HOW IMPORTANT ARE SOIL FUNGI IN THE NITROGEN CYCLE OF ARID AND SEMI-ARID ECOSYSTEMS?

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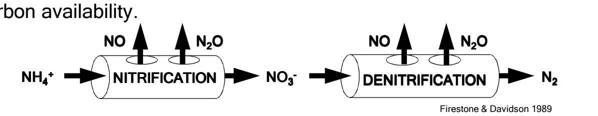
1. Introduction

• Nitrogen (N) cycling in soil was thought to be performed primarily by autotrophic bacteria and archaea that are decoupled from terrestrial carbon availability.



• Few studies have investigated microbial N transformations in arid and semi-arid soils where environmental conditions favor fungal growth. Arid ecosystems are also urbanizing rapidly, creating new ecosystems that are irrigated and fertilized.

• Recent experiments in desert and grassland soils have shown that fungi, rather than bacteria or archaea, mediate nitrification and N_2O production [2, 3, 4].

• Because fungi are heterotrophs, requiring reduced carbon substrates, fungal control of the soil N cycle may affect ecosystem responses to human activity.

QUESTION 1. Which microorganims dominate N cycling in arid and semi-arid ecosystems?

QUESTION 2. How does urbanization affect microbial control of the N cycle?

2. Methods

We collected surface soils from common ecosystems in the US Southwest:

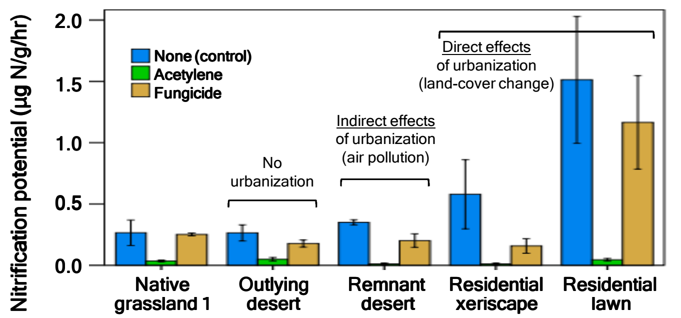
Native grassland 1- 1350 m (elevation) semi-arid grassland soil in central AZ (Agua Fria National Monument).
Native grassland 2- 1630 m semi-arid grassland soil from the Sevilleta LTER in New Mexico, in which N_2O is produced primarily by fungi [3].
Outlying desert- 300-600 m Sonoran Desert soils outside of the Phoenix airshed.
Remnant desert- 300-500 m Sonoran Desert soils in the city, indirectly affected by urbanization (e.g. atmospheric N deposition).
Residential xeriscape- Re-landscaped 'desert' yards in the city with an agricultural and lawn history, directly affected by urbanization (e.g. land cover & management) [5].
Residential lawn- Fertilized soils in the city directly affected by urbanization.

Nitrification-
We measured nitrification potential of the microbial community using shaken-slurry assays with 1. water (control), 2. acetylene (blocks autotrophic nitrification), or 3. cycloheximide (blocks fungal metabolism). We analyzed NO_3^- concentration at five time points over 24-hrs. (n = 5 replicate sites per ecosystem, except n = 4 for Residential xeriscape and n = 2 for Native grassland 1)

N_2O production-
We measured N_2O production from soils incubated for 48-hrs with: 1. water (control), **2.** streptomycin sulfate (bactericide), or **3.** cycloheximide (fungicide). N_2O gas was analyzed using gas chromatography. (n = 4 reps/trmt/ecosystem)

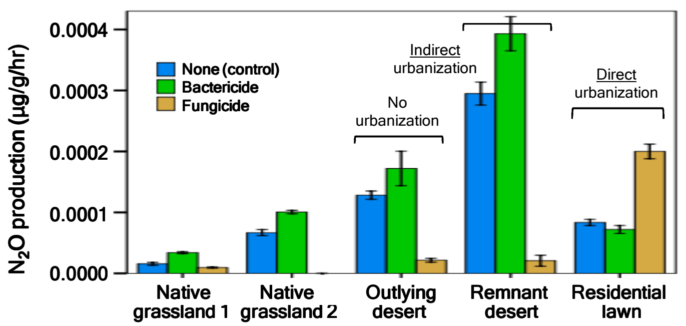
3. Results

QUESTION 1: What microbial domain?



Nitrification is controlled by autotrophic bacteria, not fungi, in these arid and semi-arid soils.

• In all ecosystems, **nitrification potential** was significantly reduced by ~ 90% by acetylene but only by 33% by fungicide compared to water controls. Patterns were similar for patch types in soils collected from under plants (shown in figure) and the space between desert shrubs (not shown).



However, fungi control N_2O production in native grasslands and deserts, but not lawns.

• Fungicide significantly reduced **N_2O production** by 90% in arid sites compared to the water controls. The bactericide treatment supports this interpretation as N_2O production is elevated at these sites, suggesting that carbon from bacterial substrates may have been used for fungal metabolism.

• In Residential lawns, however, higher rates of **N_2O** flux with fungicide compared to the water controls indicate that bacteria are the dominant N_2O producers.

QUESTION 2: Urbanization?

• The direct effects of urbanization (land cover change and management in Residential lawns compared to the Outlying desert) increased rates of autotrophic **nitrification potential** but did not affect the pattern of dominant microbial domains. The indirect effects of urbanization (air pollution in Remnant deserts) did not significantly alter rates or microbial communities. (top figure)

• The direct effects of urbanization caused shifts in the dominant microbial **N_2O producers** to bacteria (Residential lawn). Indirect urbanization (Remnant desert) increased fungal rates of **N_2O production** but did not affect the microbial players. (bottom figure)

4. Discussion/Conclusions

QUESTION 1

Fungi play a key role in N_2O production, but not nitrification, in a range of arid and semi-arid soils.

• Nitrification is primarily autotrophic in these soils, with minor contribution from fungi (and possibly from archaea). As fungi are obligate heterotrophs, it is thus likely that fungal N_2O production is associated with denitrification in arid and semi-arid soils studied here.

QUESTION 2

The indirect and direct effects of urbanization alter soil microbial communities in different ways.

• Microbial domains were similar but produced different total N_2O rates between Outlying and Remnant desert soils. Thus, the urban environment indirectly impacts the conditions under which microbial communities operate (e.g. inorganic N pools, temperature, deposition), but not the microbial communities themselves.

• However, vegetation change associated with urban land-use (i.e. grass parks) directly alters microbial community structure. In other words, land cover change and management associated with Residential lawn qualitatively modifies the mechanics of N cycling, including N_2O emissions.

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