Atmospheric nitrogen deposition in Phoenix AZ is lower than expected: Findings from a methods comparison

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Introduction

Human generated atmospheric nitrogen (N) deposition alters ecological processes and properties, including nutrient cycling, primary production, and community composition.

In arid ecosystems, estimates of total atmospheric N deposition are uncertain due to variable precipitation patterns and difficulty in quantifying dry deposition, which can be significant in dryland ecosystems.

We compared sampling approaches to quantify spatial and temporal patterns of N deposition in Phoenix and the surrounding desert, and more generally to determine the best method(s) for quantifying total N deposition in arid systems.

Table 1: Atmospheric N compounds examined in this study and sources

Atmospheric Nitrogen Compounds	*Sources in Atmosphere*
Nitrogen Oxides: NO_x (g)	Agriculture, fossil fuel combustion & natural processes
Ammonia: NH_3 (g)	
Nitric Acid: HNO_3 (g)	Oxidation of NO_2
Ammonium Nitrate: NH_4-NO_3 (particulate)	HNO_3 + NH_3

Methods

We **compared N deposition estimates in upwind, urban and downwind** locations of the Central Arizona-Phoenix Long Term Ecological Research (CAP LTER) site, using:

1) **Community Multi-scale Air Quality (CMAQ)** model (1996)[2],

2) **throughfall ion-exchange resin (IER) collectors** (NH_4-NO_3; wet + dry; 2006 – 2011);

3) **passive gas filter collectors** (NH_3, NO_x, HNO_3; 2010 - 2011) with the

Inferential method (*Deposition = N concentration * Deposition Velocity*);

4) **wet-dry buckets** (NH_4, NO_3; 2000 – 2005)[3].

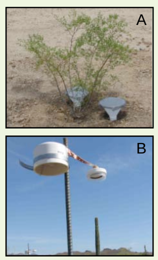


Figure 1: (A) Throughfall IER N deposition collectors (under Creosote), and (B) Passive gas filter collectors

CMAQ modeled N deposition: Predicted average: 1.1 - 3.2 mg N m^{-2} d^{-1}

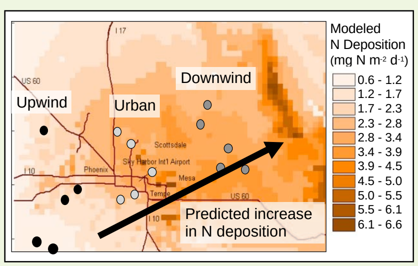


Figure 2: CMAQ model of N deposition (HNO_3, NO_x) across CAP LTER[2].

Points indicate upwind (black), urban (light gray) and downwind (dark gray) N deposition study sites.

Long-term N deposition lower than predicted: Average throughfall deposition 0.9 mg N m^{-2} d^{-1}

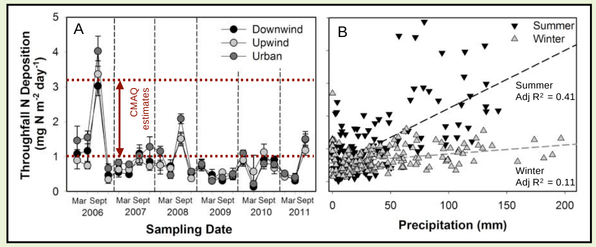


Figure 3: (A) Average N deposition (NH_4-NO_3; mg N m^{-2} d^{-1}; +/- 1SE) from throughfall IER collectors (deployed 3 - 6 mo periods) and (B) Throughfall N deposition x precipitation.

Timing & intensity of rainfall is important: N throughfall estimates are better predicted by summer monsoon rainfall than winter rainfall (**Fig. 3B**).

Lower than predicted downwind deposition may be explained because of greater winter rainfall (mean = 59.2) than summer rainfall (mean = 43.8) in downwind locations.

Gaseous N concentration: Urban > Downwind

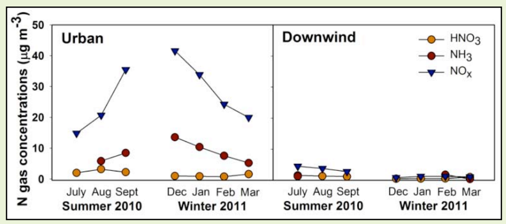


Figure 4: Average N gas concentrations (+/- 1SD) from passive filter collectors (deployed 2-3 week periods).

Passive gas collectors were used to increase precision of atmospheric N estimates by accounting for HNO_3, NH_3 and NO_x (NO_2 + NO).

Urban ambient N gas concentrations are significantly higher than downwind concentrations and are primarily composed of NO_x and NH_3, likely due to fossil fuel combustion (**Fig. 4**).

Quantifying dry deposition

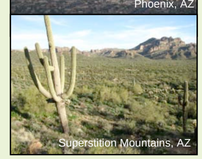
N gas concentrations (**Fig. 4**) can be used to estimate dry deposition using the inferential method during low rainfall periods.

Inferential method
Dry deposition = concentration * deposition velocity

Table 2: Estimated deposition velocities (mean & range) for the Sonoran Desert

Atmospheric N Compounds	*Deposition Velocity (cm/s)*[1]
NH_3 (g)	0.15 (0.1 - 0.19)
HNO_3 (g)	1.2 (0.15 - 3.0)
NO_x	0.01 - 0.14

Deposition velocities (**Table 2**) indicate the rate at which gases are deposited out of the atmosphere and are site specific (e.g., urban vs desert).



NH_3, HNO_3, NO_X deposition: Urban > Downwind

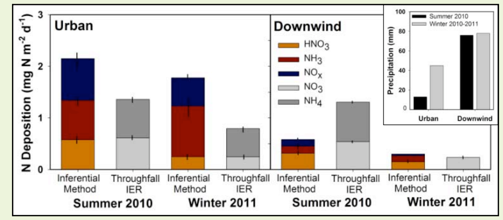


Figure 5: Average N deposition (+/- 1SE) estimated by inferential method (N gas conc x deposition velocity) compared with co-located throughfall collectors (no data for downwind winter 2011 NH_4). Inset: Total precipitation (mm) during sampling periods.

Urban dry deposition estimates (NH_3+HNO_3+NO_x) are significantly greater than downwind (**Fig. 5**).

Inferential estimates may underestimate dry N deposition in periods of high rainfall (e.g. downwind; see rainfall in Fig. 5 inset). Throughfall estimates may underestimate N deposition in low rainfall (e.g. urban).

N deposition methods comparison

Table 3: Estimated mean annual deposition rates (mg N m^{-2} d^{-1} (+/- 1SE))

Landscape position	***Modeled fluxes**[A,2]* (HNO_3 & NO_x)	***Throughfall IER collectors*** *(Total NH_4-NO_3)*	***Inferential method / passive samplers*** (HNO_3, NH_3, NO_x)	***Wet / Dry buckets**[3]* *(Total NH_4-NO_3)*
Upwind	1.1 (0.1)	0.8 (0.1)	*ND*	1.2 (0.4)
Urban	2.6 (0.3)	1.0 (0.2)	4.1 (0.8)	1.1 (0.04)
Downwind	3.2 (0.2)	0.8 (0.1)	1.1 (0.2)	1.1 (0.2)
Method uncertainties	Does not account for dynamic atm reactions	Underestimate dry deposition & canopy uptake	Uncertainty of deposition velocity estimates	Underestimate dry deposition & NH_4 volatilization
Best for…	Broad spatial estimates and predictive forecasting	Direct N deposition measurements	Estimating dry deposition & temporal variability	Quantifying pulsed wet deposition

[A] Data interpolated and averaged from CMAQ model for each CAP study site.

Conclusions and next steps

Phoenix N deposition estimates are relatively lower (~1mg N m^{-2} d^{-1}) than expected with more deposition in urban than downwind locations.

Arid N deposition varies seasonally -- influenced by timing and intensity of rainfall. Inferential methods are useful for estimating dry deposition & throughfall methods are useful for wet deposition estimates.

Despite uncertainty in each approach, mixed methods provide a broader understanding of potential atmospheric inputs during wet and dry seasons across heterogeneous locations.

References: 1: Gonzalez et al *In prep*; 2: Fenn et al 2003 *BioScience*; 3: Lohse et al 2008 *Sci Total Environment*

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