SOIL DENITRIFICATION DYNAMICS IN URBAN IMPACTED RIPARIAN ZONES THROUGHOUT TAMPA, FL

John W. Roberts[a], Michael G. Andreu[b], Kanika S. Inglett[c], Matthew J. Cohen[b], and Wayne C. Zipperer[d]

[a]UF/IFAS Palm Beach County Extension; [b]School of Forest, Fisheries, and Geomatic Sciences, University of Florida, Gainesville, FL; [c]Soils and Water Science Department, University of Florida, Gainesville, FL; [d]Southern Research Station, USDA Forest Service, Gainesville, FL

Introduction

●Urban influence on water quality:

-Altered hydrology and land cover + contaminant deposition

↓

-Diminished influence from riparian zones (via vegetative uptake and denitrification) from water bypass and lowered water tables

↓

-Reduced water quality

●Local effects on denitrification:

-Environmental factors (i.e. highly permeable soils, subtropical climate, coastal plain topography, etc.) specific to Tampa may influence urban denitrification differently than other locations from past studies.

Objectives

● Characterize soil denitrification potential and related variables in urban influenced riparian zones that may lead to nitrogen (N) control, with specific regard to nitrate (NO_3^-)

● Ascertain the influence of environmental and seasonal conditions impacting denitrification potential rates based on common land use and land cover (LULC) categories and distance from stream.

Site Selection

-Selection was based on Florida Land Use and Cover Classification System (i.e. FLUCCS codes) for common LULC categories throughout the landscape of the study area.

-Sites were preferentially selected for upland sites with high surface permeability along relatively lower order streams.

-Six sites (n = 6) were selected for each LULC category.

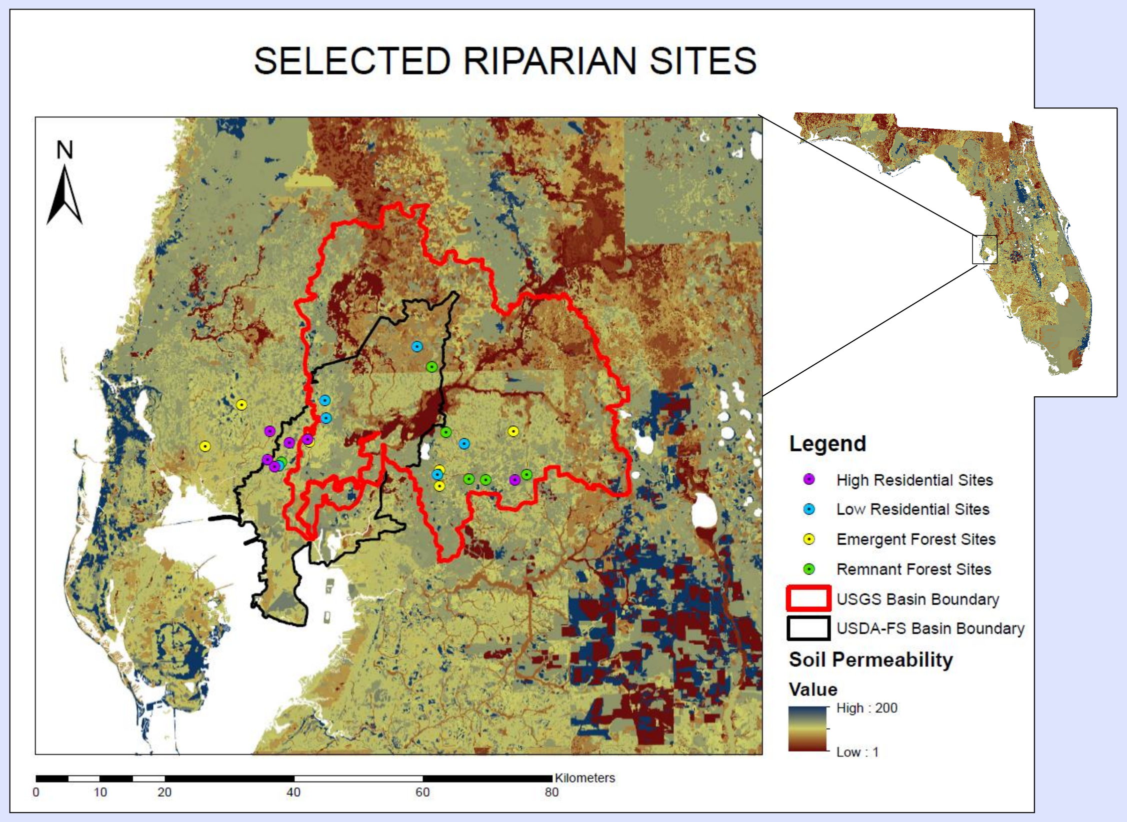


Figure 1. Field sites for Tampa and surrounding areas

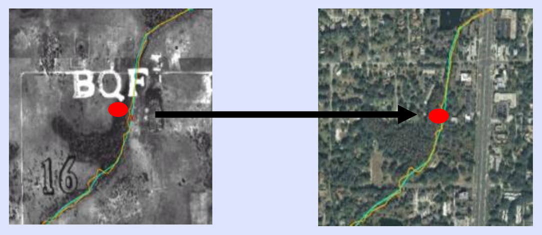
LULC categories:

Heavy Residential (HR) – ≥5 dwelling units per acre

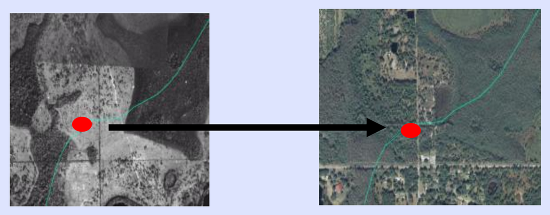
Light Residential (LR) – 0.5–2 dwellings per acre

Emergent Forest (EF) – newly established forest based past aerial imagery (≥ 50 years)

Remnant Forest (RF) – forest existing in past aerial imagery (≥ 50 years)



Example classification for a remnant forest site



Example classification for an emergent forest site

Design and Methods

● Field methods

-For each site, soil was collected within the top 5 cm at 0 m, 5 m, and 10 m from the stream along three adjacent transects spaced at 5 m. The samples from the three transects were homogenized (based on their respective distances) to account for site variability.

-Vegetation (i.e., basal area) and elevation data were recorded

-Sites were sampled in July 2012 and March 2013

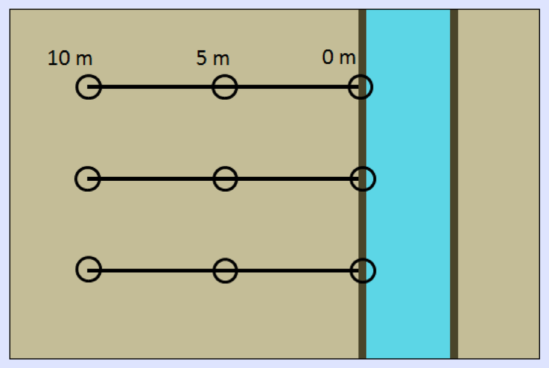


Figure 2. Sampling regime for field sites

● Lab analyses

-Denitrification enzyme activity (DEA) potential rates were measured by gas chromatography detection of N_2O from soil slurry assays placed under anaerobic conditions.

-Ancillary variables recorded:

- Total nitrogen (TN)
- Total carbon (TC)
- Soil organic matter (SOM)
- pH
- Bulk density (BD)
- Moisture content (MC)
- Extractable soil NO_3^-
- Extractable soil NH_4^+

General Results

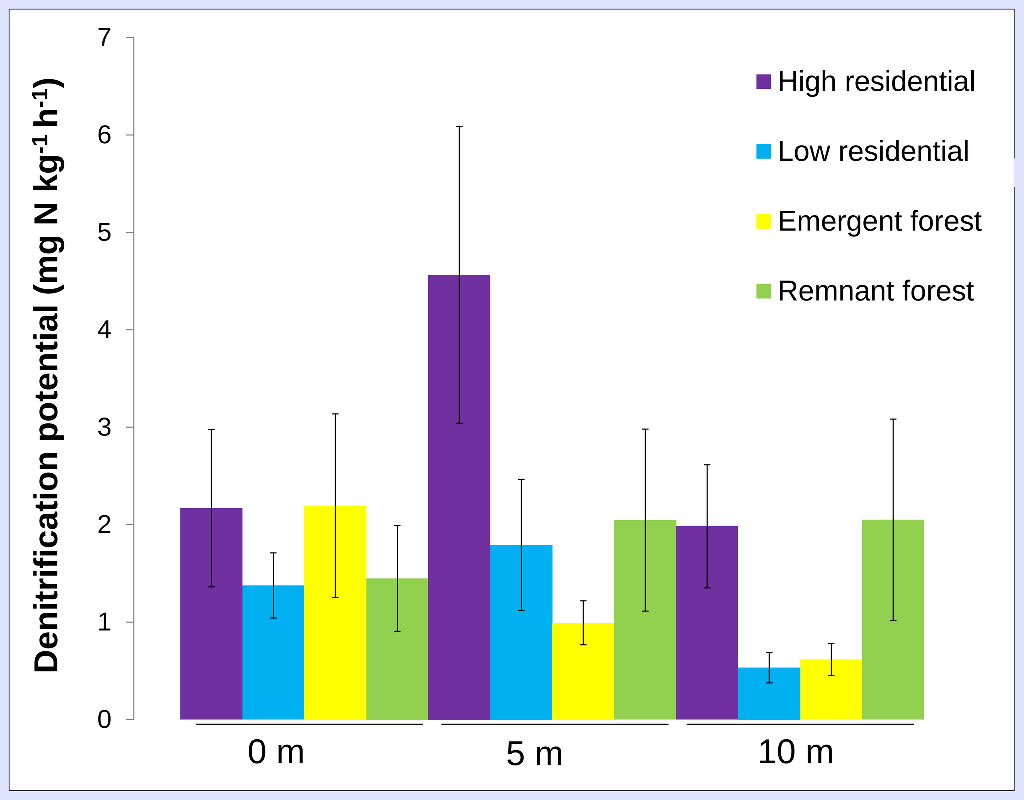


Figure 3. Average DEA potential based on LULC category and distance from stream with standard error

- High variability from site to site, but generally greater DEA rates at HR sites.
- Decreasing moisture content with distance from stream, but greater loads of N, TC, and SOM at 5 m and 10 m.
- Split-plot multivariate analyses indicated TN (p = 0.0365), TC (p = 0.05), and SOM (p = 0.0014) were the most significant variables for predicting DEA potential.
- Pearson's r indicated significant correlations between DEA and TN (p < 0.0001), TC (p = 0.0001), NO_3^- (p = 0.0001), NH_4^+ (p = 0.0001, pH (p = 0.0038), bulk density (p = 0.0438), and SOM (p = 0.0086).

Table 1. Average variables based on LULC and distance from stream with standard error

	Variable	High residential	Light residential	Emergent forest	Remnant forest
0 m	Denitrification potential, mg N kg^{-1} h^{-1}	2.17 (0.81)	1.38 (0.33)	2.2 (0.94)	1.45 (0.54)
	Soil NO_3^-, mg N kg^{-1}	3.59 (2.38)	1.96 (0.97)	3.71 (3.07)	3.47 (2.1)
	Soil moisture, g kg^{-1}	262.53 (22.27)	216.07 (11.08)	234.75 (10.65)	249.53 (25.4)
	C:N ratio	17.4 (1.44)	18.81 (1.76)	16.4 (0.63)	17.65 (0.73)
	Soil organic matter, g kg^{-1}	41.6 (18.33)	25.91 (6.97)	39.11 (11.49)	42.76 (14.68)
5 m	Denitrification potential, mg N kg^{-1} h^{-1}	4.57 (1.52)	1.79 (0.67)	0.99 (0.23)	2.05 (0.93)
	Soil NO_3^-, mg N kg^{-1}	10.89 (4.83)	4.17 (1.98)	1.36 (0.64)*	5.67 (1.54)
	Soil moisture, g kg^{-1}	119.16 (31.45)	125.67 (48.87)	115.98 (29.34)	93.82 (16.56)
	C:N ratio	15.95 (0.8)	18.92 (1.19)	21.1 (1.28)	18.86 (0.73)
	Soil organic matter, g kg^{-1}	54.21 (13.6)	109.57 (52.15)	53.01 (6.45)	66.72 (13.79)
	Tree basal area, m^2 $100^{2\ -1}$	1.44 (0.42)*	3.89 (0.42)	2.69 (0.51)	3.7 (0.51)
10 m	Denitrification potential , mg N kg^{-1} h^{-1}	1.98 (0.63)*	0.53 (0.16)	0.62 (0.15)	2.05 (1.03)
	Soil NO_3^-, mg N kg^{-1}	8.91 (2.45)	7.35 (3.47)	1.68 (0.93)	5.99 (1.26)
	Soil moisture, g kg^{-1}	107.96 (22.9)	96.24 (23.04)	119.66 (29.7)	107.13 (16.25)
	C:N ratio	14.58 (0.5)*	17.97 (1.04)	21.3 (1.14)	18.69 (1.13)
	Soil organic matter, g kg^{-1}	60 (0.95)	55.22 (21.27)	47.93 (5.46)	67.41 (11.7)

* Statistically significant difference between HR and LR columns or EF and RF columns at p < 0.05.

Results – Carbon Limitations

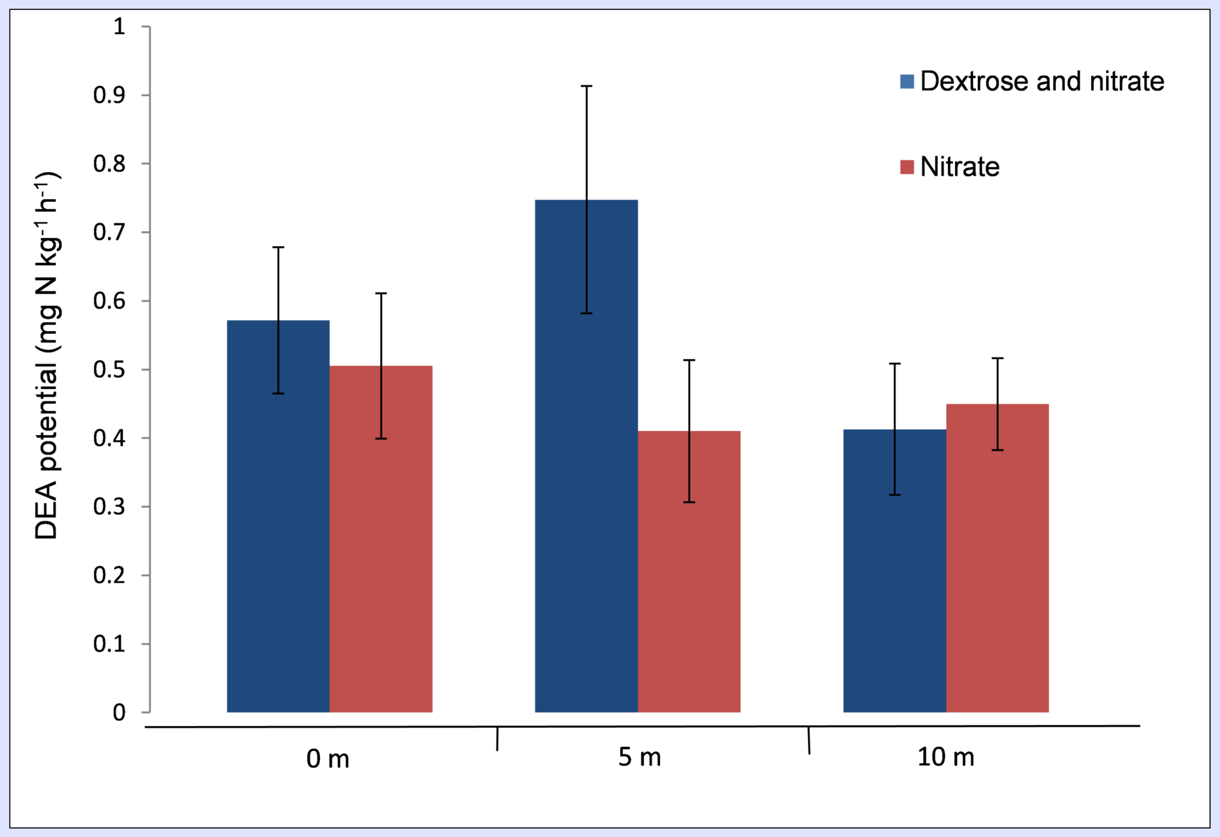


Figure 4. Average DEA potential based on distance from stream and slurry conditions with standard error

- Carbon appears to be much more limiting for sites at 5 m from the stream bank based on the lower DEA potential for slurries only amended with NO_3^-.
- Carbon to nitrogen ratios tended to be lower at 5 m and 10 m, but DEA rates at 5 m may have been greater due to the influence from stream moisture (Table 1). Labile carbon appears to be limiting for sites at 5 m, but the continuity of moisture levels over time past 5 m may not be as sufficient in promoting the anaerobic conditions needed for facultative denitrifiers to switch energy sources from oxygen to NO_3^-.
- Light residential sites showed significantly greater basal area and high soil organic matter content relative to high residential sites, but NO_3^- decreased from 10 m to 5 m for LR sites and increased for HR sites (Table 1 and Figure 4). This may indicate the influence of vegetative uptake and microbial immobilization on NO_3^- through the riparian zone.

Results – Seasonality

Table 2. Average variables based on season for all sites at 5 m with standard error

Variable	July	March
Soil NO_3^-, mg N kg^{-1}	7.13 (2.7)	5.48 (0.22)
Soil NH_4^+, mg N kg^{-1}	17.31 (2.19)*	8.85 (0.95)
Soil moisture, g kg^{-1}	166.58 (13.78)*	113.66 (1.59)
Total nitrogen, g kg^{-1}	1.44 (0.21)	1.38 (0.17)
Soil organic matter, g kg^{-1}	62.32 (9.42)*	66.72 (13.79)
C:N ratio	19.57 (0.85)	18.71 (0.61)

* Statistically significant difference between July and March columns at p < 0.05.

- Greater NO_3^- levels and soil moisture contents for samples in July, but significantly less soil organic matter
- Average ammonium (NH_4^+) was nearly double in July, which indicates sites undergo seasonal nitrogen transformations since total nitrogen did not change significantly
- Moisture content was highly correlated with DEA potential (p < 0.0001) for July, but was slightly insignificant for March 2013 (p = 0.054)
- Average monthly precipitation for June-September is 663 mm and 472 mm for October-May

Conclusions

- Relatively greater DEA potential sat 5 m were generally observed relative to 0 m and 10 m, and likely influenced stream moisture and transport of upland N and C towards lower topography and eventually into the streams.
- Greater NO_3^- loads and denitrification rates were more typical for sampled high residential sites.
- Results would be complemented from a perspective on seasonality and sites along higher stream orders, less permeable soil series, and with regularly higher water tables.