Using Satellite Data to Quantify Cropland Burning and Related Emissions in the Contiguous United States: Lessons Learned

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Introduction

- Prescribed fires in agricultural landscapes generally produce smaller burns
  - Important contributors in terms of air quality and human health
- Not wildland fires
  - Different burn seasons, management, timing, diurnal cycle
- Ground-level permitting and/or tracking varies from state to state
  - Necessitates use of remote sensing data

Data and Methods

- Four remote sensing products/approaches analyzed
  - – Burned Area
  - – $PM_{2.5}$ emissions

1. NOAA Hazard Mapping System (2006)
2. McCarty Cropland-Specific Burned Area (2005-2007)
3. SmartFire2 (2008)
4. MODIS Standard Products (2006)

❖ *2008 NEI Agricultural Fire $PM_{2.5}$ Emissions Version 1.5*

NOAA Hazard Mapping System

- Dr. Pouliot of the U.S. EPA adapted NOAA HMS data

1. If satellite detections within 2 km and at the same time as a GOES detection, the detection was deemed to be a duplicate and was removed
   - This process only removed a small number of detections over the year - less than 0.1% of all detections
2. Assigned crop type from crop maps provided by McCarty (2011); derived from USDA NASS 30 m Cropland Data Layer
3. Assigned burned area from state specific information on average field size
4. Crop type-specific emission factors, combustion efficiency, fuel loads

McCarty Cropland-Specific Burned Area

1. 8-day differencing of normalized burn ratio (dNBR) burned area maps were derived from 500 m Moderate Resolution Imaging Spectroradiometer (MODIS) Surface Reflectance Product (MOD09A1) for each MODIS tile in the CONUS
2. Areas undetected by the dNBR approach were mapped by assigning spatially non-coincident 1 km MODIS Active Fire Product (MOD14/MYD14) the average field size in each agricultural region and combined with dNBR maps
3. Assigned crop type from crop maps provided by McCarty (2011); derived from USDA NASS 30 m Cropland Data Layer
4. Crop type-specific emission factors, combustion efficiency, fuel loads

SmartFire2

- Activity data provided by Sean Raffuse of STI, Inc.

1. Fires were selected as “ag” fires if intersected with the USGS National Land Cover Dataset (NLCD) land cover types 81-Pasture Hay or 82-Cultivated Crops
2. For the analysis, assumed a nominal per fire size of 40 acres to calculate state totals
3. $PM_{2.5}$ emission estimates were calculated by utilizing an average cropland emission factors, fuel loadings, and combustion completeness values.

Official MODIS Combined

1. The 500 m MODIS Burned Area (MCD45A1) daily product derived from both Terra and Aqua detections;
   - Algorithm utilizes changes in spectral, temporal, and vegetation structural characteristics to identify and map burned areas
   - ‘Burned’ pixels are identified through statistically significant drops in 500 m MODIS daily surface reflectance data
2. The 1 km active fire detections (MOD/MYD14) from both MODIS sensors are acquired four times daily at 1030 and 2230 (Terra) and 0130 and 1330 (Aqua), equatorial local time
   - Assumed same regional average field size areas as those used in the cropland-specific burned area product; also removed overlapping active fire data before emission calculations
3. Both products combined into one product for year 2006
4. $PM_{2.5}$ emission estimates were calculated by utilizing an average cropland emission factors, fuel loadings, and combustion completeness values

Bottom-Up Approach

- $A * B * CE * e_i$ (Seiler and Crutzen, 1980), where A = burned area, B = fuel load, CE = combustion efficiency, and e_i = emission factor

Emission Calculation Variables (1/2)

Crop Type	Fuel Loading (tons/acre)	Combustion Completeness	PM2.5 (lbs/ton)
Kentucky bluegrass	2.91	0.85	23.23
Corn	4.19	0.75	9.94
Cotton	1.70	0.65	12.38
Rice	2.99	0.75	4.72
Soybean	2.50	0.75	12.38
Sugarcane	4.46	0.65	8.69
Wheat	1.92	0.85	8.07
Other/fallow/lentils	2.95	0.75	12.31

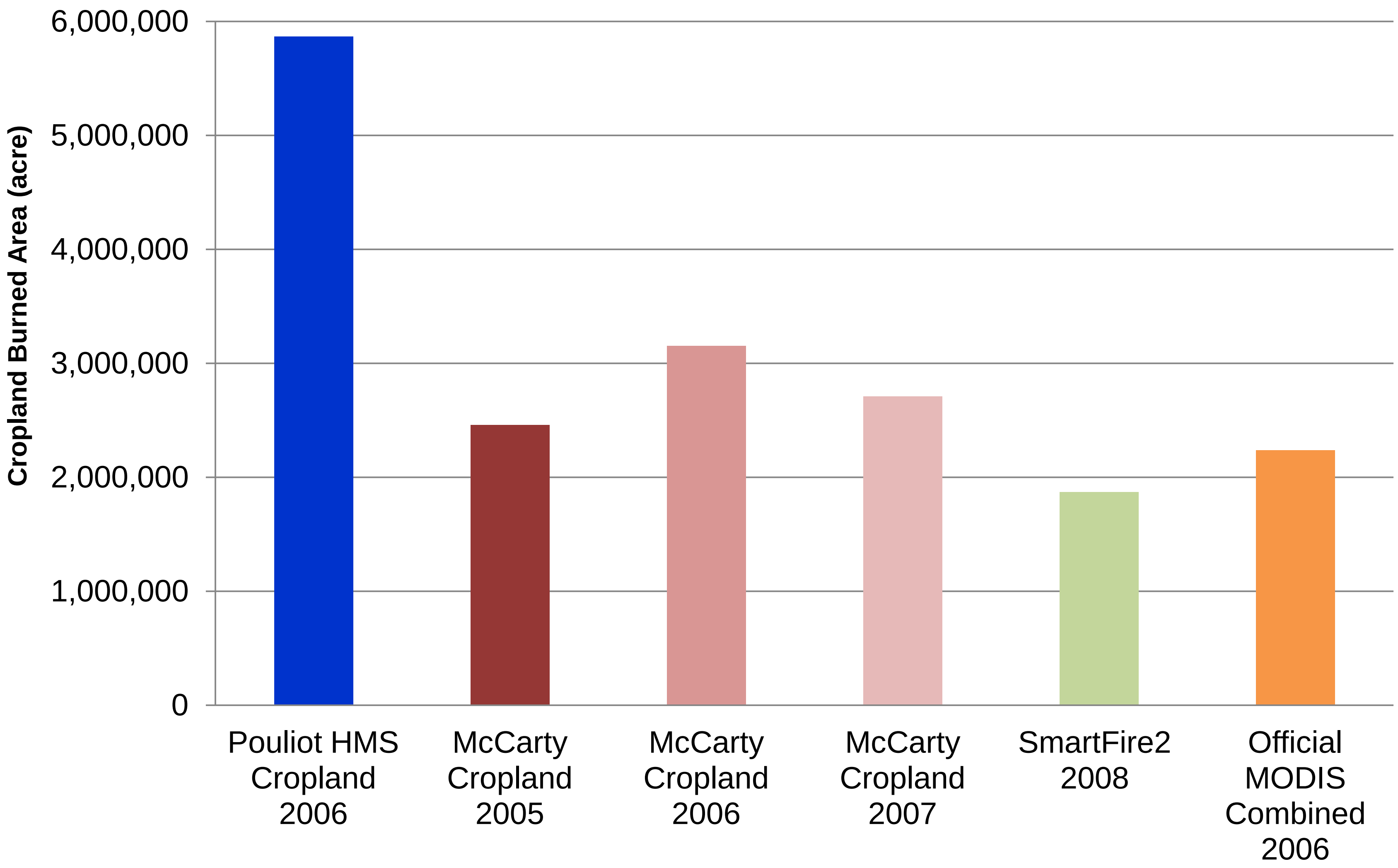
Table 1. Crop type-specific emission calculation variables used for the MODIS cropland-specific burned area analysis (McCarty Cropland) and the HMS-based analysis (Pouliot HMS Cropland).

Emission Calculation Variables (2/2)

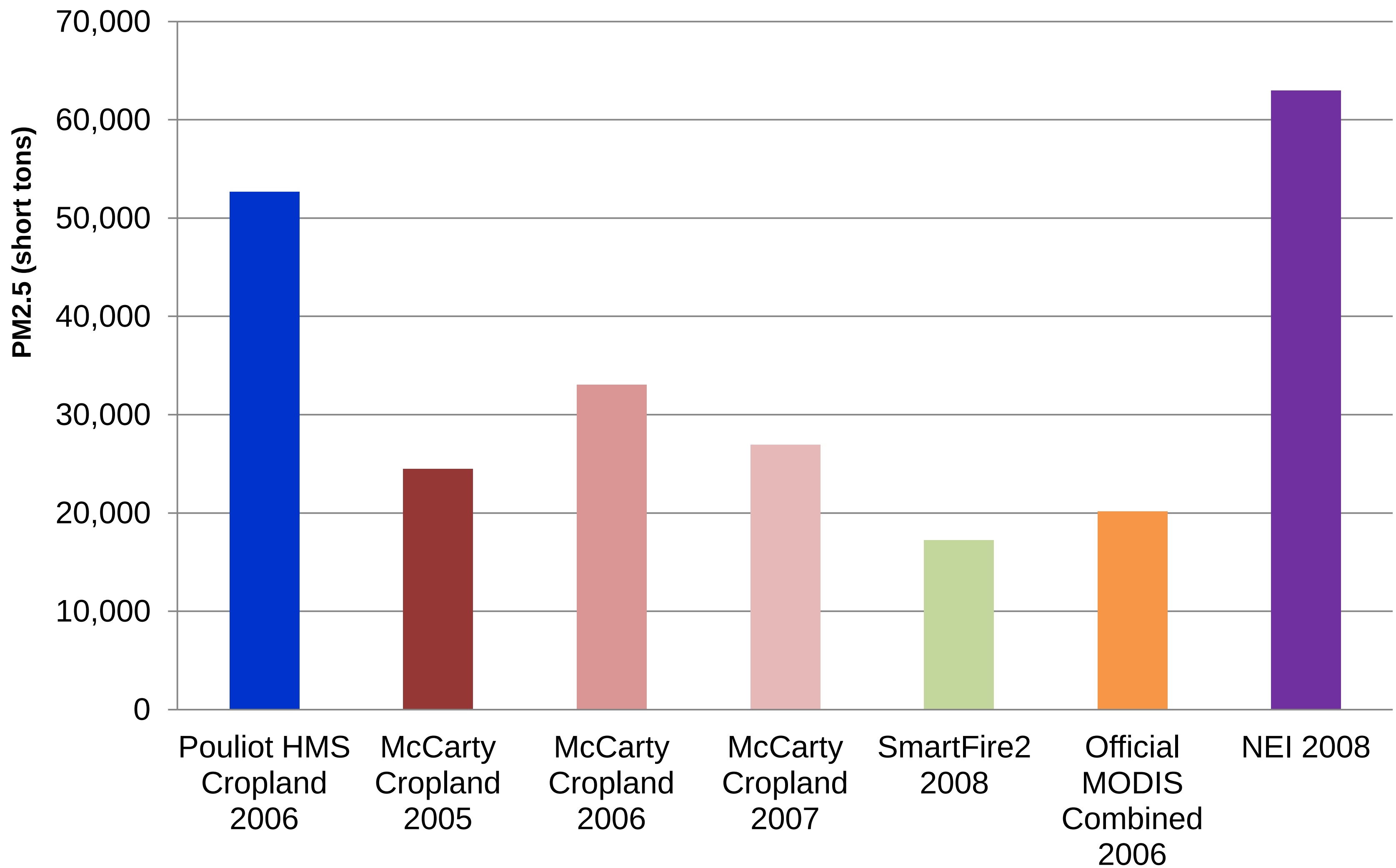
Crop Type	Fuel Loading (tons/acre)	Combustion Completeness	PM2.5 (lbs/ton)
Average Ag Class	2.95	0.75	12.31

Table 2. General "cropland" emission calculation variables used for the SmartFire2 and the MCD45A1 product combined with MOD/MYD14 product (Official MODIS Combined) emission calculations.

Results: CONUS Cropland Burned Area



Results: CONUS PM2.5 Emissions from Cropland Fire



Results: EPA Regions

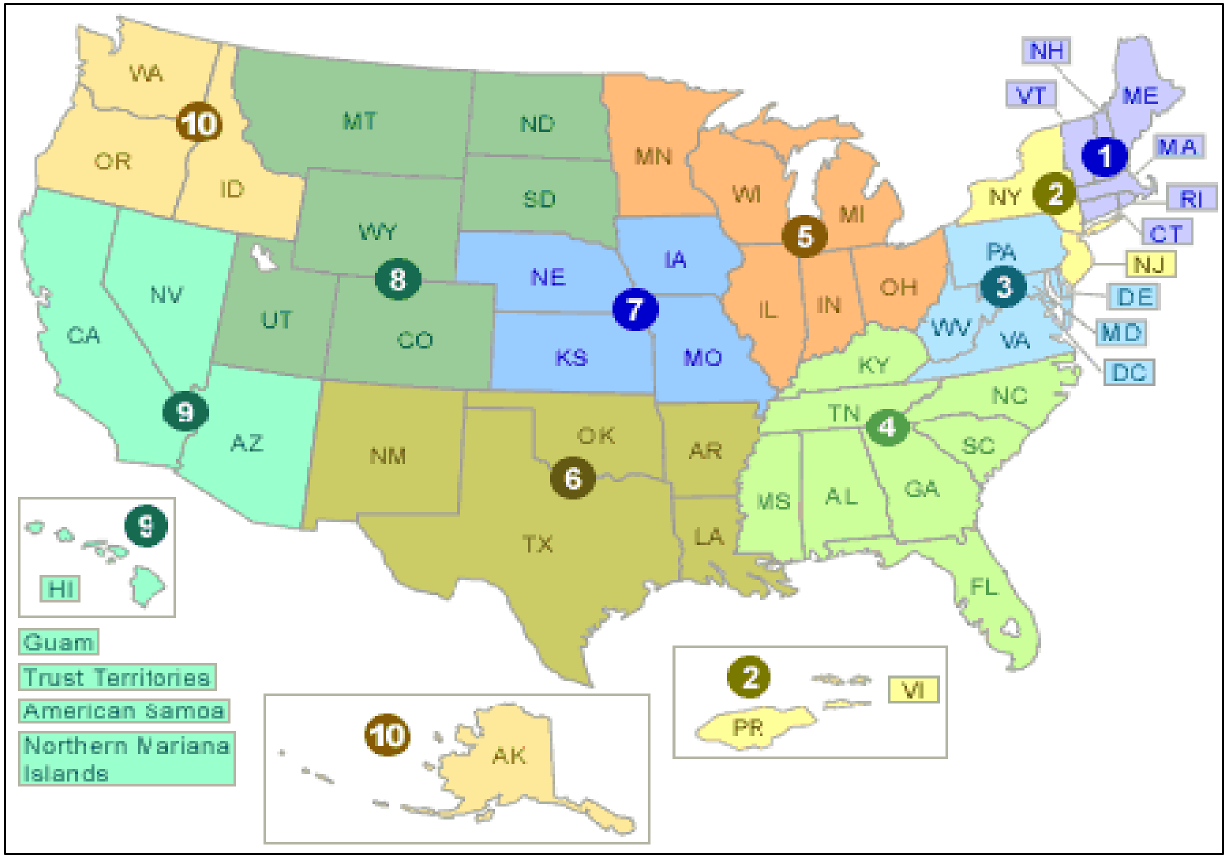
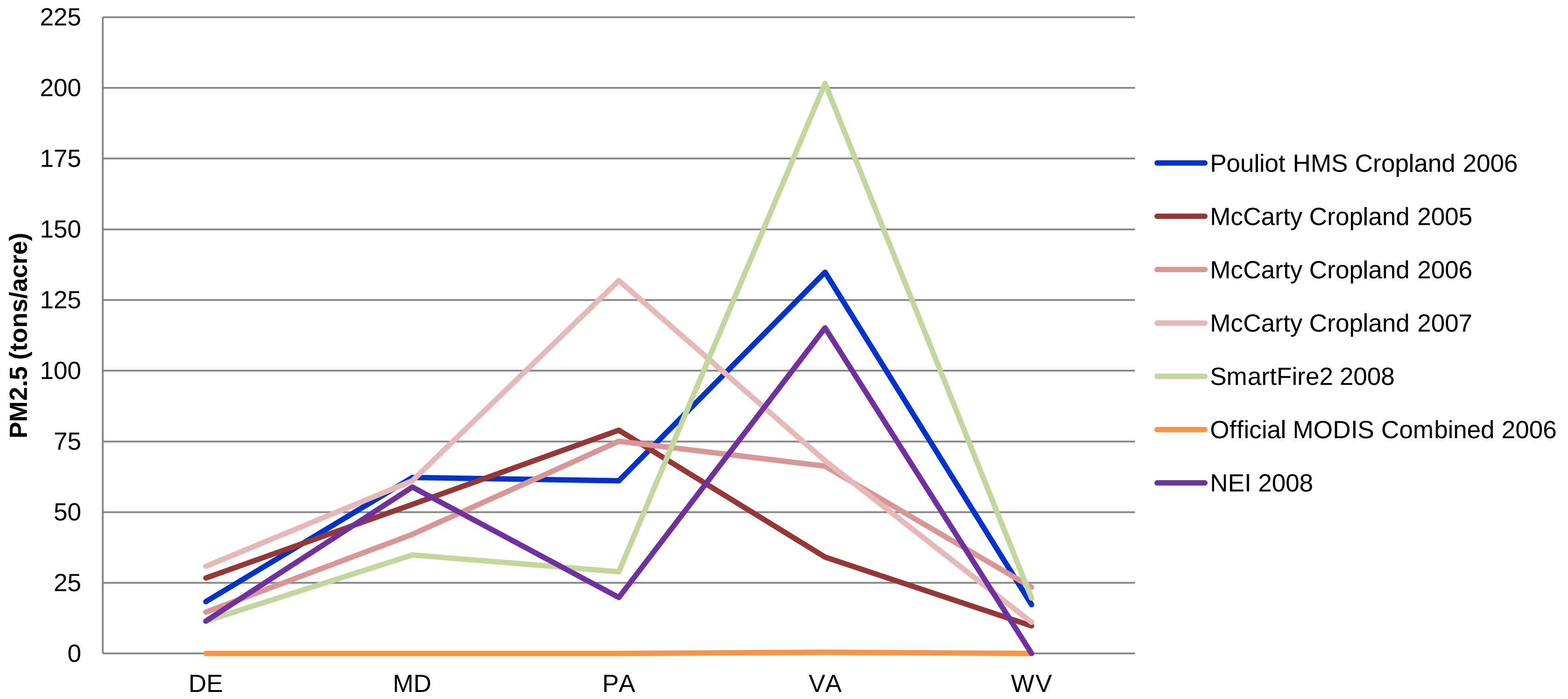
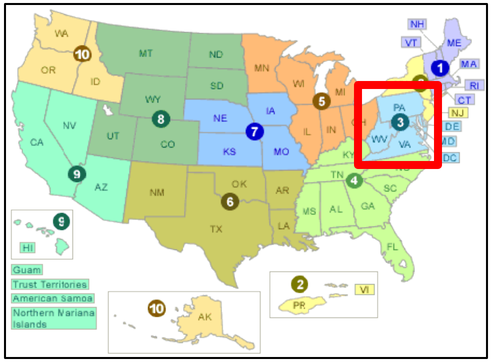


Figure 1. EPA regions (taken from ://www.epa.gov/oust/regions/regmap.htm).

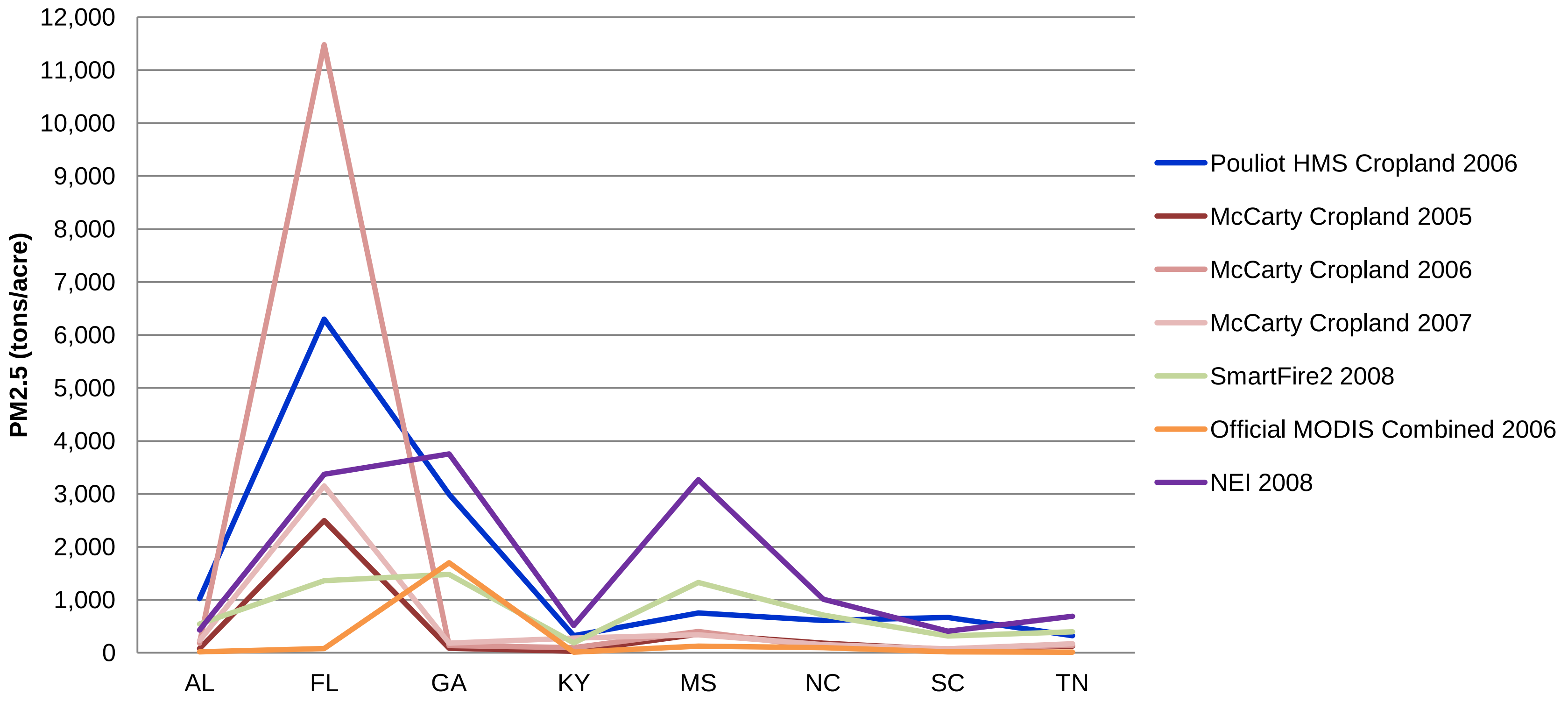
Region 3



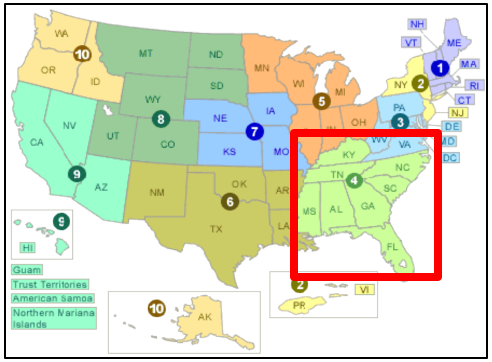
PM2.5 (tons/acre)
225
200
175
150
125
100
75
50
25
0
DE
MD
PA
VA
WV
Pouliot HMS Cropland 2006
McCarty Cropland 2005
McCarty Cropland 2006
McCarty Cropland 2007
SmartFire2 2008
Official MODIS Combined 2006
NEI 2008



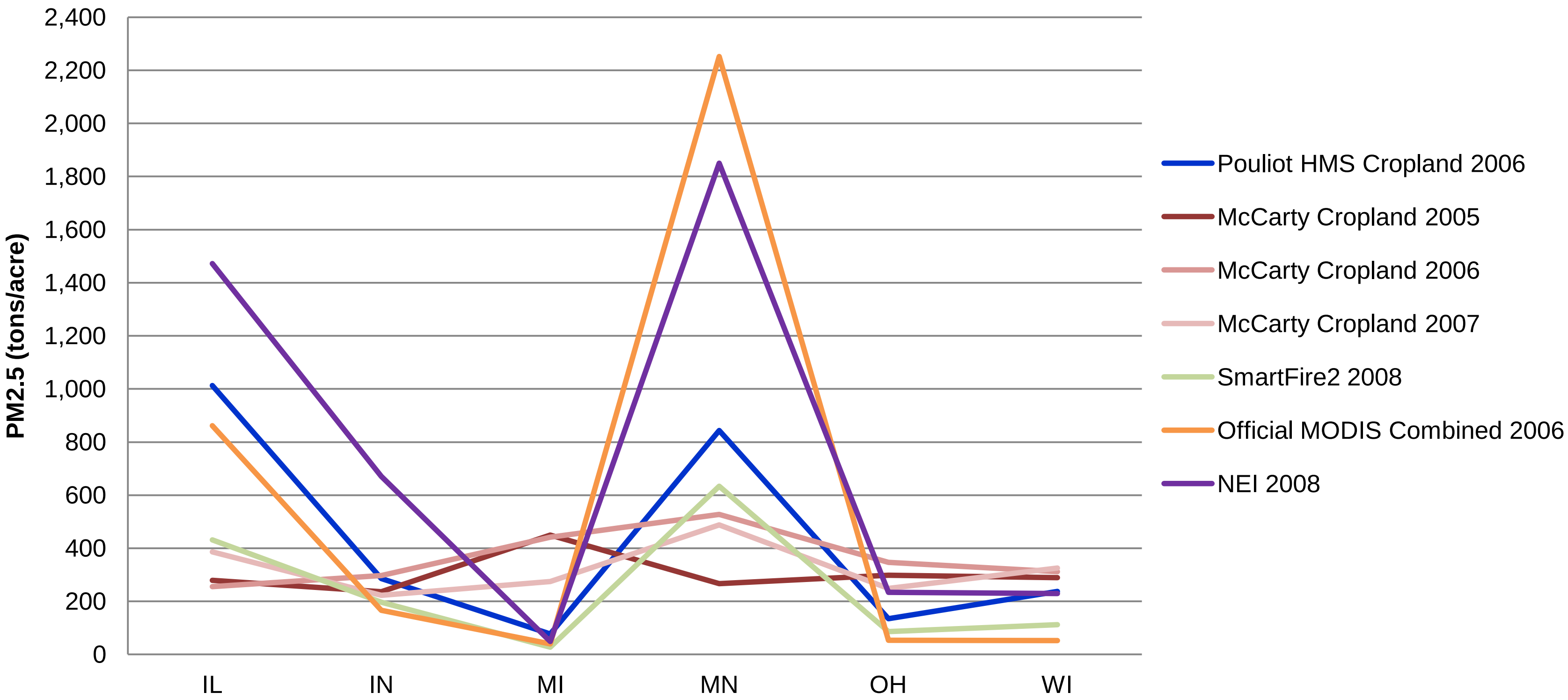
Region 4



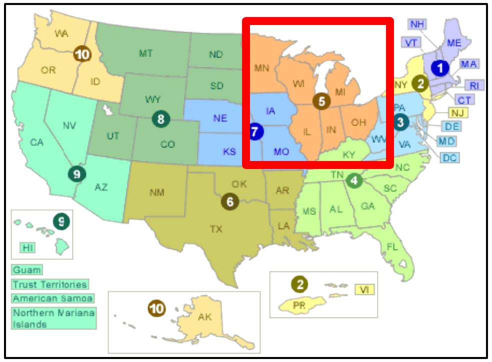
PM2.5 (tons/acre)
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
AL
FL
GA
KY
MS
NC
SC
TN
Pouliot HMS Cropland 2006
McCarty Cropland 2005
McCarty Cropland 2006
McCarty Cropland 2007
SmartFire2 2008
Official MODIS Combined 2006
NEI 2008



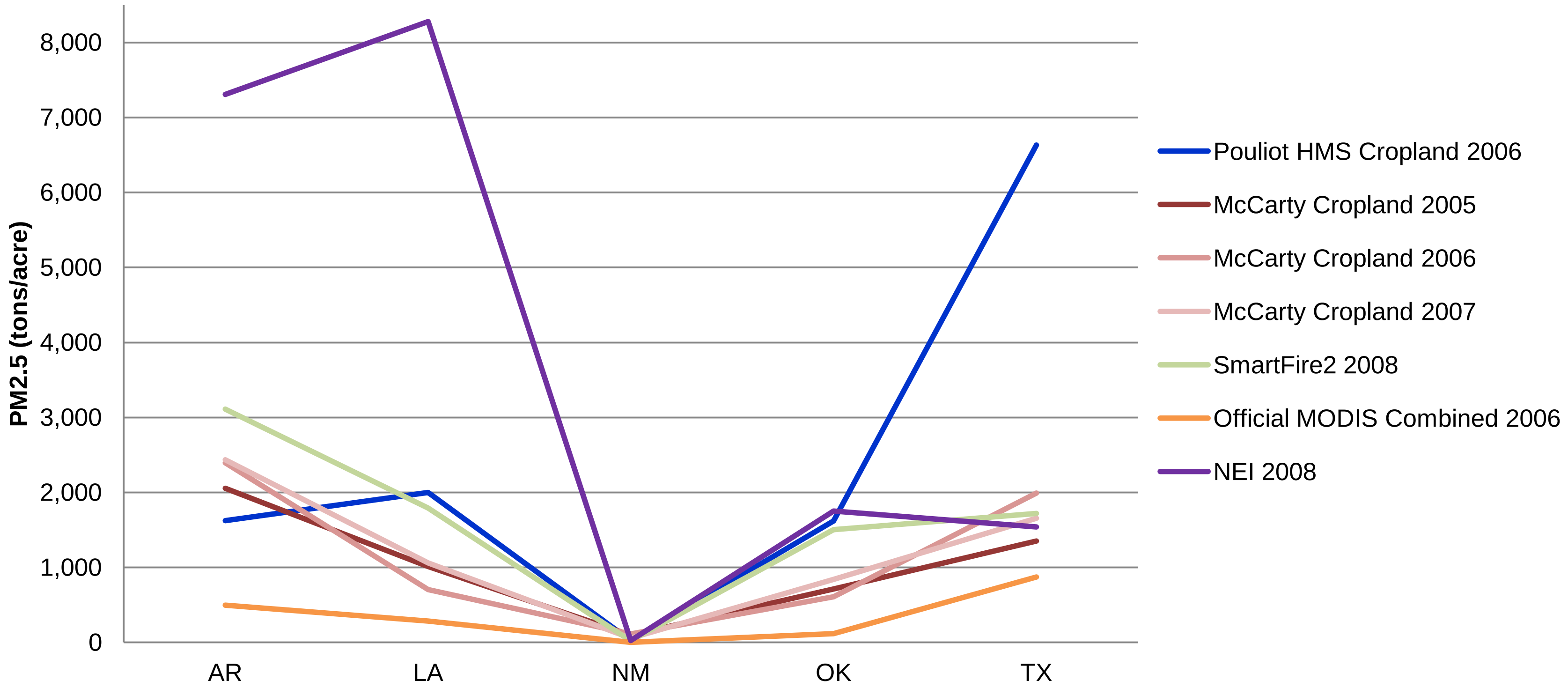
Region 5



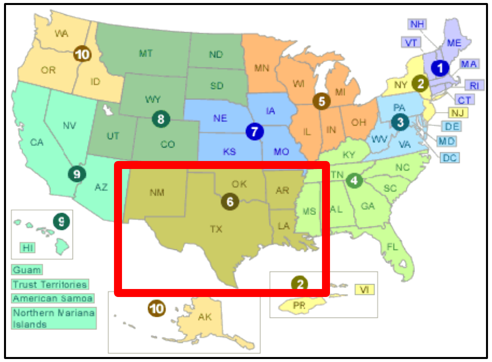
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
PM2.5 (tons/acre)
IL
IN
MI
MN
OH
WI
Pouliot HMS Cropland 2006
McCarty Cropland 2005
McCarty Cropland 2006
McCarty Cropland 2007
SmartFire2 2008
Official MODIS Combined 2006
NEI 2008



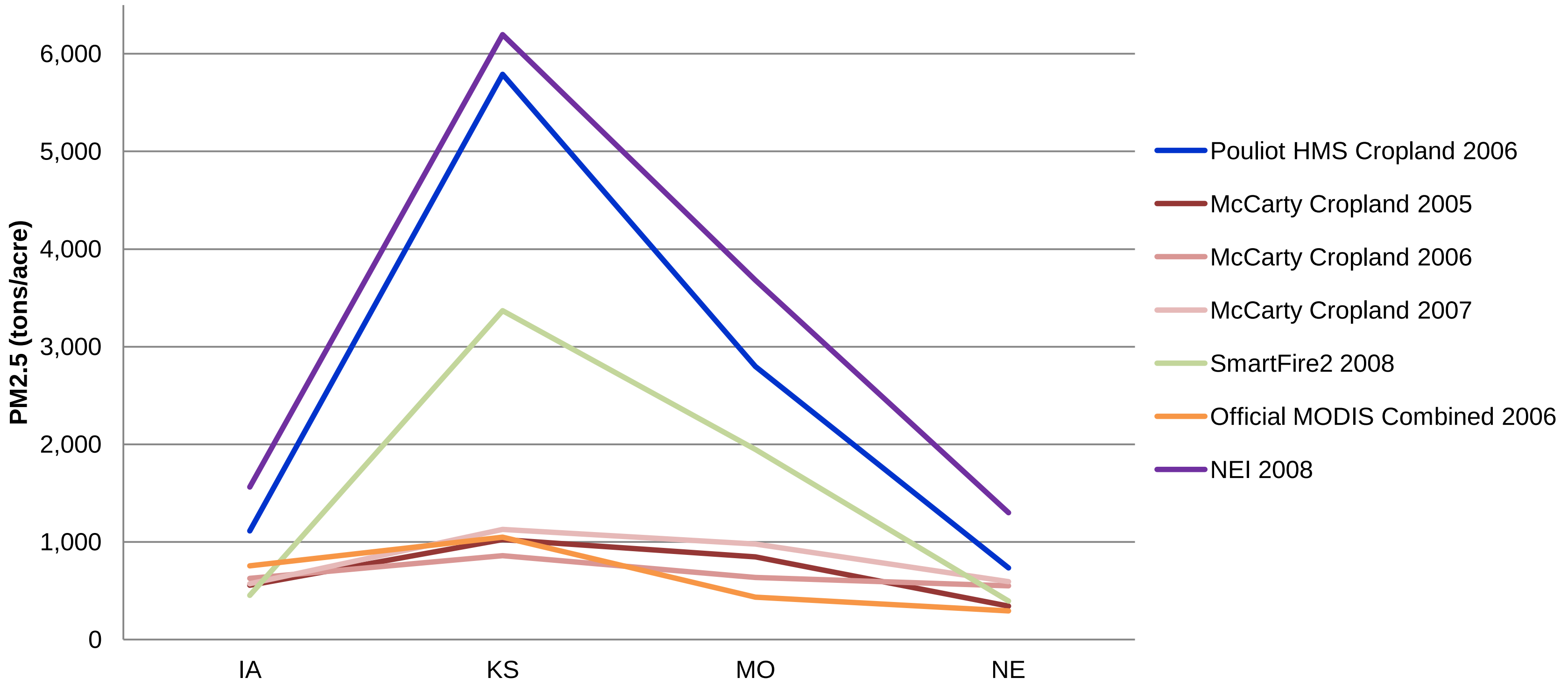
Region 6



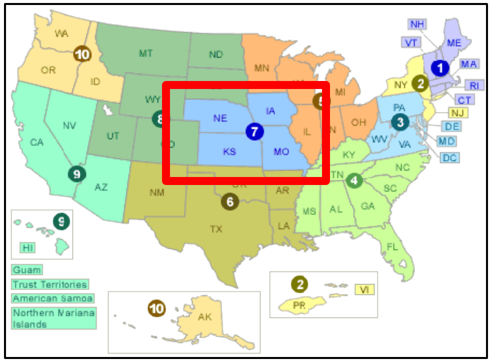
PM2.5 (tons/acre)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
AR
LA
NM
OK
TX
Pouliot HMS Cropland 2006
McCarty Cropland 2005
McCarty Cropland 2006
McCarty Cropland 2007
SmartFire2 2008
Official MODIS Combined 2006
NEI 2008



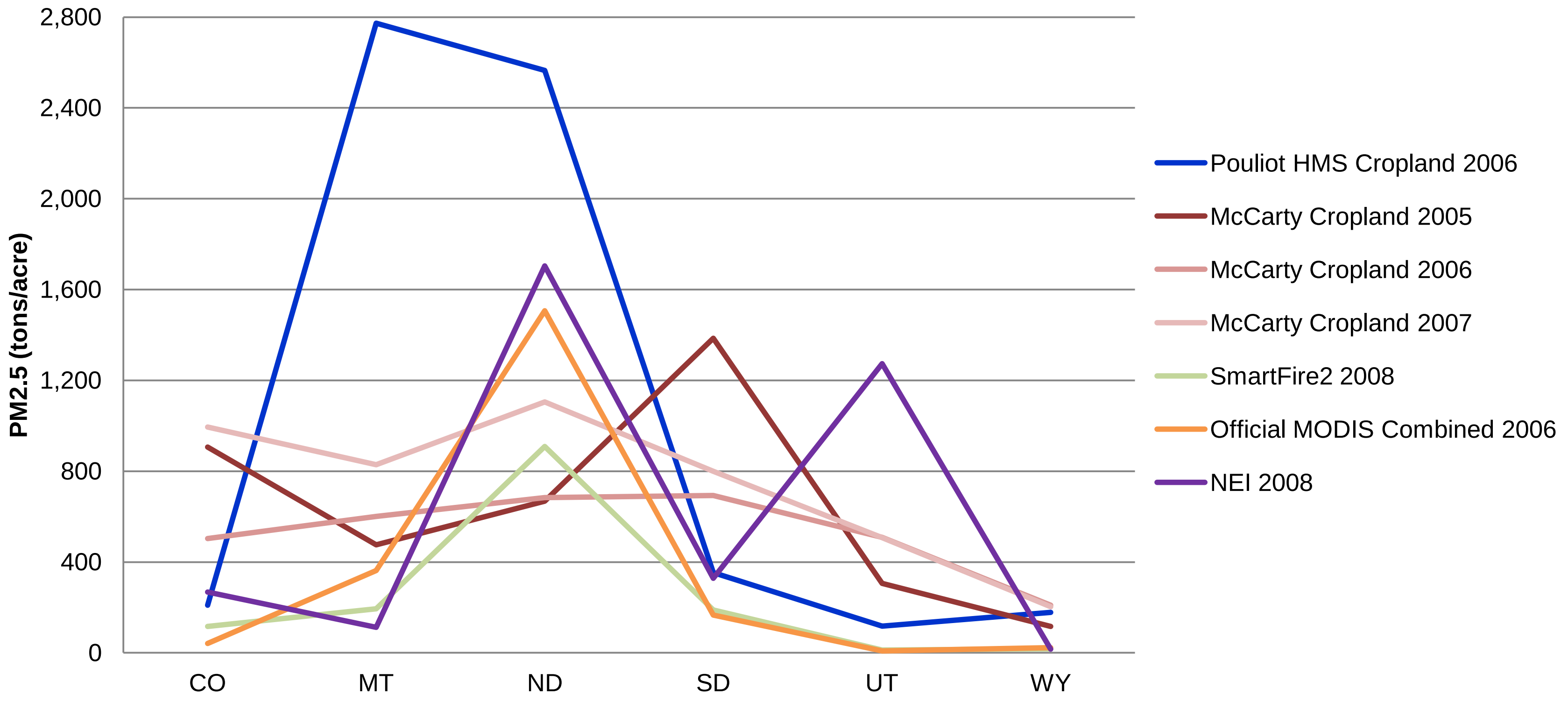
Region 7



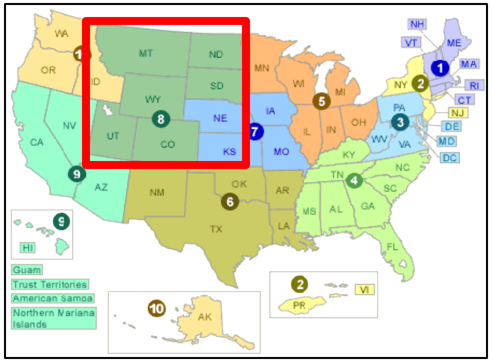
PM2.5 (tons/acre)
6,000
5,000
4,000
3,000
2,000
1,000
0
IA
KS
MO
NE
Pouliot HMS Cropland 2006
McCarty Cropland 2005
McCarty Cropland 2006
McCarty Cropland 2007
SmartFire2 2008
Official MODIS Combined 2006
NEI 2008



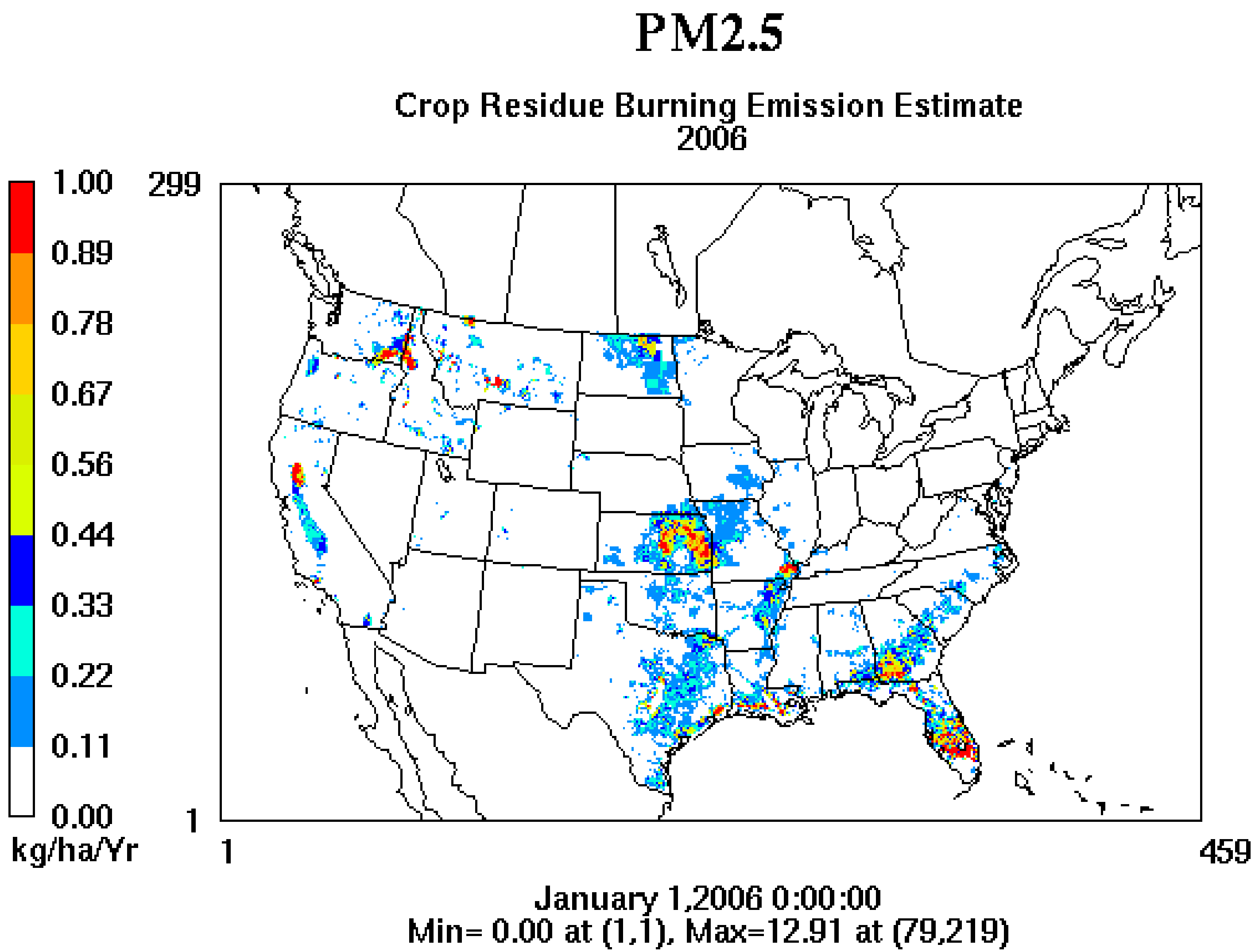
Region 8



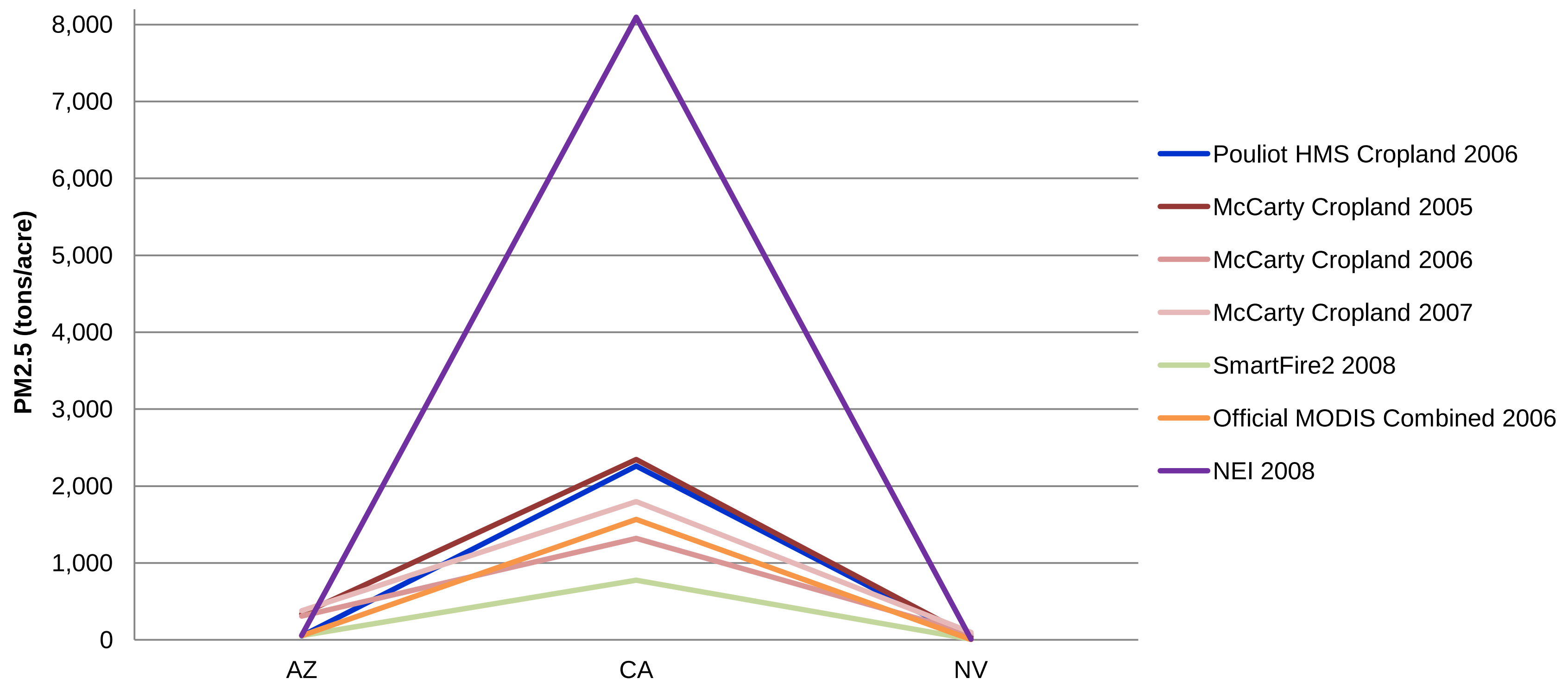
PM2.5 (tons/acre)
2,800
2,400
2,000
1,600
1,200
800
400
0
CO
MT
ND
SD
UT
WY
Pouliot HMS Cropland 2006
McCarty Cropland 2005
McCarty Cropland 2006
McCarty Cropland 2007
SmartFire2 2008
Official MODIS Combined 2006
NEI 2008



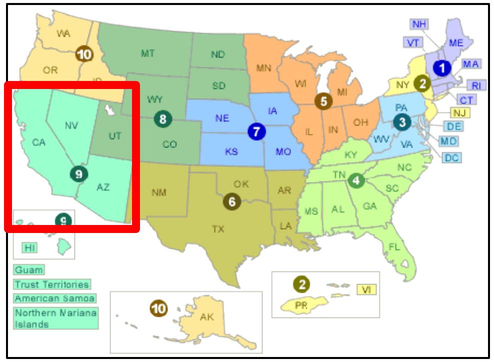
Pouliot HMS 2006 Emission Estimate



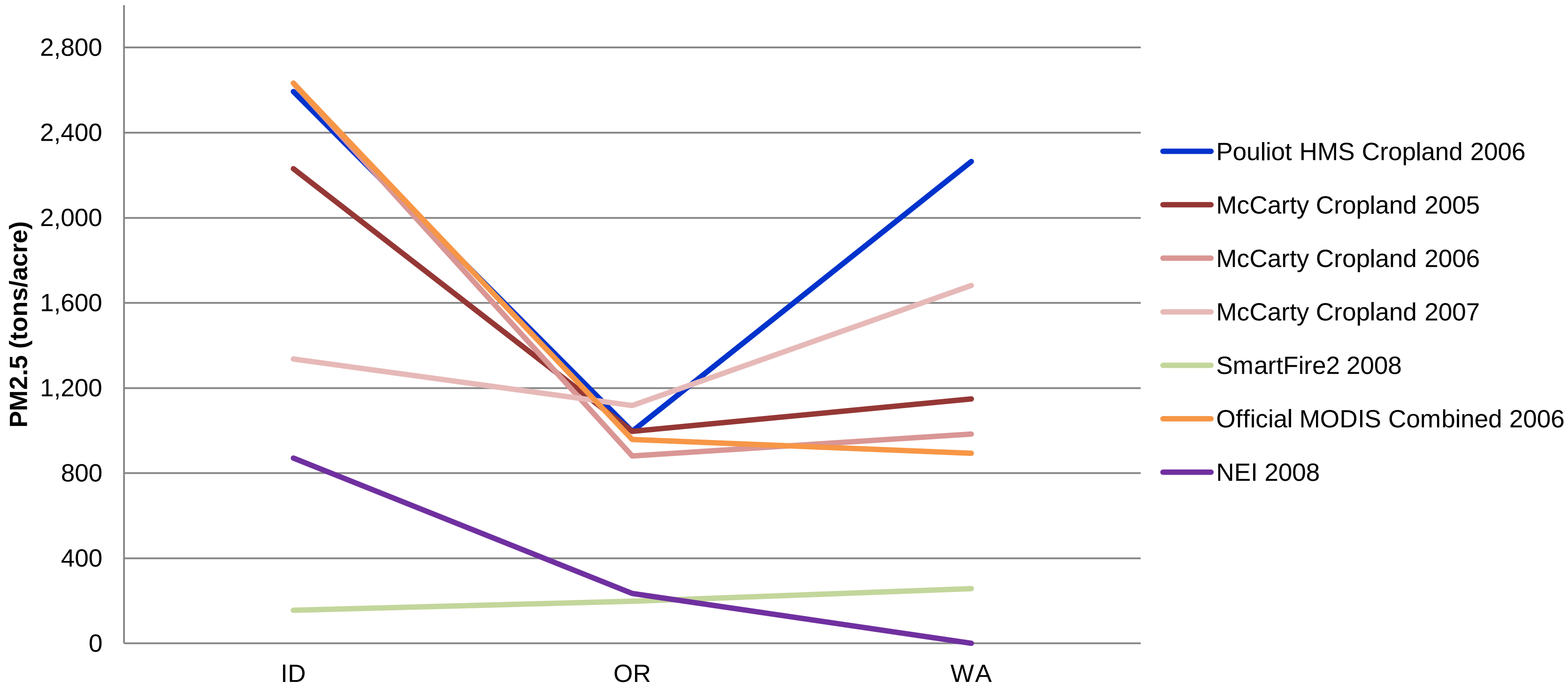
Region 9



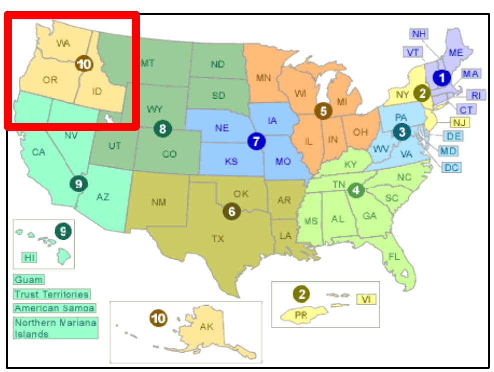
PM2.5 (tons/acre)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
AZ
CA
NV
Pouliot HMS Cropland 2006
McCarty Cropland 2005
McCarty Cropland 2006
McCarty Cropland 2007
SmartFire2 2008
Official MODIS Combined 2006
NEI 2008



Region 10



PM2.5 (tons/acre)
2,800
2,400
2,000
1,600
1,200
800
400
0
ID
OR
WA
Pouliot HMS Cropland 2006
McCarty Cropland 2005
McCarty Cropland 2006
McCarty Cropland 2007
SmartFire2 2008
Official MODIS Combined 2006
NEI 2008



Guam
Trust Territories
American Samoa
Northern Mariana Islands

Why the different answers?

- Satellite inputs: Fire
  - Spatial resolution: detection area (0.22 acres to 64 acres)
  - Assumption of average area: 40 to 120 acres
  - Temporal resolution: 15 minutes vs. daily vs. 8-day
- Definition of croplands
  - Cropland maps: Derived from USDA NASS Cropland Data Layer (crop type) vs. NLCD General Cultivated Crop/Pasture
- Emission Variables
  - Where possible, emission factors, fuel loadings, combustion completeness were the same; all from same source
  - Crop type-specific vs. General Ag Class

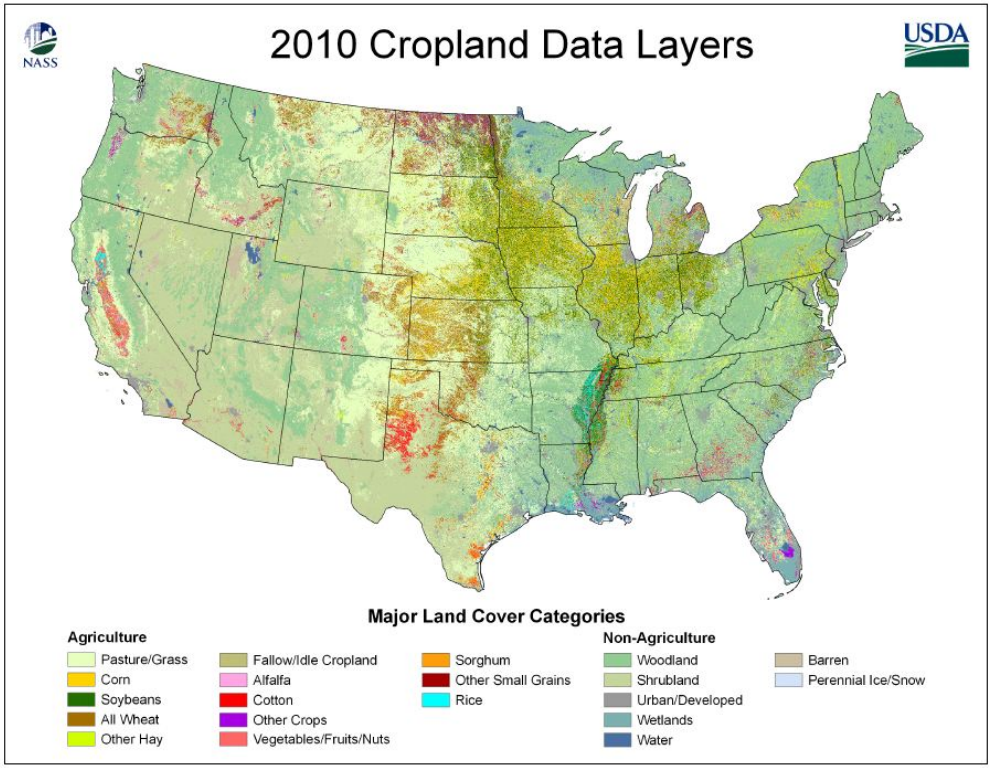
Lessons Learned

- At CONUS-level, most remote sensing methods produce similar burned area and $PM_{2.5}$ emission estimates
  - – Pouliot HMS method
    - Almost factor 2 greater

- Variable at state-level
  - – Kansas, Idaho, Montana, North Dakota

Moving Forward From Our Lessons

- Consensus on cropland extent definition
  - Cropland Data Layer
- Increase high resolution validation of prescribed burning
  - Paucity of ground truth data for prescribed burning
  - Validation standards (akin to GOFC-GOLD), sensor error bars
- Improve fuel load mapping
  - FCCS in combination with CDL (Poster)
- Emission factors
  - Crop-type specific preferred
  - Regional and seasonal




Questions?