Characterization of Suburban Nitrogen Fertilizer and Water Use on Residential Turf in Cary, North Carolina

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ADDITIONAL INDEX WORDS. residential fertilizer use, residential water use, fertilizer behavior

SUMMARY. A door-to-door survey was conducted in Cary, N.C., to determine suburban fertilizer and water use characteristics. The random survey of 300 households represented 1% of Cary households. Results from the survey demonstrated that few individuals used fertilizer on their driveways and sidewalks to melt ice and snow. Almost 90% of all residents applied fertilizer or used lawn care companies. Most residents or lawn care companies failed to sweep impervious surfaces after fertilizing. Most homeowners applied nitrogen fertilizer at a rate within North Carolina Cooperative Extension Service recommendations. Water use for landscaping related directly to summer drought conditions. Households with installed sprinkler systems used about twice as much water on their lawns as did residences with moveable sprinkler systems.

We are extremely grateful to the Student Association of the North Carolina division of the American Water Resources Association for their help as surveyors, as well as Master Gardeners from the Wake County Cooperative Extension Service, who are directed by Carl Matyak. We also thank Cary, N.C., personnel for providing information about Cary subdivisions and water use. Art Bruneau in the Crop Science Department at North Carolina State University provided useful comments on this manuscript. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Excess nitrogen (N) in the Neuse River, one of 17 major river systems in North Carolina, has been implicated in causing eutrophication and subsequent fish kills. This N originates from both point and nonpoint sources (NPS): wastewater treatment plants (24%), agricultural land uses (52%), urban land uses (8%), forest resources (14%), and atmospheric deposition (2%) (Department Environment, Health and Natural Resources, 1997).

Urban N NPS pollution comes from animal and plant waste, atmospheric deposition, and N fertilizer use. Use of N fertilizers on urban vegetation (primarily turf) is assumed to contribute the largest load of N into urban streams. However, little water quality monitoring data exists for urban North Carolina streams. In addition, no urban fertilizer-use statistics exist and little is known about the turf fertilization practices of the typical resident.

Preliminary water quality data from urban streams associated with different land uses in the upper Neuse River Basin register median nitrate-nitrogen ($\text{NO}_3\text{-N}$) concentrations ranging from almost nondetectable to about 1 ppm ($\text{mg}\cdot\text{L}^{-1}$) (G.D. Jennings, personal communication). These values are significantly lower than the $\text{NO}_3\text{-N}$ concentrations frequently measured (3 to 5 ppm) in predominantly agricultural areas in the middle Neuse River Basin (Gilliam et al., 1997). These urban stream data from the Neuse Basin are similar to $\text{NO}_3\text{-N}$ concentrations measured in urban streams throughout the United States. Storm runoff data records were reviewed for 37 residential watersheds with the average concentration clustered around 0.6 ppm $\text{NO}_3\text{-N}$, with a range of 0.25 to 1.4 ppm (Barth, 1995).

The contribution of turf fertilization to NPS nutrient runoff appears to be relatively small. Since grasses are perennials that have an extensive root system, well-managed turf should have a relatively high fertilizer N-use efficiency. However, the range of fertilizer N-use efficiency has been measured from 25% to 99% depending on grass species, fertilization rate, fertilizer formulation, and soil type (Petrovic, 1990).

Researchers have measured only very small amounts of surface runoff of N (Gross et al., 1990, 1991; Hipp et

al., 1993). These results reflect the fact that most water generally moves through turf, rather than over turf, and that most applied N is readily converted to $\text{NO}_3\text{-N}$ and moves through the soil profile rather than being lost through runoff.

Leaching losses of N also appear to be low. Under various turfgrass management practices, researchers have measured average $\text{NO}_3\text{-N}$ concentrations ranging from 1 to 30 ppm (Geron et al., 1993; Morton et al., 1988; Walker and Branham, 1992). However, the only conditions showing higher $\text{NO}_3\text{-N}$ concentrations were typically sandier soils and higher N fertilizer rates. In most studies, $\text{NO}_3\text{-N}$ concentrations were less than 3 ppm $\text{NO}_3\text{-N}$. Gold et al. (1990) measured $\text{NO}_3\text{-N}$ in shallow ground water from forest, fertilized and unfertilized home lawns, septic systems, and silage corn (*Zea mays* L.). Significantly higher amounts of N were leached through the soil profile into the groundwater for the corn 59 lb/acre ($66\text{ kg}\cdot\text{ha}^{-1}$) per year and septic systems 43 lb/acre ($48\text{ kg}\cdot\text{ha}^{-1}$) per year than the forest 1.2 lb/acre ($1.4\text{ kg}\cdot\text{ha}^{-1}$) per year, fertilized lawn 5.4 lb/acre ($6\text{ kg}\cdot\text{ha}^{-1}$) per year and unfertilized lawn 1.3 lb/acre ($1.4\text{ kg}\cdot\text{ha}^{-1}$) per year. Compared to fertilized corn fields that may routinely measure greater than 10 or 20 ppm, $\text{NO}_3\text{-N}$ leaching losses under turf are low.

Turfgrass management may be the most critical factor determining NO_3 leaching. Several researchers have observed that regardless of fertilizer formulation (slow release vs regular fertilizer) leachate concentrations did not differ (Geron et al., 1993; Gross et al., 1990; Mancino and Troll, 1990). Water quantity, however, has a marked effect on the movement of NO_3 . Excess irrigation of lawns appears to be the controlling factor determining the amount of NO_3 leached (Schueler, 1995).

Although literature from turfgrass studies suggests that well maintained lawns contribute small amounts of N into urban streams, turf comprises about 7% of the Neuse River Basin land area and therefore may be a contributory factor (Department Environment, Health And Natural Resources, 1997). To define residential fertilization and water use behavior, a lawn care survey was conducted. The objectives of the study were to 1) determine

fertilizer application behavior of urban residents, 2) determine average amount of elemental N applied per 1000 ft^2 (92.9 m^2) and 3) determine watering behavior of urban residents.

Methods

The residential lawn care survey was conducted in Cary, N.C., which is located in the upper reaches of the Neuse River Basin. Cary was selected based on 1) ongoing water quality monitoring studies of urban land uses, 2) availability of a multilayered geographical information system for many town parameters, 3) good working relations with town personnel, and 4) assumed optimal or supraoptimal amounts of fertilizer and water applied to residential turf due to the relatively high socioeconomic status of the residents.

The sampling size for the survey was 300 households or 1% of the total household population of Cary. Thirty subdivisions were selected at random for the survey and ten households per subdivision were sampled. Corollary information (average tax valuation, average lot size, and average age of the house) was obtained for each subdivision from town records. Tax valuation was selected and used as a surrogate for income level.

The door-to-door survey consisted of 15 questions (Fig. 1). To calculate N fertilization rates, the turfgrass area of each residential unit was measured. Pervious area was measured by stepping off the area in front of the house. Lawn size was then determined by estimating the percent of the turf area within the pervious area: front lawn area = front pervious area $\times$ percent turfgrass area.

Backyard turfgrass area was assessed by asking the survey participants about the size of their backyard turf area relative to their front turf area (see the door-to-door survey). The two turf areas were then added for the total turfgrass area. The backyard estimation technique was used to reduce intrusion of the residential property that was being surveyed.

Surveyors offered free soil sampling to each household surveyed. Twenty-eight percent of all homeowners surveyed or 83 residents requested a soil sample. Soils were sent to the North Carolina Department of Agriculture Soil Sampling Lab (Raleigh, N.C.) for analysis. Soil sample results

Fig. 1. Lawn care survey of Cary, N.C.

Good morning (afternoon). My name is I work for the North Carolina Cooperative Extension Service and North Carolina State University. We, along with the Town of Cary, are conducting a survey on fertilizer and water use. We will use this information to help protect our water supplies. Could I ask you a few questions about your lawn?

FERTILIZER USE

Have you ever used fertilizer as a de-icer?

Do you sweep your driveway, sidewalks, or curb area after you fertilize?

Have you had your soil tested in the last two or three years to see what type of fertilizer or lime you needed?

We need to know how much fertilizer the average homeowner uses. The next four questions will help us determine fertilizer usage.

If you fertilized during the last twelve months, when did you apply your fertilizer?

How much fertilizer did you apply in the last twelve months?

Do you fertilize both your lawn and your landscape plants (shrubs, flowers)?

What type of fertilizer do you apply?

Do you have lawn in your back yard?

Do you maintain it similarly to the lawn in your front yard?

Do you have a similar amount of lawn in your back yard?

WATER USE

The supply of drinking water for Cary residents is limited. The next four questions will help us determine watering patterns.

When do you water?

How many times per week do you water?

How long do you water?

Do you use moveable sprinklers to water or do you have an installed sprinkler system?

SURVEYOR'S NOTES

1. Landscaping plants:

Azaleas	Flowerbeds
Hollies	Dogwoods
Groundcover	Crape Myrtle

2. Estimated total square footage of permeable area:

Grass (%)	Trees/Natural Areas (%)

were reported back to the homeowners. The results were shared with the researchers with the homeowner's permission.

Water use data was obtained for most surveyed households and divided into summer and winter billing dates. Summer water use was billed in April through November 1997, and winter water use was billed in December 1997 to March 1998. Outside water use was determined by subtracting the average summer use from the average winter use. The difference in seasonal water use was assumed to be due to water

used on landscaped areas, in particular lawns.

Results were analyzed through the use of analysis of variance and regression techniques using Statistical Analysis System (SAS Institute, 1998).

Results and discussion

The average size of residential turfgrass areas in Cary was 4,893 ft² (454.7 m²). Lawn area was slightly greater among homeowners who used lawn care companies [4,945 ft² (459.6 m²)] than homeowners who maintained their own lawns [4,796 ft²

(445.7 m²)]. Estimated lawn area compares closely with the lawn care industry's estimate of 5,000 ft² (464.7 m²) for average lawn size in Cary (F.H. Yelverton, personal communication). The turfgrass area for residential lots in Cary was much lower than the state average of 17,500 ft² (1626.4 m²) (Chaffin et al., 1995). The average turfgrass area of Cary lots surveyed represented 75% of the pervious lot area, almost three times greater than the state average of 28% (Chaffin et al., 1995).

Almost 50% of all households in Cary used private lawn care services, a significantly higher rate than the state average of 2% (Chaffin et al., 1995). The use of lawn care companies (>99%) was significantly correlated to tax valuation (Fig. 2). Only 20% of residents at the lowest tax rate valuation used lawn care companies, as compared to 70% of residents living in houses with the highest tax valuations.

FERTILIZATION. Media reports convinced many farmers in the Neuse River Basin that a majority of Cary residents used fertilizers as deicers during winter storm events and as a result of this use were causing N nonpoint source pollution. Because fertilizer is a salt, it can be used to replace salt as a deicing agent. Survey results, however, demonstrated that only 3% of all homeowners had ever used fertilizer as a deicer. Due to the low amount of fertilizer used for deicing and the infrequency of frozen-precipitation events in most of the Neuse River Basin, we concluded that fertilizer used in deicing was not a large source of N nonpoint source pollution.

Cary residents soil tested their turf at a much higher rate (23%) than the North Carolina state average of 3%. Only 41% of residents, whether they maintained their own lawns or used lawn care services, swept or blew their sidewalks, curbed area and driveways after fertilization. Personnel of lawn care companies, who agreed to be interviewed for this study, were asked if they swept after fertilizing. They responded that they did not sweep because no fertilizer ever landed on impervious areas.

Although residents are doing a reasonable job in their fertilizer management, one area of concern exists: the pervious-impervious interface. Few homeowners and no lawn care company employees that we interviewed

Fig. 2. Usage of lawn care companies as a function of tax valuation of residents in Cary, N.C.

Fig. 3. Number of fertilizer applications by Cary, N.C., residents who apply their own fertilizer.

Table 1. Soil test results of turfgrass in Cary, N.C.

Variable	Units	Mean	Min	Max
CEC ^z	Meq·g ⁻¹	11.4	4.3	24.5
BS ^y	%	89.5	58	100
pH	---	6.1	4.6	7.2
PI ^x	---	51.3	0	226
KI ^x	---	57.2	16	124
Ca	Meq·g ⁻¹	63.7	34	84
Mg	Meq·g ⁻¹	25.7	10	235

^zThe cation exchange capacity (CEC) of the soil is the measure of how many nutrients the soil can hold.

^yBase saturation (BS) indicates the percentage of base nutrients (calcium, magnesium, potassium and sodium) that the soil holds on its exchange sites.

^xThe North Carolina Department of Agriculture indexes phosphorus (PI) and potassium (KI). Index values above 50 indicate that the nutrients measure in the high range and additional applications of P and K are unlikely to benefit yield.

swept or blew fertilizer off the impervious surfaces after fertilization. From walking neighborhoods, we observed that fertilizer was deposited on hard surface areas, which generally washes

directly into storm drains and, subsequently, area streams. We observed that most of the turfgrass in Cary was planted next to the impervious surfaces (curb, driveway, and sidewalks).

Shrubbed areas, flowerbeds, and natural areas were generally sited closer to the house. Fertilizer in runoff can be reduced by promoting placement of nonturf pervious areas, which are often not fertilized, next to the impervious areas. Based on our survey, educational efforts on urban turf should also focus on promoting cleanup of impervious areas after fertilization and changes in landscaping practices. Reductions in nutrient loading from fertilizer could occur immediately from a few simple changes: keeping fertilizer off hard surfaces, sweeping off the fertilizer when it does land on hard surfaces, placing borders between pervious surfaces and the grass, and reducing fertilizer usage.

All but two lawns in the survey were established in tall fescue (*Festuca arundinacea* Schreb.). For Cary residents who apply their own fertilizer, the average annual application rate of N fertilizer is 2.8 lb/1000 ft² (138 kg·ha⁻¹), whereas lawn care companies apply, on average, 3.8 lb/1000 ft² (187 kg·ha⁻¹). The annual recommended N fertilizer rate for tall fescue by the North Carolina Cooperative Extension is between 2.5 to 3.0 lb/1000 ft² (122 to 147 kg·ha⁻¹) (Bruneau et al., 1994). If grass is recycled, the fertilizer rate should be about 2 lb/1000 ft² (98 kg·ha⁻¹) of N per year. At a mean rate of 2.8 lb/1000 ft² (137 kg·ha⁻¹) of N per year, residents are at the high end or slightly over (if they recycle clippings) the recommended rate. Lawn care companies, however, are annually applying about 1 lb/1000 ft² (49 kg·ha⁻¹) more N than homeowners and the recommended rates.

The survey instrument allowed us to separate fertilizer applications to lawn areas from bedded or garden areas. So little fertilizer was applied to nonturf areas that we did not compute the amount of fertilizer used on nonturf areas.

The predominant grade of fertilizer used by Cary residents who apply their own fertilizer was of higher nitrogen content. Almost 75% of all applied fertilizers had nitrogen concentrations greater than 20%, which is the industry standard. Fertilizer application frequency, by residents maintaining their own turfgrass was adequate for maintaining turfgrass quality with most applying their fertilizer two or more times during the year (Fig. 3). Although season of application varied,

Fig. 4. Fertilizer usage as a function of tax valuation of residences in Cary, N.C.

Fig. 5. Amount of time that residents water their lawns in Cary, N.C.

Fig. 6. Relationship between type of watering system and tax valuation of residences in Cary, N.C.

the majority of residents applied fertilizer during the growing season in the appropriate months, primarily late winter and early spring and fall.

Although soil analytical data was not collected from all households sampled, the information compiled showed no obvious urban soil fertility problems. The mean soil test values were normal and the ranges were narrow (Table 1).

Average tax valuation, average lot size, and average year that the houses were built were not correlated with rate of fertilizer application. When, however, average tax valuation was regressed against the use of fertilizer, a significant correlation ($r^2 = 0.99$) was discovered (Fig. 4). Residents with a lower tax valuation were less likely to apply fertilizer to their lawns than homeowners with higher tax valuations. No relationship existed between the use of fertilizer and the year the house was built or the size of the lot.

WATERING. Questions relating to water use were more difficult for residents to answer. This was because, as most residents explained, their water use for turf maintenance was related to drought conditions that tend to vary over time. Despite resident's difficulties in answering questions, useful trends emerged from the questionnaire.

Most Cary residents water their landscapes (69%). Many of these residents, however, only water during dry spells (usually summer) or during turf establishment (usually fall). The majority of residents water in the morning (61%). The remaining residents who water (39%) do so in the evening. Over 45% of homeowners water for 0.5 h or less when they water their turf (Fig. 5).

Nine percent of households in Cary use installed irrigation systems. Average tax value and year the house was built were positively correlated with the use of installed irrigation (fixed sprinkler) systems. Higher tax value residential units and houses that were built more recently were more likely to have fixed irrigation systems installed than are households with lower tax valuation and those built less recently. Irrigation systems are more likely to be installed on properties with a higher tax valuation ($r^2 = 0.99$) (Fig. 6).

Both watering length and watering frequency vary depending on sprinkler type. Residents who have move-

Table 2. Watering length and frequency of watering for residences in Cary, N.C.

Sprinkler type	Watering length (min)			Watering frequency (d)		
	Mean	Max	Min	Mean	Max	Min
Fixed	20	70	5	3	7	2
Moveable	50	180	5	2	7	1

able sprinklers, on average, water about 50 min per watering (Table 2). Residents who have installed sprinklers water, on average, about 20 min per watering. However, residents with installed sprinkler systems water more frequently during the week than do residents with moveable sprinklers (Table 2). Using average length of watering and watering frequency to determine the total amount of time that lawns are watered on a weekly basis, residents with moveable sprinklers watered about 2 h per week while residents with fixed sprinklers water about 1 h per week. Although there was no way to ascertain the rate or amount of application directly, based on the survey results alone, it appears that residents with fixed sprinklers were no more likely to use water than residents with moveable sprinklers. Based on the frequency of watering and the amount of time that the water is applied, most residents were watering at reasonable rates.

However, when Cary water use records were analyzed, there was significant difference in water use due to sprinkler type. When actual water use data is compared by sprinkler type, residents who used moveable sprinklers water at about half the rate [60,000 gal (227,101 L) per month] as residents who used fixed sprinkler systems [112,000 gal (423,921 L) per month] ($r^2 = 0.99$). The water use records indicated that significant differences in water use occur in a few neighborhoods that have installed irrigation systems. This difference in water use between installed sprinkler systems and moveable systems was not captured with the survey instrument that we used.

Conclusions

The detailed information collected in this study on residential fertilizer-use behavior demonstrates that although in this community the majority of residents apply fertilizer or have lawn care services, most residents are applying nitrogen at the recommended rate. Because only watering behavior, not water rates could be assessed during this survey, actual household water use records were a better indicator of water application rates than survey results. In general, residents with fixed (installed) irrigation systems used water at twice the rate as residents with moveable watering systems.

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