# $NO_x$ Emissions and Uptake by Urban Soils

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## Abstract

We measured $NO_x$ uptake and emissions from soils in 3 landscape positions, including managed turf, xeriscape, and unmanaged desert remnants within the Central Arizona-Phoenix LTER site. Desert remnant soils were strong $NO_x$ sinks but became $NO_x$ sources immediately following experimental watering. In contrast, $NO_x$ fluxes in managed turf and xeriscape soils were highly variable, ranging from strong sinks to strong sources of $NO_x$, likely depending on the initial inorganic N concentration and water-filled pore space of the soil. Soil NO emissions were not strongly controlled by soil or air temperature and exhibited no diurnal trend. However, ambient atmospheric $NO_2$ concentrations peaked during the night, and air temperature was strongly correlated to net $NO_2$ consumption by soils.

Although xeric soils are known to be large sources of NO globally, particularly after rainfall, urban soils are strong sinks for anthropogenic $NO_2$ which dominates the soil-atmosphere exchange of $NO_x$ in the urban ecosystem.

## Background & Methods

Nitric oxide (NO) and nitrogen dioxide ($NO_2$; NO + $NO_2$ = $NO_x$), are common products of fossil fuel combustion in the urban atmosphere. Anthropogenic $NO_x$ gases play central roles in tropospheric ozone formation (Fowler et al. 1998), but little is known about the consequences of increased anthropogenic $NO_x$ emissions and deposition on ecosystem function in the urban environment and surrounding, undeveloped regions.

**Figure 1. The $NO_x$ team at the Psychology Bldg. Lawn site.**

We measured soil NO flux from closed chambers using a portable chemiluminescent $NO_2$ analyzer equipped with a $CrO_3$ filter that converts all NO to $NO_2$ (**Fig. 1**). $NO_x$ was allowed to accumulate in the chambers for 5 minutes before NO fluxes were determined so that interferences from $O_3$ and $NO_2$ consumption were minimal.

## Results & Discussion

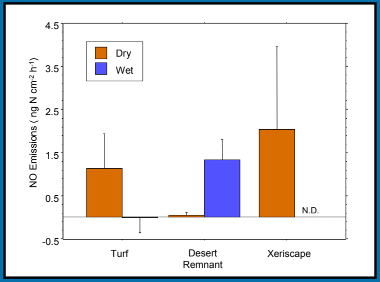

**Figure 2. Soil NO emissions before and after experimental watering.** Xeriscape soils had the largest average $NO_x$ emissions of all landscape types. Wet turf soils became $NO_x$ sinks while desert remnant soils became $NO_x$ sources within one hour after a 1 cm rain.

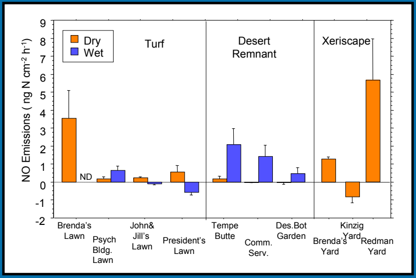

**Figure 3. High variability in NO emissions from turf and xeriscape soils compared to desert remnant soils** is likely due to human management factors that control soil $NO_x$ production, including irrigation and N fertilization.

Contrary to findings in natural and agricultural systems, urban soil NO emissions were not controlled strongly by temperature (**Fig. 5**). However, ambient $NO_2$ concentrations and soil $NO_2$ consumption were highly correlated and showed a strong diurnal trend (**Figs. 6 & 7**). High concentrations of ambient $NO_2$ likely caused increased $NO_2$ uptake by soils.

Fluxes of NO were highest from managed turf and xerisicape soils (**Fig. 2**), although these landscape types were characterized by high spatial variability typical of fertilized and irrigated systems (**Fig. 3 & 4** (see conclusion)). Rainfall suppressed emissions from turf soils where added water pooled, and in these soils NO was likely reduced to nitrous oxide ($N_2O$) or $N_2$.

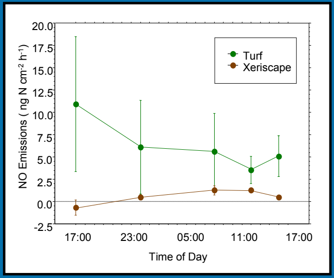

**Figure 5. Soil NO emissions are not generally controlled by soil or air temperature over the course of a day and night.** Turf soils at this site are highly variable and always larger than xeriscape soils at this site.

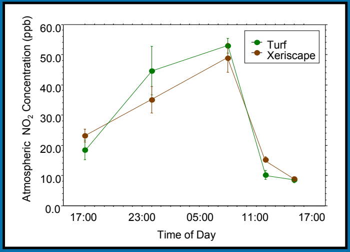

**Figure 6. Ambient atmospheric [$NO_2$] increases throughout the night and early morning**, perhaps due to oxidation of ambient NO to $NO_2$ via ozone ($O_3$) and decreased photo-oxidation of $NO_2$ back to NO after sunset.

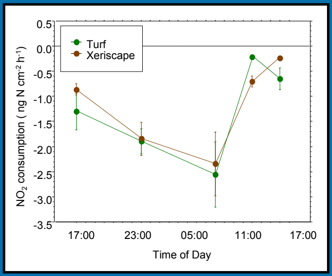

**Figure 7. Soil $NO_2$ consumption also increases throughout the night and early morning**, perhaps caused by a concentration gradient from increased night-time atmospheric [$NO_2$].

Because NO is quickly oxidized to $NO_2$ by ambient ozone ($O_3$) in the urban atmosphere, high soil NO emissions could decrease the sink strength of $NO_2$ by reducing the atmosphere-soil $NO_2$ gradient.

## Conclusion

Soils play a small but potentially significant role in regulating atmospheric $NO_x$ dynamics in the urban ecosystem. Baker et al. (2001) estimated that 33.8 Gg of $NO_x$-N enters the CAP-LTER atmosphere from anthropogenic (primarily mobile) sources each year. Using the most extreme scenario, if we assumed that the entire 12,384 $km^2$ watershed area of the CAP-LTER site was covered in fertilized turf (2.0 ng NO-N $cm^{-2}$ $y^{-1}$), and that this flux was representative of emissions throughout the year, soils would still comprise only 6.5% of total anthropogenic emissions of $NO_x$ annually. However, although urban soils are relatively small sources of $NO_x$, they may be important sinks for anthropogenic N. Furthermore, if diffusional processes cause the sink strength of soils to decline when soil $NO_x$ emissions are large, then soils will play a larger role atmospheric photochemistry then their contribution implies. The fate and residence time of deposited N in urban soils is unclear and will be a primary component of future work in this system.

**References:**

1. Fowler et al. (1998). *New Phytologist 139*, 11-23.
2. Baker et al. (2001). *Ecosystems 4*, 582-602.

**Figure 4. Various urban factors likely create high variability in soil inorganic N pools.**