Understanding the Environmental Impact of Landscape Maintenance

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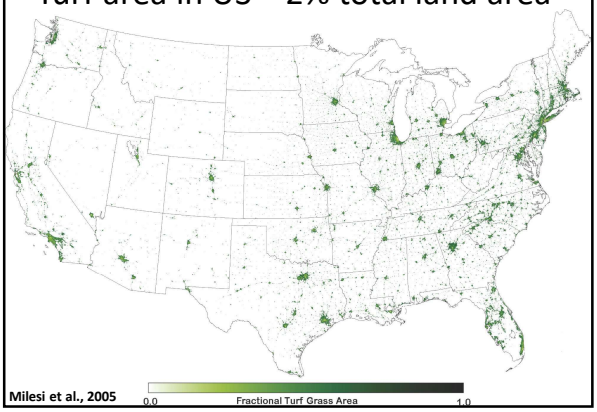
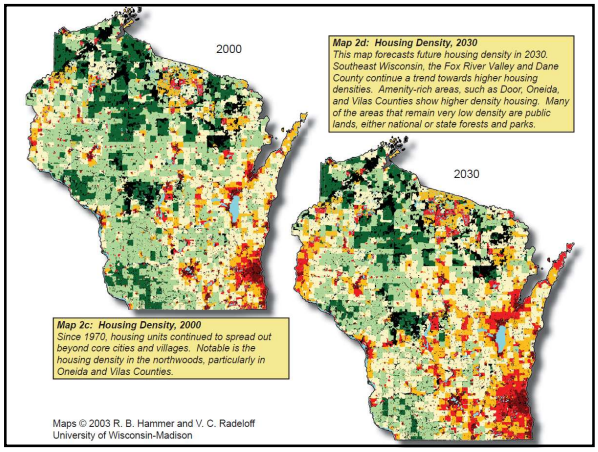
Turf area in US = 2% total land area



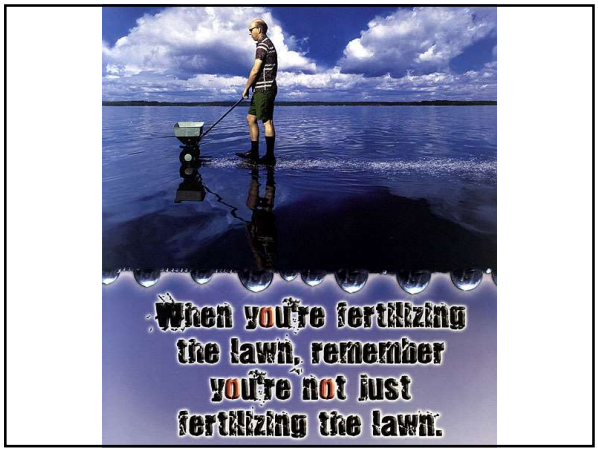
Milesi et al., 2005

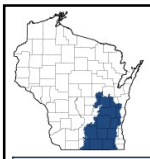


Map 2d: Housing Density, 2030
This map forecasts future housing density in 2030. Southeast Wisconsin, the Fox River Valley and Dane County continue a trend towards higher housing densities. Amenity-rich areas, such as Door, Oneida, and Vilas Counties show higher density housing. Many of the areas that remain very low density are public lands, either national or state forests and parks.

Map 2c: Housing Density, 2000
Since 1970, housing units continued to spread out beyond core cities and villages. Notable is the housing density in the northwoods, particularly in Oneida and Vilas Counties.

Photo credit: Gaylord Institute for Environmental Studies





Southeast Glacial Plains

USGS comparison of several urban and rural watersheds

Watershed	Sediment Load	Phosphorus Load
	kg/ha	kg/ha
Rural	Median: **113** Range: 15 - 6,000	Median: **0.50** Range: 0.07 – 3.2
Urban	Median: **455** Range: 60 – 1,600	Median: **0.56** Range: 0.23 – 2.1

Adapted from Corsi et al., 1997

Most turf studies find 3 – 16 kg/ha/yr
One TX study reported ~100 kg/ha/yr

Turf Watershed P Loss (kg/ha)	Reference
0.33	King et al. 2001
0.02 – 0.08	Winter and Dillon 2006
0.51	King et al. 2007
0.26	King and Balogh 2008

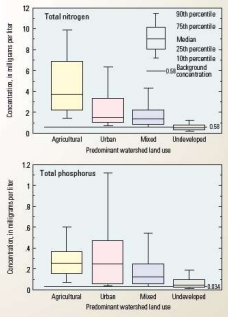
Adapted from Soldat and Petrovic, 2008

Occurrence and Distribution of Nutrients in Streams and Groundwater

Streams—Nutrients can occur naturally in water (referred to as "background"), but elevated concentrations usually originate from man-made sources, such as artificial fertilizers, manure, and septic-system effluent. All five nutrients studied—nitrate, ammonia, total nitrogen, orthophosphate, and total phosphorus—exceeded background concentrations at more than 90 percent of 190 sampled streams draining agriculture and urban watersheds.

Nutrient concentrations in streams are directly related to land use and associated fertilizer applications and human and animal wastes in upstream watersheds. Total nitrogen concentrations were higher in agricultural streams than in streams draining urban, mixed land use, or undeveloped areas, with a median concentration of about 4 mg/L—about 6 times greater than background concentrations. Nitrogen concentrations in agricultural streams generally were highest in the Northeast, Midwest, and the Northwest, which have some of the most intense applications of fertilizer and manure in the Nation. Concentrations in parts of the Midwest also are accentuated by artificial subsurface tile drains, which are used to promote rapid dewatering of poorly drained soils. Atmospheric deposition accounts for a significant portion of the nitrogen in streams in some relatively undeveloped watersheds, such as occur in the Northeast. Total nitrogen concentrations were lower in urban streams than in agricultural streams, with a median concentration of less than 2 mg/L, but still about 3 times greater than background concentrations. Some of the highest concentrations in urban streams were downstream of wastewater-treatment facilities.

Total phosphorus concentrations were highest in streams in agricultural and urban areas, with a median concentration of about 0.25 mg/L—about 6 times greater than background concentrations. Like nitrogen, high concentrations of phosphorus in agricultural settings are associated with high applications of fertilizers and manure. Urban sources may include treated wastewater effluent and septic-system drainage (in less urbanized settings), as well as runoff from residential lawns, golf courses, and construction sites.



Concentrations of total nitrogen and total phosphorus in streams.

Nutrients in the Nation's Streams and Groundwater: National Findings and Implications

Phosphorus is an urban problem, nitrogen is an agricultural problem.

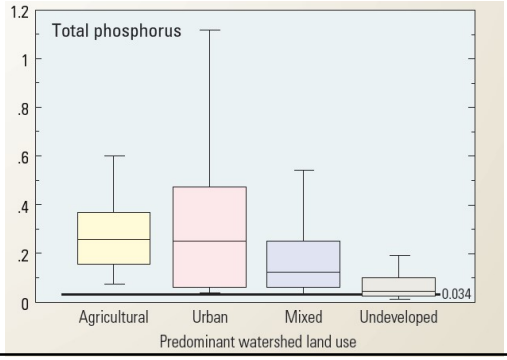
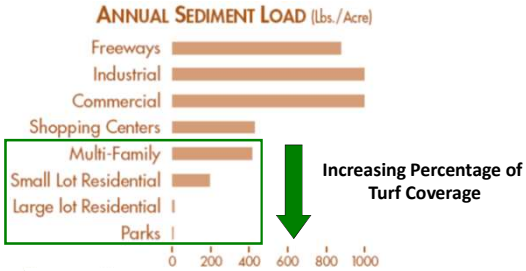


Photo credit: University of Nebraska

Urban Runoff Sources of Sediment

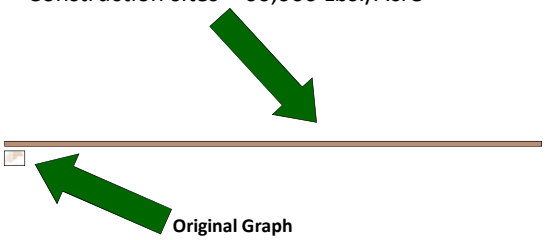
Construction sites = 60,000 Lbs./Acre



Source: UWEX, DNR
Polluted Urban Runoff: A Source of Concern

Urban Runoff Sources

- Construction sites = 60,000 Lbs./Acre



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http://www.sciencedaily.com/releases/2009/08/090817190741.htm

Water Quality Improves After Lawn Fertilizer Ban, Study Shows

ScienceDaily (Aug. 27, 2009) — In an effort to keep lakes and streams clean, municipalities around the country are banning or restricting the use of phosphorus-containing lawn fertilizers, which can kill fish and cause smelly algae blooms and other problems when the phosphorus washes out of the soil and into waterways.

But do the ordinances really help reduce phosphorus pollution? That's been an open question until now, says John Lehman, professor of ecology and evolutionary biology at the University of Michigan.

"It's one of those things where political organizations take the action because they believe it's the environmentally conscious thing to do, but there's been no evidence offered in peer-reviewed literature that these ordinances actually have a salutary effect," Lehman said.

The Huron River. In an effort to keep lakes and streams clean, municipalities around the country are banning or restricting the use of phosphorus-containing lawn fertilizers, which

University of Michigan Study
(Lehman et al., 2009)

- 36 mi^2 watershed in Ann Arbor, MI with a P ban vs. upstream watershed w/o P ban
- 5 kg/day P reduction (28%) **May – Sept** (other months not monitored)
  - Second year = 17% reduction
- "New P ordinance could have accounted for this reduction, but was a piece of a larger effort to reduce P runoff"

"The magnitudes of the TP reductions are generally greater than DP reductions, even though DP accounted for 56% (SE= 3%) of TP at all sites during the reference period and 60% (SE=3%) of TP in 2008. ***This suggests that the main effect has been reduction in the particulate P load of the river.***" Lehman et al., 2009

Construction differences?

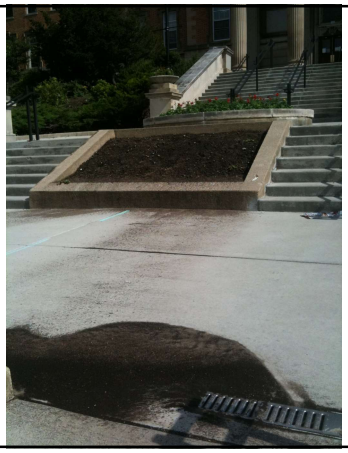
David Thompson
The Contractors Report

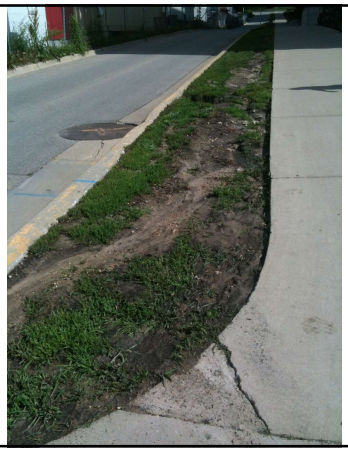
David Thompson
The Contractors Report

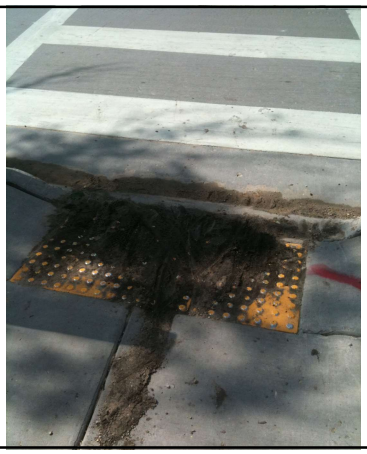
David Thompson
The Contractors Report

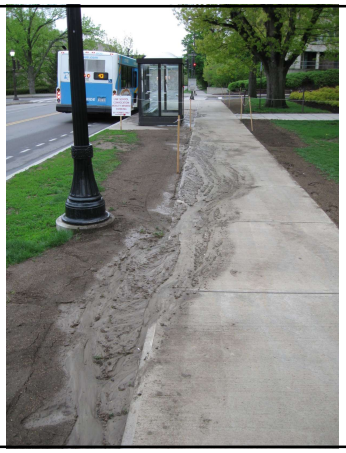
David Thompson
The Contractors Report

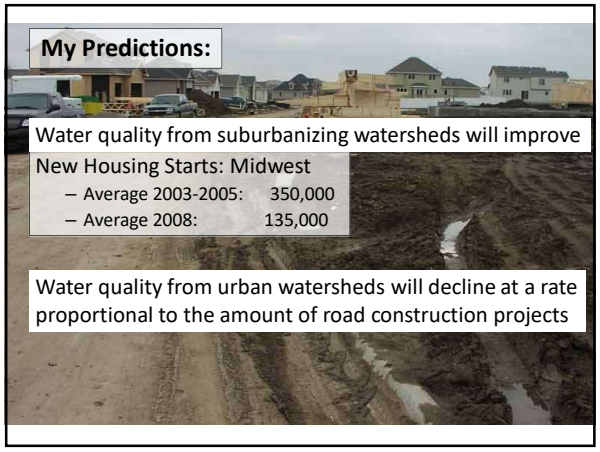
David Thompson
The Contractors Report











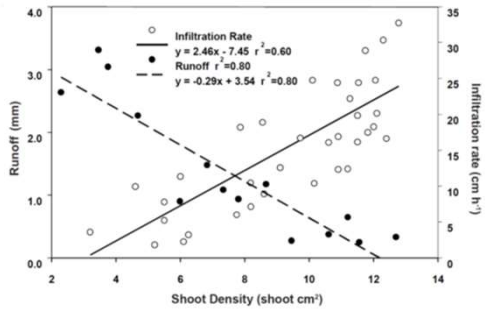


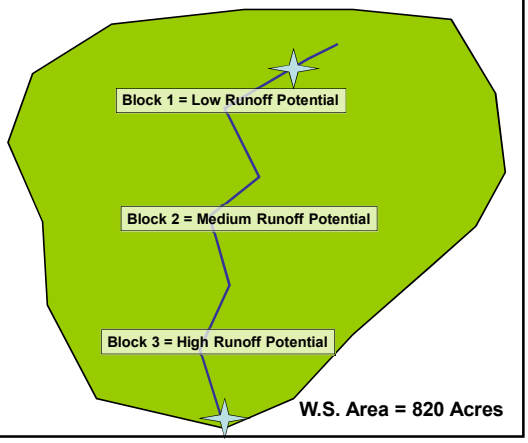
Figure 2. Effects of turfgrass shoot density on soil infiltration rate and runoff. Both infiltration and runoff were significantly affected by hillslope position.

P loss from urban watersheds

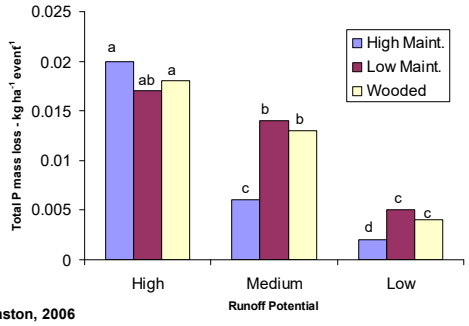
- Nine runoff collection plots installed on three landscapes

- Runoff collected from all (77) events >0.1 mm

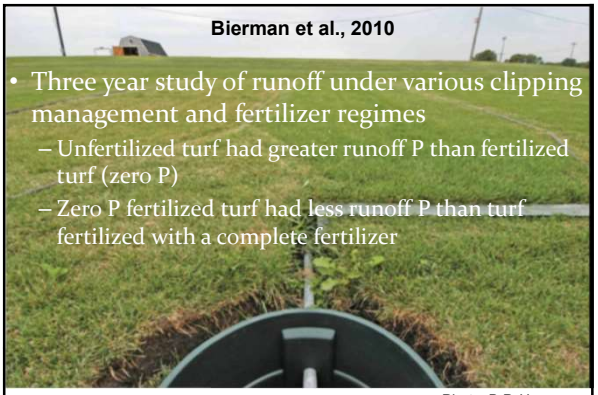
Easton, 2006



Runoff potential most important factor in predicting P loss



Easton, 2006



Bierman et al., 2010

- Three year study of runoff under various clipping management and fertilizer regimes
  - Unfertilized turf had greater runoff P than fertilized turf (zero P)
  - Zero P fertilized turf had less runoff P than turf fertilized with a complete fertilizer

Photo: B.P. Horgan

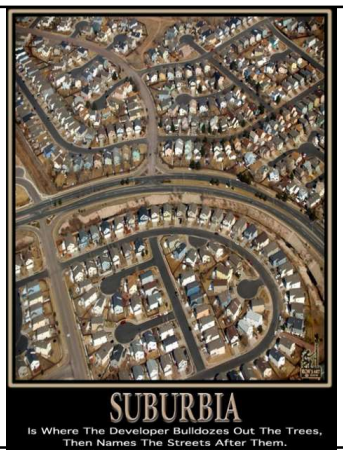
Tree Leaf Phosphorus

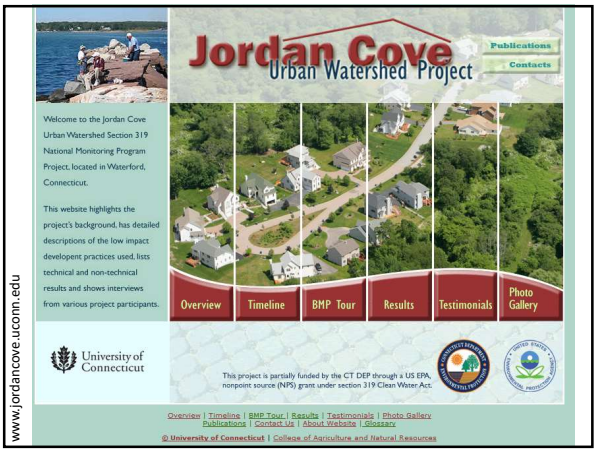
- P in street runoff (Waschuch et al., 1999)
  - Madison, WI
  - No trees = <0.1 ppm P
  - 80% tree canopy = 0.8 ppm P
- Weekly street sweeping ↓ P runoff by 42% (Shapiro and Pfannkuch, 1973, Univ. Minn.)

Storm Water Runoff, Lake Wingra, WI (Kluesner and Lee, 1974)

"This study indicated that the amount of runoff from the storm sewer basin could be accounted for by summing the area of streets in the basin (and in some cases driveways also). Thus, unless fertilizers were carelessly strewn on the impervious surfaces, it seems unlikely that the home gardener would be guilty of adding appreciable amounts of nitrogen or phosphorus to urban runoff with the types of soils found in Madison."

Kluesner, J.W., and G.F. Lee. 1974. Nutrient loading from a separate storm sewer in Madison, Wisconsin. J. Water Poll. Control Fed. 46(5):920-936.





Change in Mass Export (kg/ha/yr)

Parameter	Traditional Subdivision	Low-impact Design Subdivision
	% Change Compared To Control Watershed	
Total Kjeldahl N	+76,361***	-33*
Total Phosphorus	+46,582***	+249**
Total Suspended Solids	+64,323***	+85*
Copper	+8,900***	-50
Lead	+163	-79**
Zinc	+8,650***	-81**

*,**,*** indicate statistical significance at 0.05, 0.01, and 0.001 levels, respectively

Table 1. Costs comparisons of traditional development and BMP development, Jordan Cove watershed.

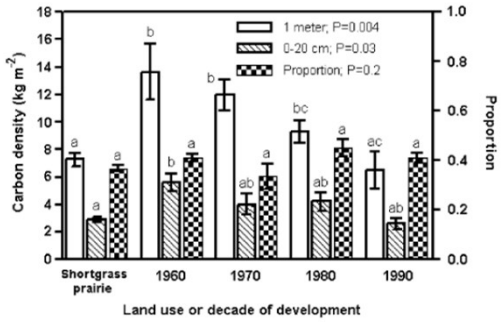
Activity	Traditional ($)	BMP ($)
Cul-de-sac bioretention	1,275	2,183
Driveway (asphalt)/lot	2,800	--
Driveway (paver)/lot	--	7,896
Erosion & sediment control/lot	322	625
Plantings	500	650
Planning and design/lot	401	808
Road and curb	23,494	102,500
Rain gardens/lot	0	575
Stormwater collection	7,770	3,600
	$36,562	**$118,837**

Dierkes et al.,2002

Carbon and Nitrogen

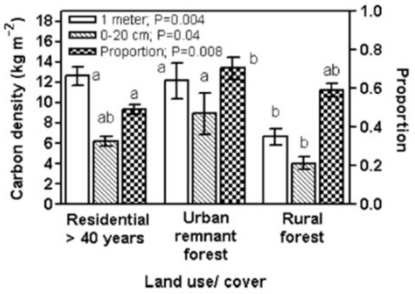
Source: Gaussoin and Shearman, 2003; Gaussoin et al., 2006

Denver, CO



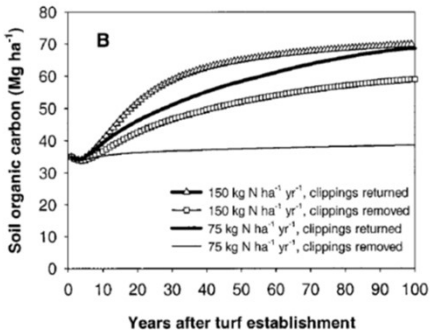
Pouyat et al., 2009

Baltimore, MD

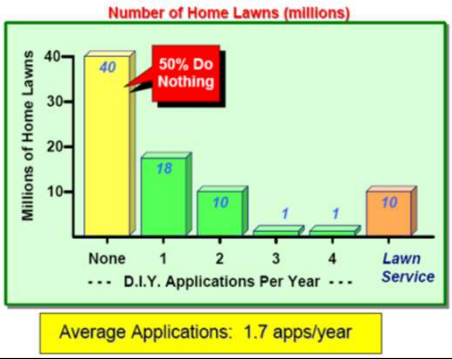


Pouyat et al., 2009

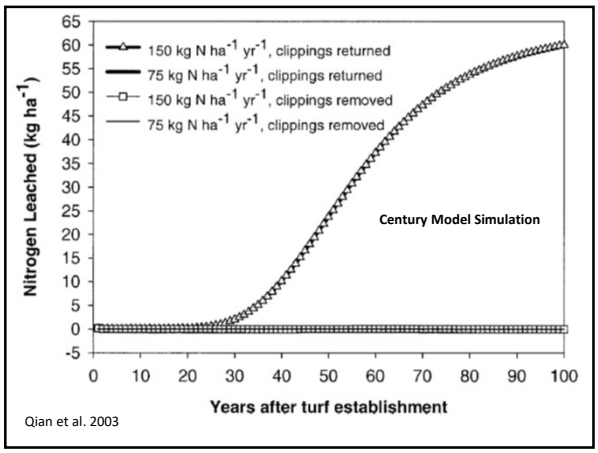
Qian et al. 2003: Long-term effects of clipping and nitrogen management in turfgrass on soil organic carbon and nitrogen dynamics



Home Lawn Care



Law et al. (2004): Average lawn in Baltimore receives 96 kg/ha annually (2 applications)



Qian et al. 2003

Baltimore Urban Ecosystem Study (Pickett et al., 2008)

"Lawns … have features that can increase N retention. For example, they have permanent cover and low soil disturbance, and they photosynthesize and take up water and nutrients for a much longer portion of the year than do forests or agricultural ecosystems. **Data from the Baltimore Ecosystem Study plots show that nitrate leaching and nitrous oxide flux from the soil to the atmosphere are not markedly higher in lawns than in forest.** Perhaps even more interesting, variation among the lawns was not related to fertilizer input. Nutrient cycling in lawns is complex, and the effects of lawns on water quality are probably less negative than anticipated."

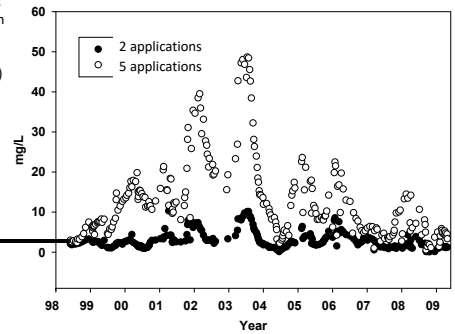
Often quoted line from an often quoted study:

- "Total leachate [nitrogen] recovery was 0.23% over the 2-yr period [1990-1991]… Whether the N was applied in the spring or late fall, rapid uptake and immobilization of the [applied nitrogen] resulted… A well-maintained turf intercepts and immobilizes [nitrogen] quickly making leaching an unlikely avenue of N loss from a turf system."

(Miltner et al., 1996)

Long-term turfgrass Leaching study from Michigan State

(Miltner et al. 1996)
(Frank et al. 2006)



90

Treatments initiated
Leaching reported minimal from both treatments for 1990-1991

Time for a Paradigm Shift?

- Ag model of N leaching = **catastrophic events** (lots of soluble N, low plant density, lots of rain, low soil organic N)
- **Soil nitrogen saturation** losses are the main concern for N in urban areas
  - Little soluble N, high plant density
  - Potential for high soil organic N
  - Soil test for N is plausible?

Baltimore Urban Ecosystem Study (Pickett et al., 2008)

"Lawns … have features that can increase N retention. For example, they have permanent cover and low soil disturbance, and they photosynthesize and take up water and nutrients for a much longer portion of the year than do forests or agricultural ecosystems. **Data from the Baltimore Ecosystem Study plots show that nitrate leaching and nitrous oxide flux from the soil to the atmosphere are not markedly higher in lawns than in forest.** Perhaps even more interesting, variation among the lawns was not related to fertilizer input. Nutrient cycling in lawns is complex, and the effects of lawns on water quality are probably less negative than anticipated."

TechCrunch

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Google Rents Goats To Replace Lawnmowers (I'm Not Kidding)

MG Siegler
May 1, 2009

Like 684 | Buzz 218 | Tweet 0 | 0 Digg | 209 Comments

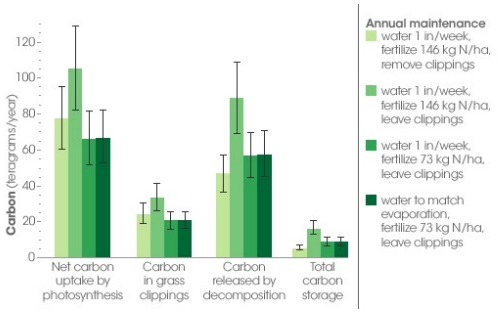
In what absolutely reads like an April Fools joke, Google has a **post** on its blog today explaining how it has rented a herd of goats to replace the lawnmowers that normally cut the grass in the fields around its headquarters. This is Google's "low-carbon" approach to maintaining its property.

Google is renting the goats from a company called **California Grazing**. Apparently, every so often a herder will bring about 200 of them to the campus and they'll roam around for a week eating the grass. Not only that, these goats will fertilize the land at the same time — yes, that way.

Google claims the goats will cost about the same as lawn mowers would. And a border collie named Jen will be brought onto Google's payroll to help with the herding as well, apparently. No word on how the maintenance workers who previously had this job feel about losing work to goats.

We've contacted PETA about the news (the first person I talked to initially chuckled), and they're going to get back to us with an official comment today.

Milesi et al., 2005



University recommendations lead to ~**10 teragrams/yr**

EPA says 800 million gallons of gas are burned each year in the name of lawn maintenance (**2.2 teragrams/year of carbon**)

- Carbon cost of fertilizer, water, NOx, Sox, carbon cost of equipment, etc?

Carbon sequestration and greenhouse gas emissions in urban turf

Amy Townsend-Small[1] and Claudia I. Czimczik[1]
GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L02707, doi:10.1029/2009GL041675, 2010

Figure 1:
Carbon sequestered vs. GHG's emitted in park turf maintenance in Irvine, CA

Townsend-Small, A. and C.I. Czimczik, 2010. Carbon sequestration and greenhouse gas emissions in urban turf. Geophysical Research Letters, vol. 37.
UC Irvine Dept. of Earth Systems Science

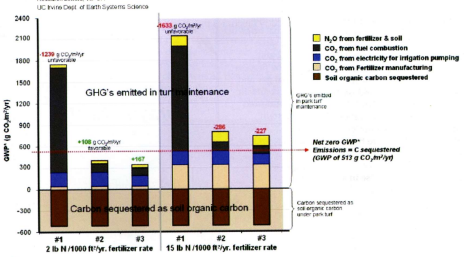


Figure 1:
#1 Original UC Irvine calculations with fuel error
#2 UC Irvine calculations with only fuel corrected
#3 Calculations with fuel use adjusted based on Toro data, and electricity use for irrigation adjusted based on Irvine ET
* Global Warming Potential (GWP) is expressed as grams of CO_2 equivalent emitted or sequestered per square meter of turf per year

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"It's unlikely for these lawns to act as net greenhouse gas sinks because too much energy is used to maintain them," Townsend-Small concluded.

Previous studies have documented lawns storing carbon, but this research was the first to compare carbon sequestration to nitrous oxide and carbon dioxide emissions from lawn grooming practices.

The UCI study was supported by the Kearney Foundation of Soil Science and the U.S. Department of Agriculture.

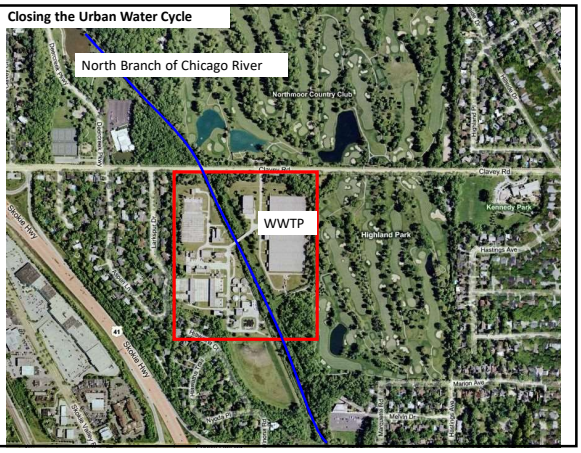
***Editor's Note**: The original version of the news release, distributed Jan. 19, has been updated here to reflect the correction of a spreadsheet error in the scientific paper regarding carbon dioxide emissions during lawn maintenance.*

- Automobile emissions control
- Consensus of scientists regarding

a greenhouse gas that's 300 times more powerful than carbon dioxide, the Earth's most problematic climate warmer.

the amount of carbon stored by ornamental grass in parks. (Credit: iStockphoto/Nicholas Campbell)

Closing the Urban Water Cycle



Wastewater treatment plant example

- Avg. daily discharge: 2.5 x 10^7 L
- TP concentration: 0.5 mg/L
- Daily TP Load: 12.5 kg (27.5 lbs)

- Avg. fertilizer contains 3% P_2O_5, or 1.3% P, equivalent of dumping 42 bags (50 lbs.) of lawn fertilizer into lake daily or 15,442 bags annually

www.warmus.com

Turfgrass as the solution to water quality?

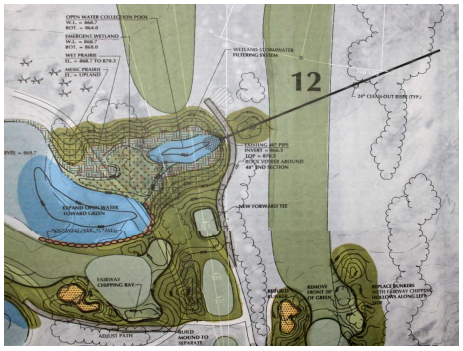
- Using wastewater as irrigation will reduce volume discharged into lake and therefore reduce P load

www.warmus.com

Alternative Irrigation Water Source Case Study

I-94 Runoff
(high salt and hydrocarbons)

Wetland Stormwater Filter
A Natural Solution



Summary

1. Some management in urban systems is often better for the environment than no management.
2. Phosphorus fertilizer is rarely required by turf, but I do not expect the phosphorus bans to noticeably affect water quality.
3. Nitrogen fertilization may be at a tipping point, and improved soil tests for more accurate recommendations are needed

Summary

4. Soil health and quality is tightly linked to water quality. We need to improve soil conservation and remediation practices in the urban environment.
5. Alternative energy sources will further improve carbon costs of lawn maintenance.
6. Water and irrigation management will be our greatest future challenge. Irrigating landscapes with potable water is (will be) indefensible.