25 January 2016

In-person Interview

Justin Locke

Executive Summary

Questions	Answers
Worst PM2.5 emissions in US	New York City Metro Area Covington City, VA Pike County, IN
Primary Sources in these areas	(Respectively) Commercial Cooking Industrial Processing: Paper & Pulp Fuel: Electric Generation - Coal
IL PM2.5 change over time	Large growth in last 3 Years (+15%)
Leading Factors Predicting PM2.5 emissions	Land Area, Population, Acres Harvest, Annual Vehicles Miles Traveled, Road Miles
Areas to Focus for greatest effect	NYC Metro Area - Commercial Cooking Cook County - Construction Dust

Why and how are PM2.5 emissions dangerous?

Why is it dangerous?

May **lead to plaque deposits in arteries**, causing vascular inflammation and a hardening of the arteries which can eventually lead to **heart attack and stroke**.[1]

How dangerous is it?

Every 10 micrograms per cubic meter ($\mu g/m^3$) increase in fine particulate air pollution correlates with:

- 4% increase in all-cause mortality
- 6 % increase cardiopulmonary mortality
- 8% increase in lung cancer mortality

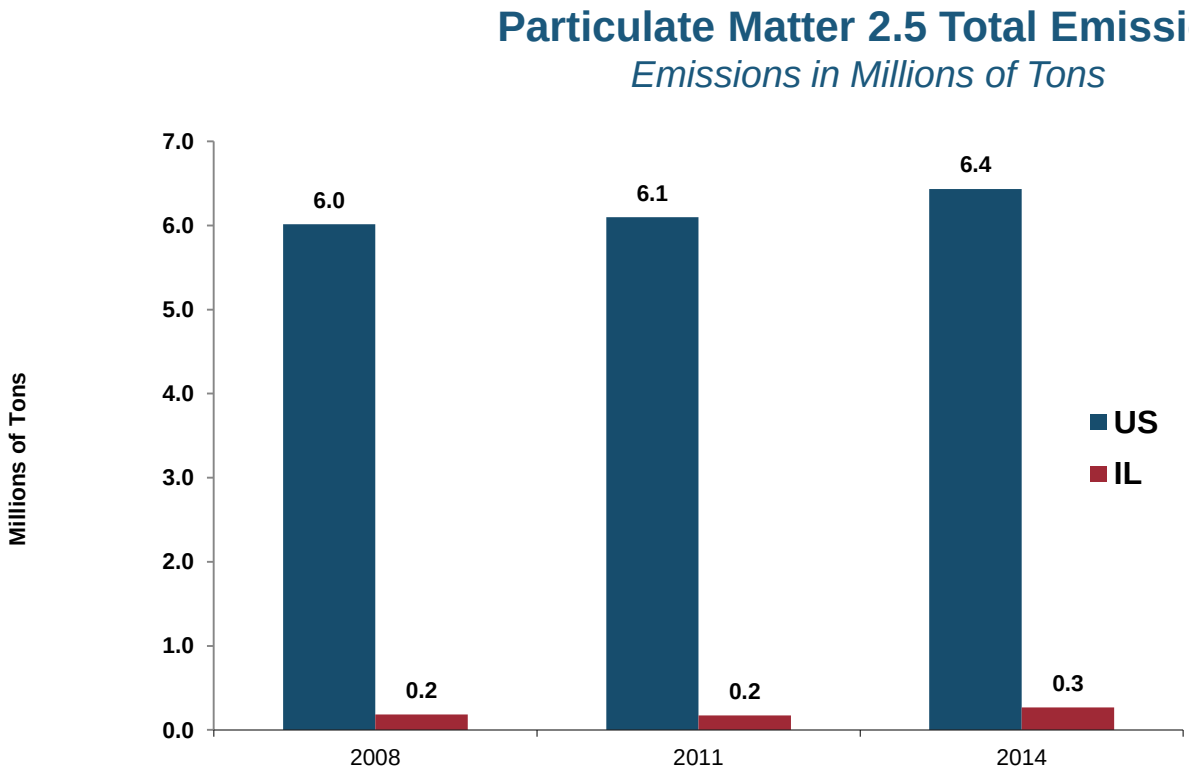
Birth defects

congenital heart disease, cleft palate and hydrocephalus (an excess of liquid in the brain), asthma

[1] Source: Journal of the American Medical Association, “Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution.” **(**link here)

[2] Source: Link here

US PM2.5 emissions are stable, while IL grew substantially growth from 2011 to 2014, although they were small in absolute terms



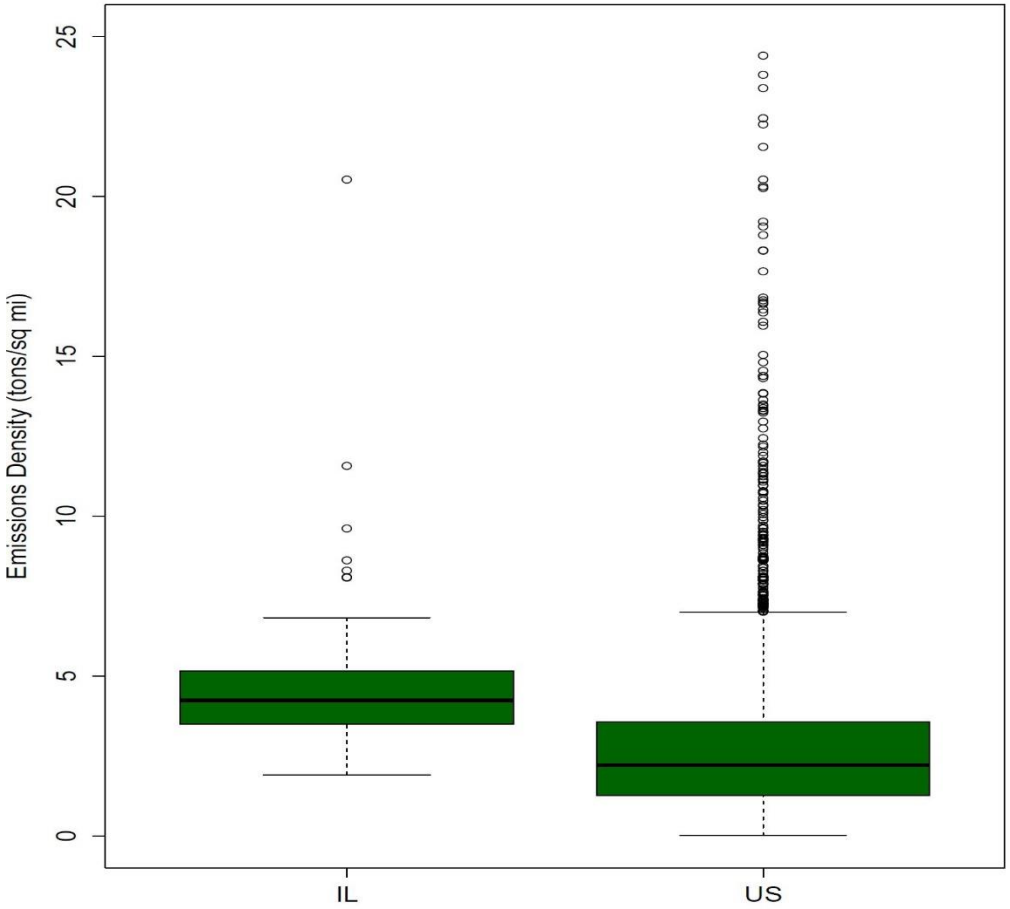
Percentage Change in emissions (Annualized)s

	2011 vs 2008	2014 vs 2011
US	0.5%	1.8%
IL	1.8%	15.8%

Summary statistics and a boxplot show counties in IL have a higher PM2.5 emission density than the average US county

Boxplot of US & IL Counties

PM2.5 Emissions Density (tons/sq. mi)



Summary Statistics for US & IL Counties

Emissions Density

Measure	US	IL
Maximum	502.5	20.5
3rd Quartile	3.6	5.2
Mean	3.2	4.7
Median	2.2	4.2
1st Quartile	1.3	3.5
Min	~0.0	2.0

Note - For graphing purposes the Y Scale was truncated at 25 (eliminating 18 large outliers on US)

Converting EPA's recommendation to our data requires some conversions along with some "simplifying" assumptions

EPA Recommended exposure level not to exceed →

Converting EPA's recommendation to our unit of measure

Unit of measure	24 Hrs	1 Year
micrograms/meters^3	**35 µg/m^3**	**15 µg/m^3**
tons/meters^3	3.85809e-11	1.6535e-11
tons/miles^3	.160812	0.06892
[1]tons per miles^2 (daily)	.160812	0.06892
[2]pollutions buildup? (from pervious days)	0.0	0.0
Tons per miles^2 (years)	58.75	25.17

Assumptions:

[1]Atmosphere is 1 mile high tall (simplifying assumption)

[2]Pollutions buildup is zero (i.e. wind fully refreshes air)

*Relaxing these assumptions (i.e. lower atmosphere height, and more buildup) would lower our threshold for dangerous emissions (tons/miles^2), but can safely assume the counties above 25 are hazardous

Conversion Factors :

1 microgram yields 1.10231e-12 US ton

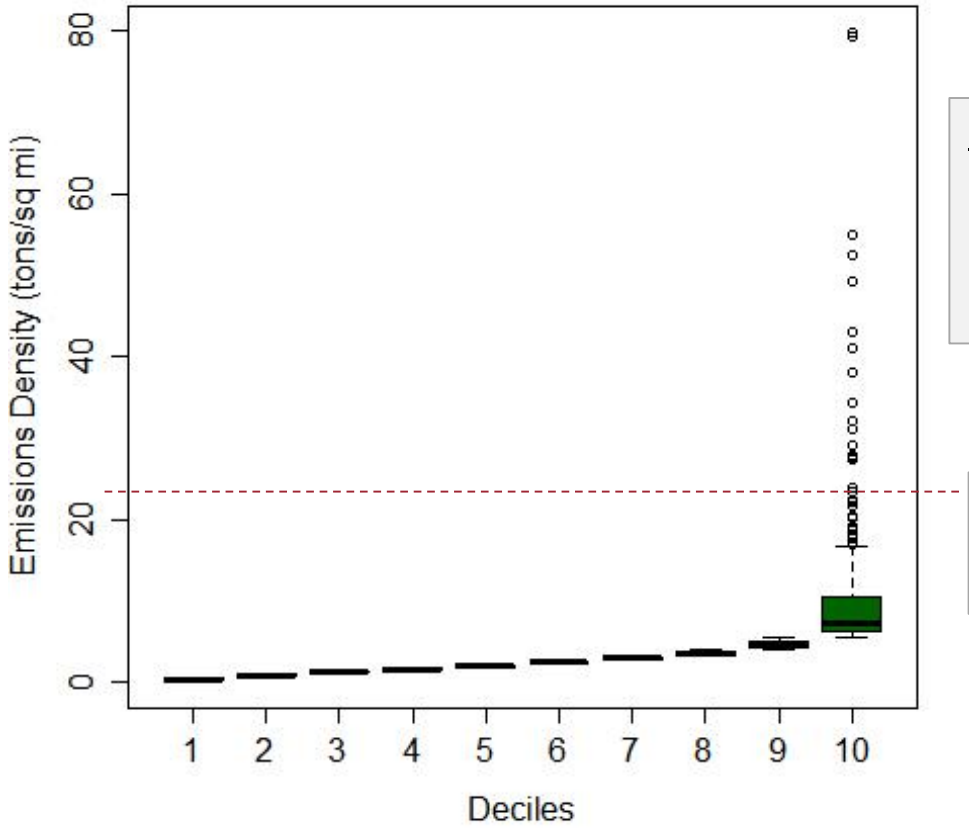
1 meter^3 yields = 2.39913e-10 miles^3

1 years has 365.25 days

Emissions Density increases greatly in the 10th decile (highest emissions).

IL Counties 2014 PM2.5 Emissions Density

By Deciles (10= highest tons/sq mi)



Outliers Not Graphed

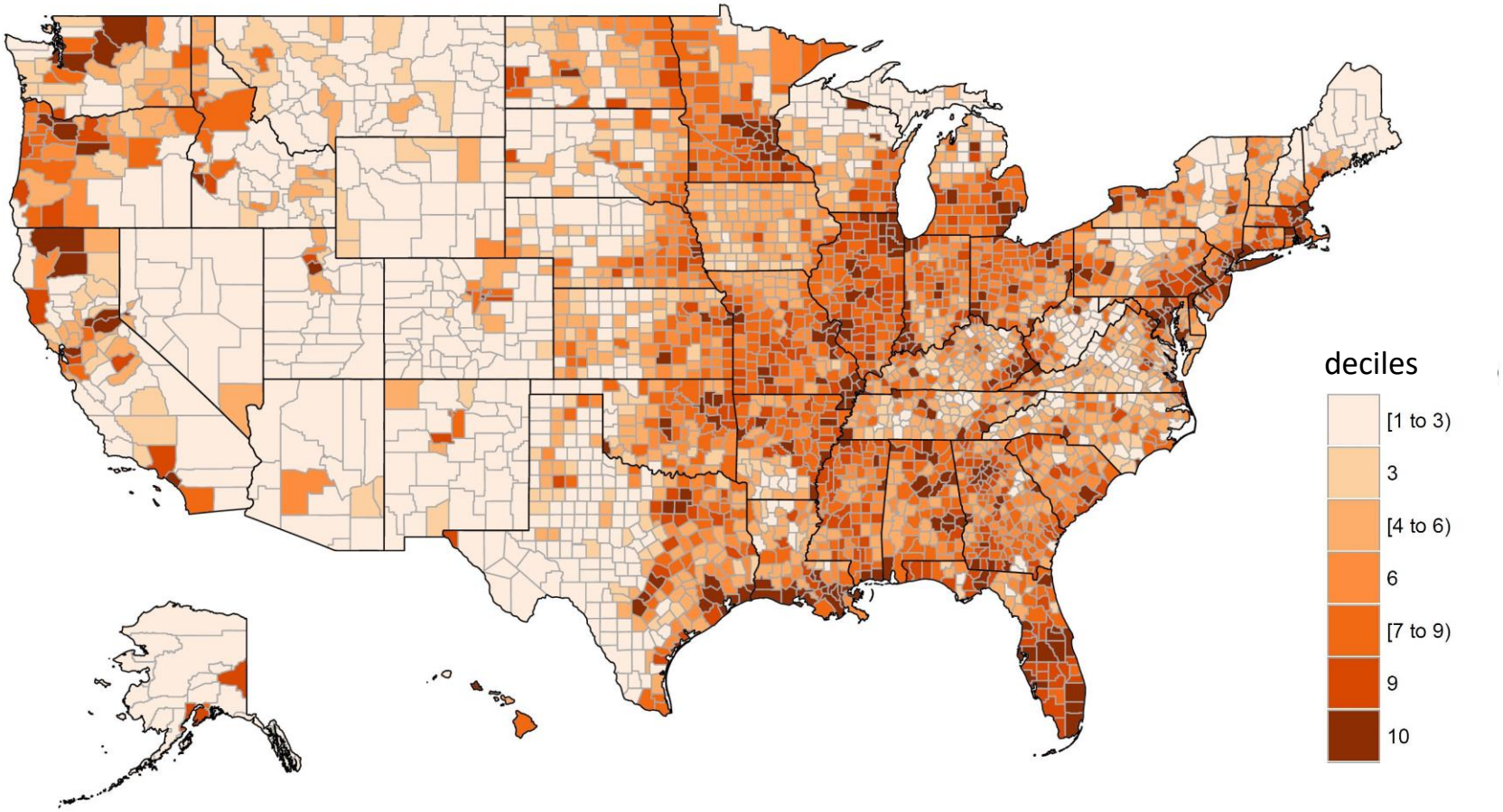
County	Value
New York County, NY	502
Covington City, VA	128
Kings County, NY	113

Estimated hazardous threshold

PM2.5 emission density is highest in counties with large population centers, some western counties (fires), and the midwest

US Counties 2014 PM2.5 Emissions Density (tons / sq mi)

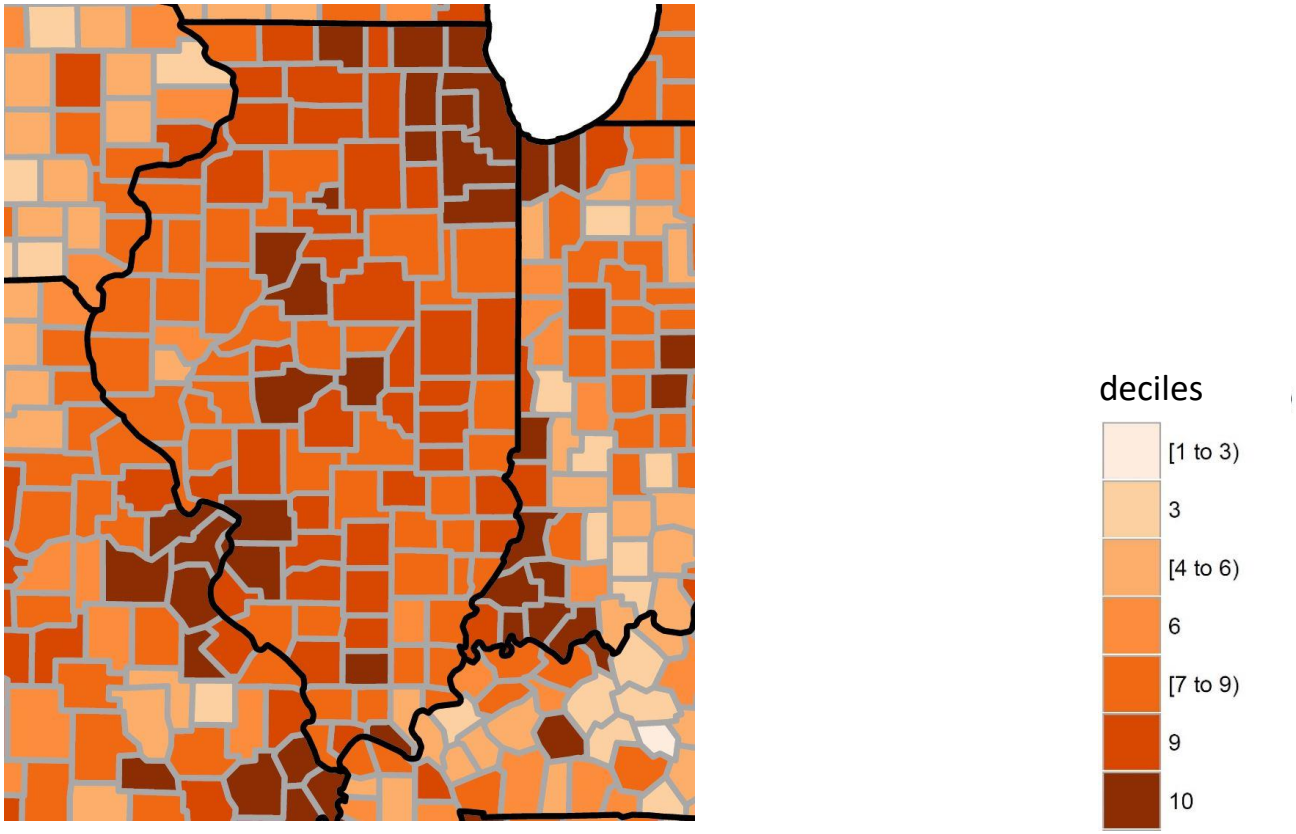
Continuous Scale



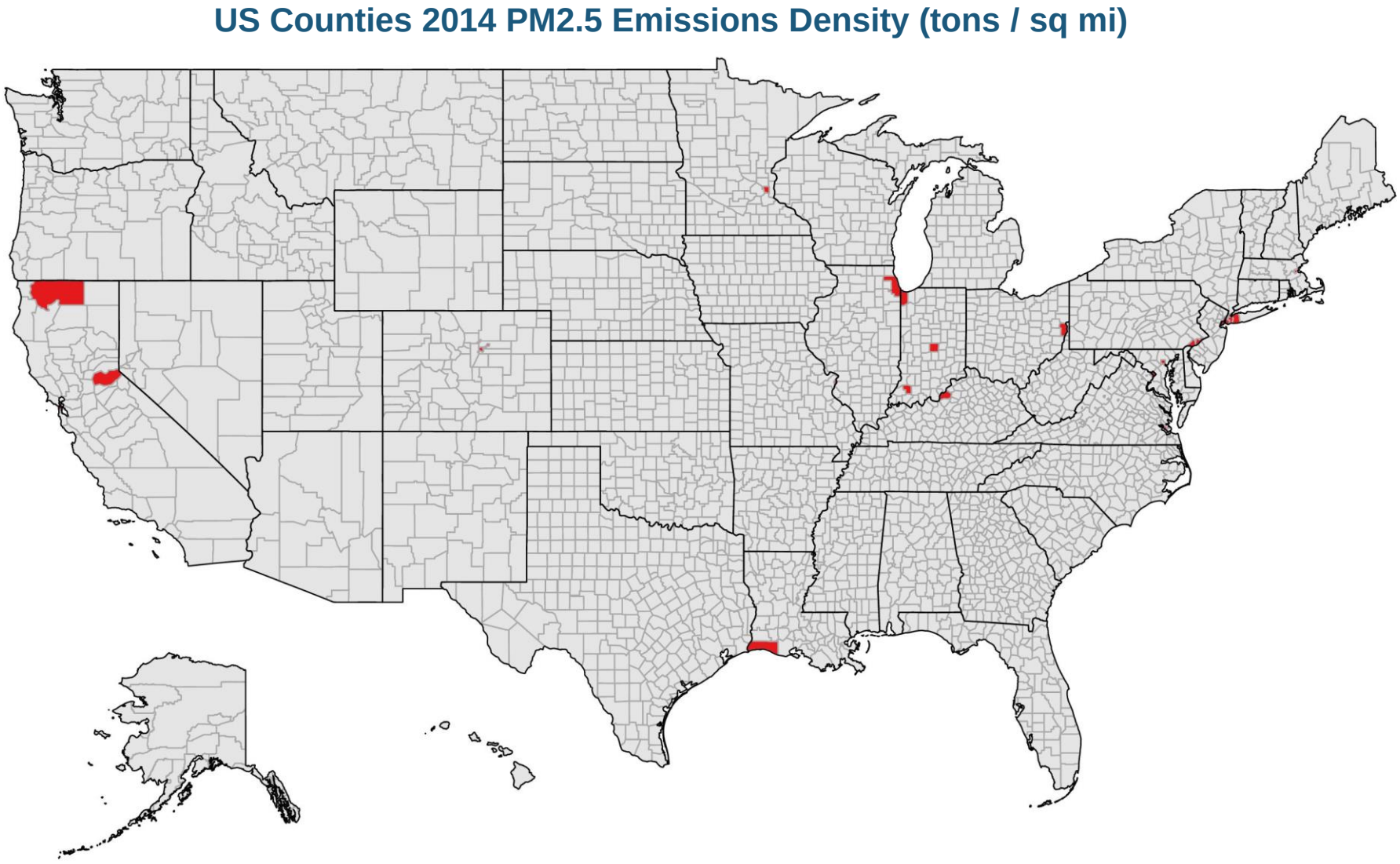
In IL, for 2014, emission density is highest in the counties containing Metro areas of Chicago, East St. Louis, Peoria, Decatur, and Marion.

IL Counties 2014 PM2.5 Emissions Density

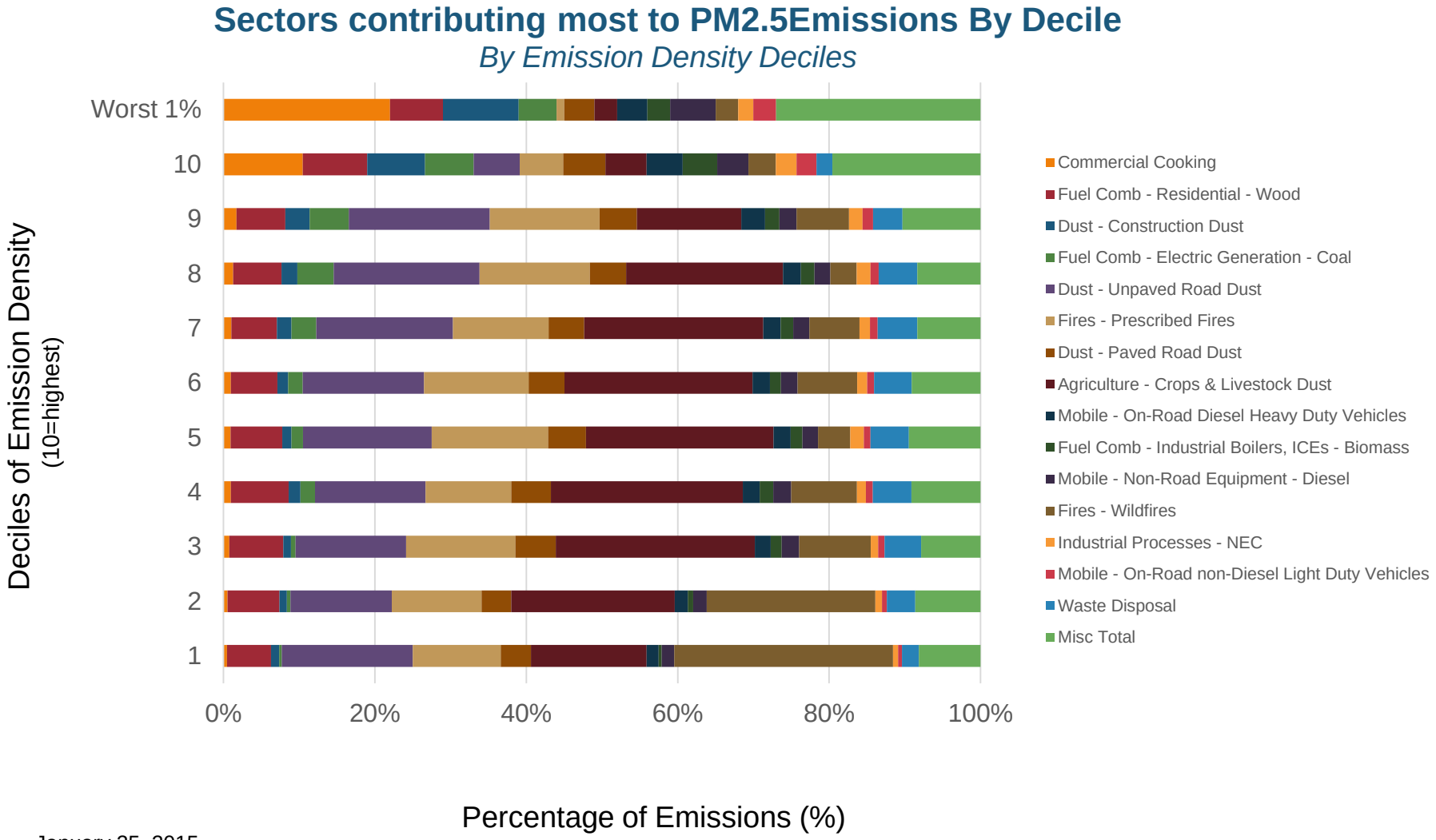
By Deciles (10= highest tons/sq mi)



Counties with the worst 1 percent emission density are:



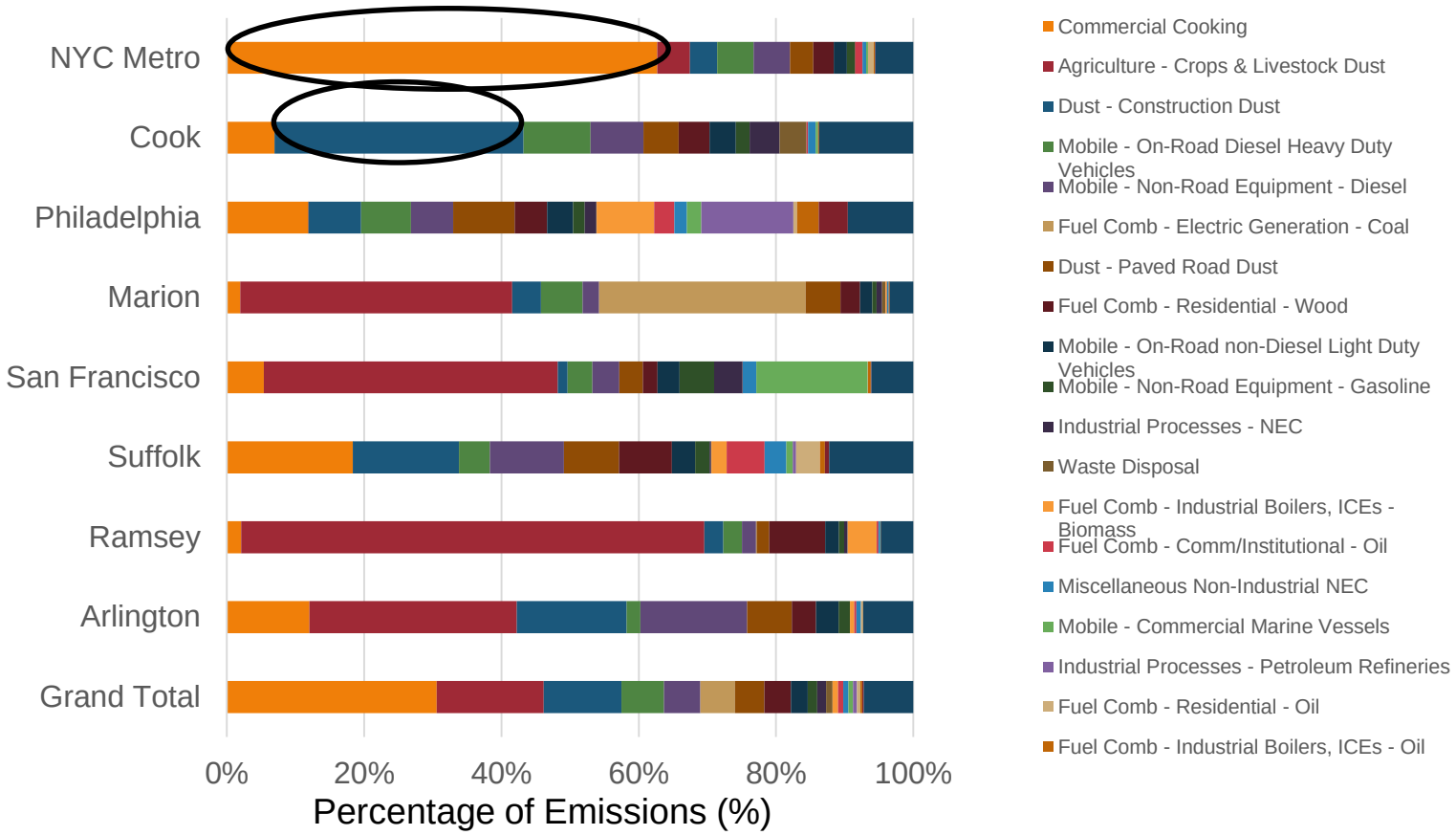
The counties with **worst** PM2.5 density (decile 10 and worst 1%) have:
more emissions from commercial cooking, construction dust, coal, diesel equip, misc
fewer emissions from fires, agriculture



In “high leverage” geographies (i.e. worst 1% emission density AND large population), Cook County’s construction and NYC commercial cooking emerge as key focal points

Population (in millions)	Emission Density
9.0	74
5.2	20
1.5	29
0.9	38
0.8	41
0.7	32
0.5	49
0.2	34
18.9	

Sectors contributing to the “high leverage” geographies



Note – 5 Counties in or around New York City (Bronx, Kings, Nassau, New York, Queens) were consolidated to NYC Metro due to their similarities and geographic proximity

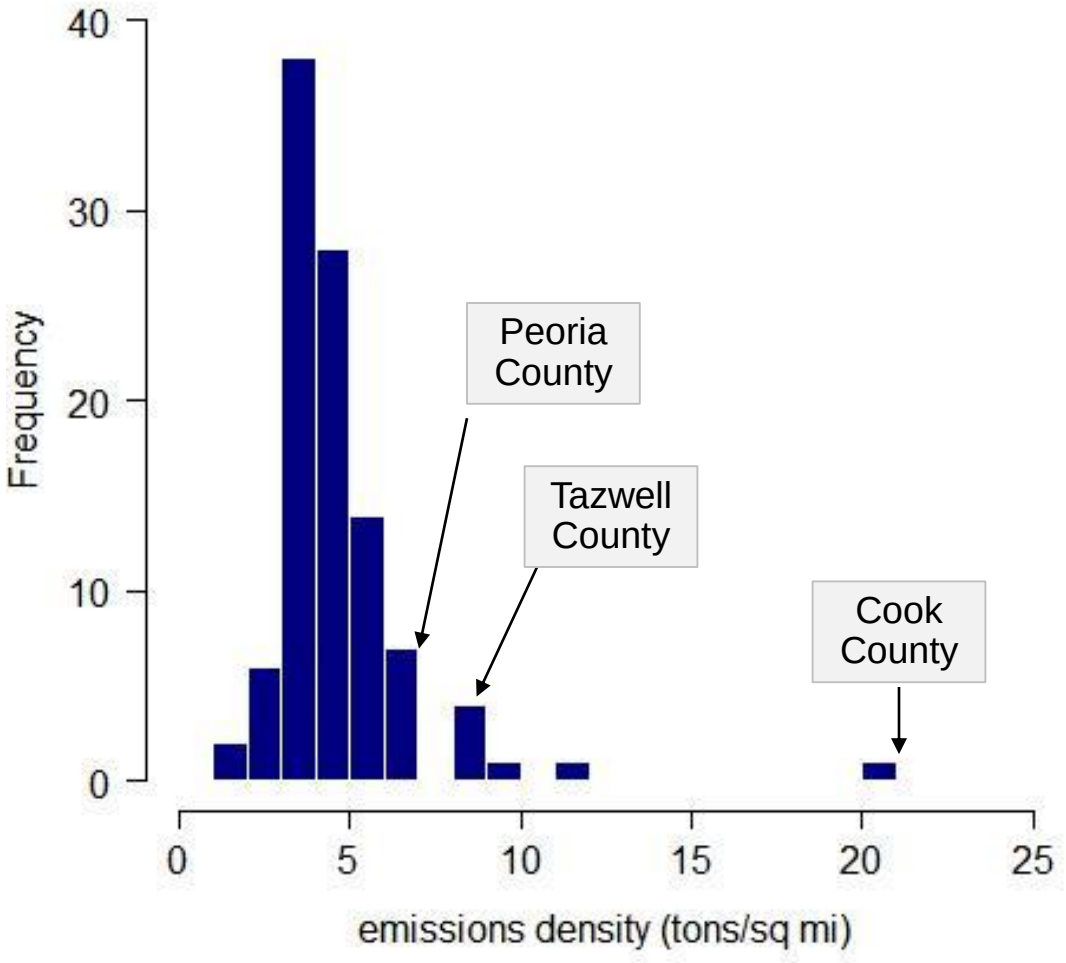
These counties have small populations but very high emissions densities

State	County	Emission Density (tons/sq. mi)	Pop.	Primary Sectors	Percentage Contribution to Total Emissions
Virginia	Covington City	128	5,961	Industrial: Paper & Pulp Industrial: NEC Industrial: Storage & Transfer	44% 22% 14%
Indiana	Pike County	55	12,845	Fuel: Electric Coal	97%
Virginia	Hopewell City	52	22,591	Industrial: Paper & Pulp Industrial: Chemical Manuf. Fuel: Industrial Boilers	23% 21% 18%
Virginia	Falls Church	43	12,332	Construction Dust	70%
Louisiana	Cameron Parrish	31	6,839	Fires: Wildfire Fires: Prescribed	63% 36%
California	Siskiyou	22	44,900	Fires: Wildfire	97%
		Total 105,468			

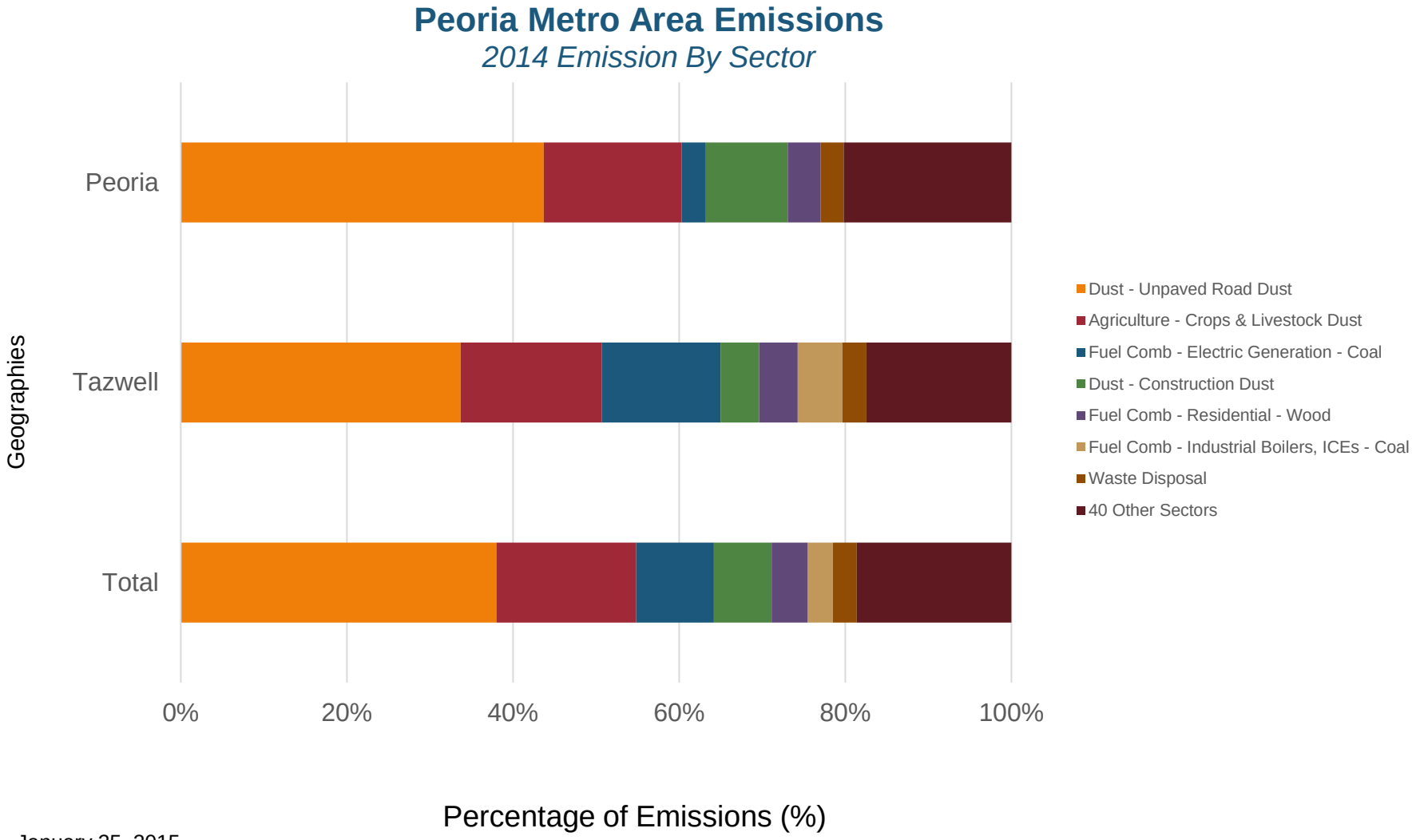
A histogram of emissions density in IL counties shows Cook county as an outlier with Peoria and Tazwell also on the high side

Histogram of IL Counties

2014 PM2.5 Emissions Density (tons/sq mi)



In the Peoria Metro Area the primary contributors are Unpaved Road dust, Agriculture dust, and Electric Coal generation (especially in Tazwell county)

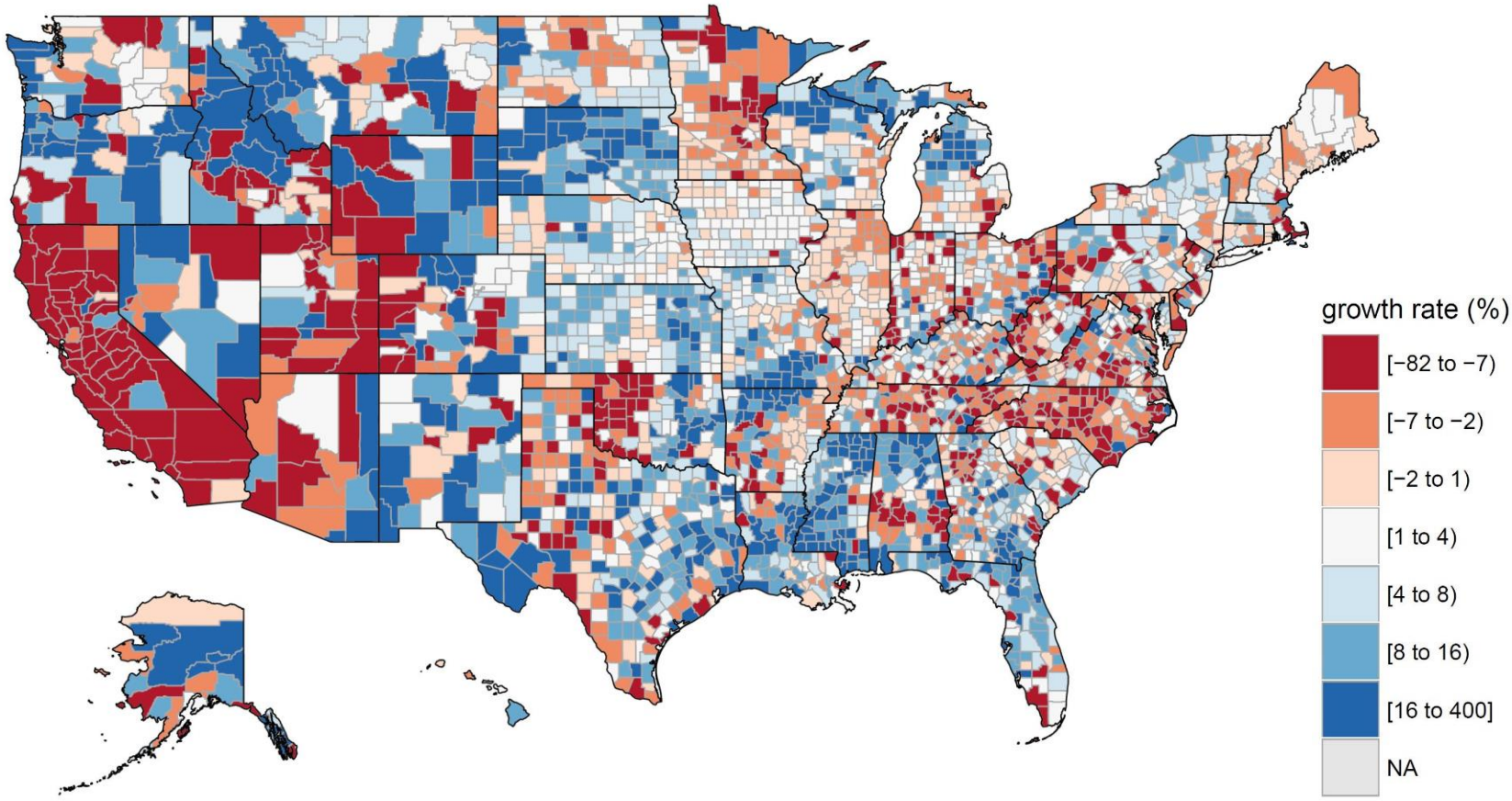


Change over Time

From 2008 to 2011 the US, growth rates show decreases in IL, with significant decreases in the west and mid-atlantic.

US Counties 2008-2011 PM2.5 Emissions Growth Rate

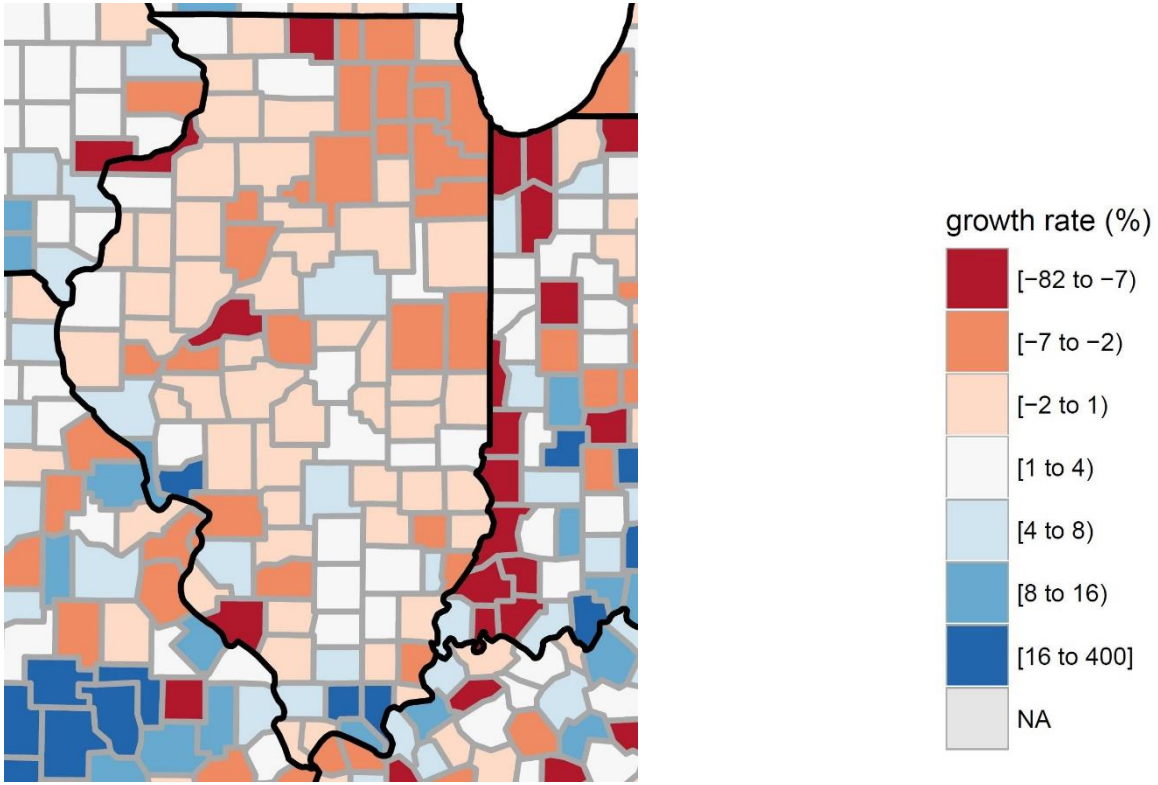
(Annual % Increase)



In IL, from 2008 to 2011 there were sizable decreases in emisions

IL Counties 2008-2011 PM2.5 Emissions Growth Rate

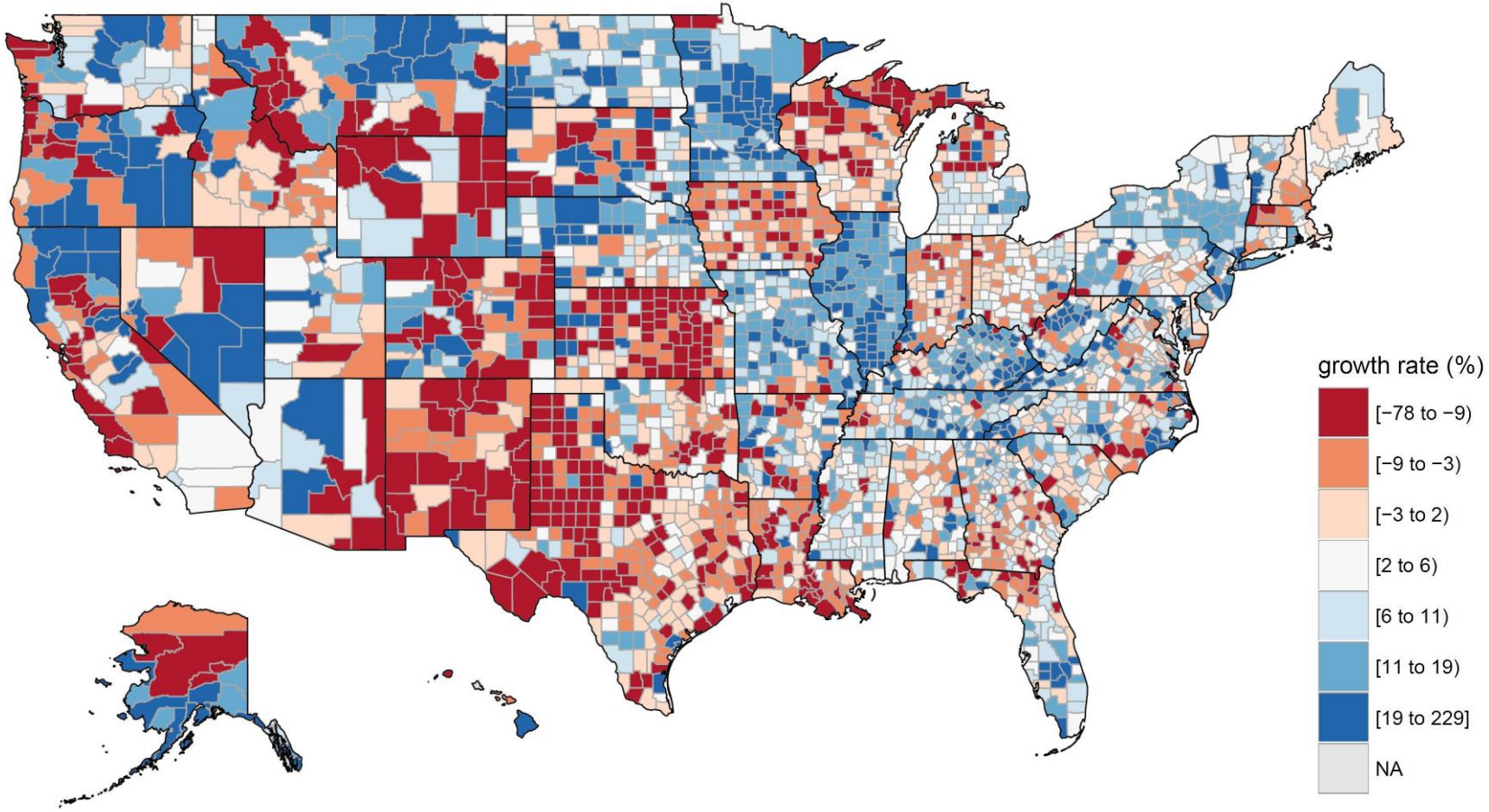
(Annual % Increase)



From 2011 to 2014, US showed grow in a variety of patches with declines in the middle of the country

US Counties 2008-2011 PM2.5 Emissions Growth Rate

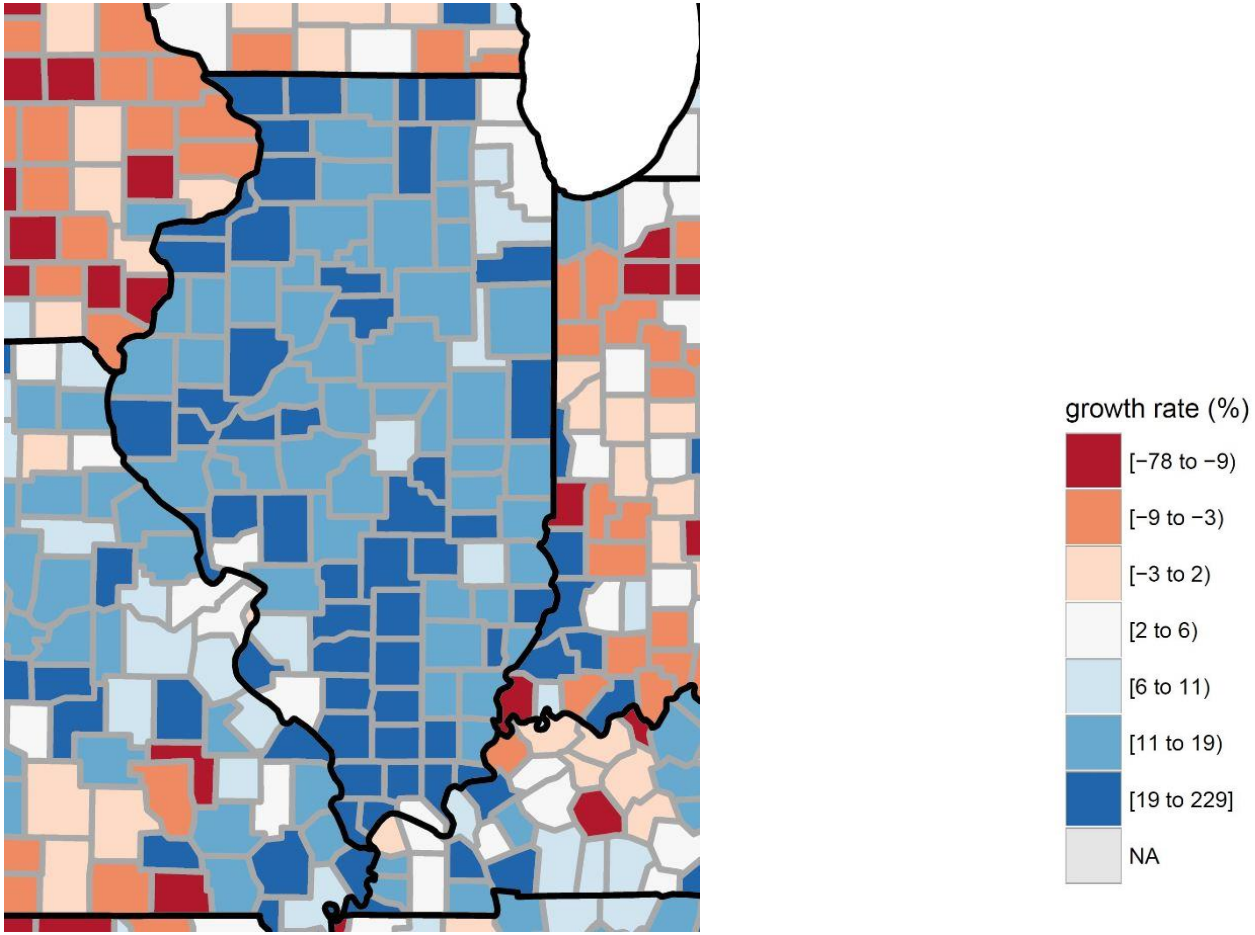
(Annual % Increase)



In IL, there were large increases in emissions from 2011 to 2014

IL Counties 2011-2014 PM2.5 Emissions Growth Rate

(Annual % Increase)



Relationship and Correlations

A number of additional data sets were added with significantly correlations to emissions

Stats Applicable to Entire US

	Geo	Correlation
Land Area	US	.44
	IL	.81
Population	US	.52
	IL	.87
Population Density	US	.53
	IL	.89
Housing Units	US	.51
	IL	.83
Housing Density	US	.71
	IL	.89

Individual Sectors for Illinois

	Sector	Correlation
Annual Vehicle Miles Traveled	Paved Road Dust	.98
	Unpaved Road Dust	.58
Acres Harvested	Ag Dust	.48
Road Miles: Paved and Unpaved	Unpaved Road Dust	Data sourced but not cleaned
	Paved Road Dust	Data sourced but not cleaned

Next Step for Analysis

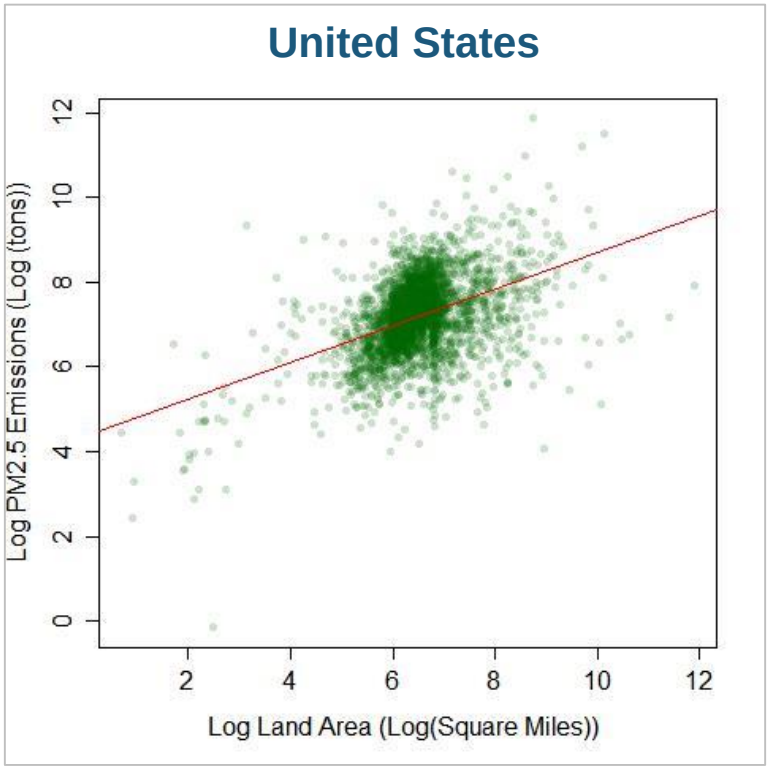
- Additional Predictors
  - Agricultural Crop & Livestock Dust - Acres No Till, vs Conventional Tilled
  - Commercial Cooking - Number of restaurants
  - Construction Dust - Construction Areas (square miles)
  - Pulp & Paper Processing - Paper Production Output
- Investigate correlation among predictors matrix
- Build linear regression model
  - Model type would be goal dependent (broad US or large Metros)
  - Investigate prediction of individual sectors
  - Test Assumptions of Linear regression
    - Linear and additive
    - Multivariant normality
    - No multicollinearity
    - No autocorrelation
    - No heteroscedasticity

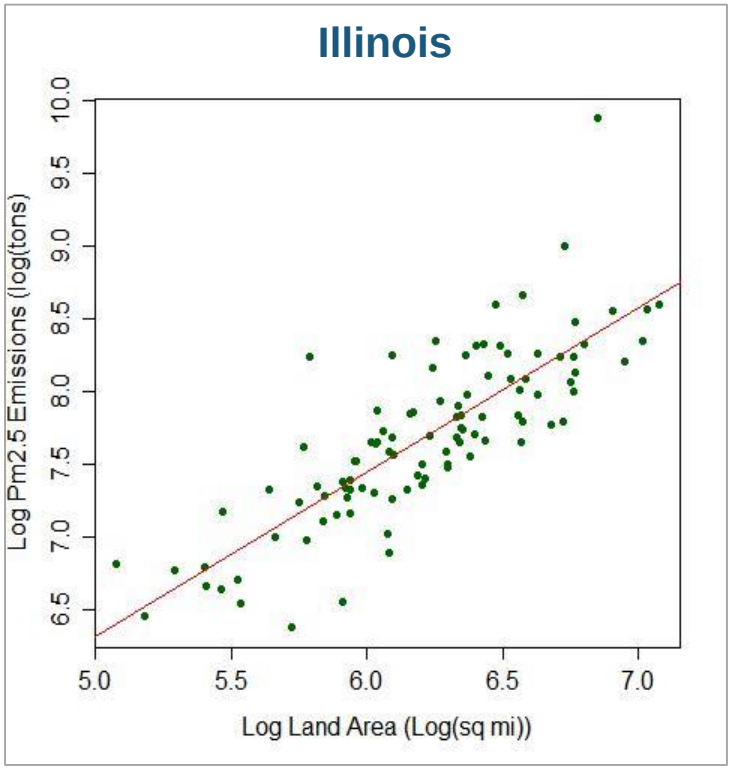
Appendix: Correlations & Relationships:

Land Area correlates strongly with PM2.5 emissions

Scatterplot of Land Area vs Emissions

emission from 2014, population from 2010 census



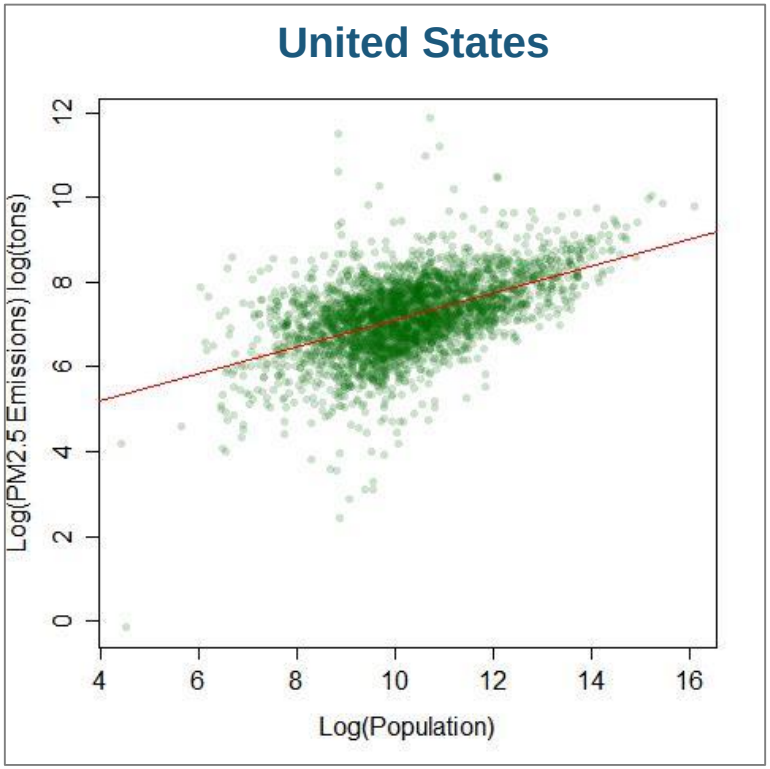


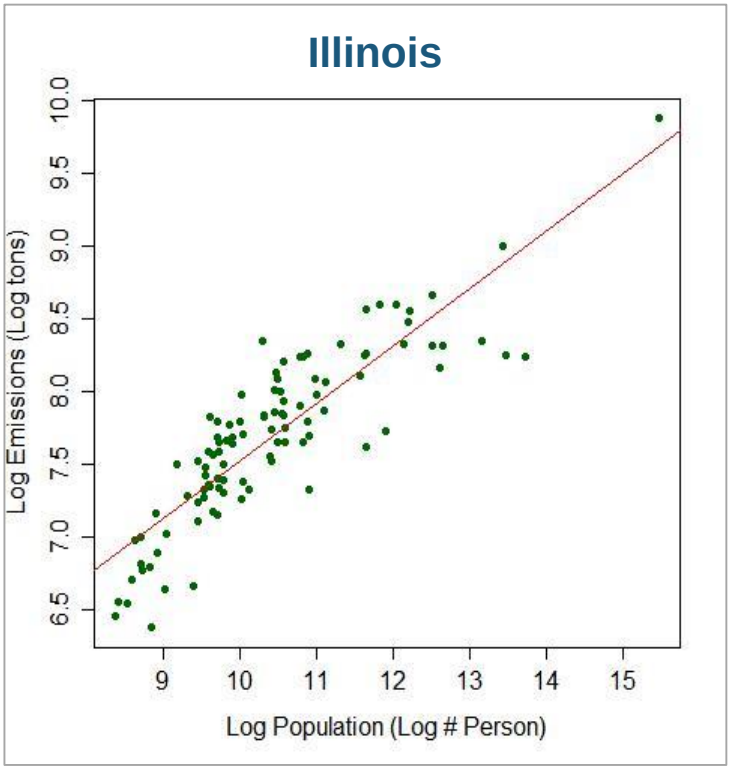
Pearson Correlations	**.44**	**.81**

Population also correlates strongly with PM2.5 emissions

Scatterplot of Population vs Emissions

emissions from 2014, population from 2010 census



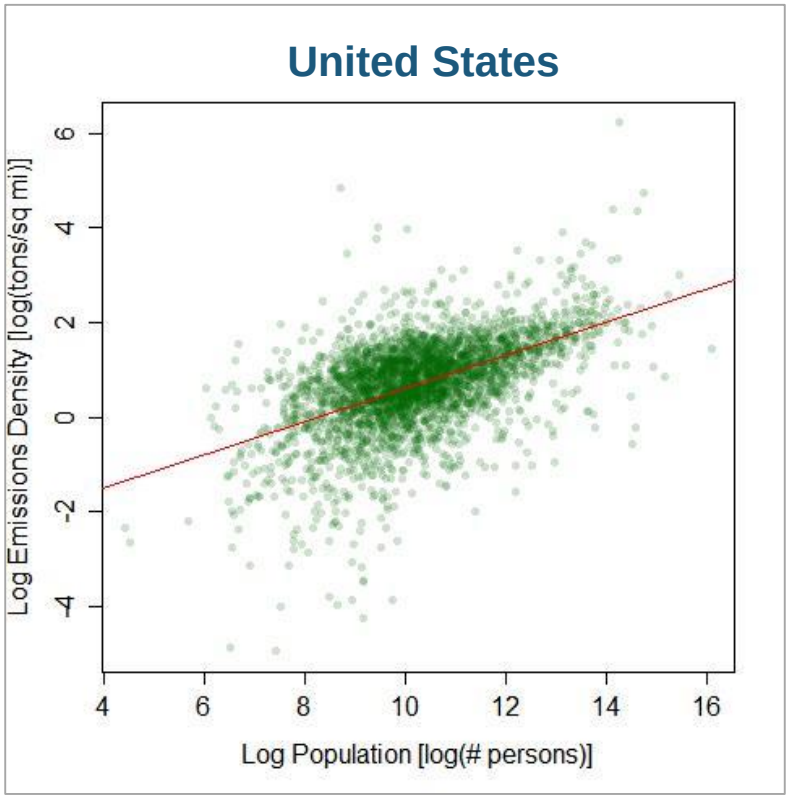


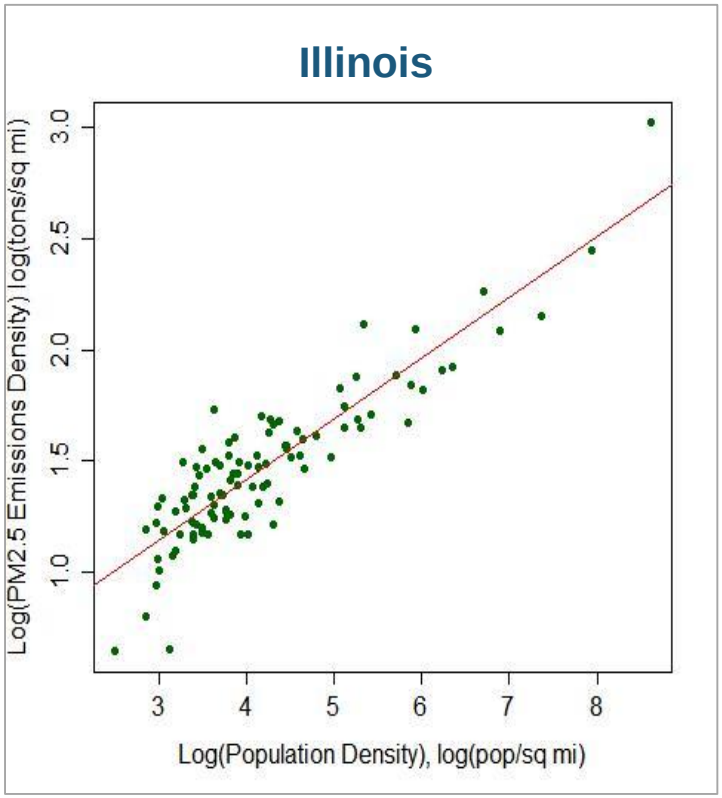
Pearson Correlations	**.52**	**.87**

Population Density incorporates both Population and Land Area and is also a very strong predictor, ex

Scatterplot of Population Density vs Emissions

emissions from 2014, population from 2010 census



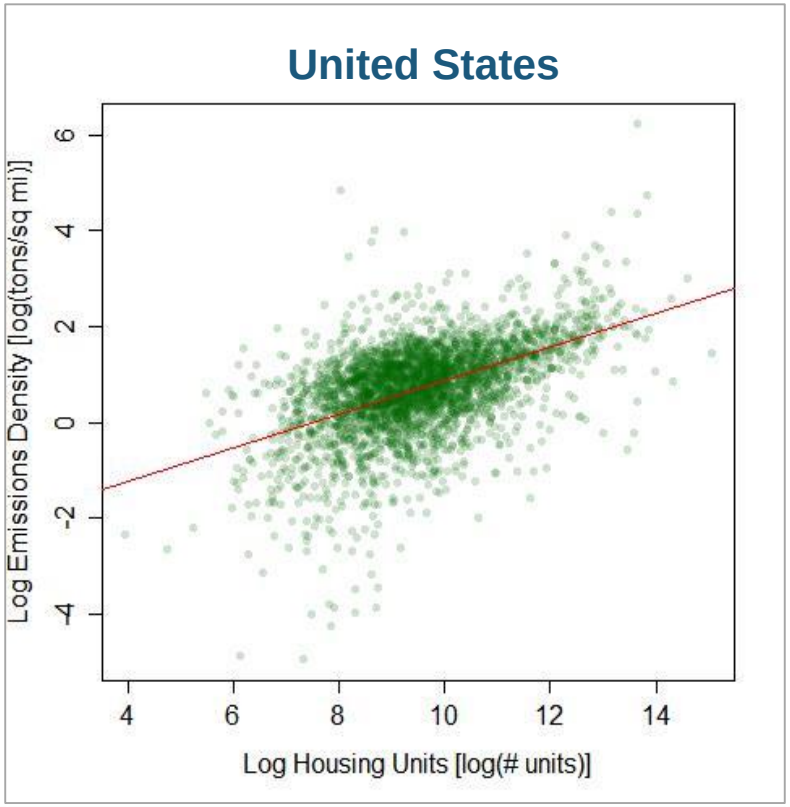


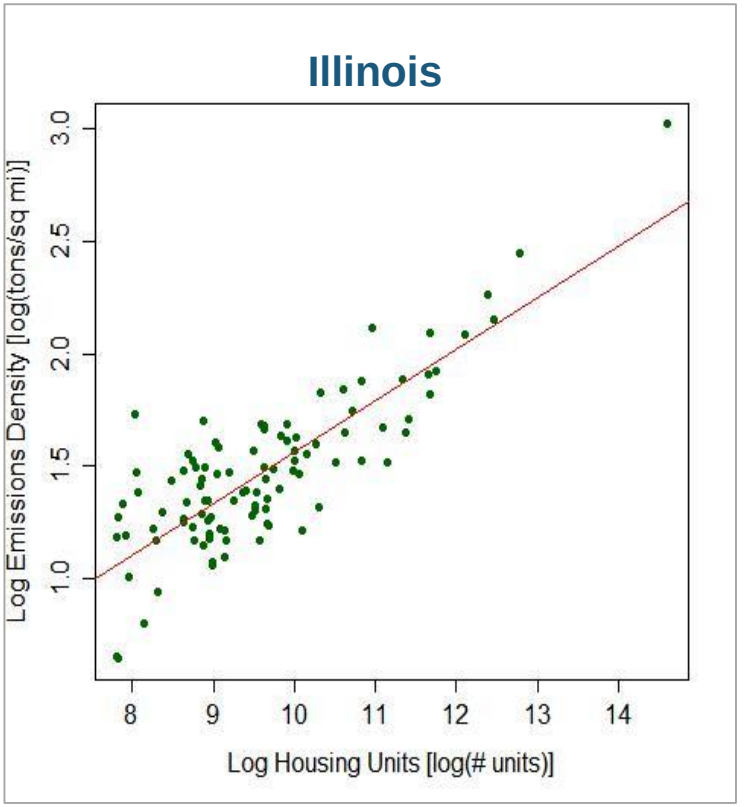
Pearson Correlations	**.53**	**.89**

Housing is similar to Population and is also a very strong predictor, ex

Scatterplot of Housing vs Emissions

emissions from 2014, population from 2010 census



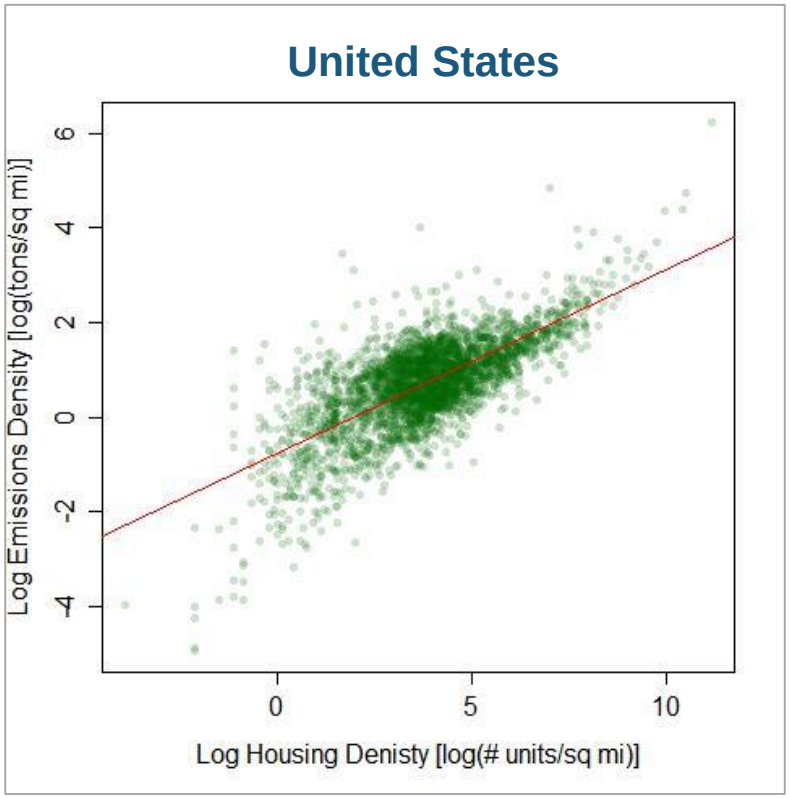


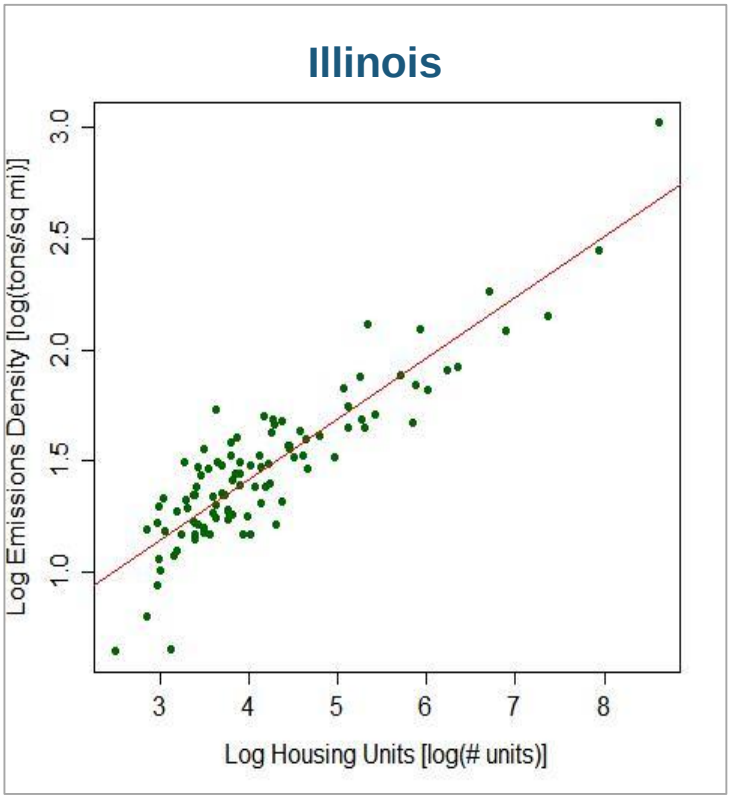
Pearson Correlations	**.51**	**.83**

Housing Density is similar to Population Density and has a very strong correlation

Scatterplot of Housing Density vs Emissions

emissions from 2014, Housing Density from 2010 census

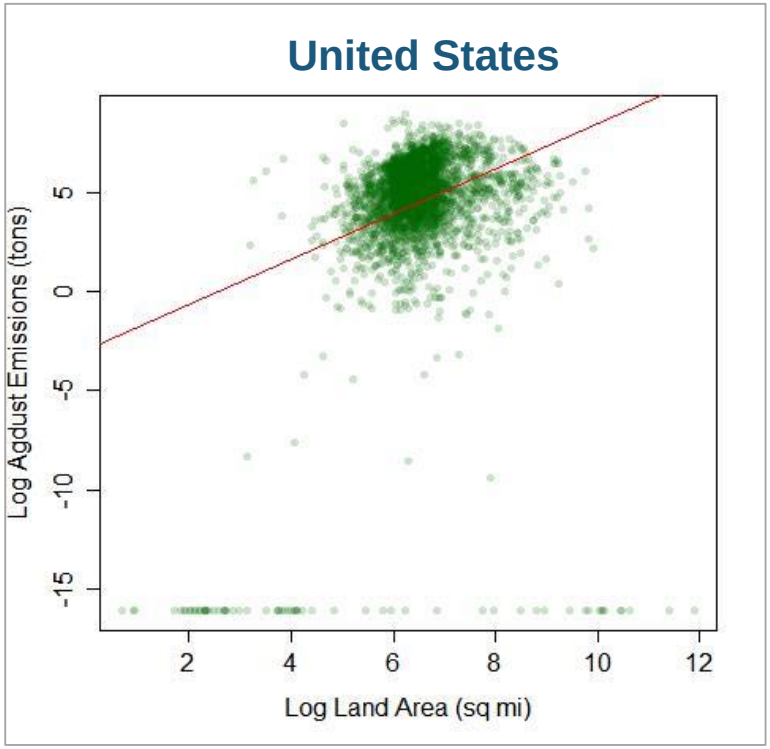


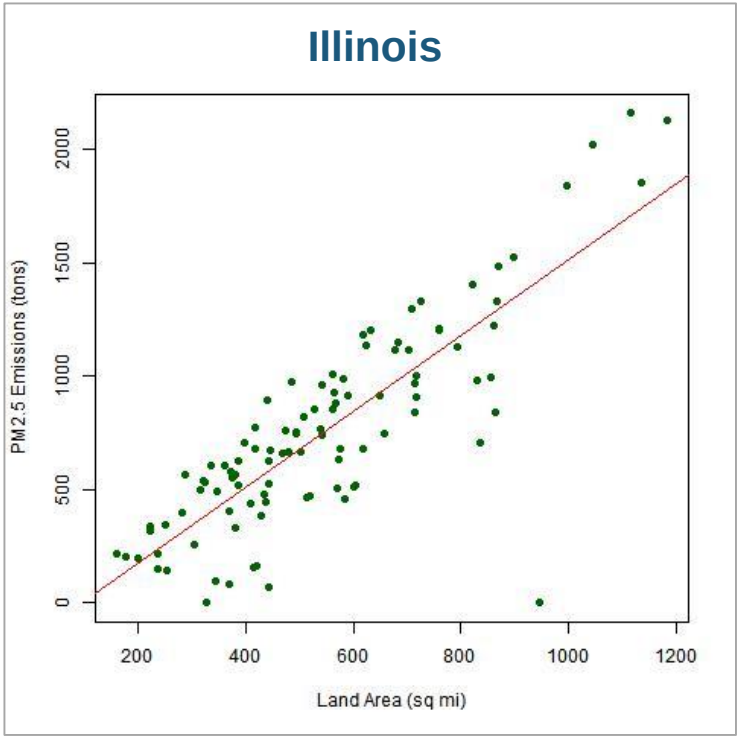


Pearson Correlations	**.71**	**.89**

For US **Agriculture Dust (crop & livestock), Land Area** requires a log transform and is slightly correlated, IL correlation is strong (no transform

Scatterplot of *2014* Agdust emission to Land Area



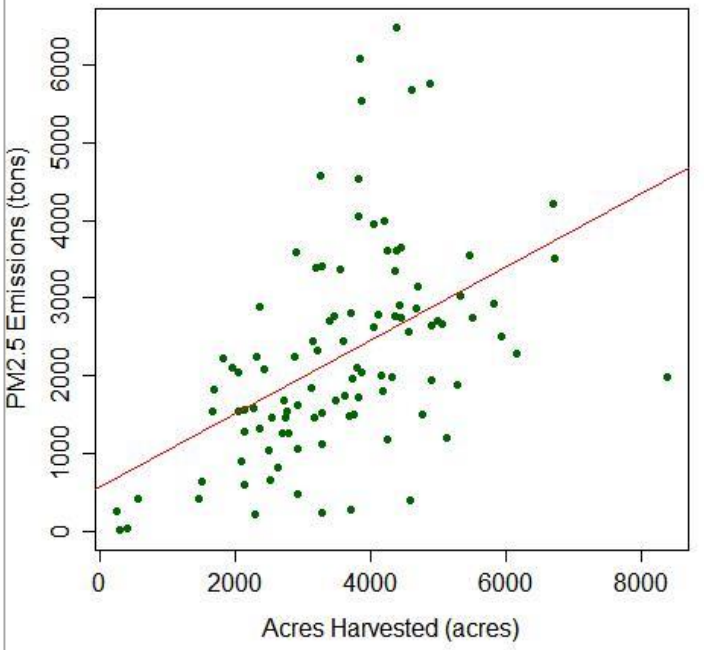


Pearson Correlations	**.29**	**.84**

Harvested Acres and is strong predictor, though surprisingly not as strong as Land Area

Scatterplot of Population Density vs Emissions

emissions from 2014, population from 2010 census

	United States	Illinois
	Data Not Available	
Pearson Correlations	**N/A**	**.48**

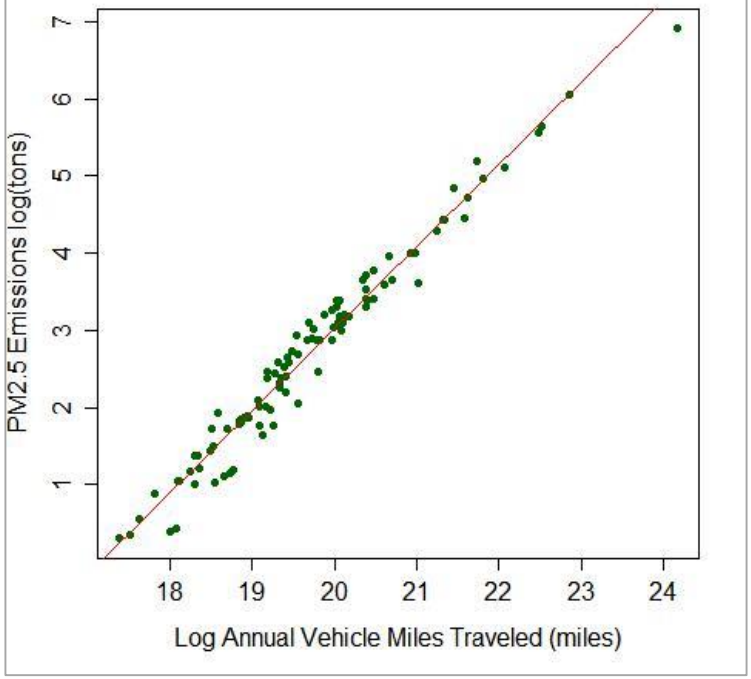
For Paved Road Dust, Annual Vehicle Miles Traveled and is almost perfectly correlated with emissions

Paved Road Dust emission vs Annual Vehicle Miles Traveled

United States

Data Not Available

Illinois



Pearson Correlations	**.98**

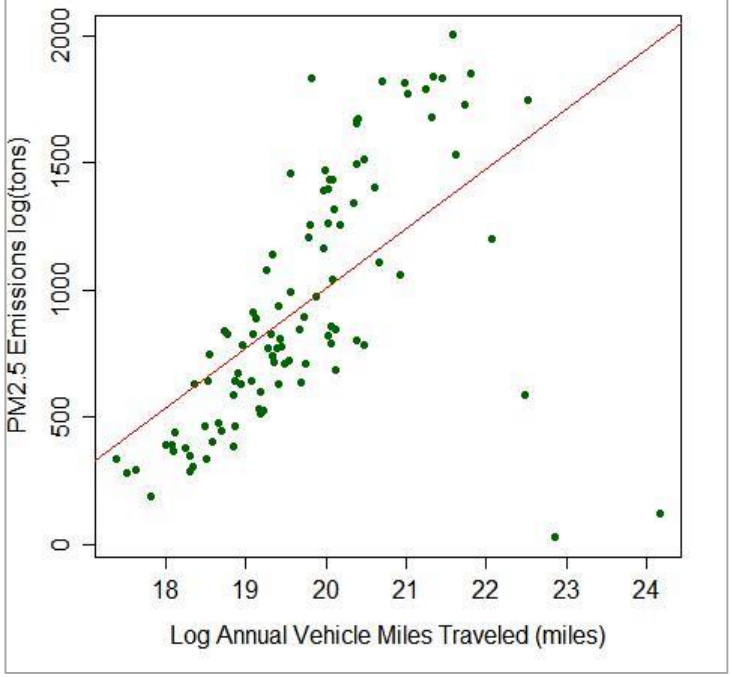
For Unpaved Road Dust, Annual Vehicle Miles Traveled and is strong predictor, with the few large outliers

Unpaved Road Dust emission vs Annual Vehicle Miles Traveled

United States

Data Not Available

Illinois

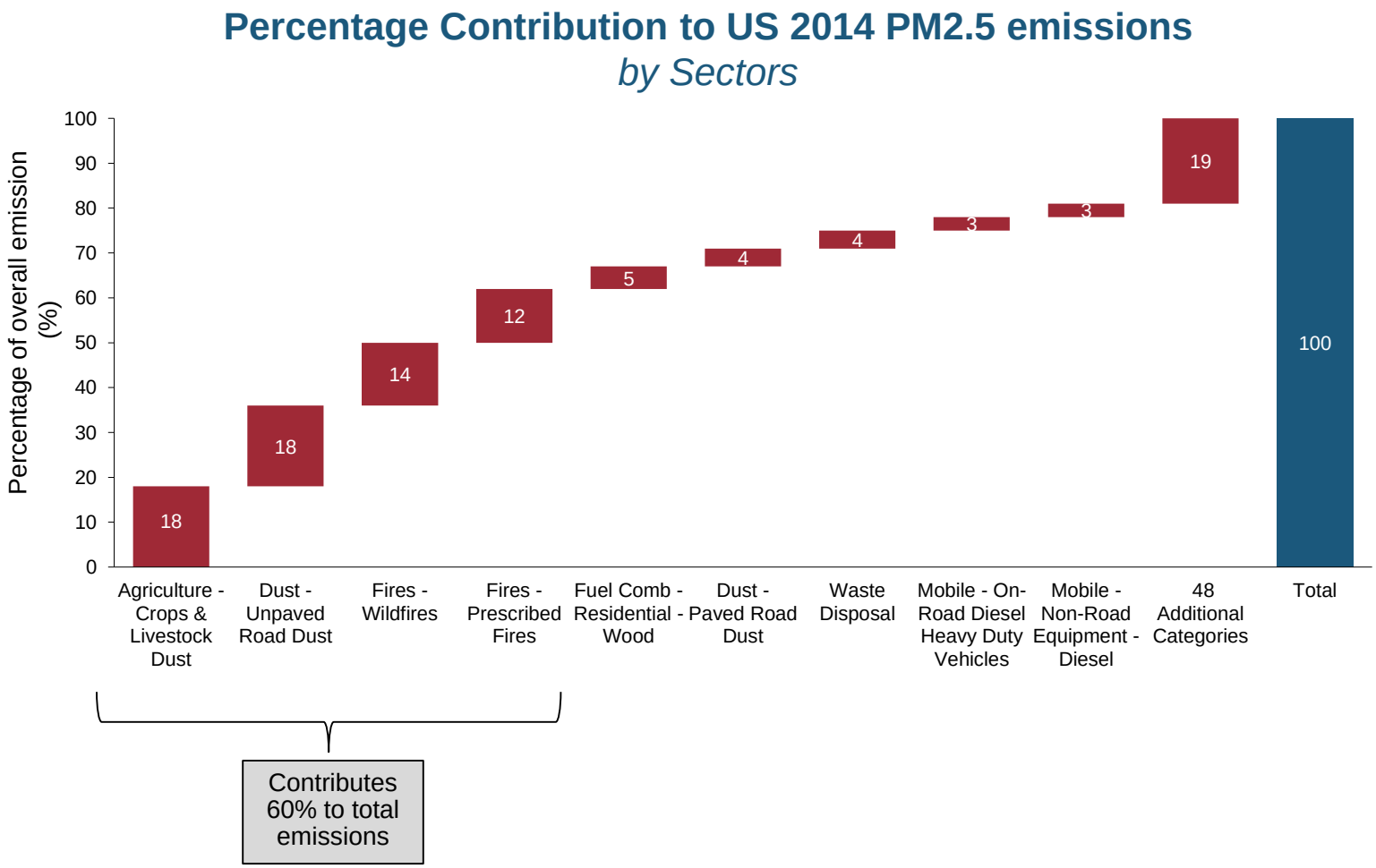


Note There are some notable Outliers for IL could likely be improved by slicing road miles by type of road (unpaved, versus paved)

Pearson Correlations	**.58**

Appendix: Analysis of Sectors: Detail

Analysis by Sectors shows that 9 sectors are responsible for 81% of US emissions, and 4 responsible for 60%



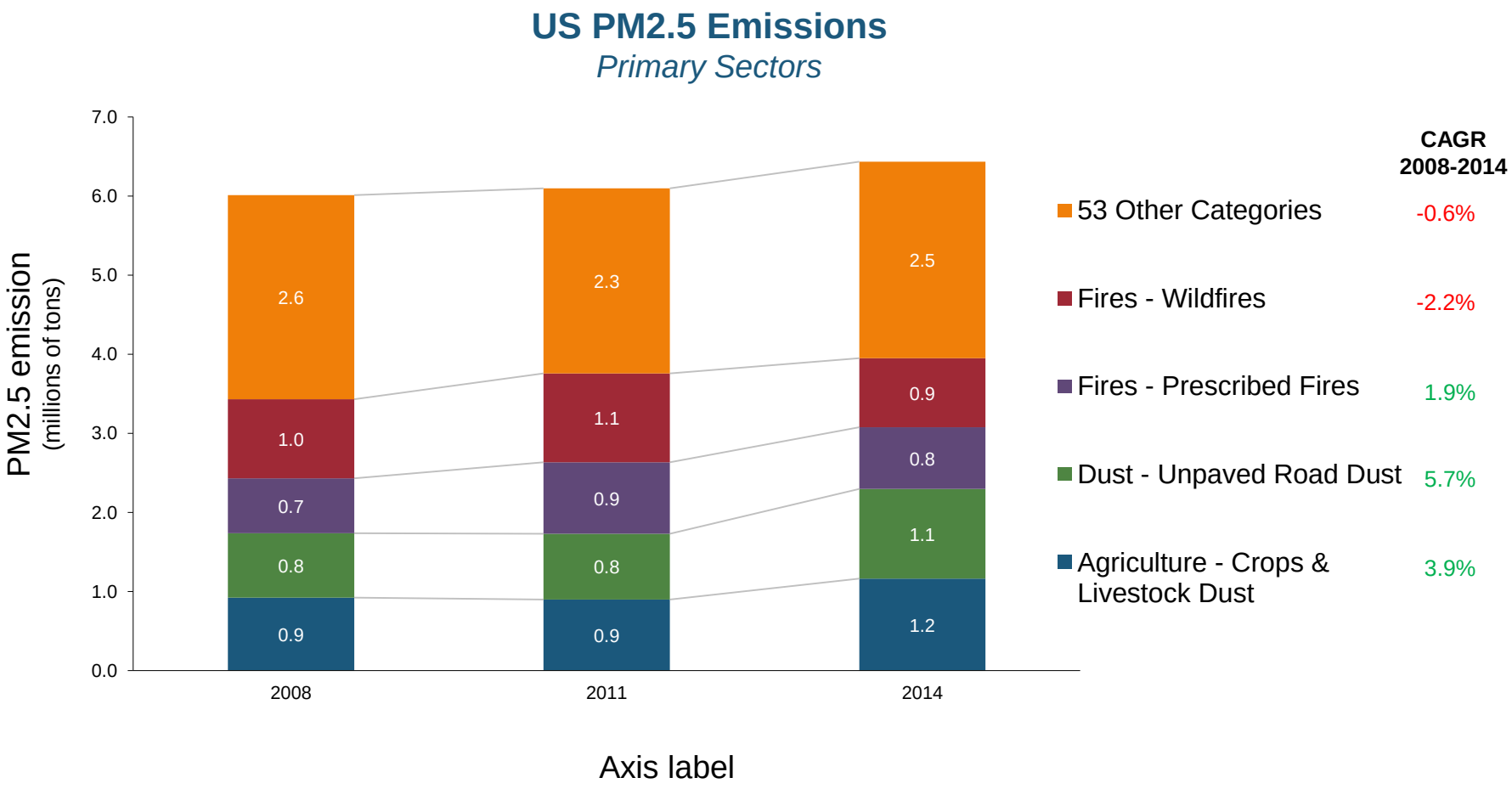
Some sectors contribute more or less each census, though Fires (wild & prescribed), Agriculture, and Unpaved Roads are consistent

Percentage Contribution to PM2.5 Emissions

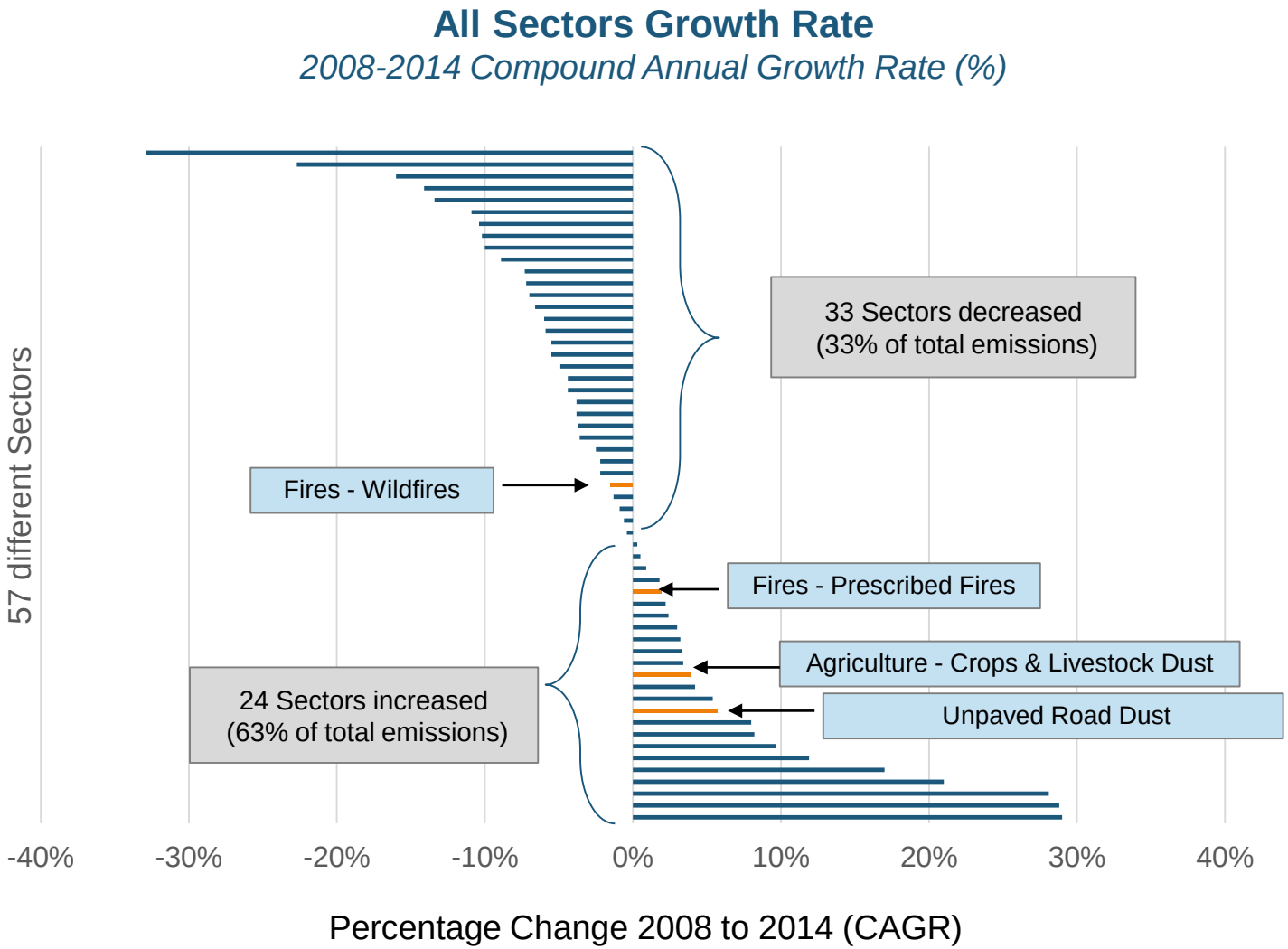
(worst offending sectors)

	2008	2011	2014
Fires - Wildfires	17%	18%	14%
Agriculture - Crops & Livestock Dust	15%	15%	18%
Dust - Unpaved Road Dust	14%	14%	18%
Fires - Prescribed Fires	12%	15%	12%
Fuel Comb - Residential - Wood	6%	6%	5%
Dust - Paved Road Dust	5%	4%	4%
Fuel Comb - Electric Generation - Coal	5%	3%	2%
Dust - Construction Dust	4%	3%	2%
Waste Disposal	3%	3%	4%
Mobile - On-Road Diesel Heavy Duty Vehicles	3%	2%	3%
Mobile - Non-Road Equipment - Diesel	2%	2%	3%
All others	14%	15%	15%

Prescribed fires, unpaved roads, and agriculture dust contribute to both large emissions (52% of total) as well as above average growth



A greater number of sectors had *decreases* in PM2.5 emissions, but 3 of the largest 4 areas are growing



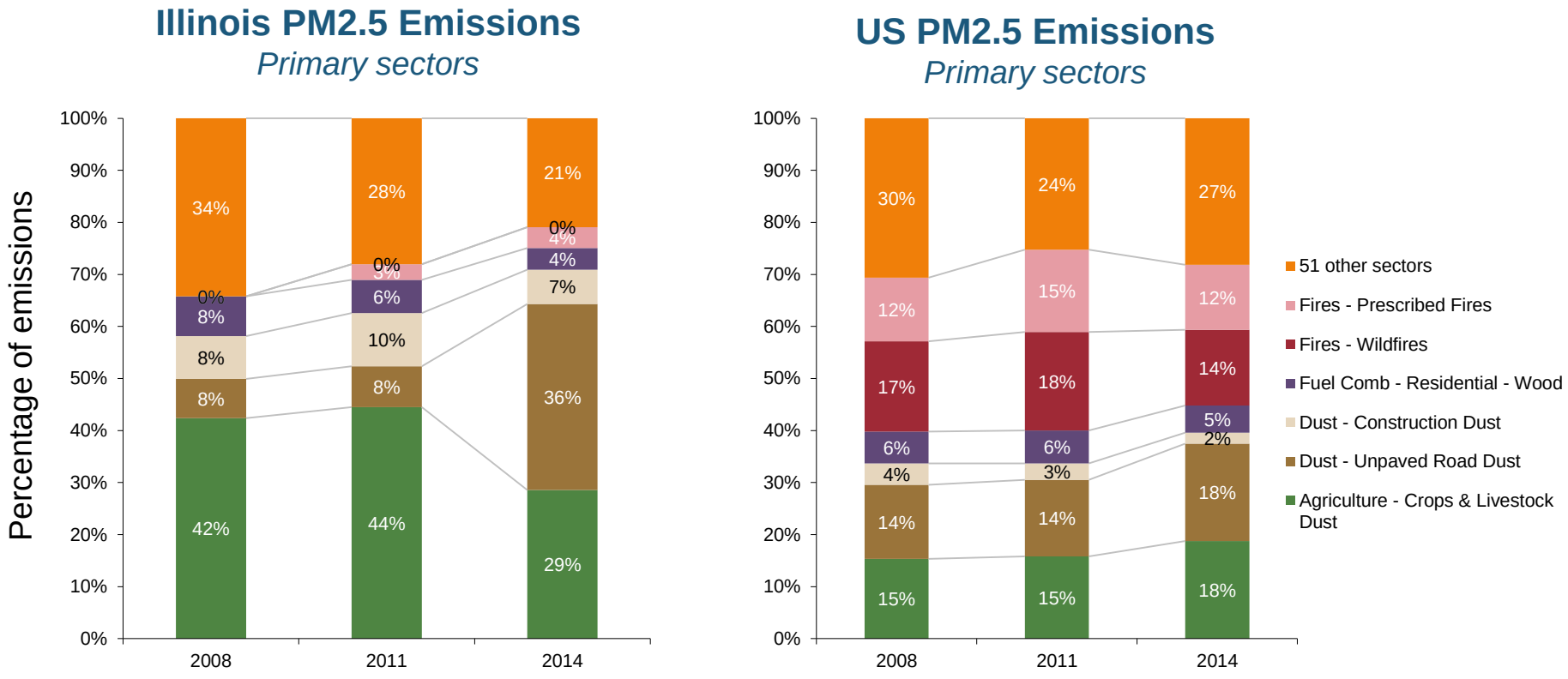
A more detailed view of the largest growth sectors show big increases but are small in absolute terms

Top 10 Sectors with largest increases in PM2.5 emissions

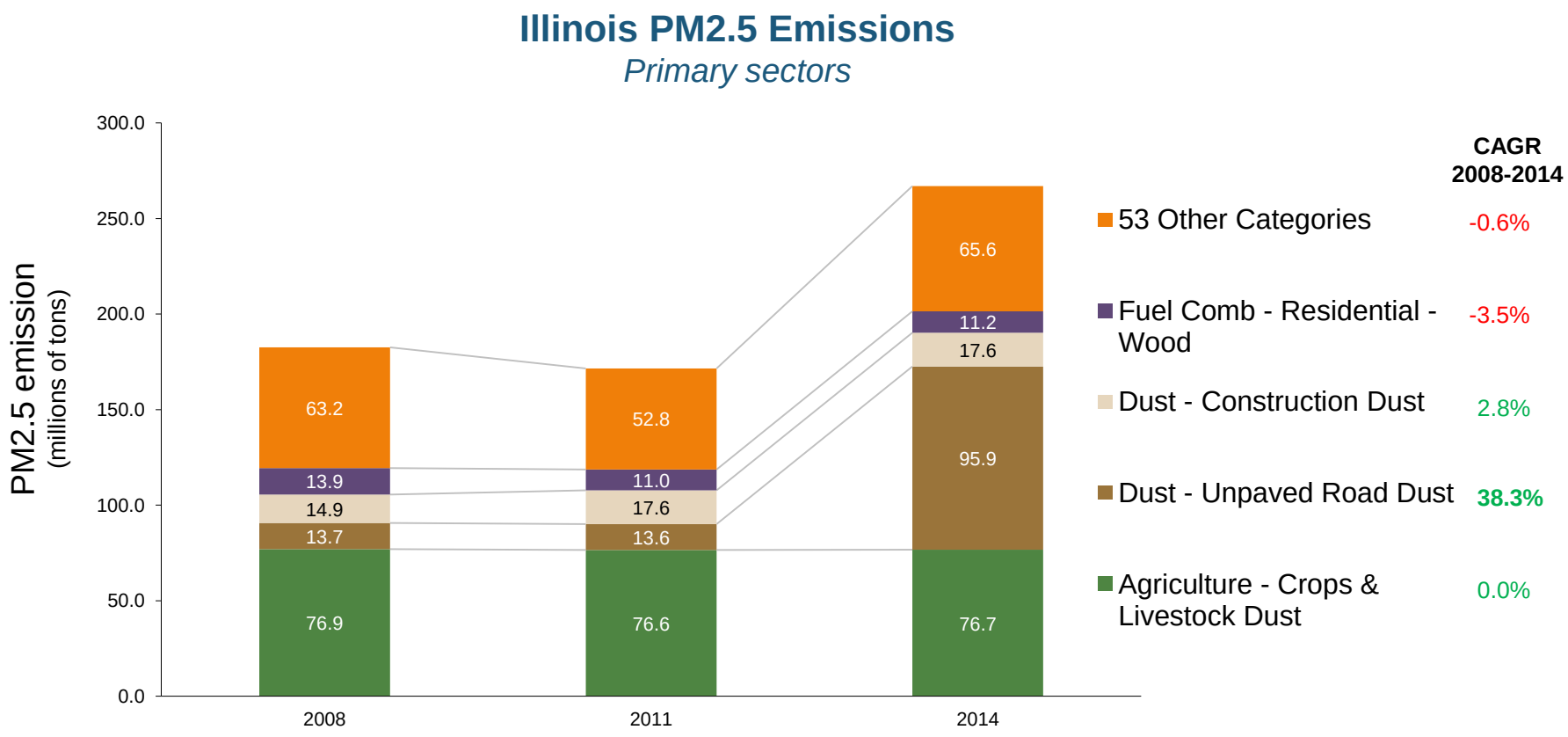
Sectors	2008-2014 CAGR	Contribution to 2014 PM2.5 emissions
Fuel Comb - Industrial Boilers, ICEs - Biomass	29.0%	2.0%
Miscellaneous Non-Industrial NEC	28.8%	<1%
Fuel Comb - Comm/Institutional - Biomass	28.1%	<1%
Industrial Processes - Oil & Gas Production	21.0%	<1%
Mobile - Aircraft	17.0%	<1%
Mobile - Locomotives	11.9%	1%
Mobile - On-Road Diesel Light Duty Vehicles	9.7%	<1%
Commercial Cooking	8.2%	2.0%
Fuel Comb - Electric Generation - Other	8.0%	<1%
Mobile - Non-Road Equipment - Diesel	5.4%	<1%

Total Contribution: ~8%

Relative to US, Illinois has much greater emissions from agricultural crops, unpaved roads, and construction with much less fires



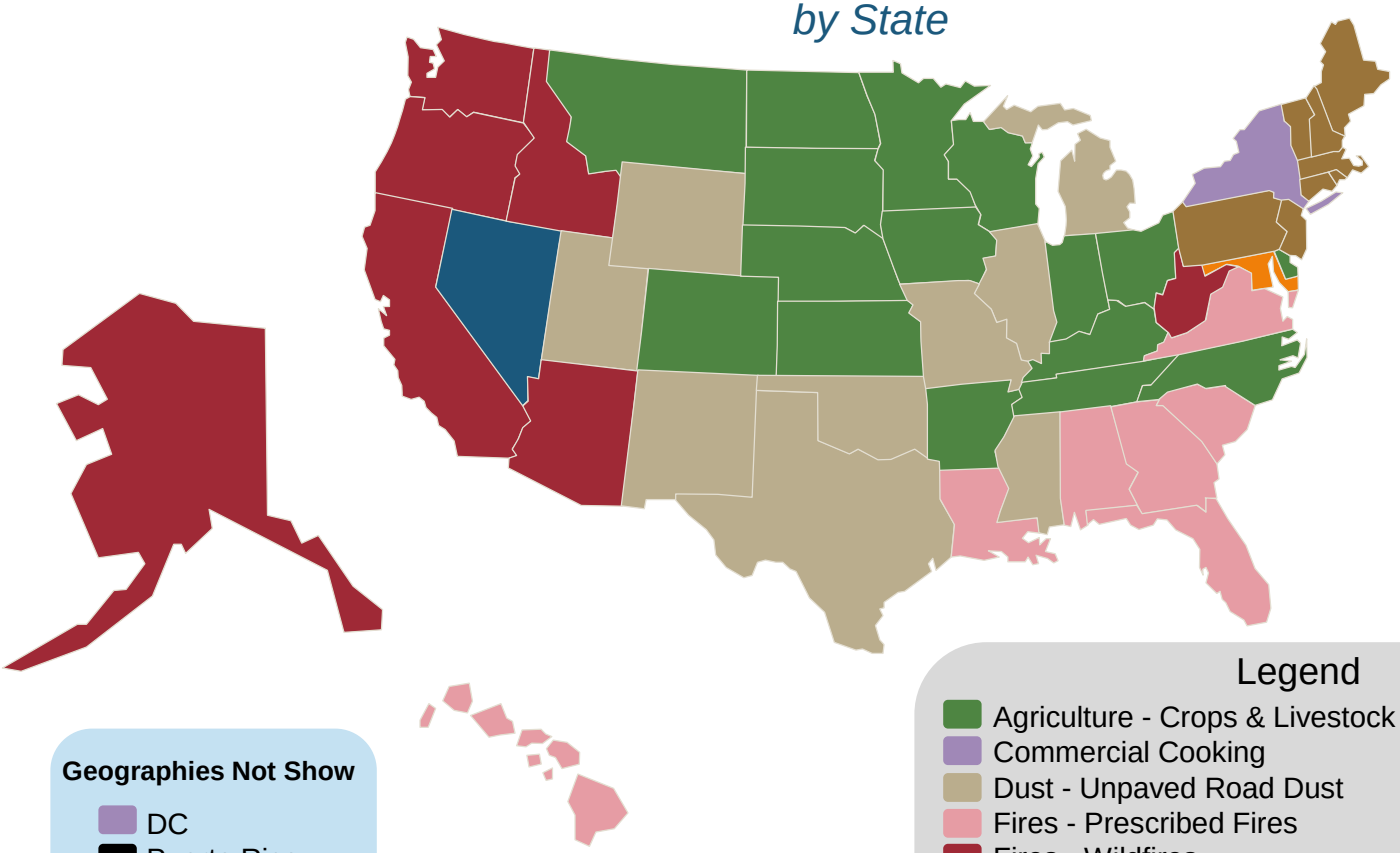
IL showed large growth in PM2.5 emissions primarily from Unpaved Road Dust



In any state the worst sectors can vary, however patterns are clear in each region

Sectors contributing the most to 2014 PM2.5 emissions

by State



Geographies Not Show

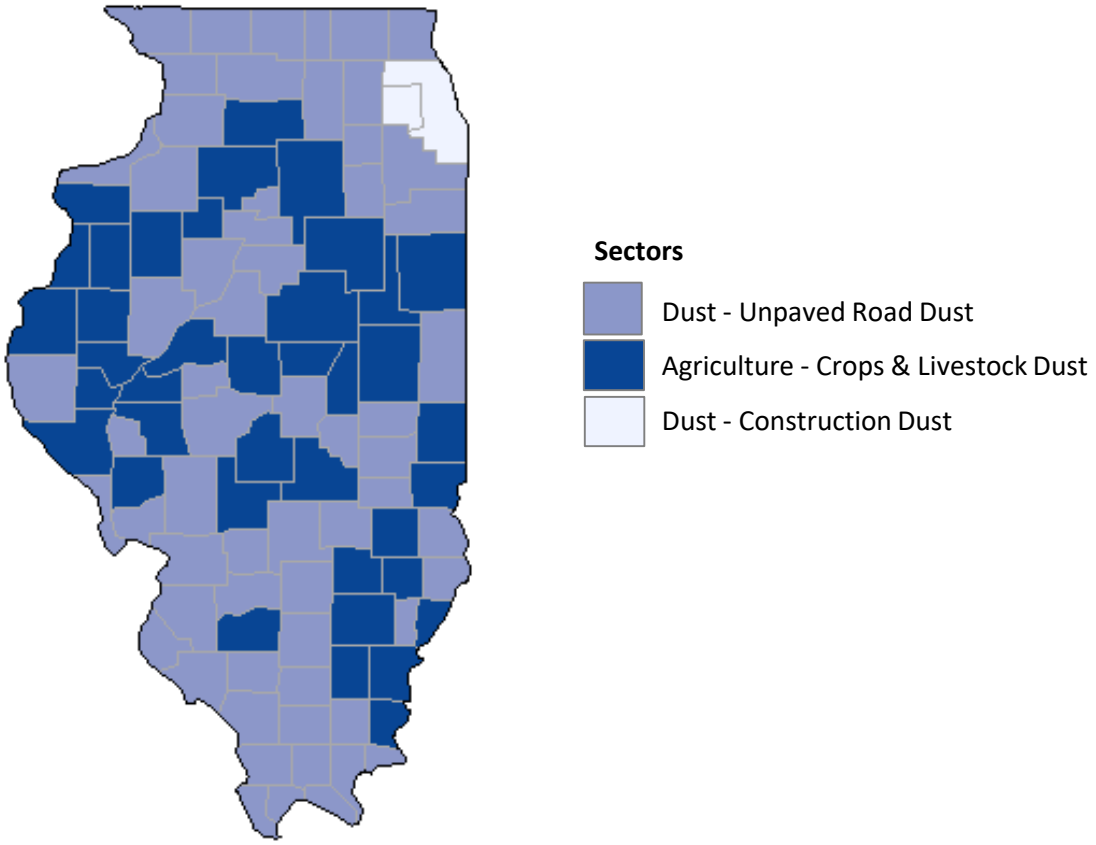
- DC
- Puerto Rico
- Tribal Areas
- Virgin Islands

Legend

- Agriculture - Crops & Livestock Dust
- Commercial Cooking
- Dust - Unpaved Road Dust
- Fires - Prescribed Fires
- Fires - Wildfires
- Fuel Comb - Electric Generation – Coal
- Fuel Comb - Electric Generation – Oil
- Fuel Comb - Residential - Wood
- Industrial Processes - Mining
- Waste Disposal

Chicago area's largest sector is construction dust, while the rest of IL is either Agricultural dust (low population) or Unpaved Road (hi pop)

IL Largest Sectors contributing to PM2.5 emissions 2014



For IL the primary 4 sectors are Unpaved Road Dust, Agricultural dust, Construction dust, and Wood Fuel

Percentage Contribution to PM2.5 Emissions

(worst offending sectors)

	2008	2011	2014
Dust - Unpaved Road Dust	8%	8%	36%
Agriculture - Crops & Livestock Dust	42%	44%	29%
Dust - Construction Dust	8%	10%	7%
Fuel Comb - Residential - Wood	8%	6%	4%
Fires - Prescribed Fires	0%	3%	4%
Mobile - Non-Road Equipment - Diesel	4%	3%	3%
Waste Disposal	4%	0%	3%
Mobile - On-Road Diesel Heavy Duty Vehicles	4%	3%	2%
Fuel Comb - Electric Generation - Coal	4%	4%	2%
Dust - Paved Road Dust	4%	5%	2%
Industrial Processes - NEC	2%	2%	1%
All others	13%	10%	8%