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Quantifying Impacts of Fertilizer Workshops on Nitrogen Leaching and Subsequent Economic Impacts: A Case Study[1]

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Introduction

Excess nitrogen (N) and phosphorous (P) are leading causes of water quality impairments in surface waters across Florida. A water body being impaired by nutrients means that the nutrients existing in the water are higher than state-mandated concentrations defined by the Total Maximum Daily Load (TMDL) program (https://floridadep.gov/dear/water-quality-evaluation-tmdl/content/total-maximum-daily-loads-tmdl-program), which is a derivative of the Federal Clean Water Act. Although both N and P can lead to water quality impairments, N can be particularly troublesome due to the variety of different natural and human-influenced sources of N on the landscape. There are multiple ways that N can make its way into water bodies, including both natural (e.g., as rainwater) and human-derived (e.g., from fertilizer runoff). When surface waters are impaired, significant local, state, and/or national government funds are needed to return them into compliance, or "clean them up." Nutrients can also feed aquatic vegetation and contribute to the prevalence of algae blooms (for more information on the relationship between nutrients and algal blooms, see "Rethinking the Role of Nitrogen and Phosphorus in the Eutrophication of Aquatic Ecosystems," available at https://edis.ifas.ufl.edu/publication/SG118). Despite the multitude of different N sources on the landscape, urban fertilizer has been an increasingly targeted N source for management action (for more information on N sources in urban landscapes, see "Sources and Transformations of Nitrogen in Urban Landscapes," available at https://edis.ifas.ufl.edu/publication/SS681). For example, more than 50 counties and municipalities in Florida now have formal fertilizer ordinances (for more information on urban fertilizer ordinances, see the Florida Friendly Landscaping™ (FFL) app at https://ffl.ifas.ufl.edu/fertilizer/ and "Urban Fertilizer Ordinances in the Context of Environmental Horticulture and Water Quality Extension Programs: Frequently Asked Questions," available at https://edis.ifas.ufl.edu/ae534).

The University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) has multiple programs targeted at reducing nutrient pollution from residential landscapes while still maintaining acceptable landscape quality (e.g., the FFL program [https://ffl.ifas.ufl.edu], which includes the Green Industry Best Management Practices [GIBMP] program [https://gibmp.ifas.ufl.edu]). In an effort to protect and improve Florida's water quality by minimizing N pollution of surface waters, these programs are used or adopted by counties, UF/IFAS Extension offices, utility providers, and other entities throughout the state.

Despite the various programs and numerous individuals working towards minimizing residential landscape

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management effects on water quality, it remains difficult to quantify the impacts these programs have on water quality. There are multiple issues associated with quantifying the water quality impacts of Extension programs: water quality impacts may take a long time to show up in the water bodies; benefits from one approach may be counteracted by negative impacts elsewhere in the watershed (such as lift station overflows, pet waste, or septic tanks); data or resources may not be available; or analytical capabilities may be lacking. Despite this lack of quantifiable benefits, it is often assumed by the Florida Department of Environmental Protection (FDEP), the Florida Department of Agriculture & Consumer Services (FDACS), the general public, and others that UF/IFAS residential landscape management programs benefit the environment.

However, quantifying the environmental or economic impacts of UF/IFAS residential landscape management programs on water quality is essential. By quantifying these impacts, we can provide empirical data to our stakeholders on how effective individual programs are at achieving water quality goals. Furthermore, demonstrating the impacts of a program increases the likelihood of receiving new or continuing funding for individual programs from a variety of sources. Directly quantifying the benefits of UF/IFAS residential landscape Extension programs via improved water quality in the water bodies themselves will likely remain difficult for the foreseeable future due to issues mentioned above (long time horizon of impacts, lack of data, multiple potential conflicting impacts). To overcome these difficulties, there are alternative approaches to estimate impacts of UF/IFAS Extension programs on outcomes related to water quality and to subsequently make scientifically based assumptions related to water quality benefits.

The goal of this document is to demonstrate a quantitatively based approach to estimating the water quality and subsequent economic benefits of UF/IFAS Extension programming related to nutrient management in residential landscapes. Specifically, we provide calculations for estimating the effects of a residential fertilizer Extension program on nitrogen (N) leaching from residential landscapes into groundwater and associated economic impacts when

- there is an increase in the proportion or percent of slow-release N in fertilizer products applied.
- the regulations of a fertilizer ordinance are followed in comparison to UF/IFAS and commercial recommendations that were developed without fertilizer ordinances in mind.

This document is not intended to assess the environmental impacts of fertilizer ordinances directly (as mentioned above, see https://edis.ifas.ufl.edu/ae534 for more detail on what we know/don't know about fertilizer ordinances). Rather, this document uses published scientific research by UF/IFAS researchers to assess how behavior changes made by fertilizer users would likely affect N leaching in a range of landscape conditions. This document does not advocate for or against ordinances because the environmental, economic, and social costs and benefits of fertilizer ordinances extend beyond N dynamics.

We also note that this approach is not intended to be used to support or refute fertilizer ordinances or as a basis to modify fertilizer recommendations. Fertilizer recommendations have been developed by UF/IFAS turfgrass specialists and are available at https://edis.ifas.ufl.edu/lh014. These fertilizer recommendations are developed to provide the maximum plant health benefit with the least amount of fertilizer applied, and different maintenance levels allow for differing goals for turfgrass lawn condition. The approach described in this document to quantify the impacts of changes to fertilizer management does not state whether these modifications to fertilizer applications will affect plant health. Rather, this approach seeks to estimate how much less N would leach through the soil given targeted behavior changes implemented through educational efforts.

In addition to providing a step-by-step guide for how to perform these calculations, we provide example text that a UF/IFAS county Extension agent could modify and use for their annual Report of Accomplishment or promotion packet.

Landscape Practices Expected and Assumed to Have Water Quality Benefits

Protecting or improving water quality is an important but difficult task to accomplish. There are multiple practices that are implemented and often recommended by UF/IFAS Extension for their expected water quality benefits, but quantifying the impacts those practices have on water quality is complicated by multiple factors. It is difficult to quantify the impacts of these practices on downstream water quality due to the diffuse nature of N pollutant sources on the landscape, including point and nonpoint sources, natural and human-made sources, and sources from urban and agricultural activities.

Despite these difficulties, it is necessary to develop approaches to estimate the impacts of UF/IFAS Extension on water quality. This can be done by quantifying changes in behavior as a result of Extension programming that is expected to have a water quality impact. In the case study presented here, we use science-based estimates to quantify how behavior changes associated with UF/IFAS Extension programming might reduce N loading to the environment, subsequently improving/protecting water quality. We provide examples for quantifying the effects of behavior changes related to fertilizer application rates and fertilizer sources based on a case study of *Fertilizing Effectively in Sandy Florida Soils Workshops* (hereafter referred to as Fertilizer Workshops) implemented through UF/IFAS Extension programming.

Workshop and Evaluation Approach: A Case Study in Seminole County

Fertilizer education is of importance to Florida counties, UF/IFAS Extension, FDACS, and FDEP. For this reason, funding was available for Seminole County to offer Fertilizer Workshops for residents and professionals alike. FDEP 319 grant funds assisted in addressing nonpoint source pollution, specifically fertilizer. For UF/IFAS Extension in Seminole County, the fertilizer education program started in 2018. Funding was used to hire a fertilizer educator who worked in conjunction with the FFL agent to offer workshops. An effort was made to offer in-person workshops to participants two times per month. To attract attendees, funding was used to purchase appropriate bags of fertilizer that were provided to participants at the end of the workshop or by the use of a voucher system in the case of libraries or other locations such as community centers. The emphasis of the workshops was on having healthy turf and clean waterways, not regulation or enforcement. This was an important way to bring all partners to the table, including those that did have it in their capacity to enforce regulations, but preferred education over regulation enforcement as the best method. The partnership also fostered the creation of national award-winning public service announcements (PSAs), billboards, publications, fact sheets, and other programmatic materials (available at www.FertilizeFlorida.com).

Efforts in 2020 morphed into virtual programs, where we saw an increase in participation from landscapers and were able to attract them by offering continued educational units (CEUs) by registering our workshop with FDACS. Using this combination of workshop approaches, we were able to host 70 workshops (Oct. 2018–Sept. 2020) reaching 2,142 group-learning participants. To achieve behavior change, Fertilizer Workshops were typically two hours long, started off with educating about water quality and watersheds, and then turned to focus on FFL Best Management Practices (the BMPs) related to landscape and fertilizer use. Regardless of the workshop format (in-person or virtual), participants always received a survey immediately after attending to assess knowledge gained and their intention to change based on the workshop. Intention to change was both general and focused on specific behavior changes, such as selecting a 50% or higher slow-release N product, following summer ordinance restrictions, etc. Three to six months after the class, a follow-up survey was administered to the same participants to see if they had in fact changed some of their behaviors based on the class. In follow-up surveys we did have clients report changes in their behaviors and a high percentage that adopted the recommended behaviors from the class. When the program started, there was no way to calculate the impacts these classes were having, even though the survey responses indicated behaviors around fertilizer had indeed changed. The next section explores the ways we set out to quantify the impacts of the program.

Calculating Impacts

To estimate the environmental and economic impacts of the changed landscape management behaviors, we used data from the previously mentioned Fertilizer Workshops and results from scientific publications. We estimated the amount of N applied as fertilizer by an average consumer using typical commercially available fertilizer products (following the recommendations on the bag) and UF/IFAS fertilizer application recommendations (Shaddox 2017). We split the total N being applied from commercial products or UF/IFAS recommendations into the proportion applied as slow-release N (SRN) or quick-release N (QRN; also known as water-soluble N).

We estimated high and low leaching scenarios for N leaching through soil into the groundwater based on two separate UF/IFAS scientific studies (Wang and Alva 1996; Saha et al. 2007). The Wang and Alva (1996) study applied fertilizer to bare, sandy soil, which led to larger amounts of fertilizer leached (high leaching scenario). In contrast, the Saha et al. (2007) study used well-maintained St. Augustinegrass, which mitigated leaching of applied fertilizers via N uptake by plants (low leaching scenario). We calculated the proportion of QRN, SRN, and total N applied as fertilizer that eventually leached out. These publications provide a range of possible scenarios typically experienced in an average residential landscape. From here on, we will refer to these studies as high leaching (Wang and Alva 1996) and low leaching (Saha et al. 2007). We used the estimated leaching proportions calculated from the publications to calculate the different scenarios of two separate behavior changes targeted by the Fertilizer Workshops. This allowed us to estimate the total N leaching reduction and economic value of the reduced N leaching achieved by the Fertilizer Workshops.

The high leaching scenario found that 30% of SRN and 88% of QRN ended up leaching through a column (Wang and Alva 1996). The low leaching scenario found that 4.2% SRN and 9.6% of QRN (average of two QRN treatments) leached through a column with healthy St. Augustinegrass (Saha et al. 2007). We multiplied the proportion of annual N applied following commercial recommendations as SRN and QRN by the proportion of SRN and QRN that would leach under high and low leaching scenarios to estimate an annual N leachate loss under both scenarios (lb N/1000 ft^2/yr). These calculations and estimates are provided in Table 1.

Next, we calculated the amount of total N, SRN, and QRN that is recommended for St. Augustinegrass at a high maintenance level for central Florida following UF/IFAS recommendations (Shaddox 2017; https://edis.ifas.ufl.edu/lh014) and a 50% SRN composition of the fertilizer (Seminole County ordinance during the time that Fertilizer Workshops were administered). We performed the same calculations as above to estimate annual N leaching from SRN + QRN if these recommendations are followed. Finally, we calculated the reduction in N leaching achieved by following the UF/IFAS recommendations and the Seminole County law compared to the average N leaching from three commercial products under high and low leaching scenarios. All calculations are provided in Table 1. This approach found that using 50% SRN (Seminole County ordinance) and applying N-fertilizer at the UF/IFAS recommended rate would be expected to reduce annual N leaching by 0.05 (low leaching) to 0.60 (high leaching) lb N/1000 ft^2/yr. One can also consider these annual N leaching reductions as a percentage reduction of leachate based on what we would expect from someone following the recommendations of a commercially available product (which, we note, are not in line with UF/IFAS recommendations). The average annual N leaching from commercially available products is 0.40 (low leaching) to 3.55 (high leaching) lb N/1000 ft^2/yr (Table 1, Column J). Therefore the annual N leaching reductions described above represent a 13% (low leaching) or 17% (high leaching) reduction in annual N leaching compared to the average of three commercially available products.

Case Study: Following UF/IFAS Slow-Release Recommendation

Using these same estimates for N load reduction, we calculated the impacts of Seminole County Fertilizer Workshops based on the number of participants who stated that they followed UF/IFAS, and Seminole County recommendations based on the workshop. Using the workshop evaluations described above, 332 participants expressed that they did follow UF/IFAS recommendations and used at least 50% SRN fertilizer. To quantify the impacts of that behavior change, we assumed an average lawn size of 3,000 ft^2 per home, and a value of $500 per lb N removed from the environment (Seminole County Watershed Mgmt. Division). Based on these estimates, an individual who followed UF/IFAS recommendations and used 50% SRN would reduce N leaching by 0.15 (well vegetated/low leaching) to 1.79 (bare soil/high leaching) lb N per individual per year. As the calculations for leachate reduction are the same as above, the percentage reduction remains the same, with each individual exhibiting a 13% (low leaching) to 17% (high leaching) reduction in annual N leaching compared to the average of three commercially available products. Coupling the individual leaching reduction with the 332 participants who stated they would use at least 50% SRN and follow UF/IFAS fertilizer recommendations allows us to estimate a reduction in annual N leaching by 50.7 (low leaching) to 595 (high leaching) lb N per year directly attributable to the Fertilizer Workshops outlined above, providing an economic benefit of $25,350 to $297,500 annually. These calculations are all described in Table 2.

Case Study: Abiding by Local Fertilizer Ordinance Restricted Period

Seminole County has a fertilizer ordinance that prohibits N fertilizer from being applied between June 1st and September 30th each year. Based on the UF/IFAS recommended fertilizer application timings (Shaddox 2017; https://edis.ifas.ufl.edu/lh014) for medium- to high-maintenance St. Augustinegrass in central Florida, there is one recommended application of SRN (applied at no more than 2.0 lb N/1000 ft^2) during the fertilizer restricted period. We calculated how much N would leach from a 2.0 lb application of 100% SRN (UF/IFAS recommendation for the application that would have occurred during the fertilizer restricted period) or a 50% SRN fertilizer (minimum recommended by Seminole County) following the same approach as above. This calculation assumes that an individual that follows the fertilizer ordinance simply skips the one recommended SRN application. It is alternatively possible that individuals would add an extra application immediately before or after the fertilizer-prohibited period, but it is difficult to know. Therefore, we are assuming that individuals simply skip this single fertilizer application.

One individual who followed the ordinance (e.g., skipping one fertilizer application between June and September) and used a 100% SRN fertilizer would reduce N leaching by 0.25 (low leaching) to 1.8 (high leaching) lb N per year. These equate to 25% (low leaching) or 17% (high leaching) reductions relative to commercially available product recommendations. One individual following the ordinance (e.g., skipping one fertilizer application between June and September) and used a 50% SRN fertilizer would reduce N leaching by 0.41 (low leaching, 50% SRN fertilizer) to 3.5 (high leaching, 50% SRN fertilizer) lb N per year, equating to 35% (low leaching) or 33% (high leaching) reductions relative to commercially available product recommendations. Based on the 247 individuals who stated they followed the ordinance during the case study, this equated to a total leaching reduction of 62 (low leaching, 100% SRN fertilizer) to 874 (high leaching, 50% SRN fertilizer) lb N/yr, with a monetary value estimated between $31,122 and $437,190. These calculations are all described in Table 3.

Cumulative Impacts of Seminole County Fertilizer Workshops

When we combine those individuals, the impacts of using both a slow-release N product and following the county restricted period as a response to the Fertilizer Workshops, we see that Fertilizer Workshops **reduced N leaching by 112.7 (lowest leaching scenarios) to 1,469 (highest leaching scenarios) pounds, providing an economic benefit of $56,350 to $734,500 for Seminole County and Florida.**

Sample Impact Statement

Federal and state water quality regulations have led to the identification of impaired water bodies throughout the state of Florida, which have subsequently received total maximum daily load (TMDL) limits for contaminants of concern and basin-wide management action plans (BMAPs) to reach associated TMDL limits. Individual TMDLs are established for various contaminants, including bacteria, dissolved oxygen, heavy metals, and nutrients. As of 2021, there were 1,116 water bodies with established TMDLs according to the Florida Department of Environmental Protection. Of those 1,116 impaired water bodies, 60% (670) were identified as impaired by some form of nutrient. More specifically, 33% (372) were impaired specifically by nitrogen (https://prodenv.dep.state.fl.us/DearTmdl/tmdlReportAction.do?method=report). Given the multitude of sources of N in urban landscapes (Reisinger et al. 2020; https://edis.ifas.ufl.edu/ss681) and the expected expansion of the urban population of Florida over the coming decades (Carr and Zwick 2016), it is essential to reduce N pollution from residential landscapes throughout the state. UF/IFAS Extension addresses the need to reduce N pollution from residential landscapes by conducting educational programming throughout the state. For example, the third principle of the FFL program is to fertilize appropriately (https://ffl.ifas.ufl.edu/about-ffl/9-principles/principle-3-fertilize-appropriately/).

Within the fertilizer management (or insert specific program name here) program run by the Extension agent, the target audience was residents who fertilize their lawn in their home landscape. The agent conducted fertilizer workshops throughout 2020 (or insert current year) and found that 332 (insert the number of participants that responded to the evaluation, as identified in Table 2, Column B) of the participants stated that in response to the program they had used a 50%+ slow-release N product, which reduced annual N leaching by 50.7 to 595 (Table 2, Column F) pounds, providing an economic benefit of $25,350 to $297,500 (Table 2, Column H). The pounds reduced are based on the methodology outlined by (insert reference to this EDIS document). Furthermore, 247 (Table 3, Column J) surveyed participants reported that because of the workshop, they followed the fertilizer ordinance restriction period requirements. These 247 participants equated to a total reduction of annual N leaching by 62 to 874 pounds (Table 3, Column K), providing an economic benefit estimated between $31,000 and $437,000 (Table 3, Column L).

Caveats to This Approach

This document provides an approach for estimating the reduction in N leaching due to changes in residential landscape fertilizer application practices. The approach is based off of two laboratory-based leaching studies covering two extremes: bare soil and well-maintained turfgrass. In reality, most residential landscapes likely fall between these two extremes, which is why the method provides a range of impacts (both in terms of N load reduction and monetary benefits). Furthermore, we recognize that applying laboratory-based estimates to conditions in the real world can be difficult. Using laboratory observations was necessary, however, because field-based trials in Florida to our knowledge have primarily used water-soluble N sources or have not quantified all forms of N leachate, which would not allow us to estimate the effects of SRN sources on total N leaching. The monetary benefits are based upon an assumption of a pound of nitrogen removed from the environment being worth $500. This estimate is based on discussions with regulatory officials at the county and state level. To calculate the impacts of another fertilizer workshop, information in Tables 1–3 would need to be modified to reflect local conditions (e.g., fertilizer recommendations, ordinance restrictions, SRN requirements).

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Table 1. Calculations for quantifying N leaching in soluble release N, quick release N, and total N forms from different fertilizer formulation types.

A	B	C	D	E	F	G	H	I	J
Product	**Scenariobased on**	**Annual N application (lb N/1000 ft2/yr)**	**Proportion of N as SRN**	**Annual SRN, QRN application rate**	**Prop of SRN leached annually (high leaching, low leaching)***	**Prop of QRN leached annually (high leaching, low leaching)***	**SRN leached annually (high leaching, low leaching; lb N/1000 ft2/yr)**	**QRN leached annually (high leaching, low leaching; lb N/1000 ft2/yr)**	**Total N leached annually (high leaching, low leaching; lb N/1000 ft2/yr)**
A	Product label	4.84	0.28	1.37, 3.48	0.3, 0.042	0.88, 0.096	0.41, 0.06	3.06, 0.33	3.47, 0.39
B	Product label	4.04	0.125	0.51, 3.54	0.3, 0.042	0.88, 0.096	0.15, 0.02	3.11, 0.34	3.26, 0.36
C	Product label	5.12	0.20	1.02, 4.10	0.3, 0.042	0.88, 0.096	0.31, 0.04	3.60, 0.39	3.91, 0.44
Average of A–C	Average of 3 products	4.67	0.20	0.96, 3.70	0.3, 0.042	0.88, 0.096	0.29, 0.04	3.26, 0.36	3.55, 0.40
50% SRN	UF/IFAS + Seminole County Recs	5.00	0.50	2.5, 2.5	0.3, 0.042	0.88, 0.096	0.75, 0.11	2.20, 0.24	2.95, 0.35
Notes:				C × D	High leaching scenario: Wang and Alva (1996); Low leaching scenario: Saha et al. (2007)		E (SRN) × F	E (QRN) × G	H + I
N leaching reduced by following UF/IFAS + Seminole County recommendations (Calculated as the difference between the average of Products A – C and the 50% SRN + UF/IFAS recommendations scenario).									0.60, 0.05

Table 2. Approach to calculating the N load reduction and economic benefits of fertilizer workshop participants converting to 50% SRN fertilizer products (compared to the average of three commercially available products described in Table 1).

A	B	C	D	E	F	G	H
Scenario	**# of individuals who converted to 50% SRN**	**Average size of lawn (in 1000 ft2)**	**N leaching reduced (lb N/1000 ft2/yr)**	**N leaching reduced per person (lb N/yr)**	**N leaching reduced by program (lb N)**	**Value of reducing N by 1 lb**	**Value of participants switching to 50% SRN**
High leaching estimate (bare soil)	332	3	0.60	1.79	595	$500	$297,500
Low leaching estimate (healthy grass)	332	3	0.05	0.15	50.7	$500	$25,350
Average	332	3	0.32	0.97	323	$500	$161,500
Notes:	An agent could update this number to reflect participants that responded that they now use at least 50% SRN from your program.	This number is based on an assumption of an average lawn being 3,000 ft^2.	These estimates are based on N leaching reduction calculations shown in Table 1.	C × D	B × E	Estimate based on Seminole County values used for N reduction.	F × G

Table 3. Approach to calculating the N load reduction and environmental benefits of fertilizer workshop participants following the fertilizer ordinance guidelines and skipping one fertilization period. This table presents two fertilizer scenarios and two leaching scenarios. The fertilizer scenarios include assuming that an individual was using at least 50% SRN (Seminole County recommendation) or 100% SRN for the summer application (UF/IFAS recommendation). The high and low leaching scenarios are outlined in the text and in Table 1.

A	B	C	D	E	F	G	H	I	J	K	L
Ordinance window	**SRN prop**	**Leaching scenario**	**N app. decrease due to ordinance (lb N/1000 ft2)**	**N leachate avoided per application (lb N/1000 ft2)**	**Average lawn size (1000 ft2)**	**Leachate avoided per person (lb N)**	**Value of reducing N in the environment ($/lb N)**	**Value of one individual following the ordinance**	**# of individuals reporting behavior change**	**N leaching avoided due to workshop (lb N)**	**$ value of N leachate reduction**
June–Sept	1.0	High	2.0	0.6	3	1.8	$500	$900	247	445	$222,500
	0.5	High	2.0	1.18	3	3.5	$500	$1,770	247	874	$437,000
	1.0	Low	2.0	0.08	3	0.25	$500	$126	247	62	$31,000
	0.5	Low	2.0	0.14	3	0.41	$500	$207	247	102	$51,000
Source:	Seminole County, UF/IFAS Fertilizer Recommendations			Product of N applied (D) and leaching estimates from Table 1	Estimate	E × F	Seminole County	G × H	Fertilizer workshop evaluations	G × J	I × J