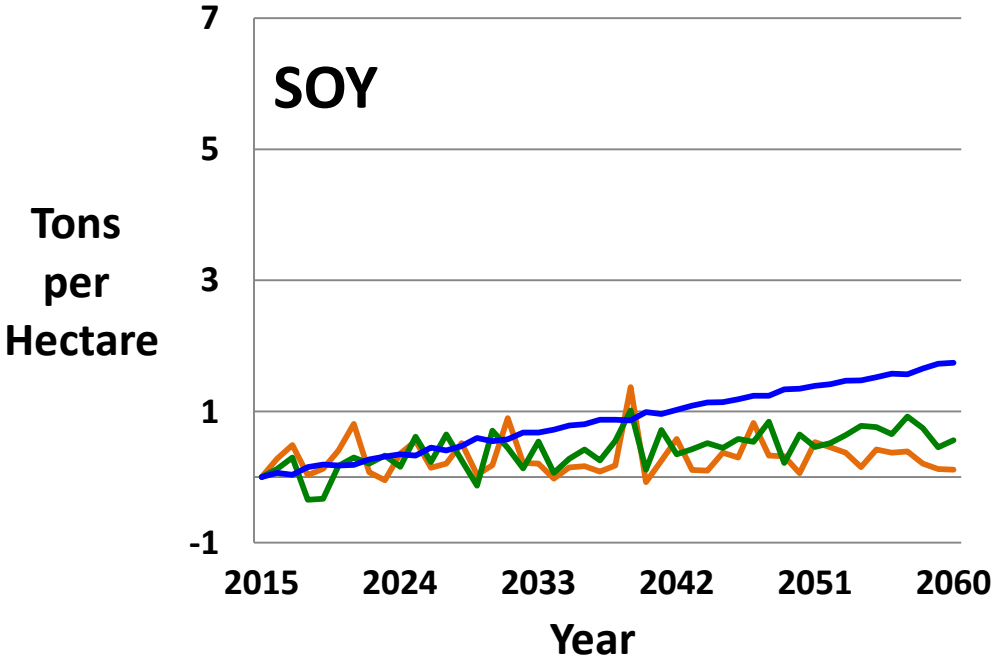

- Small downward trend due to climate impact alone
- It may be possible to overcome climate impact through agricultural innovation
- Conversion to dryland farming possible as groundwater resources decline
  - Corn yield reduced by 70%
  - Soy yield reduced by 43%
- Similar results found in all 14 representative counties

Dryland (climate impact only)
Dryland Projection
Irrigated Projection

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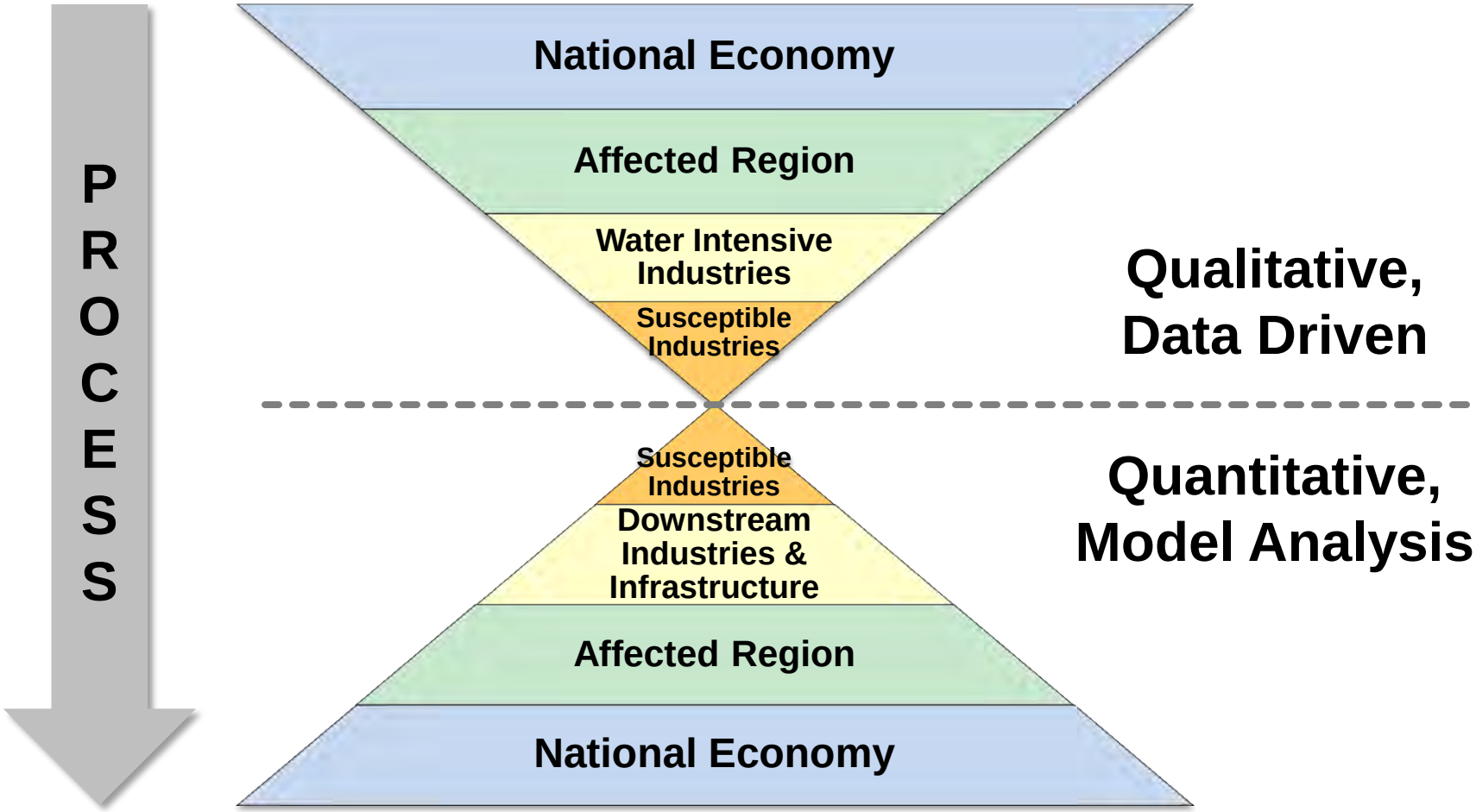
Economic Modeling



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Economic Model: Market Participation

PREVIOUS RESEARCH

- Characteristics contributing to exit in farm industry
- Farm and farm operator attributes:
  - Age of operator
  - Size of farm
  - Farm specialty
- Hoppe and Korb, 2006

NISAC RESEARCH

- Additional characteristics of concern for High Plains Aquifer:
  - Irrigation
  - Irrigation costs
- *Results: $1,000 increase in cost to pump corresponds to a 2.62% increase in the probability of exit

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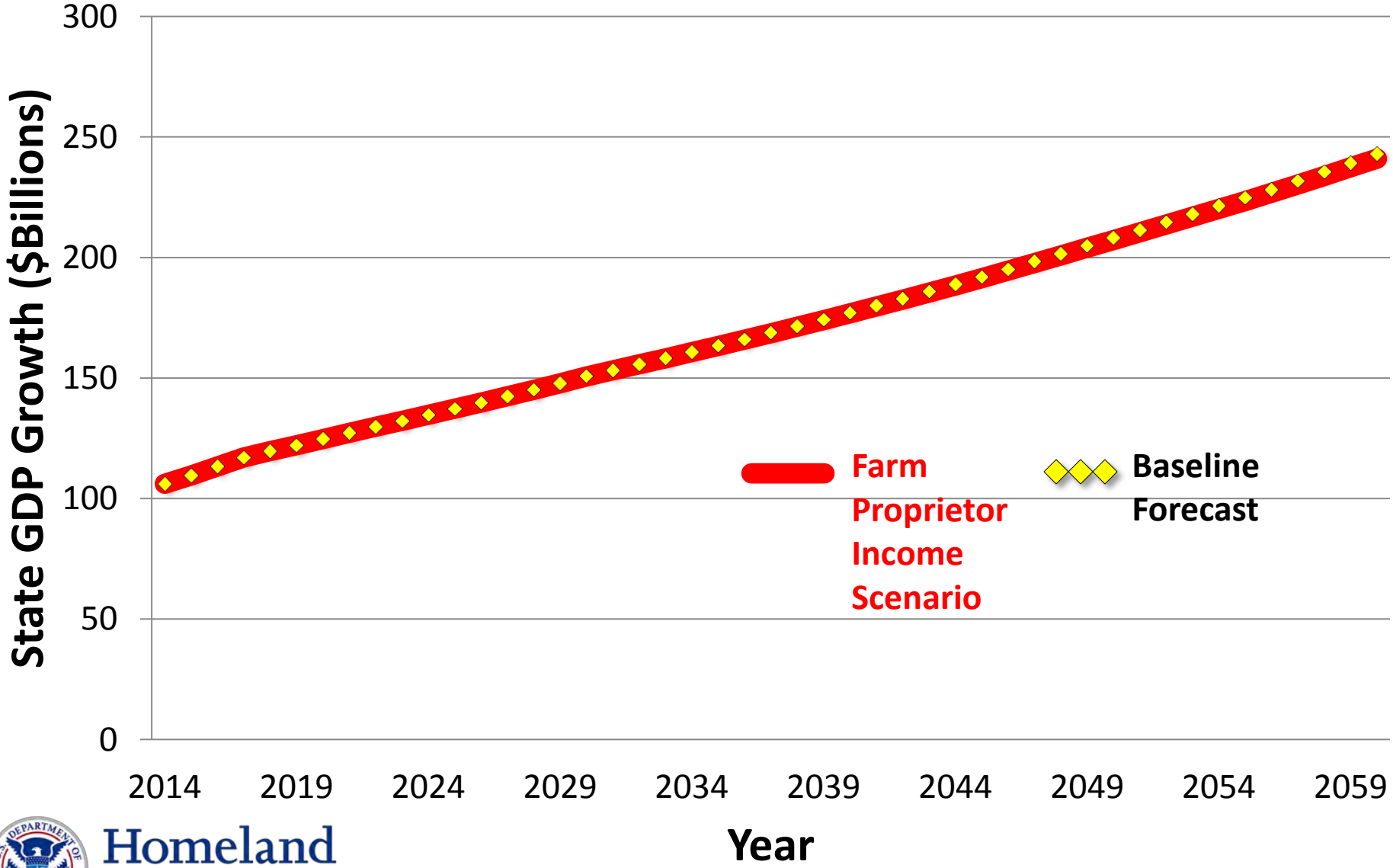
*Economic results are dependent on proprietary USDA data and cannot be used for regulation or legal procedures.

Nebraska: State GDP Growth Forecast



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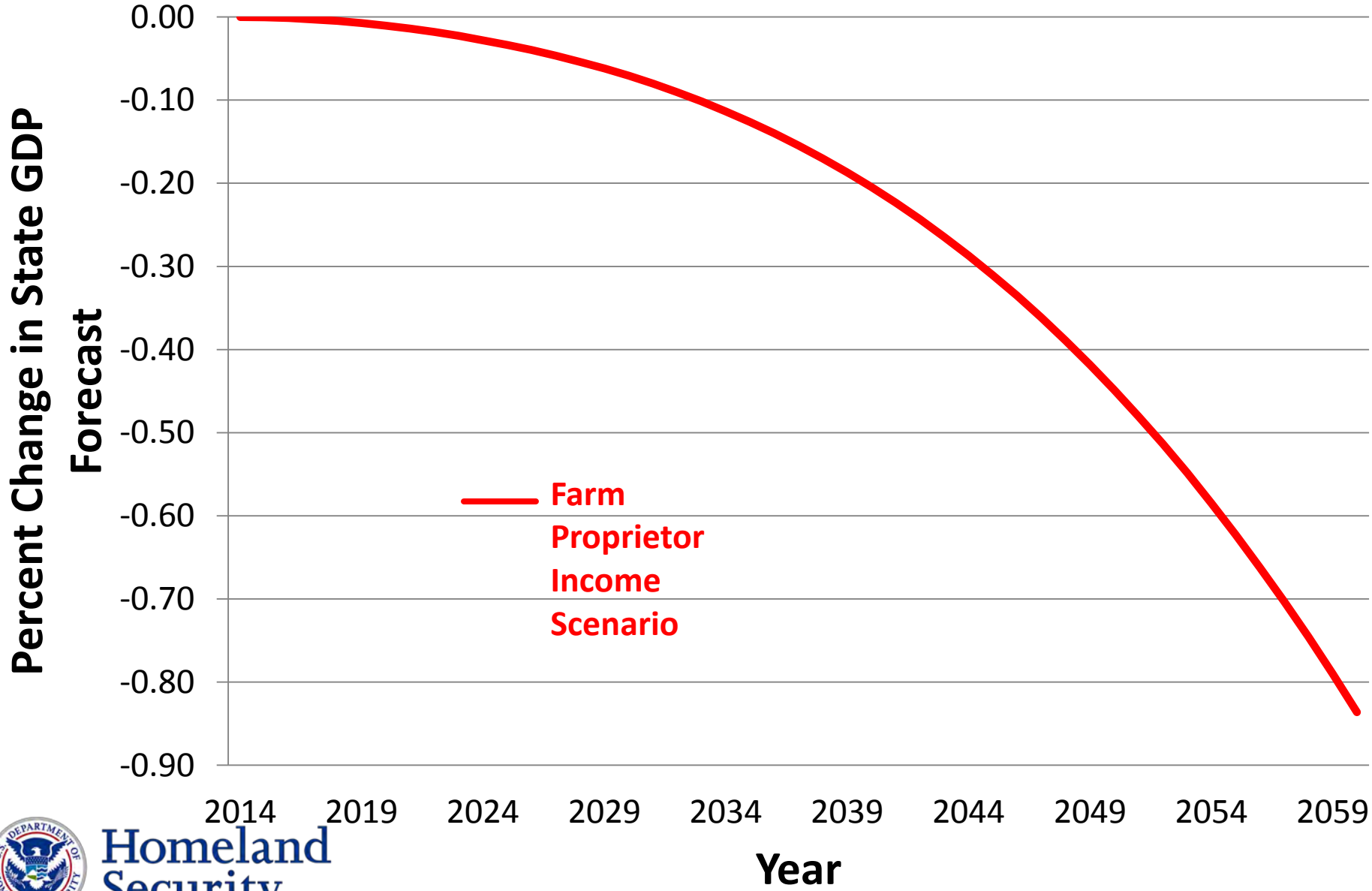
Macroeconomic Results: Nebraska



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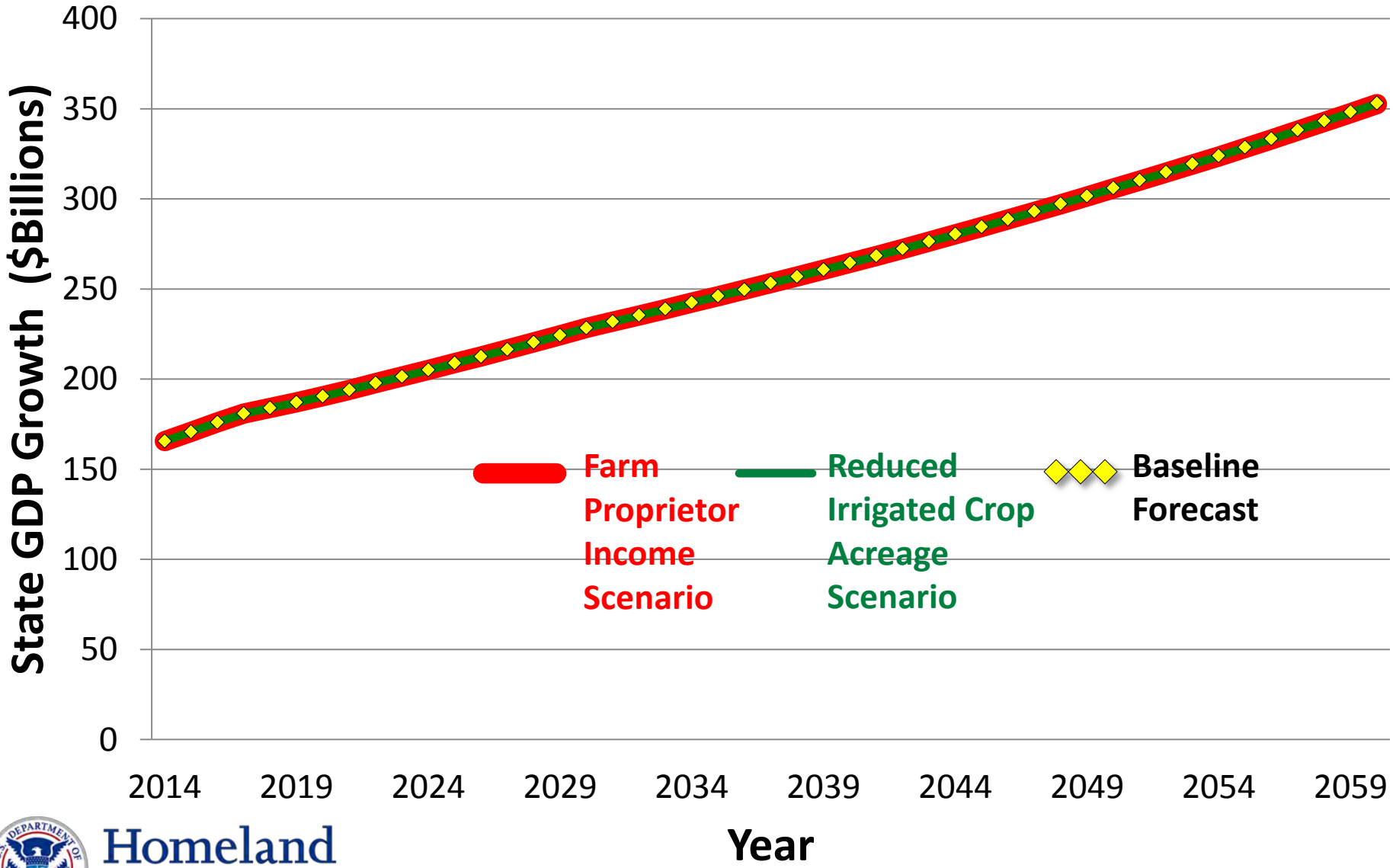
Kansas: State GDP Growth Forecast



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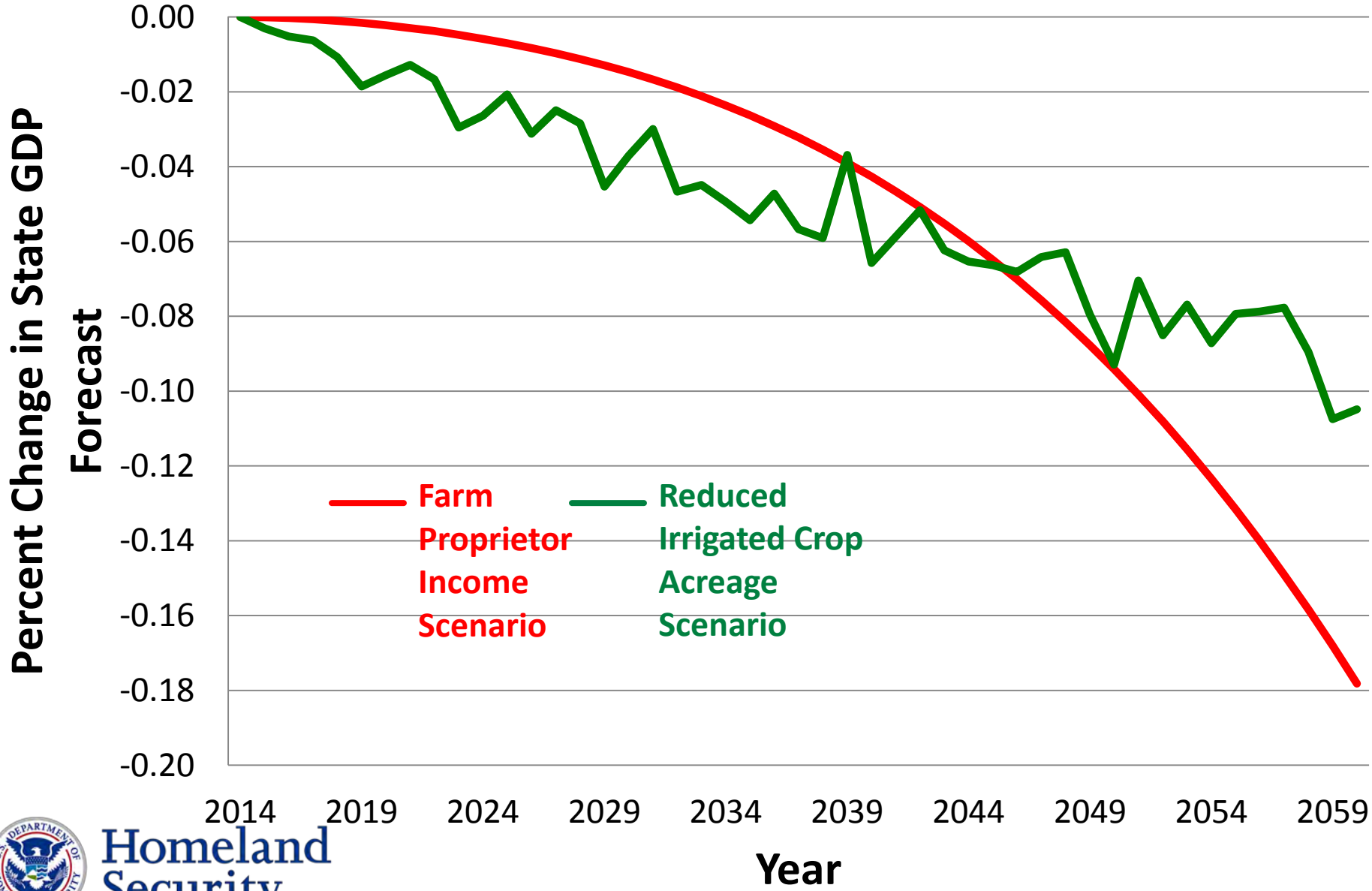
Macroeconomic Results: Kansas



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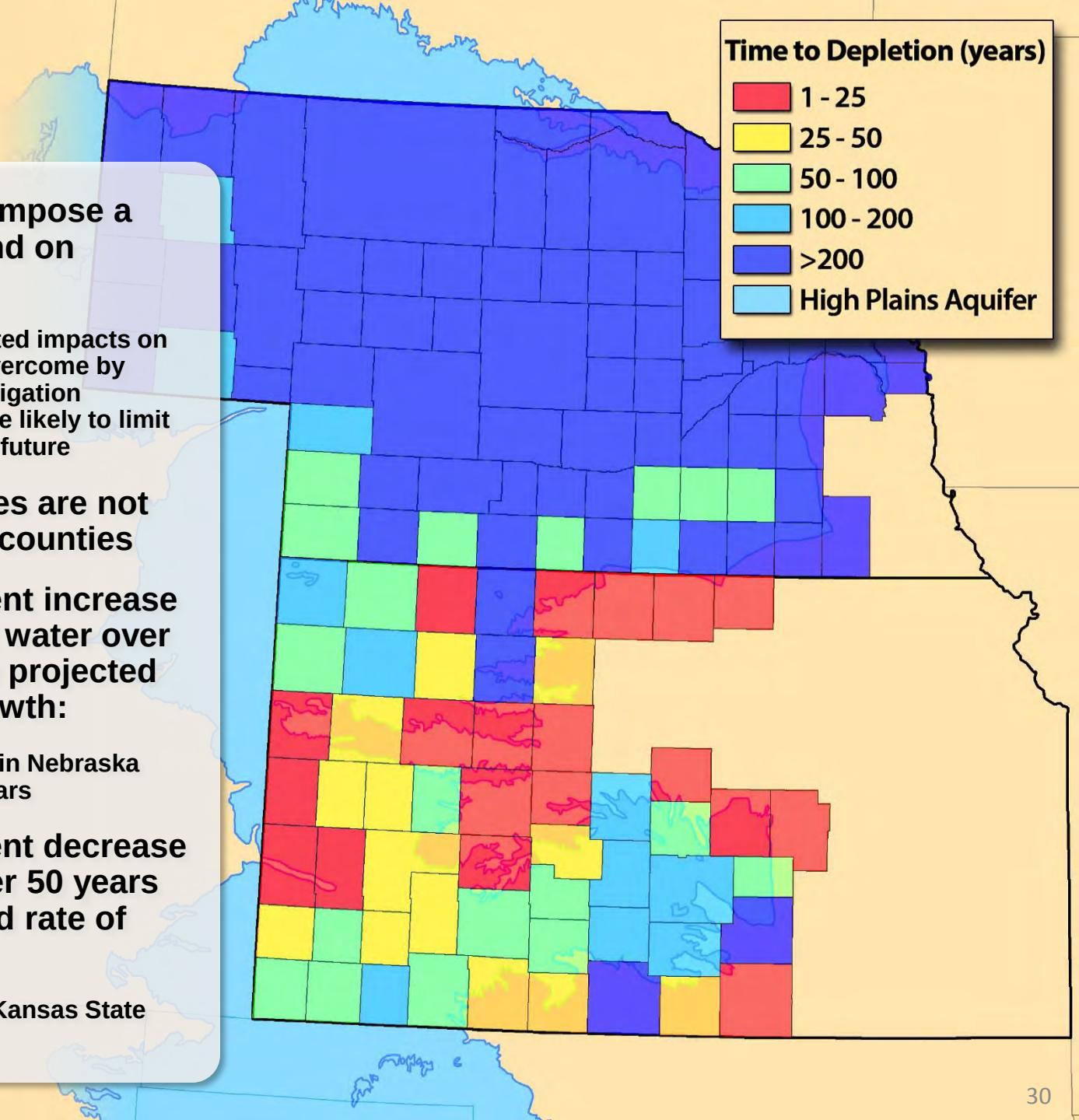
Summary

- **Climate projections impose a slight downward trend on dryland crop yields**
  - Historically, climate-related impacts on agriculture have been overcome by innovations including irrigation
  - Declining water levels are likely to limit such adjustments in the future
- **Current pumping rates are not sustainable in some counties**
- **Assuming a 25 percent increase in the cost to extract water over 50 years reduces the projected rate of economic growth:**
  - 0.8 percent decrease in Nebraska State GDP over 50 years
- **Assuming a 25 percent decrease in irrigated acres over 50 years reduces the projected rate of economic growth:**
  - 0.1 percent decrease in Kansas State GDP over 50 years



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For more information visit:
www.dhs.gov/criticalinfrastructure

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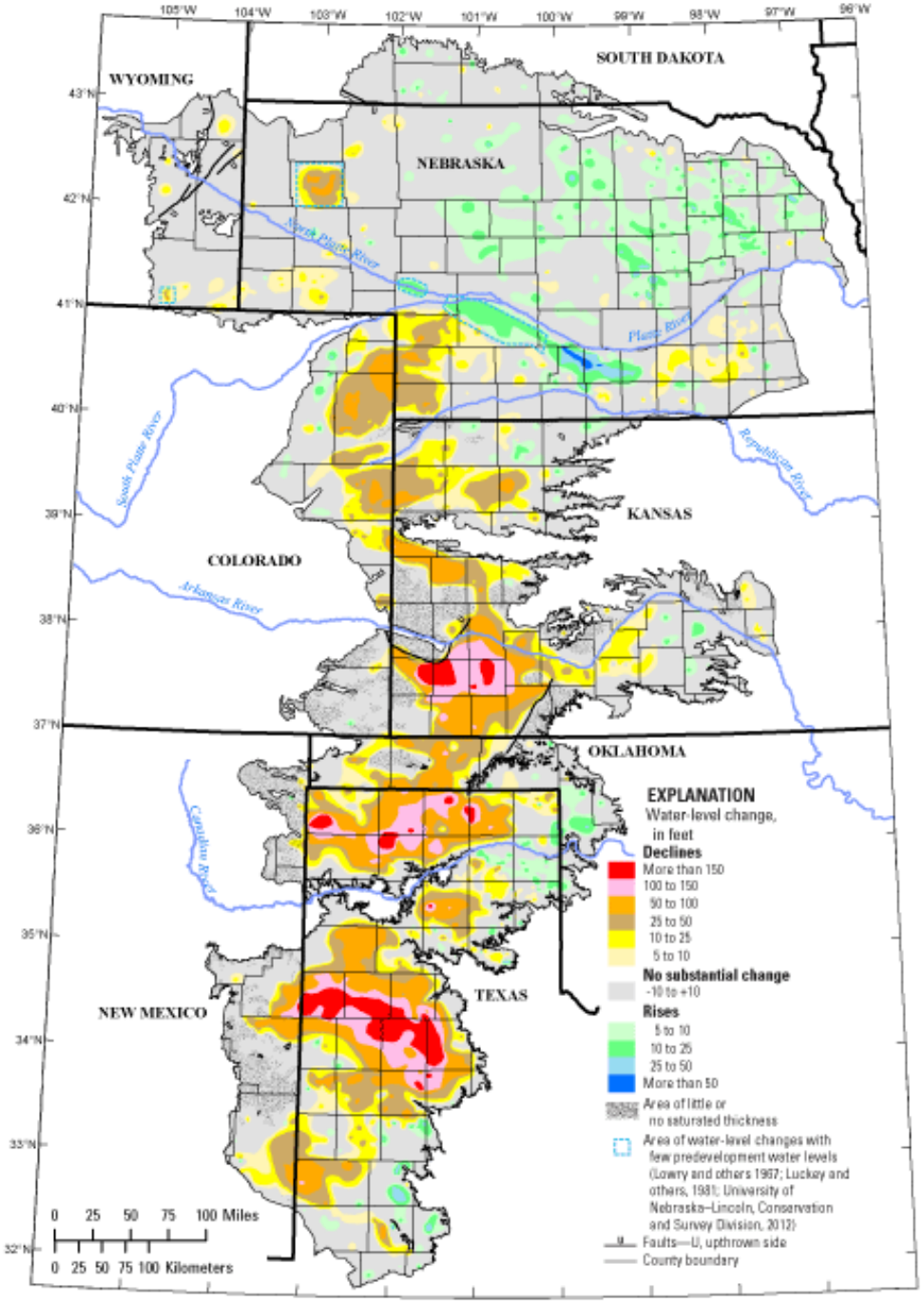
Groundwater Level Decline: Predevelopment to 2011 (USGS)



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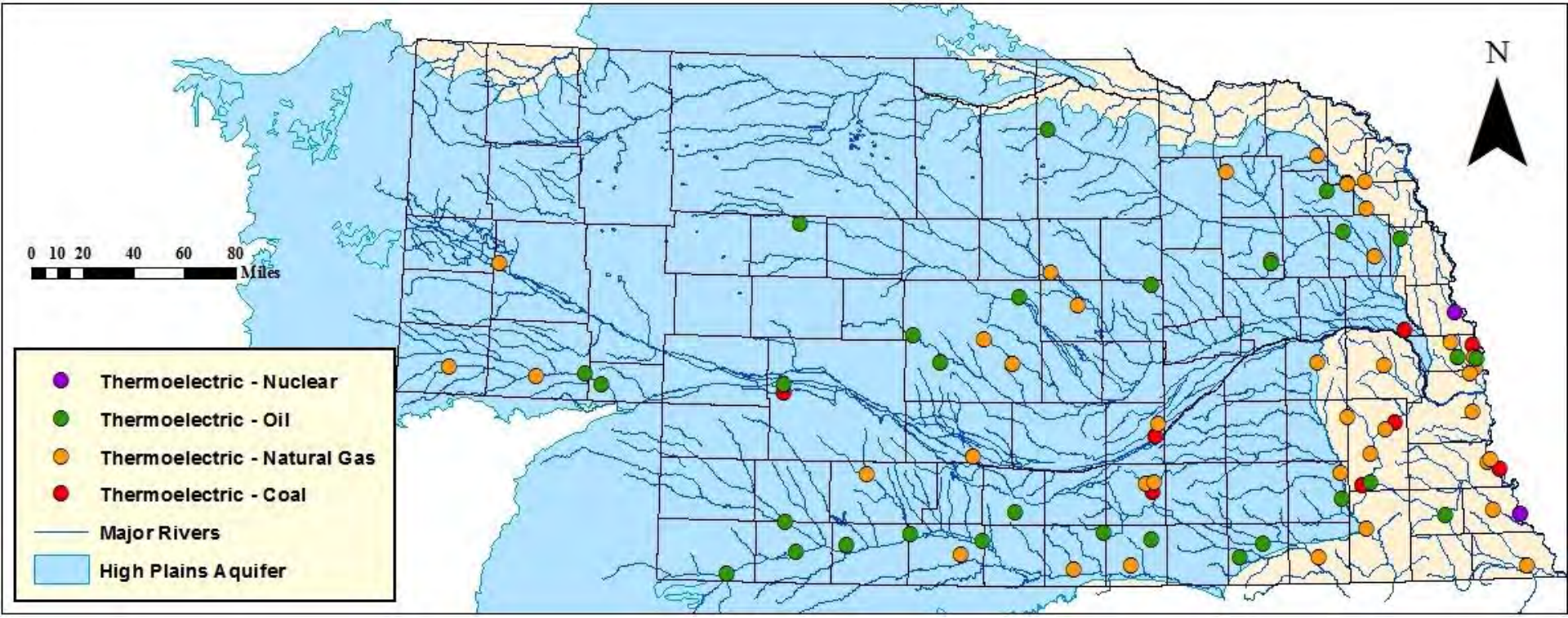
Nebraska Thermoelectric Power



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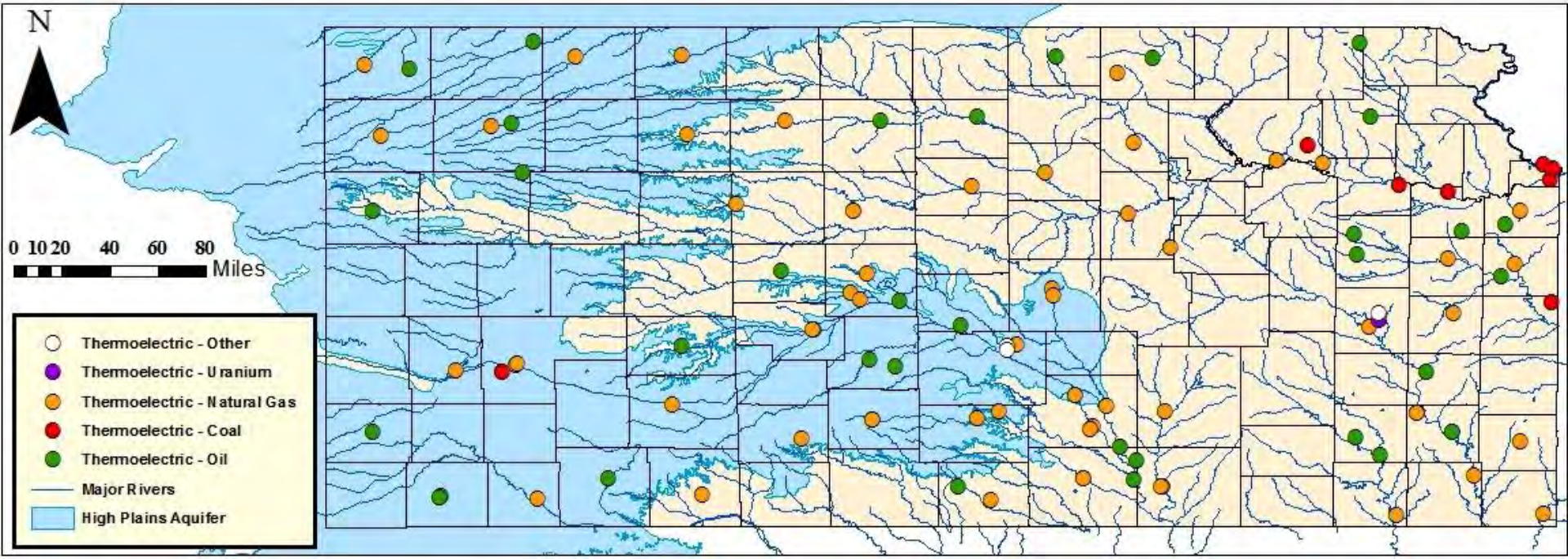
Kansas Thermoelectric Power



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Accomplishments to Date

- **Economic Modeling**
  - Used methodology for linking local, regional, and national economic impacts to critical infrastructure
  - Identified 2- and 3-digit North American Industry Classification Sectors by economic relevance
  - Performed qualitative assessment of water use intensity by industry sector
  - Began estimating when farm operations may exit the market
  - Worked on site at USDA-NASS to access critical farm operation economic data for the years 1982 to 2012

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Economics: Scenario Descriptions

- **Farm Proprietor Income Scenario**: *Decrease in market participation (farm exit)*
  - Micro-econometric empirical model estimates marginal effect of increased utility (energy) costs on farm exit
  - Combined with hypothetical increases in utility expenditures
    - Separately estimates effects of utility cost increases of 25%, 50%, and 75%

- **Reduced Irrigated Crop Acreage Scenario**: *Decrease in farm output (irrigated acreage)*
  - Estimates expected change in agricultural industry output associated with reduction in percentage of irrigated acreage for corn, soybeans, winter wheat, and sorghum
  - Per-acre difference in yield associated with switching from irrigation to dryland is calculated from the crop modeling portion of analysis
  - Exogenous decrease in irrigated acreage by 25%, 50%, and 75%
    - Assumes non-irrigated acreage increases by corresponding amount

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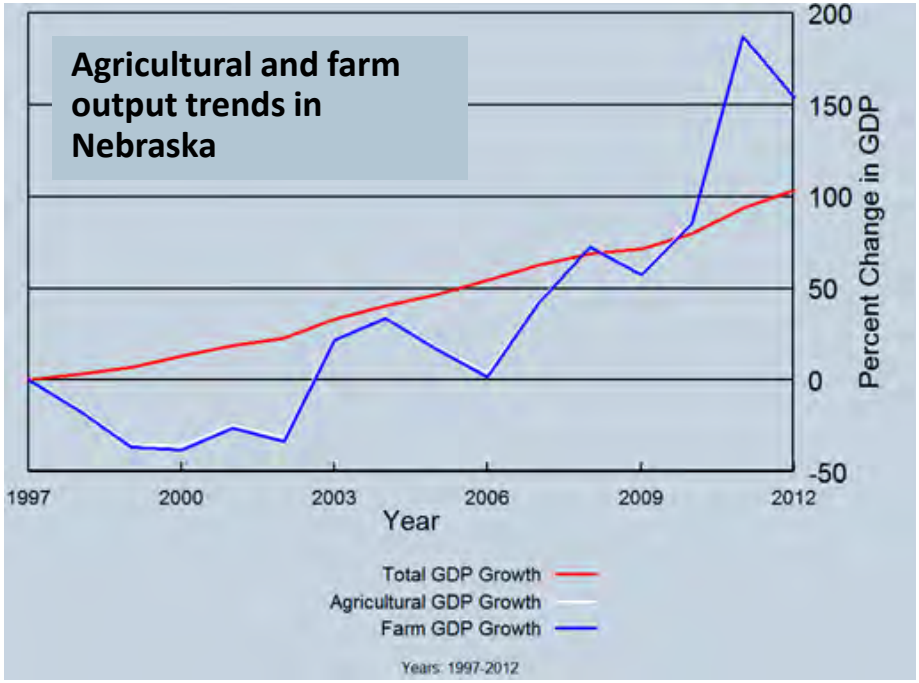
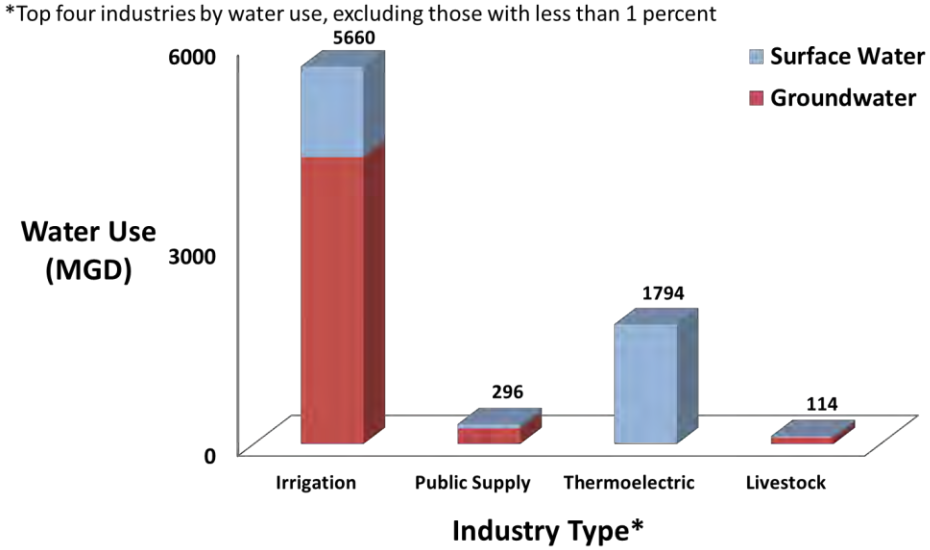
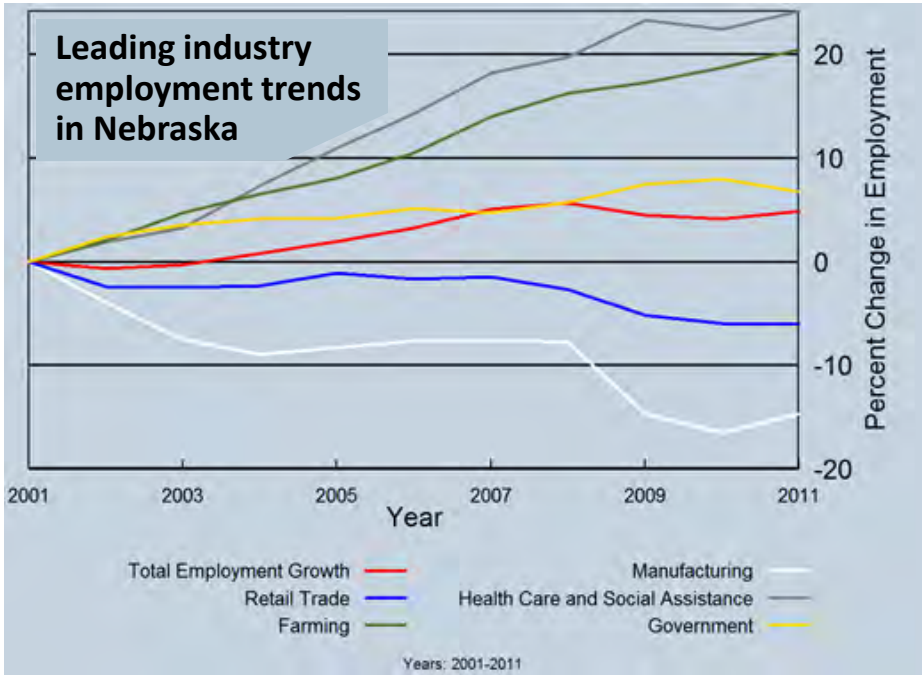
Qualitative Results: Nebraska







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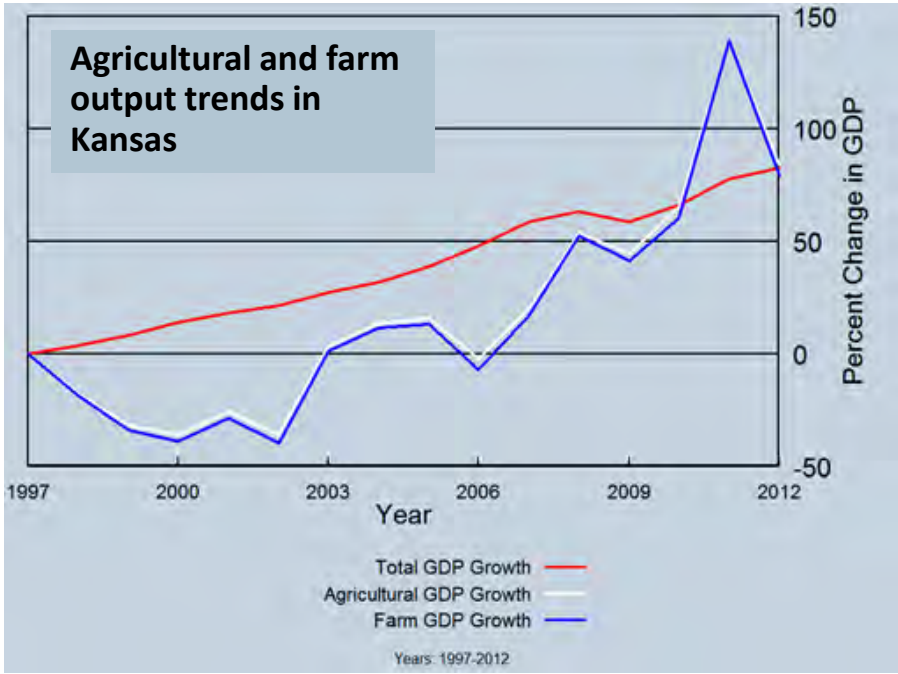
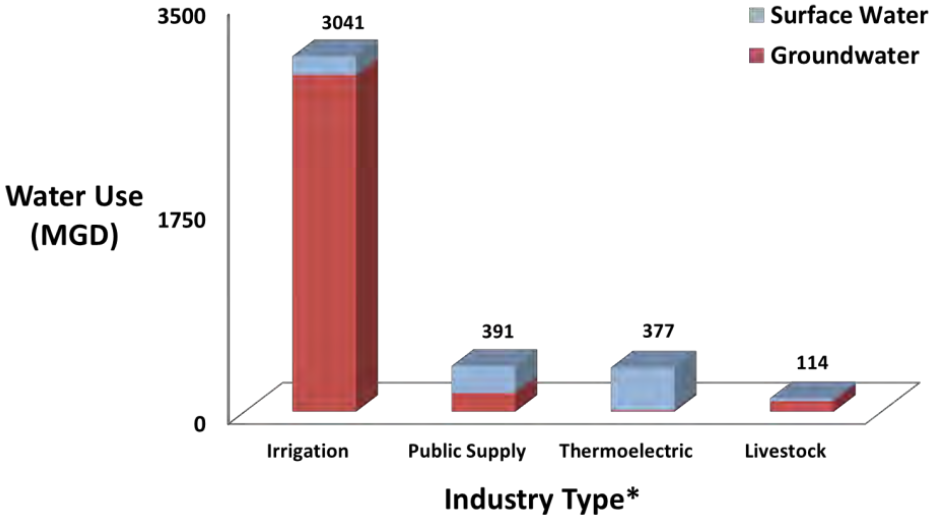
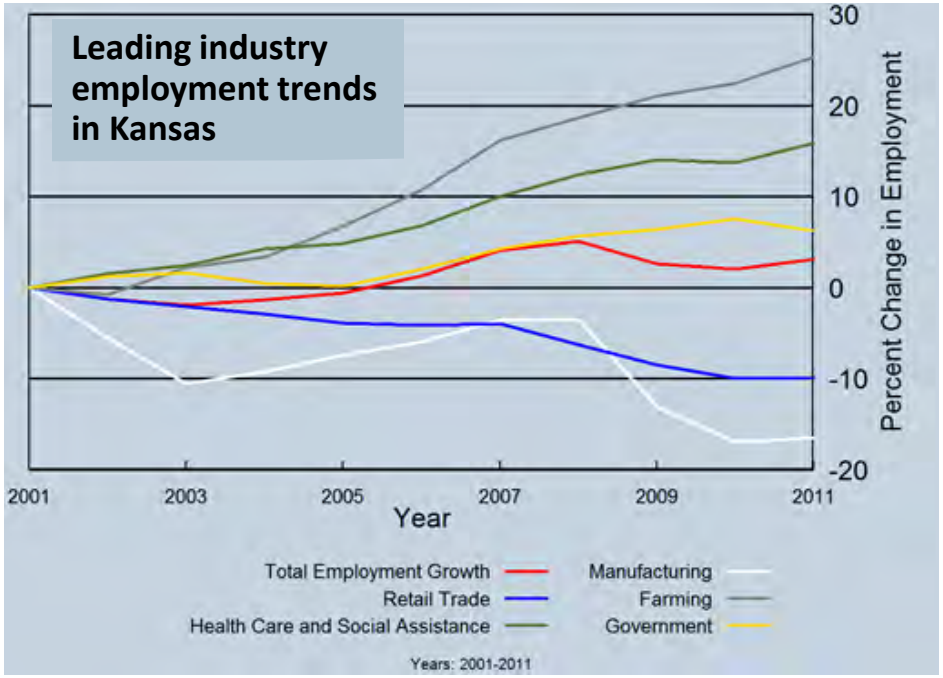
Qualitative Results: Kansas



*Top four industries by water use, excluding those with less than 1 percent





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Census of Agriculture Data

- Data from surveys starting with 1982 to 2012
  - Data from 1978 is available but limited, observations are missing
  - Transition from Census to the USDA and the paper to electronic transition
- Starting with the 2002-2012 Survey
  - 37 Sections, 158 questions
- The 1982-1997 Survey contained more questions and sections
- Ogallala County Data
  - 308,126 observations representing 76,057 unique farm operations
- Farm Characteristics Evaluated (summary representation)
  - Year farm operation began
  - Total value of production
  - Type of operation
    - Beef or hog, Crop for grain, or cash crops
  - Expenditure on fuels and oil
  - Expenditure on utilities
  - Loans received
  - Irrigated land harvested
  - Total acres harvested
  - Cattle by weight or dairy
  - Hours worked off farm

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Methodology and Mathematical Model

- A random effects logistical regression model is used to estimate annual exit probabilities for farm operations
  - Random effects approach accounts for variability in longitudinal data for of single farm operation
    - Longitudinal data have the potential to bias the results
    - Random-effects error term corrects the bias
  - The probability of firm exit is estimated using a logistic regression model
    - The annual probability of exit is a vector of farm- and time-specific water costs and farm operation and farm-operator characteristics

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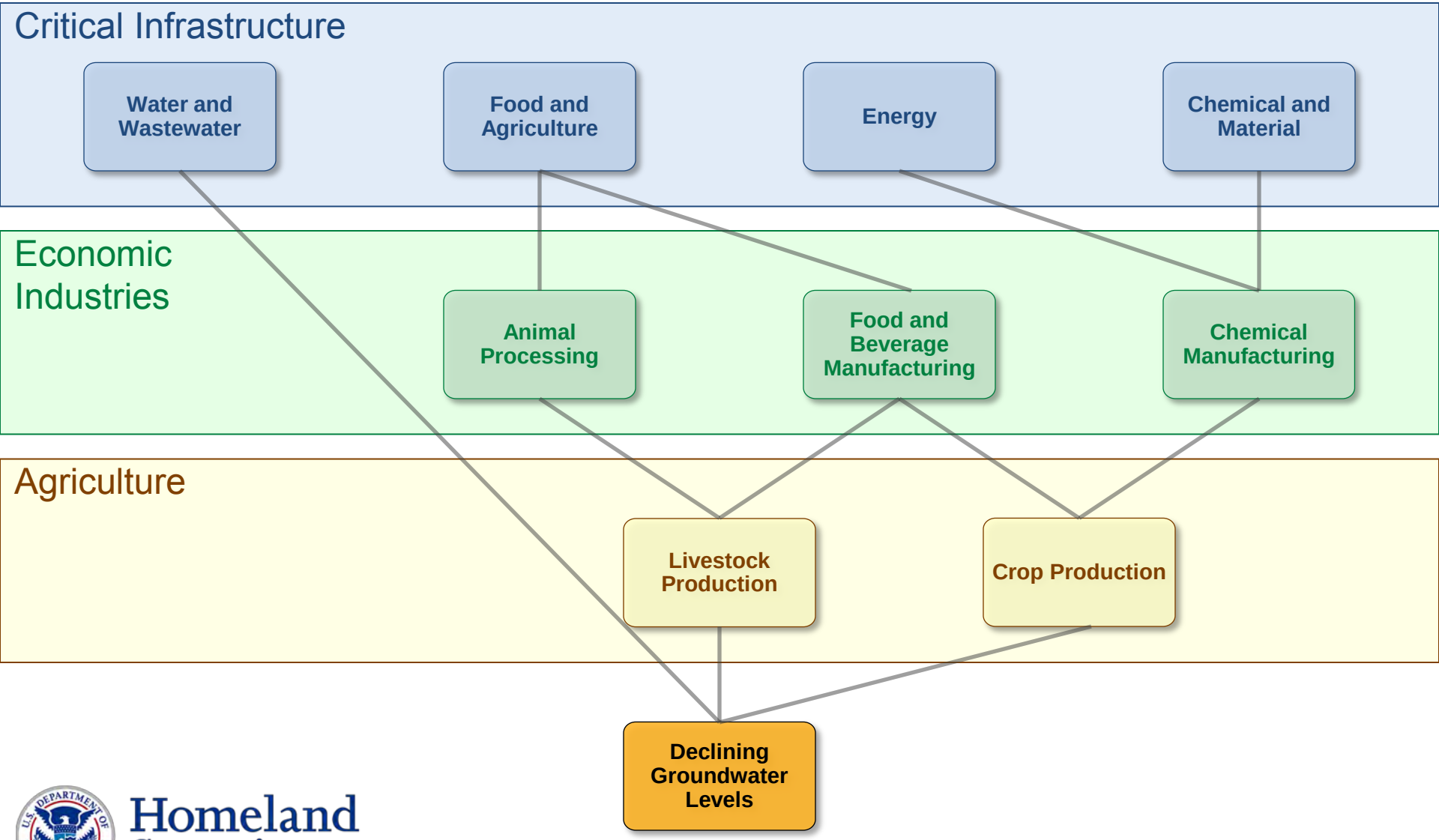
Determinants of Farm Exit

Variable	1	2
Ogallala County (Reference: Not Located on aquifer)	-0.1212***	-0.3413***
	(0.0273)	(0.0379)
Irrigated Crops	-0.5668***	-1.5625***
	(0.035)	(0.0374)
Irrigated Pasture	-0.4128***	-0.1656***
	(0.0318)	(0.0427)
Irrigated Crops x Cashcrops Specialty		1.5138***
		(0.0168)
Irrigated Pasture x Beef Speciality		0.1790***
		(0.0174)
Irrigated Pasture x Dairy Specialty		-0.5654***
		(0.0353)
Utility Expenditures ($1,000s)	0.0012***	0.00245***
	(0.0003)	(0.00028)
Fuel & Oil Expenditure ($1,000s)	-0.0009***	-0.00357***
	(0.0003)	(0.00035)
Variable	**1**	**2**
Sales Class (Reference: Less than $1,000)		
$1,000 to $9,999	-0.2060***	-0.1710***
	(0.0268)	(0.0277)
$10,000 to $49,999	-0.2881***	-0.3401***
	(0.028)	(0.029)
$50,000 to $99,999	-0.6188***	-0.7746***
	(0.0324)	(0.0335)
$100,000 to $249,999	-0.8580***	-1.0882***
	(0.0306)	(0.0317)
More than $250,000	-0.8346***	-0.8573***
	(0.0296)	(0.0309)
Days Worked Off Farm (Reference: 0 to 199)		
200 Days or More	-0.4434***	-0.4217***
	(0.0263)	(0.0272)
Variable	**1**	**2**
Specialty		
Beef	0.1251***	-0.3839***
	(0.0437)	(0.0489)
Hogs	-1.2363***	-1.5115***
	(0.0433)	(0.0516)
Cash Crops	-0.5932***	-1.4573***
	(0.0666)	(0.0691)
Dairy	-1.7336***	-1.8377***
	(0.0599)	(0.0671)
Variable	**1**	**2**
Year (Reference: 2012)		
1987	5.6906***	6.5521***
	(0.134)	(0.2143)
1992	4.9921***	5.8703***
	(0.0292)	(0.0315)
1997	4.5424***	5.4544***
	(0.0293)	(0.0315)
2002	3.8844***	4.4959***
	(0.0274)	(0.0292)
2007	5.0851***	5.1644***
	(0.0252)	(0.0252)
Constant	-1.4448***	-1.2885***
	(0.1941)	(0.2004)
Observations	234,142	234,142

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Relationships



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Improved Integrated Assessment for Strategic Planning

Challenges	Hi-res Data	Spatial Scale	Timescale
Solutions	Early stakeholder engagement	Requires non-standard assumptions	Variant model and data needs
Future Work	Detailed and unique data requests	Improved linkages between models	Improved model functionality

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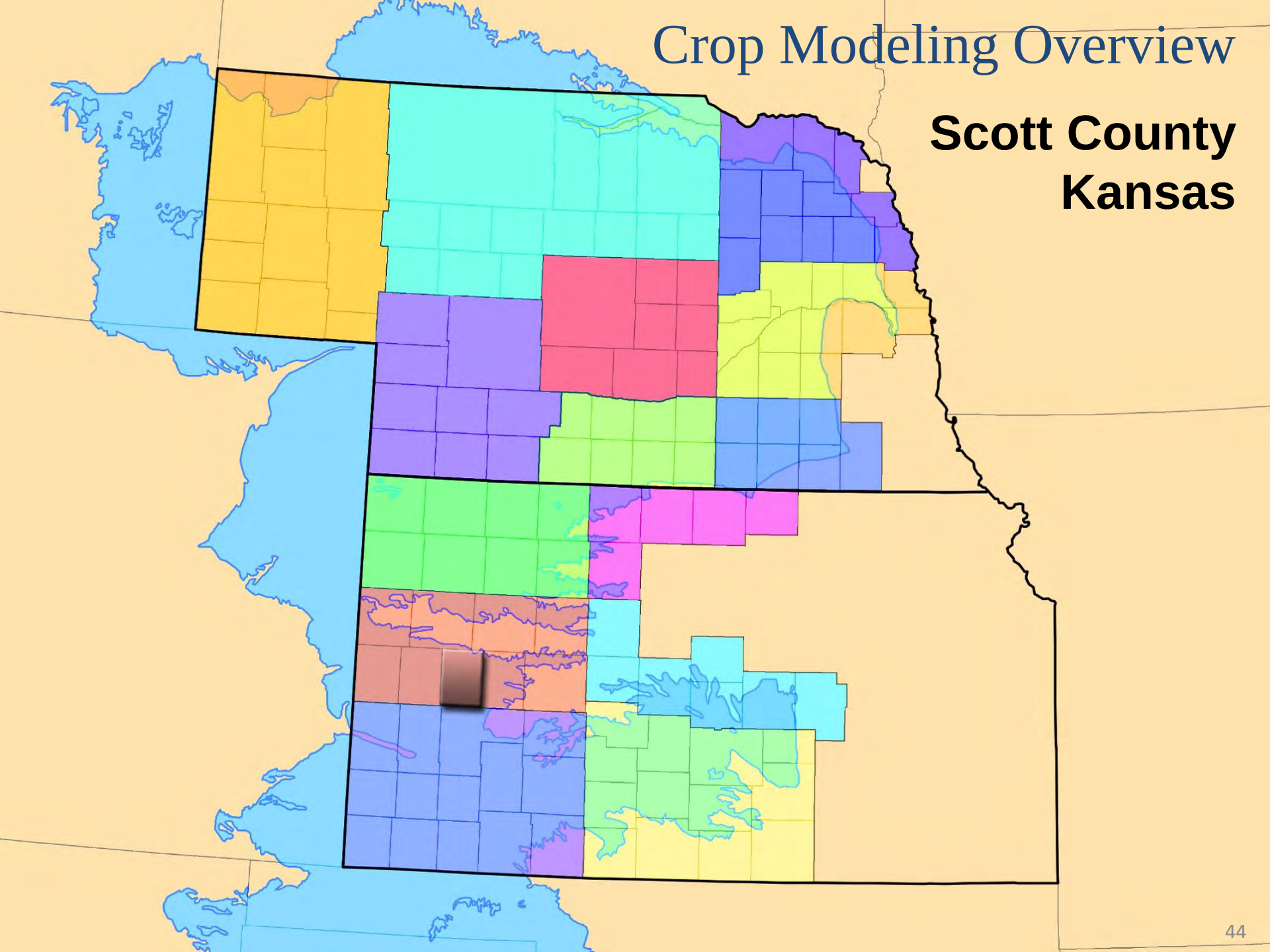
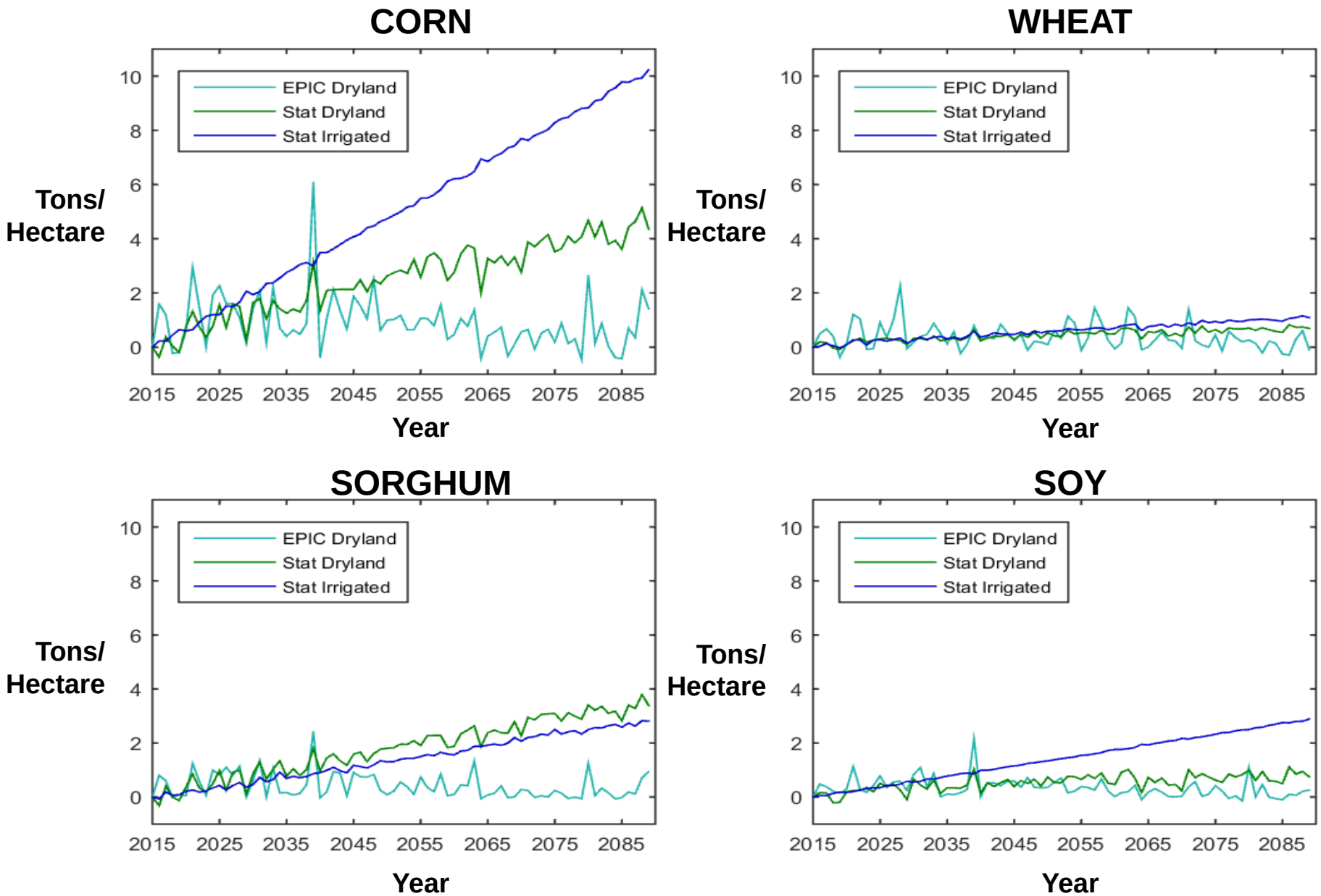
Crop Modeling Overview

Scott County Kansas



Scott County, Kansas

Crop Modeling Overview



Value

- Results provide an integrated view of potential impacts of climate on the economy and critical infrastructure of High Plains region.

- Analysis provides:
  - Most vulnerable sectors of the economy,
  - Estimate of the potential degree of impact on
    - the economy
    - job production
    - farm exit
    - critical infrastructure
  - Distinguishes state level impact as well as the resultant impact on the Nation

- Results inform mitigation and adaptive strategies to manage potential impacts of climate change and growing water stress in the High Plains region.

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