Twin Cities
Household Ecosystem Project

Homeowner behaviors that affect nitrogen and phosphorus fluxes in household landscapes

Watershed District and Watershed Management Organization Report

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Table of Contents

List of Figures

List of Tables

About the Twin Cities Household Ecosystem Project

The Twin Cities Household Ecosystem Project (TCHEP) is an interdisciplinary project that examines the fluxes (flows) of carbon (C), nitrogen (N) and phosphorus (P) entering and leaving households in the Twin Cities in relation to the activities that create these fluxes and what influences those activities. The TCHEP project has collected detailed information from approximately 3,000 single-family, owner-occupied homes along an urban-to-rural gradient in Ramsey and Anoka Counties. Data were collected through a mail survey, by collecting household energy records, by analysis of GIS parcel data, and, for a subset of 360 homes, by direct measurement of trees on the properties of survey respondents. Data were analyzed using a computational tool, the "Household Flux Calculator", to estimate the fluxes of carbon (C), nitrogen (N), and phosphorus (P) for six major household activities: household energy use, auto travel, air travel, diet, and landscape management. We also asked respondents a suite of questions regarding demographics and about their attitudes towards specific activities.

Our goal is to estimate the fluxes of C, N and P through households based on the behaviors we measured, and understand what influences a household to perform certain behaviors. Ultimately, the results of this project will yield insights into activities that affect urban nutrient flows, as well as what the drivers are behind common household activities. These findings will be valuable to inform homeowners about the environmental impact of their choices and help policy makers in their efforts to mitigate this pollution and improve the quality of urban environments.

The TCHEP combines researchers from the University of Minnesota-Twin Cities in the Departments of: Ecology, Evolution and Behavior; Fisheries, Wildlife and Conservation Biology; Forest Resources; Soil, Water and Climate, and the Water Resources Center, as well as the University of California-Santa Barbara Department of Geography, all with an interest in urban ecosystems.

For publications, summary materials, and future plans see: **www.tchep.umn.edu**

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Executive Summary

Households are a key player in pollution management for urban ecosystems, as each homeowner functions as a separate decision-making unit influenced by multiple social and demographic factors. They can also bring a new focus to watershed management that could have a significant influence on the quality of our urban ecosystems. In the Twin Cities Household Ecosystem Project (TCHEP), we examine the fluxes (flows) of some common pollutants (carbon-C, nitrogen-N and phosphorus-P) entering and leaving households in relation to several of the primary human behaviors and what influences those behaviors. This report is a product of the TCHEP, an interdisciplinary study funded by the National Science Foundation and conducted by researchers at the University of Minnesota-Twin Cities and University of California-Santa Barbara. The overall study focuses on household behaviors relating to household member diet and physical activity, pets, energy consumption, lawn care and landscaping, management of household waste, transportation, and the attitudes behind some of these specific behaviors.

This report specifically focuses on household lawn care and landscaping attitudes and behaviors measured by the TCHEP among surveyed households in Ramsey and Anoka Counties. To make this information useful, we analyzed the data across four watershed districts (WDs) in this area (Capitol Region, Ramsey Washington Metro, Rice Creek and Coon Creek) and four watershed management organizations (WMOs) where we had sufficient sample sizes (Six Cities, Grass Lake, Vadnais Lake Area and Lower Rum River). Initial ideas for this report and its contents were guided by interviews conducted with several of the aforementioned WD/WMO staff during the summer of 2009. While the report is directed towards the WD/WMOs listed, these results are applicable to a wider audience, and could be beneficial for communities and organizations outside of Ramsey and Anoka Counties.

In this case, our goal is to help the WD/WMOs better understand homeowner landscape attitudes and behaviors in their respective districts in order to more effectively target education and programming towards landscape management that may negatively affect water quality. Household lawns have been estimated to cover approximately 872,660 acres in Minnesota (Meyer et al. 2001), and this number increased as more houses and their associated lawns, were built in subsequent years. The aggregated landscape management decisions of all of these households certainly have a significant influence on water quality.

Throughout this report, we discuss what the total N and P fluxes are through a typical household in Ramsey/Anoka County, look at the sources of landscape N and P fluxes to determine values of potential N and P losses from household lawns, identify important lawn management practices affecting these losses, explore a few influences of fertilization behavior and determine the management implications of these findings. Results demonstrate that there was variation in the amounts of potential pollution exiting households. For example, this disproportionality was seen in the case of household nitrogen fertilizer flux, which showed a skewed distribution where only 20% of the households contributed almost 70% of the total nitrogen fertilizer flux. Additional findings focus on six behaviors that influence household landscape N and P: choices of household pets, leaf raking, leaf disposal, lawn clipping disposal, choice to fertilize and frequency of fertilization.

Insights and Management Implications:

We provide the following insights and management implications from our findings, in order to help reduce negative effects that contribute to potential water pollution by improving our understanding and attitudes about these landscape decisions (See pg. 30 for a full discussion):

- **Targeting fertilization behavior can address potential N runoff and leaching**: roughly 50% of the households in our study normally fertilize their lawn and are likely or extremely likely to fertilize in the future. In addition, the majority of households also do not consider fertilization to be a likely contributor to water pollution. Therefore, since it has been shown that N runoff and leaching from household landscapes does in fact contribute to poor water quality, a message to homeowners needs to clearly link high fertilization rates with potential N runoff and leaching, as this is a behavior the majority of homeowners perform.
- **Targeting pet waste management can address excess P runoff:** waste from pets constituted 83% of the P input to the landscape in this study, and messages directed toward pet waste management could increase awareness about the potential contribution of pet waste to P runoff in winter and summer months.
- **There is a link between grass clipping management and fertilization that should be included in outreach material:** among the households that normally fertilized their lawns, 62% also left grass clippings on their lawns. Therefore, households may not be considering grass clippings as a source of recycled N on the landscape, and adjusting their fertilizing decisions.
- **WD/WMOs should maintain their relationships with area lawn service companies:** roughly 18% of households in our study normally hire lawn service companies to fertilize their lawn, and these companies tend to fertilize at relatively high rates of N addition.
- **Household yard waste decisions are linked:** homeowners that left their leaves on their property either by mulching, composting or adding to a garden, were more likely to also report leaving their lawn clippings on their lawn as well. Messages about integrated biomass management would serve the interests of these homeowners.
- **The dominant criteria for landscape vegetation choices were options that 'Create a Beautiful Yard' and are 'Easy to Maintain':** these criteria were the most cited reasons for landscape vegetation choices among homeowners in this area. These motivators should be considered when developing arguments for a particular yard management option that would improve water quality.

As household landscape decisions are quite varied and also very complex, water resource management staff have a difficult job on their hands as they work to encourage homeowners to make more environmentally friendly landscape choices. These staff members also have to deal with tight budgets, limited resources and an audience that varies in their landscaping behavior. Past studies have demonstrated the importance of considering a household's attitudes and behaviors surrounding their lawn management (Caraco et al. 1999, Peterson et al. 2009) to more effectively tailor their education campaigns as well as effectively design policy. If WD/WMOs in Ramsey and Anoka Counties can have a better understanding of how the homeowners in their respective areas are managing their lawns and why they are performing certain behaviors, staff can make the most of their limited resources and better target and tailor their outreach and education programs.

Introduction and Background

TCHEP estimates the “budgets” of carbon (C), nitrogen (N) and phosphorus (P) for a household: how much enters, how much leaves, and how much accumulates. We are also learning about the relationship of these budgets to household demographic characteristics, behaviors and what influences these behaviors. This report focuses only on the household fluxes associated with landscapes, namely the flows of N and P into and through the landscape. These fluxes are important because N and P can move into storm sewers in runoff, and from there be transported to lakes and streams. Excessive amounts of these nutrients cause eutrophication, which is characterized by increased algae growth (sometimes called “pond scum”). Eutrophication can reduce water clarity, cause bad odors, interfere with the food webs of lakes and streams, and reduce recreational enjoyment of waterways.

Households are important to the landscape nutrient cycling of N and P in urban ecosystems because homeowners make many individual decisions that can affect the fluxes of N and P. These decisions can be quite different among homeowners, resulting in variation in the amount of N and P pollution each household contributes to urban water bodies. For example, in addition to being affected by lawn size and soil type, N and P runoff from lawns is also affected by management practices such as vegetation selection, and irrigation and fertilization practices. This TCHEP report provides information about what these total landscape fluxes are through households in each WD/WMO in Ramsey and Anoka Counties.

Watershed districts (WDs) and watershed management organizations (WMOs) work to minimize nutrient inputs to surface waters. One way they do this is to increase individual homeowners' awareness of how their actions contribute to water quality. Many programs have been developed to educate and inform homeowners about the potential negative effects their landscape decisions can have on area water resources, using workshops, distributed information and targeted programming. To target programming and educational materials towards household behaviors affecting landscapes, it is necessary to have a good understanding of what lawn management behaviors matter the most to water quality and how household attitudes influence those behaviors.

Past studies have demonstrated the importance of considering a household's attitudes and behaviors when addressing their lawn management. In New England the New Hampshire Sea Grant Extension examined what motivates environmentally responsible landscape behavior in order to better design outreach programs aimed at “do-it-yourself” household lawn management (Peterson et al. 2009). They found that there was a significant lack of knowledge about the effect an individual household can have on water quality, but that homeowners were willing to accept more environmentally friendly lawn care practices. A similar survey conducted in the Chesapeake Bay area was used to investigate which household landscape behaviors contributed the most to poor water quality and which had the highest potential for behavior change (Caraco et al. 1999). Knowing this information, the study's goal was to help managers find the most effective educational messages to change these behaviors. This study found that many of the educational messages that homeowners found effective and useful were not ones that managers used. For example, homeowners cited television and newspaper advertisements as being the most prevalent ways they would like to receive information regarding pro-environmental watershed behavior. Water resource staff members, however, were using outreach programming in the form of educational and training workshops. This study therefore highlights the importance of not only understanding what the most prevalent behaviors in a watershed are, but also knowing the effectiveness of the educational programs that are aimed at these behaviors.

It is our hope that, as was the case with the studies described above, WD/WMO managers and staff in Ramsey and Anoka Counties will find the information from the TCHEP study helpful for enhancing their understanding of household landscape influences and behaviors in their respective areas. Ultimately, we hope that water resource managers will be able to use this knowledge when making management decisions regarding how to improve water quality.

Goals and Objectives

The goal of this report is *to inform watershed district/watershed management organization staff and citizens in Ramsey and Anoka Counties of the Twin Cities Household Ecosystem Project landscape findings and to discuss possible implications for improved nutrient management in order to further future partnerships with WD/WMOs in Ramsey and Anoka Counties.*

Specific objectives of this report to achieve these goals are to:

- Identify total N and P fluxes through a typical household in Ramsey/Anoka County,
- Examine the sources of landscape N and P fluxes and apply the TCHEP Household Flux Calculator to determine values of potential N and P losses from household lawns,
- Identify patterns in important lawn management practices that affect the fluxes of N and P on household landscapes,
- Explore a few influences/underlying attitudes of fertilization behavior, and
- Determine management implications from analysis of lawn management attitudes and behaviors.

Summary of Overall TCHEP Methods

In the TCHEP, we used a combined approach that incorporated a mailed survey, on-the-ground landscape measurements and models to obtain values for the major nitrogen (N) and phosphorus (P) fluxes through households; in this report we focus only on the landscape N and P fluxes. First of all, during the summer of 2008, a 22-page survey (Nelson et al. 2008; Appendix A) was sent to 15,000 randomly selected households in Ramsey and Anoka Counties along an urban to rural gradient and randomly distributed proportional to housing density. The survey asked questions regarding household behavior including household member diet and physical activity, household energy consumption, lawn care and landscaping behavior, household waste behaviors, transportation, attitudes about specific behaviors, and demographic variables about the household. The figures below show the locations of our survey respondents with respect to housing density (Figure 1), and the locations of our survey respondents with respect to WD/WMO boundaries (Figure 2). We also determined the number of survey participants for each of the respective WD/WMOs (Table 1).

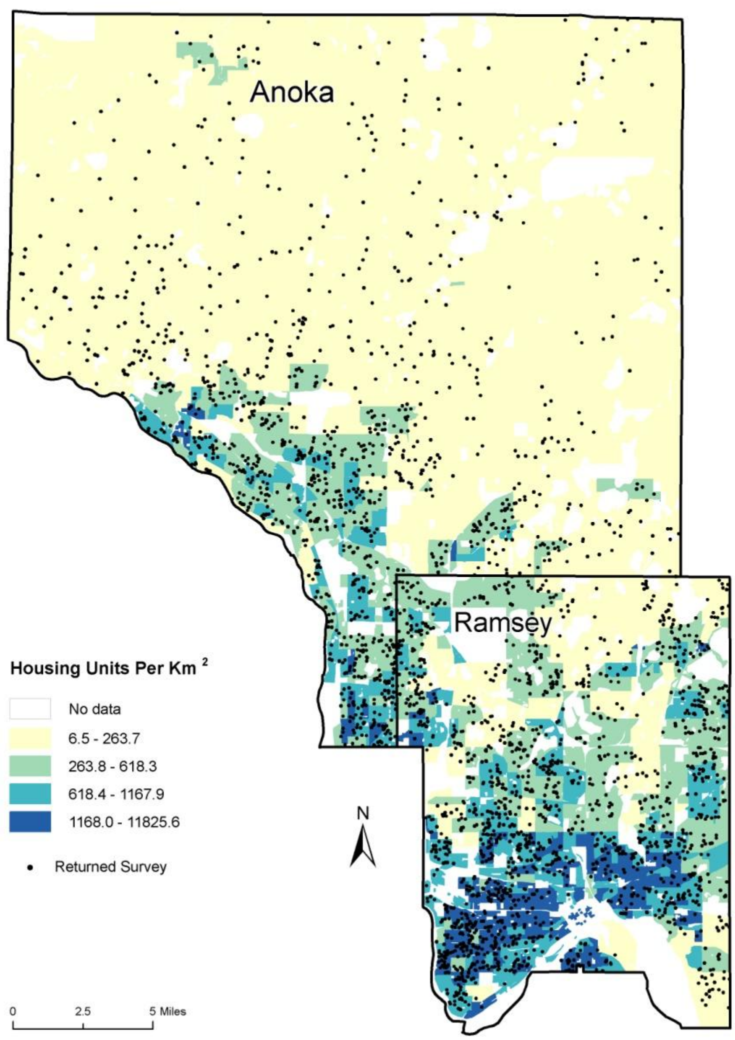

Figure 1: Location of household survey respondents (2008) and housing density (2000), Ramsey and Anoka Counties, Minnesota, (n = 2786). *Points have been geomasked to protect the privacy of respondents.

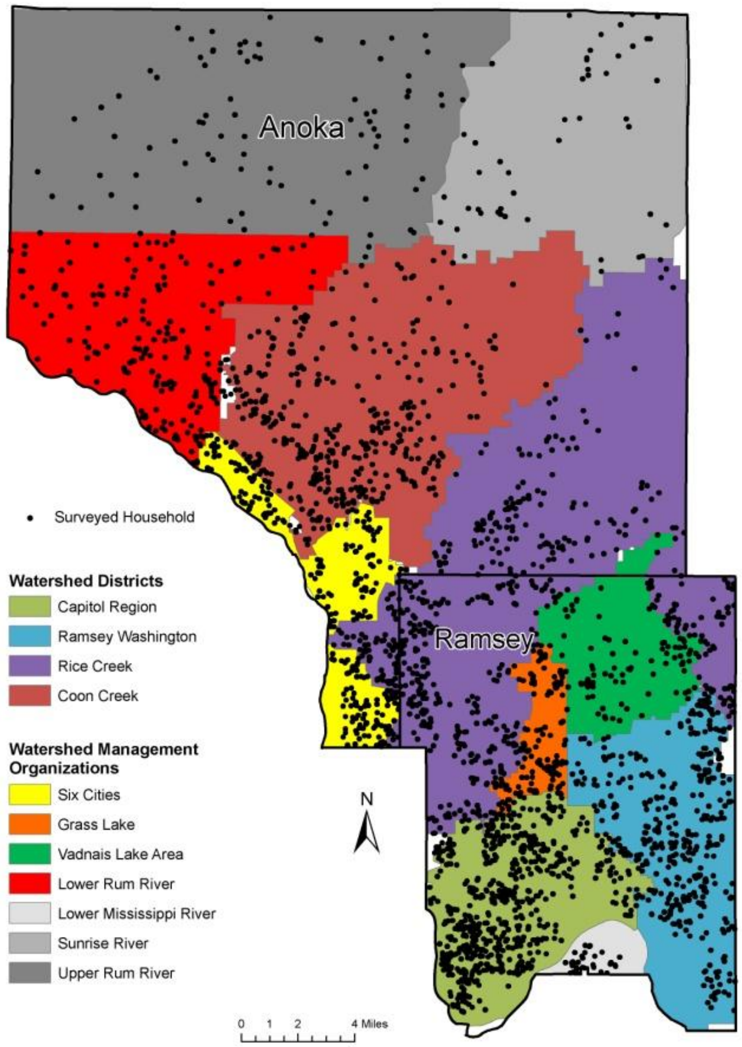

Figure 2: Location of household survey respondents and Watershed District/Watershed Management Organization boundaries, Ramsey and Anoka Counties, Minnesota, (n = 2786), 2008. *Points have been geomasked to protect the privacy of respondents.

Table 1: Number of household survey respondents from each Watershed District/Watershed Management Organization, Ramsey and Anoka Counties, Minnesota, 2008.

	# of Survey Respondents
Ramsey and Anoka Counties	2795
WDs	
Capitol Region	599
Ramsey Washington Metro	389
Rice Creek	588
Coon Creek	372
WMOs	
Six Cities	234
Grass Lake	128
Vadnais Lake Area	86
Lower Rum River	173
Additional WMOs*	
Lower Mississippi River	32
Sunrise River	45
Upper Rum River	87
Mississippi River	8
Orphan	13
Valley Branch	3
Other**	38

*Additional watershed management organizations not included in the analysis of this report due to small response number from these areas.
**Households not listed within WD or WMO in parcel data

Second, we received signed permission from 2101 respondents to obtain their home energy records and have energy information for 1850 of those respondents. Third, we conducted landscape measurements at 360 households willing to let researchers visit their property to survey vegetation. Finally, we obtained "parcel" databases for households in Ramsey and Anoka Counties, which includes information such as age and size of home, value of the property, size of lot, etc. These different sources of information were then included to form three different sample sizes for the main TCHEP study (Table 2). All of the above data sources were used as inputs to a computational tool developed by project members called the "Household Flux Calculator," which quantifies the fluxes of C, N and P through the households of our study.

Table 2: Description of household survey respondent sample sizes and four data sources, Ramsey and Anoka Counties, Minnesota, 2008.

	n = 360	n = 1850	n = 2795
Site Vegetation Survey	X		
Energy Records	X	X	
Full Mail Survey and GIS Parcel Data	X	X	X

For more information about further TCHEP methods, the "Household Flux Calculator", and key assumptions made, please see Appendices B, C, and D.

Respondent Characteristics

Table 3a: TCHEP survey respondent characteristics, Watershed Districts, Ramsey and Anoka Counties, Minnesota, 2008.

		Ramsey and Anoka Counties	Capitol Region	Ramsey Washington Metro	Rice Creek	Coon Creek
	Sample Size (n)	2795	599	389	588	372
Respondent	**Gender**					
	Male	59.5%	51.1%	64.6%	59.6%	63.7%
	Female	40.5%	48.9%	35.4%	40.4%	36.3%
	Average Age	55.9	55.1	57.1	56.3	53.5
	Race					
	White	95.0%	94.0%	94.8%	96.0%	96.2%
	Person of Color	5.0%	6.0%	5.2%	4.0%	3.8%
Household	**Income (k = thousands)**					
	Under $30k	9.8%	9.1%	10.1%	8.3%	7.0%
	$30k - $49k	15.4%	15.6%	22.0%	13.7%	14.3%
	$50k – $74.9k	20.3%	19.2%	25.8%	19.1%	18.7%
	$75k - $99.9k	21.2%	19.0%	17.7%	21.3%	24.5%
	$100k - $149.9k	20.7%	24.0%	13.0%	24.4%	22.4%
	$150k - $199.9k	7.6%	7.2%	7.8%	8.3%	9.0%
	$200k - $249.9k	2.4%	3.2%	0.9%	2.7%	1.5%
	$250k - $299.9k	1.1%	1.6%	0.9%	0.8%	0.6%
	$300k or more	1.4%	1.1%	1.7%	1.4%	2.0%
	Average # of Household Members	2.53	2.52	2.39	2.51	2.82
	Average # of Years Owned	20.0	19.9	21.6	20.9	16.0

Table 3b: TCHEP survey respondent characteristics, Watershed Management Organizations, Ramsey and Anoka Counties, Minnesota, 2008.

		Ramsey and Anoka Counties	Six Cities	Grass Lake	Vadnais Lake Area	Lower Rum River
	n =	2795	234	128	86	173
Respondent	**Gender**					
	Male	59.5%	58.0%	64.6%	61.2%	60.1%
	Female	40.5%	42.0%	35.4%	38.8%	39.9%
	Average Age	55.9	58.5	59.7	58.8	55.8
	Race					
	White	95.0%	93.5%	97.6%	95.2%	94.8%
	Person of Color	5.0%	6.5%	2.4%	4.8%	5.2%
Household	**Income (k = thousands)**					
	Under $30k	9.8%	18.9%	4.5%	6.2%	6.9%
	$30k - $49k	15.4%	15.2%	12.7%	11.1%	15.6%
	$50k – $74.9k	20.3%	23.0%	14.5%	14.8%	25.0%
	$75k - $99.9k	21.2%	21.7%	20.9%	14.8%	28.1%
	$100k - $149.9k	20.7%	15.2%	25.5%	25.9%	11.9%
	$150k - $199.9k	7.6%	4.1%	14.5%	9.9%	5.6%
	$200k - $249.9k	2.4%	0.9%	2.7%	8.6%	5.0%
	$250k - $299.9k	1.1%	0%	1.8%	4.9%	0.6%
	$300k or more	1.4%	0.9%	2.7%	3.7%	1.3%
	Average # of Household Members	2.53	2.27	2.51	2.53	2.62
	Average # of Years Owned	20.0	23.5	23.9	23.1	17.8

Results

In the following sections, we present the results of our study that are relevant to household landscaping and consequently to potential stormwater pollution. We first show the percent of total household nitrogen (N) and phosphorus (P) fluxes that are due to landscape activities and management, including the average values for these N and P inputs as well as the range from the participants in our study. We give particular emphasis to the fluxes of N and P through the landscape that could contribute to N and P available for runoff, seepage or, in the case of N, denitrification.

We then provide information on the household choices that affect the fluxes of N and P through the landscape (household pets, leaf and lawn clipping management and fertilization practices) and compare these behaviors across the Watershed Districts (WDs) and Watershed Management Organizations (WMOs). Finally, we focus on the main influences that guide a household's lawn behaviors: preferences of vegetation choice and attitudes towards fertilizer application. Attitudes towards fertilization include beliefs about the advantages (lawn greenness and attractiveness) and disadvantages (time and water pollution) of fertilization and fertilization intent. Fertilization intent is also compared to the participant's claim to fertilize in order to determine the effect intent has on actual fertilization behavior.

A Few Organizing Principles

There are three main organizing principles for this section of the report. First, all figures for WDs and WMOs are presented separately for ease of reading and comparison among organizations of similar structure. Within these graphs, WD/WMOs are organized by increasing average property size (Table 4). Finally, hereafter in this results section, anytime the term "household" is used, we are referring to the respondent households from our 2008 TCHEP survey.

Table 4: Average lawn and property sizes for WD/WMO survey respondents, Ramsey and Anoka Counties, Minnesota, 2008.

	Average Lawn Size (ft^2) *(n = 360)*	**Average Property Size (ft^2)** *(n = 2787)*
Ramsey and Anoka Counties	15680	30014
Watershed Districts		
Capitol Region	5610	7617
Ramsey Washington	8325	12379
Rice Creek	14019	29970
Coon Creek	21396	35646
Watershed Management Organizations		
Six Cities	9399	11706
Grass Lake	11096	14841
Vadnais Lake Area	26064	29707
Lower Rum River	37888	70752

Nitrogen & Phosphorus Fluxes

Inputs of Nitrogen and Phosphorus to a Household

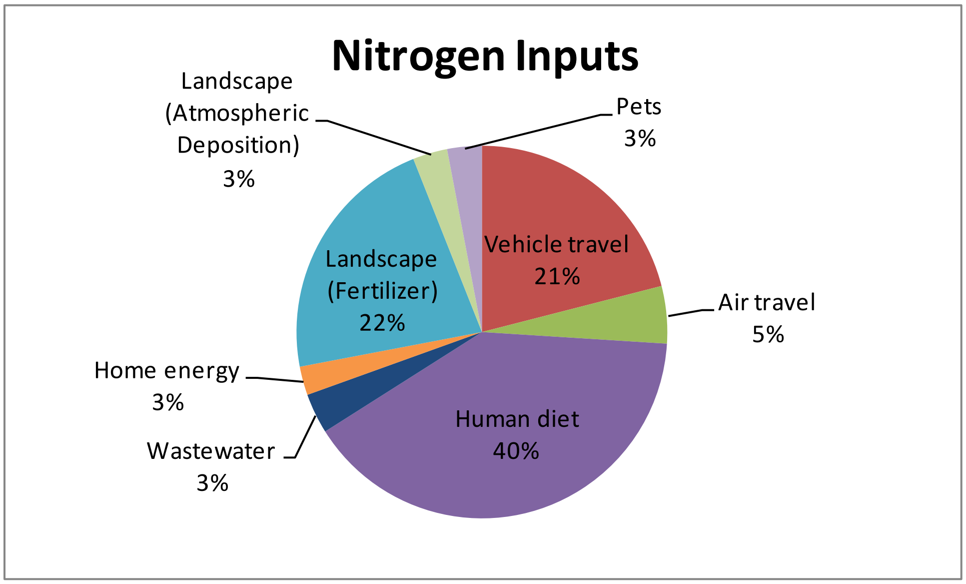

Figure 3: Household nitrogen inputs, Ramsey and Anoka Counties, Minnesota, (n = 360), 2008.

Our results show that 25% of the total nitrogen that enters a typical household enters via the household landscape (Figure 3). This input is second only to nitrogen that enters the household via the human diet.

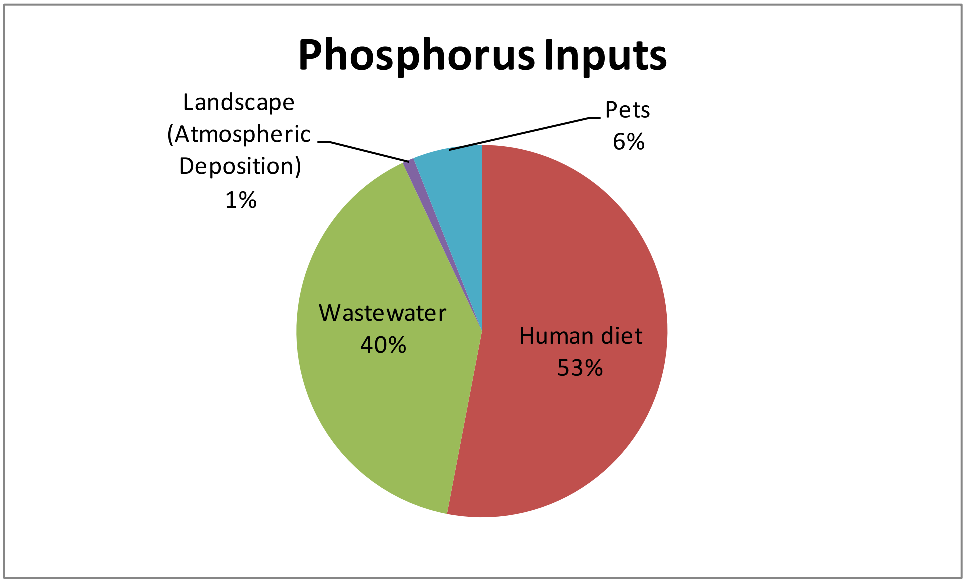

Figure 4: Household phosphorus inputs, Ramsey and Anoka Counties, Minnesota, (n = 360), 2008.

Because of the statewide phosphorus restriction for lawn fertilizer, phosphorus entering the household via the landscape and pets is a smaller proportion of the total phosphorus flux (Figure 4). Human diet is again the biggest contributing factor of phosphorus inputs to a household.

Fluxes of Nitrogen and Phosphorus into and through a Household Landscape

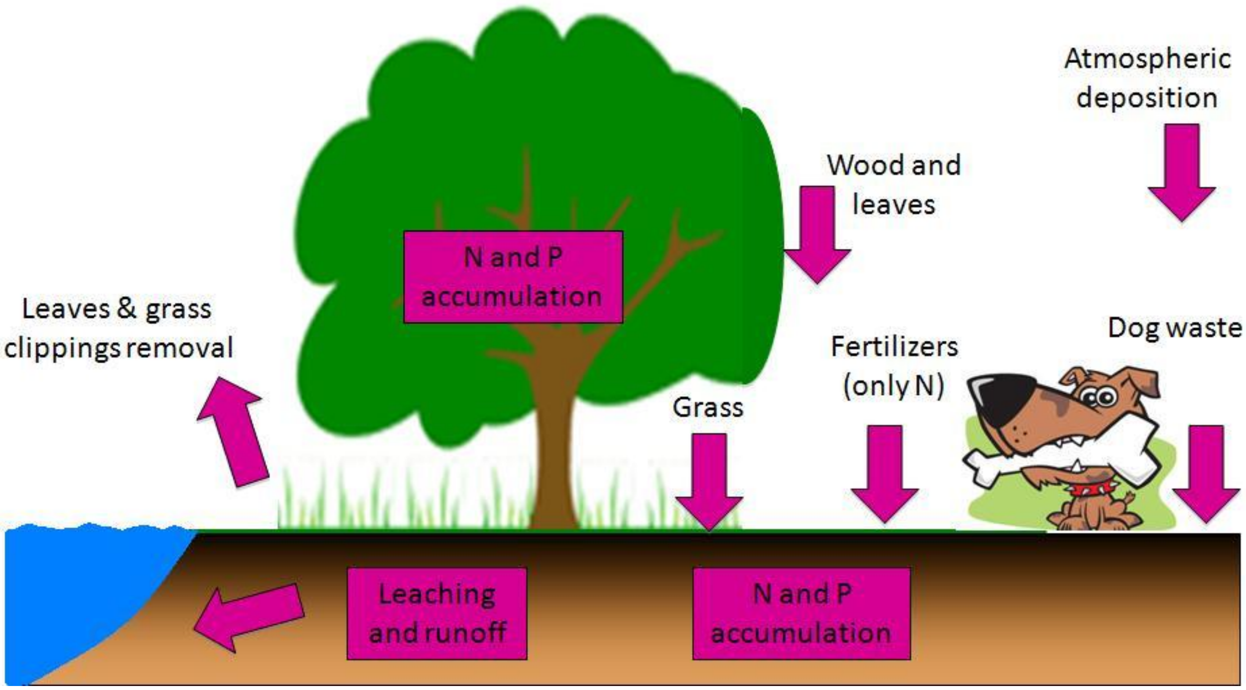

Figure 5: Fluxes of nitrogen and phosphorus into and through a household landscape, TCHEP, 2008.

Nitrogen enters/exits the household landscape in many different ways (Figure 5). On average, landscape pet waste accounted for 9% of N input to household landscapes, atmospheric deposition accounted for 11%, and fertilization accounted for 80%. Within the landscape, N is recycled by grass clippings and literfall (tree leaves and branches) if these are left on the lawn to return nutrients to the soil. If litter and grass clippings are removed they represent losses of N from the household landscape.

Nitrogen can accumulate in lawns and trees, especially if yards contain lots of growing trees and if soil organic matter is increasing because organic inputs to the soil from plants exceed decomposition. If N is present in excess of what plants and soils can accumulate, it can also leave the lawn in one of three ways: (1) in runoff to streets and storm sewers, (2) as N gasses (e.g., NO, N_2O, N_2), that are formed in a process called denitrification, and (3) as leaching to groundwater. When excess N leaves a lawn in runoff, it flows into storm sewers, and from there, to streams and lakes. Addition of N (and P) from lawns contributes to eutrophication of these waters, characterized by decreased clarity, and increase in undesirable algae (pond scum), and, when extreme, poorer fishing.

Inputs of P to household landscapes come from wet and "dry" (dust) atmospheric deposition (17% of the total) and pet waste (83% of the total). We assumed that no P entered the landscape through fertilizer application, since the application of P fertilizer is restricted under the Minnesota Phosphorus Lawn Fertilizer Law enacted in the Twin Cities region in 2002 (MN Department of Agriculture 2007).[1] We know, however, that this assumption is not quite true. A 2007 report "Effectiveness of the Lawn Phosphorus Fertilizer Law", written by the Minnesota Department of Agriculture found that statewide

[1] These restrictions are not required for trained golf course sod farms, and also exempt the establishment of new turf or if a soil test shows the need for additional phosphorus (MN Department of Agriculture 2007).

use of lawn P fertilizer decreased from 292 tons of P in 2003 (before the law was passed) to 151 tons in 2006 (after the law was passed), a decrease of 48%. However, because many people had started reducing their use of P fertilizers before the P law was passed, the actual use of lawn fertilizer P was quite low by 2006. The reported 151 tons of lawn fertilizer P sold, if distributed equally across 780,000 acres of turf in Minnesota, would account for only 0.01 lb P/1000 ft^2, a very low rate.

As with N, phosphorus taken up by plants is returned to soils in the form of grass clippings and tree leaves if these stay on the property (mulched or composted). Phosphorus can also accumulate in the landscape in soil and trees, can be removed from the lawn in leaves and grass clippings, and can exit the lawn via runoff, erosion, or leaching. The amount of P in runoff is related to the amount of available P in soils (soil "test" P), so as stores of P become depleted over time after P fertilizer use is discontinued, the amount of P in runoff should decrease. This depletion occurs because grass and other plants take up available soil; some of this P may be lost via runoff as plants decompose. For soils with high levels of available P, this depletion may take many years.

A small number of households use far more N fertilizer than most others (Figures 6a and 6b). Figure 6a shows the percentage of households that account for the cumulative percentage of all N fertilizer added by all households in the study, where 20% of the households in our study contributed almost 70% of the total N fertilizer added by all households! About 75% of all respondents either did not fertilizer, or applied N fertilizer once or twice per year (corresponding to an estimated 0 to 544.77lbs N $acre^{-1}$ yr^{-1}), while the disproportionately large contribution to total N inputs across all households was due to the remaining 25% of households which either relied on lawn care companies (which applied on average 866.19 lbs N $acre^{-1}$ yr^{-1}) or applied N fertilizer in amounts from 789.92 to 1334.70 lbs N $acre^{-1}$ yr^{-1} (Figure 6b). These rates are consistent with those reviewed by Law et al. (2004) for a different region in the United States.

Therefore, some households could be contributing a lot more to area water pollution than others as a result of these decisions. These differences can have large implications for management, as high polluting households could be targeted for behavior change, since these households are contributing a significant amount more to water pollution than the average homeowner (Baker et al, 2007).

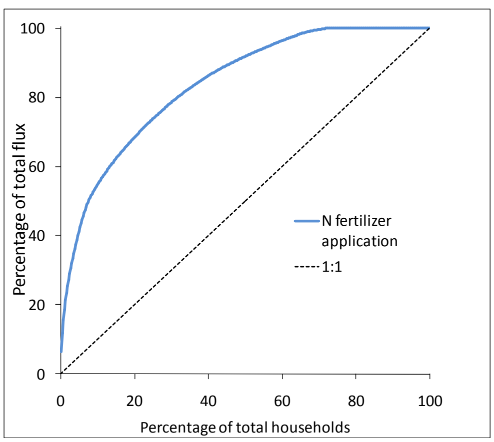

Figure 6a: Cumulative household contribution to total nitrogen fertilizer flux, Ramsey and Anoka Counties, Minnesota, (n = 360), 2008.

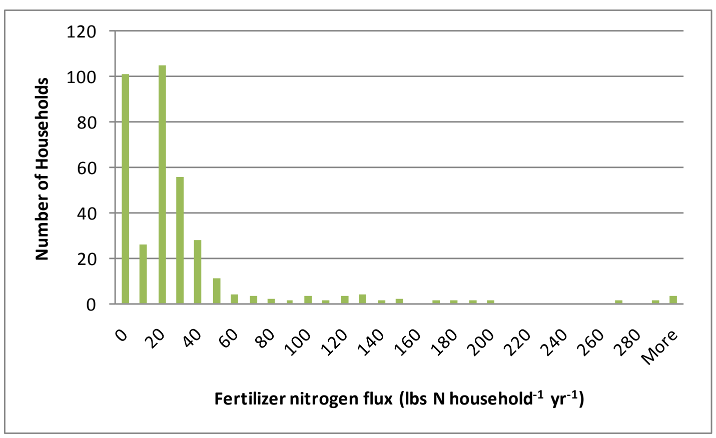

Figure 6b: Individual household contribution to total nitrogen fertilizer flux, Ramsey and Anoka Counties, Minnesota, (n = 360), 2008.

Potential Landscape Nitrogen and Phosphorus Losses from a Household

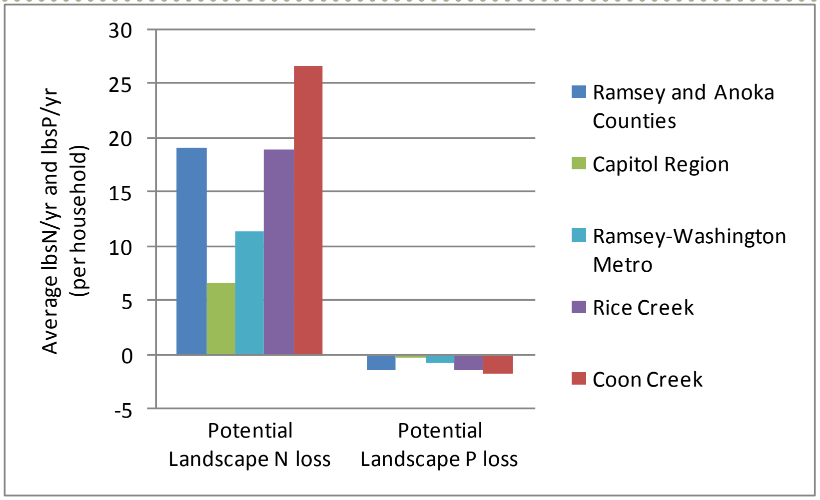

Figure 7a: Average potential landscape nitrogen and phosphorus losses (per household) for Watershed Districts, Ramsey and Anoka Counties, Minnesota, (n = 360), 2008.

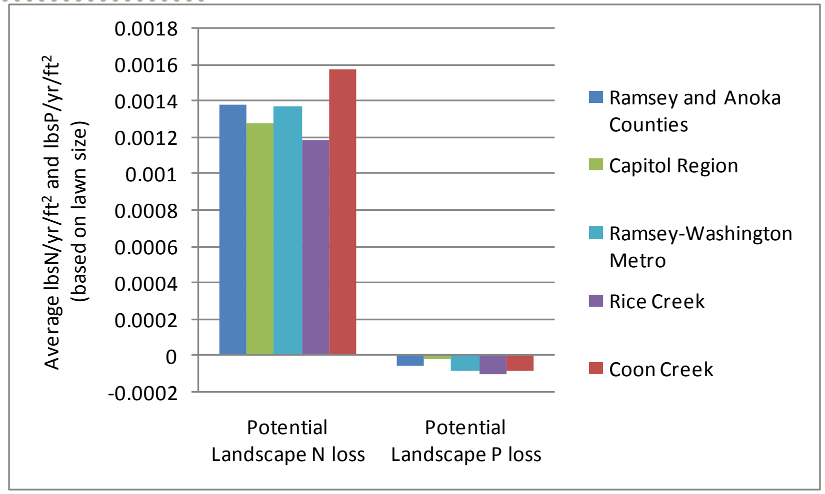

Figure 8a: Average potential landscape nitrogen and phosphorus losses (per ft^2) based on lawn size for Watershed Districts, Ramsey and Anoka Counties, Minnesota, (n = 360), 2008.

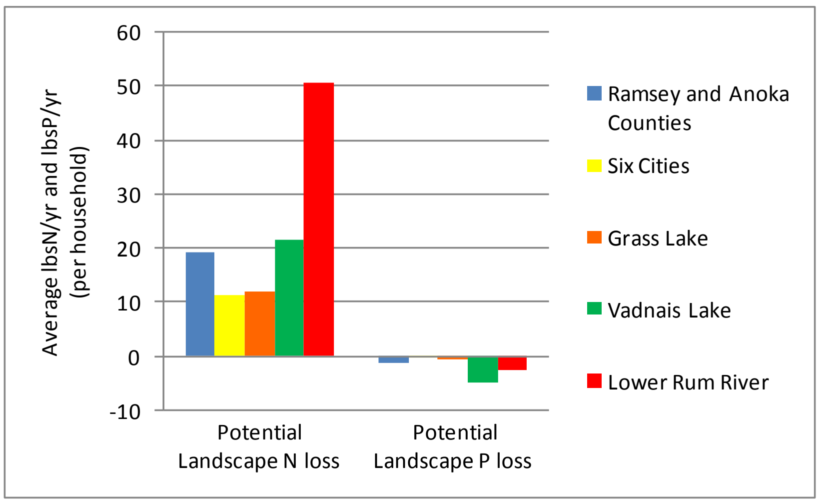

Figure 7b: Average potential landscape nitrogen and phosphorus losses (per household) for Watershed Management Organizations, Ramsey and Anoka Counties, Minnesota, (n = 360), 2008.

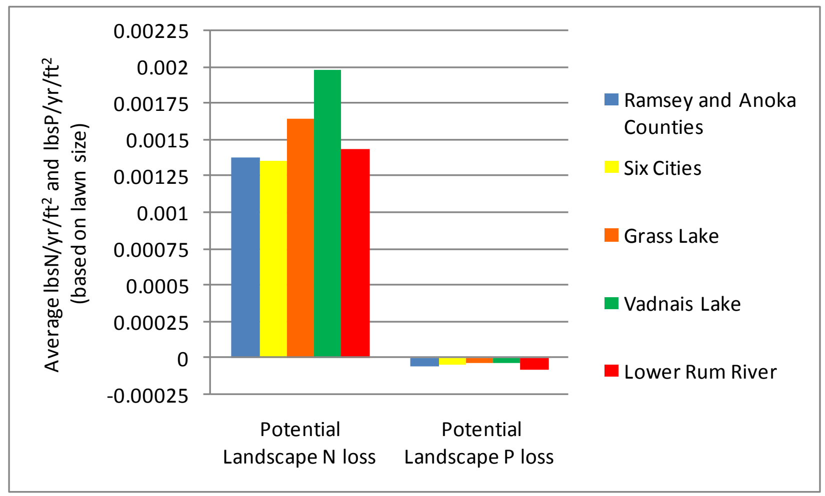

Figure 8b: Average potential landscape nitrogen and phosphorus losses (per ft^2) based on lawn size for Watershed Management Organizations, Ramsey and Anoka Counties, Minnesota, (n = 360), 2008.

Large differences were found between WD/WMOs with respect to potential landscape N and P losses when examining these losses on a per household basis (Figures 7a/b). Since this could be the result of increasing property size, however, this was also examined by normalizing with respect to lawn size. When normalized with respect to lawn size, potential landscape N and P losses show much less variation (Figures 8a/b).

Negative values of potential landscape losses of P are seen in all of the above graphs (both per household and per lawn size), which indicates that P is not in excess on the household landscapes we studied. This is likely related to the aforementioned P fertilizer ban. Therefore, because we restrict P, there is generally no P being applied in excess of what landscape biota need. Under these conditions, biota could be effectively "mining" available P that has been accumulating in soil over the years. Back-of-envelope calculations show that it may take several decades to mine the available P from highly P-enriched soils down to a level that would cause plant stress.

Behaviors Affecting Nitrogen and Phosphorus Fluxes

There were many household characteristics and behaviors measured that affect the fluxes of N and P occurring on a household landscape. These are: number and weight of household pets, leaf and lawn clipping management, and fertilizer application.

Household Pets

Households were asked whether or not they owned a dog or a cat (these were the only two animals considered) and how much each weighed. Here, we focus on dogs, as all cat waste was assumed to exit the household via household trash, while part of dog waste was assumed to transit through the landscape. The amount of N and P that enters the landscape as dog waste is related to both the number and weight of dogs, as these two variables affect the amount of N and P consumed as dog food. This value in turn can have a large impact on the fluxes of N and especially P through the landscape and consequently to stormwater pollution, considering that these elements leave the household boundaries untreated in lawn runoff that then makes its way to the nearest body of water. Therefore, households with more and/or heavier dogs contribute more potential N and P runoff from lawns than households with no or fewer and/or lighter dogs.

Amounts and Weights of Dogs

Table 5: Number and weight of dogs per household, Ramsey and Anoka Counties, Minnesota, 2008.

	Sample Size (n)	% of households that own at least one dog	Average number of dogs per household among households that own dogs*	Average individual dog weight among households that own dogs**	Average weight of dogs per household among households that own dogs**
Ramsey and Anoka Counties	2795	35.8%	1.3	34	45
WDs					
Capitol Region	599	32.4%	1.2	37	44
Ramsey Washington	389	32.9%	1.3	35	46
Rice Creek	588	33.7%	1.3	32	42
Coon Creek	372	40.9%	1.3	37	48
WMOs					
Six Cities	234	35.0%	1.4	31	43
Grass Lake	128	20.3%	1.2	33	40
Vadnais Lake Area	86	40.7%	1.4	25	35
Lower Rum River	173	42.2%	1.3	37	48

* Amounts have been rounded to the nearest tenth
** Amounts have been rounded to the nearest pound

Leaf Management

Households were asked over what portion of their lawn they raked or removed their leaves, and also how they disposed of these leaves. Possible answers included: 1) mulching leaves into lawn, composting on property, or adding to garden; 2) removing leaves from property; and 3) burning on site.

Leaf Raking

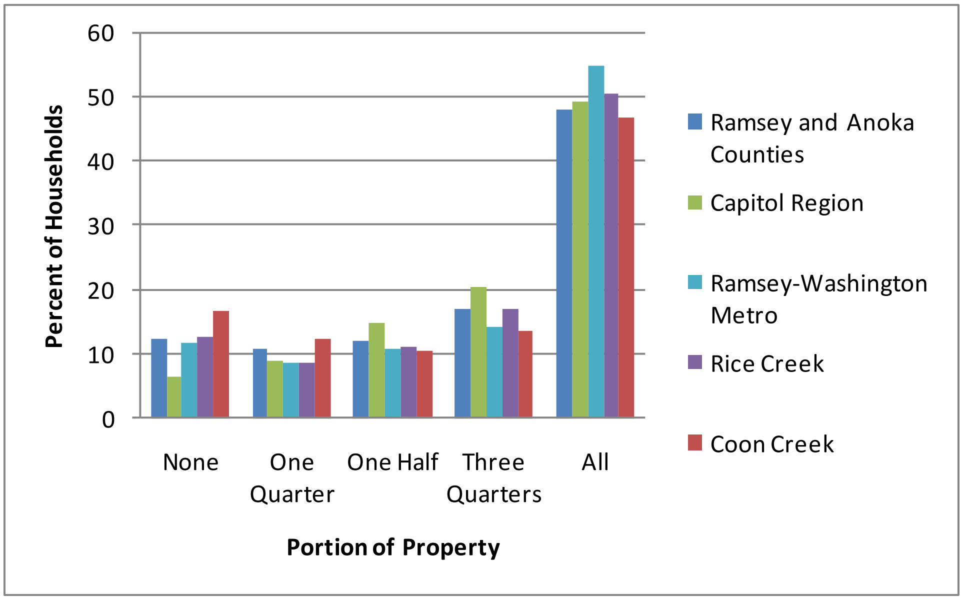

Figure 9a: Respondents' answers to "Over what portion of your property do you rake or remove leaves?" Watershed Districts, Ramsey and Anoka Counties, Minnesota, (n: Total = 2758, Capitol Region = 589, Ramsey Washington = 386, Rice Creek = 580 and Coon Creek = 366), 2008.

Almost half of the households in Ramsey and Anoka Counties raked their entire property (Figure 9a). Capitol Region WD had higher percentages of households who raked one-half or three-quarters of their property compared to the three other WDs, while Coon Creek had higher percentages of households that raked one-quarter or none of their property.

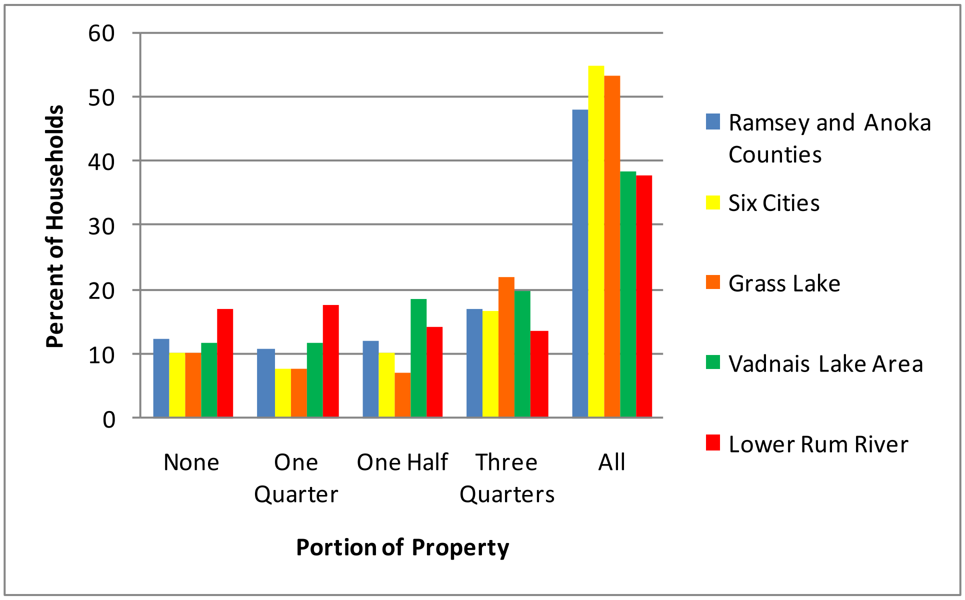

Figure 9b: Respondents' answers to "Over what portion of your property do you rake or remove leaves?" Watershed Management Organizations, Ramsey and Anoka Counties, Minnesota, (n: Total = 2758, Six Cities = 232, Grass Lake = 128, Vadnais Lake Area = 86, Lower Rum River = 170), 2008.

In Six Cities and Grass Lake, around 53-54% of households raked their whole property, as compared to 37-38% of households in Vadnais Lake Area and Lower Rum River (Figure 9b).

Leaf Disposal

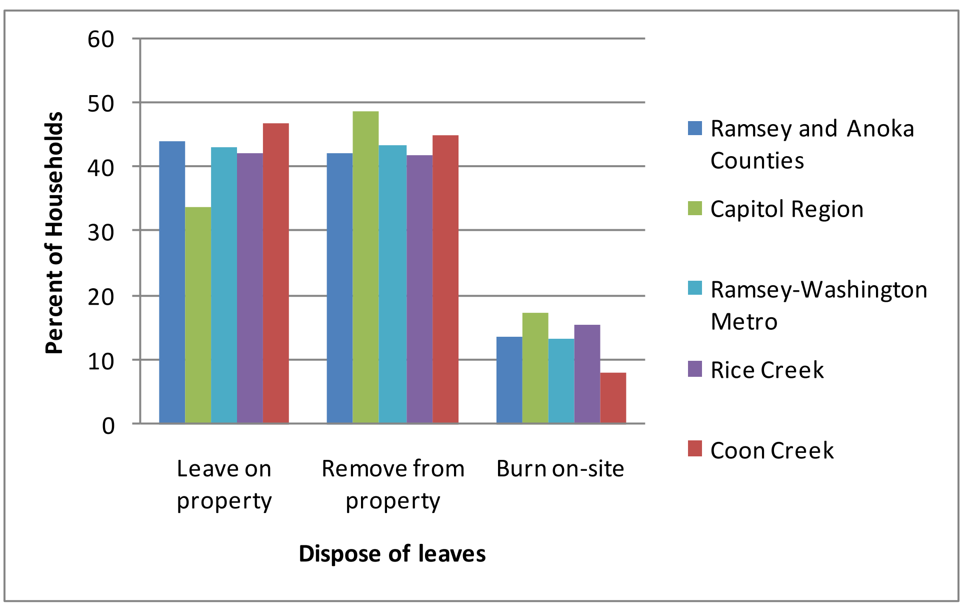

Figure 10a: Respondents' answers to "How do you dispose of tree leaves?" Watershed Districts, Ramsey and Anoka Counties, Minnesota, (n: Total = 2737, Capitol Region = 588, Ramsey Washington = 385, Rice Creek = 578 and Coon Creek = 361), 2008.

A majority of households in the WDs of Ramsey and Anoka Counties mulched their raked leaves onto their lawns or removed them from their property (Figure 10a). Within WDs, of the households surveyed who raked their entire lawn, 58% of them subsequently removed these leaves from their property, 28% of them mulched or composted them, and 14% of them burned their leaves on-site. Capitol Region WD exhibited the most variance around the average, with more households removing leaves from their property as opposed to mulching them on their property.

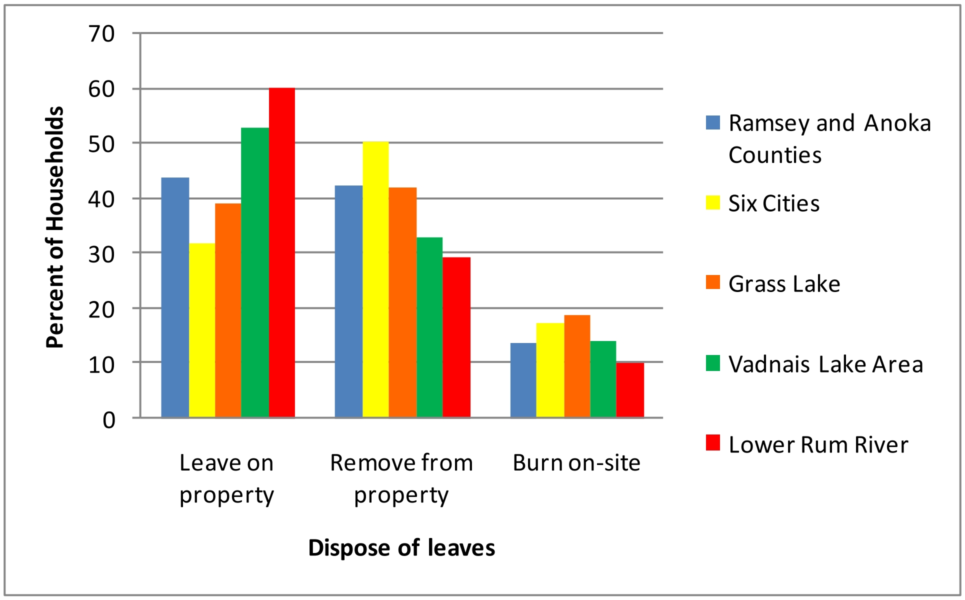

Figure 10b: Respondents' answers to "How do you dispose of tree leaves?" Watershed Management Organizations, Ramsey and Anoka Counties, Minnesota, (n: Total = 2737, Six Cities = 228, Grass Lake = 128, Vadnais Lake Area = 85, and Lower Rum River = 166), 2008.

Vadnais Lake Area and Lower Rum River had more households who mulched or composted their leaves and had fewer households who removed the leaves from their property than households in Six Cities and Grass Lake (Figure 10b). Within WMOs, of the households surveyed who raked their entire lawn, 55.4% of them removed these leaves from their property, 30.4% mulched or composted them, and 14.2% burned their leaves on-site.

Lawn Clipping Management

Households were asked how they disposed of their lawn clippings. Possible answers included: 1) disposing of clippings off-site; 2) leaving clippings on lawn; or 3) composting clippings on property.

Lawn Clipping Disposal

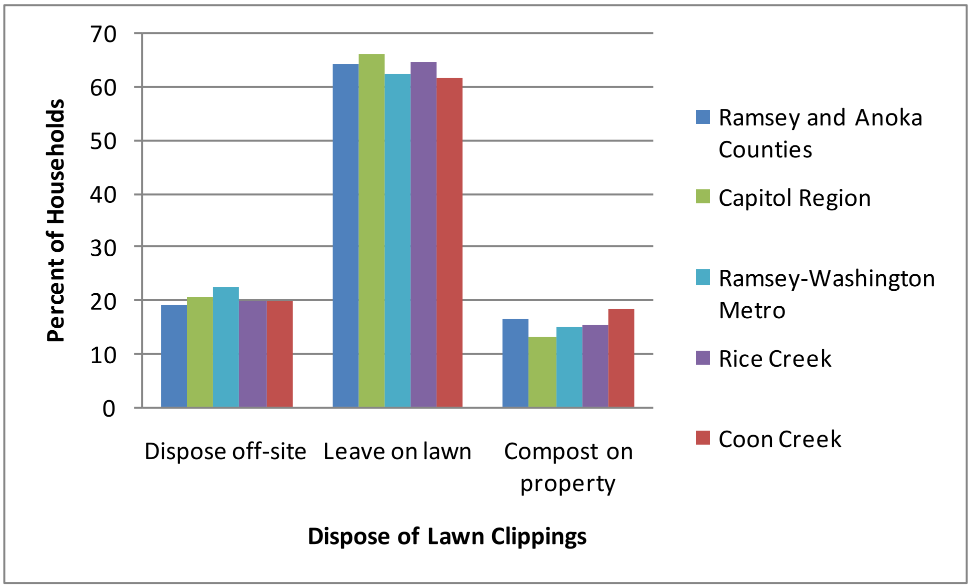

Figure 11a: Respondents' answers to "How do you dispose of lawn clippings?" Watershed Districts, Ramsey and Anoka Counties, Minnesota, (n: Total = 2749, Capitol Region = 590, Ramsey Washington = 386, Rice Creek = 578, and Coon Creek = 357), 2008.

Households behaved relatively consistently across the four main watershed districts of Ramsey and Anoka Counties with respect to lawn clipping management (Figure 11a). The majority (64%) left their lawn clippings on the lawn, while roughly 19% disposed of their clippings off-site, and 17% composted them on the property.

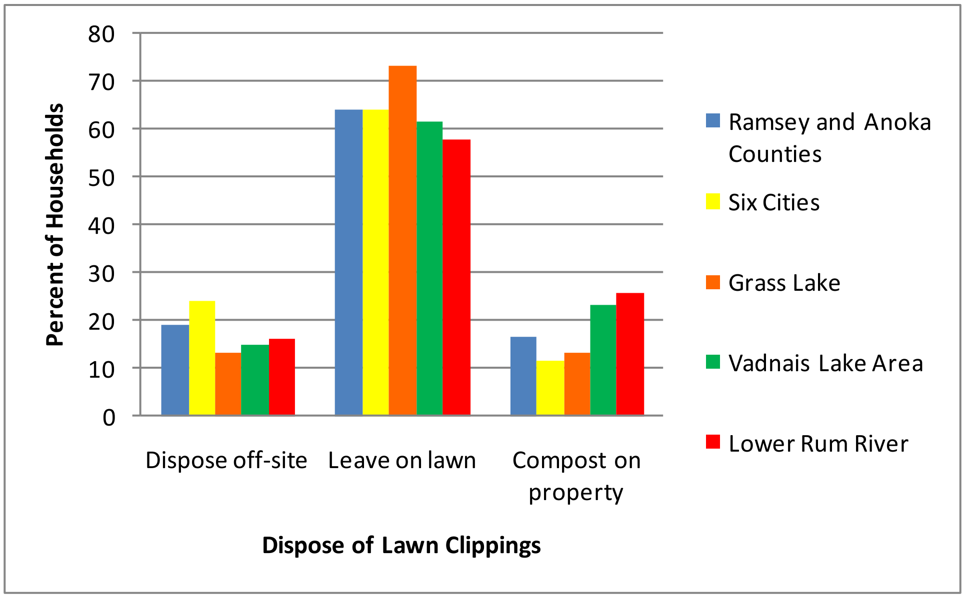

Figure 11b: Respondents' answers to "How do you dispose of lawn clippings?" Watershed Management Organizations, Ramsey and Anoka Counties, Minnesota, (n: Total = 2749, Six Cities = 231, Grass Lake = 128, Vadnais Lake Area = 86 and Lower Rum River = 171), 2008.

More households in Vadnais Lake Area and Lower Rum River composted their lawn clippings on their lawn as compared to Six Cities and Grass Lake (Figure 11b). Households across Ramsey and Anoka County were also more likely to manage their raked leaves and lawn clippings similarly: of the 1194 households that left leaves on their property (through mulching, composting or adding to their garden), 66.4% also left lawn clippings on their lawn (n = 2795).

Fertilizer Use

Households were asked questions regarding whether or not they normally fertilized their lawn, and if they did fertilize, how many times they fertilized in 2007. Fertilization amounts were then determined by the size of a household's lawn and how many times the household fertilized in a year (based on application rates of 1.024 lb N/1000 ft^2 per application as indicated on fertilizer packaging instructions). Households were also asked if they used a lawn service company if they normally fertilized. A flat fertilization rate was assumed for those households that used a lawn care company for fertilization (about 18% of households surveyed). This rate was based on annual fertilization amounts used by the top lawn care companies in the region (the most common lawn care company in the study area was TruGreen – Chemlawn).

Choice to Fertilize

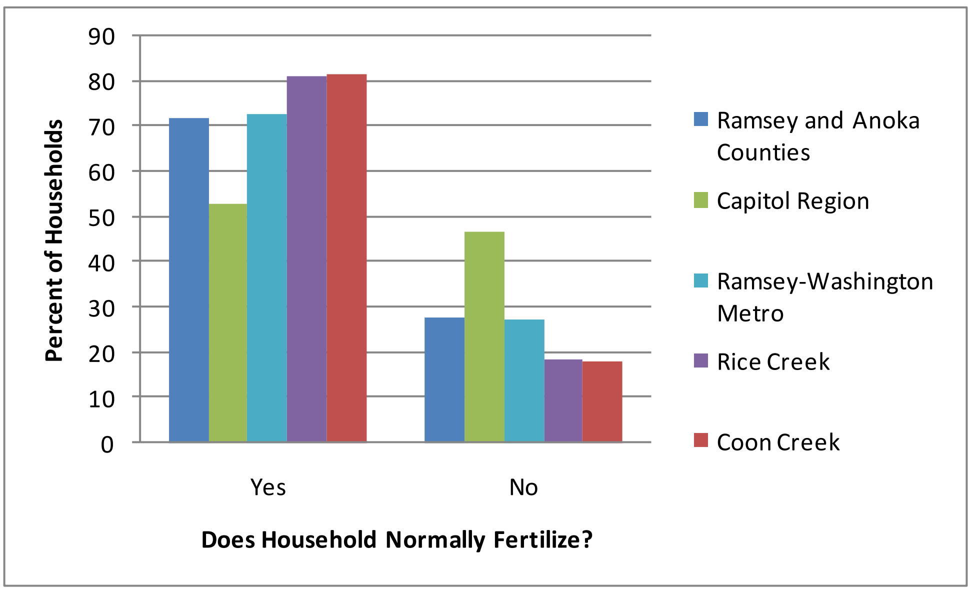

Figure 12a: Respondents' answers to "Do you normally fertilize your lawn, either by fertilizing it yourself or by hiring a lawn service company?" Watershed Districts, Ramsey and Anoka Counties, Minnesota, (n: Total = 2776, Capitol Region = 594, Ramsey Washington = 387, Rice Creek = 585 and Coon Creek = 368), 2008.

The average number of households who fertilized in Ramsey and Anoka Counties was just over 70% (Figure 12a). Coon Creek and Rice Creek, however, had more households who fertilized than the average of all surveyed households, while Capitol Region had a much lower percentage of households who fertilized. Among all of the households who fertilized their lawns, roughly 62% of these households also left their grass clippings on their lawns (n = 1988). These and the remaining households who dispose of grass clippings may not seriously consider that grass clippings are a source of recycled N for the landscape and that leaving grass clippings on the lawn after mowing can reduce the need for N applications contained in fertilizer.

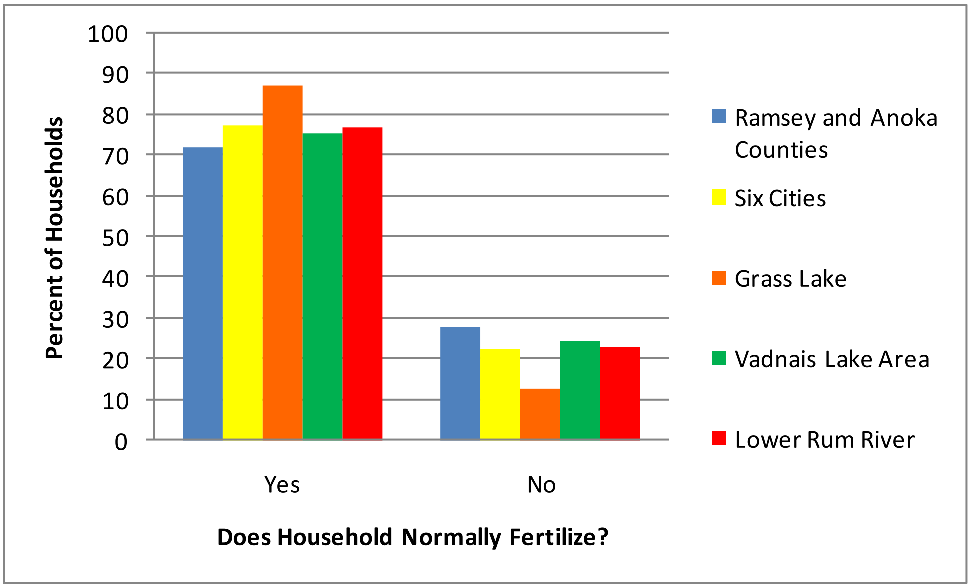

Figure 12b: Respondents' answers to "Do you normally fertilize your lawn, either by fertilizing it yourself or by hiring a lawn service company?" Watershed Management Organizations, Ramsey and Anoka Counties, Minnesota, (n: Total = 2776, Six Cities = 234, Grass Lake = 128, Vadnais Lake Area = 86, and Lower Rum River = 170), 2008.

All watershed management organizations are slightly above the average of all surveyed households, with Grass Lake having the highest percentage of households who fertilized (Figure 12b).

Frequency of Fertilization

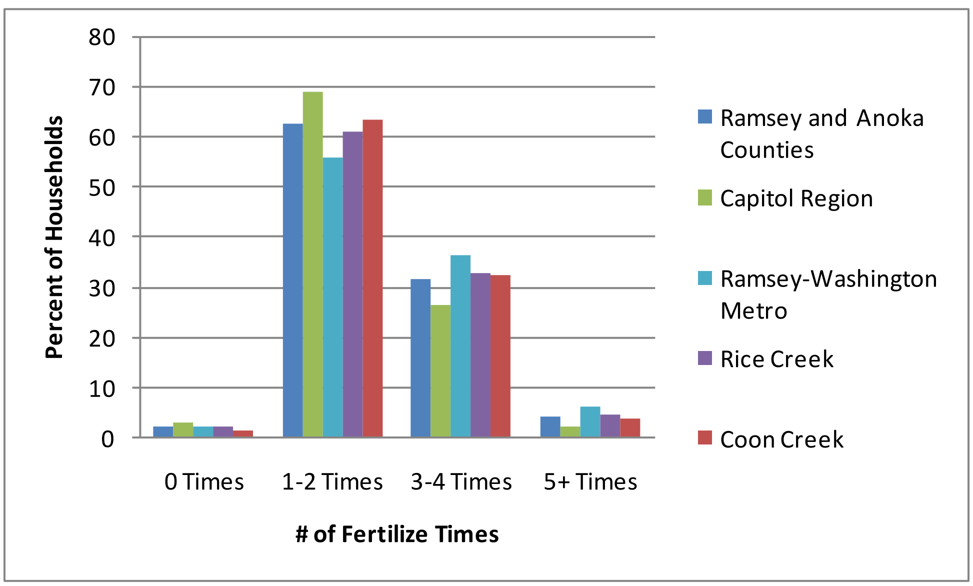

Figure 13a: Among respondents who responded yes to normally fertilizing their lawn, respondents' answers to "About how many times did you fertilize your lawn in 2007?" Watershed Districts, Ramsey and Anoka Counties, Minnesota, (n: Total = 2486, Capitol Region = 506, Ramsey Washington = 341, Rice Creek = 585 and Coon Creek = 333), 2008.

More than 60% of the fertilizing households in Ramsey and Anoka Counties fertilized their lawns 1-2 times (Figure 13a). Capitol Region WD had more households fertilize 1-2 times as compared to >3+ times (roughly 69% as compared to 28%, respectively).

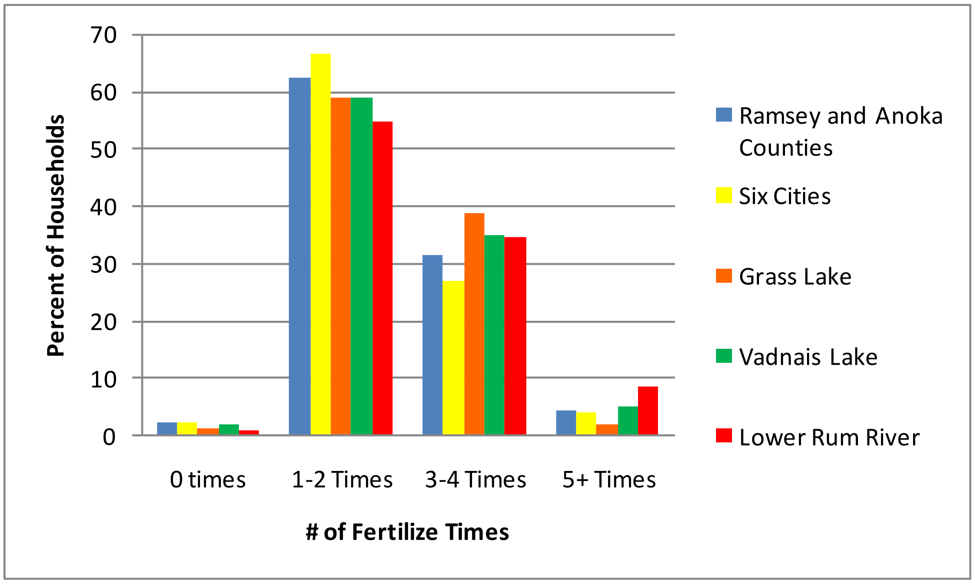

Figure 13b: Among respondents who responded yes to normally fertilizing their lawn, respondents' answers to "About how many times did you fertilize your lawn in 2007?" Watershed Management Organizations, Ramsey and Anoka Counties, Minnesota, (n: Total = 2486, Six Cities = 213, Grass Lake = 98, Vadnais Lake Area = 77 and Lower Rum River = 160), 2008.

Six Cities had a higher number of households who fertilized 1-2 times per year than any of the other WMOs (Figure 13b). Vadnais Lake Area and Lower Rum River had higher percentages of households who fertilized 5 or more times than Six Cities and Grass Lake.

Comparison of respondents' fertilization practices with University Extension guidelines

Responsible lawn management practices can minimize the potential for N losses to air or water during the growing season. Responsible lawn management includes making sure no fertilizer or lawn clippings are left on sidewalks or in the street and applying appropriate amounts of N fertilizer. According to the latest University of Minnesota Extension guidelines[2] (SULIS 2010), appropriate rates of N fertilizer application vary by the use-level of a lawn, grass type, organic matter content of the soil, sun exposure, watering practices, and grass clippings management.

In order to compare the fertilization rates of households in our sample to the rates recommended by Extension, we assumed the lawns in our sample have typical Midwestern grass types (Kentucky bluegrass or a mixture of Kentucky bluegrass and fine fescues), average use-levels, medium soil organic matter content (3.1% – 19%), and full sun exposure. We then estimated the N fertilizer rate that would be recommended by Extension for each household based on the watering and grass clippings practices they reported in the survey (Table 6; for more details on this comparison, see Appendix E).

Within the WDs and WMOs covered by our survey, between 24% and 41% of households apply N fertilizer at a higher rate than would likely be recommended by Extension given their watering and grass clippings practices (Table 7). Among households who applied fertilizer themselves, only 12% to 29% applied more fertilizer than would be recommended (Table 8). However, because the most popular lawn service company in our sample applied just over 3 lbs of N per 1000 ft^2 at the time of our survey, we estimate that all households who hired a lawn service company applied N at a higher rate than would be recommended based on the latest Extension studies (SULIS 2010). Applying more fertilizer than necessary increases the potential for contaminating lawn runoff with nitrogen. It can also lead to excessive shoot and leaf growth, reduced root growth, low plant carbohydrate (food) reserves, increased susceptibility to environmental stresses, and some diseases (SULIS 2010). Thus, it's possible that lawn service companies could cut costs, reduce the risk of N loss, and improve turf quality by lowering N application rates to recommended levels.

The proportion of households who applied N fertilizer at lower rates than would likely be recommended (including those households that didn't fertilize at all) ranged from 18% to 41% among WDs and WMOs in our sample (Table 7). Most soils need supplemental N fertilizer to maintain turfgrass quality and density. Shortages of N can cause slow growth, yellowing of the plants, thinning out of the turf, and increased incidence of some diseases (SULIS 2010).

Table 6: Recommended rate of annual nitrogen fertilizer application (lbs per 1000 ft^2) by watering and grass clipping management practices, TCHEP, 2010.

	Removes grass clippings	Leaves grass clippings on lawn
Waters lawn regularly	3	2
Does not water lawn regularly	2	1

Adapted from University of Minnesota Sustainable Urban Landscape Information Series (SULIS) guidelines, 2010.

[2] In addition to changes in the recommended annual N application rates, the Extension's latest recommendations also advise the use of at least 50% slow-release N fertilizer at each application, and discourage the application of fertilizer in the late fall (October and November).

Table 7: Assessment of respondent fertilization practices based on the latest fertilization rate recommendations by the University of Minnesota Extension Service, TCHEP, 2010.

	Sample Size (n)	% who fertilized *more than* recommended rate	% who fertilized *at* recommended rate	% who fertilized *less than* recommended rate
Watershed Districts				
Capitol Region	599	24	35	41
Ramsey Washington	389	37	41	22
Rice Creek	588	34	46	20
Coon Creek	372	36	43	21
Watershed Management Organizations				
Six Cities	234	37	36	27
Grass Lake	128	41	41	18
Vadnais Lake Area	86	35	41	24
Lower Rum River	173	35	37	28

Table 8: Comparison of fertilization rates of respondents who normally fertilize at the latest fertilization rates recommended by the University of Minnesota Extension Service, with a comparison between fertilizer application by homeowner and by lawn company*, TCHEP, 2010.

	% of households who normally fertilized at recommended rates	% of fertilizing households who hired a lawn service company in 2007	% of self-fertilizers who fertilized more than recommended
Watershed Districts			
Capitol Region	53	30	12
Ramsey Washington	73	24	29
Rice Creek	81	27	18
Coon Creek	82	25	19
Watershed Management Organizations			
Six Cities	77	31	22
Grass Lake	88	31	24
Vadnais Lake Area	76	25	22
Lower Rum River	77	24	24

* Because the most popular lawn service company in our sample applied just over 3 lbs of N per 1000 ft^2 at the time of our survey, we estimate that all households who hired a lawn service company applied N at a higher rate than would be recommended.

Appropriate N application rates should ultimately be decided on a case-by-case basis; for instance, application of N fertilizer at the rates suggested above may lead to nitrate-N leaching for lawns underlain with sands and sandy loams, such as those on the Anoka Sand Plain—much of the northern Metro region. Nonetheless, our estimates suggest that many households in our sample were applying N at higher or lower rates than would be recommended based on forthcoming Extension data. In the interest of maximizing turfgrass and water quality, households can consult the latest Extension fertilizing recommendations to determine if they or their lawn service companies are applying N fertilizer at an optimal rate, given the form of N added and the specific conditions of their lawn and soils.

Influences of Landscaping Behaviors

Our survey asked questions regarding the influences behind household landscaping behaviors, including the criteria that guide landscape vegetation choices and attitudes towards fertilization. Attitudes measured included advantages (lawn attractiveness and greenness) and disadvantages (time and water pollution) of fertilizing, as well as intent to fertilize.

Criteria Guiding Landscape Vegetation Choice

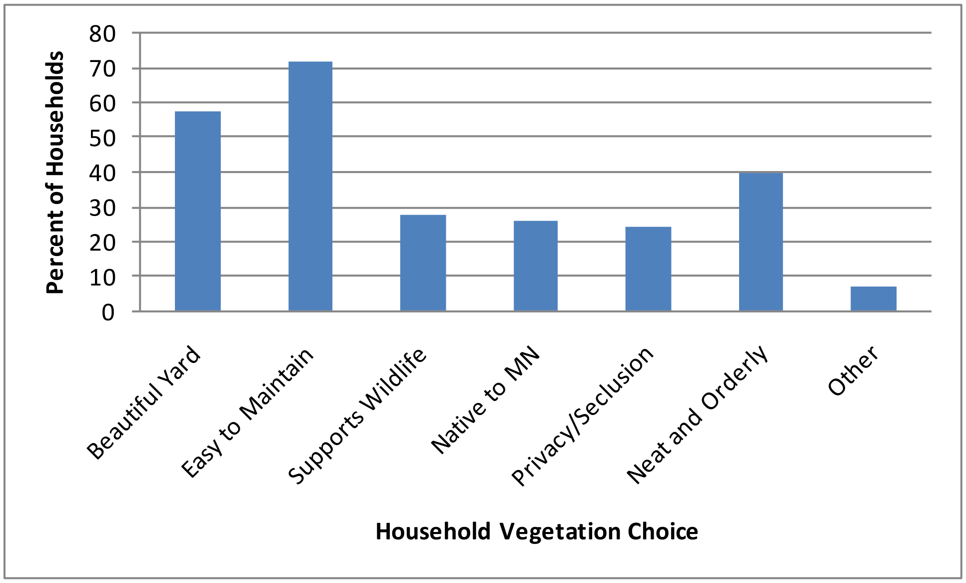

Figure 14: Respondents' answers to "What criteria guide your landscape vegetation choices?" Ramsey and Anoka Counties, Minnesota, (n = 2795), 2008.

Respondents were allowed to select more than one option when asked what criteria guide their vegetation choices. Households in Ramsey and Anoka Counties ranked vegetation that is "Easy to Maintain" (72%) and "Creates a Beautiful Yard" (58%) as the first and second choices, respectively, that guided their landscape vegetation choices (Figure 14). Less than 30% of households chose "Supports Wildlife" and "Native to Minnesota" as criteria that guide their choices. Households that chose "Other" listed items such as "Provides Food", "Shade" and "Whatever is Growing/Whatever was there when I moved in" as reasons for their vegetation choice.

Attitudes towards Fertilization

Households across Ramsey and Anoka Counties generally believed that fertilizing their lawns will likely result in an attractive lawn and a greener lawn (Tables 9a/b), with a distribution skewed towards extremely likely. It is important to note that households in Ramsey and Anoka Counties value fertilization for these advantages, as these could be the driving forces behind the choices they make in lawn management.

In general, households believed it is likely that fertilizing their lawns will take time, with a distribution slightly skewed towards this being extremely likely (Tables 9a/b). Households believed fertilization was neither extremely likely nor extremely unlikely to result in water pollution, with a normal distribution of responses (Tables 9a/b). This suggests households did not connect their landscape's potential contribution from their fertilization actions to water pollution. Recent research has shown that fertilization of household lawns is a significant contributor to water pollution (Barten and Jahnke 1997; Law et al. 2004). These results, however, indicate that homeowners in Ramsey and Anoka Counties did not consider this to be true.

Thinking about future actions, households had a bimodal distribution between extremely likely and extremely unlikely to fertilize this year, with an average of 2.67 (Tables 9a/b). There were few variations among watershed districts in intent to fertilize, with the exception of Capitol Region WD, which was significantly different than Ramsey and Anoka Counties ($p < 0.001$), and households were less likely to intend to fertilize their lawns.

Table 9a: Averages of respondents' answers to questions regarding statements about the advantages and disadvantages of fertilization, and intention to fertilize, 5pt Likert Scale (1 = extremely likely and 5 = extremely unlikely), Watershed Districts, Ramsey and Anoka Counties, Minnesota, 2008.

	Ramsey and Anoka Counties *(n = 2795)*	**Capitol Region** *(n = 599)*	**Ramsey Washington** *(n = 389)*	**Rice Creek** *(n = 588)*	**Coon Creek** *(n = 372)*
Advantages of Fertilization					
Fertilizing my lawn this year will result in an attractive lawn.	1.88	2.08[a]	1.87[b]	1.78[b]	1.79[b]
Fertilizing my lawn this year will produce a greener lawn.	1.69	1.81[a]	1.67	1.64[b]	1.67
Disadvantages of Fertilization					
Fertilizing my lawn this year will take time.	2.57	2.73	2.49	2.53	2.64
Fertilizing my lawn this year will result in water pollution.	2.88	2.58[a]	2.96[b]	2.88[b]	3.11[b]
Intent to Behave					
I intend to fertilize my lawn this year.	2.67	3.19[a]	2.63[b]	2.45[b]	2.37[b]

[a-b] Different superscripts are significantly different at $p < 0.05$ based on z-tests adjusting for multiple comparisons through the Bonferroni method.

Table 9b: Averages of respondents' answers to questions regarding statements about the advantages and disadvantages of fertilization, and intention to fertilize, 5pt Likert Scale (1 = extremely likely and 5 = extremely unlikely), Watershed Management Organizations, Ramsey and Anoka Counties, Minnesota, 2008.

	Ramsey and Anoka Counties *(n = 2795)*	**Six Cities*** *(n = 234)*	**Grass Lake** *(n = 128)*	**Vadnais Lake** *(n = 86)*	**Lower Rum River** *(n = 173)*
Advantages of Fertilization					
Fertilizing my lawn this year will result in an attractive lawn.	1.88	1.86	1.89	2.04	1.69
Fertilizing my lawn this year will produce a greener lawn.	1.69	1.68	1.64	1.77	1.54
Disadvantages of Fertilization					
Fertilizing my lawn this year will take time.	2.57	2.57	2.51	2.62	2.26
Fertilizing my lawn this year will result in water pollution.	2.89	2.89	3.04	2.74	3.13
Intent to Behave					
I intend to fertilize my lawn this year.	2.67	2.60	2.35	2.67	2.47

*There were no significant differences in averages between water management organizations.

Perceptions of Normal Fertilizer Use and Future Fertilization Intentions

Households who answered that they normally fertilized their lawn were significantly more likely to answer that they have a greater likelihood of intent to fertilize (those that answered that they were likely/extremely likely to fertilize) ($p < 0.05$) (Figure 15). Therefore, current household behavior is a good predictor for future behavior. Households who do not normally fertilize were significantly less likely to fertilize in the future (those who answered that they were unlikely or extremely unlikely to intend to fertilize their lawn in 2008) ($p < 0.05$). Roughly 51% of households who answered that they normally fertilize and were likely to continue in the future and roughly 20% of households answered that they did not normally fertilize and were unlikely to do so in the future (Table 10).

There are therefore three main types of households in our study: those who fertilize annually, those who do not fertilize, and those who fertilize occasionally. Each of these household groups would require a unique message when addressing fertilization behavior.

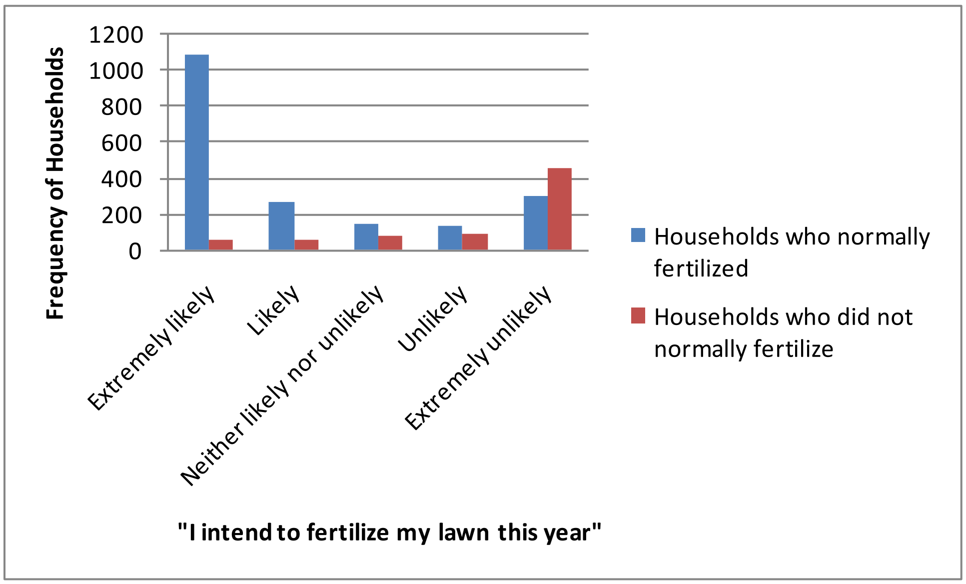

Figure 15: Respondents answers to “I intend to fertilize my lawn this year.” with a comparison between households that normally fertilized and households that did not normally fertilize, Ramsey and Anoka Counties, Minnesota, (n = 2795), 2008.

Note: Households who normally fertilized were significantly different than households who did not normally fertilize in every level (extremely likely to extremely unlikely) of intent to fertilize.

Table 10: Relationship of respondents' reported normal fertilizing choice and their intent to fertilize in the future, 5pt Likert Scale (1 = extremely likely and 5 = extremely unlikely), Ramsey and Anoka Counties, Minnesota, (n = 2658), 2008.

		Do you normally fertilize your lawn? Yes	No
I intend to fertilize my lawn this year.	Likely or extremely likely	50.8% (1350)	4.1% (109)
	Percent with 50/50 likelihood of fertilizing or not fertilizing	5.4% (145)	2.8% (75)
	Unlikely or extremely unlikely	16.5% (438)	20.4% (541)

Insights and Management Implications

Targeting fertilization behavior can address potential nitrogen (N) runoff and leaching.
Approximately 51% of the respondent households in Ramsey and Anoka Counties normally fertilized their lawns and stated they were likely or extremely likely to do so in the future (Table 10). Another 20% had not fertilized their lawns in 2007 but were unlikely or extremely unlikely to do so in the future (Table 10). Also, these households strongly believed that fertilization would result in positive outcomes: an attractive and a greener lawn (Tables 9a/b). Fertilizing is a prevailing behavior in this area that homeowners intend to continue, and it is the largest contributor to potential N loss from the landscape. It is not likely there will be major changes in the percent of households who fertilize. Interestingly, some households may be contributing significantly more to potential N runoff and leaching by fertilizing many times a year (Figure 6a/b). Therefore, management for decreased fertilizer use could target high users of fertilizer to reduce the number of times they fertilize, rather than treating all households as equal contributors (Baker et al. 2008b). Messages could emphasize the normal fertilizing rates of neighbors that still result in a green, attractive lawn.

In addition, we found that homeowners do not consider fertilization to be a likely contributor to water pollution (Tables 9a/b). This shows homeowners in this region are not broadly convinced that lawn fertilization contributes to water pollution when in fact there is a general relationship between lawn fertilization and nutrient loss to runoff (though many other factors are involved) (Baker et al. 2008a). The views of the majority of homeowners suggest that a message to homeowners needs to clearly link high fertilization rates with the potential for increased N runoff and leaching, possibly contributing to greener and less attractive lakes. Finally, we found that homeowners did not believe lawn fertilizing is likely to take a significant amount of time (Tables 9a/b), so any message promoting time savings would likely have a minimal influence on homeowner fertilization behavior.

Targeting pet waste management can address potential phosphorus (P) runoff.
Because our study assumes that no P is applied to the household landscape through fertilization, waste from pets constituted 83% of the P input to the landscape in this study (pg. 10). Not picking up pet waste can result in excess P being lost to runoff, contributing to water pollution. Messages directed towards pet waste management could increase awareness about the potential contribution of pet waste to P runoff from household landscapes. For example, a Chesapeake Bay study found that dogs are a bigger problem than most residents believed, and 44% of dog walkers would not pick up after their dog even if they were threatened with a fine (Caraco et al. 1999). It is therefore important to start with increasing awareness in order to get homeowners to even consider cleaning up after their pets to reduce their impact on water systems.

There is a link between grass clipping management and fertilization that can be included in outreach material.
Among the households who normally fertilized their lawns, 62% of these households also left grass clippings on their lawns (pg. 20). These and the remaining households who dispose of grass clippings may not seriously consider that grass clippings are a source of recycled N for the landscape and that leaving grass clippings on the lawn after mowing can reduce the need for N applications contained in fertilizer. As homeowners are not necessarily making the connection between the use of grass clippings as a replacement for fertilizer, they may also not understand the relationship between how planting

trees and irrigating/fertilizing at modest levels would increase the accumulation of nutrients (N and P) on their landscape, and thus reduce potential losses of nutrients.

A message could encourage homeowners to leave grass clippings on the lawn to reduce the amount of fertilizer required, as leaving clippings on the lawn recycles approximately 1 lb of N per 1000 ft^2 annually. In bare patches of lawn that are prone to erosion, fertilization and watering may help grasses establish strong root systems, which could reduce soil loss and therefore decrease the amount of potential P losses resulting from erosion. An indirect effect of this message could be a reduction in the collection of grass clippings that require waste disposal. Watershed managers have noted that grass clippings are often dumped in brushy areas along streams or in wetland areas near the yard. A change in behavior from dumping grass into piles to leaving the clippings on the lawn would reduce the concentration of degrading biomass contributing to runoff, another source of high concentrations of N and P.

WD/WMOs should maintain and expand their relationships with lawn care companies.
Roughly 18% of households in our study normally hire lawn care companies to fertilize their lawn (pg. 20), resulting in increased percentages of overfertilization as compared to doing it themselves (Table 8). While this is a comparatively small percentage of households, it is still important to foster relationships with lawn care companies in the area, as these companies have an influence not only on household landscapes, but also serve as an information source that could influence homeowner attitudes. If there are landscape management practices that WD/WMOs wish to promote in order to improve water quality, convincing lawn care companies to adopt these practices could be an effective strategy not only to reduce fertilizer use, but also to convey information to homeowners.

Household yard waste decisions are linked.
Roughly 43% of households left their leaves on their property (by mulching, composting or adding to their garden). Of these households, 66% reported also leaving their lawn clippings on their lawn (pg. 19). This suggests household yard waste decisions are linked, with homeowners performing similar behaviors for both leaf and lawn clipping management. Therefore, designing a message to target both of these behaviors at once, or focusing on one (leaf management) with the knowledge that the homeowner will likely perform similarly in the other (grass clipping management) could be more effective.

The dominant criteria for landscape vegetation choices were options that are 'Easy to Maintain' and 'Create a Beautiful Yard'.
The criteria that homeowners most often cited as reasons for landscape vegetation choices were options that are 'Easy to Maintain' (72%) and 'Create a Beautiful Yard' (58%) (n = 2795). Consider these motivators when developing arguments for a particular yard management option that would improve water quality. When creating messages that are encouraging or discouraging a particular vegetation type or management practice, messages reinforced with information about how the target behavior will contribute to a beautiful yard and will also be easy to maintain may be most effective. Such messages will align with current homeowner landscape objectives, increasing their positive attitudes toward the management practice (Figure 14). Of course, if such an argument is not reasonable (i.e., if changing practices would be difficult to maintain or would reduce the 'beauty' of the yard), homeowners may likely have a negative attitude toward changing that behavior. Before implementing any programs involving homeowner vegetation management, it would be informative to conduct small studies about homeowner perceptions of attractiveness/beauty and difficulty of vegetation maintenance. Even a small pilot study could help with crafting effective outreach messages.

What does this mean for you?

This report touched on many household behaviors that influence the potential landscape nitrogen (N) and phosphorus (P) losses from households. This important nonpoint source of pollution is a significant target for pollution reduction when trying to improve water quality in urban aquatic systems; yet households are also an essential part of the solution. Households have highly variable characteristics, such as property and lawn sizes. Property size could have a large effect on the percent of their property from which households raked and removed their leaves, how they decided to dispose of their leaves and grass clippings, how much of their landscape they chose to fertilize, and how frequently they fertilized.

Next, households can be highly variable in the decisions they make on their landscapes and why they choose to make those decisions. There were multiple behaviors that showed a very disproportional distribution of households towards particular behaviors. The amount of times a household fertilized, for example, was highly skewed. Messages can be targeted towards specific groups (high fertilizing groups vs. those who do not fertilize at all) which would be more effective than a single message sent to all (Baker et al. 2008b). Differences in behaviors can also be attributed to income and other sociodemographic factors that will be examined in-depth in future TCHEP publications.

Finally, households are an important decision-making unit at the WD/WMO scale. Households make individual decisions regarding their landscape choices, but are influenced by neighbors, friends, local governments, etc. Therefore, their decisions and what influences their decisions need to be considered when crafting messages for behavior change and designing effective programming and policy. End-of-pipe solutions have limitations which can be enhanced by encouraging household landscape behaviors that support water quality. Oftentimes, however, households may not even realize how a simple behavior on their landscape can negatively affect area water bodies, and that these changes do not have to be extreme in order to collectively result in a measurable improvement in water quality.

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Appendix A: "Our Household Choices in Urban Living" Survey (Nelson et. al, 2008).

A copy of our full survey may be found on our website: **www.tchep.umn.edu**

Appendix B: Summary of Extended Overall TCHEP Methods

Initial pilot research for this study was collected through interviews with 35 households in Falcon Heights during the summer of 2007 (Baker et al, 2007). This pilot study helped guide the direction of the Twin Cities Household Ecosystem Project (TCHEP) and the methodological design.

We obtained data for the TCHEP through a 40 question survey that was distributed to 15,000 randomly selected households in Ramsey and Anoka Counties beginning in May of 2008. Households were selected from census blocks that had at least 50% of land area that met three criteria: the land represented an "upland" hydrologic type, had greater than 0% impervious surface, and had housing units classified as 'single-family detached' homes. Through the help of Survey Sampling International, all homes in these census blocks that were owner-occupied and had telephones were identified, and the final 15,000 households were a stratified random sample from this grouping. More homes were selected in more highly populated census blocks so that our sample would have a geographic distribution proportional to housing density of the target population.

There were 3100 returned surveys (resulting in a 21% response rate), 1940 survey participants agreed to provide energy information, and 1899 households agreed to let researchers come for a site visit, of which 360 were randomly selected for visits. Of the 3300 returned surveys, 2795 contained full mail survey information, 1850 contained full mail survey information and had additional energy records provided, and 360 contained full mail survey information, had additional energy records provided, and also contained site vegetation survey data from the site visit.

The final survey contained questions falling under several different categories: getting to know you and your household, household member diet and activities, household energy consumption, lawn care and landscaping behavior, household waste behaviors, and socio-demographic variables about the household. In addition, the survey asked questions about the household's attitude toward various behaviors in order to gain insight as to why the household performed certain behaviors. Answers from these questions were then used to estimate the carbon, nitrogen and phosphorus flux associated with each of the behaviors measured. These fluxes were aggregated to estimate the total fluxes for an entire household.

In addition to the survey, we gathered home energy information from various energy companies for all survey respondents who agreed to provide this information. On-the-ground landscape measurements were also taken from households who were willing to let researchers from the project visit their property to survey landscape vegetation. These measurements included: land cover types on the property, total number of trees, and characteristics of the trees (such as species, height, percent canopy, etc). These visits occurred during the summer of 2008 and were conducted by University of Minnesota undergraduate students working for the project. Finally, we obtained parcel data for the area which was then interpreted using GIS.

Appendix C: TCHEP Household Flux Calculator

Using all data sources described in the above methods section, the group developed a computational tool called the "Household Flux Calculator" (HFC), which converts all the information we gathered (from the returned surveys, energy records, parcel data, and landscape assessment) into annual fluxes of carbon, nitrogen, and phosphorus using a series of algorithms and conversions based on available literature.

The HFC is organized into seven main components (motor vehicle and air travel, household energy consumption, human diet, pet diet, landscaping, and paper and plastic consumption) and two sub-components (food waste and wastewater) (Figure 16). Every component of the HFC receives inputs of carbon, nitrogen, and phosphorus in different forms (e.g., food for human and pet nutrition, fuel for transportation) that then leave the household as outputs (e.g., CO_2 from human and pet respiration; CO_2 and NOx from fuel combustion). Fluxes for each of these seven components were analyzed independently and then as a main flux for each element for the household.

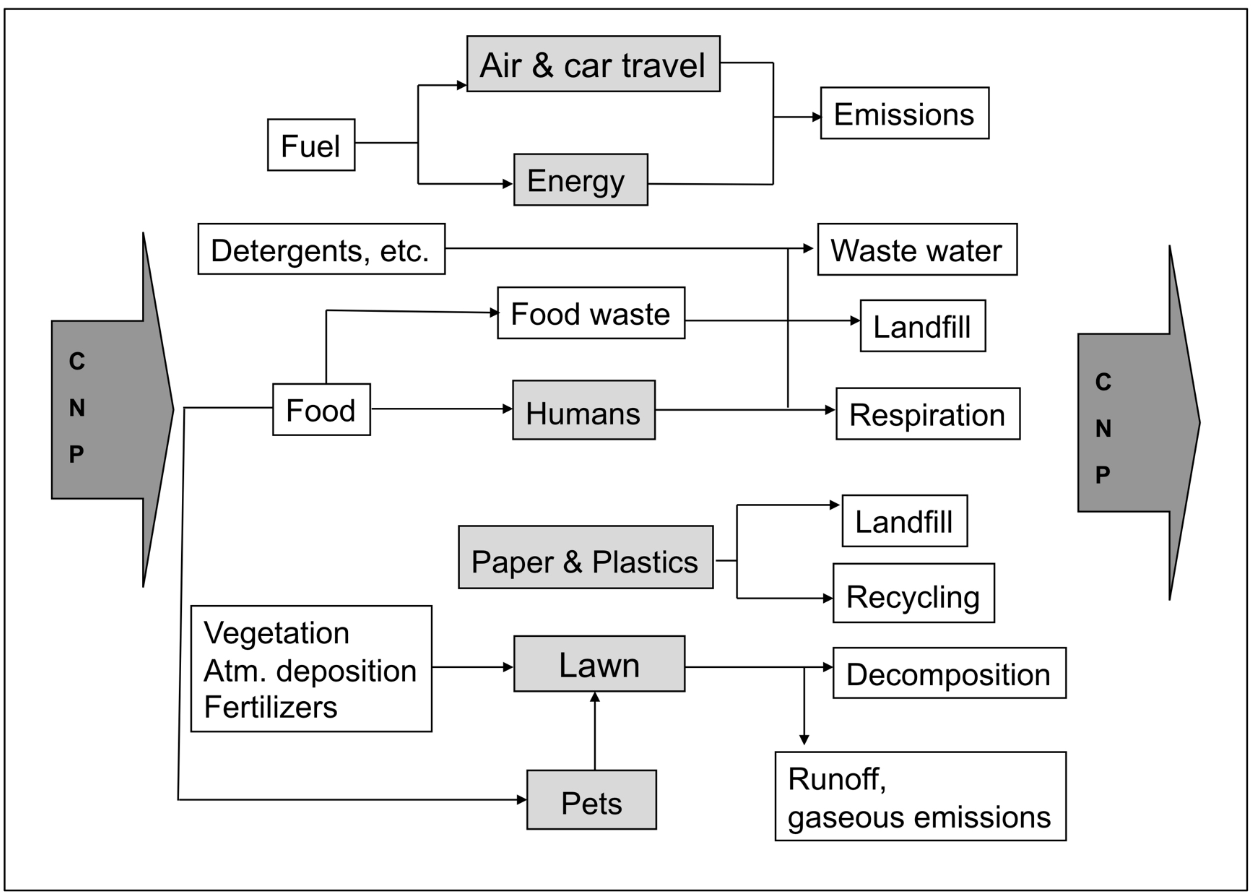

Figure 16: Basic Schematic of the Household Flux Calculator, TCHEP, 2009.

Appendix D: Key Assumptions from the TCHEP

Estimates of input and output fluxes of N and P through the household landscape use a number of assumptions as direct calculations were either impossible to conduct or were unavailable in the literature. Of great importance to this report are the estimates of undifferentiated N and P fluxes (labeled as "potential landscape nitrogen and phosphorus losses" throughout the text of this report) through the landscape. These estimates rely on our calculations of inputs and output fluxes as well as the accumulation of N and P on a landscape.

Assumptions were made concerning atmospheric deposition of N and P and were based on available measurement for the region. We assumed atmospheric deposition was uniform across households and across the entire property.

Inputs of N fertilizer are assumed to occur at 0.002 lbs N/ft^2, as suggested by fertilizer manufacturers, and we assumed homeowners (or lawn care companies) applied fertilizer uniformly on the entire landscape area. Obviously this may lead to an overestimate of actual N fertilizer applied if homeowners limit fertilization to a portion of their property. We also assumed that the lack of response to questions concerning fertilizer application in the survey reflected no use of fertilizer by the household.

We based our estimates for N and P content in leaves on the GlopNet database (Wright et al. 2004). We assumed the information provided by homeowners concerning their landscape management habits was accurate and we conducted our calculations accordingly.

Inputs of N and P entering the landscape as dog waste were estimated by assuming that 40% of dog excrement is not removed by pet owners and is left on site to decompose. We assumed all N and P contained in dog urine entered the landscape. These assumptions may not reflect actual behaviors as we do not know, for instance, where pet owners walk their dogs (for example: a city park rather than a neighbor's yard) and exactly what percent of them scoop up after their dog.

Accumulation of N and P in soil and wood was estimated based on stoichiometric equations from available data on N% and P% from the literature.

Appendix E: Methods for Fertilizing Recommendations Comparison

The University of Minnesota Extension guidelines recommend appropriate rates of N fertilizer based on a variety of factors including the use-level of a lawn, grass type, soil organic matter content, sun exposure, watering practices, and grass clippings management. We assumed that the lawns in our sample have typical Midwestern grass types (Kentucky bluegrass or a mixture of Kentucky bluegrass and fine fescues), medium soil organic matter content (3.1% – 19%), average use-levels, and full sun exposure. For such lawns, the Extension recommends applying N at an annual rate of 3 lbs of N per 1000 ft^2 if the lawn is irrigated, or 2 lbs of N per 1000 ft^2 if the lawn is not irrigated. However, leaving grass clippings from lawn-mowing on the lawn recycles approximately 1 lb of N per 1000 ft^2 annually, reducing the need for N fertilizer application to 2 lbs of N per 1000 ft^2 for irrigated lawns and 1 lb of N per 1000 ft^2 for non-irrigated lawns.

To classify our households based on these recommendations, we examined the questions from our survey corresponding to lawn clipping management and frequency of lawn watering. The question from our survey dealing with lawn clippings asked: "How do you dispose of lawn clippings?" and options were: "Dispose of clippings off-site", "Leave clippings on the lawn", and "Compost clippings on my property". If the respondent answered with "Leave clippings on lawn", we credited them with 1 lb of N per 1000 ft^2 as suggested by Extension. The question from our survey dealing with frequency of lawn watering asked: "How often do you water your lawn?" and options were: "Regularly – once or more per week", "Occasionally – when grass is dry", and "Rarely/Never". If their response was "regularly", we considered them to be "irrigators". Based on responses to these two survey questions, we computed recommended N fertilizer application rates for each household.

Households in our survey reported the number of times they fertilized their lawns in 2007. To calculate the rate of N application from fertilizer, we assumed that households applied 1 lb of N per 1000 ft^2 at each application, as is recommended on most bags of lawn fertilizer. For households that used lawn companies, we obtained information on N application rates from these lawn companies. For each household, we then compared the recommended rate of N fertilizer application with the rate reported to classify each household as fertilizing more than recommended, less than recommended, or at the recommended rate.