

# Using Moss to Detect Fine-Scaled Deposition of Heavy Metals in Urban Environments

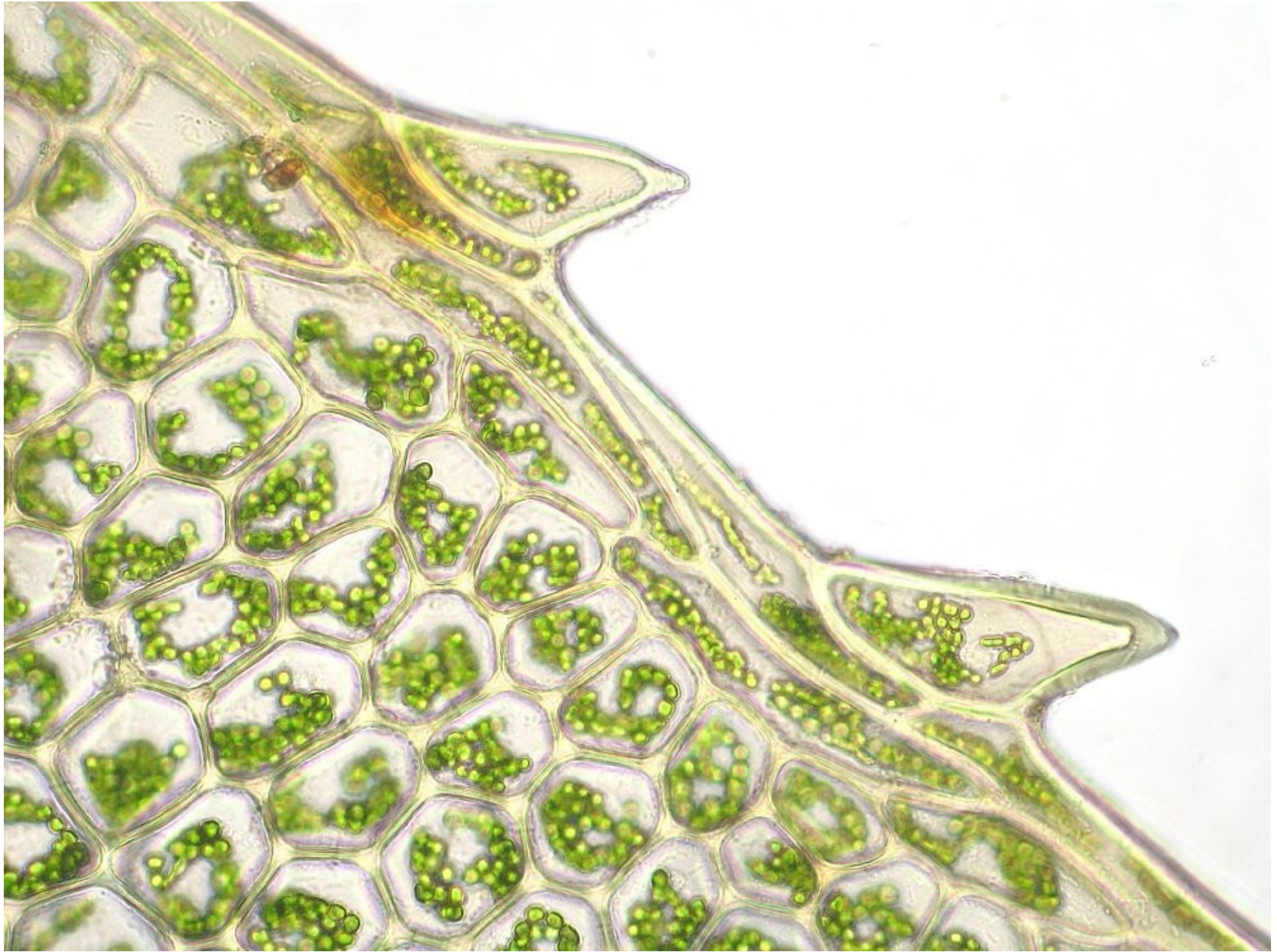


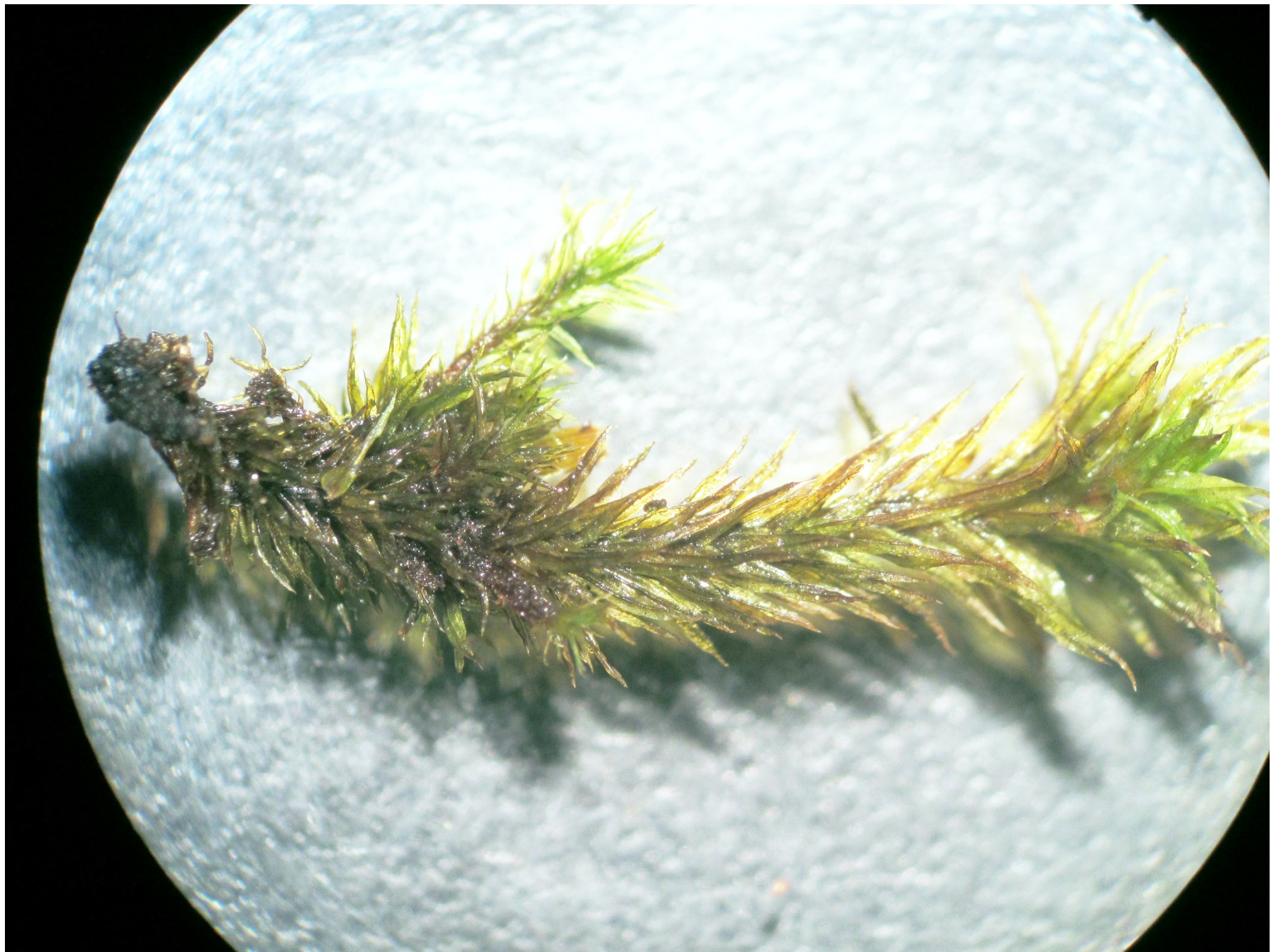
Sarah Jovan<sup>1</sup>, Michael C. Amacher<sup>2</sup>, Vicente Monleon<sup>1</sup>, Geoffrey Donovan<sup>1</sup>, Demetrios Gatzliolis<sup>1</sup>, Alyssa Shiel<sup>3</sup>

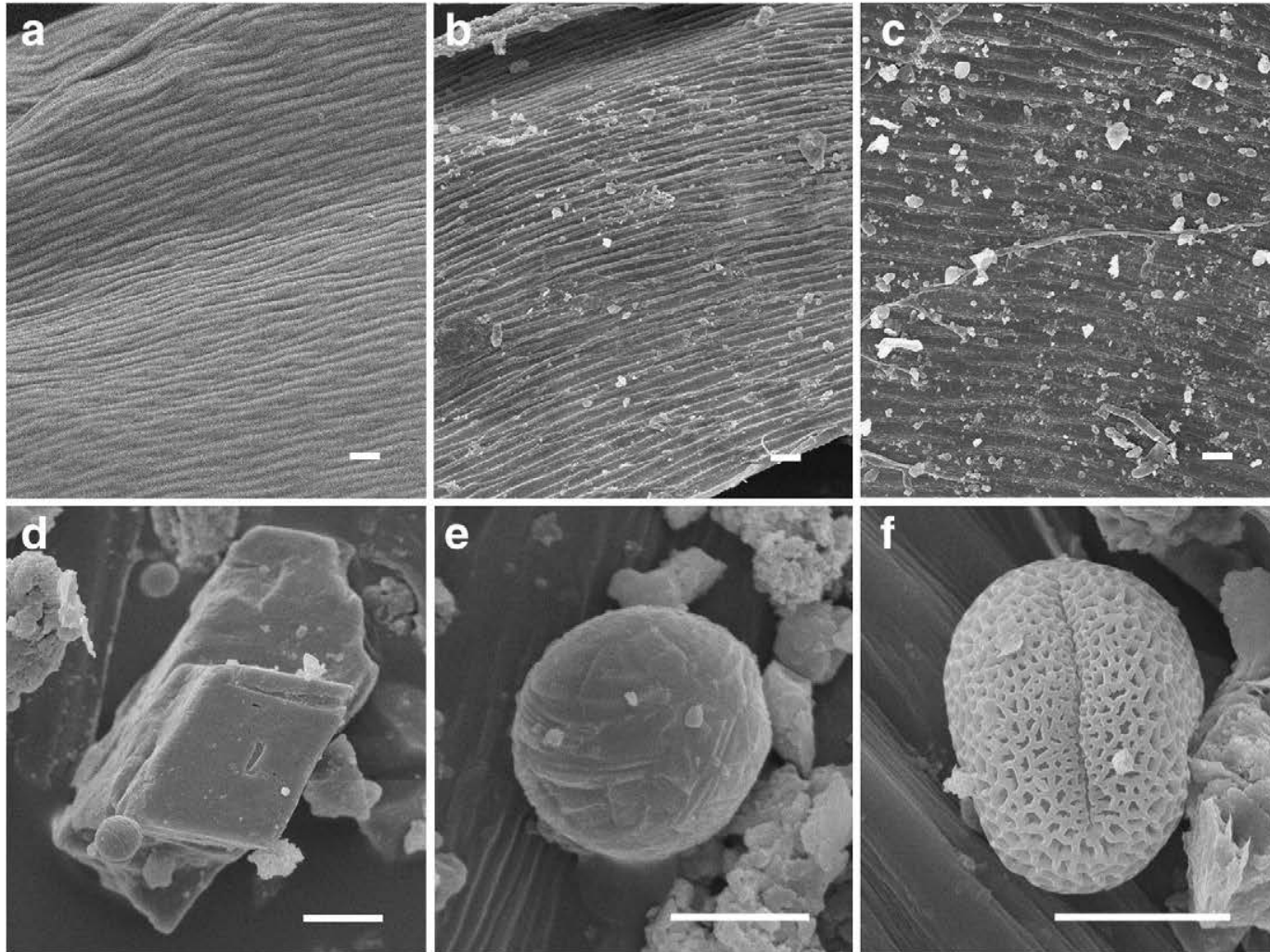
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**Fig. 5.** SEM micrographs of moss leaflets before (a) and after exposure (b,c) in the green (b) and roadside (c) site pair nr. 9 of Fig. 1, and enlargement of particulate matter (d,e) and pollen grain (f). Bar = 10  $\mu\text{m}$  (a-d, f); 3  $\mu\text{m}$  (e).

# Why use bio-indicators?

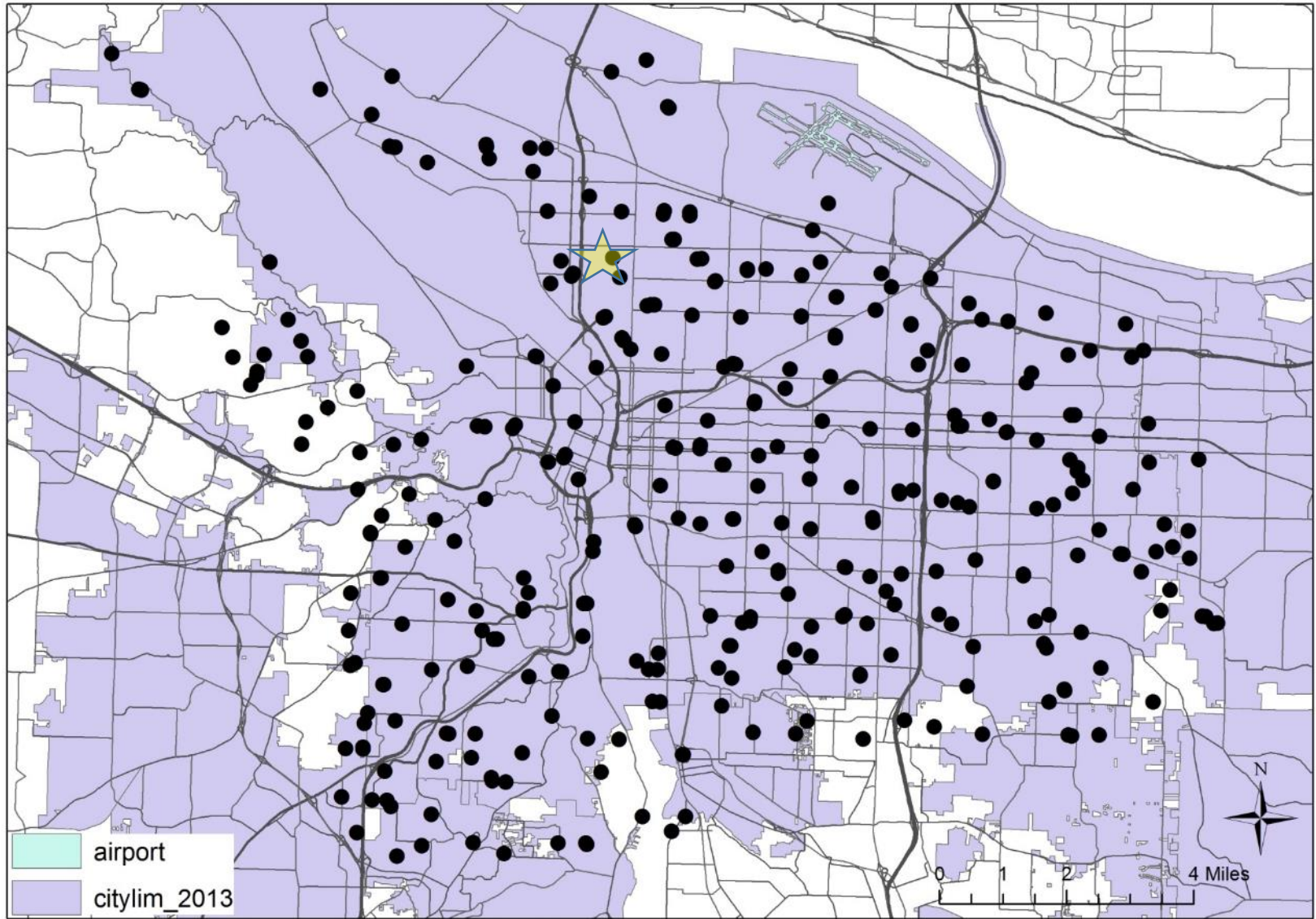
## Per site costs:

- Moss site: ~\$150
- Active instruments: ~\$40K annually to measure metals

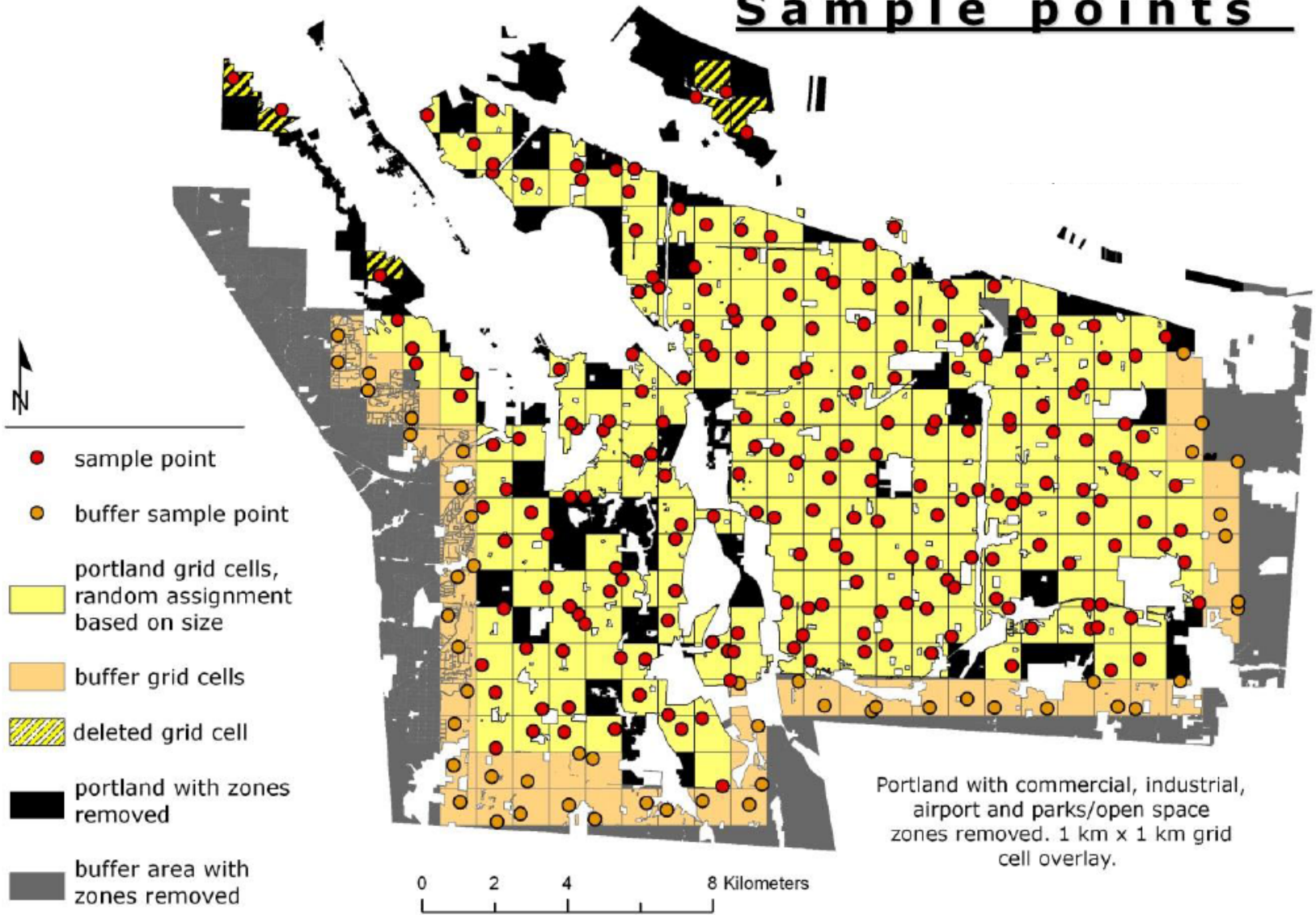


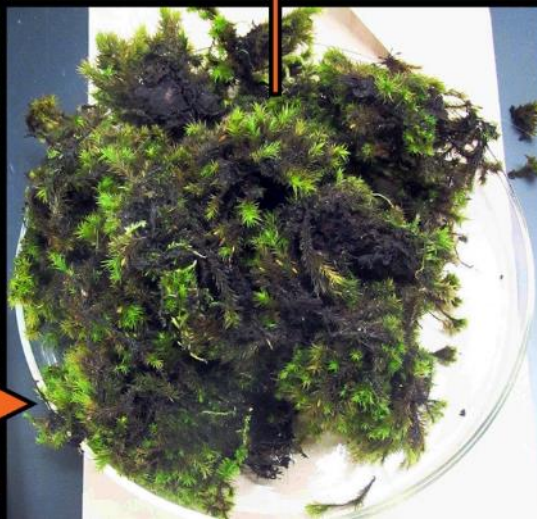
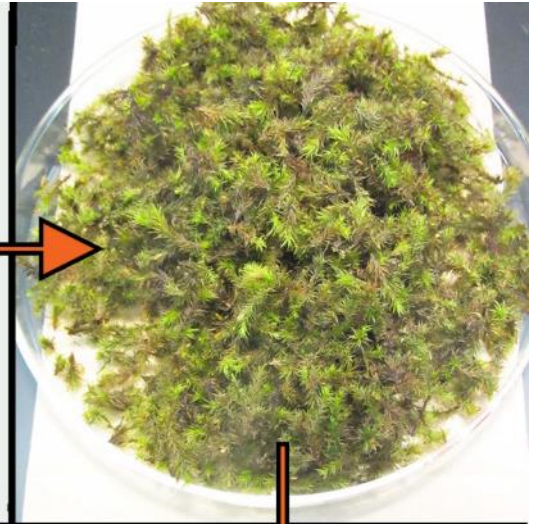
Moss samples = 346 in 2013

★ Air quality monitor



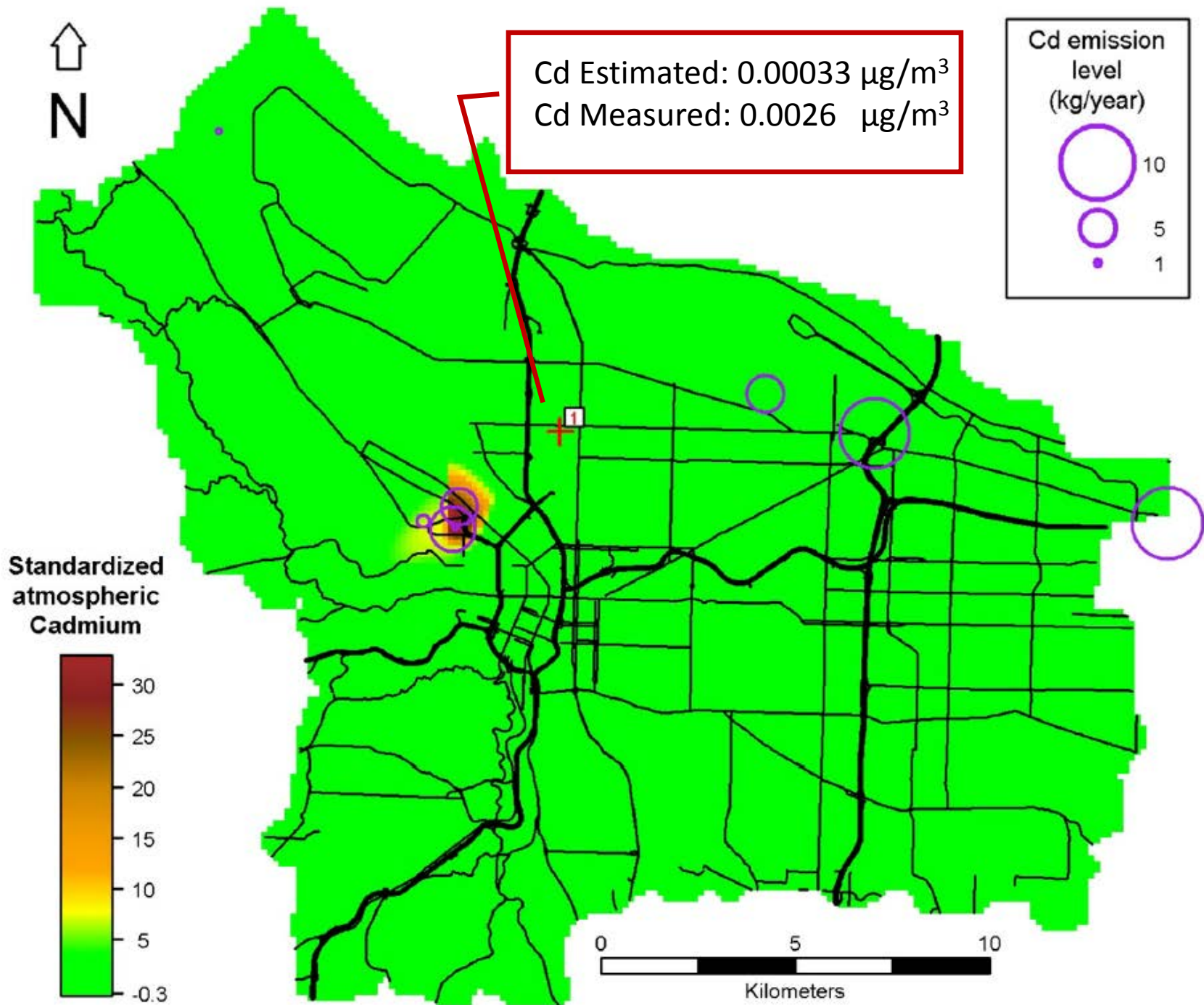
# Sample points





Analysis by ICP-OES:  
Al, As, B, Ba, Ca, Cd,  
Co, Cr, Cu, Fe, K, Mg,  
Mn, Mo, Na, Ni, P,  
Pb, S, Se, Si, Sr, Zn





# Spatial modeling

- Built a spatial linear model of  $\text{Ln}(\text{Cd})$  in moss using an exponential covariance structure
  - Backwards, step-wise model selection
  - Models estimated using restricted maximum likelihood (SAS 9.4 MIXED)
- Used final model to estimate Cd on a 50m grid across the city

# Covariates

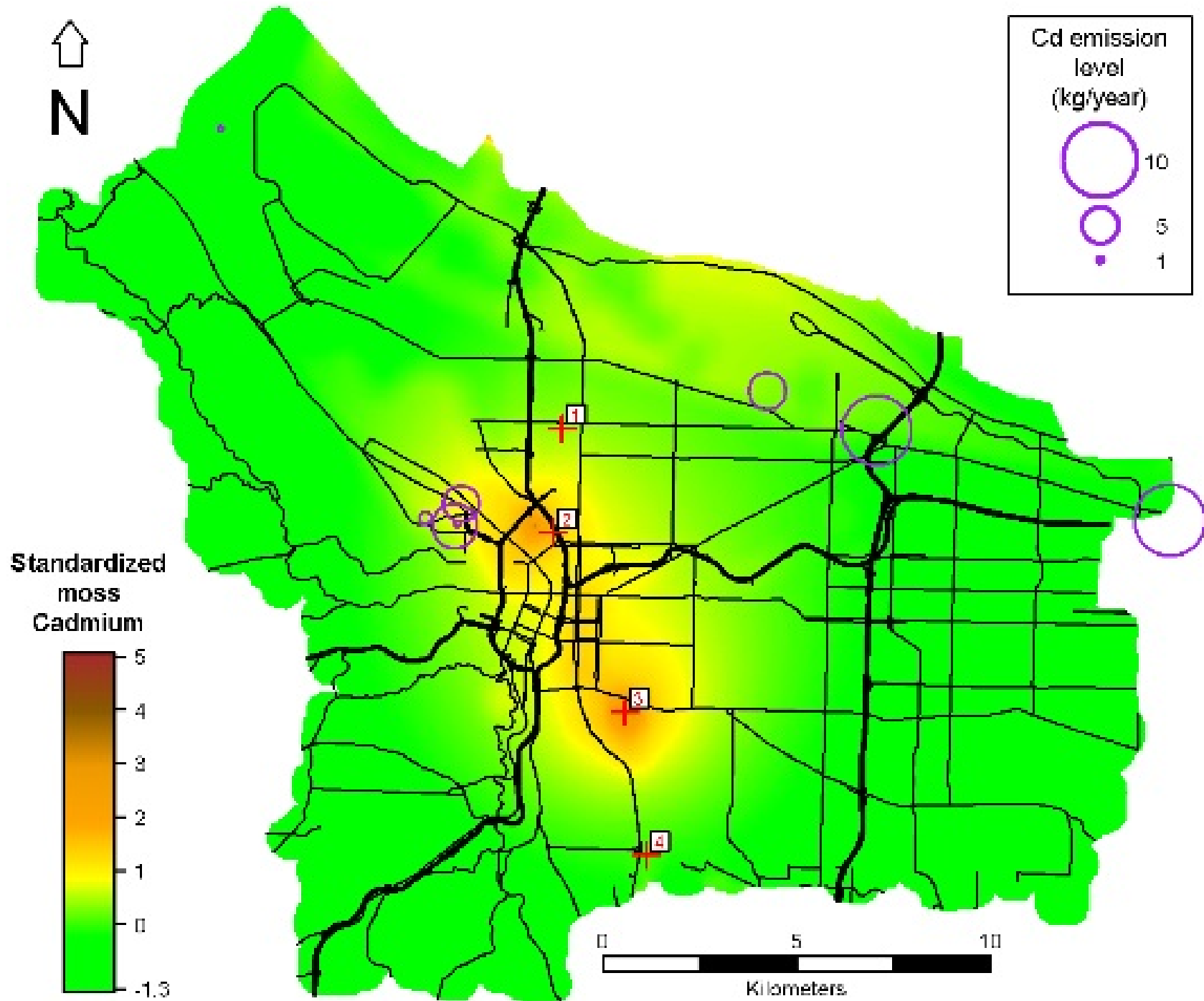
- Tree genus
- Weather (precipitation, temperature)
- Density of roads (IDW, 500m buffer)
- Tree canopy cover (IDW, 500m buffer)

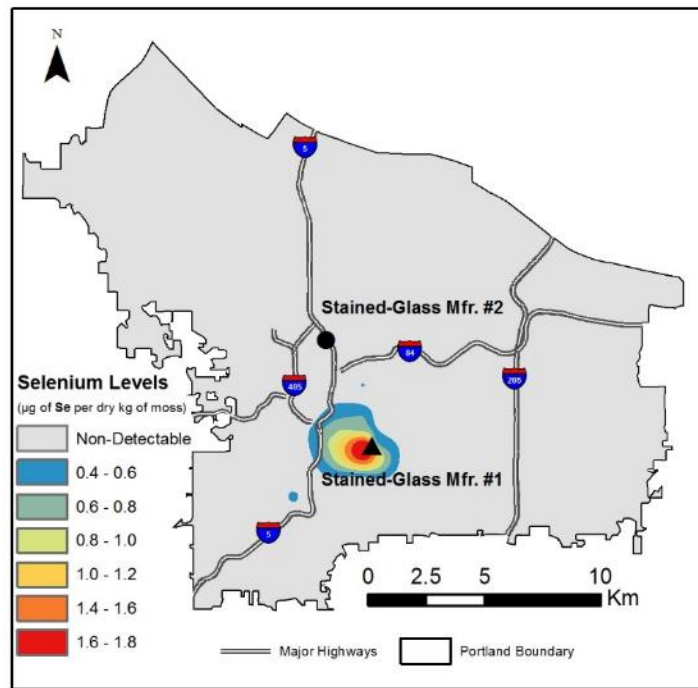
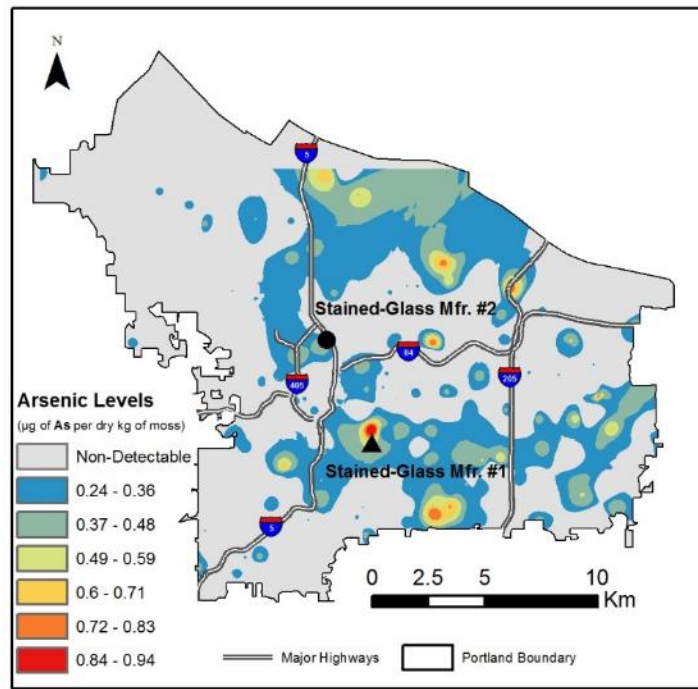
# Covariates

- Distance to permitted Cd emitters

# Covariates

- **Distances to 2 unpermitted stained glass factories**
- Distance to Washington border
- Percent industrial land (500m)
- Percent residential land (500m)





Due to an EPA exemption, these emissions technically weren't illegal...







# Wyden: Loophole 'The Size Of A Lunar Crater' Allowed Portland Pollution

by Cassandra Profita [Follow](#) OPB | Feb. 18, 2016 4:18 p.m. | Updated: Feb. 18, 2016 5:41 p.m.

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U.S.

## Toxic Moss in Portland, Ore., Shakes City's Green Ideals

By KIRK JOHNSON MARCH 2, 2016

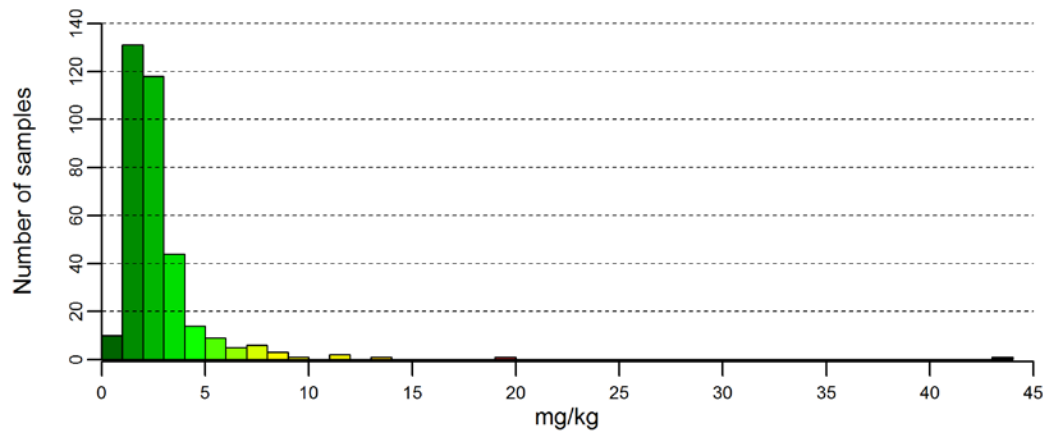
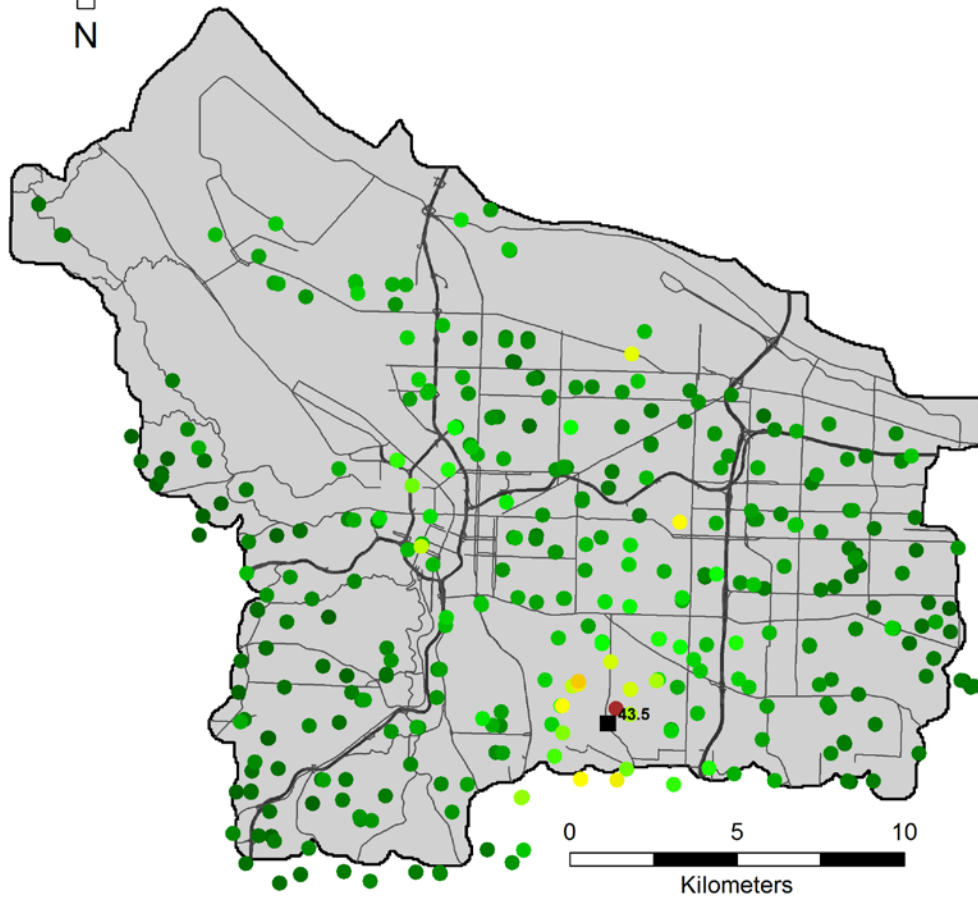
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## Study impact:

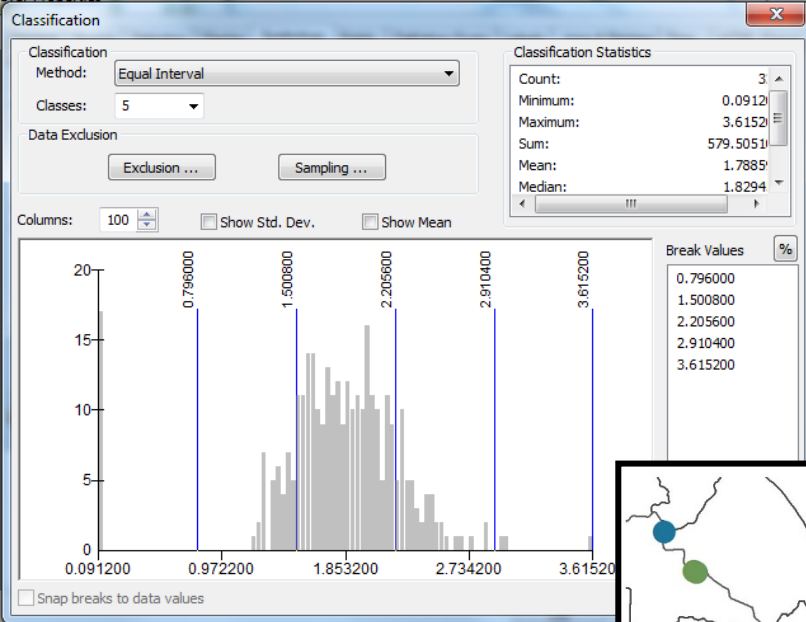
- Baghouses were installed on Bullseye's 18 furnaces
- The other glass facility moved operations to Mexico...
- Air quality improved dramatically
- EPA/DEQ reevaluated national furnace emissions regulations, closed the 'loophole'
- Governor created the "Cleaner Air Oregon" Program to overhaul toxics regulations (to replace technology-based standards with health-based standards).

# Nickel (Ni)

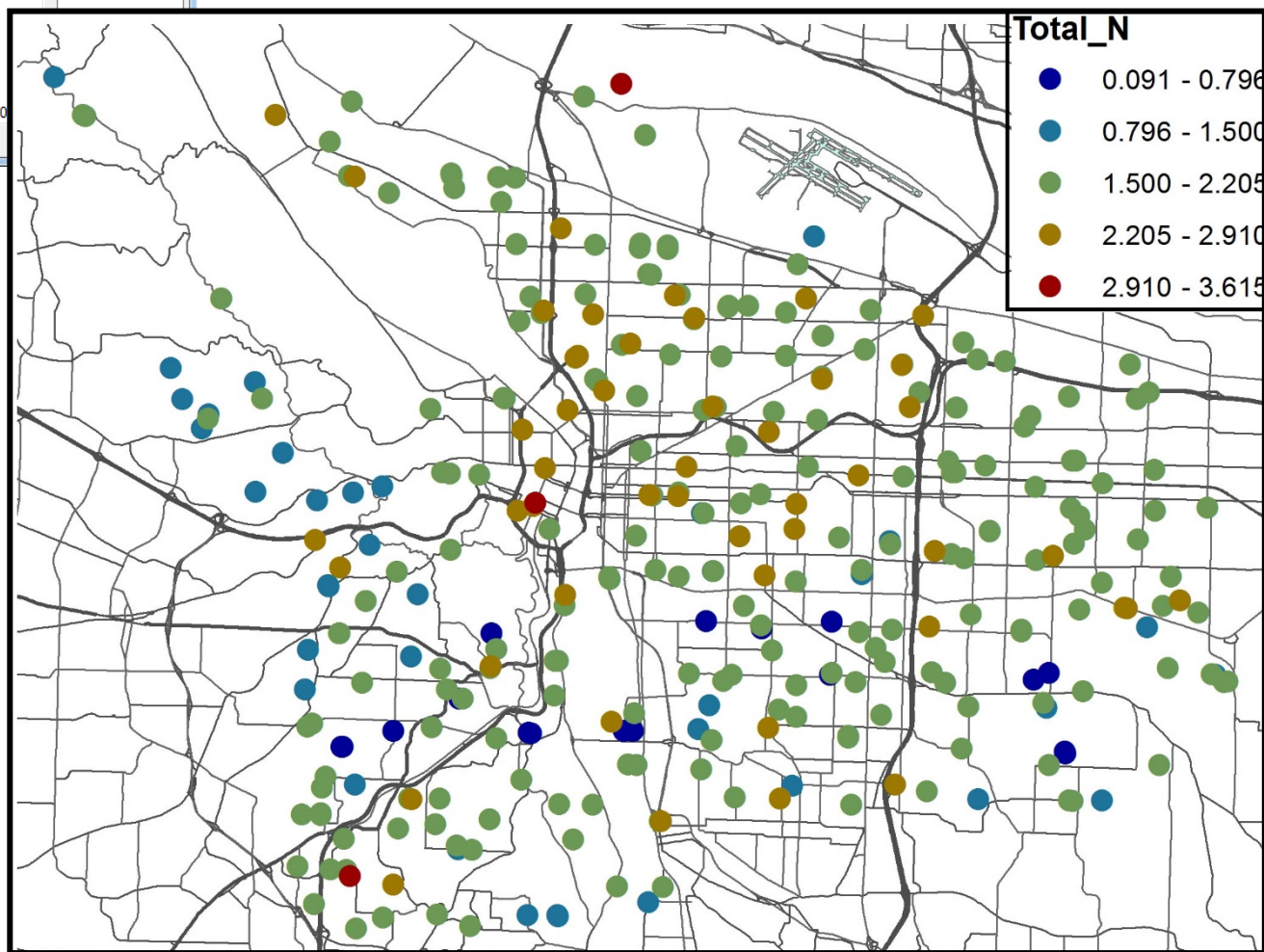


# Other data and next steps...

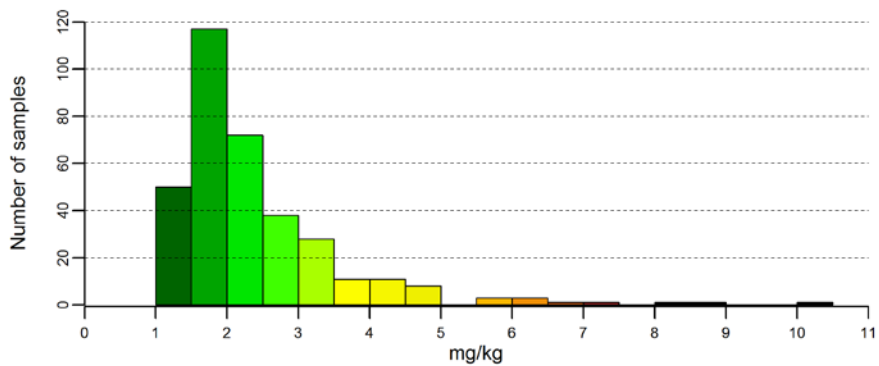
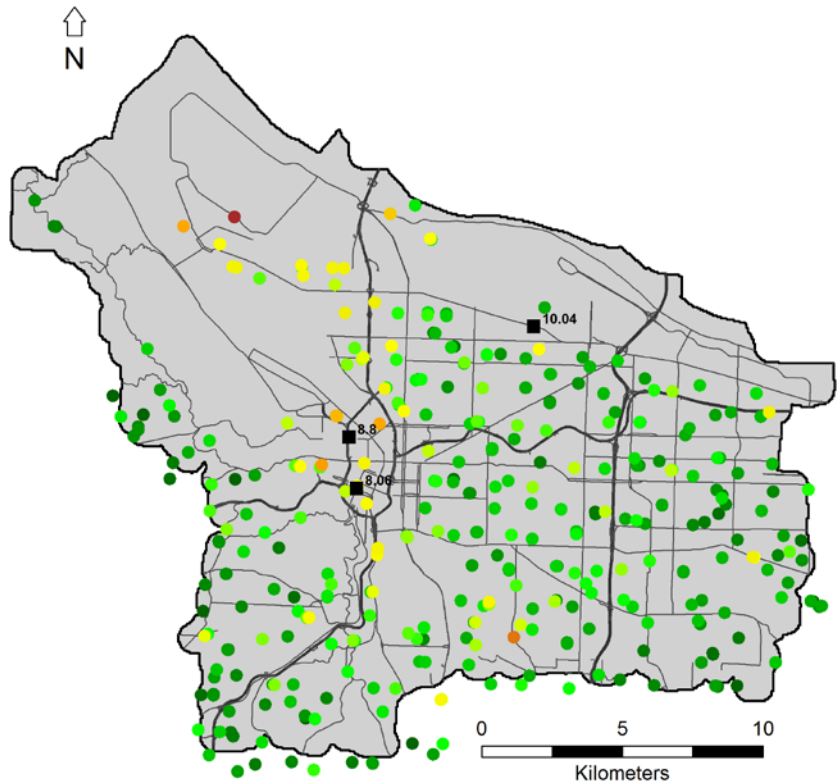




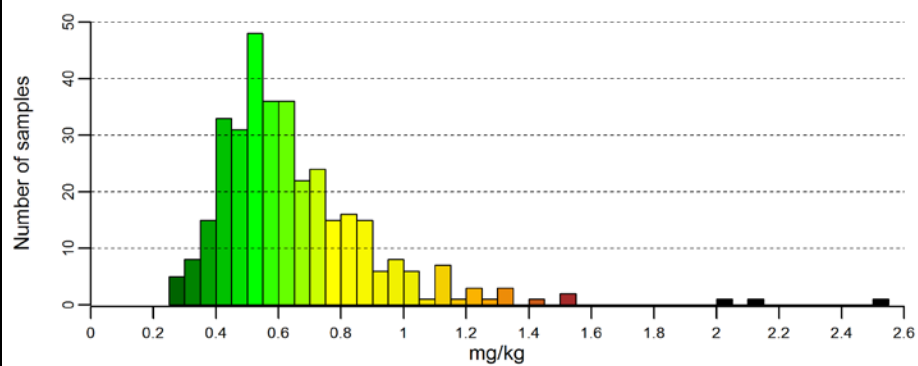
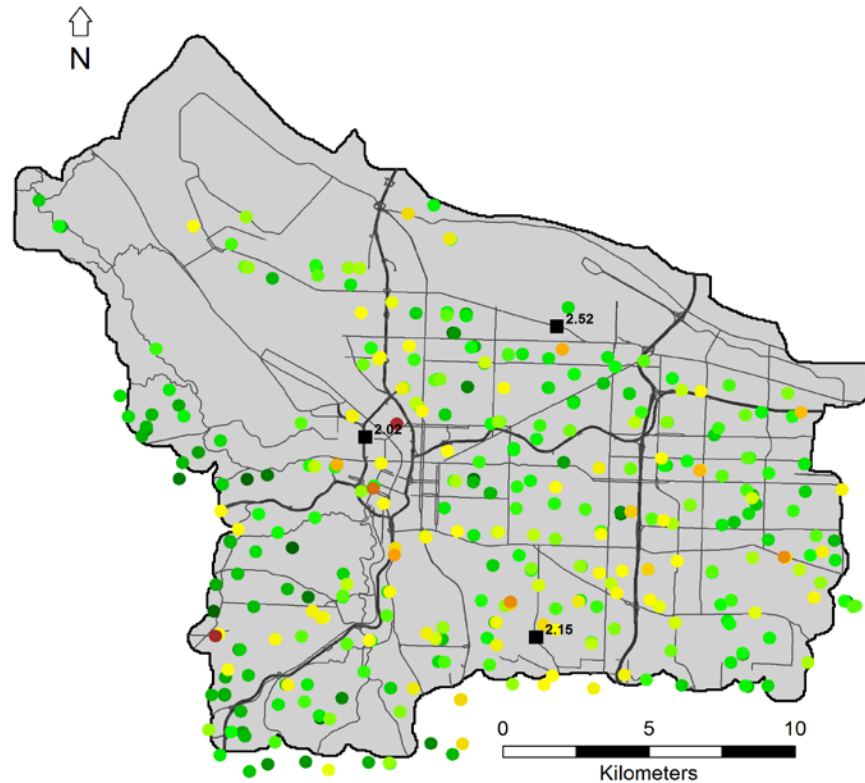
%N in moss  
Equal Interval bins



### Chromium (Cr)

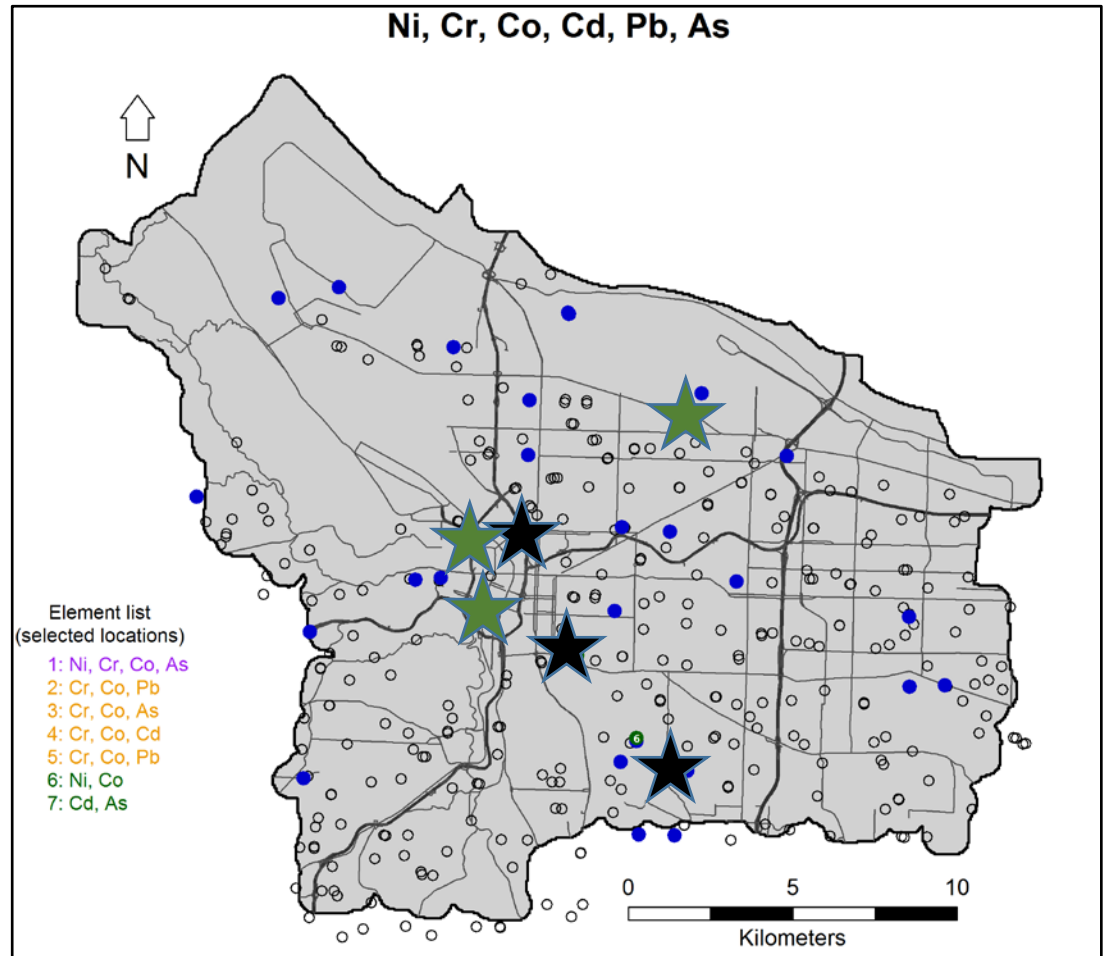


### Cobalt (Co)



# Follow-up – DEQ/FS partnership

- Prioritized sites with multiple toxics (Ni, Cr, Co, Cd, Pb, As) with high outlier values
- Blue sites have 1 high outlier – most haven't been investigated yet.



# Interpretation issues...

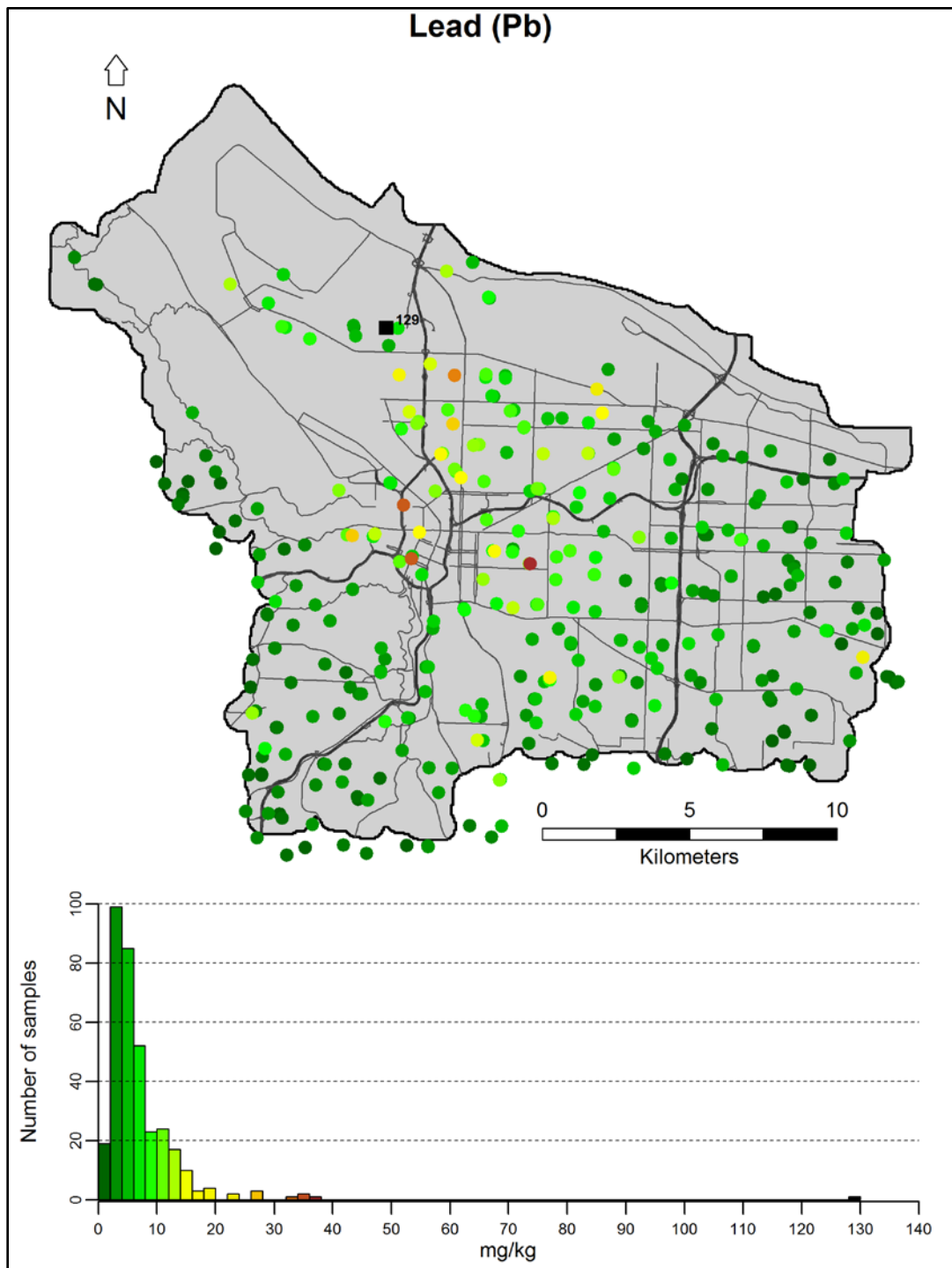
- We know moss concentrations generally correlate with atmospheric concentrations...but how well?
- Other factors affecting moss uptake/retention:
  - Weather effects on accumulation/loss?
  - Particle solubility?
  - Particle size?
  - Tree canopy characteristics?
  - Etc etc etc
- What timeframe is represented by the moss?



## Calibration study design.

- Compare monthly air measurements vs moss for 14 months
- 8 monitoring sites exposed to various pollution environments
  - **PM<sub>10</sub> monitor** (n = 1; N-FRM; 16.67 LPM, ARA Instruments)
  - **Bulk deposition** (n = 3)
  - **In-situ moss** (n = 3)
  - **Weather** (temp, precip, humidity, wind speed & direction)
- 3 of 8 sites will also host a reciprocal transplant study
- **Partners:** Portland State University, DEQ, Lane Regional Air Pollution Agency, ARA Instruments, Portland Parks, Reed College, University of Portland, Columbia Slough Watershed Council
- Completed pilot phase. Installing monitoring sites in Nov.

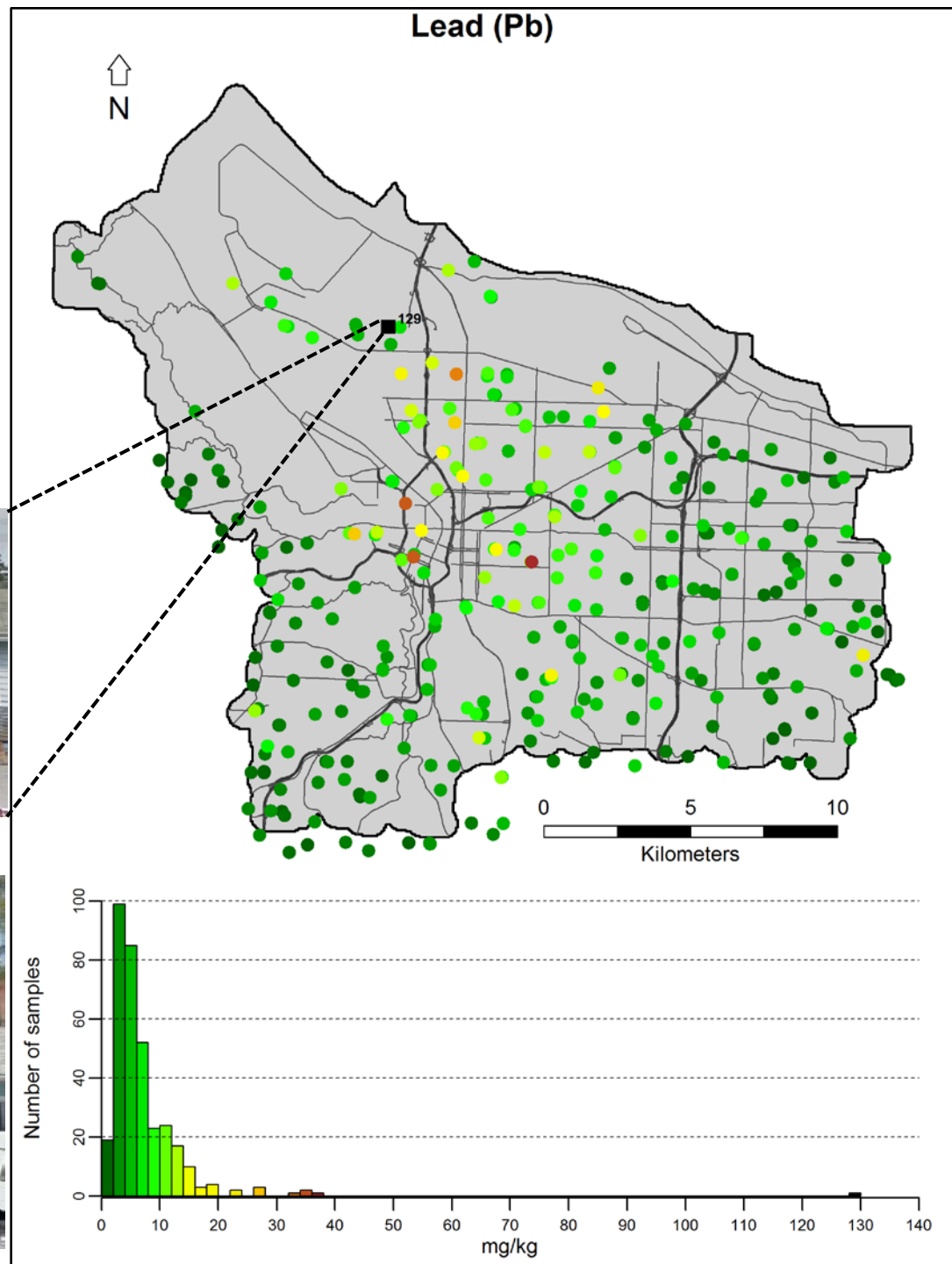
- What are the Pb sources?
- Point vs distributed sources?
- Extant sources or legacy?
- Is air the primary or secondary reservoir (from re-suspended soil)?



## Demo Pilot:

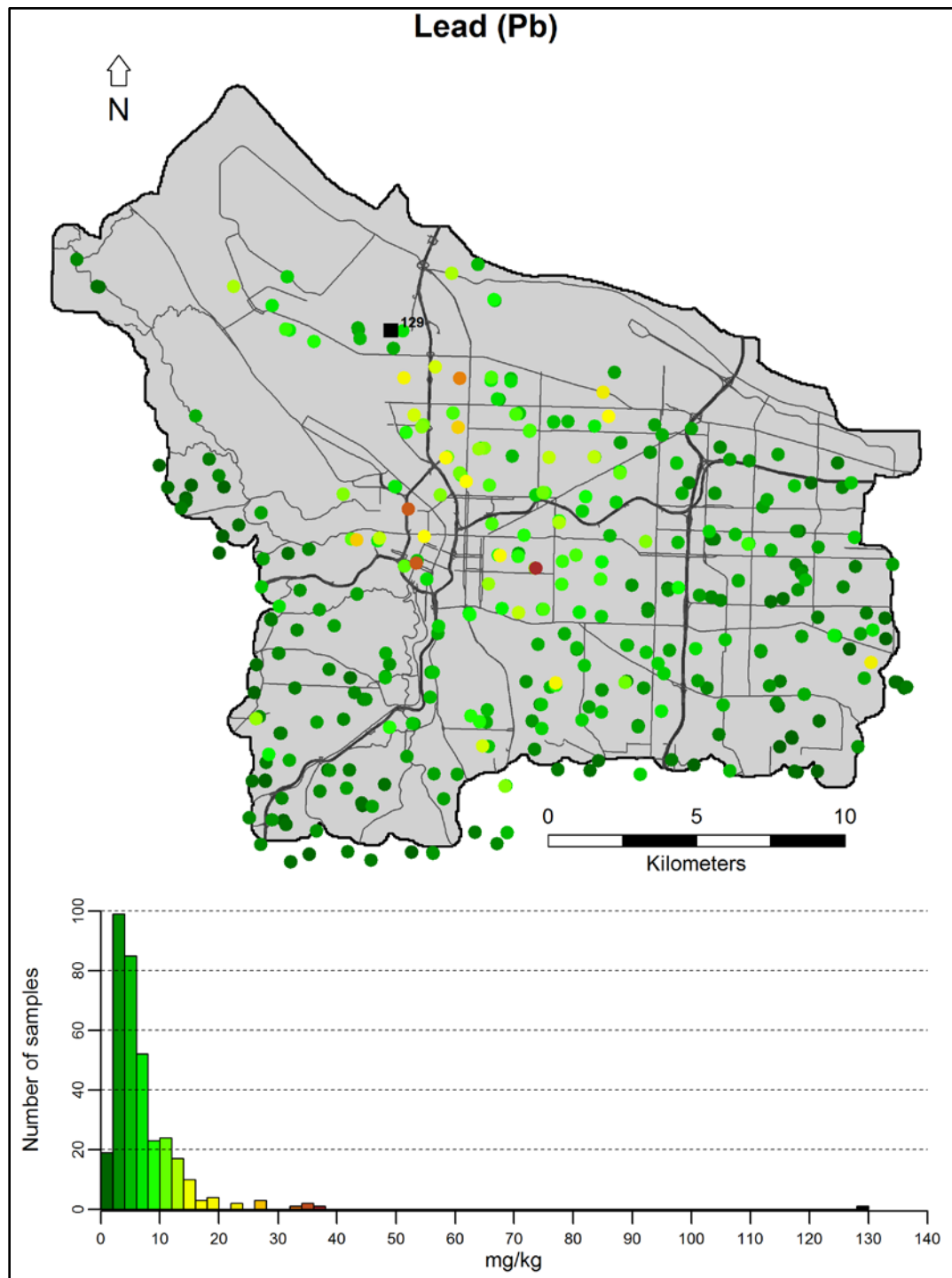
- Halfway done
- Tracking Pb concentrations and isotopes in moss sampled near demolition of homes with lead paint

Moss sampled before, after, and @ 1mo, 3 mo., 6 mo., 1 year



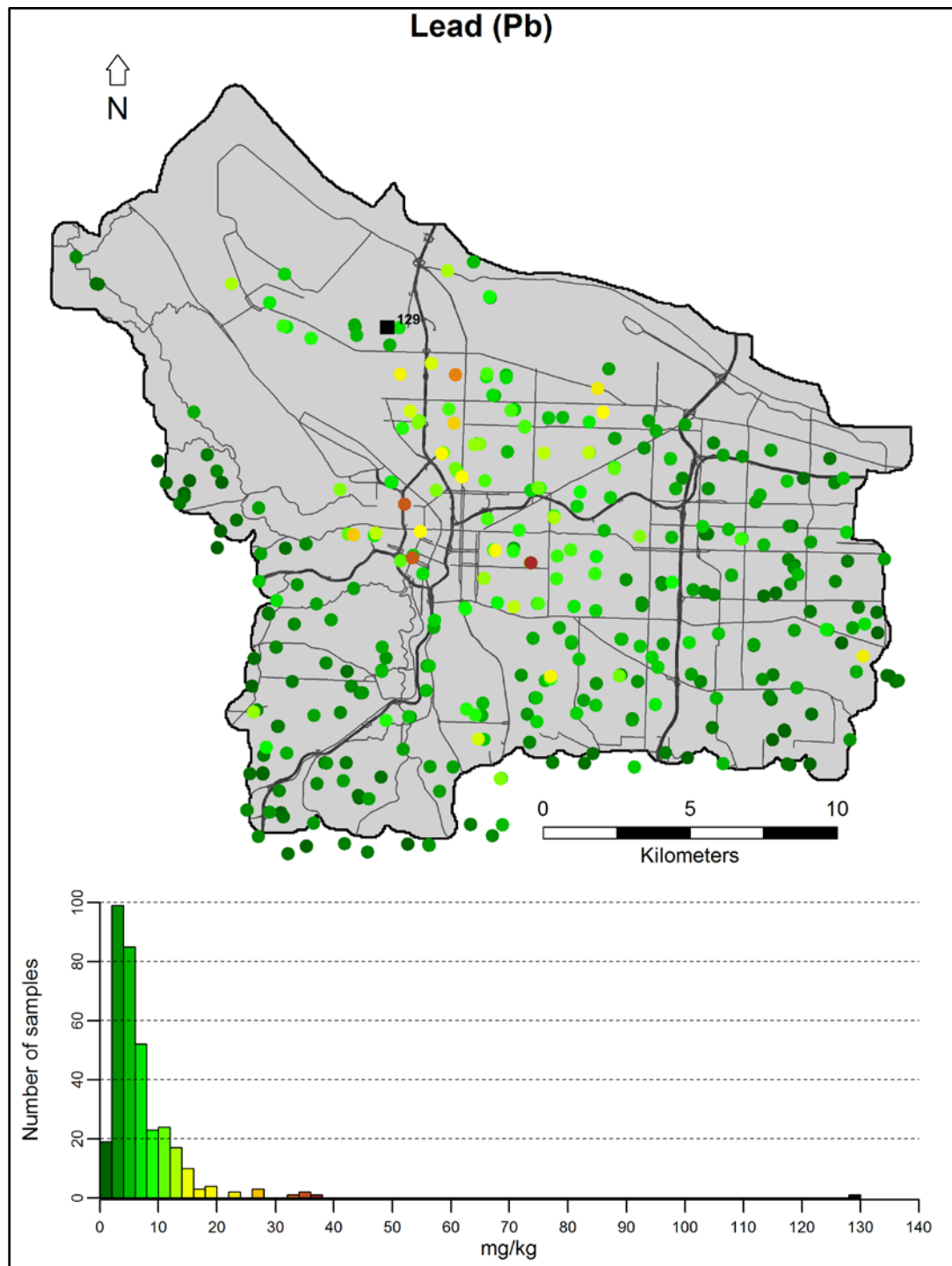
## Preliminary observations:

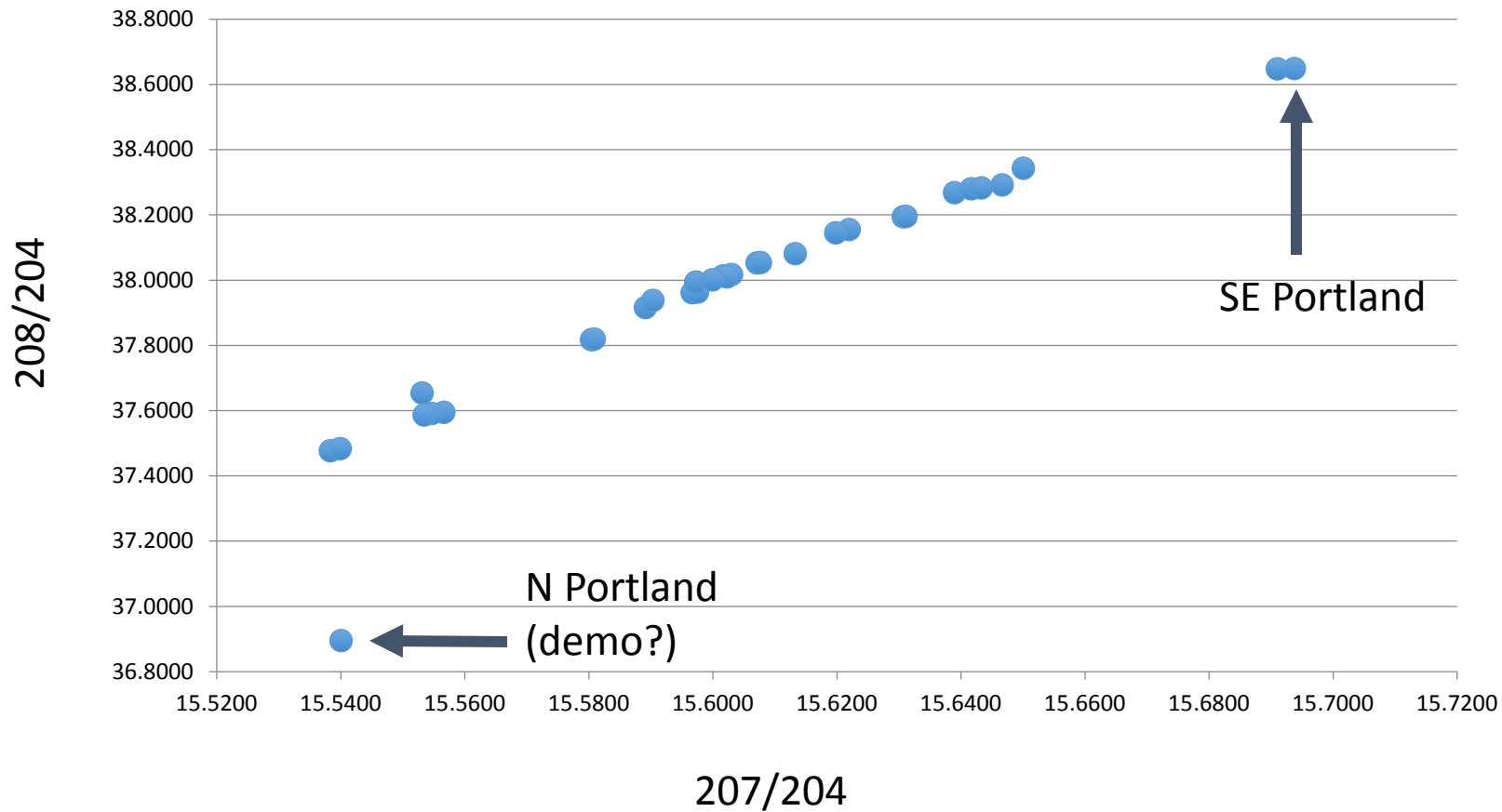
- Pb increased in all samples within 100ft
- Pb sometimes increased up to 300ft
- Values varied tremendously
- Couldn't control for factors like amount of lead paint, wind direction, humidity, precip, etc.
- But we can say that very locally, demos contribute to lead loads



Pb isotope ratios in 2013  
moss samples:

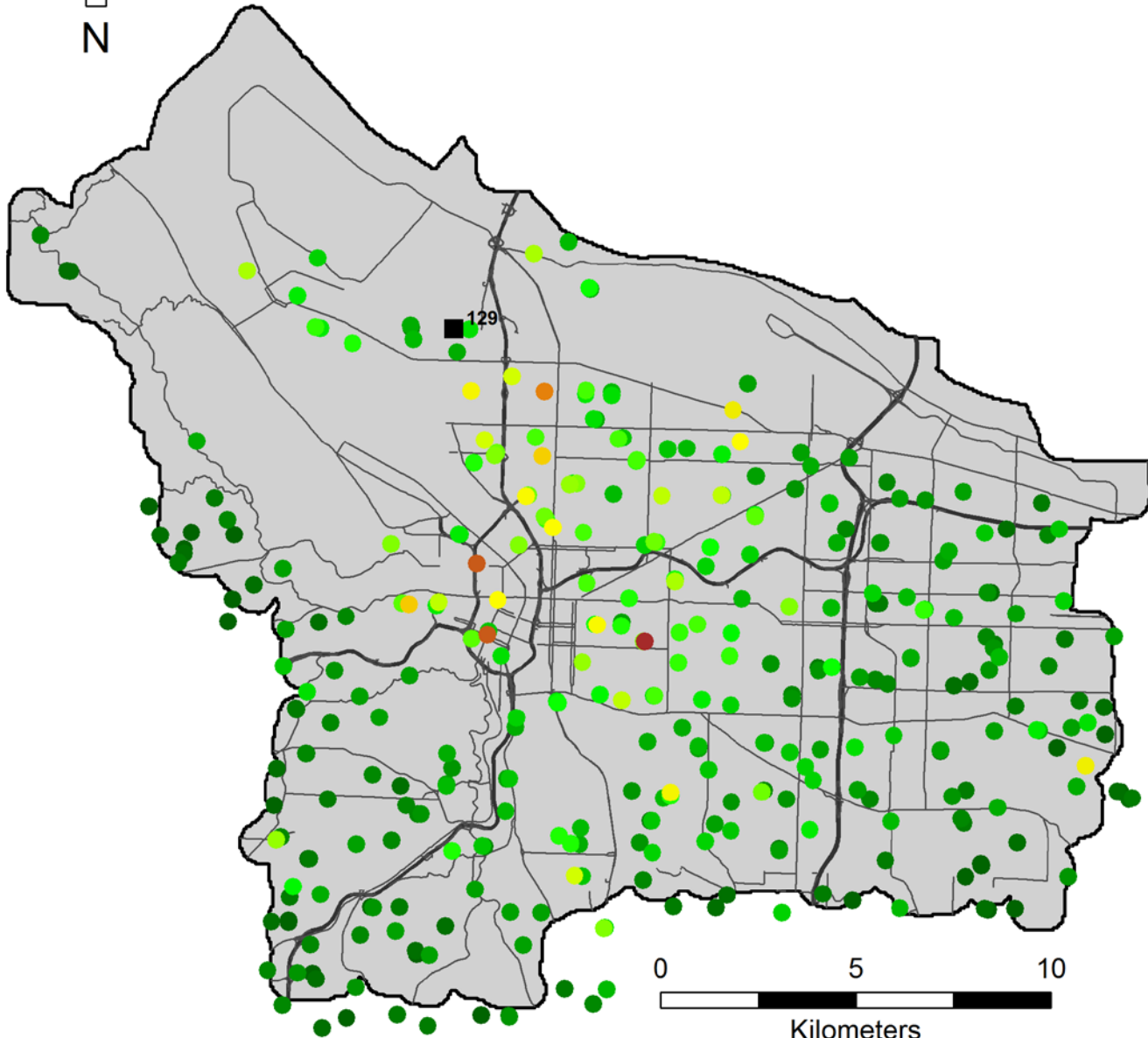
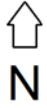
- Just getting started...
- We have results for the first batch of 20 samples...





We have at least 2 distinct, small-scale, non-industrial lead sources in PDX neighborhoods.

# Lead (Pb)

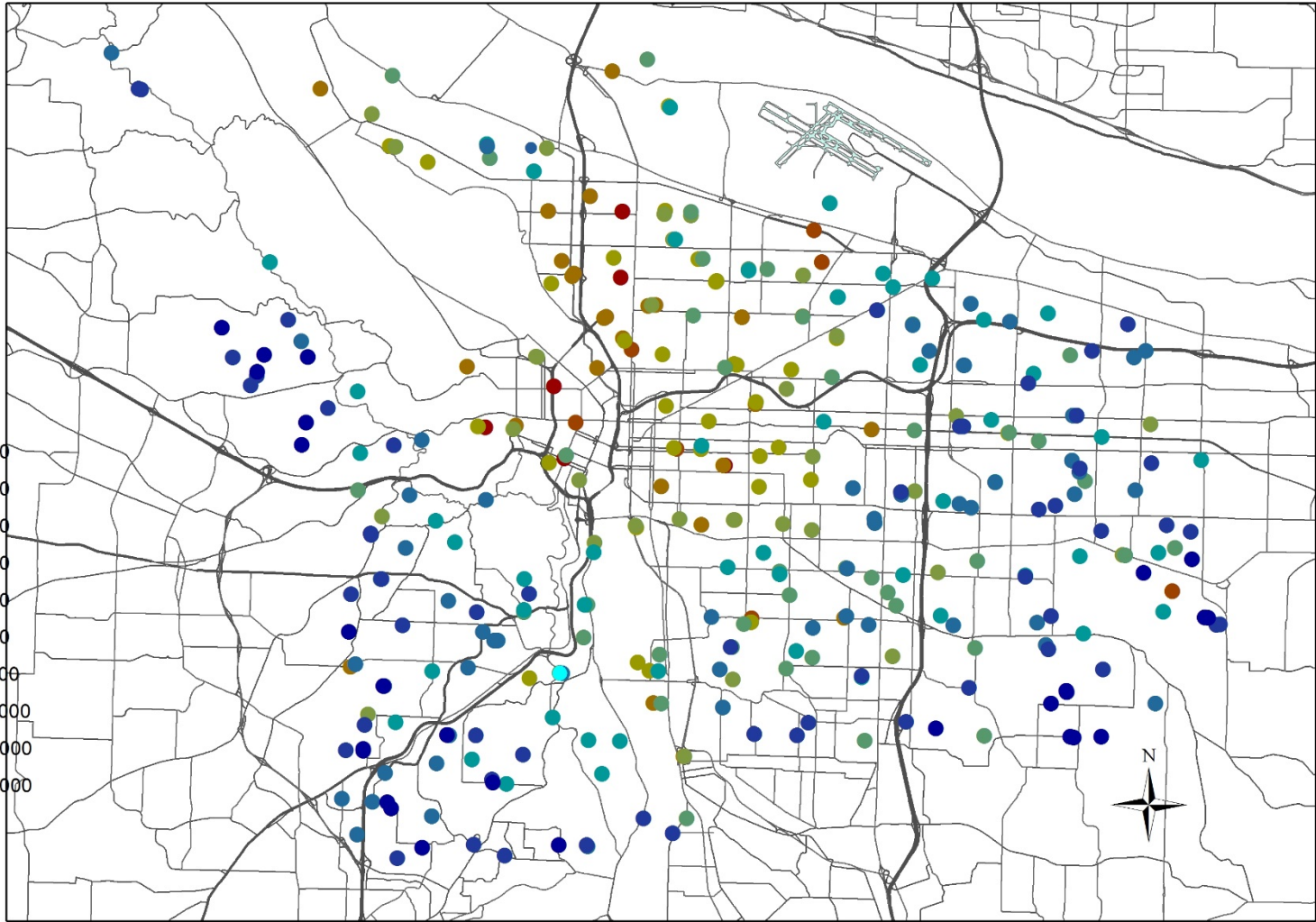


**Legend**

**Pb\_2013\_nooutlier**

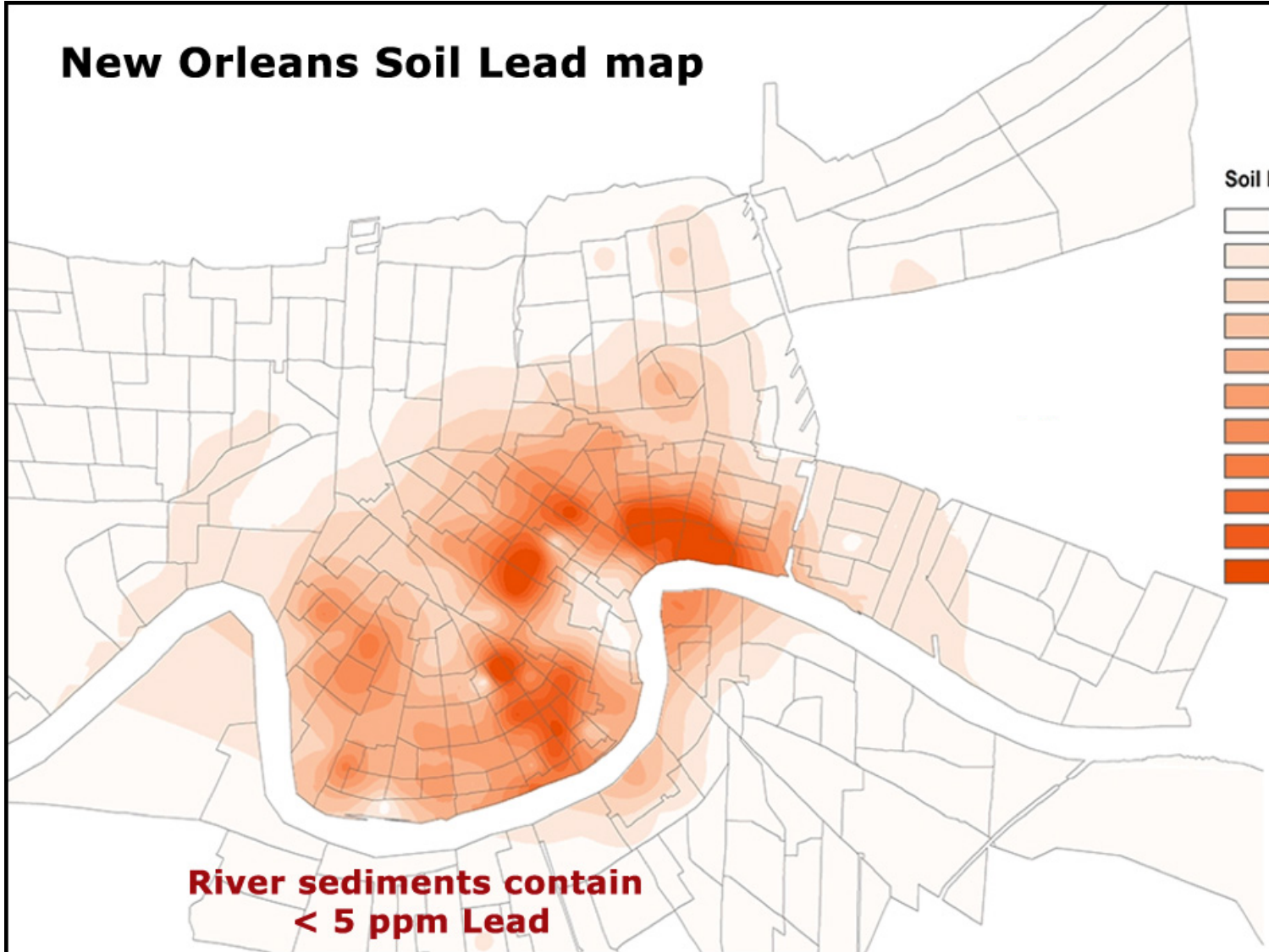
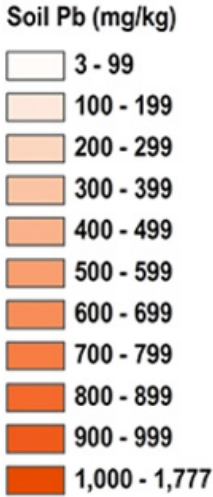
**Pb**

- 1.030000 - 2.270000
- 2.270001 - 3.340000
- 3.340001 - 4.290000
- 4.290001 - 5.620000
- 5.620001 - 7.090000
- 7.090001 - 9.070000
- 9.070001 - 11.930000
- 11.930001 - 15.645000
- 15.645001 - 23.295000
- 23.295001 - 37.530000

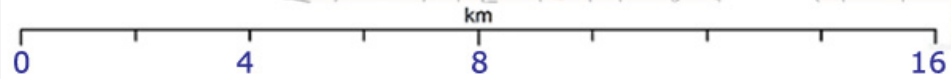




# New Orleans Soil Lead map



**River sediments contain  
< 5 ppm Lead**



## Brainstorming and amassing datasets:

- Soil
  - Compare soil elements in moss (Ca, Si, Al, Ti, Fe) to Pb
  - Compiling available PDX soil data
  - Collect new soil data...?
  - Construction permits – ground disturbance?
- Lead paint
  - City demolition database
  - Taxlot info
- Roads
  - Traffic volume, historic data
- Other Pb sources
  - Distance to armories, shooting ranges
  - Industrial sources, past and present



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