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Food Protection

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IFPTI Fellowship Cohort VII: Research Presentation

Justin McConaghy, M.S.

Oklahoma Weather Effects on *E. coli* in Surface Water and Produce Safety

Justin McConaghy, M.S.
IFPTI 2018-2019 Fellow
Oklahoma Dept. of Agriculture, Food, and Forestry

Background

Contaminated irrigation water is a known cause of introducing pathogens onto fresh produce.

Romaine lettuce outbreaks in April 2018 from Arizona and November 2018 from California

Surface water is most susceptible for contamination.

Background

- FSMA Produce Safety Rule attempts to reduce outbreaks by required water testing and statistical analysis.
- Water sources with generic *Escherichia coli (E. coli)* cfu higher than 126 GM or 410 STV require corrective measures.
- Corrective measures can be a water treatment system or waiting on a die-off prior to harvest.
- Highly debated part of the Produce Safety Rule.

Background

Oklahoma Water Resources Board

- Over 10,000 water tests in summer months between 2001 and 2015
- Tested for generic *E. coli*
- Locations marked by GPS

Oklahoma Water Survey

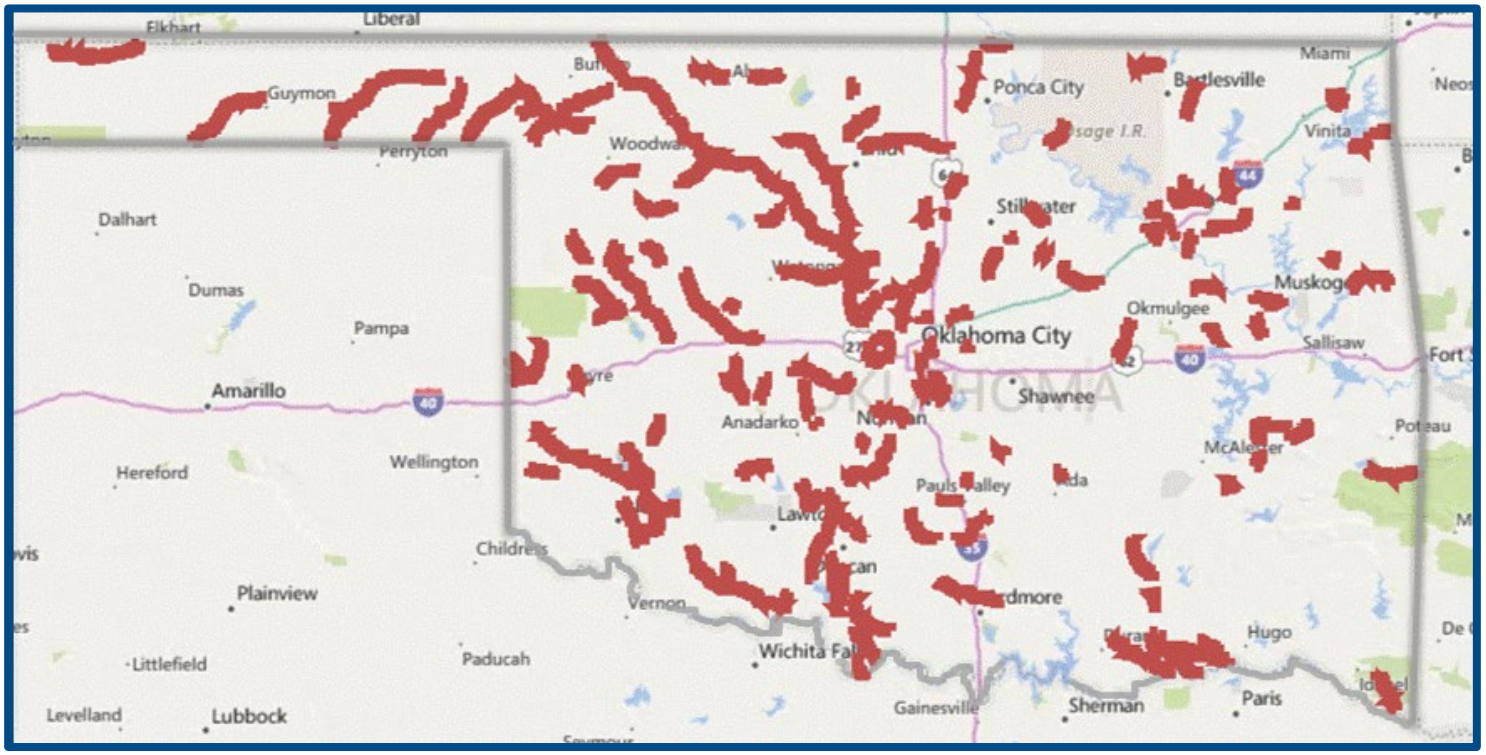
- 25 test sites with 10 tests from each site
- Randomly taken in summer months of 2018
- Tested for generic *E. coli* and marked by GPS

Background

- Section 303(d) of the Clean Water Act
  - States biannually create a 303(d) list of impaired bodies of water for the EPA
  - 154 bodies of water are designated impaired by *E. coli* in Oklahoma
  - Curiously, no lakes in Oklahoma are 303(d) listed for *E. coli*

Background

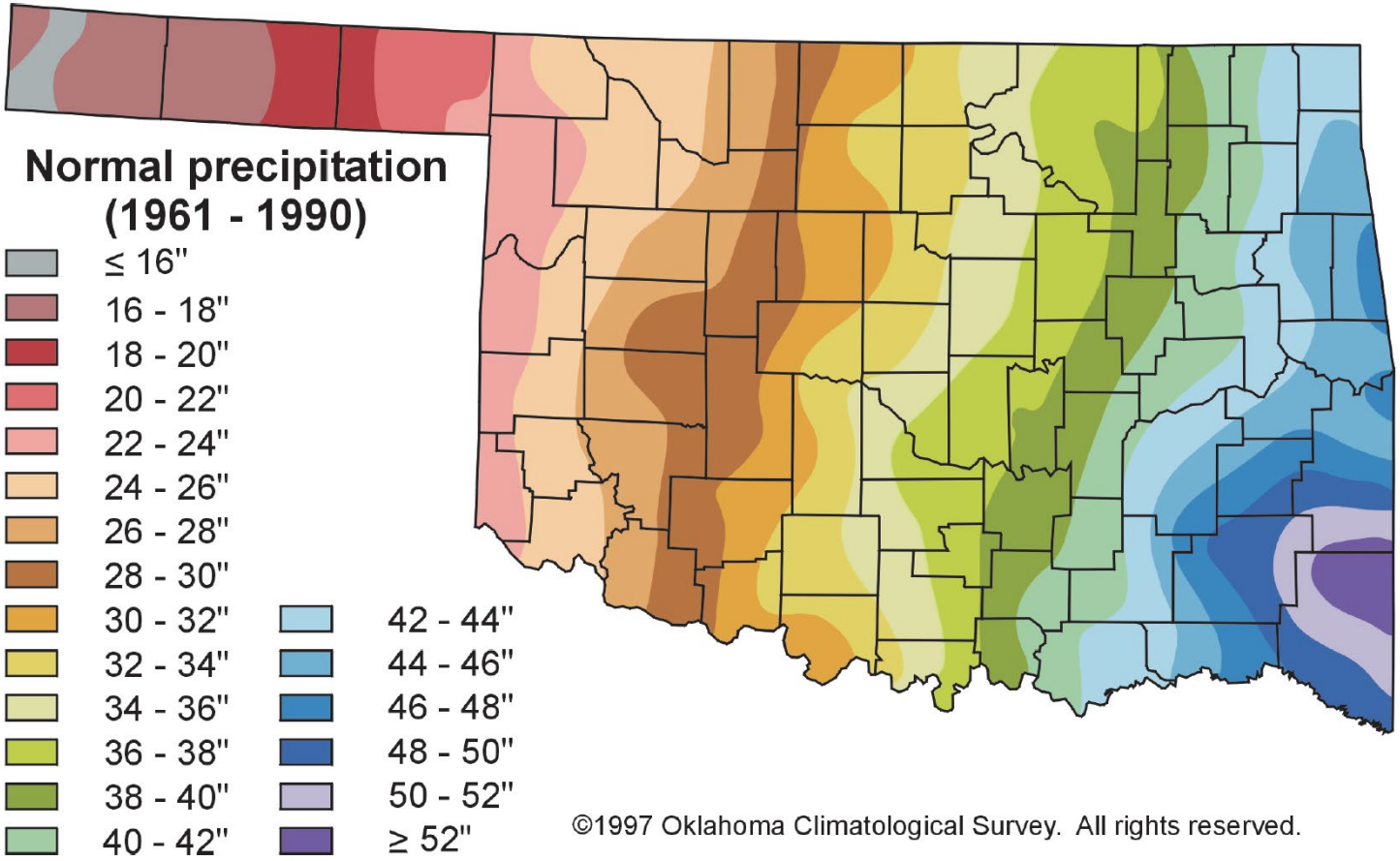
303(d) *E. Coli* impaired water bodies



Source: https://gis.deq.ok.gov/maps/

Background

Average Annual Rainfall



Source: OSU Factsheet E-993, "Oklahoma's Native Vegetation Types"

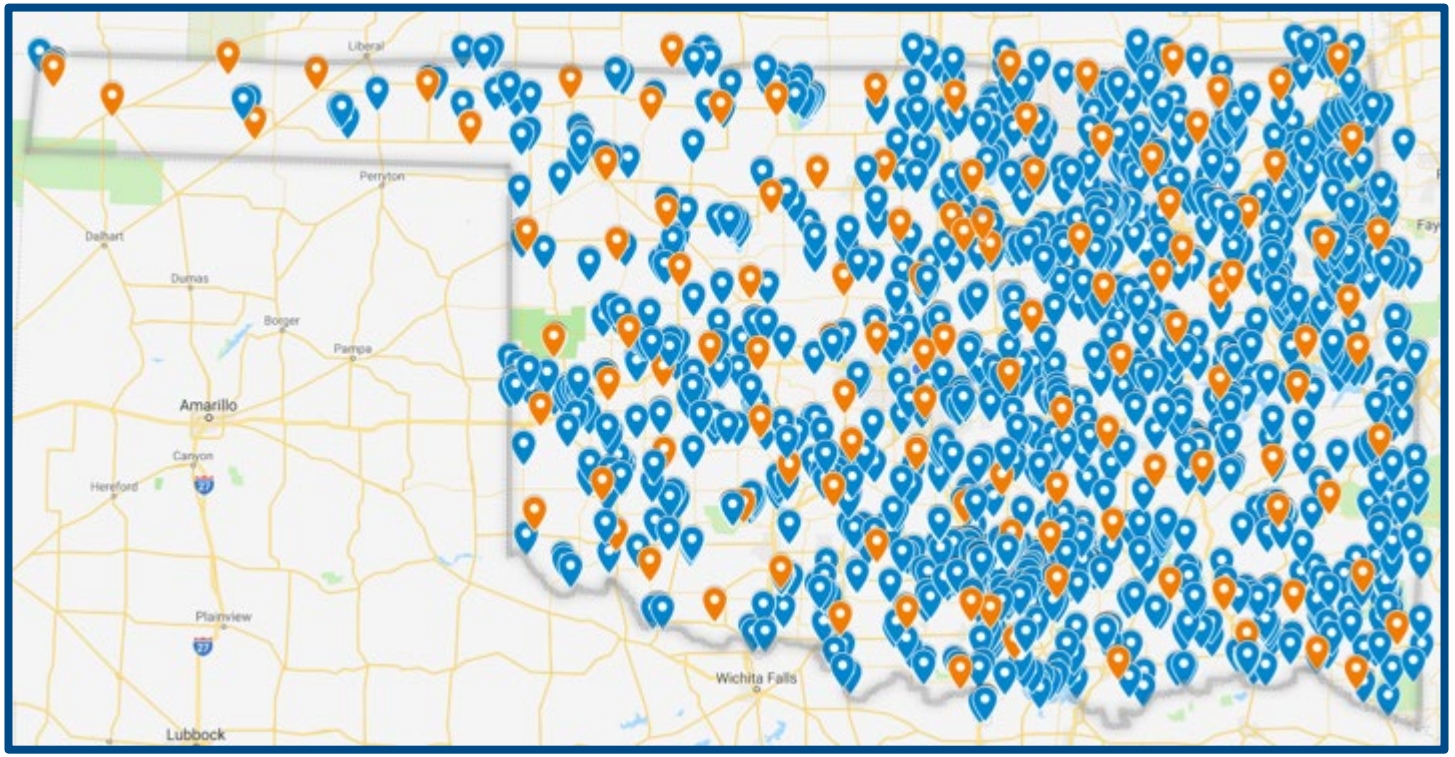
Background

- Oklahoma Mesonet
  - Started in 1994
  - 120 stations across the state
  - Monitors air temperature, soil temperature, rainfall, wind, solar radiation, soil moisture, barometric pressure, etc.

Image Source: www.mesonet.org

Background

- Mesonet sites
- Water test collection sites



Problem Statement

The relationship between weather events and *E. coli* load in surface waters in Oklahoma is unknown at this time.

Research Questions

1. What is the relationship between weather data and the water testing data?
2. Can the relationships found between weather data and water data provide useful guidance for farmers?
3. Is the method used in this project applicable to other states?

Methodology

- Match water test data with the dates and locations of nearest Mesonet weather data.
- Perform Pearson Correlation to determine linear correlation between the *E. coli* cfu and each independent variable.
- Variables included:
  - East or West side of the state
  - Stream or Lake
  - 17 daily weather data variables

Methodology

Daily weather variables:

Maximum Air Temperature	Minimum Air Temperature	Average Air Temperature
Maximum Wind Speed	Minimum Wind Speed	Average Wind Speed
Maximum Barometric Pressure	Minimum Barometric Pressure	Average Barometric Pressure
Total Solar Radiation	Inches of Rainfall	Maximum 5 minute rainfall rate
Soil Temperature 5 cm under sod	Dew Point	Average Humidity
Change in Barometric Pressure	Days since a Rain greater than 0.20 inches	

Methodology

Statistical significance was based on a P-value of 0.05 or less

- The lower the P-value, the more likely to have a false correlation

Strong correlation coefficients are numbers closer to +/-1

- Positive correlation means an increase in that variable results in an increase in *E. coli*
- Negative correlation means an increase in that variable results in a decrease in *E. coli*

Study Population

- Surface water data from the Oklahoma Water Resources Board on lakes and streams all over the state from 2001-2015
- Surface water data from the Oklahoma Water Survey in 2018
- All water samples were taken in the months of May through October
- Used only water data with 100 cfu or greater of *E. coli*, resulting in 2,036 samples

Results

- **Statewide Analysis**
  - Showed significance ($p<.05$) in Maximum Wind Speed, Maximum, Minimum, and Average Barometric Pressure, Total Solar Radiation, Rainfall, and Maximum 5 minute rainfall rate
  - All had very low correlations
  - Highest correlation was rainfall with a positive correlation of 0.1355 and $p<0.0001$

Results

- **East and West Analysis**
  - More arid western half of the state had no significant variables
  - Eastern half of the state had many significant variables
    - Only Minimum Wind Speed, all Barometric Pressure measurements, and Dew Point not significant
  - Highest correlation in the East was in Rainfall (0.24366), Solar Radiation (-0.14666), and Maximum 5 minute rainfall rate (0.14579) all with $p<0.0001$

Results

- **Stream and Lake Analysis**
  - Streams had several significant but very low correlations (under 0.1)
  - Rainfall was highest correlated variable (0.16479) in the streams
  - Lakes had Change in Barometric Pressure (0.17128) and Average Humidity (-0.19623) as the only significant variables
  - A greater change in barometric pressure could signify a storm occurring, increasing the wake.

Results

- **Individual Site Analysis**
  - 24 individual sites with 20 or more samples were analyzed individually
  - Six sites had no significant correlations
  - Remaining sites had some highly correlated coefficients (±0.4 to ±0.9), but the significant variables differed by each site
  - Rainfall and Maximum 5 minute rainfall rate were the most common significant variables with 7 sites all positively correlated

Conclusions

- Statewide recommendation on monitoring certain weather factors is not advisable.
- A farm could monitor individual sites to determine what weather factors affect their individual water supplies.
- The differences between East and West show that using weather as a guidance may be more feasible in Eastern states.
- Rainfall was the most common and highest correlated weather variable throughout the study.

Recommendations

1. Farmers could keep weather records to determine if their water sources are affected by the weather.

2. Further research should be conducted on how weather may affect small ponds and irrigation canals.

3. Further research should also be conducted to determine why Oklahoma's man-made lakes are not impaired by *E. coli*.

Acknowledgements

- Oklahoma Water Resources Board
- Oklahoma Mesonet
- Oklahoma Water Survey
- Dr. James Enderby Bidlack, Professor of Biology at the University of Central Oklahoma
- Bryan Buchwald, Oklahoma Department of Agriculture, Food, and Forestry
- IFPTI Fellowship staff and mentors

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Questions?

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Supporting Information Table of Contents

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Individual Correlation Examples

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Correlation Coefficients

	Beaver River 1	Beaver River 3	Big Cabin Creek	Black Bear Creek	Blue River	Brushy Creek
MAXTEMP	0.07898	0.23421	-0.40185	0.07726	-0.5154	-0.18276
MINTEMP	0.12809	0.11893	-0.18709	-0.40528	-0.36166	-0.21098
AVGTEMP	0.14201	0.21905	-0.28718	-0.16492	-0.49306	-0.42534
WINDMAX	-0.30798	-0.49331	0.63286	-0.32503	0.26888	0.63136
WINDMIN	-0.21062	-0.05984	0.01484	-0.16086	-0.23815	-0.02347
WINDAVG	-0.30882	-0.31799	0.20075	-0.24307	0.03714	0.076
PRESSMAX	-0.07699	0.55765	0.06524	0.28663	0.29036	0.02503
PRESSMIN	-0.03915	0.58449	-0.1785	0.35424	0.20544	0.02276
PRESSAVG	-0.06332	0.58888	-0.01788	0.31725	0.25708	0.04798
PRESSCHG	-0.15589	-0.32207	0.57492	-0.19444	0.16519	0.00799
TOTSOL	0.21749	0.15822	-0.48977	-0.09903	-0.22408	-0.55477
RAIN	-0.05408	-0.30174	0.92785	-0.2114	0.6644	0.78182
MAXFIVE	-0.04911	-0.31575	0.89297	-0.15344	0.64609	0.60301
SOILTEMP	0.09289	0.27508	-0.17761	-0.23737	-0.32012	0.33586
DEWPNT	0.32938	-0.25293	0.00295	-0.36848	0.05955	0.02933
HUMAVG	0.11596	-0.10705	0.42327	-0.39074	0.46401	0.40011
RAINDEL	-0.11614	-0.0077	-0.38777	0.74218	-0.15421	-0.42677

Green highlight indicates statistically significant (p<0.05)

Overall Coefficients and P-values

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	MAXTEMP		MINTEMP		AVGTEMP		WINDMAX		WINDMIN		WINDAVG	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Overall	-0.00586	0.1385	-0.01183	0.3305	-0.03941	0.0781	0.08641	0.8837	-0.30809	0.4148	0.01168	0.5084
East	-0.1347	0.0001	-0.07794	0.8737	-0.17155	0.0001	0.19643	0.8837	-0.87173	0.1993	0.07985	0.814
West	0.01656	0.048	0.00409	0.5269	0.01222	0.6902	0.03848	0.3871	-0.0587	0.0976	-0.01178	0.4768
Stream	-0.05355	0.0284	-0.0148	0.2811	-0.05392	0.0223	0.07021	0.8834	-0.20587	0.4923	0.01581	0.2743
Lake	0.17529	0.1158	0.00226	0.9845	0.09503	0.2198	-0.025	0.7529	0.03948	0.6182	0.01231	0.7286
	PRESSMAX		PRESSMIN		PRESSAVG		PRESSCHG		TOTSOL		RAIN	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Overall	-0.04908	0.0271	0.04871	0.8737	-0.04871	0.0181	0.01454	0.4949	-0.04987	0.0182	0.15555	<.0001
East	-0.03117	0.2474	0.04865	0.3281	-0.0396	0.2103	0.06185	0.8579	-0.19866	<.0001	0.21486	<.0001
West	-0.05912	0.0534	-0.05486	0.8018	-0.05712	0.0584	-0.01894	0.5361	0.03668	0.3961	0.01268	0.2809
Stream	-0.04817	0.0959	0.04984	0.8113	-0.04817	0.097	0.01849	0.4761	-0.08119	0.0077	0.16479	<.0001
Lake	0.10586	0.1886	0.06856	0.2875	0.08848	0.2643	0.17528	0.8269	0.15694	0.0163	-0.83963	0.7537
	MAXFIVE		SOILTEMP		DEWPNT		HUMAVG		RAINDEL			
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value		
Overall	0.07496	0.0886	-0.01278	0.3816	-0.03571	0.128	0.02259	0.3086	-0.30963	0.188		
East	0.31579	<.0001	-0.11898	0.8002	-0.04153	0.3514	0.11245	0.8805	-0.18064	0.0015		
West	0.03182	0.477	0.00386	0.3761	-0.02496	0.4171	0.01969	0.3235	0.00028	0.9992		
Stream	0.08809	0.0881	-0.0138	0.3066	-0.03911	0.1198	0.03886	0.3116	-0.08809	0.0987		
Lake	0.80402	0.9577	0.15701	0.8538	-0.0686	0.3948	-0.39623	0.8135	0.12153	0.1132		

Green highlight indicates statistically significant (p<0.05)

Livestock Concentrations

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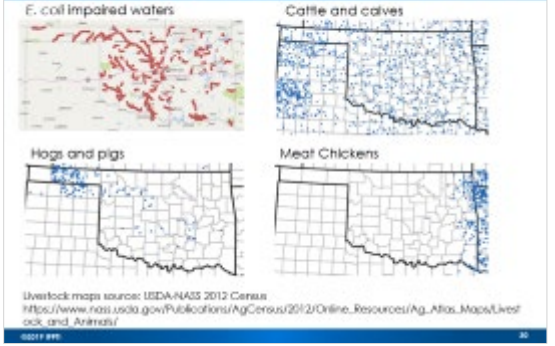

Livestock maps source: USDA-NASS 2012 Census
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Other Research

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- Research by Whitman and Nevers (2008) at the recreational beaches of Lake Michigan has shown:
  - *E. coli* count fluctuations were simultaneous in time at neighboring beaches
  - *E. coli* concentrations are more closely correlated for beaches that are more closely located
  - Julian day, wave height, and barometric pressure explained up to 40% of the variation in *E. coli* concentration

Vegetation and Precipitation

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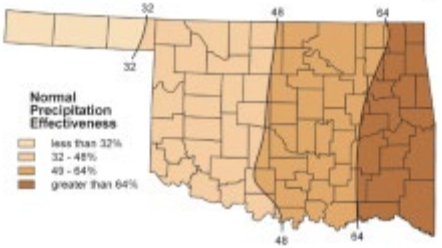
Precipitation Effectiveness (Precip/Evap in 24h)



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RAINDEL	-0.11614	-0.0077	-0.38777	0.74218	-0.35421	-0.42677

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Overall Coefficients and P-values

	MAXTEMP		MINTEMP		AVGTEMP		WINDMAX		WINDMIN		WINDAVG	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Overall	-0.03586	0.1065	-0.02163	0.3305	-0.03941	0.0761	0.06641	0.0027	-0.01809	0.4148	0.02168	0.3284
East	-0.1247	0.0001	-0.07794	0.0157	-0.12135	0.0002	0.10942	0.0007	0.02773	0.3893	0.07985	0.013
West	0.01616	0.598	0.01939	0.5269	0.01222	0.6902	0.03948	0.1971	-0.0507	0.0976	-0.02178	0.4768
Stream	-0.05365	0.0204	-0.0249	0.2821	-0.05292	0.0222	0.07021	0.0024	-0.01587	0.4923	0.02501	0.2792
Lake	0.12523	0.1158	0.00156	0.9845	0.09603	0.2286	0.025	0.7529	0.03946	0.6192	0.02232	0.7786
	PRESSMAX		PRESSMIN		PRESSAVG		PRESSCHG		TOTSOL		RAIN	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Overall	-0.04908	0.0271	-0.05021	0.0237	-0.04871	0.0283	0.01514	0.4949	-0.04987	0.0282	0.13555	<.0001
East	-0.03737	0.2474	-0.04915	0.1281	-0.0396	0.2202	0.06105	0.0579	-0.14666	<.0001	0.24366	<.0001
West	-0.05912	0.0534	-0.05696	0.0628	-0.05772	0.0594	-0.01894	0.5362	0.02669	0.3961	0.03268	0.2869
Stream	-0.04857	0.0359	-0.04984	0.0313	-0.04827	0.037	0.01669	0.4702	-0.06319	0.0077	0.16479	<.0001
Lake	0.10386	0.1898	0.06856	0.3875	0.08848	0.2643	0.17128	0.0298	0.15634	0.0513	-0.02913	0.7137
	MAXFIVE		SODTEMP		DEWPNT		HUMAVG		RAINDEL			
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value		
Overall	0.07591	0.0006	-0.01278	0.5855	-0.03571	0.109	0.02219	0.3186	-0.02953	0.183		
East	0.14579	<.0001	-0.12698	0.0002	-0.04533	0.1614	0.11245	0.0005	-0.10204	0.0015		
West	0.02182	0.477	0.04366	0.1761	-0.02496	0.4171	-0.01965	0.5225	0.00026	0.9932		
Stream	0.08829	0.0001	-0.0249	0.3065	-0.03551	0.1259	0.03686	0.1116	-0.03909	0.0907		
Lake	0.00422	0.9577	0.16701	0.0538	-0.0686	0.3948	-0.19623	0.0135	0.12533	0.1132		

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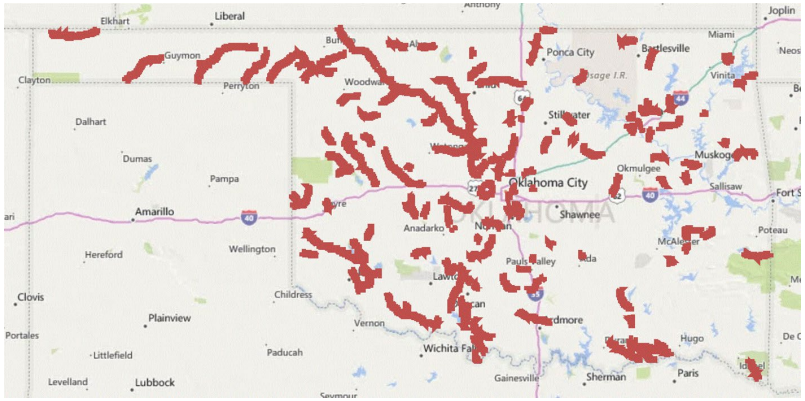
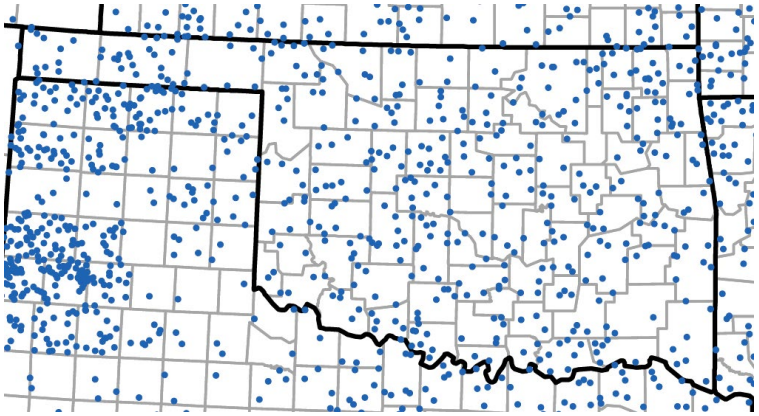
Livestock Concentrations

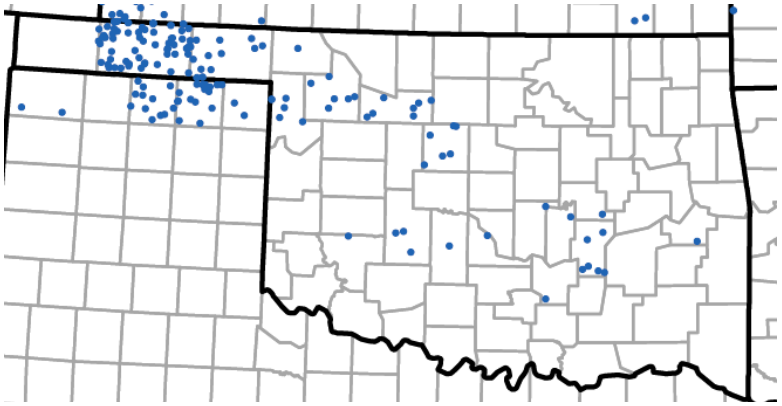
E. coli impaired waters



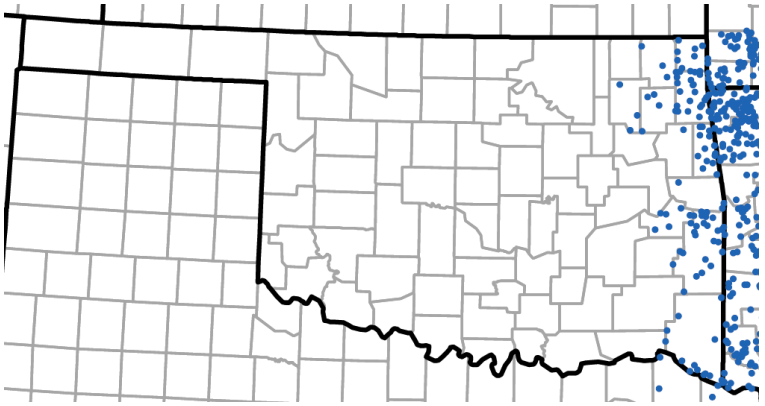
Cattle and calves



Hogs and pigs



Meat Chickens



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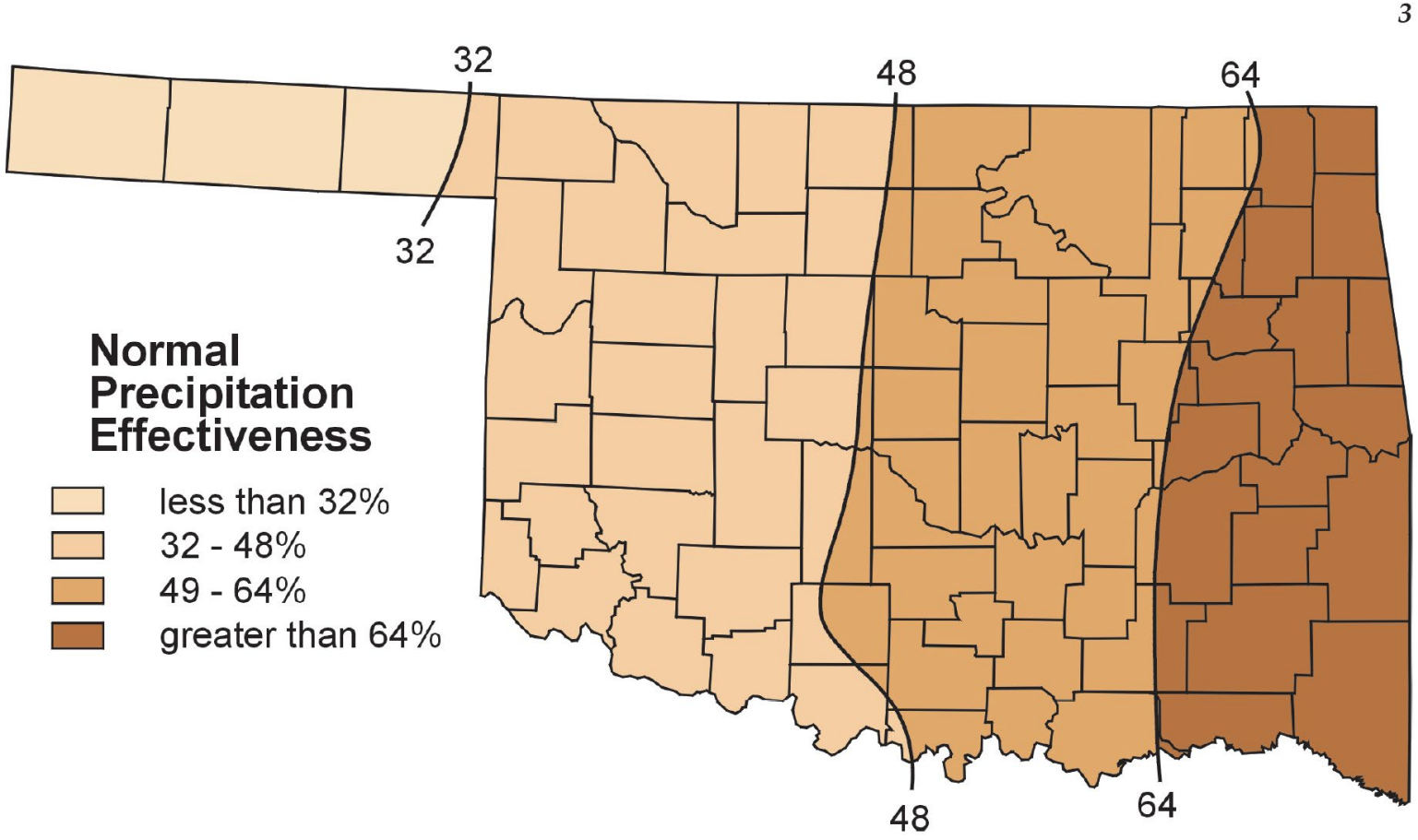

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