# Long-term drivers of winter annual wildflower production in the Sonoran Desert

Hannah R Heavenrich[1], Julea Shaw[2], Sharon J Hall[1]
[1]School of Life Sciences, Arizona State University, Tempe, AZ; [2]Department of Plant Sciences, University of California Davis, Davis, CA

Central Arizona-Phoenix Long-Term Ecological Research CAP LTER

## How does climate and urbanization impact Sonoran Desert winter annual wildflowers?

Annual wildflowers play an important role in dryland systems. As primary producers, they provide food for herbivores, improve soil quality, and create beautiful landscapes for outdoor enthusiasts, as well as respond quickly to precipitation which prevents nutrient losses. Wildflower growth is driven by precipitation, nutrient availability, and soil characteristics, all of which are likely to be altered by climate change and nearby urbanization.

## Research Questions

1. **What is the relative importance of climate, nutrients, and soil physical properties on the growth of winter annual wildflowers in the Sonoran Desert?**
2. **How are these drivers influences by heterogeneous landscape patches formed by shrubs?**
3. **How does proximity to an urban area influence the drivers of winter wildflower growth?**

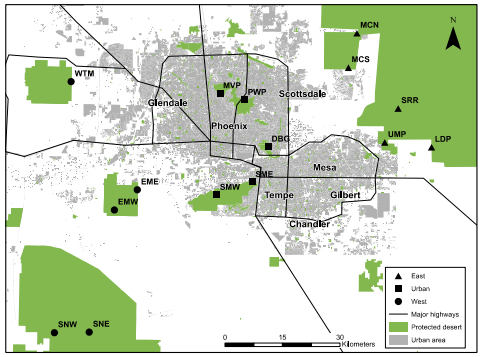
**Hypotheses**: Winter annual wildflower growth will follow a climate-driven cascade of resource limitation. We expected:

- Rainfall: Low winter rainfall→ little to no biomass production with. Average rainfall→ moderate nitrogen (N) limitation of plant growth, and a positive effect of surface rocks. Above-average rainfall→ strong N and phosphorus (P) limitation of plant growth and negative effect of rock cover
- Growth under shrubs > growth between shrubs.
- Urban wildflower growth> outlying desert due to atmospheric N deposition.
- Resource availability will predict winter annual plant growth through time.



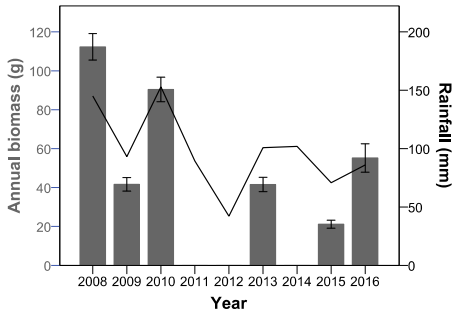
## CAP's Desert Fertilization Experiment

The DesFert project includes 15 sites in protected desert across the Phoenix area. We collected aboveground biomass of winter annual plants from quadrats within 20m x 20m plots that were fertilized for 10 years with N, P, or N+P, as well as a control (no N/P). Previous studies show that precipitation and N enrichment drive wildflower productivity[1]. Additionally, N-deposition was found to be higher in the urban core compared to outside the city[2].

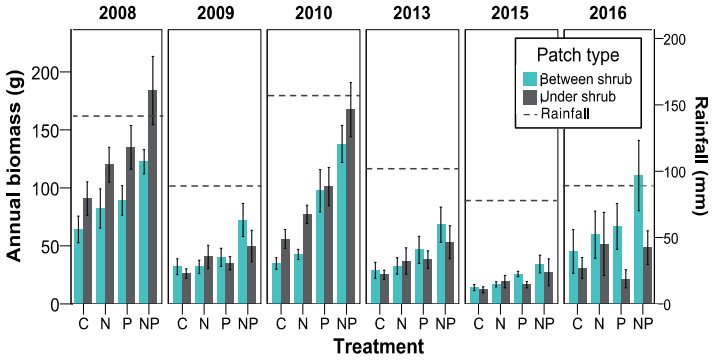



## Growth of Sonoran Desert wildflowers is declining over time in Urban and West Valley parks

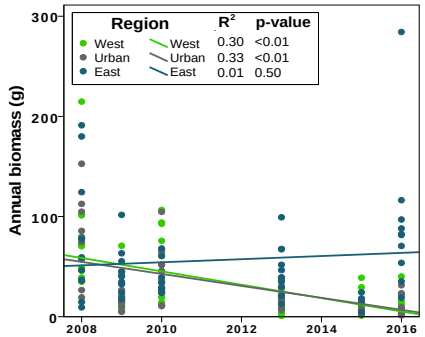
**Wildflower production is becoming less sensitive to seasonal rainfall over time.** Rainfall is the strongest driver of winter annual growth. However, after controlling for seasonal rainfall, growth declines over time (Control plots only, ANCOVA, effect of Year: p<0.01). Declining wildflower growth could be due to changes in precipitation patters, higher temperatures[3,4] or changes in communities of pollinators, seed dispersers[5], or herbivores.




**Winter annual wildflowers grew better under shrubs in seasons with above-average rainfall (>150 mm/season).** In contrast, in low or average rainfall seasons (2009, 2013, 2015, 2016), wildflowers grew better in patches between shrubs, possibly due to competition for water with their host shrub (Patch type, p=0.06; Year:Patch type, p<0.001)




**The decline in wildflower growth is greatest in the lower-rainfall sites.** When separated by region, wildflower growth significantly declined in urban and western desert parks but not in the eastern desert parks.




## Precipitation, followed by a suite of abiotic factors, drive wildflower growth

**Rock Cover and Water holding capacity are significantly associated with wildflower growth.** The results of the multi model inference revealed that although rainfall was the strongest driver of wildflower production, followed by N, P, soil properties were also significantly related to wildflower growth.

- Water holding capacity (WHC) influences how fast surface soil water will evaporate and infiltrate, contributing to how much water is available for annuals with shallow roots.
- Surface rock cover was negatively associated with wildflower growth, probably because rocks at these sites are too small to provide beneficial microclimates, or because they prevent plant emergence.

**Relative variable importance**

| Between shrub | Weights* | Under shrub | Weights* |
|---|---|---|---|
| Rainfall | 1.00 | Rainfall | 1.00 |
| Nitrogen addition | 1.00 | Nitrogen addition | 0.94 |
| Phosphorus addition | 0.99 | Phosphorus addition | 0.85 |
| WHC | 0.98 | Total rock cover | 0.70 |
| Total rock cover | 0.89 | WHC | 0.30 |

*Importance is the sum of the Akaike weights for each model that contains the parameter of interest.

| | | Between shrub | Under shrub |
|---|---|---|---|
| **Variable or Interaction** | **df** | **p-value** | **p-value** |
| (Intercept) | 240 | <0.001 | <0.001 |
| Rainfall | 69 | **<0.001** | **<0.001** |
| Year | 69 | **<0.001** | **0.016** |
| N | 240 | **<0.001** | **<0.001** |
| P | 240 | **<0.001** | **<0.001** |
| Total Rock Cover | 240 | **<0.001** | **0.001** |
| WHC | 13 | 0.798 | 0.331 |
| N : WHC | 240 | **0.034** | **<0.001** |
| P : WHC | 240 | **0.044** | 0.170 |
| Year : N | 240 | 0.073. | 0.679 |
| Year : P | 240 | 0.483 | 0.771 |
| N :P | 240 | 0.377 | 0.053. |
| Year : Total Rock Cover | 240 | 0.476 | 0.328 |
| N : Total Rock Cover | 240 | 0.441 | 0.993 |
| P : Total Rock Cover | 240 | 0.378 | 0.522 |

**References:** **1**: Hall et al. 2011; **2**: Cook et al. 2014 (unpublished); **3**: Kimball et al. 2009; **4**: Chollet et al. 2014; **5**: Forrest 2015; **6**: Davis et al. 2015; **7**: Baez et al. 2006. **Acknowledgements:** We especially thank our field assistants and support provided by the CAP LTER and CAP community and all members of the Hall lab for discussions, help and use of facilities and equipment. This work is based upon work supported by the National Science Foundation under grant number BCS-102686, Central Arizona-Phoenix Long-Term Ecological Research (CAP LTER).