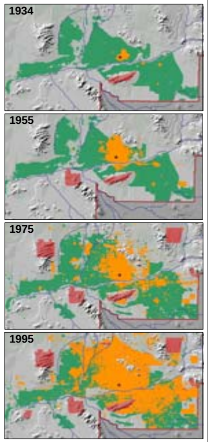
The Effects of Urbanization on Belowground Processes in the Sonoran Desert

Rachel Davies and Sharon Hall, Arizona State University, Tempe, Arizona

Transforming Landscapes

- Rapid urban growth has led to widespread conversion of agricultural land to residential use (Figure 1).
- Xeric landscaping is a significant land cover type in the Phoenix area[1] as many homeowners replace grass lawns with drought-tolerant or native plants.
- Urbanization alters climate[2], leaf tissue chemistry[3], and insect[4], bird[5], and mammal[6,7] communities.
- These aboveground ecosystem processes interact with belowground nutrient cycling and resource availability.
- Little is known about the cumulative effects of land use, urban climate, and native plants on belowground ecosystem function in large arid cities like Phoenix.

Figure 1. Land use changes in the Phoenix metropolitan area 1934 – 1995. Photos from CAP LTER database.



How Does Urbanization Affect Availability and Distribution of Soil Resources?

1. How does human management affect available resources?
   - Prediction: Effects of human management are evident as elevated nutrients, organic matter, and microbial activity in xeriscaped yards compared to urban desert sites.
2. How does proximity to the urban center influence soil resources?
   - Prediction: Undisturbed desert within the urban core (i.e. urban desert) has enriched soil resources compared to outlying desert.
3. How does the distribution of soil resources vary across a gradient of human influence?
   - Prediction (Figure 2): Soil resources in outlying desert show characteristic islands of fertility beneath plants. Islands of fertility are reduced in magnitude in urban areas, with xeriscaped yards supporting the most even distribution of soil resources.

Figure 2. Predicted results

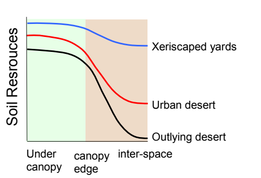
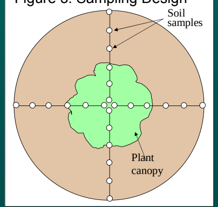


Figure 3. Sampling Design



Soil sampled in outlying desert, urban desert, and xeric yards

Sampling was conducted beneath two native Sonoran desert plants common in residential landscaping, brittlebush (*Encelia farinosa*) and Palo verde trees (*Parkinsonia spp.*). 5-cm soil cores were collected (N = 5 for each landscape type) along four transects extending from the base of the plant and away from the canopy (Figure 3). Soil was analyzed for extractable pools of ammonium and nitrate, rates of net potential N cycling (N mineralization and nitrification), percent soil organic matter, and percent moisture. Sampling was conducted during the dry summer season before the beginning of monsoon season.

Desert in and around Phoenix

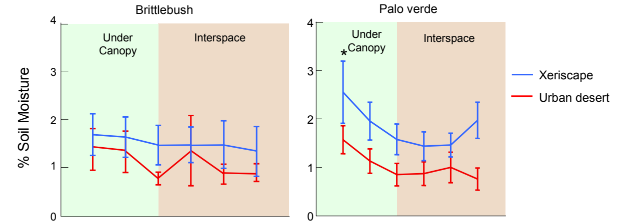
Xeric residential yard landscaped to look like desert

Direct Human Management Raises Soil Moisture but Lowers Net N Cycling

- Soil moisture is higher beneath and between plants in xeric yards (Figure 4).
  - Drip irrigation and increased organic matter may contribute to elevated soil moisture beneath Palo verdes, but do not explain elevated soil moisture between plants.
  - Increased clay content, shade from dense planting, or high atmospheric humidity in residential areas could contribute to elevated soil moisture.

Dense planting beneath a Palo verde in a xeriscaped yard

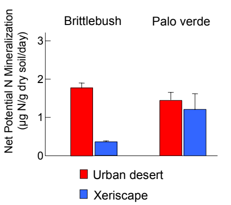
Figure 4. Percent soil moisture is elevated beneath brittlebush and Palo verde in xeric yards.



* One xeric Palo verde received drip irrigation immediately prior to sampling. Soil moisture at the base of this tree was more than quadruple any other sampling location, and is omitted in this graph.

- Xeriscaped yards and urban deserts have similar levels of soil organic matter and inorganic nitrogen pools.
- Xeriscaped yards have significantly lower net potential N cycling rates around brittlebushes than urban deserts, despite elevated moisture, similar total inorganic nitrogen pools (Figure 5), and similar organic matter content. Palo verde show a similar trend.

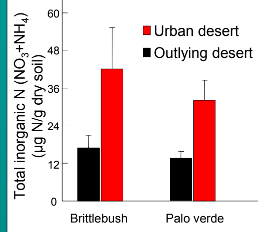
Figure 5. N cycling is lower in xeric yards than in urban deserts.



Urban Climate Increases Soil Resource Availability

- Although urban deserts have never been fertilized, exposure to the urban climate has increased the availability of inorganic soil nitrogen, a key limiting nutrient for Sonoran desert plants (Figure 6).
  - Enriched pools of inorganic nitrogen may result from deposition of atmospheric pollution or altered aboveground communities.
- Similarly, net potential N processing rates (nitrification and N mineralization) are higher in urban desert than outlying desert.
- Organic matter is higher around brittlebushes in urban deserts than outlying deserts.

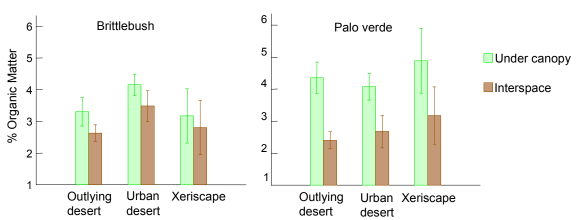
Figure 6. Pools of inorganic N are elevated inside the city.



Importance of the Urban Climate Varies Between Palo verde and Brittlebush

- Palo verde trees have a stronger affect on soil resources than urban influences, as no significant differences were found beneath Palo verde canopies across site types with the exception of soil moisture (Figure 7).
- Brittlebushes do not accumulate soil resources beneath their canopies for any variables measured. Rather, urban influences were more important to the availability of soil resources than the presence of brittlebush.

Figure 7. Palo verde trees create resource islands beneath their canopies, while brittlebushes doe not. Organic matter is shown as a representative example.



Possibilities for future work include:

- Decomposition experiments and soil respiration to compare accumulation of organic matter between land use types
- ^{15}N isotope study to assess gross rates of nitrogen cycling
- Leaf tissue chemistry, plant community structure, and insect and/or small mammal population sampling to explore connections between above- and below-ground processes

Contact: Rachel.Davies@asu.edu

[1] CAP LTER Database, unpublished data.

[2] Brazel, A., N. Selover, R. Vose, and G. Heisler. 2000. The tale of two climates – Baltimore and Phoenix urban LTER sites. *Climate Research* **15**: 123 – 135.

[3] Bony Ahmed, unpublished data

[4] Faeth, S, P. Warren, E. Shochat, and W. A. Marussich. Trophic Dynamics in Urban Communities. *Bioscience*. **55**(5): 399 – 407.

[5] Blair, R. B. Land use and avian species diversity along an urban gradient. *Ecological Applications* **6**(2):506 – 519.

[6] Donovan, T. M., P. W. Jones, E. M. Annand, and F. R. Thompson III. 1997. Variation in local-scale edge effects: mechanisms and landscape context. *Ecology* **78**(7): 2064 – 2075.

[7] Tigas, L. A., D. H. Van Vuren, and R. M. Sauvajot. 2002. Behavioral responses of bobcats and coyotes to habitat fragmentation and corridors in an urban environment. *Biological Conservation* **108** (3): 299 – 306.