Atmospheric deposition of nutrients across a desert city: Spatial and temporal patterns of wet and dry deposition

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CAP LTER
Central Arizona–Phoenix Long-Term Ecological Research

Introduction

Atmospheric deposition has long been recognized as an important source of nutrient inputs to many ecosystems, particularly those in arid environments. Urbanization is significantly enhancing atmospheric deposition of some nutrients and many pollutants in cities as well as in downwind recipient ecosystems on regional scales. Despite these trends, there are relatively few studies of the spatial patterns in atmospheric deposition of nutrients and major ions across urban areas. The objective of this research was to quantify the spatial and temporal patterns in wet and dry deposition chemistry across the Central Arizona-Phoenix (CAP), one of the two urban sites within the National Science Foundation's Long Term Ecological Research program. We conducted this study over a four to six year period and determined mean annual nutrient loads and relationships between rainfall characteristics and event-based wet deposition.

Study Site

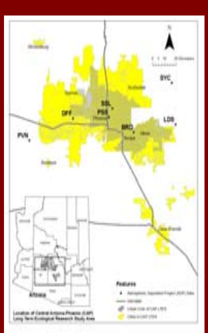
The CAP LTER study site encompasses the rapidly expanding Phoenix metropolitan area and surrounding agricultural and desert land. The climate is arid and hot, with two main periods of rainfall, the summer monsoons, associated with convective storms, and more evenly distributed winter rain. Seven wet-dry collectors (ADP sites) were located to form a transect running approximately W-E across the study area from outlying desert to the west, upwind of the prevailing synoptic wind direction, through agriculture to urban core sites, to two downwind sites in the desert to the east and northeast (Fig 1). Collectors were co-located with state/county air quality/meteorology monitoring stations.

Methods

Rainfall samples were collected from the 'wet side' of the AeroChemetrics wet-dry bucket samplers after each major rainfall event. Samples of dry deposition were collected from the 'dry side' on a monthly basis. Wet samples were filtered and analyzed for NO_3^--N, NH_4^+-N, soluble reactive P (SRP), Cl^- on a Lachat QC80000 auto analyzer, DOC was determined using a Shimadzu TOC analyzer, and Ca^{2+}, Mg^{2+}, Na^+, K^+ were determined with a Varian flame AA spectrograph. Dry bucket samples were processed by adding 500 ml of deionized water to the bucket and agitating it for 15 minutes on a orbital shaker, after which the water-soluble components were filtered and analyzed as the wet samples.

Figure 1: CAP LTER-ADP sites

Site	Position	Type
Palo Verde Power Station (PVN)	Upwind	Desert
Duncan Family Farm (DFF)	Upwind	Agric.
Phoenix Supersite (PSS)	Core	Urban
Sunny Slope (SSL)	Core	Urban
Brooks Road (BRD)	Core	Urban
Lost Dutchman (LDS)	Downwind	Desert
Sycamore Creek (SYC)	Downwind	Desert



Results

1. Temporal patterns of dry and wet deposition

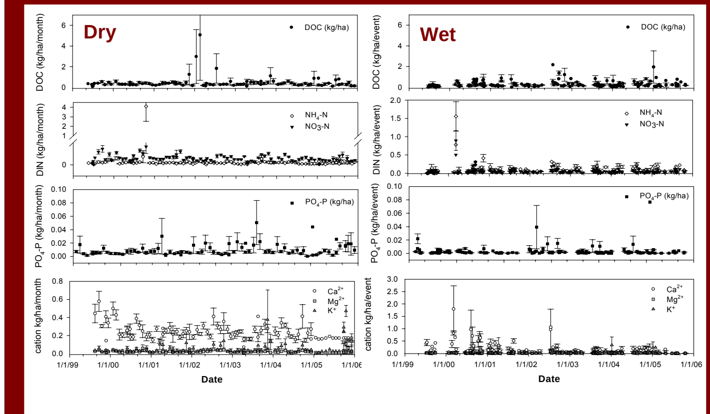


Figure 1.1: Temporal pattern of dry and wet deposition fluxes of nutrients (kg/ha) across the CAP region (mean±SE).

- ► Dry deposition generally dominated inputs to desert city
- ► Regionally elevated loads of dry deposition NH_4^+ were observed across the CAP LTER region in fall 2000. Wet deposition of NH_4^+ and NO_3^- were elevated in spring 2000 and this appeared to be balanced by Ca [2+] loads. Otherwise deposition inputs of both NH_4^+ and NO_3^- were surprisingly low.
- ►Dry and wet deposition of DOC were high relative to other nutrients.

2. Spatial patterns in mean annual loads of wet and dry deposition

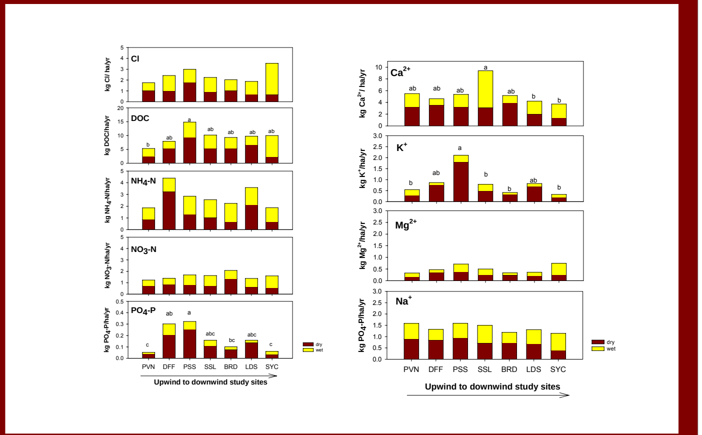
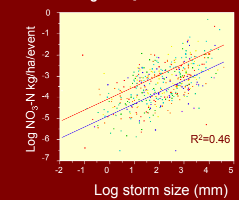


Figure 2.1: Mean annual dry and wet deposition of anions and cations at the 7 sites Different lower case letter indicate significant differences among sites across CAP LTER region (p<0.05, Tukey HSD).

- ► Mean annual loads of DOC (dry and wet) were significantly elevated in the urban core (PSS) relative to the upwind desert site (PVN).
- ► Mean annual loads of SRP, predominately as dry deposition, were significantly elevated in the urban core (PSS) relative to the upwind and downwind desert sites (PVN, SYC).
- ►Total annual loads a Ca^{2+} and K^+ in the urban core were significantly elevated relative to desert sites.

3. Storm size and season as predictors of wet deposition

NO_3^- Deposition

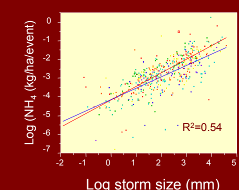


Summer (May – September)

Winter (October - April)

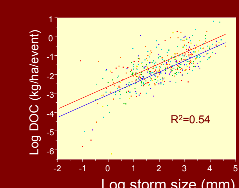
► NO_3^- in wet deposition was significantly higher during summer versus winter rains and positively correlated with the amount of rainfall during a storm.

NH_4^+ Deposition



► NH_4^+ in wet deposition was also correlated with season and storm size, but unlike NO_3^- these two factors interacted to influence deposition.

DOC Deposition



► Season and storm size were also significant predictors of DOC. In addition, time since last rainfall also explained a small percentage of the variation in DOC deposition.
► Overall, storm size explained the most variation in wet deposition.
► Surrounding land use type did not seem to affect event-based deposition rates.

Conclusions

- ►Mean annual loads of nutrients are dominated by dry deposition, particularly DOC. We found a significant urban enhancement of annual DOC, PO_4^{3-}, and Ca^{2+} inputs relative to desert sites. However, measured dry/wet N and DOC deposition were lower than modeled estimates (~18 kg N ha yr and ~30 kg DOC ha yr) for the CAP LTER study area.
- ►As with Welter et al. (2005), we found storm size and season are useful predictors of deposition rates, and this finding may help to improve deposition estimates for nutrient input budgets to such systems.
- ►Our findings suggest atmospheric deposition may behave differently in arid urban centers compared to coastal cities. Volatilization of N compounds from surrogate surfaces to the atmosphere in this arid environment and differences in deposition velocities may help to explain the disparity between modeled and observed rates of deposition. Detailed studies of gaseous and aerosol atmospheric N chemistry are underway.

References: Welter, J.R., S.G. Fisher, and N.B. Grimm. 2005. Nitrogen transport and retention in an arid land watershed: Influence of storm characteristics on terrestrial-aquatic linkages. Biogeochemistry 76: 421-440.

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