

Quantifying Nitrogen Leaching from Residential Soils in Florida

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ABSTRACT

The expansion of residential landscapes throughout Florida, coupled with water quality concerns arising from the management of these residential landscapes, has the potential to cause nutrient pollution of surface waters and groundwater throughout the state. Despite being a contentious issue, the role of residential landscapes, particularly turfgrass, as a driver of water quality impairment has not been well studied *in situ* under real-world conditions throughout Florida. For this project, we aimed to improve our understanding of nitrogen (N) exported beyond the surficial rooting zone of residential soils via leachate. We installed 20 lysimeters and collected 100 soil cores (50 each during wet and dry seasons) from paired turfgrass and mulched bed landscapes from residences

throughout Alachua County, primarily focused on the western, karst sensitive areas of the county, to quantify nutrient leaching across a range of landscape types and management styles. Across all lysimeters we found no differences in N or phosphorus (P) leaching between mulched bed or turfgrass lawn lysimeters. However, when directly comparing lysimeters from the same residence, we found a potential effect of elevated leaching of N as nitrate+nitrite (NO_x; p=0.099) and total dissolved N (p=0.073). Additionally, we found that leaching loads increased with the property value of a home and in newer homes. These results suggest that individual management decisions must be considered as a driver of nutrient pollution arising from urban areas.

OBJECTIVES AND METHODS

The overall objectives of this project were to:

- 1) Directly quantify nitrogen leaching dynamics from typical residential soils
- 2) Establish the impact of different landscape management factors and age of landscape on the amount and form of N leaching from residential soils.

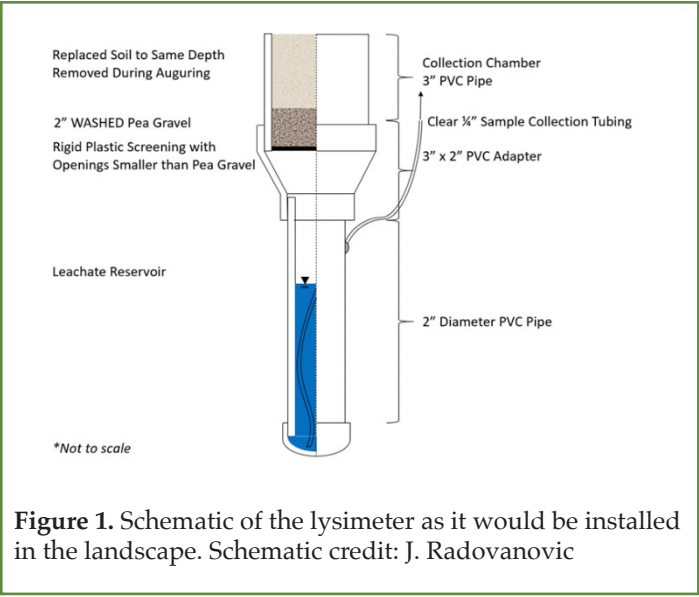
This specific project funding from FNGLA was used to supplement the personnel budget for an ongoing project funded by the Alachua County Environmental Protection Department. The specific objectives from this FNGLA supplemental salary funding was to allow increased sampling frequency.

This project was split into two separate components: 1) field-based leaching estimates using lysimeters and 2) soil core leaching estimates from residential soils.

Field-based leaching estimates

We quantified nutrient leaching from residential landscapes by installing 20 lysimeters at 12 different residential landscapes. At all 12 residential landscapes, we installed a lysimeter below a turfgrass area. At 8 of the landscapes, we installed an additional lysimeter underneath a mulched bed area (not all landscapes had mulched bed areas appropriate for lysimeter installation).

Lysimeters were constructed by coupling a 3” (inner diameter) x 9” long PVC pipe to a 2” (inner diameter) x 24” long PVC pipe with a 3” to 2” reducer measuring 3” in length. The total length of the lysimeter was 36”. The upper portion of the lysimeter serves as a collection area and the lower 2’ portion of the lysimeter represents a reservoir where leachate accumulates (**Figure 1**). We installed lysimeters in areas seemingly representative of the broader landscape, and attempted to avoid downspouts or tree lines to reduce the likelihood of installing a lysimeter in an area that would receive artificially high (e.g., at a downspout) or low (e.g., below a tree) precipitation and runoff. Lysimeters were fitted with peristaltic pump tubing that reached the bottom of the collection reservoir and cut to a length to be long enough to extend to the soil surface.



Once the installation location was identified, we pulled up the turfgrass or mulch and set it aside. We then hand-augured a 48” hole into the soil profile, maintaining soil removed with the auger in depth-integrated buckets (to allow us to recreate the original soil profile above the lysimeter). The lysimeter was then installed vertically into the augured hole. The peristaltic tubing for sampling the reservoir was threaded up the soil profile and covered with an irrigation control box installed adjacent to the lysimeter. Soil was then taken from appropriate depth increments and placed back into the collection area of the lysimeter and on top of the entire lysimeter installation. We reconstructed the soil profile from the upper 24” within the augured hole to maintain as close to the original bulk density and compaction as possible. Following the filling of the augured hole, we replaced the turfgrass or mulch on top of the lysimeter. Ultimately, this lysimeter design allows for the collection of approximately 1.5 liters (0.4 gallons) of leachate before the reservoir fills entirely. All leachate collected for this project first percolated through the top 2’ of the soil profile, below the typical rooting depth of turfgrass.

All lysimeters were installed in April 2019. After installing lysimeters, we sampled them approximately weekly. For each sampling trip, we would visit every lysimeter and pump all leachate from the reservoir, recording the volume of leachate collected and then filtering a sub-sample of the leachate into two 20mL scintillation vials. All leachate was filtered by hand in the field using a 60mL syringe connected to a filter-holder apparatus loaded with a 1.0um (nominal pore size) glass fiber filter. Upon returning to the lab, all samples were acidified to pH < 2.0 using concentrated sulfuric acid and refrigerated at 4°C until they were transported to the analytical lab. Within 1 week (typically within 24h), samples were taken to the UF | IFAS Analytical Research Laboratory, where they were analyzed for various dissolved N and P species, including ammonium (NH₄⁺-N), nitrate+nitrite (NO_x-N), total kjeldahl nitrogen (TKN), ortho-phosphate (PO₄³⁻), and total dissolved phosphorus (TDP). We calculated dissolved organic nitrogen (DON) as the difference between TKN and NH₄⁺-N, and total dissolved nitrogen (TDN) as the sum of TKN and NO_x-N. Samples were analyzed according to standard methods, which can be reviewed at <https://ar1.ifas.ufl.edu/>.

We calculated leachate load for each different nutrient form as:

$$Load = \frac{(C \times V)}{A}$$

where Load (mass per area) is the estimated nutrient load for a given sampling event, C is the concentration of leachate for a given nutrient form (mass per volume), V is leachate volume from the respective lysimeter, and A is the surface area of the collection apparatus of the lysimeter (area). We express load as lbs/1000 ft². We report total leachate volume as the absolute volume (in liters) of leachate collect for each lysimeter.

We assume that the area of soil contributing to the lysimeter is directly equal to the surface area of the lysimeter itself. Due to differences in soil porosity and flow paths, this assumption is not likely correct, but is necessary for these comparisons. We calculated the cumulative load estimate as the sum of individual sampling events for each lysimeter.

Residential soil cores

We identified 15 additional landscapes to collect soil cores to estimate leaching using soil core leaching approaches. In September 2019 (wet season) and February 2020 (dry season), we collected soil cores from these additional landscapes and the lysimeter locations. At each of these 15 landscapes, we collected two soil cores - one from an area covered with turfgrass and one from an area covered with a mulched bed. We also collected soil cores near each soil lysimeter location, leading to a total of 50 cores collected in both wet (September 2019) and dry (February 2020) seasons. Soil cores (2" inner diameter within aluminum soil core liners) were collected to a depth of 6" using a slide hammer, attempting to minimize compaction as much as possible during the collection.

Soil cores, kept intact within 6" aluminum liners, were returned to the lab where they were leached according to a rapid soil core leaching protocol. Briefly, soil cores were set on top of a felt-lined Buchner funnel on top of a graduated cylinder. Slowly, 200mL of deionized water was added to the core. This is the equivalent of a 3.89in (9.88mm) rain event. Over 0.5 to 2h, leachate was collected from the bottom of the core. We set the end of the leachate period when individual drops were coming from the funnel at a frequency of <1 drop per 10 seconds. Leachate volume was recorded and a sub-sample was filtered and processed in the same way as samples from lysimeters. Leachate samples were then analyzed at the U/IFAS Analytical Research Lab for N and P species similar to that of the field lysimeters. Leachate loads were estimated as the product of the leachate volume and nutrient concentration. We scaled leachate loads from soil cores areally based on the surface area of the cores.

Statistical Analyses

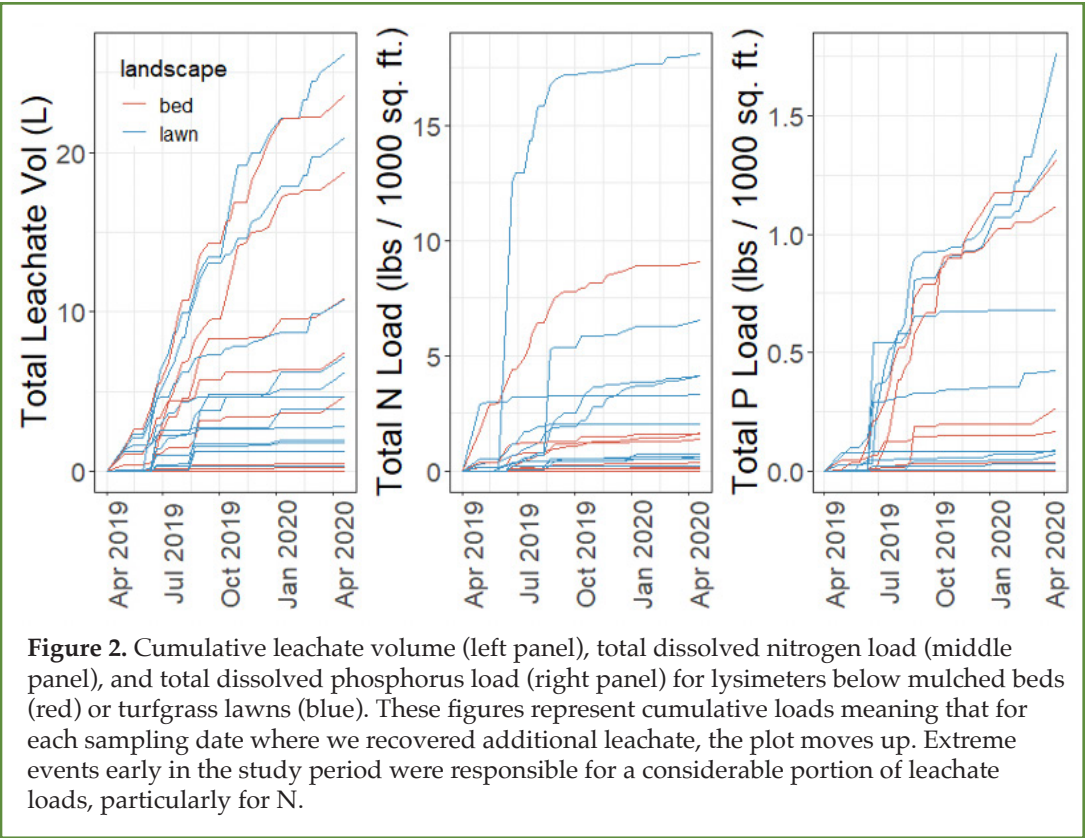
We tested for the effects of landscape type (mulched bed or turfgrass) using two separate approaches. First, we compared all sites throughout the study using a one-way analysis of variance (ANOVA) in which leachate load was the response variable and landscape type was the fixed effect. Due to the unbalanced nature of our study (i.e., some landscapes only had turfgrass lysimeters), we also directly tested the effect of landscape type from individual homes with both mulched bed and turfgrass lysimeters using paired t-tests. Soil core leaching data was analyzed using two-way ANOVAs with nutrient leaching load as the response variable and landscape type (turfgrass vs. mulched bed) and season (wet vs. dry) as the fixed effects.

RESULTS

Lysimeter leaching estimates

There was considerable variation in the volume of water and the nutrient leaching load estimates collected from the 20 lysimeters from April 2019 - April 2020 (Figure 2). Over the entire year, the average leachate volume 7.7 L (range: 0 to 26.2 L). Average total N and total P leachate loads over the entire year were 2.77 (0.00 to 18.12) lbs N/1000 ft² and 0.37 (0.00 to 1.76) lbs P/1000 ft² across all lysimeters.

When including all 20 lysimeters, there were no significant differences in leachate volume or nutrient load between turfgrass and mulched bed lysimeters (ANOVA: p>0.1 for all analyses; **Figures 2 and 3**).



When we directly compared leaching from lysimeters from the same residential households using T-tests (in an attempt to control for differences in management strategies across households), we found a potential for NO₃⁻ (p=0.099) and TN (p=0.073) leaching loads to be higher in lysimeters under turfgrass compared to mulched beds, although these results were not significant at the traditional threshold of p=0.05. Although there were no differences between turfgrass lawns and mulched beds, both TDN and TDP loads were related to total leachate volume, property values (\$/ft² of the entire parcel area) and home age, with more N and P leaching from more expensive and newer homes (p<0.05 for each relationship; Figure 4). Leachate volume was also related to home age and property value, suggesting that at least some of the N and P leaching response to increased socioeconomic status is due to increased leaching, potentially due to irrigation inputs.

Soil Core Leaching

Our soil core leaching approach, designed to compare nutrient leaching through soils underneath turfgrass and mulched beds, found no differences in NH₄⁺, NO_x, DON, TDN, PO₄³⁻ or TDP potential leaching loads between cores collected from turfgrass and mulched bed areas (p>0.1 for all nutrient forms; Figure 3). There was also no differences between the total volume of water leached from turfgrass or mulched bed cores. Although there were no differences between landscapes, there were seasonal differences found for potential leaching of various nutrient forms. Both NH₄⁺ (p=0.024) and TDN (p=0.018) leaching estimates from cores were higher during the dry season. In contrast PO₄³⁻ (p=0.003) and TDP (p<0.001) leaching estimates from cores were higher during the wet season (**Figure 3**).

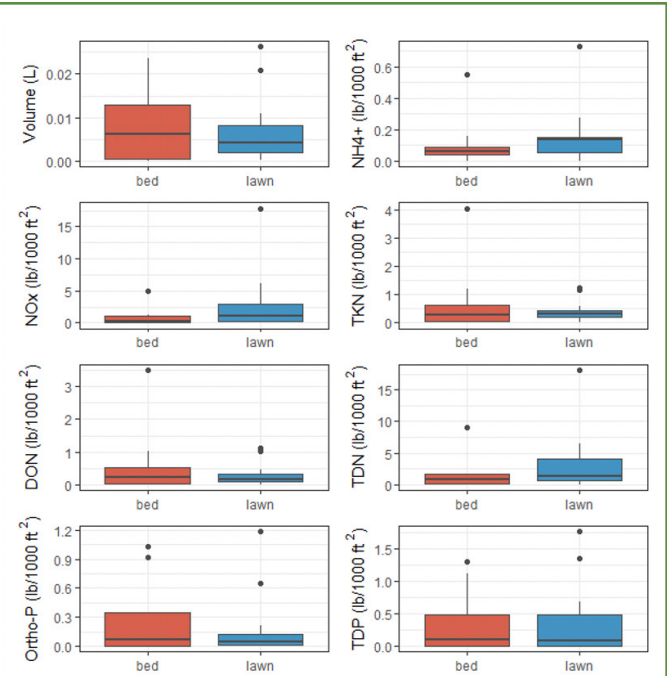


Figure 3. Cumulative leaching estimates (04/19 - 04/20) from lysimeters installed under mulched bed (red) and turfgrass lawn (blue) landscapes. There were no significant differences between landscapes. Box plots show all of the data, with lines representing the median, boxes representing the 25th through 75% percentiles of the data, whiskers extending to the 5th and 95th percentiles, and dots representing data beyond these values.

CONCLUSIONS

Results from this study suggest that there may be a difference between mulched bed and turfgrass lawn leaching when other variables such as socioeconomic factors or landscape age are taken into account. It appears that individual socioeconomic factors, which likely drive landscape management decisions, are the dominant factors controlling N and P leaching from residential landscapes, but comparing lysimeter estimates from within the same landscape, turfgrass areas potentially leached more NO_x-N (p=0.099) and TDN (p=0.073). This current project focused on improving our understanding of nutrient leaching under typical landscape management practices. Moving forward, more controlled studies in which residential landscape management practices are controlled are needed to identify alternative approaches to landscape management in order to improve water quality. Although this study focused on nutrient leaching, surface runoff into the stormwater system remains an additional concern for managing water quality.

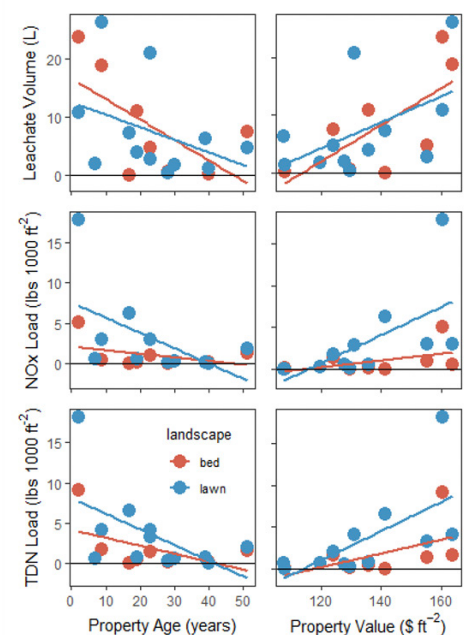


Figure 4. Total leachate volume (top panels), NO_x load (middle panels) and TDN load (bottom panels) decreased with property age (left panels) and increased with property value (\$ per square foot) for mulched bed (red) and turfgrass (blue points) landscapes. Lines represent the best linear fit for each response.

RECOMMENDATIONS

This research indicates that landscape management practices are likely more important than what type of plant material is included in the landscape. Future research on the efficacy of landscape management practices (e.g., compost topdressing vs. traditional fertilizer vs. biosolids) is planned to develop more specific recommendations. It remains to be seen what specific practices drive the relationship between socioeconomic status and nutrient leaching, although it is possible that residences with higher socioeconomic status may be more willing/able to pay for more landscape inputs, such as increased irrigation and fertilizer. If landscape management inputs are increased in a non-environmentally responsible way (e.g., overirrigation, overapplication of fertilizer), increased nutrient leaching would be expected. Our results suggest that turfgrass landscapes may leach more N through the rooting zone than mulched bed landscapes, although additional factors related to socioeconomic conditions may be stronger drivers of N leaching than plant material itself.

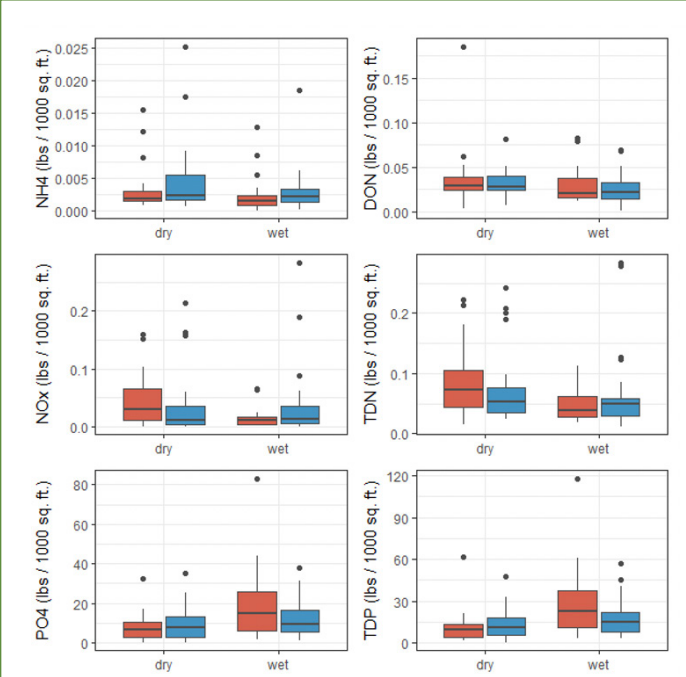


Figure 5. Potential nitrogen and phosphorus leaching based on soil core leaching experiments from residential soils under mulched beds (red) and turfgrass lawns (blue) during dry (February, 2020) and wet (September, 2019) seasons. No differences were observed between landscape types, although ammonium (NH₄) and total dissolved nitrogen (TDN) leaching was higher during the dry season, whereas phosphate (PO₄) and total dissolved phosphorus (TDP) leaching was higher during the dry season. Box plots show lines representing the median, boxes representing the 25th through 75% percentiles of the data, whiskers extending to the 5th and 95th percentiles, and dots representing data beyond these values.