Is the answer still blowing in the wind? Plant growth in urban areas

Christofer Bang[1], John L. Sabo[1] and Stanley H. Faeth[2]

[1]School of Life Sciences, POB 874501, Arizona State University, Tempe AZ 85287-4501
[2]Biology Department, The University of North Carolina at Greensboro, 312 Eberhart Building, Greensboro, NC 27402-6170

Summary

Perennial plants grow significantly better in urban areas rather than open desert or remnant sites, despite being subject to same water conditions. One hitherto overlooked, yet conspicuous difference in local climate is wind speed and its effect on productivity, an often ignored consequence of urbanization. We hypothesized that reduced wind in the city directly or indirectly increase plant performance. To test this we exposed brittlebushes to different levels of urbanization and wind speed, keeping water availability and soil nutrients constant. In addition, we logged local climate variables such as temperature, soil moisture and relative humidity. Change in aboveground biomass was measured during the growth season. As predicted, wind exposed plants in desert and remnant areas had a significantly lower biomass increase than wind protected plants, which increased similarly to exposed urban plants. This supports our hypothesis. Wind speed is however not the single factor responsible for increased productivity, but acts also as a facilitator to other processes leading to increased productivity, and should be incorporated in future simulation models.

Background

Previous field experiments show that Brittlebush (*Encelia farinosa)*, a shrub common to the Sonoran Desert, grow significantly better in urban areas of Phoenix, AZ, than in the surrounding desert, even when water and nutrient availabilities are the same. We think this is connected with the city structure, which reduces wind speed and increases shade as compared to open desert. Our hypothesis is that urban structures facilitate plant growth by reducing wind speed, and thereby increasing temperature and relative humidity.

In three desert locations, three city locations and three desert remnant (remnant) locations we put 20 plants on drip irrigation in pots. Half were protected against wind, while the other half were unprotected during the growth season of 2008. All plants had optimal water and nutrient conditions. Remnant areas have similar landscape structure to desert areas, but are located within the city. Assuming similar air quality between remnant and urban areas, remnant areas functioned as our control for potential effects of air quality. The plastic used in the wind barrier reduced direct sunlight by 10-15% (photosynthetic photon flux µmol m^{-2} s^{-1}), but only at times when the sun was not directly above the plants.

Because remnant and desert areas are open spaces relative to urban locations, we predicted that plants protected from wind would grow better than plants exposed to wind in the desert and remnant locations, while the difference in plant growth would not be significant in the city. It was also expected that temperature and relative humidity would increase within the wind protection.

Plant growth *in a nutshell*

- Photosynthesis requires water, CO_2 and light
- The opening and closing of stomata is a compromise between transpiration and carbon uptake
- Strong wind speeds remove the boundary layer, potentially increasing transpiration, but enhancing carbon uptake
- Wind speed may reduce leaf area ratios due to a decrease in specific leaf area
- If wind increases leaf respiration, a decrease in net assimilation rate may be associated with reduced growth
- Lower wind speeds reduce leaf temperatures due to an increase in convective cooling
- This requires that the water pressure in the plant is sufficient to compensate for transpiration

(Lambers et al. 1998)

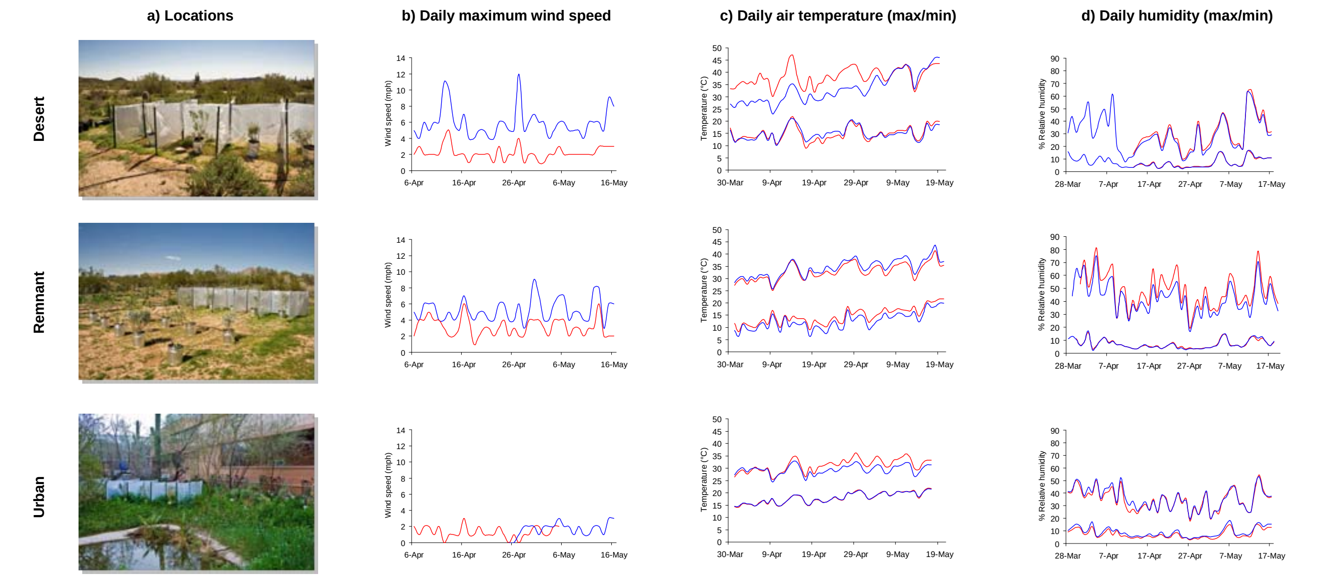

Figure 1: Experimental design and measures of environmental variables measured 0.8m above ground for a period of the growing season. RED lines are measures among wind protected plants; BLUE lines are measures between wind exposed plants. a) Representative locations for each habitat type. b) Wind speed. c) Maximum and minimum air temperatures. d) Relative humidity. Data logger malfunction caused some missing data.

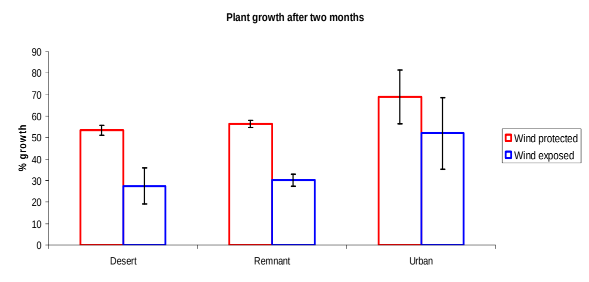

Figure 2: Increase in aboveground biomass of Brittlebush, *Encelia farinosa*, in wind protected and wind exposed areas in three habitat types. Error bars show standard error (n=9), and the effect of wind is significant (mixed model ANOVA, $F_{1, 166} = 21.02$, $P < 0.0001$). The fixed effect of habitat is not significant (Type III ANOVA, $F_{2, 6} = 1.5$, $P = 0.2963$).

Conclusion

- Although plant growth is an extremely complicated process with many interacting factors, we have demonstrated that urban structures may reduce wind speed and facilitate plant growth.
- The fact that remnant areas, which have similar air quality as other urban areas, display similar plant growth as in the desert, suggests that air quality is not a major factor controlling plant growth in the city.
- Wind speed as an effect of urbanization has been overshadowed by the heat island effect, nitrogen depositions and altered water availability. These are important factors, but wind may alter their effects on plant growth.

Results

- Measures of wind speed within and outside the wind barrier demonstrate that it effectively reduced wind speeds in the desert to levels similar to urban areas (Fig. 1b). In the reduced wind treatment, maximum air temperature was higher in the desert (Fig. 1c). In the remnant area minimum temperatures were higher in the protected area. Reduced wind speed did not increase humidity, except for in the remnant area (Fig.1d). Soil moisture measured in the pots did not reveal any clear differences between the habitat types, except being slightly higher in the wind exposed area in the desert (not shown).
- Increase in plant biomass based on height diameter relationships reveals a significant difference in plant growth between wind protected plants and plants exposed to wind in desert and remnant habitats (Fig. 2). Desert and remnant areas show similar patterns, while the urban areas had an overall high increase for both protected and exposed plants.
- Other environmental variables were obtained from nearby meteorological stations, such as O_3, NO and CO concentrations. Ozone levels were generally higher going from south-west to north-east, following the change in elevation. These data varied considerably locally, and could not provide for more detailed interpretations related to our study.

Reference
Lambers, H., Chapin III, F. S. and Pons, T. L. 1998. Plant physiological ecology. — Springer-Verlag.

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CAP LTER
Central Arizona–Phoenix Long Term Ecological Research

ASU SCHOOL OF Life Sciences
ARIZONA STATE UNIVERSITY