# Urban *v.* Rural Trends in Trace Metal Concentrations as Indicated by the Spines of Long-Lived Cacti

Cyrus Hester[1] and Gwyneth Gordon[2]

[1]School of Sustainability, Arizona State University, [2]School of Earth and Space Exploration, Arizona State University

ASU JULIE ANN WRIGLEY GLOBAL INSTITUTE *of* SUSTAINABILITY
ARIZONA STATE UNIVERSITY
Central Arizona-Phoenix Long-Term Ecological Research
CAP LTER

## Background

- **Metals (e.g., Cu, Pb, Zn) are an integral part of an industrial society. But, they have also been shown to promote neurodegenerative disorders, co-select for antibiotic resistance, and promote metal-tolerant flora and fauna.**
- **In the Phoenix area, CAP LTER researchers have found soils and lichen to be enriched in As, Cd, Cu, Pb, and Zn.**
- **Yet, the source(s) of urban metal pollution in the region remain uncertain. In part, this is because a long-term, biogeochemical record is lacking.**
- **This project evaluated the potential for long-lived saguaro (*Carnegiea gigantea*) to offer a proxy record of biogeochemical change in the Sonoran Desert.**

## Research Questions

- **Are the concentrations of metals in the spines of urban and rural saguaro significantly different?**
- **How have these concentrations changed over time?**

## Methods

- **Sampling was conducted at the Phoenix Desert Botanical Gardens (an urban site) and the Kofa Mountains National Wildlife Refuge (a rural site).**
- **All areoles (i.e., spine clusters) occurring in a single column were sampled from a ~4m tall cactus at each site.**
- **In the lab, spines were rinsed twice for 10 mins. in sonicated, DI water and dried at 70ºC for 3 days.**
- **Samples were then ground to a powder-like texture using a liquid nitrogen ball mill and dissolved in a mixture of $HNO_3$, HF, and HCl.**
- **Next, samples were microwave digested for 20mins using EPA method 3052X-Xpress. Digested samples were then taken to near dryness on hot plates and diluted to a known volume.**
- **Finally, element concentrations were estimated using a Thermo X Series quadrupole ICP-Mass Spectrometer.**


**Table 1.** Summary statistics of metal concentrations (ppb) in the spines of Saguaro cacti inhabiting urban and rural ecosystems.

| | | Ag | As | Cd | Cr | Cu | Ni | Pb | Sb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| Urban (n = 62) | Mean (± *s.d.*) | 59.1 (*± 38.7*) | 82.5 (*± 39.1*) | 138.0 (*± 256.2*) | 9 953.0 (*± 19 867.5*) | 15 034.1 (*± 27 752.7*) | 2 822.6 (*± 5 476.9*) | 5 140.7 (*± 10 313.8*) | 418.7 (*± 793.1*) | 33 286.9 (*± 64 798.9*) |
| | Median | 57.0 | 68.8 | 63.6 | 4 363.8 | 6 526.5 | 1 053.7 | 2 185.0 | 197.7 | 14 309.6 |
| Rural (n = 60) | Mean (± *s.d.*) | 64.0 (*± 31.7*) | 49.0 (*± 29.1*) | 39.4 (*± 30.2*) | 6 188.0 (*± 4 521.3*) | 2 542.4 (*± 3 584.4*) | 848.5 (*± 598.9*) | 1 205.3 (*± 830.5*) | 67.9 (*± 37.5*) | 4 311.4 (*± 3 550.7*) |
| | Median | 65.5 | 53.8 | 34.9 | 4 902.0 | 1 895.5 | 731.2 | 1 140.9 | 66.2 | 3 646.2 |

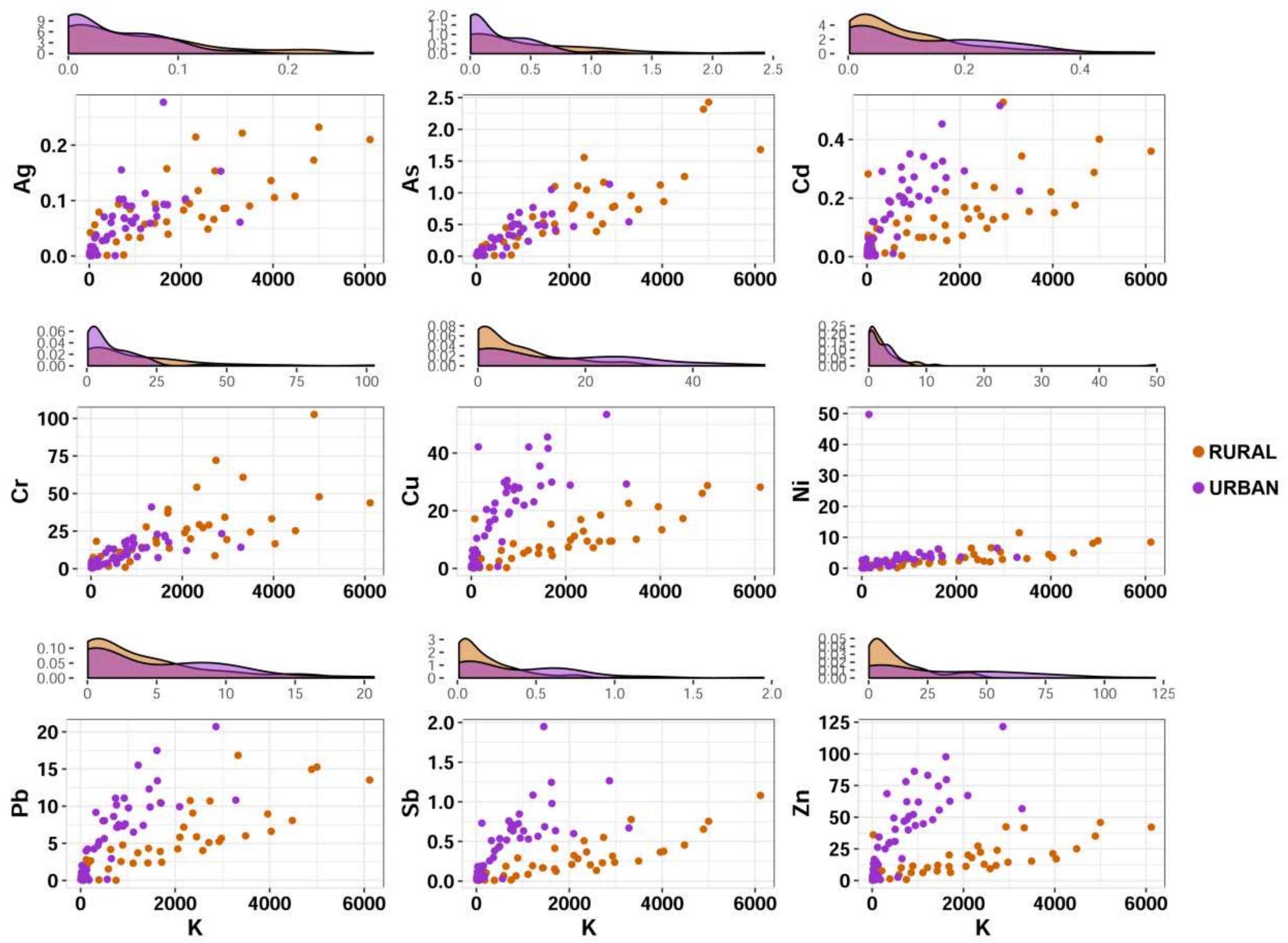


**Fig 1.** Density and Scatterplots showing the relationship between potassium (K) and metal levels in saguaro spines.

## Metal Enrichment Trends

Our results indicate that copper (Cu), lead (Pb), antimony (Sb), and zinc (Zn) are elevated in the urban saguaro, compared to the rural cactus (e.g., Fig. 1). There is also significant variation in metal concentrations that may indicate changes over time (Table 1).

Indeed, trends in the metal:potassium ratios over time suggest that the urban and rural biogeochemistry was initially rather similar (Fig. 2). But, over the course of multiple decades, the urban site was simultaneously enriched by Cu, Pb, Sb, and Zn.

Surprisingly, despite its remote location, the rural saguaro also exhibits signs of rising metal levels in recent years (Fig. 2).

## Accounting for Growth Rates

One possible explanation for changes in metal concentrations over time is that periods of more rapid growth result in greater quantities of metals being taken up along with other resources (e.g., water, nutrients). Hence, it is important to account for changes in plant physiology over time.

Below a critical threshold concentration, Potassium has been shown to increase with biomass production and relative growth rates. Plotting metal concentrations against potassium levels shows a consistent linear relationship (Fig 1), suggesting that growth rates have influenced saguaro metal levels.

To account for this, our subsequent analyses focus on trends in metal:potassium ratios (e.g., Fig 2), which should be less influenced by changes in cacti physiology.

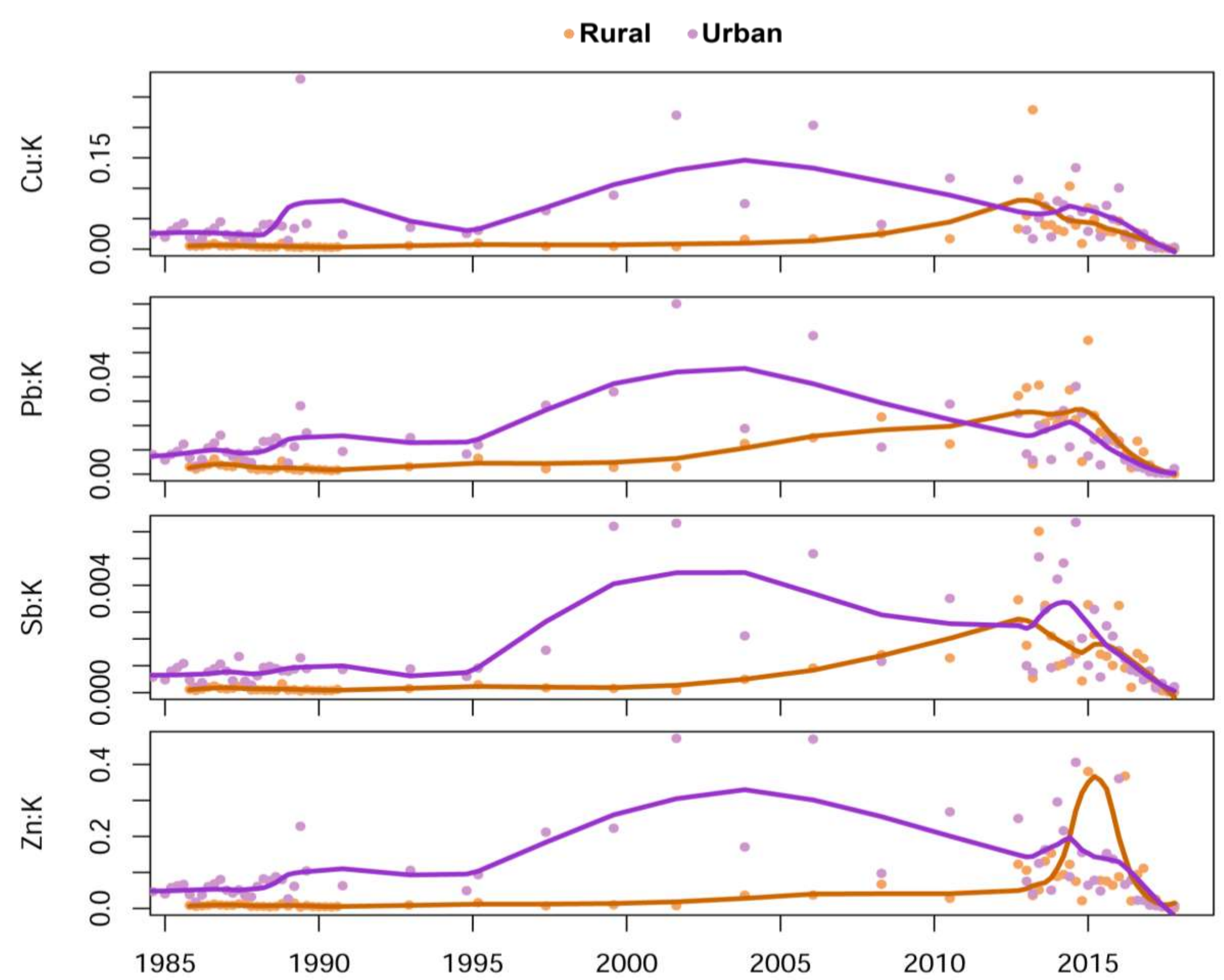


**Fig 2.** Changes in metal:potassium ratios over the last three decades, as indicated by saguaro spine chemistry. Note, years were estimated by assuming a constant growth rate of five areoles per year.

## Summary

- After adjusting for changes in the growth rate, our results suggest that metal enrichment in Phoenix occurred over the course of multiple decades—tentatively dated between 1995-2012 (Fig 2).
- Interestingly, the timing of these apparent urban pollution episodes appears to be correlated across metals, perhaps suggesting a common source (e.g., non-exhaust vehicle emissions) or transport mechanism (e.g., haboobs).
- At the start and end of the record, the biogeochemistry of the urban and rural sites are more similar. But, early on this is because concentrations were low at both sites. Today, the similarity seems to be resulting from the metal enrichment of the rural ecosystem.

## Discussion

- **Metals have great utility in a wide range of technological applications. But, they can also present risks to human health and the environment.**
- **Their central role in urbanization and industrialization means that addressing society's use (and misuse) of metals is a significant sustainability challenge. But, managing these resources requires a clear understanding of how and why heavy metal concentrations have changed over time.**
- **Our preliminary analyses suggest that saguaro spines may provide an effective proxy record of metal pollution in arid environments. Thus, offering a new tool for understanding long-term, socioecological change.**

## Future Research

- **These results will be compared to trends in particulate chemistry from the study area in an effort to validate the saguaro proxy record.**
- **More accurate dating will be accomplished using radiocarbon ($^{14}C$) and light isotope patterns ($\delta^{13}C$).**
- **Subsequent work will also attempt to identify the source(s) of urban metal pollution using a combination of patent record analysis and landscape history.**

**Acknowledgements**: We thank Rebecca Shelton and Kevin Hultine for their help in the field; Trevor Martin, David Dettman, and Panjai Prapaipong for lab and methodological assistance; and Everett Shock for early discussions on the topic. This project was funded by a graduate research grant from the CAP LTER (NSF Award #1637590).