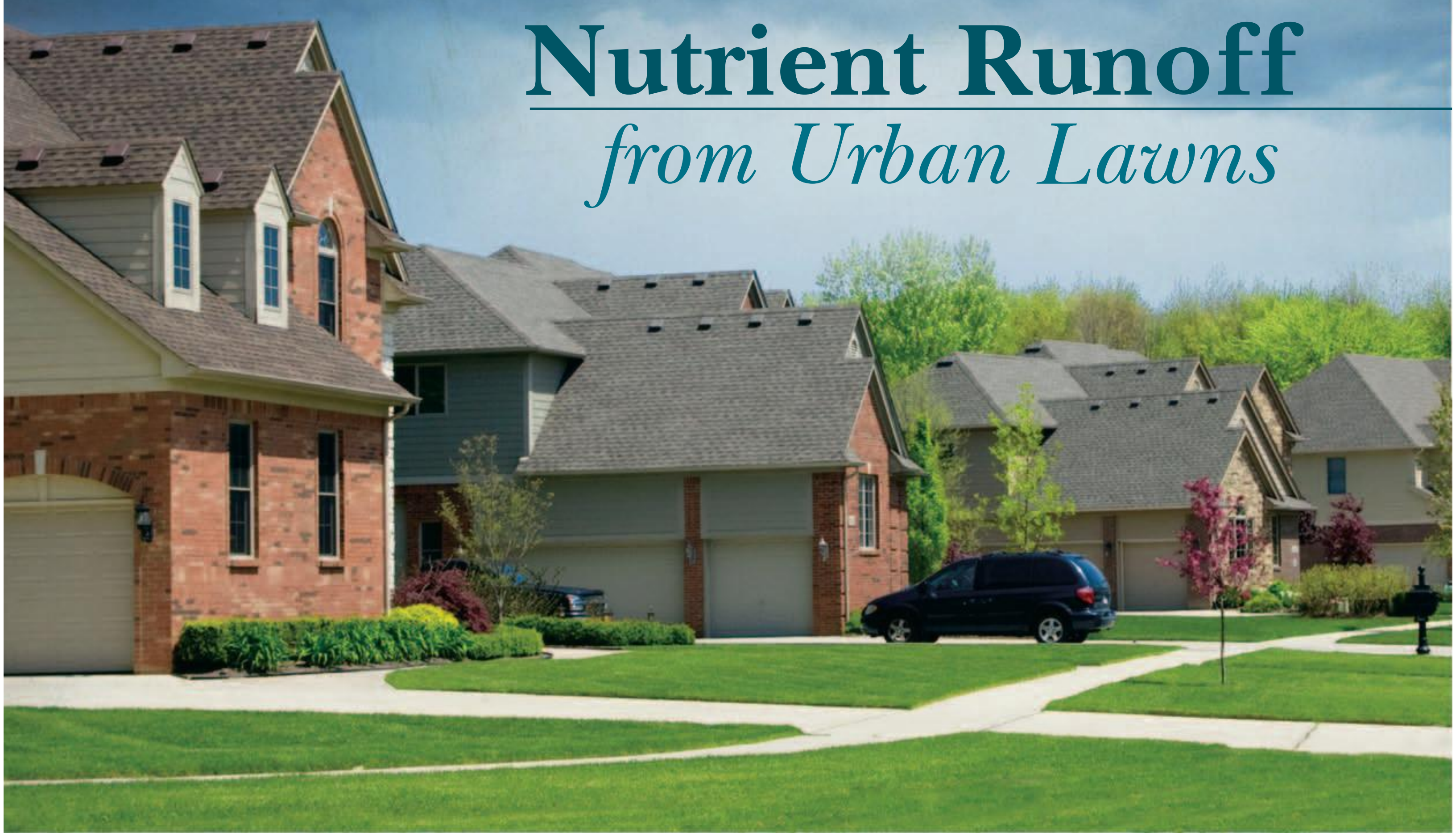
Nutrient Runoff from Urban Lawns



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The protection of groundwater and surface waters from nutrient contamination is an environmental issue and public concern. Specifically, nitrate (NO_3^-) and phosphates (HPO_4^{--}, $H_2PO_4^-$) continue to receive much attention. Urbanization results in more and connected, impervious surfaces (roads, parking lots, rooftops), fewer pervious ground covers (forests and fields), less water infiltration and greater runoff. As the volume of runoff increases, the potential for pollution of surface waters with nutrients, sediments and other compounds also increases.

In 2005, based on satellite imagery, total turf area in the U.S. was estimated to be 40.3 million + 9.6 million acres (Milesi et al. 2005). Lawns and roadsides account for the greatest and second-greatest amounts of managed turf, respectively. There are an estimated 70 million detached single-family homes nationwide (U.S. Census Bureau 2010). If the average home-lawn size ranges from 1/4 to 1/3 acre, this represents about 17.5 to 23 million acres.

Lawns are a highly visible and very important component of an urban environment. When properly sited, designed, installed and managed, they form a dense, perennial and erosion-resistant vegetative cover capable of absorbing carbon dioxide and water at low mowing heights. They also generate oxygen, cool the air in summer, trap dust and organic compounds (which are then degraded by soil microorganisms) and contribute organic matter to the soil.

The need for fertilizer

Soils in which turfgrasses are maintained seldom provide enough nitrogen (N) and may lack adequate phosphorus (P) or potassium (K) to support healthy lawns. As a result, supplemental granular or foliar applications of fertilizer containing N, P and/or K are often recommended. These three essential mineral nutrients vary in ionic, plant-available form and movement within soils (Table 1). A basic soil test performed in a soil-testing laboratory will determine soil phosphorus, potassium and pH levels. Fertilization and liming guidelines based on soil-test results most often accompany the soil test results.

Many people believe that lawn fertilization contributes substantially to nutrient runoff in urban areas. This perception has led to proposals to limit inputs and reduce the size of lawns. In an effort to reduce the amounts of suspended solids and nutrients in urban runoff and to comply with the U.S. Clean Water Act, some states and municipalities have enacted legislation restricting lawn fertilization. For example, in 2005, Minnesota became the first state to ban most turf applications of P-containing fertilizers. Michigan, North Carolina, Virginia, Washington and Wisconsin have, or are considering, enacting similar bans. In January 2011, New Jersey passed the most restrictive law (The New Jersey Fertilizer Law, A2290) to date, limiting applications of both N and P to lawns.

According to research conducted within the last 20 years, stormwater runoff from a healthy, dense lawn growing on soils of even moderate compaction and slope rarely occurs. In all but very intense rainfall occurrences, stormwater runoff from a healthy, dense lawn is at or near zero. Most notable exceptions include 1) very steep slopes, 2) saturated or 3) frozen soils and 4) severe soil compaction.

A research summary

This summary is based on a much more comprehensive article by Drs. Stier and Soldat, titled "Lawns as a Source of Nutrient Runoff in Urban Environments," published in the Fall 2011 issue of the *Watershed Science Bulletin*, journal of the Association of Watershed and Stormwater Professionals (the references cited below are listed on page 34).

- According to a three-year study conducted in the area of Baltimore, Maryland, N deposits from the atmosphere averaged 10 lbs. per acre, compared to 12.8 lbs. per acre from fertilizers, as potential inputs to the watershed (Groffman et al. 2004).

- Kentucky bluegrass and perennial ryegrass are able to absorb 70% to 80% of an application of 50 lbs. soluble N per acre within 24 hours and almost all of the applied N within 48 hours following application (Bowman et al. 1989).

- According to sales data, Scotts Miracle-Gro estimates that about 50% of U.S. homeowners fertilize the lawn (Augustin 2007). On average, the number of annual fertilizer applications of about 50 lbs. N per acre per application was 1.8, including an estimated 10 million lawns receiving professional lawncare treatments. This frequency of application of N is much lower than that usually recommended by most University Extension turf professionals.

- In 1999, it was estimated that the atmosphere deposits 0.36 lbs. P per acre per year (UN Environment Programme 1999).

- In Wisconsin, a conventionally recommended lawn fertilization program of 130 lbs. N per acre per year, using a 27:1.3 N:P fertilizer, would supply 6.2 lbs. P per acre per year. Researchers at the University of Wisconsin (Soldat and Petrovic 2008) found a range of 0 to 17 lbs. P per acre per year reported in turf field-plot research projects, with typical losses from established turf of about 0.4 lbs. P per acre per year. This compares to annual P losses from native prairies of about 0.18 lbs. P per acre, from conventionally tilled agricultural systems of about 1.69 lbs. P per acre and from construction sites of more than 11.5 lbs. P per acre (Daniel et al. 1979; Sharpley 1995).

- In many cases, runoff is reduced as the stand density of a lawn increases. The contiguous mass or matrix of aerial shoots of turfgrass plants creates a "tortuous pathway," slowing the flow of water and allowing greater infiltration (Linde et al. 1995; Kussow 2008). In one investigation conducted on a mixture of cool-season turfgrasses, runoff was reduced threefold when infiltration increased as shoot density increased in response to fertilization (Easton and Petrovic 2004).

- Returning clippings to the lawn as it is mowed does not appear to contribute to P runoff (Bierman et al. 2010).

- Surface roughness coefficients are commonly used by civil engineers to predict the potential of surfaces to contribute to overload water flow. High coefficient values reflect a potential for less runoff. In a simulated rainfall experiment, pavement had a low roughness coefficient (about 0.01); Short grass prairie, a value of 0.15; and both bluegrass and bermudagrass sod, a value of about 0.4 (Engman 1986).

- Most or all of the runoff from lawns can occur when soils are frozen or saturated (Kussow 2008; Steinke et al. 2007). A study evaluating the effect of prairie and turf buffer strips on runoff from concrete slopes revealed that a vegetative buffer twice the size of the sloped (5%) concrete area reduced annual runoff by more than 60%, compared to a 1:1 concrete-to-buffer design (Steinke et al. 2007). However, the 1:1 concrete-to-buffer design was effective, allowing less than 1.5% of precipitation to run off during non-frozen conditions. Most of the runoff from both prairie and turf plots occurred when soils were frozen, at which time runoff totals for both types of vegetation were similar.

- Many naturalized areas in a home landscape have a rough texture and are capable of retaining precipitation. A properly designed and sized, bermed rain garden (flat-bottomed depression planted with trees, shrubs and native veg-

Table 1. Symbol, Ionic Form and Relative Soil Mobility of Thirteen Essential Plant Mineral Nutrients.

Major Nutrient	Symbol	Ionic Form(s) Commonly Absorbed By Plants	Relative Mobility in Soil[1]
Nitrogen	N	NH_4^+, NO_3^-	NH_4^+ Immobile; NO_3^- Mobile
Phosphorus	P	$H_2PO_4^-$, HPO_4^{2-}	Mainly Immobile
Potassium	K	K^+	Somewhat Mobile
Calcium	Ca	Ca^{2+}	Mainly Immobile
Magnesium	Mg	Mg^{2+}	Immobile
Sulfur	S	SO_4^{2-}	Very Mobile
Micronutrient			
Boron	B	BO_3^{3-}	Mobile
Chlorine	Cl	Cl^-	Mobile
Copper	Cu	Cu^{2+}	Immobile
Iron	Fe	Fe^{2+}, Fe^{3+}	Immobile
Manganese	Mn	Mn^{2+}	Mobile
Molybdenum	Mo	MoO_4^{2-}	Somewhat Mobile
Zinc	Zn	Zn^{2+}	Immobile

[1] Soil texture, structure, pH, clay type and organic-matter content influence nutrient retention and/or plant availability in soil (Roberts 2000). For example, sandy soils usually hold fewer nutrients and have higher water-infiltration rates than soils high in clay (e.g., clay, clay loam, sandy clay and silty clay). The availability (solubility) of boron, copper, iron, manganese, phosphorus and zinc for uptake by plants is reduced in soils having a very high pH. Other nutrients (including calcium, magnesium, potassium and sulfur) are readily available for plant uptake from soils with a high pH. Montmorillonite clay is capable of holding more nutrient cations (positively charged ionic form) than illite or kaolinite. The nutrient-holding capacity of a soil most often increases as the organic-matter content increases.

etation) or turf swale can intercept flowing water before it reaches an impervious surface (Asleson et al. 2007; Schneider 2007).

- Soil compaction may contribute to runoff. A study of 15 lawns in central Pennsylvania revealed that a soil's condition, structure and history may be more likely to affect water infiltration rates in lawns than the texture (percent sand, silt and clay) of the soil (Hamilton and Waddington 1999). The researchers noted that the condition, structure and history of a soil are largely a function of construction practices before planting.

- Recent research in an upper Midwest lawn demonstrated that, in some cases and over time, the effect of pre-plant soil compaction on the rate of water infiltration may be less of a problem than perceived (Kussow 2008). A silt loam soil with a 5% slope was intentionally compacted using a vibratory roller before an additional 3 inches of silt loam topsoil was placed on top of the compacted area and either tilled or left in a layer before seeding Kentucky bluegrass. By year two of the study, runoff amounts from both compacted and non-compacted plots were similar (e.g., 1.2 to 1.5 inches of runoff annually from 25.2 total inches of annual precipitation).

- Core aerification of established turfgrasses growing in compacted soils can improve the speed at which water moves into soil (Partsch et al. 1993; Stier 2000). The growth of turfgrass roots, freezing and thawing of soil and the activity of soil macro-organisms, including earthworms, can also improve infiltration (Easton et al. 2005).

- The loss of sediment from healthy lawns is often very low (Soldat and Petrovic 2008) and is unrelated to the level of P in soil unless it is unusually high (Soldat et al. 2009). The small but consistent level of soluble P in runoff waters from turf probably originates from plant tissue (Soldat et al. 2009).

- When reactive P loss from unfrozen turf fertilized for three years with a high P:N (1:2) fertilizer was compared to reactive P loss from unfrozen turf receiving a low P:N (1:27) fertilizer, a K:N fertilizer and no fertilizer annually, a significantly greater reactive P loss (0.1 lb. P per acre) from turf receiving the high P:N fertilizer occurred in the first year only (Bierman et al. 2010). In the second and third years of the study, reactive P losses from non-fertilized turf were greater than those from any of the fertilized turfs. The researchers attributed this increase to limited density and higher runoff volumes compared to fertilized turfs.

Final thoughts

Runoff from lawns is typically 5% or less of precipitation if the soil is not saturated or frozen and the lawns are not maintained on severe slopes. Nutrient loads in runoff from urban areas appear to be directly related to runoff volume, which can be reduced by maintaining a dense lawn and, possibly, by creating swales of turf and/or bermed rain gardens between vegetated sites and paved areas designed to concentrate and funnel runoff into storm sewers or surface waters.

Nitrogen and P should not be applied to turfs when soils are saturated or frozen, or when turfgrasses are not actively growing or are dormant. Phosphorus should be applied in accordance with soil-test recommendations.

If turf is irrigated, water should not be allowed to "pool" on the lawn surface for long periods of time or to move onto impervious surfaces such as driveways, sidewalks and roads. Similarly, fertilizer granules lying on impervious surfaces after fertilizing should be brushed or blown back into the lawn.

References

Asleson, B. C., R. S. Nestingen, J. S. Gulliver, R. M. Hozalski and J. L. Nieber. 2007. The development and application of a four-level rain garden assessment methodology. Anthony Falls Laboratory Engineering, Environmental, Biological, and Geophysical Fluid Dynamics Project Report No. 501. University of Minnesota.

Augustin, B. 2007. Perception vs. reality: How much nitrogen do homeowners put on their lawn? Paper presented at the annual meeting of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, New Orleans, Louisiana, November 4-8.

Bierman, P. M., B. P. Horgan, C. J. Rosen, A. B. Hollman, and P. H. Pagliari. 2010. Phosphorus runoff from turfgrass as affected by phosphorus fertilization and clipping management. Journal of Environmental Quality 39:282–292.

Bowman, D. C., J. L. Paul, and W. B. Davis. 1989. Nitrate and ammonium uptake by nitrogen-deficient perennial ryegrass and Kentucky bluegrass turf. Journal of the American Society for Horticultural Science 114:421–426.

Daniel, T. C., P. E. McGuire, D. Stoffel, and B. Miller. 1979. Sediment and nutrient yield from residential construction sites. Journal of Environmental Quality 8:304–308.

Easton, Z. M., and A. M. Petrovic. 2004. Fertilizer source effect on ground and surface water quality in drainage from turfgrass. Journal of Environmental Quality 33:645–655.

Easton, Z. M., A. M. Petrovic, D. J. Lisk, and I.-M. Larsson-Kovach. 2005. Hillslope position effect on nutrient and pesticide runoff from turfgrass. International Turfgrass Society Research Journal 10:121–129.

Engman, E. T. 1986. Roughness coefficients for routing surface runoff. Journal of Irrigation and Drainage Engineering 112:39–53.

Groffman, P. M., N. L. Law, K. T. Belt, L. E. Band, and G. T. Fisher. 2004. Nitrogen fluxes and retention in urban watershed ecosystems. Ecosystems 7:393–403.

Hamilton, G. W., and D. V. Waddington. 1999. Infiltration rates on residential lawns in central Pennsylvania. Journal of Soil and Water Conservation 54:564–568.

Kussow, W. R. 2008. Management practices affecting nitrogen and soluble phosphorus losses from an Upper Midwest lawn. In: The fate of nutrients and pesticides in the urban environment, vol. 997, ed. M. Nett, M. J. Carroll, B. P. Horgan, and A. M. Petrovic, 1–18. Washington, DC: American Chemical Society.

Linde, D. T., T. L. Watschke, A. R. Jarrett, and J. A. Borger. 1995. Surface runoff assessment from creeping bentgrass and perennial ryegrass turf. Agronomy Journal 87:176–182.

Milesi, C., S. W. Running, C. D. Elvidge, J. B. Dietz, B. T. Tuttle, and R. R. Nemani. 2005. Mapping and modeling the biogeochemical cycling of turf grasses in the United States. Environmental Management 36:426–438.

Partsch, C. M., A. R. Jarrett, and T. L. Watschke. 1993. Infiltration characteristics of residential lawns. Transactions of the American Society of Agricultural and Biological Engineers 36:1695–1701.

Schneider, J. 2007. Urban rain gardens for controlling stormwater runoff and increasing groundwater recharge. MS thesis, University of Wisconsin–Madison.

Sharpley, A. 1995. Identifying sites vulnerable to phosphorus loss in agricultural runoff. Journal of Environmental Quality 24:947–951.

Soldat, D. J., and A. M. Petrovic. 2008. The fate and transport of phosphorus in turfgrass ecosystems. Crop Science 48:2051–2065.

Soldat, D. J., A. M. Petrovic, and Q. Ketterings. 2009. Effect of soil phosphorus levels on phosphorus runoff concentrations from turfgrass. Journal of Water, Air and Soil Pollution 199:33–44.

Steinke, K., J. C. Stier, W. R. Kussow, and A. Thompson. 2007. Prairie and turf buffer strips for controlling runoff from paved surfaces. Journal of Environmental Quality 36:426–439.

Stier, J. C. 2000. Lawn establishment and renovation. Extension Bulletin A3434. Madison, WI: University of Wisconsin.

U.N .Environment Programme. 1999. Planning and management of lakes and reservoirs: An integrated approach to eutrophication. International Environmental Technology Centre Technical Publication 11. Paris, France: UN Environment Programme.