CUTT

A Healthy Ecosystem

Concern about increasing pollution in suburban waters has raised questions about the contribution of differing land uses to surface water contamination.

Land-Use Effects on Water Quality

As suburban areas continue to grow in the majority of the United States, their role in water quality protection is of the utmost importance. Concern about increasing pollution in suburban waters has raised questions about the contribution of differing land uses to surface water contamination.

Suburban environments are composed of a mosaic of land uses from impervious surfaces like roads, parking lots, building rooftops, and sidewalks to pervious landscapes like parks, lawns, athletic fields, wooded areas, abandoned lots, cemeteries, and golf courses. It is unclear how and if these land uses detrimentally impact water quality. Therefore, the function of these areas must be studied in greater depth and more intensively to draw conclusions as to the role of suburban land uses in water quality and ecosystem function.

Nitrogen (N) and phosphorus (P) historically have been of primary concern in surface water bodies due to their roles as limiting nutrients for aquatic plant growth. In freshwater, N is generally not the limiting nutrient (however, it can be in costal estuaries), and tends to flush from the system relatively quickly, leaving P as the major limiting nutrient in freshwater surface supplies in the temperate Northeast. Phosphorus detected at the $\mu g\ L^{-1}$ level can cause eutrophication, and as a result impaired water quality. Recent work done by Owens, et. al. in the New York City watershed indicates that dissolved phosphorus (DP) levels as low as 0.024 $mg\ L^{-1}$ can cause the growth and subsequent proliferation of cyanobacteria. Frossard, et al. have shown DP to have a larger effect on eutrophication levels than particulate P.

Multifunction Land Use

Landscape performance is increasingly important in mixed land use areas such as suburban areas. The landscape is expected to function as a filter and reservoir for drinking water, filter storm runoff, and provide habitat and recreational benefits to residents. There is increasing scrutiny of how land uses impact the surrounding ecosystem. In these mixed land use watersheds, there are numerous sources of contaminants which can affect water quality. Some are clearly anthropogenic, and applied purposely, such as fertilizers and pesticides applied to home lawns, or deicing and traction enhancing materials applied to roadways. Some are anthropogenic, but not purposely applied, such as the volatilization and subsequent airborne deposition of pesticides, leaking hydrocarbons from an automobile or misapplication of fertilizers and pesticides to impervious surfaces. Some sources are natural, such as pollen deposition from trees, leaching of nutrients from plant tissue or airborne particulate deposition. The impact of each source on pollutant levels in surface waters is heavily dependent on the characteristics of each watershed. However,

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Cornell University Turfgrass Times
New York Greengrass Association
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Latham, NY 12110

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when numerous contaminant sources are subjected to high runoff losses inherent in developed areas, the impact on water quality can be great.

Land use and land cover within a suburban area can clearly influence nutrient runoff losses to surface water. Fertilization, construction, road debris, and plant matter can all introduce nutrients and sediments to surface water bodies. Forested areas, while generally unfertilized, can introduce nutrients to surface water by sediment erosion, through leaching of nutrients (especially P) from leaf litter, as well as pollen deposition either directly to water bodies or to the soil surface where the potential exists for transport via runoff.

Atmospheric deposition of nutrients via precipitation or dry deposition can often be significant and can contribute to surface water nutrient loading. Septic systems can also be a source of considerable contamination in many watersheds. In many suburban areas, high value landscapes (i.e. turfgrass, ornamentals, etc.) receive fertilizer application to maintain and promote growth. Fertilization on steep slopes or saturated soils can result in nutrient contamination of surface water. However, much research has shown that fertilization can increase plant biomass and density, ultimately reducing loss. Unmanaged or low maintenance landscapes (i.e. abandoned areas, minimally managed home landscapes) are a potential source of nutrients and particularly sediment loss. Runoff losses from these landscapes tend to be higher than from the more managed landscapes, due in part to reduced plant density and biomass which can reduce evapotranspiration and subsequent uptake of nutrients.

Nitrogen

Groffman, et al. report NO_3^--N losses from urban and suburban watersheds to be 10-20 times higher than from forested watersheds in the Baltimore, Maryland area. They identified residential developments as potential sinks for N due to the significant amounts of lawn present which have a high demand and uptake of N. Nearly 75% of the N input (dominated by fertilizer) was retained in the watershed. This is particularly intriguing considering that turfgrass areas are increasingly being considered as treatment sites for suburban storm water. Therefore, practices that promote infiltration and subsequent uptake by plants can provide significant biological remediation and storage for suburban nonpoint source pollutants.

Gold, et al. also found fertilized home lawns to be a potential N sink. In this Rhode Island study, N concentrations and leachate mass losses from home lawns and forests were identical. Over the two-year study, the average N concentrations were 0.21 mg L^{-1} and N mass losses were 1.35 kg ha^{-1} for both fertilized lawns and forest.

Phosphorus

Other research has shown that the mass of P lost to surface water (P loading rate) varies by site conditions (infiltration rate, rainfall intensity, soil moisture level), P application rate and source, and plant density, but is generally elevated in suburban areas which may be due to a number of sources. Waschbusch, et al. found that forested areas, roofs and streets all contributed significant amounts of P in water. Garn determined the concentration of N and P in runoff collected from four landscapes in Wisconsin: regular fertilized lawns, non-P fertilized lawns, unfertilized lawns, and unfertilized wooded sites. Of the analyzed data, DP concentrations were highest in the fertilized lawns receiving P applications.

However, the highest concentration of total P (TP) or DP in runoff water was from the unfertilized wooded sites, but the author excluded these data from the statistical analysis because they were unexpectedly higher than the lawn results and speculated that these sites may not be representative of other wooded sites because of steep slopes. The author estimated that lawns contributed about 1.14 kg $ha^{-1}yr^{-1}$ of P to the lake from the 89 ha of lawns sounding the lake.

Easton and Petrovic found annual P loading rates in turfgrass runoff to range between 0.2 and 1.3 kg ha^{-1} depending on fertilizer source and P application rate, with the highest loading from low density-unfertilized turfgrass. Linde and Watschke observed P loading in runoff ranging from 0.9 to 1.8 kg ha^{-1} yr^{-1}, the lower loading in runoff from the more dense bunch-type perennial ryegrass. Established St. Augustinegrass (*Stenotaphrum secundatum* Walt. Kuntze) was found to have a much lower N runoff than a landscape containing a newly established mixture of 12 species of shrubs, ornamental grasses, trees, and groundcovers, presumably due to less runoff production from the dense, established grass.

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Impervious areas prevent precipitation from infiltrating the soil, increase soil moisture levels and subsequently increase runoff and pollutant losses, particularly for compounds such as NO_3^--N, sediment and P.

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Urbanization

The increase in impervious areas associated with urbanization is considered a major cause of impaired water quality in many watersheds. Impervious areas prevent precipitation from infiltrating the soil, increase soil moisture levels and subsequently increase runoff and pollutant losses, particularly for compounds such as NO_3^--N, sediment and P. In Massachusetts the Quabbin Reservoir watershed provides water to 40% of the state's residents. Managers have identified urbanization as a major problem affecting water quality and are attempting to restore forest cover to previously developed areas to enhance water quality. Total P and total N concentrations in urban storm water flows were measured to be in excess of 9 and 18 mg L^{-1}, respectively. Morse et al. measured significant increases in NO_3^--N, total soluble salts and specific conductance, and a decrease in dissolved oxygen, as impervious areas in a watershed increased.

In a study of the Chesapeake Bay watershed, it was found that urbanization increased the freshwater input to the bay due to increased runoff losses. This runoff increased sediment, turbidity and eutrophication in the bay. Increased mass transport of dissolved solutes has been documented as a result of urbanization in the Philadelphia area. They report that the increases are dramatic and directly proportional to the amount of land urbanizing.

Other Factors

In many watersheds, however, the actual land use contribution is likely to be overshadowed by other factors such as landscape position. On temperate Northeast hill slopes there are generally significant gradients in soil particle distribution, depth to the water table or impermeable layer, and soil moisture levels. Since soil water generally follows the hydraulic gradient, water will tend to accumulate at the bottom of slopes, especially when the slope flattens. This causes the water table in these areas to be closer to the surface and more easily influenced by precipitation. In many of these areas the water table can rise to the soil surface causing runoff, even if the unsaturated infiltration rate of the soil is greater than the precipitation rate. This phenomenon, termed 'shallow through flow' coupled with finer textured soils can increase soil moisture levels dramatically at the bottom of a hill slope. Some studies have reported soil moisture differences of up to 35% between the top and bottom of a hill.

Easton and Petrovic report soil moisture differences of 20% between the top and bottom of a slope over a horizontal distance of only 70 m, and runoff losses differed by a factor of five between the bottom and the top of the hill slope. Impermeable or fragipan restricting layers are generally closer to the soil surface near the bottom of a hill slope. Convergence of this layer with the root zone is not uncommon and can have important implications for runoff and nutrient management. Impeded drainage and rapid saturation of the root zone can, in some cases (depending upon the depth), cause runoff losses orders of magnitude higher than in similar textured soil, which are not underlain by a shallow restricting layer.

Shallow depth to an impermeable layer coupled with clayey soils can promote runoff losses even in correctly managed landscapes. Roadways, parking lots and building roofs present a significant area of impermeable surface, which prevents runoff from infiltrating the soil, subsequently increasing the likelihood of

runoff. Similar to compacted, heavily trafficked soil in agricultural watersheds, compacted soil in many suburban areas may increase runoff losses as well.

Storm drains, sewers and gutters often drain directly into streams and or surface water bodies which can short-circuit the natural attenuation process provided by the soil. The combination of these factors can cause runoff losses from suburban watersheds to be orders of magnitude higher than from forested watersheds. In many suburban watersheds, storm runoff is generally the source of the greatest pollutant losses and these events tend to dominate flow from the watersheds. This is of concern because pollutants are less likely to be remediated by sorption to soil particles or organic matter or undergo biological uptake if they are first subjected to runoff processes.

Cornell Research

A study was conducted at Cornell to better understand how three different landscapes—high maintenance (HM), low maintenance (LM) and wooded (FR)—in a small suburban watershed affect stream flow nutrient losses via runoff. The study began by first measuring the effect of and differences between landscapes, then measuring the effect of the integrated suburban landscape on surface water, and correlating the individual contribution of each land use studied to stream water quality.

A 332 ha watershed in Ithaca, NY was selected, which is 40% developed. Runoff collected from 98 precipitation events and three landscapes was analyzed for dissolved P (DP), particulate P (PP), total P (TP), ammonium (NH_4^+-N), and nitrate (NO_3^--N), and mass losses calculated. Monitored landscapes included low (LM) and high (HM) maintenance lawns, and wooded (FR) areas. Stream gauges were installed at the stream entrance to the developed area and the watershed outlet to monitor the impact of the landscapes on stream water quality.

A multivariate analysis of the data revealed that the most important factor to consider when assessing water quality is the location of a landscape. Areas closer to the watershed outlet had an order of magnitude more runoff and higher nutrient losses than areas higher up in the watershed. Soluble nutrients (DP, N) were measured in higher concentrations from the HM landscape, but with the lower runoff losses measured in the fertilized landscapes, mass losses were not significantly different between the three landscapes.

Particulate P and TP concentrations and mass losses were highest from the FR landscapes due to little or no ground cover to prevent runoff. As the stream flowed through the developed area, there was an increase in DP, PP and TP concentrations and loads, higher flow rates under storm conditions and lower flow rates under dry conditions than the predominately forested upper watershed. N concentrations and loads were as high, and in many cases higher at the inflow to the developed area, than at the watershed outlet. A regression analysis of the individual landscapes on stream flow and nutrient loads has revealed a direct association between the landscape DP, PP and TP loads to the corresponding stream component. This is important because it indicates that reducing runoff or nutrient loads in the individual landscapes will reduce storm flows, or nutrient loads, in the stream. Ultimately, it is imperative to assess landscape performance under varying environmental conditions in order to reduce contamination of surface water.

Zachary Easton

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