

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 NO₂ concentrations peaked during the night, and air temperature was strongly correlated to net NO₂ 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 NO₂ which dominates the soil-atmosphere exchange of NO_x in the urban ecosystem.

Background & Methods

Nitric oxide (NO) and nitrogen dioxide (NO₂; NO + NO₂ = 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 NO₂ analyzer equipped with a CrO₃ filter that converts all NO to NO₂ (Fig. 1). NO_x was allowed to accumulate in the chambers for 5 minutes before NO fluxes were determined so that interferences from O₃ and NO₂ consumption were minimal.

Results & Discussion

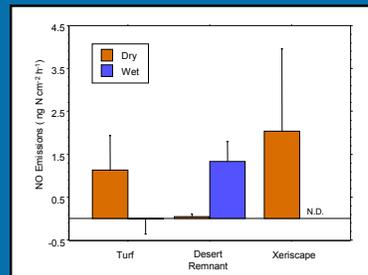


Figure 2. Soil NO emissions before and after experimental watering. Xeriscape soils had the largest average NO_x emissions of all landscape types. Wet turf soils became NO_x sinks while desert remnant soils became NO_x sources within one hour after a 1 cm rain.

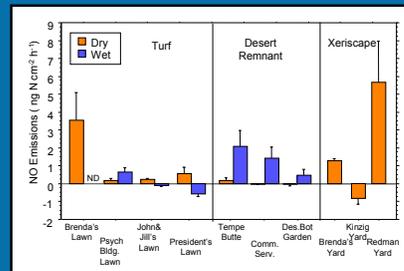


Figure 3. High variability in NO emissions from turf and xeriscape soils compared to desert remnant soils is likely due to human management factors that control soil NO_x production, including irrigation and N fertilization.

Contrary to findings in natural and agricultural systems, urban soil NO emissions were not controlled strongly by temperature (Fig. 5). However, ambient NO₂ concentrations and soil NO₂ consumption were highly correlated and showed a strong diurnal trend (Figs. 6 & 7). High concentrations of ambient NO₂ likely caused increased NO₂ uptake by soils.

Fluxes of NO were highest from managed turf and xeriscape 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 (N₂O) or N₂.

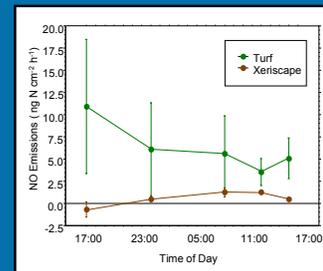


Figure 5. Soil NO emissions are not generally controlled by soil or air temperature over the course of a day and night. Turf soils at this site are highly variable and always larger than xeriscape soils at this site.

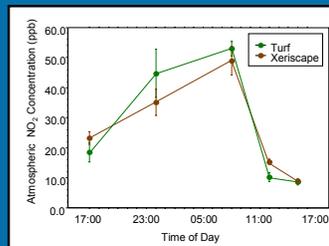


Figure 6. Ambient atmospheric [NO₂] increases throughout the night and early morning, perhaps due to oxidation of ambient NO to NO₂ via ozone (O₃) and decreased photo-oxidation of NO₂ back to NO after sunset.

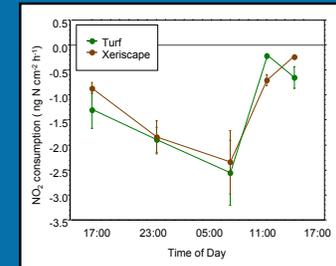


Figure 7. Soil NO₂ consumption also increases throughout the night and early morning, perhaps caused by a concentration gradient from increased nighttime atmospheric [NO₂].

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 km² 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 than 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:

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



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

Because NO is quickly oxidized to NO₂ by ambient ozone (O₃) in the urban atmosphere, high soil NO emissions could decrease the sink strength of NO₂ by reducing the atmosphere-soil NO₂ gradient.