Opportunities for Reducing Vegetative Ozone Exposure through U.S. Power Plant Carbon Standards

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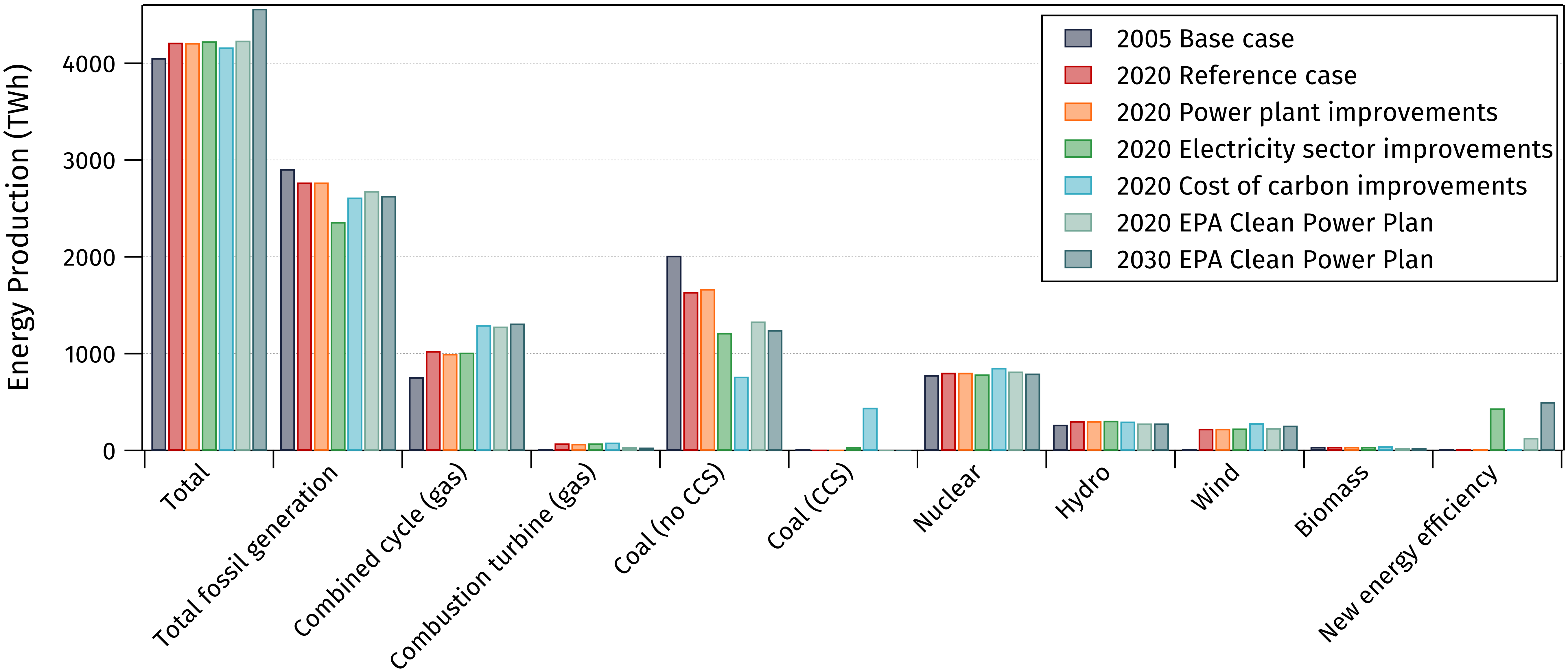
Scenarios Relevant to Implementation of EPA Proposed Clean Power Plan (CPP)

- **2005 Base case**
- **2020 Reference case:** NRDC & BPC; EIA demand; existing regs
- **2020 Scenario 1:** BPC; heat-rate improvements for coal-fired EGUs
- **2020 Scenario 2:** NRDC; demand-side efficiency; moderate CO_2 standards
- **2020 Scenario 3:** BPC; tax based on social cost of carbon
- **2020 EPA Clean Power Plan:** proposed option 1, partial implementation
- **2030 EPA Clean Power Plan:** proposed option 1, full implementation

Natural Resources Defense Council (NRDC) | Bipartisan Policy Center (BPC) | Energy Information Administration (EIA)

Driscoll et al., *Nature Climate Change* (2015)

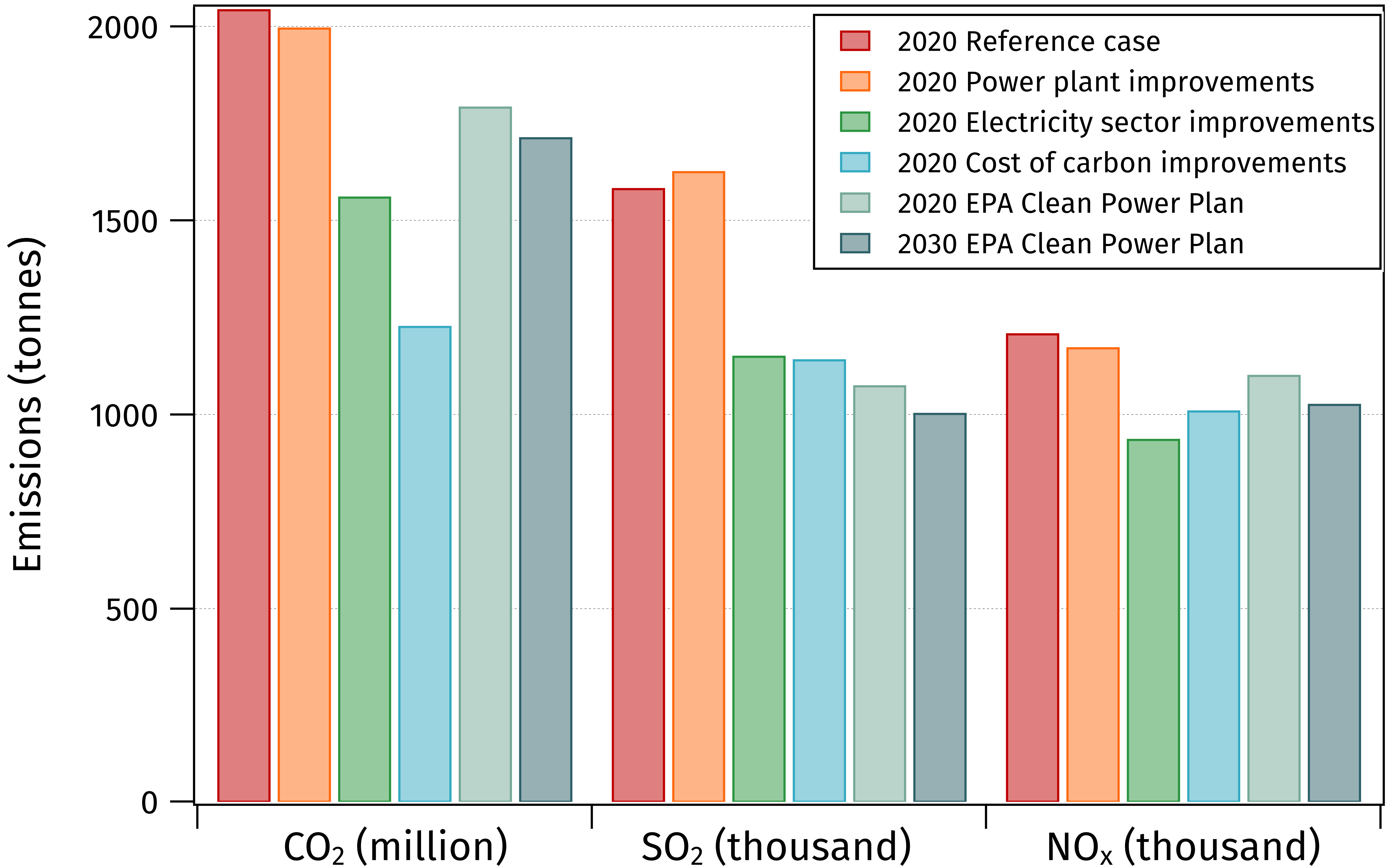
Energy Generation in Each Scenario



- Developed using the Integrated Planning Model (IPM)
- 2,417 fossil-fuel based EGUs in US included

Driscoll et al., *Nature Climate Change* (2015)

Emissions Resulting from Each Scenario



Driscoll et al., *Nature Climate Change* (2015)

CMAQ & BenMAP Modeling of Scenarios

- 2007/2020 modeling platform from EPA $PM_{2.5}$ RIA
- 12-km x 12-km horizontal resolution
- WRF v3.1 meteorology fixed at 2007

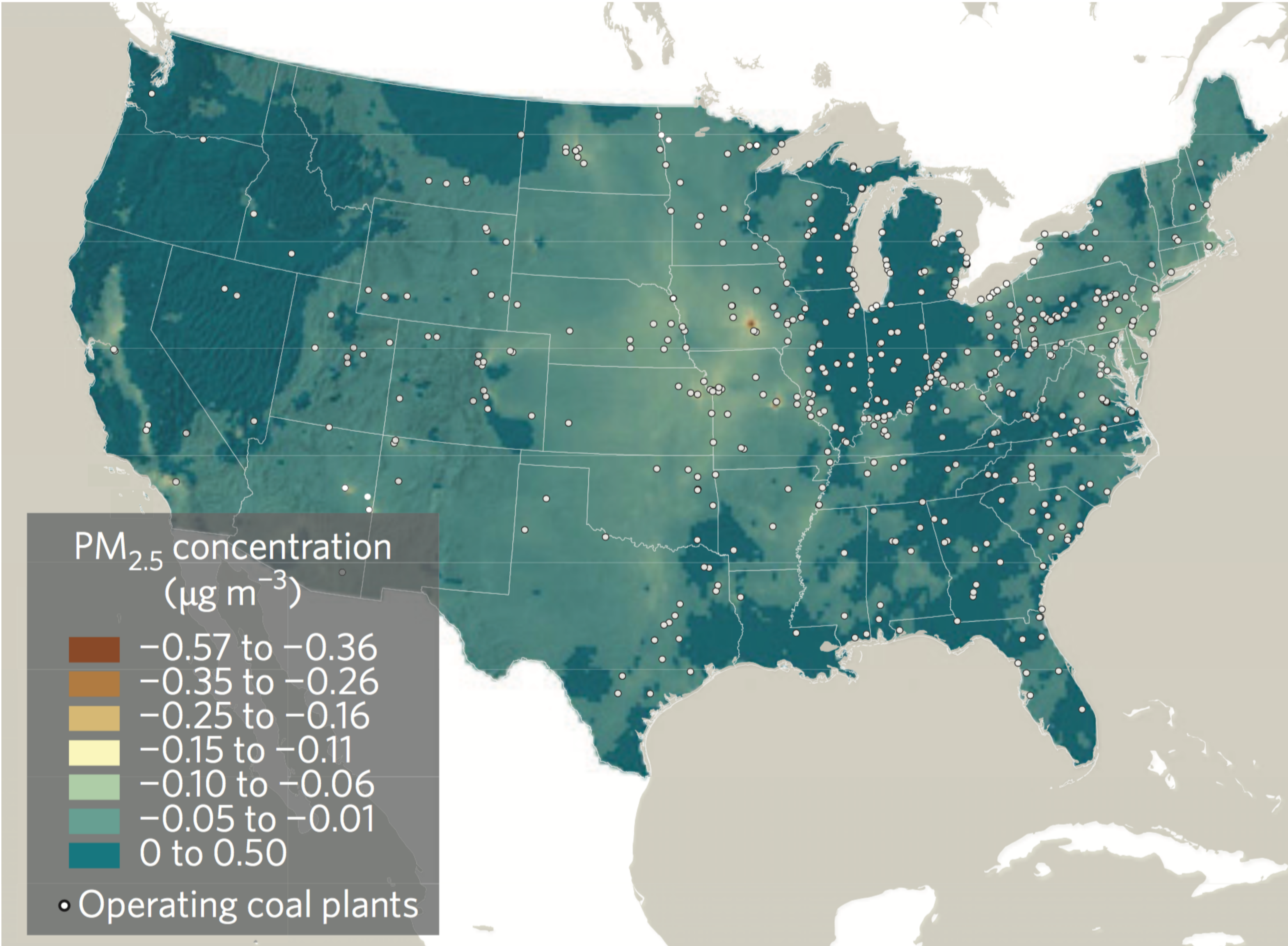
- CMAQ version 4.7.1
  - CB05 gas chemistry
  - AE5 aerosol chemistry
  - mercury chemistry

- 1% increase in all-cause mortality rate for adults ≥25 yo per μg m^{-3} increase in annual average $PM_{2.5}$ concentration (Roman et al., 2008)

- respiratory mortality risk for adults ≥30 yo as function of the ozone season average of the 1-hour maximum (Jerrett et al., 2009)

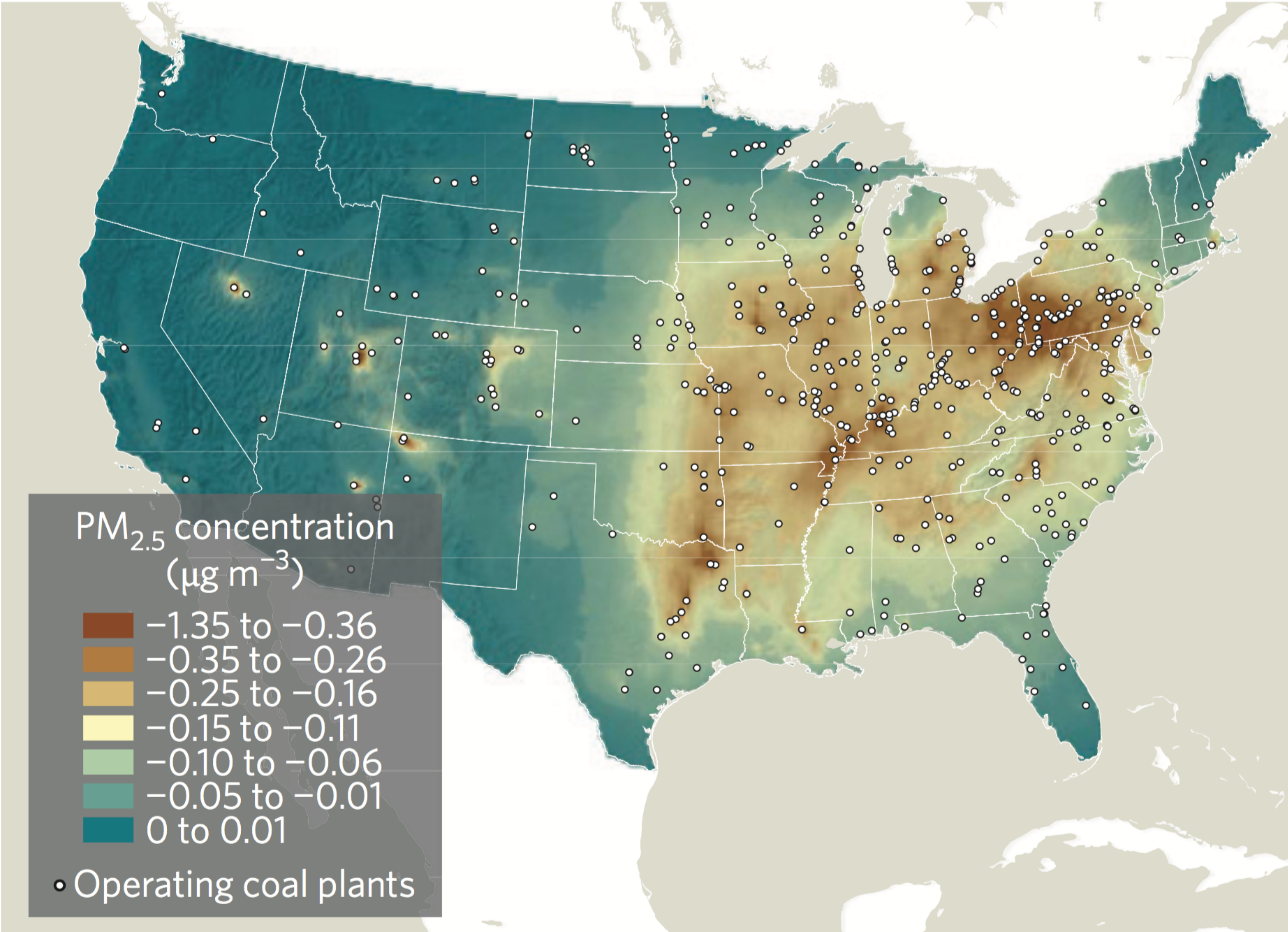
Driscoll et al., *Nature Climate Change* (2015)

Air Quality Co-benefits: $PM_{2.5}$ | Scenario 1



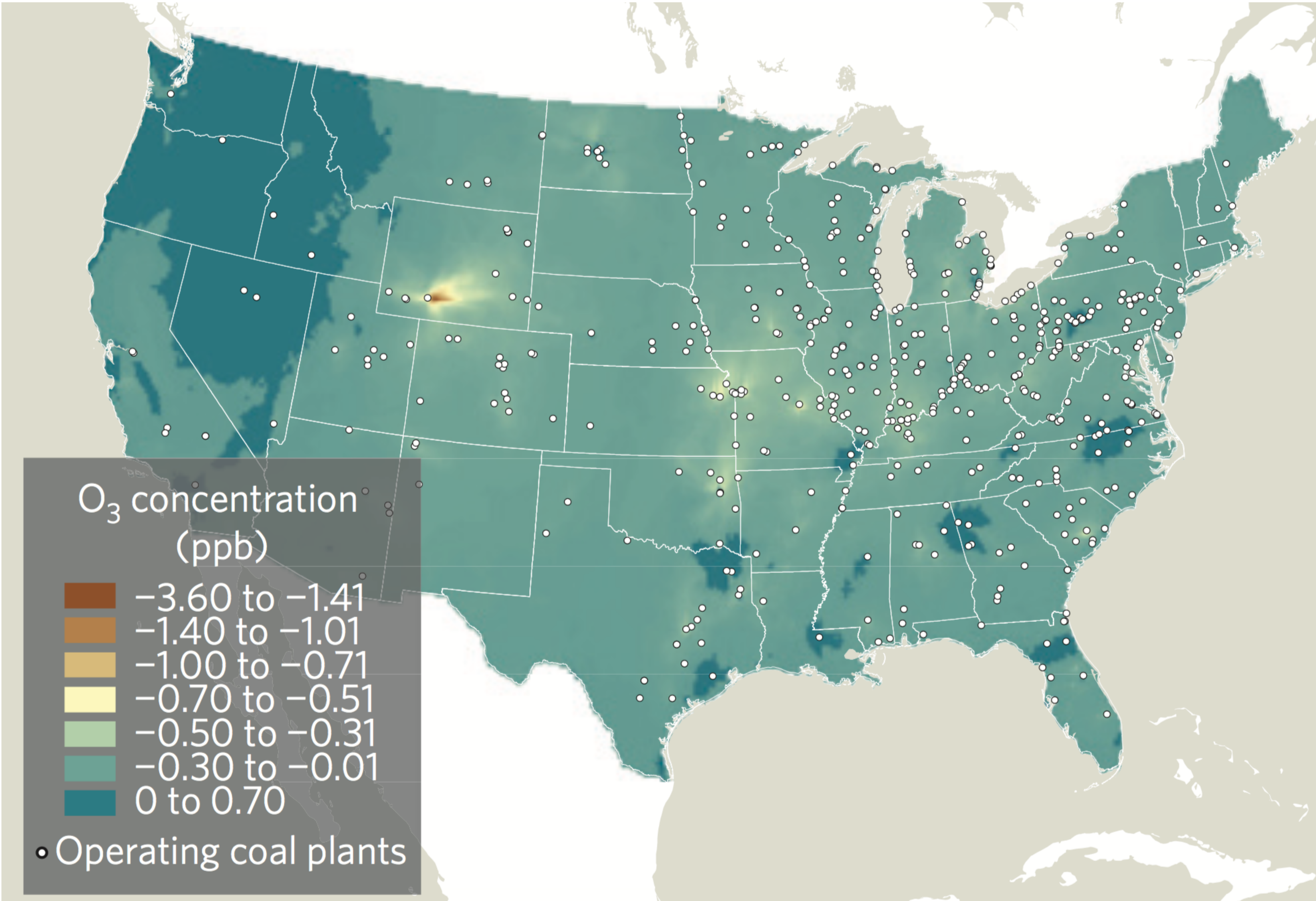
difference from 2020 Reference | annual average | Driscoll et al., *Nature Climate Change* (2015)

Air Quality Co-benefits: $PM_{2.5}$ | Scenario 2



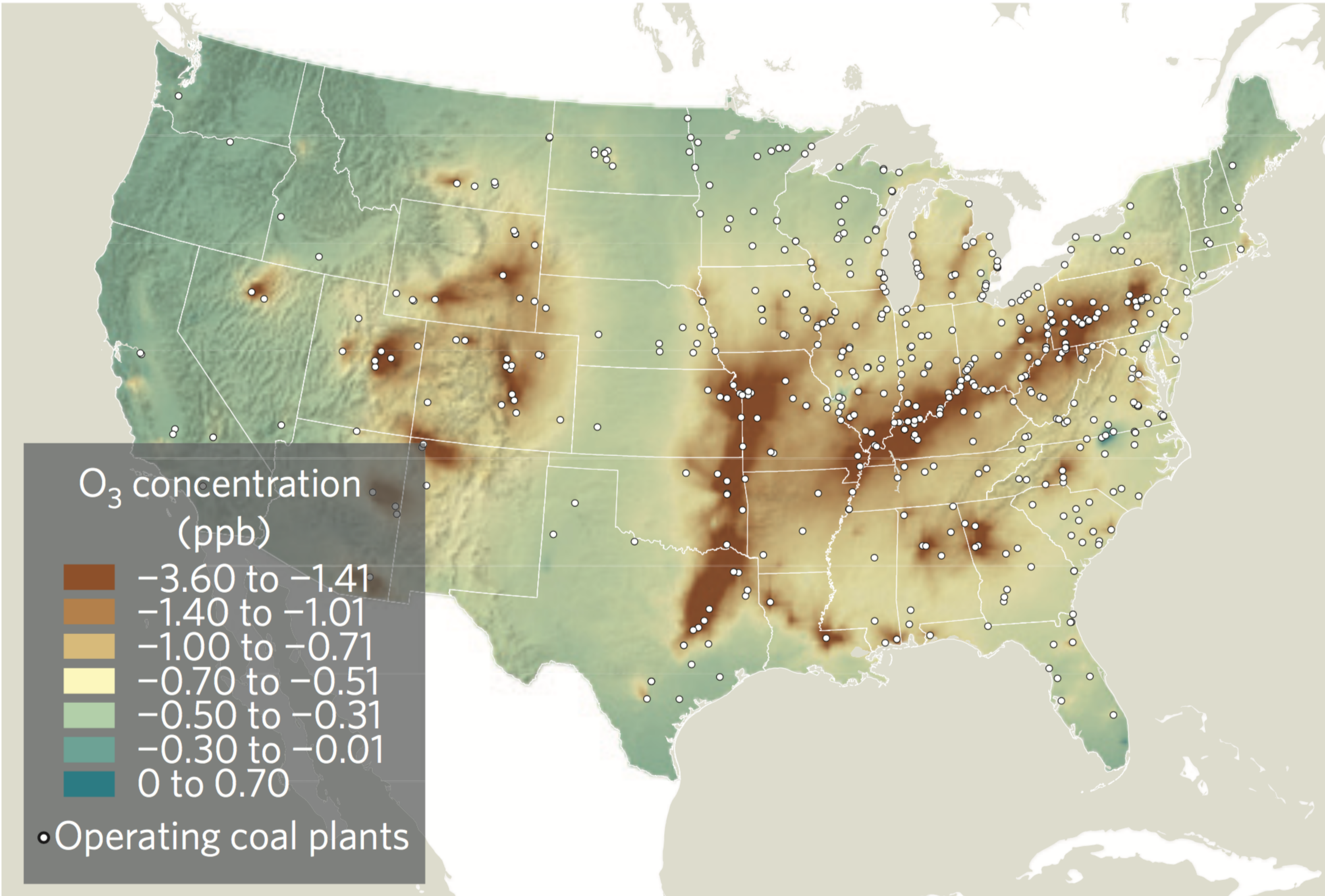
difference from 2020 Reference | annual average | Driscoll et al., *Nature Climate Change* (2015)

Air Quality Co-benefits: O_3 | Scenario 1



difference from 2020 Reference | 6-mn mean 1-hr max | Driscoll et al., *Nature Climate Change* (2015)

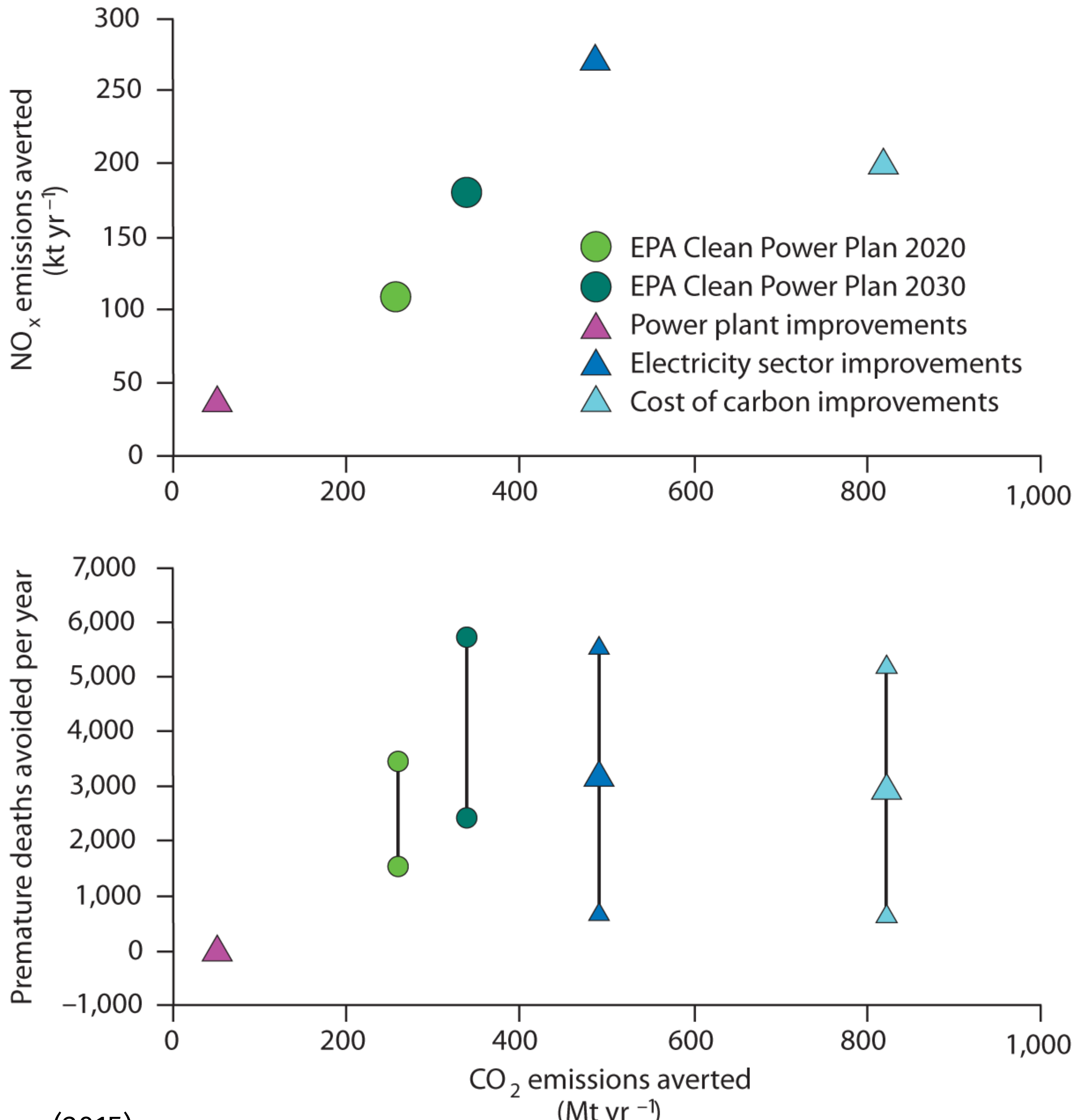
Air Quality Co-benefits: O_3 | Scenario 2



difference from 2020 Reference | 6-mn mean 1-hr max | Driscoll et al., *Nature Climate Change* (2015)

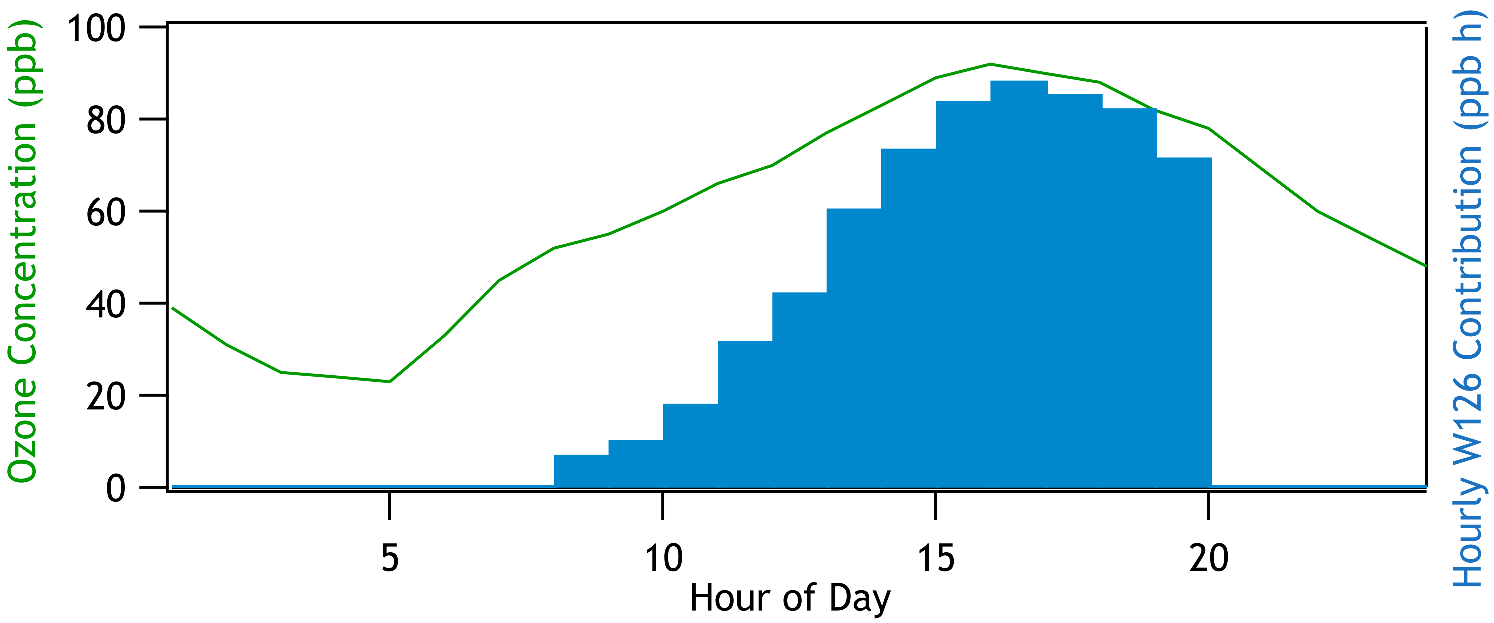
Human Health Co-benefits

- NO_x emissions contribute to both O_3 and $PM_{2.5}$ formation
- $PM_{2.5}$ and O_3 contributions to the mortality rate included



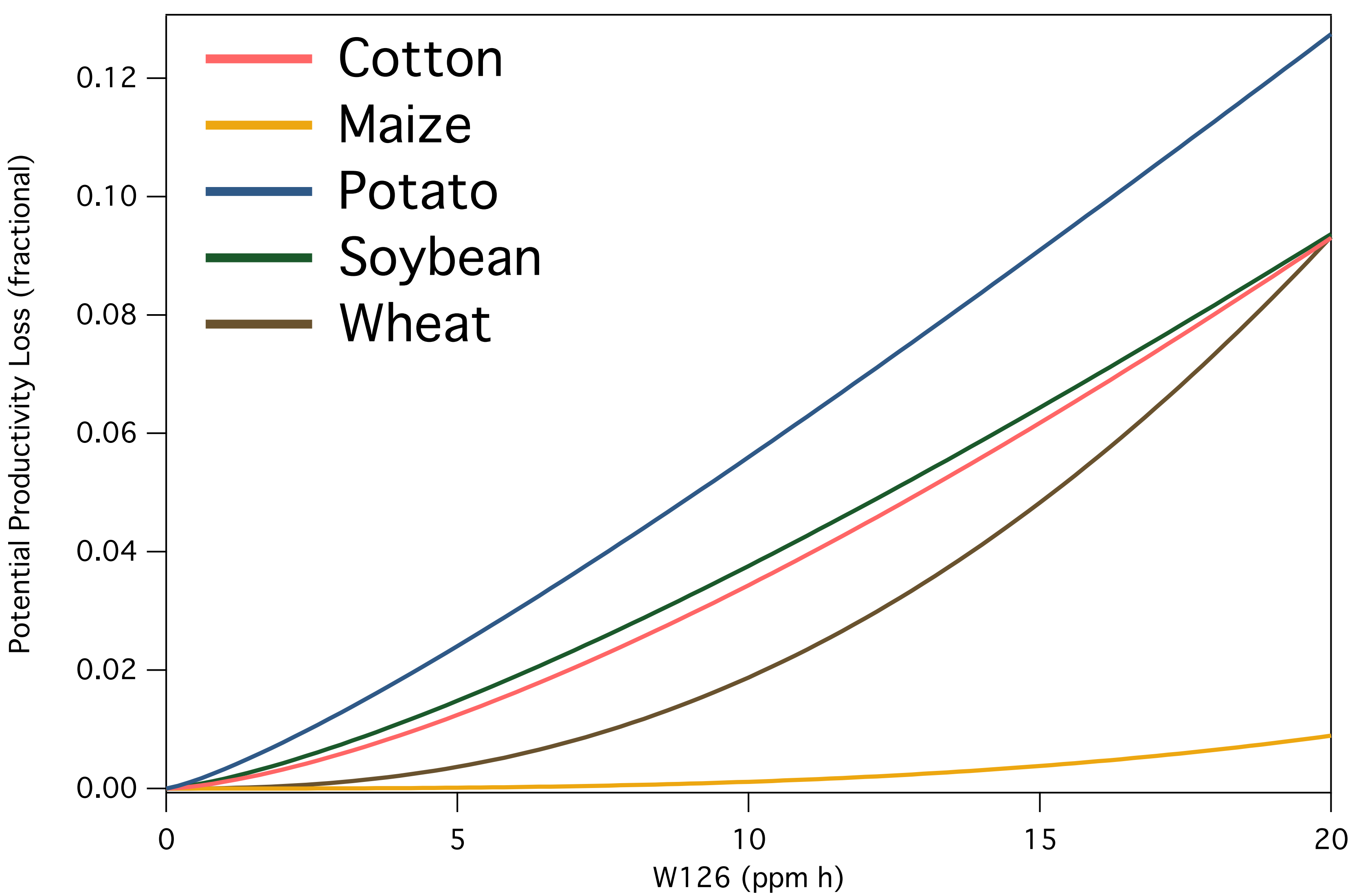
Driscoll et al., *Nature Climate Change* (2015)

Exposure-Response of Vegetation



$$W126_{90\ day} = \left[\sum_{i=1}^{90} \left(\frac{[O_3]}{1+\left(4403e^{-126[O_3]}\right)} \right) \Bigg|_{i,8am\text{-}8pm\ (LST)} \right]$$

$$RYL = 1 - \exp\left[-\left(\frac{W126}{A_i} \right)^{B_i} \right]$$

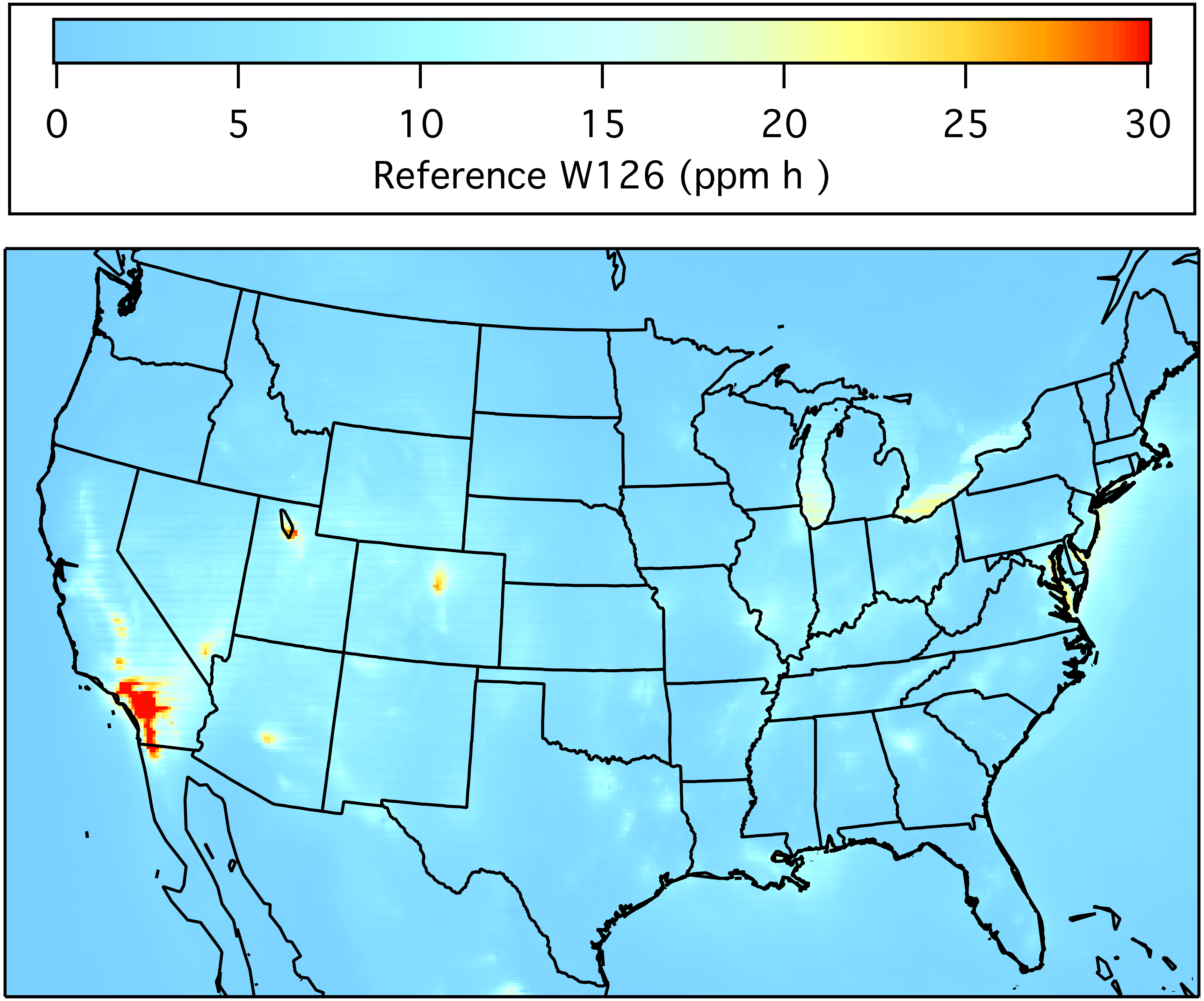


Relative yield loss (RYL) as a function of the W126 ozone exposure metric has been empirically determined for 5 crops and 11 tree species.

Multiplying RYL by the productivity determines the potential productivity loss (PPL) of each species.

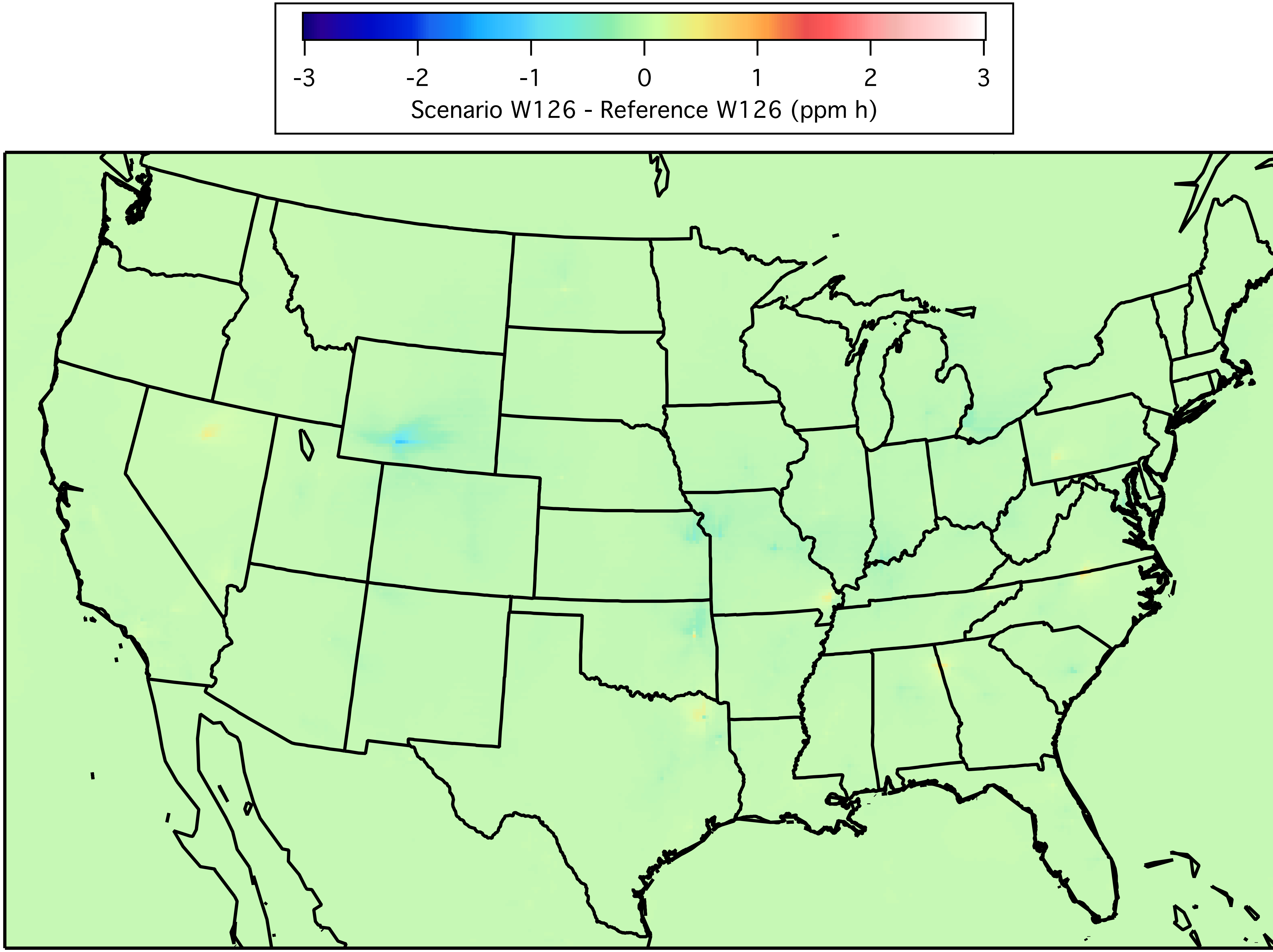
Lehrer, A. et al., EPA 452/R-07-002, (2007)

Reference Case: W126



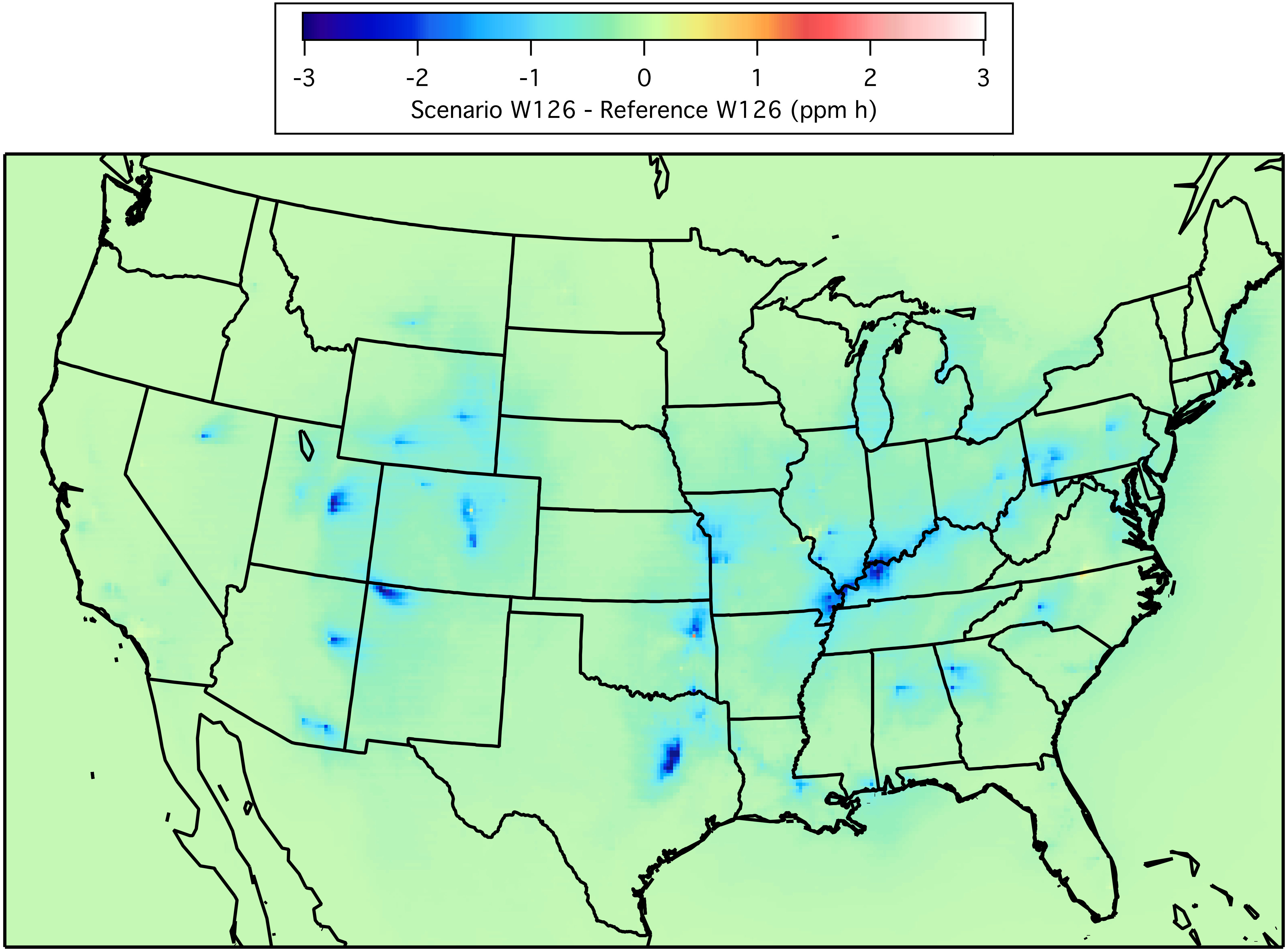
Capps et al., *in review*

Air Quality Co-benefits: W126 | Scenario 1



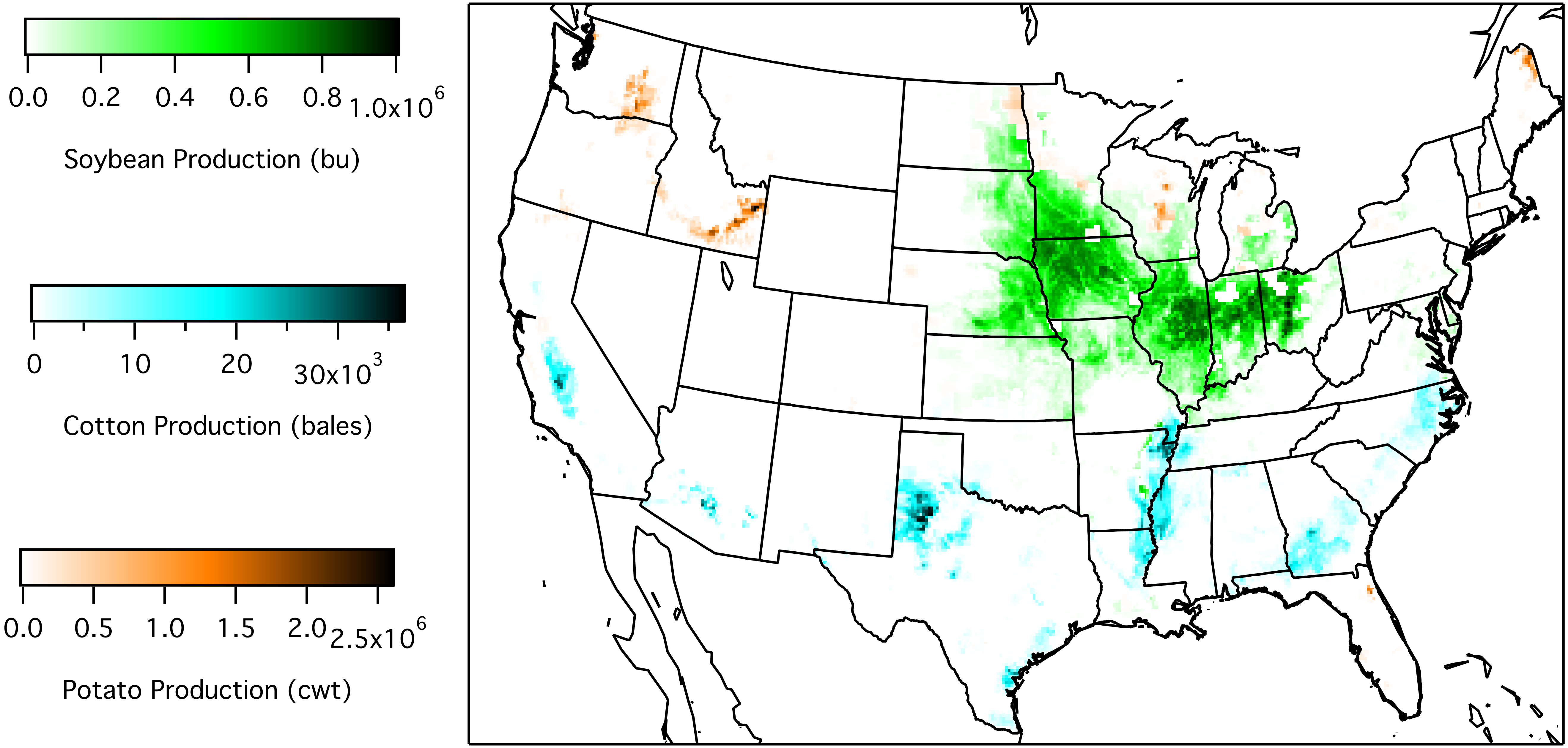
Capps et al., *in review*

Air Quality Co-benefits: W126 | Scenario 2



Capps et al., *in review*

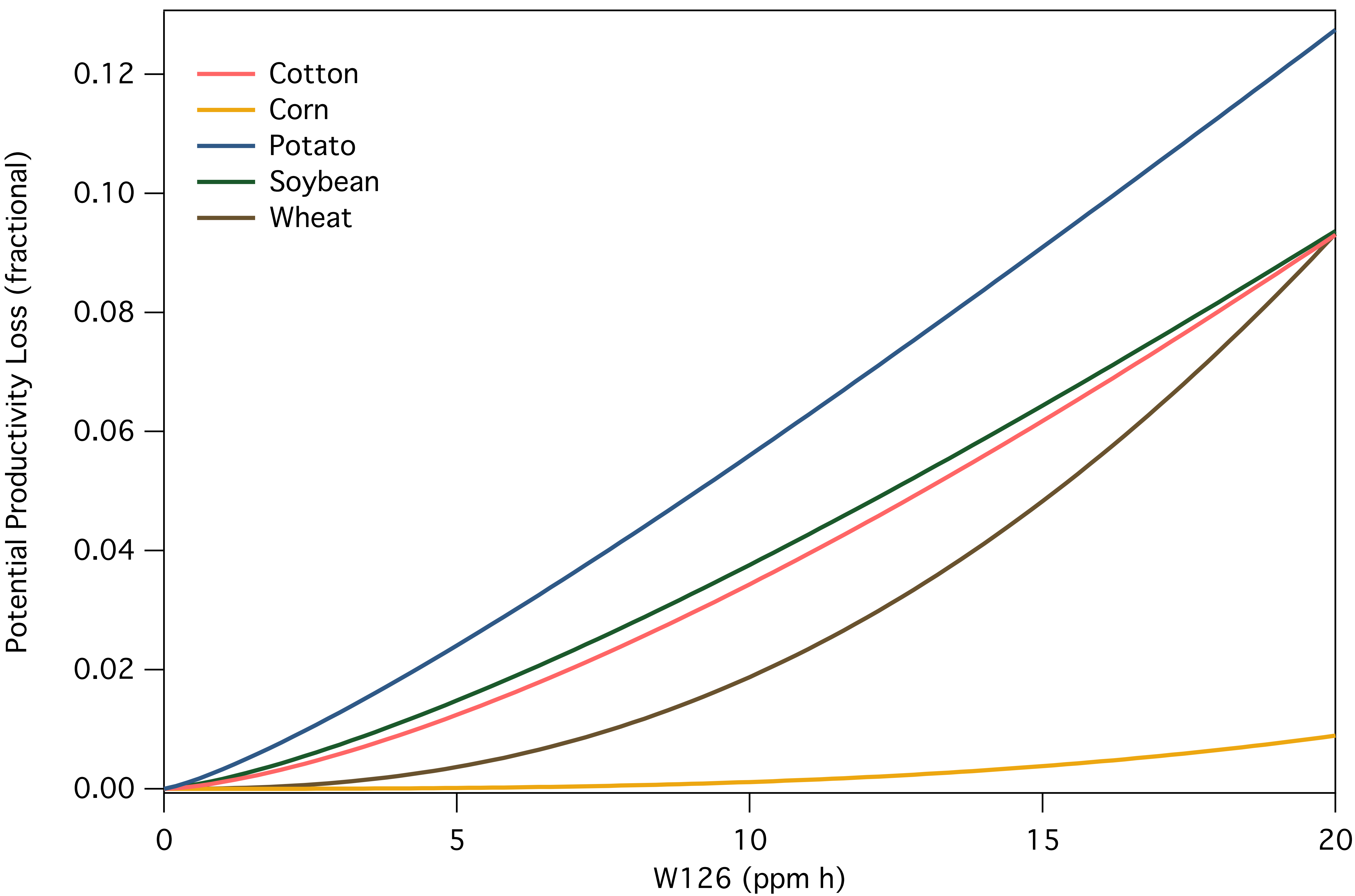
Crop Distribution



USDA National Agricultural Statistics Survey (NASS) 2007 crop production distributed in accordance with the Biogenic Emissions Landuse Database (BELD) v.4.
(R. Pinder, E. Cooter)

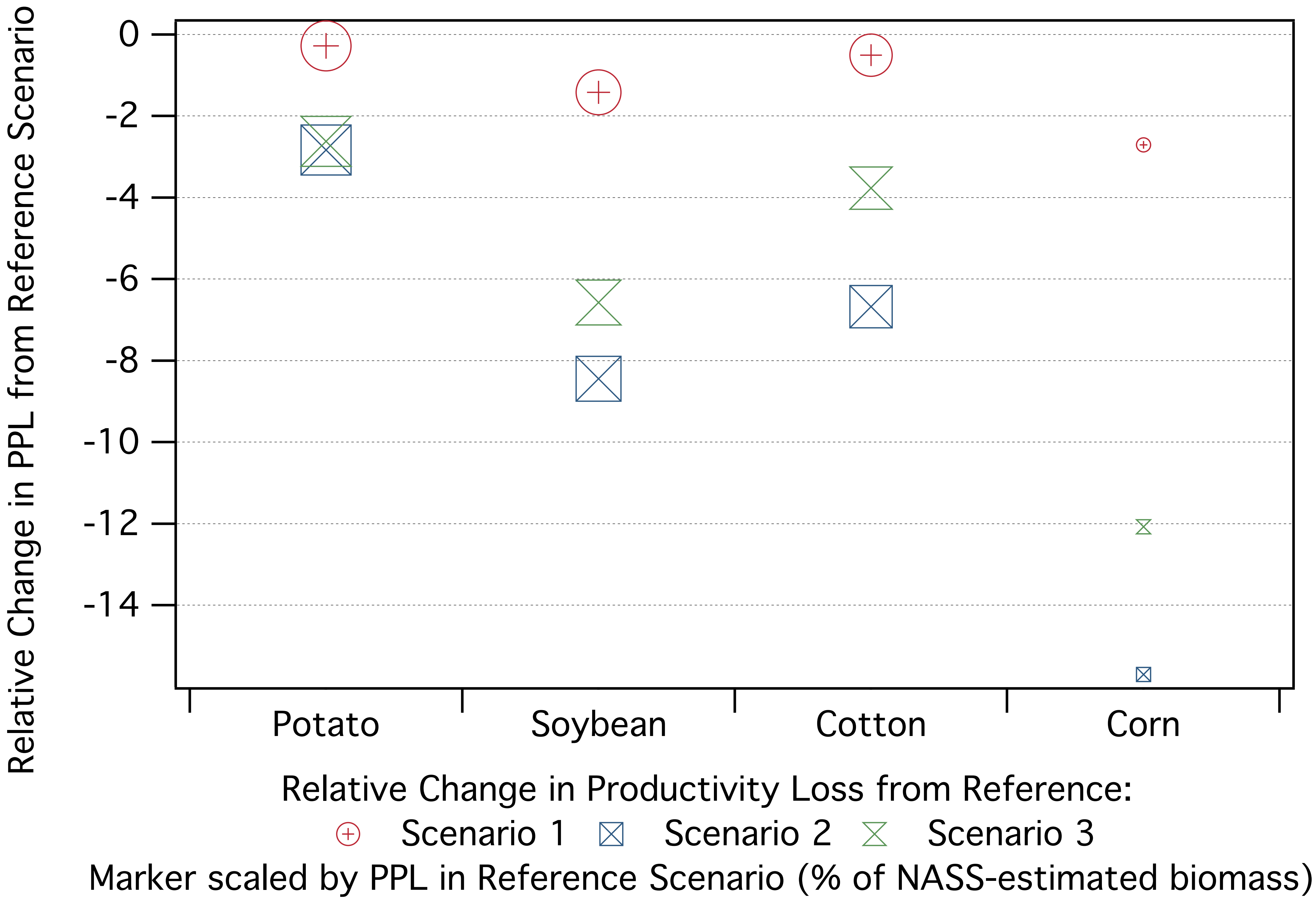
Capps et al., *in review*

Crop Exposure-Response Functions



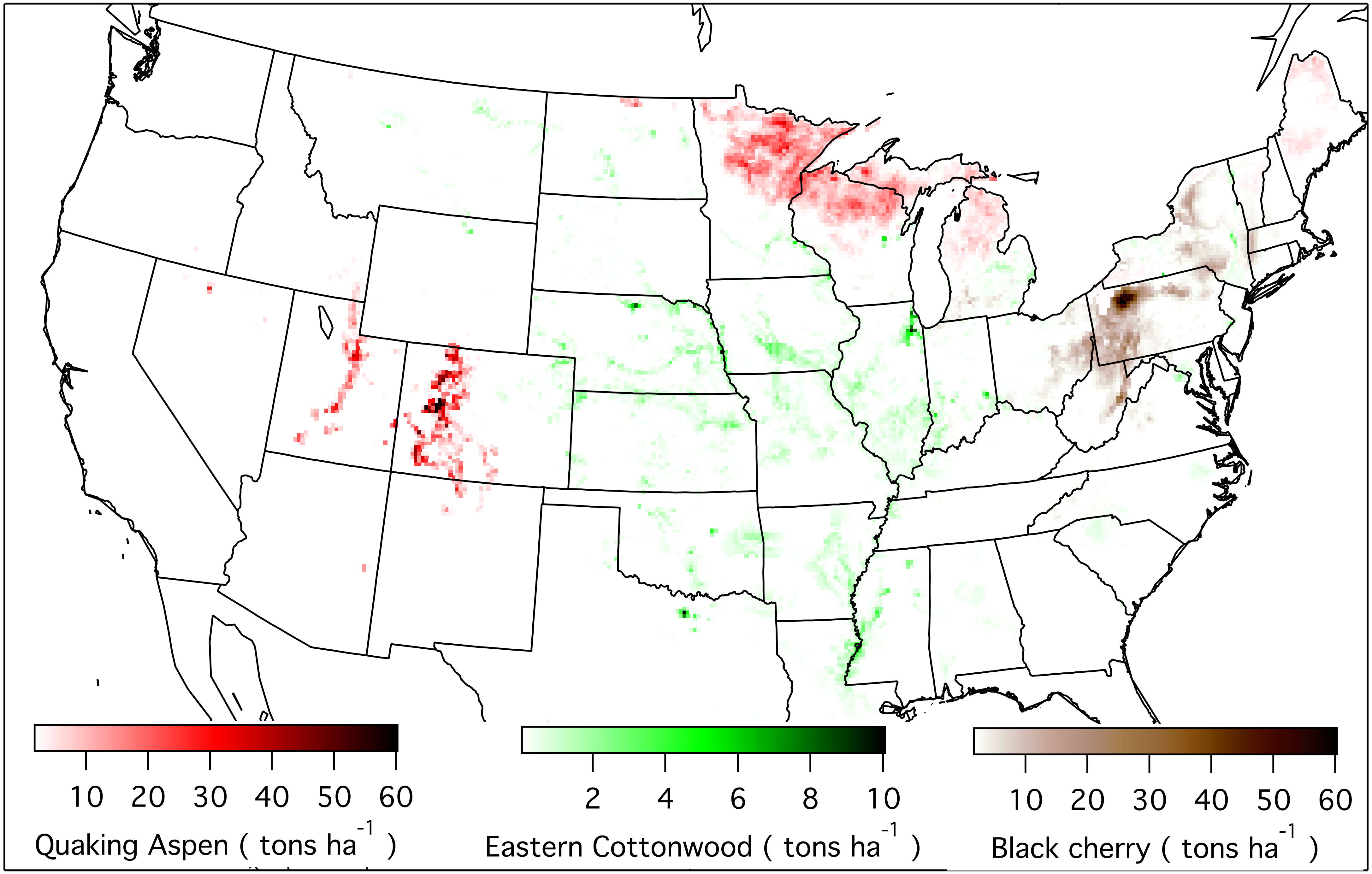
Lehrer, A. et al., EPA 452/R-07-002, (2007)

Crop Potential Productivity Co-benefits



Capps et al., *in review*

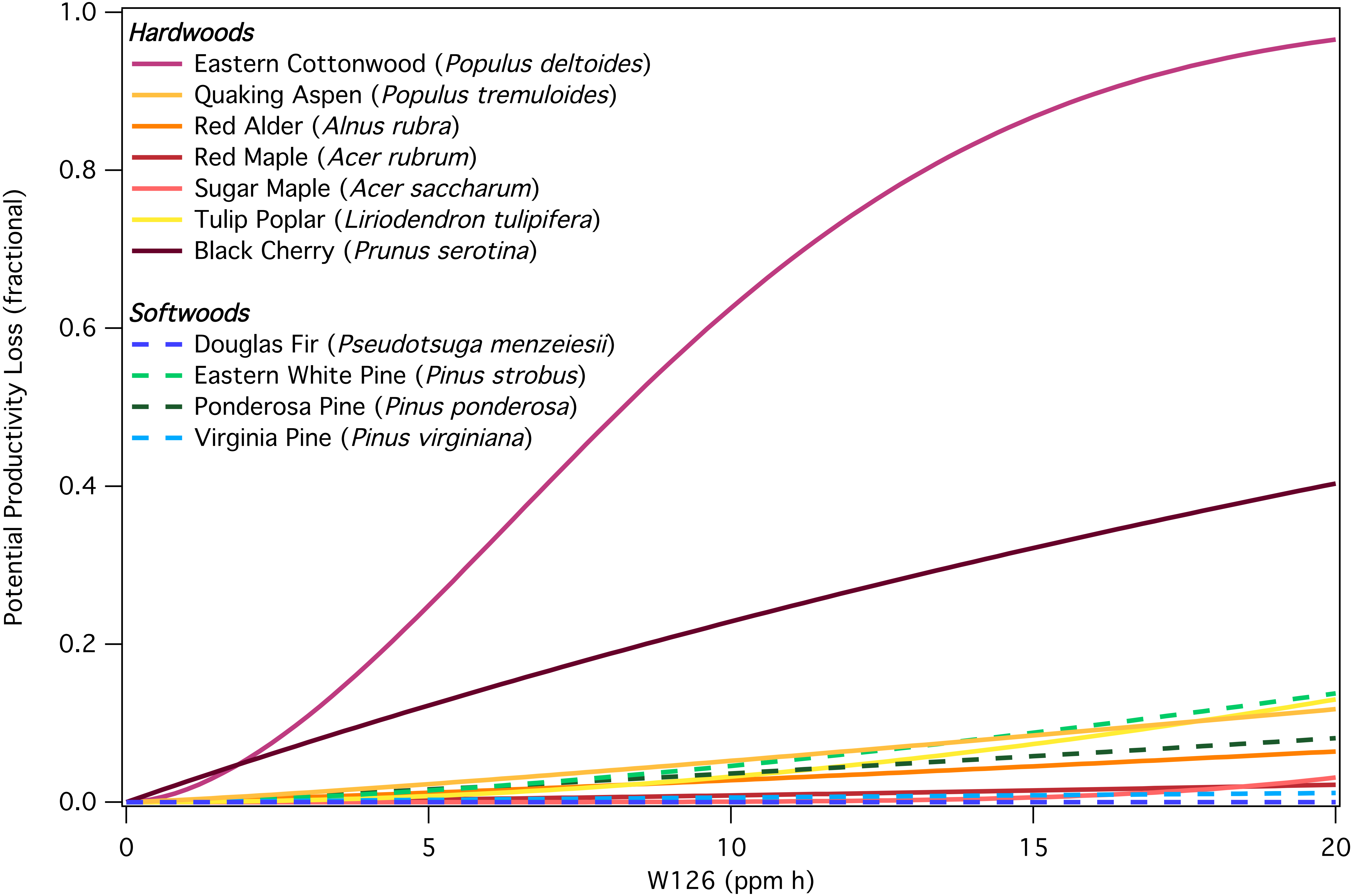
Tree Distributions



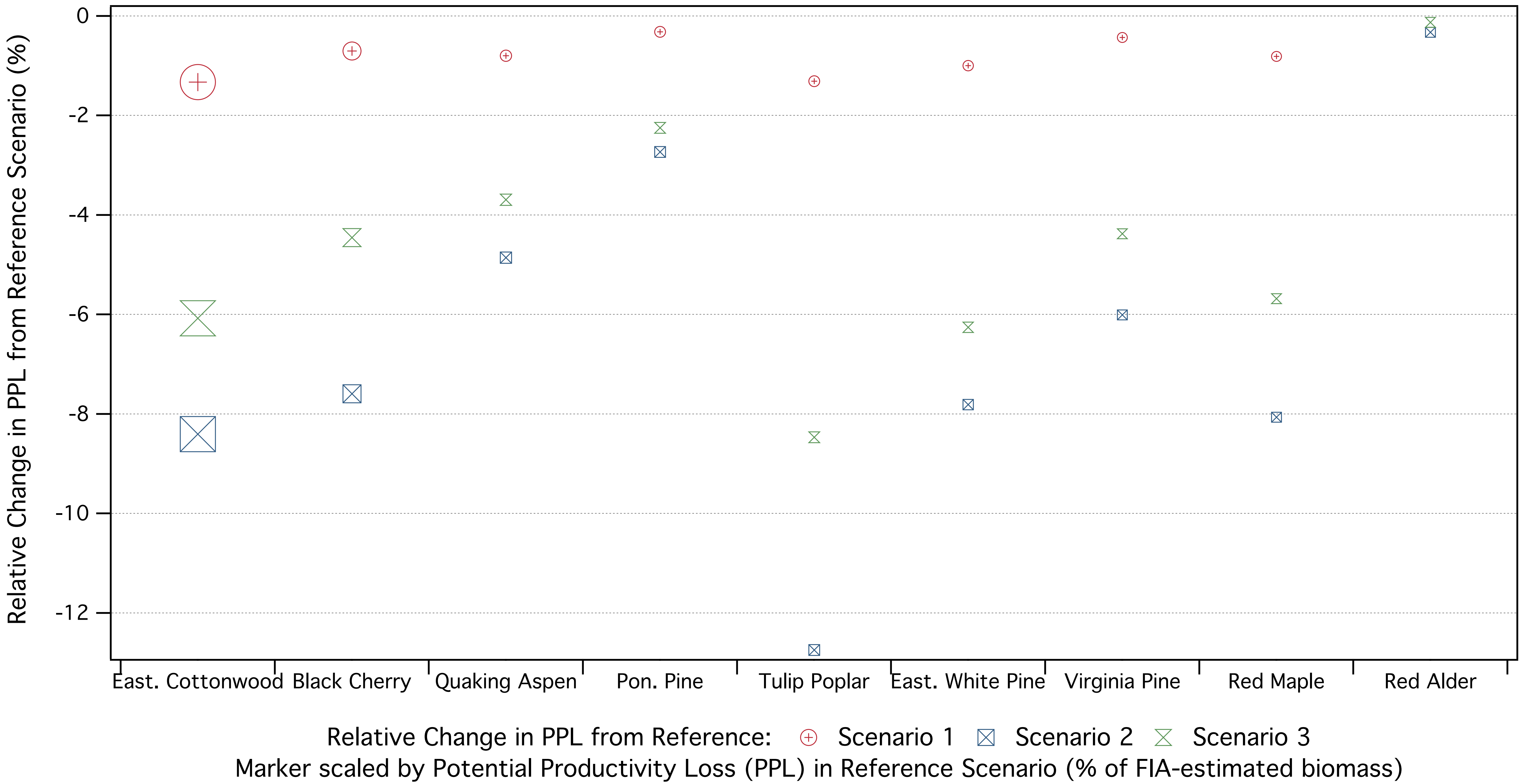
USDA Forest Inventory Analysis tree biomass distributed in accordance with the National Land Cover Database; MODIS-derived image composites and percent tree cover; and other geographic and climatological parameters. (Bash et al., 2016)

Capps et al., *in review*

Tree Exposure-Response Functions



Tree Potential Productivity Co-benefits



- Consistent with the exposure-response functions, eastern cottonwood is most impacted by ozone exposure.
- Tulip poplar and black cherry respond most significantly to change in W126.

Conclusions

- The reduction of co-pollutant emissions with the potential implementations of the Clean Power Plan could improve both ***human health and public welfare***.

- Due to coincident NO_x emission reductions with CO_2 emissions mitigations, ***more substantial gains for crops and trees are possible with moderately stringent CO_2 emissions standards*** or a CO_2 tax than with power plant improvements.

  - reductions in potential productivity losses (PPL) up to 15.6% for corn and up to 8.4% for soybean crops

  - reductions in PPL up to 7.6% for black cherry and up to 8.4% for eastern cottonwood trees

Additional Resources

- Project website
- Shannon Capps, Drexel University
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- Charles Driscoll, Syracuse University
  - ctdrisco@syr.edu

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