Landscape and Watershed Processes

Characterization of Turf Practices in Five North Carolina Communities

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ABSTRACT

Limited information exists on specific urban lawn care practices in the United States. We conducted a door-to-door lawn care survey in five North Carolina communities to determine suburban fertilizer, pesticide, and water use. These communities, Cary, Goldsboro, Kinston, New Bern, and Greenville, are mostly located within the Neuse River basin, a nutrient-sensitive water resource. Residents in Cary used lawn care companies more than twice as frequently as residents in the other communities (43 compared with 20%). Cary had the smallest mean lawn size (445 m^2), while the largest was in Goldsboro (1899 m^2). Tall fescue [*Festuca arundinacea* Schreb.] was the predominant grass type in Cary (99%), and centipedegrass [*Eremochloa ophiuroides* (Munro) Hack.] or centipedegrass mixtures were the predominant grass types in Greenville and New Bern. Kinston had the lowest fertilizer usage with only 54% of the residents using fertilizer; Cary had the highest rate of 83%. The average N fertilizer rate applied to the lawns was dissimilar ranging from 24 to 151 kg N ha^{-1}. Analysis of variance results for fertilizer rates and household income indicated a significant difference ($P < 0.05$) in application rate between high- and medium-income levels and the low-income level. Cary, Goldsboro, and Greenville had approximately the same number of fertilizer applications per year (1.5), whereas the average number of fertilizer applications per year in New Bern was 3.0. Most household residents (53%) used instructions on the bag and either grass type and/or lawn area to guide them on fertilizer application rates.

Surface and ground water contamination from both nutrients and pesticides have become increasing concerns throughout the USA (USEPA, 1995). The USEPA estimates that only 40% of the streams and rivers are fully supporting, meaning that the streams and rivers meet their designated uses, such as swimming, fishing, and drinking, only 40% of the time (USEPA, 1995). Approximately 75% of the lakes and ponds and 95% of the estuaries fully support their designated uses.

The sources of pollution are diverse, although the majority of the pollutants are delivered from nonpoint sources as opposed to point sources. The USEPA estimates that agriculture contributes 53%, construction 10%, mining and other activities 13%, miscellaneous sources 12%, and urban runoff 12% to the nonpoint-source pollution load in the USA (USEPA, 1995). Since nonpoint-source pollutants originate from urban, as well as agricultural lands, it is essential to assess the effects of lawn care practices, especially in residential areas.

Although urban N nonpoint-source pollution originates from inputs of animal and plant waste, septic systems, atmospheric deposition, and N fertilizer, N fertilizer use in the landscape (primarily turf) is expected to contribute the largest load of N into urban streams. In North Carolina, as in many other locations throughout the USA, no urban fertilizer-use statistics exist and little is known about turf fertilization practices of typical residents.

Although no urban fertilizer use data in North Carolina exist, limited information as related to mass transport and loss of N in addition to characterization of surface waters is available. Established residential areas, golf courses, and new construction sites measured higher N mass losses than a fescue pasture or newly established residential areas (Line et al., 2002). Preliminary water quality data from urban streams associated with different land uses in the upper Neuse River basin document median nitrate nitrogen (NO_3–N) concentrations ranging from almost nondetectable to approximately 1 mg L^{-1} (G.D. Jennings, personal communication, 2002). Additional urban stream monitoring data from Charlotte, NC generally report stream concentrations around 2 mg L^{-1} total N, with the majority of the N as organic N rather than NO_3–N (Bales et al., 1999). These urban stream data from the Neuse River basin are similar to NO_3–N concentrations measured in urban streams throughout the United States. Storm runoff data records from throughout the United States were reviewed for 37 residential watersheds with the average concentration clustered around 0.6 mg L^{-1} NO_3–N, with a range of 0.25 to 1.4 mg L^{-1} (Barth, 1995). Both state and national urban stream N concentrations are lower than the NO_3–N concentrations frequently measured (3–5 mg L^{-1}) in predominantly agricultural areas in the middle Neuse River basin (Gilliam et al., 1997).

The contribution of turf fertilization to total N nonpoint-source losses appears to be relatively small on a river basin scale. Researchers have measured only small amounts of N in surface runoff from turf (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, unless in a slow release or organic form, is readily converted to NO_3–N and moves through the soil profile rather than being lost through runoff. Since grasses are perennials with extensive root systems, well-managed turf should have relatively high fertilizer N-use efficiency and thus lower leaching losses. The range of fertilizer N-use efficiency has been measured from 25 to 99%, depending on grass

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species, fertilization rate, fertilizer formulation, and soil type (Petrovic, 1990).

Leaching losses of N under turfgrass appear to be low. Under various turfgrass management practices, researchers have measured average NO_3–N concentrations ranging from 1 to 30 mg L^{-1} (Geron et al., 1993; Morton et al., 1988; Walker and Branham, 1992). The only conditions that resulted in the higher NO_3–N concentrations were typically sandier soils with high N fertilizer rates. A recent nitrate leaching study on extremely well-managed golf courses in North Carolina demonstrated shallow ground water NO_3–N concentrations from negligible to 12 mg L^{-1}, with the greater shallow ground water N concentrations occurring on sandy soils (Adams, 1999). Gold et al. (1990) measured NO_3–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 ground water from the corn system (66 kg ha^{-1} per year) and septic systems (48 kg ha^{-1} per year) than the forest system (1.4 kg ha^{-1} per year), fertilized lawn (6 kg ha^{-1} per year), and unfertilized lawn (1.4 kg ha^{-1} per year). Compared with fertilized cornfields that may routinely measure greater than 10 mg L^{-1} NO_3–N, leaching concentrations under turf appear to be low, generally around 3 mg L^{-1} NO_3–N (Geron et al., 1993; Morton et al., 1988; Walker and Branham, 1992; Adams, 1999).

Turfgrass management may be the most critical factor determining NO_3–N 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–N. Excess irrigation of lawns appears to be a controlling factor determining the amount of NO_3–N leached (Schueler, 1995).

The North Carolina Environmental Management Commission (NCEMC) is the environmental rule making committee for the State of North Carolina. The NCEMC instituted point and nonpoint source rules for the Neuse River basin that became effective 1 Aug. 1998 (North Carolina Department of Environment and Natural Resources, 1997a). Estimates for N pollutant loads from the different sectors (agriculture and urban) are somewhat uncertain, although the total load is measured at approximately 3.6×10^6 kg total N yr^{-1}. Little information was available to help determine loads and sources. Even less information related to urban homeowner lawn care practices, particularly fertilizer use and management, was available. Due to the imposition for the Neuse Estuary of a total maximum daily load by the USEPA, it becomes even more important to determine load contributions from the different sources of pollution (North Carolina Department of Environment and Natural Resources, 1999).

Although literature from turfgrass studies suggests that well-maintained lawns contribute small amounts of N into urban streams, turf comprises approximately 7% of the Neuse River basin land area and therefore may be a contributory factor (North Carolina Department of Environment and Natural Resources, 1997b). Knowing fertilizer use habits of homeowners is important to assess potential N nonpoint-source losses from urban areas. This study was conducted to address the data gaps associated with turf fertilization and cultural practices. A door-to-door lawn care survey was conducted in five communities, primarily in the Neuse River basin, to better define residential fertilizer and water use behavior. The objectives of this study were to (i) characterize fertilizer, pesticide, and water use in selected urban North Carolina areas, (ii) determine if uses differed due to community demographics, and (iii) use the information to direct lawn care education programs.

METHODS

The five communities sampled are in the Neuse and Tar–Pamlico River basins (Fig. 1). Surface waters in these basins

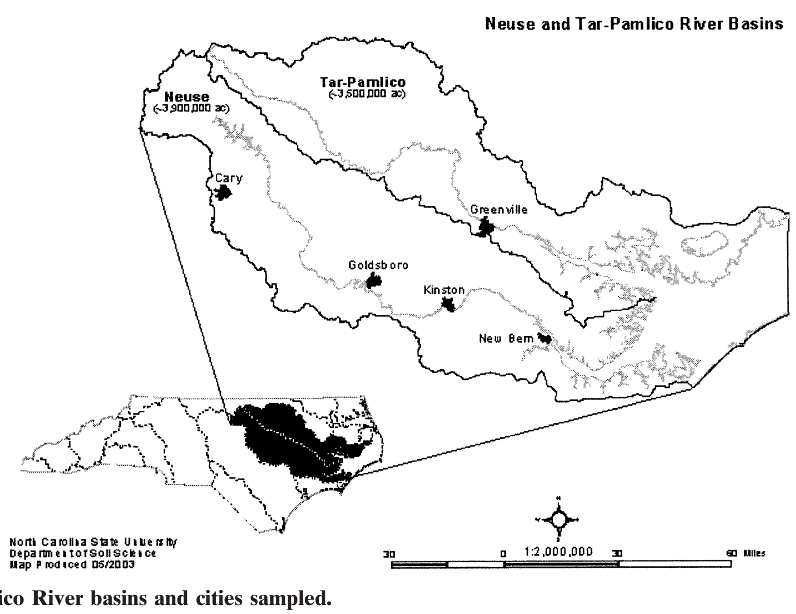

Fig. 1. Neuse and Tar–Pamlico River basins and cities sampled.

are classified as nutrient sensitive and have water quality regulations to control nutrient loading. In the Neuse River basin, there are state regulations to reduce N by 30%, as well as the federally imposed total maximum daily load standard for chlorophyll *a* (North Carolina Department of Environment and Natural Resources, 1999). Four of the five communities sampled are located in the Neuse River basin (Cary, Goldsboro, Kinston, and New Bern), while Greenville is located in the Tar–Pamlico River basin. Both basins drain into the Albemarle–Pamlico Sound, the second largest estuary in the United States.

Community Characteristics

The five communities used in this survey were selected based on diversity in size, household income, and physiographic location in either the Neuse or Tar–Pamlico River basins (Fig. 1).

Cary is located in the Piedmont region of the Neuse River basin. It is in close proximity to the Research Triangle Park, an international center for research and development of computers, pharmaceuticals, and agricultural chemicals, providing Cary with the highest growth rate and median yearly income (Town of Cary, personal communication, 1997). Table 1 presents the total population, growth rate, and median yearly income for Cary and the other communities. In Goldsboro, a community in the middle Coastal Plain, Seymour Johnson Air Force Base provides much of the economic foundation and population of the city (Wayne County Chamber of Commerce, personal communication, 1998). Kinston is located in the middle Coastal Plain, approximately 25 miles east of Goldsboro. Although it has prospered in years past from agriculture, it is presently losing population (Town of Kinston, personal communication, 1998). The most eastern city in the Neuse River basin is New Bern, located where the Neuse River widens to form the estuary in the flat topography of the Coastal Plains. Much of the growth of New Bern is due to retirees from out-of-state locating in the New Bern area (City of New Bern, personal communication, 1998). The fifth community is Greenville, which is one of two major towns located in the Tar–Pamlico River basin. The population in Greenville is primarily due to a major North Carolina university (East Carolina University) and major medical center (Town of Greenville, personal communication, 1998).

Survey

The primary survey instrument used in this study is found in Fig. 2. Due to varying local interests of volunteers, surveys varied slightly among communities. Differences among surveys were minor. No pesticide questions were included in the Cary survey; residents of Goldsboro were asked if they used wells; and residents of New Bern were asked where they stored pesticides.

Homeowners were usually able to tell us the amount of fertilizer applied. We had a list of all the fertilizer types sold in each community and when homeowners could not remember the type of fertilizer used, they usually could select the fertilizer type they applied from the list. Only rarely did a homeowner know the rate at which they applied fertilizer. To calculate N fertilization rates, we had to determine the area to which the fertilizer amount was applied.

We found turf area by determining the front pervious area (the area not covered by pavement or the house). We calculated front pervious area by pacing its length and width. An estimate was then made of the percentage of turfgrass within the pervious 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 (Fig. 2). The backyard estimation technique was used to reduce the time it took to survey and to avoid disturbing the participant. The two turfgrass areas were then summed for the total turfgrass area.

Table 1. Total population (1998), growth rate, and median yearly income for the five communities surveyed.

Community	Total population	Growth rate (10 yr)	Median yearly income
		%	$
Cary	86 613	>200	67 250
Goldsboro	47 814	17.5	43 200
Kinston	24 974	negative	36 200
New Bern	22 048	27	30 410
Greenville	56 853	22.8	25 527

Sample Size and Data Collection

For a given community, the intended sample size design was 1% of the total household population of each community. Due primarily to differences in growth characteristics and willingness of volunteers, the following sample sizes were attained: Cary, 1% ($n = 300$); Goldsboro, 0.4% ($n = 86$); Kinston, 1.2% ($n = 130$); New Bern, 0.7% ($n = 66$); and Greenville, 0.5% ($n = 130$). The lower sampling rate in Goldsboro is somewhat deceptive in that the intent was to sample only in the Stoney Creek Watershed area of Goldsboro in support of an ongoing watershed study. The actual sample was acquired by randomly selecting subdivisions and 10 households per subdivision. Less than 1% of the households selected refused to be surveyed.

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 as a surrogate for income level. Low-income level is defined as a tax valuation of ≤$125 000, whereas medium income tax level has a tax valuation between $126 000 and $174 000 and high valuation is ≥$175 000. Tax valuation information by subdivision sampled was not available for the New Bern and Goldsboro locations. Results were analyzed by the analysis of variance technique using the Statistical Analysis System (SAS Institute, 1998).

RESULTS

Turf Management and Fertilization

Mean lawn size varied by community: Cary (445 m^2), Goldsboro (1899 m^2), Greenville (810 m^2), Kinston (1168 m^2), and New Bern (873 m^2). Cary has the smallest total turf area per household.

More than one-half of urban homeowners surveyed across all communities use fertilizer on turf (Table 2). A number of households (16–43%) used lawn care services for fertilization, although this is highly variable by community. Cary, which has the highest median income, used lawn care companies with the greatest frequency. Fertilization was based on soil testing for only 20% of the households, although New Bern had a slightly higher rate of 35% (Table 2). Soil test reports recommend phosphorus (P) and potassium fertilization rates based on the soil test value for these two nutrients. Nitrogen fertilizer recommendations, however, are simply based on the predominant grass type. Cary, Goldsboro, and Greenville had approximately the same number of fertilizer applications per year (1.5), whereas the average

Initials_________ ________________________

1. Do you use a lawn care company to apply fertilizer? Yes No
If no, skip to question 3.
2. If you use a company, what is the company's name? Companies name_______________ Now skip to question 12.
3. Do you soil test? yes no
4. What type of grass is in your lawn?
Centipede grass _____ Zoysia ______ St. Augustine_______ Bermuda________
Tall fescue________ Other________________ Don't know __________
4. Do you fertilize your lawn? Yes No If no, skip to question 12?
5. How many times per year do you apply fertilizer?
6. If you fertilize your lawn, what months do you apply your fertilizer?
7. What type or analysis of fertilizer do you apply?
8-8-8_____ 10-10-10_____ 5-2-20 ______ 26-3-4______ 12-3-4______
16-4-8 ________ 15-0-15________ Other__________
8. How much fertilizer do you apply at each application?
9. When you fertilize, how do you know how much to apply? Circle all that apply.
Based on soil test results Based on instructions on the back of the bag
Based on grassed area Based on grass type
No criteria used
10. How do you apply your fertilizer?
Drop spreader Spinner spreader Hand spinner Hand
11. Do you sweep or blow your curb and driveway after you fertilize? Yes No
If yes, is the fertilizer moved off the hard surfaces and either put on the grass or back into the fertilizer spreader or bag? Yes No
12. Do you bag your clippings? Yes No
13. Do you have lawn in your backyard? Yes No If no, skip to lawn area estimation.
14. Do you maintain your back yard lawn similarly to the lawn in your front yard?
15. Do you have a similar amount of lawn in your back yard?

- Front yard is ______% greater than the back yard.
- Back yard is ______% greater than the front yard.
- Front yard = Back yard

Lawn Area Estimation

Paced length and width of lot size

% Lawn	% Other

Fig. 2. Continued on next page.

number of fertilizer applications per year in New Bern was 3.0. More than one-half (53%) of all households surveyed (exclusive of Cary that was not sampled for this question) recycle their clippings (Table 2).

Nitrogen fertilizer rates ranged from 0 to 2147 kg N ha^{-1} with mean annual rates of 151 kg N ha^{-1} (Cary), 73 kg N ha^{-1} (Greenville), 29 kg N ha^{-1} (Kinston), and 24 kg N ha^{-1} (New Bern). The highest recorded N application rate is probably a result of recording error. Annual N rates appear to be related to predominant turf type that varied among communities, as well as the percentage of households that fertilize. In Cary, located within the Piedmont region, tall fescue was most common (99% of lawns) and the mean annual N rate of 151 kg N ha^{-1} was close to the recommended range of 122 to 147 kg N ha^{-1} (Bruneau et al., 1994). Commercial lawn care businesses (Cary only), on average, applied 200 kg N ha^{-1}, about 50 kg greater per ha than residential application rates. Centipedegrass and centipedegrass mixtures were most common in the Coastal Plain communities, occupying nearly 50% or greater of turf areas (Goldsboro, 44%; Kinston, 50%; New Bern, 83%; Greenville, 75%). The range of N application rates across these communities was 0 to 56 kg N ha^{-1} as compared

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Pesticide Questions

16. Are pesticides used for weeds, insects, or diseases in your lawn? Yes No
If no, skip to question 24.
17. Pesticides are applied for: Weeds______ Insects________ Disease_______
18. When you apply pesticides, what type of equipment is used?
Hand pump sprayer _________ Drop or spinner spreader__________
Hose_______ Premixed spray product______ Other________
19. Do you have any concerns of safety when you apply pesticides? Yes No
If no proceed to question 22.
20. What are your concerns about pesticides?
Personal safety_________ Water Quality__________ Wildlife___________
Pets___________ Other Plants___________ Other_______________
21. What safety precautions to you take when applying pesticides. Check all that apply.
Properly identify pest_________ Select safest product ___________
Follow label direction___________ Wear appropriate clothing____________
Spot treat ______________ None____________ Uncertain_______________
22. Do you know how to calibrate equipment prior to applying pesticides? Yes No
23. Do you calibrate equipment prior to applying pesticides? Yes No

Water Questions

24. Do you obtain your drinking water from well? Yes No
25. Do you water? Yes No If no skip to question 30.
26. When do you water? (season or climatic situation)
27. What time of day do you water?
28. When you water, how many times per week do you water?
29. How long do you water each time you water?
30. Do you use moveable sprinklers to water or do you have an installed sprinkler system?

Information Questions

31. Who do you contact about lawn and garden information? Retailer______
Neighbor_______ Cooperative Extension__________ Other_________
32. Have you ever heard of the Cooperative Extension Service? Yes No

Fig. 2. Lawn care, pesticide use, and water use survey.

with the recommended rate for centipedegrass (24 kg N ha^{-1}). Although rates within this range exceed the recommended levels for centipedegrass, it was not the only species grown and some of the turf species grown require higher N application levels.

Results from the survey indicate that for fescue, the majority of the fertilization is occurring in the late winter and early spring, February through April (Fig. 3). Fescue fertilization should occur in September, November, and February. Most homeowners were only applying their spring applications to fescue. Timing of fertilizer applications to the warm-season grasses (zoysiagrass [*Zoysia japonica* Steud.], common bermudagrass [*Cynodon dactylon* (L.) Pers.], and centipedegrass) by homeowners occurred primarily in the spring (March and April) and the fall (September, October, and November), rather than in the summer months (May, June, July and August) (Fig. 3). Lawn care providers also tended to fertilize during the wrong season for warm-season grasses (Fig. 3). Inappropriately timed applications are being made to both cool- and warm-season grasses during periods of low growth or dormancy, thus reducing the efficiency of fertilizer use.

Not only may loss potential of N be caused by inefficiency of fertilizer use via poor timing, it may be related to the fertilizer analysis and rate and uniformity of application. Across all communities, the type of fertilizer used was highly variable, although most fertilizers had a low N analysis, defined here as ≤15% N (Fig. 4). More than 30% of fertilizer use by residents in Cary and Greenville consisted of a high analysis N fertilizer

Table 2. Percentage of households fertilizing, using lawn care services, testing soil, and bagging grass clippings.†

Community	Fertilizing	Using lawn care service	Testing soil	Bagging grass clippings
	%			
Cary	83 (2.2)	43 (2.9)	23 (2.6)	NA‡
Goldsboro	66 (5.1)	16 (4.0)	20 (4.3)	50 (5.4)
Kinston	54 (4.4)	16 (4.0)	16 (3.2)	43 (4.3)
New Bern	72 (5.3)	18 (4.7)	35 (5.8)	40 (6.0)
Greenville	73 (4.6)	26 (3.9)	18 (3.4)	57 (4.3)

† Values in parentheses are ±SE.
‡ Not applicable.

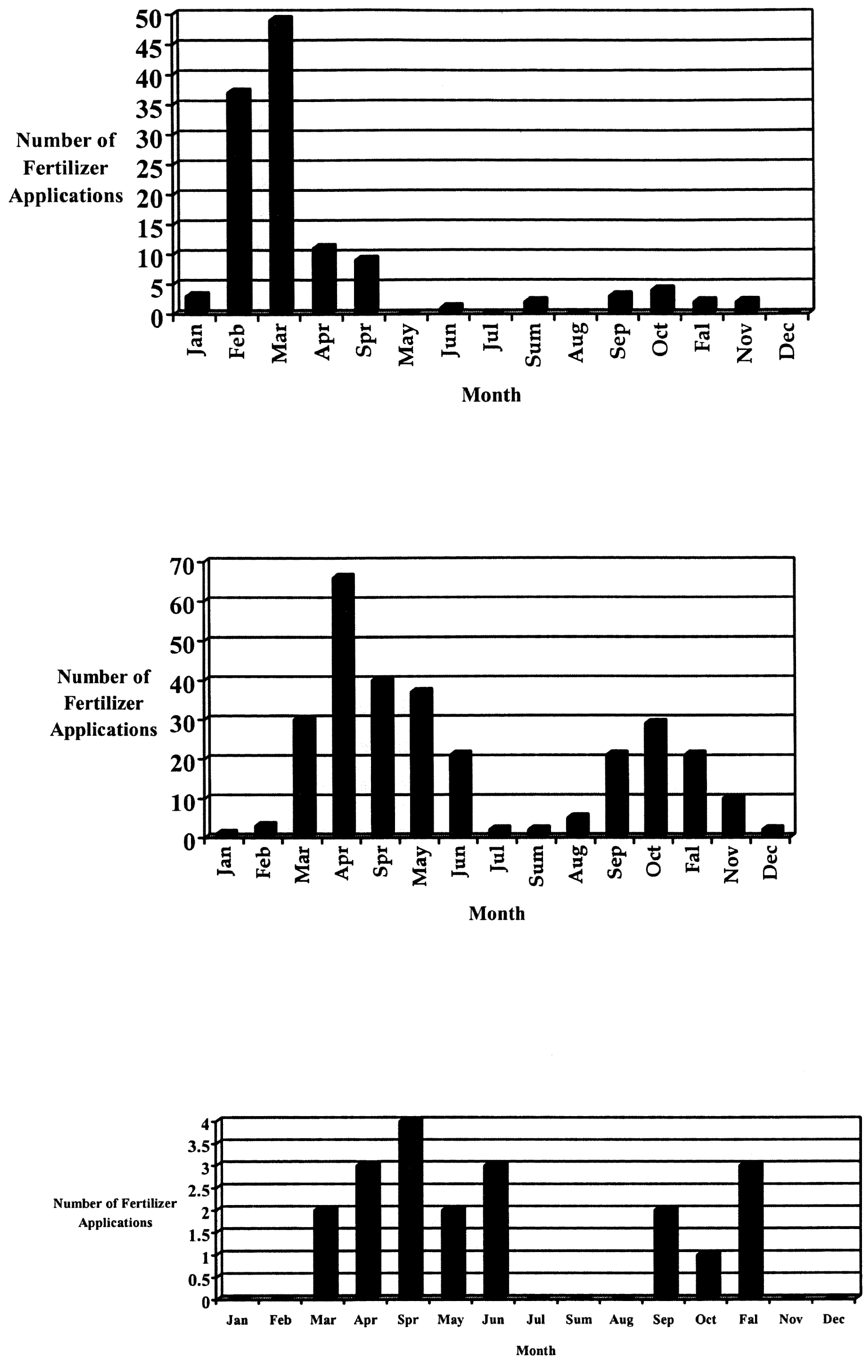

Fig. 3. Timing of fertilizer use for fescue by homeowners (top), warm-season grasses by homeowners (middle), and warm-season grasses by lawn-care providers (bottom).

(>15% N). High analysis N fertilizers are appropriate for tall fescue and at rates of 56 kg N ha^{-1} are easy to uniformly apply, but a uniform application of one-half of this rate, as needed for centipedegrass in Greenville, would be difficult to achieve.

Socioeconomic consideration of fertilizer use was also considered since income levels varied among communities. When yearly fertilizer rate was regressed against income, there was a significant difference ($P < 0.05$) in application rate between high- and medium-income levels and the low-income level: 132 kg N ha^{-1} for high-income residents, 148 kg N ha^{-1} for medium-income residents, and 78 kg N ha^{-1} for low-income residents.

Most household residents (53%) used instructions on the bag and either grass type and/or lawn area to guide them on fertilizer application rates. Grass area or grass type was used by 21% of households to determine fertilizer rate. Eleven percent of the respondents used soil tests to guide their fertilizer application rates. We were unable to discern any fertilizer application criteria for about 15% of the residents.

Most respondents use either drop or spinner spread-

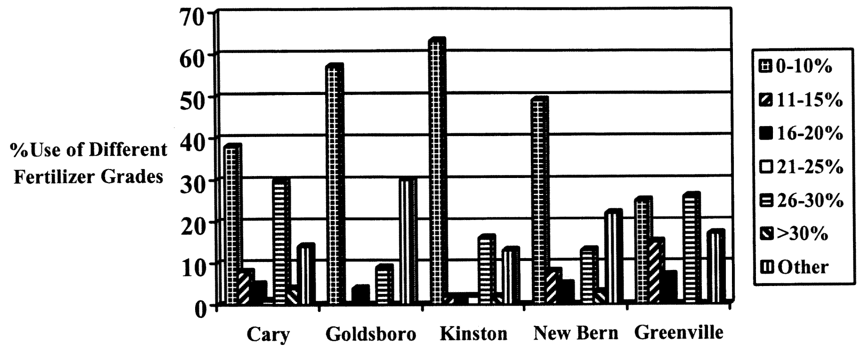

Fig. 4. Nitrogen fertilizer analyses used in the different communities.

ers (77%) or their hands (18%) to distribute fertilizer. On average, 52% of households blew or swept fertilizers off driveways and other impervious surfaces. Residents in Cary had the lowest rate of removing fertilizer (41%), while residents in Greenville, New Bern, and Goldsboro had the highest rate (approximately 67%).

Water Use

Water use is an important consideration because it significantly influences leaching of mobile nutrients such as NO_3–N. The overall average of residents who water during dry periods was 67%. Households in New Bern were more likely to water than households in the other communities (Table 3). Watering frequency, the number of times per week that residents watered, was greater in Greenville and Goldsboro than the other communities, although there was no significant difference ($P <$ 0.0001) among the communities in their watering frequency. The range in watering frequency was from 0.5 to 7 times per week.

The average watering duration was greater in Greenville and Goldsboro than some communities (Table 3). There was a high significant difference ($P < 0.0001$) in watering duration between Cary vs. Greenville and Goldsboro. The range in the length of watering was from 5 to 300 min. When duration of watering was regressed against income (tax valuation), there were no differences between the low and high incomes. Medium-income households, however, watered significantly more (65 minutes) than either high- (53 minutes) or low- (50 minutes) income households.

Kinston has the largest number of residents that use hand sprinklers (25%) whereas hand watering is infrequent in the other communities. New Bern has the highest use of fixed irrigation systems (36%), while Greenville, Cary, and Goldsboro have a similar percentage of fixed sprinklers (approximately 15%). The fixed sprinkler systems may explain why New Bern had the greatest percentage of residents who water and Kinston had the lowest percentage of people who water.

Pesticide Use

The results for this section do not include responses from Cary residents since pesticide use questions were not included in the Cary survey. About 60% of all households use pesticides, with the greatest frequency in Greenville and the lowest in Kinston (Table 4). Typically, more residents use pesticides to treat weeds than either insects or diseases (Table 4). Plant diseases are the least likely problem treated by pesticides.

Approximately 70% of all respondents were concerned about safety issues when applying pesticides. This concern was rather consistent among communities. Overwhelmingly, the greatest concern was for family health, followed by the health of pets. Water quality and wildlife interests were about half as important as family health. Concern about other plants was infrequent.

Respondents were also asked what safety precautions are taken when applying pesticides. In general, reading the label was cited most frequently, followed by wearing protective clothing. Spot treating and pest identification tied as the third most cited precautions. The least cited precaution was selection of the safest pesticide.

Respondents were asked if they knew how to calibrate their equipment, to which 82% responded positively. Most respondents (78%) also said they calibrated before applying pesticides. In most communities the number of people who knew how to calibrate was greater than the number who actually calibrated. We assume that individuals who say they know how to calibrate are reading labels and following instructions rather than actually calibrating spreaders or sprayers.

Homeowners obtain lawn care advice as often from North Carolina Cooperative Extension as they do from retail outlets (Table 5). Advice is also sought from neighbors, but less frequently than from retail outlets or extension. On average, 77% of the residents surveyed had heard of the North Carolina Cooperative Extension Service.

Table 3. Percentage of households that water the lawn, watering frequency, and watering duration.

Community	Watering the lawn†	Watering frequency	Watering duration
	%	d wk^{-1}	min
Cary	69 (3.49)	2.4a‡	49a
Goldsboro	61 (7.89)	3.0a	72b
Kinston	54 (5.04)	2.4a	60ab
New Bern	89 (5.62)	2.3a	58ab
Greenville	69 (6.28)	3.1a	67b

† Values in parentheses are ±SE.
‡ Least significant differences determined at the 95% confidence level (P = 0.05) by GLM SAS procedure; means in each column followed by the same letter are not statistically different.

Table 4. Percentage of households using pesticides and intended use.

Community†	Pesticide use‡	Intended use		
		Weeds	Insects	Disease
	%			
Goldsboro	46 (2.88)	69	29	2
Kinston	35 (4.18)	45	39	16
New Bern	63 (5.94)	45	50	5
Greenville	91 (2.51)	59	36	5

† Information not collected in Cary.
‡ Values in parentheses are ±SE.

DISCUSSION

When the rules to reduce N nonpoint-source pollution were initially established in the Neuse River basin, stakeholder groups were defensive about their sector's contribution of N to the estuary. Urban and suburban homeowners were criticized for overuse of N fertilizer and data were not available nationally, statewide, or locally to refute or confirm this thesis. Approximately every five years, the Statistics Division of the North Carolina Department of Agriculture and Consumer Services conducts a statewide turf survey (Chaffin et al., 1995; Kneas and Smith, 2001). The information derived from these surveys is limited, especially when trying to extrapolate urban fertilizer use. These surveys provide information on percentages of homeowners who fertilize, water their lawn, and recycle their clippings, and average turf area. No information on fertilizer use (rate, timing, and analyses) is provided, nor is information about length of watering and other pesticide use attributes obtained.

Although the pesticide portion of the present survey was generic and of secondary interest, general trends were observed. Pesticide use was widespread in all communities (60% of homeowners) with herbicides being the predominant pesticide. Consumers appeared to be using pesticides correctly by using the designated application rates, calibrating equipment, reading labels, wearing protective clothing, and selectively treating affected areas. The most frequent concern that users have is danger to the health their family or pets.

Water use is definitely driven by lack of rainfall in all communities. 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 approximately 2 h per week while residents with fixed sprinklers watered about 1 h per week. Although there was no way to ascertain the rate or amount of water 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.

Table 5. Sources from which lawn care information is obtained.

Community†	Extension	Retail	Neighbor
	%		
Goldsboro	51	33	16
Kinston	37	42	21
New Bern	38	51	11
Greenville	37	38	25

† Information not collected in Cary.

The survey instrument did not collect data on actual rates of water use. Since inappropriate watering can increase N losses, it is critical to obtain reliable water use information. The Town of Cary compared metered water used between households with different sprinkler types (Town of Cary, personal communication, 1998). Residents who used moveable sprinklers water at about half the rate (2.3×10^5 L mo^{-1}) as residents who used fixed sprinkler systems (4.2×10^5 L mo^{-1}) ($R^2 = 0.99$). The water use records indicated that significant differences in water use occur in a few neighborhoods that have installed irrigation systems. Based on these additional data, it appears that increased water usage may occur under installed irrigation systems thus increasing the chances of N leaching.

The need for soil testing by homeowners as well as landscape professionals was also evident. Although soil testing is unnecessary for N fertilization considerations, it is important to have optimum fertility as related to pH and nutrient levels so grass can efficiently utilize N. In some areas P losses are of greater concern than N, which is why we wanted to capture urban soil testing rates. The low rate of soil testing by homeowners in all communities demonstrates the need to stress soil testing, both to individuals as well as lawn care companies. (No lawn care companies that we interviewed soil-tested on a routine basis.) Initial soil testing of lawns in Cary found that the majority of the lawns did not need additional P. Without soil testing, homeowners will continue to add unnecessary P fertilizers and may have very low N use efficiency in lawns where fertility is otherwise not optimum.

Any fertilizer that lands on hard surfaces is subject to direct discharge into surface waters via stormwater systems. Only 52% of homeowners clean impervious surfaces after fertilization. Removing fertilizer inadvertently applied to impervious surfaces would decrease direct fertilizer discharge to surface waters and greatly reduce fertilizer pollution in urban areas.

The average urban–suburban lawn area from our survey is 0.1 ha or 1000 m^2. The average lawn size collected in the aforementioned North Carolina Department of Agriculture and Consumer Services' statewide turf survey was 0.2 ha, about twice the size of lawns in our survey (Kneas and Smith, 2001). Their survey averaged both urban and rural residents, so it is not surprising that the average lawn size was lower in our survey where our residents tend to reside in denser suburban areas.

Approximately 70% of all homeowners in these communities apply N fertilizer (compared with the statewide average of 50%), with its use in most communities being slightly higher than the recommended levels for the types of grass grown. Since approximately 50% of homeowners recycle their grass clippings without giving N credits, this increases overapplication of N. Grass clippings can act as a continuous fertilizer source, and thus N fertilizer rates can be reduced as much as 30% (Osmond and Bruneau, 1999) to 50% (Heckman, 2001) when clippings are recycled. Commercial applicators generally applied more fertilizer than residents.

There appears to be evidence of overfertilization in

Table 6. Yearly N fertilizer application amounts by community.

Community	Persons per household	Number of households	Average lawn size	Mean annual fertilizer rate	Total fertilizer amount
			ha	kg N ha^{-1}	kg N community^{-1}
Cary	2.6	33 313	0.0445	151	223 845
Kinston	2.3	10 858	0.1168	29	36 778
New Bern	2.3	9 586	0.0873	54	45 190
Greenville	2.4	23 689	0.0810	73	140 073

the centipedegrass growing areas, since fertilizer N inputs were as much as 200% greater than recommended rates. This overapplication of 200% assumes a centipedegrass lawn, with the highest average rate of fertilization (56 kg N ha^{-1}), and recycling of all lawn clippings. Overfertilization also potentially exists in the Piedmont where lawn care service is used and lawn clippings are left on the turf surface. Although turf is generally highly efficient in utilizing applied fertilizer N (Petrovic, 1990), potential exists for unused portions of applied N to move off-site in the sandy soil of the Coastal Plains region. Jacobs and Gilliam (1985) estimates that 95% of N losses from fertilized areas occur through subsurface flow of shallow ground water containing NO_3–N.

Additional concerns of fertilizer use must also consider timing of N applications due to the differences in seasonal uptake of N relative to turf type. The recommendation for tall fescue, the predominant grass type in Cary, is an application of 156 kg N ha^{-1} split equally over three applications (normally occurring in September, November, and February). The spring application was generally made at the correct time, but fall applications were negligible. In the Coastal Plain, where centipedegrass occupies at least half of the turf area, a single N application is recommended, normally in June. Centipedegrass, along with the other warm-season grasses, was receiving fertilizer more often at the inappropriate times (spring and fall) than the correct times. This probably reduces fertilizer use efficiency, as well as turf health. Fertilizer application timing must be stressed more in our outreach programs.

The number of applications and types of fertilizer used were often not matched to the specifics of the area. We need to focus more education on fertilizer distributors. Homeowners in Greenville, where the predominant grasses were centipedegrass or centipede mixtures (centipedegrass mixed with other grass species), frequently used high N analysis fertilizers. Because of the low N requirements of centipedegrass, these high N analyses were inappropriate and probably added to the excess N application rates in Greenville. Retail outlets in Greenville should be encouraged to carry mostly low N analysis fertilizer to match the needs of centipedegrass. More educational effort needs to focus on selection of proper fertilizer grades.

The total amount of fertilizer use was greatest in Cary. Total N fertilizer use in Cary was 7 times greater than in Kinston, 5 times greater than in New Bern, and 1.6 times greater than in Greenville (Table 6). The greater total N use in Cary is due to the higher N fertilizer rates needed to fertilize tall fescue, the largest proportion of the population that applied fertilizer, and the greatest number of households. The overall use of fertilizer in Cary would have been higher except that average grass area was smaller than any other community. Grass type, town size, and intangible factors, such as owning or renting a house, rather than absolute income, confound fertilizer use patterns.

CONCLUSIONS

Determining nonpoint-source pollution contributions from various sectors is one of the most difficult problems regulators have when trying to assign pollution reduction targets. A very important use of the information generated from this survey has been to determine fertilizer use on turf in North Carolina and then relate it to the potential nonpoint-source contributions from turf. Fertilizer use data were unavailable before this survey.

To determine total N application to urban turf, we first had to determine the amount of urban land use area for the entire state of North Carolina. We obtained land use data from the North Carolina Center for Geographic Information and Analysis. Urban area comprises 286 508 ha with 175 230 ha being high-density development and the remainder, 111 278 ha, being low-density development.

Not all urban areas are pervious nor is all the pervious area in turf. We assumed that 50% of the total urban area (143 254 ha) is turf. Based on our survey, we found that 70% of the turf was fertilized, so we assumed a 70% fertilization rate or 100 278 ha of fertilized turf. Because we had a range in N fertilizer use (0–155 kg N ha^{-1} year), we assumed an average N use of 111 kg N ha^{-1} yr^{-1}. This translates to a total application rate of 11.1×10^6 kg N yr^{-1} on urban turf in North Carolina.

Golf courses comprise another major turf area. During the debate on the sources of N into the Neuse River, golf courses were often cited as major contributors. A survey of the majority of the golf courses in the Neuse River basin was conducted (Osmond et al., 1999). Total N applied to all golf courses in North Carolina was determined to be approximately 2.6×10^6 kg N yr^{-1}, based on an estimated 550 golf courses with an assumed average size of about 60 ha per course. (Osmond et al., 1999). The average fertilizer N use is 77.6 kg N ha^{-1} yr^{-1} on each of the 60 ha. In reality some parts of the course are not fertilized while other parts are fertilized intensively.

In addition we determined N use on roadside turf in North Carolina. There are nearly 1.6×10^6 highway road kilometers within North Carolina. Not all these road kilometers are fertilized every year. Using numbers provided by the North Carolina Department of Transportation on the number of road kilometers fertilized annually, we estimated 30 000 km with approximately 6 m of roadside and/or median width, or 18 000 ha. The average N fertilization rate of roadside turf is 8.9 kg N ha^{-1} yr^{-1} or 1.6×10^5 kg N yr^{-1}.

Based on our statewide analysis, 13.9×10^6 kg N are applied to residential turf, golf courses, and roadsides each year in North Carolina. The accuracy of the original land use data and the assumptions on N fertilizer rates on turf affect the veracity of the estimates. These data, however, allow us to begin to estimate the relative proportions of fertilizer use for turf as compared with agricultural crops. Approximately 30.0×10^6 kg N yr^{-1} are applied to agricultural crops in the Neuse River basin alone. This assumes there is 4.9×10^5 agricultural ha in the Neuse River basin with an average N application rate of 56 kg N ha^{-1} yr^{-1}. Thus there is two times as much fertilizer used on agricultural crops in one river basin than used on turf in the entire state of North Carolina. The rate of N application on a per hectare basis, however, is greater for turf than agricultural crops.

In conclusion, the information collected in this door-to-door lawn care survey has allowed us to establish a targeted educational program to urban audiences. Five areas where the data suggested turf care improvements by homeowners are needed were as follows: timing of fertilizer applications, cleaning fertilizers from impervious surfaces, N fertilizer rates (especially for centipedegrass), selection of appropriate fertilizer analyses, and soil testing. There was little overfertilization of fescue by homeowners, although in the one community where we obtained data from lawn care industry, it appeared that there is overapplication of N fertilizer by lawn care providers. Centipedegrass was overfertilized more than was fescue. This appeared to be a function of mismatched fertilizers and grass types. Fertilizer distributors should match the fertilizer analyses they sell to the needs of the grass types. Fertilizer on impervious surfaces is of considerable concern since fertilizers are readily washed into storm drains during rainstorms and this drainage leads directly to streams. Educational messages have been focused on these areas. As an example, a 30-min television public-service stormwater announcement has just been released that, along with other topics, discusses managing fertilizers in urban areas.

Water use is currently being addressed through local ordinances. Due to the four-year drought (1998–2002), most communities throughout North Carolina are either restricting watering year round (such as Cary) or during summer drought episodes (summer 2002). With decreased watering comes a reduction in potential runoff. However, with drought, homeowners also need to be adjusting N fertilizer rates.

In addition to using the data to determine relative proportions of fertilizer used by the different land users, this survey has provided information for other uses. Recently the turf fertilization rate data were incorporated into the Sparrow model that is being used by U.S. Geologic Survey to partition N and P sources, in an attempt to meet some of the requirements for the Neuse River total maximum daily load requirement. As other total maximum daily loads are developed, this urban fertilizer use information will be of use to both the research and regulatory communities. For example, satellite data can be used both at the state as well as the river basin scale and would allow for basin-by-basin estimates of N fertilizer use on residential turf.

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