IonE DISCOVERY GRANT FINAL REPORT

Project Title:	Connecting People, Land, and Water in Urban Ecosystems		
Project Number:	DG-0008-11	**Project Start Date:**	1/1/2011
Today's Date:	7/31/2016	**Project End Date:**	5/15/2016

A. PROJECT PERSONNEL

Role	Name	U of M Dept. or External Org	Email
PI (only 1 allowed)	Sarah E Hobbie	Ecology, Evolution And Behavior	shobbie@umn.edu
Co-PI	Larry Baker	Bioproducts And Biosystems Engineering	baker127@umn.edu
Co-PI	Kristen Nelson	Forest Resources/Fisheries, Wildlife, Conservation Biology	nelso468@umn.edu
Co-PI	Carissa Schively Slotterback	Humphrey Institute Of Public Affairs	schiv005@umn.edu
Collaborator	Jacques Finlay	Ecology, Evolution And Behavior	jfinlay@umn.edu
Collaborator	Joe Knight	Forest Resources	knight@umn.edu
Collaborator	Bruce Wilson	Bioproducts And Biosystems Engineering	wilson@umn.edu
Collaborator	Robert Sterner	Ecology, Evolution And Behavior	stern007@umn.edu
Collaborator	Valentine Cadieux	Geography	cadieux@umn.edu
Collaborator	David Fulton	Fisheries, Wildlife, Conservation Biology	dcfulton@umn.edu
Collaborator	Marv Bauer	Forest Resources	mbauer@umn.edu
Post-Doc	Ben Janke	Ecology, Evolution And Behavior	janke024@umn.edu
PhD Student	Daniel Nidzgorski	Ecology, Evolution And Behavior	dnidz@civiceco.org
PhD Student	Anika Bratt	Ecology, Evolution And Behavior	bratt075@umn.edu
Grad Student	Hilary Waters	Geography	wate0119@umn.edu
PhD Student	Amanda Meyer	Natural Resource Science And Management	meye1986@umn.edu
PhD Student	Mike Barnes	Natural Resource Science And Management	barne369@umn.edu
Grad Student	Michael Varien	Humphrey School Of Public Affairs, Urban And Regional Planning	varie001@umn.edu

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PROGRAM AREAS (check all that apply)

- ☐ Bioenergy & Bioproducts
  - ☐ Algae
  - ☐ Biological Catalysis
  - ☐ Biomaterials
  - ☐ Biopower
  - ☐ Chemical Catalysis
  - ☐ Next Generation Feedstock
  - ☐ Transportation Fuels
  - ☐ Waste Stream Remediation - Bio
- ☐ Conservation & Energy Efficiency
- ☐ Hydrogen Production, Storage & Use
- ☐ Policy, Economics & Ecosystems
  - ☐ Life Cycle Analysis
  - ☐ Carbon Sequestration
- ☐ Solar
  - ☐ Photovoltaic
  - ☐ Thermal Energy
  - ☐ Waste Stream Remediation – Solar
- ☐ Wind, Hydro & Geothermal
  - ☐ Geothermal
  - ☐ Hydroelectric
  - ☐ Wind
  - ☐ Waste Stream Remediation – Geothermal

B. EXTERNAL COLLABORATIONS

Name	Company/Organization	Explanation of Relationship

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C. LEVERAGED FUNDS

Status: Awarded | Award Date: 3/1/2012

Project Title: Tracing nutrient sources at the land-water interface in urban environments

FOA # or Title: Minnesota Water Resources Center Grant

Primary Funding Org:	US Geological Survey	Amount: $	29,742
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	

Status: Awarded | Award Date: 2013-2014

Project Title: N/A

FOA # or Title: City Arts Collaboratory Fellowships to Daniel Nidzgorski and Valentine Cadieux

Primary Funding Org:	City of St Paul	Amount: $	1500
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	

Status: Awarded | Award Date:

Project Title: Using stable isotopes to identify sources of organic and inorganic phosphorous and nitrogen in the Twin Cities watershed

FOA # or Title: STAR Fellowship to Anika Bratt

Primary Funding Org:	Environmental Protection Agency	Amount: $	180,000
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	

Status: Awarded | Award Date: 2013

Project Title: Green Cities and Clear Waters: Can urban trees help protect our lakes and streams?

FOA # or Title: Fellowship to Daniel Nidzgorski

Primary Funding Org:	Center for Urban and Regional Affairs	Amount: $	20,000
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	

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Status: Awarded | Award Date: 2013

Project Title: Summary and Analysis of Water Quality Data from the Capitol Region Watershed District's Stormwater Monitoring Program, 2005-2012

FOA # or Title:

Primary Funding Org:	Capitol Region Watershed District	Amount: $	21,267
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	

Status: Awarded | Award Date: 2012

Project Title: Germplasm improvement of low-input fine fescue in response to consumer attitudes and behaviors.

FOA # or Title: Specialty Crops Research Initiative

Primary Funding Org:	US Department of Agriculture	Amount: $	$256,485
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	

Status: Awarded | Award Date: 2014

Project Title: CRWD-UMN Data Analysis Projects: (1) Villa Park Wetland System Analysis, (2) Climate Sensitivity Analysis of Stormwater Nutrient Loading, and (3) Estimating Tree Nutrient Inputs to St. Paul Streets

FOA # or Title:

Primary Funding Org:	Capitol Region Watershed District	Amount: $	24,683
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	

Status: Awarded | Award Date: 2016

Project Title: Stormwater research priorities and pond maintenance

FOA # or Title:

Primary Funding Org:	Minnesota Pollution Control Agency	Amount: $	102,000
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	
Other Matching Org:		Amount: $	

IonE DISCOVERY GRANT FINAL REPORT

E.1 PUBLICATIONS

List the publications to date (including in-press and accepted) that have resulted from funding to support this research. Please include the full citation: Last Name, First Initial.; Last Name, First Initial. Title. *Journal*. **Year**, *Volume*, Pages.

Status	Full Citation (see format instructions above)
Published	Janke, B., J. C. Finlay, S. E. Hobbie, L. A. Baker, R. W. Sterner, D. Nidzgorski, B. N. Wilson. "Contrasting influences of stormflow and baseflow pathways on nitrogen and phosphorus export from an urban watershed". Biogeochemistry (2014) 121:209-228
Published	Nidgorski, D. "Nutrient transport, transformation, and retention in urban landscapes". PhD Dissertation, University of Minnesota (2014)
Published	Janke, B. D., J. C. Finlay, S. E. Hobbie, and L. A. Baker. Importance of storm drain baseflow to nutrient loading. Stormwater Assessment and Maintenance Updates (2013) 8(6).
Published	Nidzgorski, D. A. and S. E. Hobbie. 2016. Urban trees reduce nutrient leaching to groundwater. Ecological Applications (in press)
Submitted	Bratt, A. R., J. C. Finlay, S. E. Hobbie, B. D. Janke, Adam Worm, and K. L. Kemmitt. submitted. Contribution of leaf litter to nutrien export during winter months in an urban residential watershed. Environmental Science and Technology
Submitted	Hobbie, S. E., J. C. Finlay, B. Janke, D. A. Nidzgorski, D. B. Millet, and L. A. Baker. to be submitted imminently. Household actions in leaky watersheds dominate sources of urban water pollution.
Published	
Published	
Published	
Published	
Published	
Published	
Published	
Published	

Additional publications may be submitted in a separate document as an appendix.

E.2 PRESENTATIONS

List all of the presentations to date that have resulted from funding to support this research.

Type	Full Citation
Presenter	Nidzgorski, D. A., S. E. Hobbie, L. A. Baker, C. Fissore, J. Y. King, J. P. McFadden, K. C. Nelson. 2014. Reduce, redirect, or recycle? Quantifying opportunities to increase household nutrient sustainability. Ecological Society of America Meeting, Sacramento, CA
Presenter	Hobbie, S. E., J. Finlay, L. Baker, B. Janke, P. Kalinosky, M. Bauer, J. O'Neil-Dunne, D. Nidzgorski, C. Buyarski. 2013. The role of trees in mediating land-water nutrient flows in urban landscapes. Ecological Society of America Meeting, Minneapolis, MN
Presenter	Janke, B., J. Finlay, S. Hobbie, L. Baker, R. Sterner, D. Nidzgorski, B. Wilson. 2013. The importance of storm drain baseflow in nutrient export from urban watersheds. Ecological Society of America Meeting, Minneapolis, MN
Presenter	Nidzgorski, D. and S. Hobbie. 2013. Plant tree, save a lake: urban trees reduce groundwater nutrient pollution. Ecological Society of America Meeting, Minneapolis, MN
Presenter	Nidzogorski, D. A., and S. E. Hobbie. 2012. Can urban trees help protect our lakes and streams? Species effects on nitrogen and phosphorus leaching. Ecological Society of America Meeting, Portland, OR
Speaker	Hobbie, S. E. Duke University, Graduate Student Invited Speaker, A Watershed Approach to Understanding Urban Eutrophication, 10/14
Speaker	Hobbie, S. E. Carnegie Institution for Science, Department of Global Ecology, A Watershed Approach to Understanding Urban Eutrophication, 6/14
Speaker	Hobbie, S. E. Arizona State University, A Watershed Approach to Understanding Urban Eutrophication, 4/14
Speaker	Hobbie, S. E. Institute on the Environment, University of Minnesota, A Watershed Approach to Understanding Urban Eutrophication, 5/1
Keynote speaker	Hobbie, S. E. Trees, turf, and tails: understanding sources of nutrient pollution to urban watersheds. Distinguished Faculty Luncheon, University of Minnesota, 10/13
Keynote speaker	Hobbie, S. E. Our Water in a Changing World: Climate Change and the Urban Watershed. Presentation to the Friends of Diamond Lake, 2014
Keynote speaker	Hobbie, S. E. Our Water in a Changing World: Climate Change and the Urban Watershed, Presentation at the Science Museum of Minnesota, sponsored by SMM and Friends of the Mississippi, 2014
Presenter	Baker, L., S. Hobbie, J. Finlay, P. Kalinosky, and B. Janke. Moving upstream to reduce urban stormwater phosphorus loading (invited abstract), Session on Water, Energy and Society in Urban Systems, organized by D. Jenerette, J. Loperfido, A. Watts and C. Welty, Dec. 9, 2013 AGU meeting, San Francisco.
Presenter	Baker, L. Rethinking nutrient management in cities. International Low Impact Development (LID)

	Symposium, St. Paul, MN, August 18-21, 2013.

Additional presentations may be submitted in a separate document as an appendix.

F. PATENTS

Status	Patent Information
Pending	
Pending	
Pending	
Pending	

G. POSTDOCS

Name	Current Professional Position
Ben Janke	Research Associate, Saint Anthony Falls Laboratory, University of Minnesota

H. DEGREES AWARDED

Name	Degree Type	Major	Title of Dissertation/Thesis
Daniel Nidzgorski	PhD	EEB	Nutrient transport, transformation, and retention in urban landscapes
Michael Varien	MA	MURP	n/a
Elizabeth Appleby	MA	MURP	n/a
	PhD		
	PhD		

I. WEBSITE

http://environment.umn.edu/urbanvegetation/index.html

J. PROJECT OVERVIEW

Background. Urban vegetation confers numerous ecosystem services such as climate and air quality regulation, recreational opportunities, and psychological benefits. Yet the impacts of vegetation (trees, lawns, wetlands) versus impervious surface on hydrology and nutrient loading of urban streams and lakes is poorly known, despite implications for water quality. Nor is it well understood how sociopolitical factors influence decisions about urban vegetation on private and public lands within constraints imposed by multiple scales of governance. This original overall aim of this project was to better understand the dynamic relationships between the social and natural landscapes in urban areas towards enhancing human well-being and environmental quality in urban ecosystems.

Original Project Goals. For our original project goals, we aimed to determine (1) what motivates actions related to management of urban vegetation on private lands, and how this influences social networking regarding urban vegetation and water quality, (2) how different cover types in urban landscapes in turn influence urban water quality, and (3) how current governance structures and institutions respond to perturbations in vegetation cover and water quality in urban systems in ways that either promote or hinder the development of human-environment feedbacks that improve human wellbeing. We aimed to identify the major motivations and institutional constraints that shape management of urban land cover, as well as determine the consequences of these management actions for aquatic ecosystems, and their potential to deliver ecosystem services.

Evolved Project Goals. As our project evolved, our goals evolved slightly as well. Objective 1 narrowed to focus on household decisions around composting, asking what motivates actions related to management of urban vegetation and composting on private lands. Objective 2 broadened to ask what are the sources of nutrients to urban watersheds and the major pathways by which nutrients move from land to water? Objective 3 remained unchanged, asking how current governance structures and institutions respond to perturbations in vegetation cover and water quality in urban systems in ways that either promote or hinder the development of human-environment feedbacks that improve human wellbeing. Because we were asked to spread our two-year project over four years, the three objectives became less integrated than they might have been under our original plan.

Key Findings:

1) Drivers of change in yard waste removal include convenience, cost, and relationships. Strengthening and reaching out to neighborhood networks and developing educational programs at compost sites may be important first steps in encouraging new environmental stewardship practices.

2) The high impervious cover of urban watersheds makes them particularly "leaky" for phosphorus, which moves readily into streets, storm drains, and eventually into lakes and rivers, via leaves that fall into streets, runoff during snowmelt, and lawn runoff during heavy rains. Nitrogen is also exported to surface waters via these pathways, but additionally leaches to groundwater and is exported in storm drains during baseflow periods between storms. Trees adjacent to impervious surfaces promote nutrient loss from land to surface waters because their nutrient-rich leaves fall onto streets and end up in storm drains. On the other hand, trees away from streets reduce leaching losses to groundwater.

3) Significant disconnects exist between land use planning, which includes efforts that relate to vegetation cover and water quality, and water-related planning. Even with a relatively consistent framework for planning offered by the Metropolitan Council, there seems to be a disconnect in terms of the personnel writing the land use and water-related content, as well as variations in language and approach. Much of the focus of land use planning language is focused on private sector development, while water-related planning is focused on public infrastructure.

K. PROJECT IMPACTS

Leveraged Funds. This project leveraged approximately $750,000 in research funding from state and federal sources.

External partnerships/collaborations. This project helped to establish and solidify a research partnership between the University of Minnesota and the Capitol Region Watershed District (CRWD). Specifically, this collaboration resulted in (1) new surveys of CRWD homeowners about yard waste management; (2) new analyses by UMN researchers of long-term stormwater monitoring data collected by CRWD, showing that much of the nutrient pollution exported from urban areas via the storm drain network occurs in between rain events during "baseflow" periods; (3) new year-round monitoring by UMN researchers and CRWD staff of stormwater pollution in the Arlington-Hamline Underground Facility, an underground stormwater vault, extending the "warm season" sampling done by CRWD to include winter and early spring snowmelt periods, and showing that about half of the nutrient export from urban areas occurs during snowmelt; (4) UMN laboratory analyses of new forms of nutrient pollutants previously unmeasured in stormwater samples collected by CRWD, showing that most of the nutrient pollution is exported in the form of organic nutrients, and indicating the importance of tree leaves and lawns as sources of nutrient pollution to storm water; and (5) content analysis of watershed management plans.

Impacts to Minnesota. The project has increased knowledge of how homeowner's make decisions related to managing nutrients in yards; the sources of nutrient pollution to urban watersheds and storm water, the leading cause of pollution for Minnesota's urban waters; and the connections between governance of land and water. Residential fertilizer is the single largest input of nitrogen to urban watersheds in Minnesota, while pet waste is the single largest input of phosphorus. These nutrients are readily moved into streets and storm drains through leaves that fall from street trees into city streets in the fall, during snowmelt runoff in the spring, and from lawn runoff during heavy rain storms in the summer. Further, as much nitrogen is exported during baseflow periods between storms as during storms. These results suggest that traditional approaches to stormwater management might not be effective in dense urban watersheds, where there is limited space to install storm water management infrastructure, such as storm water ponds. Thus, alternative approaches to reducing nutrient pollution of surface waters might prove effective, such as focusing on reducing sources of nutrients to watersheds and streets, e.g., by finding ways to reduce over-use of nitrogen fertilizer and increasing street sweeping in the fall. Changing homeowner behavior likely will require tapping into homeowner relationships.

Student successes. This project helped to support research of three PhD students, two MS students, and one postdoctoral scholar. The project also also helped students leverage $200,000 in fellowship support through an Environmental Protection Agency STAR Fellowship and with a fellowship from the Center for Urban and Rural Affairs at UMN.

Environmental impacts. The project informed the Como Neighbor Network (CNN), which augments city street sweeping each fall by mobilizing a network of citizens to remove leaves from city streets in the Como Park neighborhood, reducing nutrient pollution in Como Lake. The project provided the CNN with information about which streets to target for leaf pickup and with estimates of phosphorus removal that resulting from its efforts.

Public impacts (e.g. educating the public). Researchers presented the results of the study to numerous public audiences, including the Friends of the Mississippi River, the Friends of Diamond Lake, the Capitol Region Watershed District, the MN Association of Landscape Architects, the MN Environmental Quality Board, and the MN Water Conference.

Section B. External Collaborations, cont.

Name	Company/Organization	Explanation of Relationship
Adam Robbins, Rachel Coyle	Saint Paul Parks and Recreation	They partnered with us to locate trees in St Paul city parks to determine effects of trees vs. turfgrass on nutrient cycling and leaching.
Udai Singh, Jennifer Keville	Mississippi Watershed Management Organization	They shared monitoring data with us.
Mark Doneux, Bob Fossum, Britta Suppes, Elizabeth Beckman	Capitol Region Watershed District	We have partnered with them to collect wintertime runoff data; they have provided us with baseflow and runoff pollutant data that we analyzed and published in a peer-reviewed article.
Two 4th Grade Classrooms (40 students each	Harambee Elementary School	Volunteered to sample network of urban lakes for lake water quality
20 Citizen Scientist Volunteers	Various	Volunteered to sample network of urban lakes for lake water quality
Janna Caywood	Como Active Citizens Network (formerly Como Lake Neighbor Network)	We have provided this group with data to help them target particularly streets and times for their neighborhood street cleanup efforts; we have also helped them quantify phosphorus removal from these efforts
Staff	Ramsey County Yard Waste	We received data from the Ramsey County Yard Waste Sites on brush and tree disposal numbers as well as programs offered over the years.

Section C. LEVERAGED FUNDS, cont.

Funded. 06/01/15. Environment and Natural Trust Fund (ENRTF), LCCMR-MN, Bee Pollinator Habitat Enhancement – Phase 2. Nelson $160,709 of $387,000.

Funded. 05/01/2015. University of Minnesota, Office of Vice President for Research; Serendipity Grant. The mental health of green space: Leveraging big data and new models for planning smart cities. Nelson $6,000

Funded: 07/01/2014. USDA Forest Service, Northern Research Station. The Future of Urban Forests in a World of Rapid Change and Great Uncertainty: Innovative Perspectives from Futures Research. $14,000.

Rejected. NSF Urban Sustainability Research Network. Natural Cities: Examining Tradeoffs of Green and Grey Infrastructure to Provide Urban Services. $11,658,581.

Rejected. 1/23/14: NSF Ecosystem Science. Preliminary Proposal: An Ecosystem Approach to Understanding Eutrophication of Urban Waters.

Rejected. 11/19/13. NSF Dynamics of Coupled Natural and Human Systems. CNH: Understanding Feedbacks among Governance, Economics, and Water Quality towards Improving Urban Sustainability. $1,499,343.

Rejected, 10/12: NSF Dynamics of Coupled Natural and Human Systems. CNH: A challenge for the future: governance of urban land-lake connections under climate change. $1,499,925.

Rejected, 10/12. NSF Dissertation Improvement Grant. DDIG: Can urban trees help protect our lakes and streams? Species effects on nutrient loading to stormwater. $19,760

Rejected, 10/12: Local Roads Research Board. Improving street sweeping for water quality improvement. $198,246.

Rejected, 1/9/12: NSF Ecosystem Science. Preliminary Proposal: Sources and Fates of Nutrients in Urban Landscapes.

Rejected, 2011: NSF Sustainability Network. Preliminary Proposal: Low Carbon And Sustainable Cities - Interdisciplinary Systems Integration of People and Infrastructures at the….

Rejected. 2011. Water Resources Center Competitive Grants Program. Carbon Footprinting in the Urban Environment. $37,881

Section D.2. PRESENTATIONS, cont.

Type	Full Citation
Speaker	Baker, L. The water environment of urban ecosystems: from theory to the street. Minnesota Association of Landscape Architects Annual Education Conference, St. Paul, April 20, 2012
Speaker	Baker, L., S. Hobbie, J. Finlay. Pathways of nutrient movement through urban systems. City of St. Paul Public Works Department, August 10, 2012.
Speaker	Nelson, K.C. 2014. Urban Ecosystems: Residential Yards and Homeowner Decisions—social drivers of plant biodiversity and nutrient fluxes. Graduate Student Invited Speaker, Natural Resources Ecology and Management Seminar, Iowa State University, Ames, IA., September 19th.
Speaker	Nelson, K.C. 2014. Report on Twin Cities Household Ecosystem Project (TCHEP), Invited Speaker, Minnesota Environmental Quality Board, January 15th meeting, University of Minnesota, St. Paul, 40 people.
Presenter	Janke, B. 2012. Importance of Hydrologic Pathways to Urban Nutrient Loading and Implications for Current Stormwater Management Practices. Minnesota Water Conference, Oct 16, 2012, St. Paul, MN

Speaker	Janke, B. 2014. St. Paul's Buried Streams: How Baseflow in Storm Drains Influences Nutrient Export from an Urban Watershed. Water Resources Science Seminar Series - University of Minnesota, St. Paul, MN
Presenter	Finlay, J.; Hobbie, S.; Baker, L.; Janke, B.; ECOSYSTEM REGULATION OF NUTRIENT TRANSPORT IN URBAN LANDSCAPES Joint Aquatic Sciences Meeting, May 18-23, 2014, Portland OR. (Abstract ID: 13963)
Presenter	Bratt, A. Finlay, J.C., Janke, B.D., and Worm, A. 2014. Nutrient Export And Litter Decomposition During Winter Months In An Urban Residential Watershed. Presented at the *Third Symposium on Urban Stream Ecology*, Portland, OR. Presented on May 15 2014.
Presenter	Finlay, J.C. et al. 2012 Nutrient sources and transport along urban flowpaths to aquatic ecosystem American Geophysical Society Meeting, San Franscico CA
Presenter	Meyer, A.J., K.C. Nelson, and S.E. Hobbie. 2016. Influencing environmental stewardship in urban yard waste management, ISSRM, Houghton, MI, June 24, poster
Speaker	Nelson, K.C., M. Barnes, A. Meyer, B. Horgan, E. Watkins, C. Yue, S. Bonos, B. Clarke, B. Huang, W. Meyer, J. Murphy, B. Park, and P. Koch. 2015. Public Land Mangers: A Research Agenda Focused on Preferences and Influence Regarding Low-Input Fine Fescue, ASA, CSSA, & SSSA Meetings, Minneapolis, MN, November 17
Presenter	Nidzgorski, D. A., S. E. Hobbie, J. C. Finlay, T. Marcus. Urban trees drive stormwater nutrient pollution: the role of phenology and litter chemistry. Ecological Society of America Meeting, Baltimore, MD
Keynote Speaker	Hobbie, S. E. *Trees, Pets, and People: A Watershed Approach to Understanding Urban Eutrophication*. Gordon Research Seminar, From Molecular Processes to Water Management Practices: Translational Environmental Science 6/16
Speaker	Hobbie, S. E. *Trees, Pets, and People: A Watershed Approach to Understanding Urban Eutrophication* University of Minnesota Ecology, Evolution and Behavior Graduate Program Welcome Week, 1/16
Speaker	Slotterback, C.S. *Connecting Local Land Use and Watershed Planning. Water After Borders Summit*. University of Illinois – Chicago. Chicago, IL, April 23-24, 2015
Speaker	Janke BD, Finlay JC, and Hobbie SE. "Does Urban Tree Canopy Enhance Nutrient Export by Stormwater?" Society for Freshwater Science 2015 Annual Meeting, Milwaukee, WI. May 17-21, 2015.
Speaker	Janke BD, Finlay JC, and Hobbie SE. "Understanding the Role of Urban Trees in the Management of Nutrients in Stormwater." 2015 Minnesota Water Resources Conference, St. Paul, MN. Oct 13-14, 2015.

MEDIA COVERAGE

Star Tribune, October 28, 2013. *Minneapolis and St. Paul leaf sweeps are on, despite late fall*. By Steve Brandt.

Minnesota Daily, October 9, 2013. *Leaf pollution makes urban lakes reek*. By Katelyn Faulks

Section L. TECHNICAL REPORT - DG-0008-11, Connecting People, Land, and Water in Urban Ecosystems

Urban vegetation confers numerous ecosystem services such as climate and air quality regulation, recreational opportunities, and psychological benefits. Yet the impacts of vegetation (trees, lawns, wetlands) versus impervious surface on hydrology and nutrient loading of urban streams and lakes is poorly known, despite implications for water quality. Nor is it well understood how sociopolitical factors influence decisions about urban vegetation on private and public lands within constraints imposed by multiple scales of governance. This project aims to better understand the dynamic relationships between the social and natural landscapes in urban areas towards enhancing human well-being and environmental quality in urban ecosystems.

We aimed to determine (1) what motivates actions related to management of urban vegetation management choices and composting on private lands, (2) the role of urban vegetation and other land cover types in influencing urban water quality, and (3) how current governance structures and institutions respond to perturbations in vegetation cover and water quality in urban systems in ways that either promote or hinder the development of human-environment feedbacks that improve human wellbeing. We aimed to identify the major motivations and institutional constraints that shape management of urban land cover, as well as determine the consequences of these management actions for aquatic ecosystems, and their potential to deliver ecosystem services.

Below, we outline the specific aims, activities, and findings for each of the three research objectives.

Objective 1: What motivates actions related to management of urban vegetation management choices and composting on private lands?

As explained in Meyer et al. (2016), our changing understanding of urban ecosystems continually inspires new environmental stewardship practices for urban green spaces, a large percentage of which is private residential yards. Yard waste disposal practices have significant impacts on urban watershed nutrient budgets (Hobbie et al. submitted) and can impact urban water quality as nutrient inputs to streets and downstream surface waters (Fissore et al., 2012). To encourage environmental stewardship practices in homeowners, we must learn what drives their decisions about yard care and what role local government may play in these decision processes. Specifically we addressed the following questions: (1) What influences homeowners' choices for yard waste management? and (2) How do public yard waste disposal programs impact management choices?

The method was semi-structured in-depth interviews collected with 18 owners of randomly selected single family homes across the Capitol Region Watershed District in Saint Paul, Minnesota. Residents were interviewed about their habits regarding disposal of yard waste, and their knowledge and use of public yard waste disposal programs and facilities. Participants

also completed a questionnaire regarding the usefulness and trustworthiness of various yard waste management information resources as well as demographic questions. All recorded interviews and notes were transcribed and entered into NVivo for analysis. The transcripts were coded and analyzed based on the factors of trustworthiness, usefulness, knowledge sources, collaboration, and challenges.

From our interviews, we gained several key insights. First, yard care is often completed in collaboration with family and close neighbor networks. As one homeowner explained, “I come from a family of eight so it's usually my dad if he can come up and then my second oldest sister. And she's into the lawn care thing so she's always like, 'I'm comin’ up and I'm doing your leaves!’… So it's kind of nice.” Second, residents view neighbors and family as the most trusted and most useful information sources regarding yard waste disposal methods. As one man said, “I’m sawing with [my neighbor] during the winter. We collect wood during the summer… and it’s when we’re sawing that we talk… So he basically has educated us into everything that happens in the neighborhood and what we do with… the compost and stuff.” Third, the most widely appreciated public yard waste programs were free, county-run compost sites. Many report opinions, such as the following, “I was very impressed when we moved to St. Paul and I found out about this place and we were tending to a yard and suddenly had all this stuff we needed to do something with – that something like that existed and that the city had organized that and that it was free to use, so I think what they have already available is great and serves our needs really well.” Fourth, newcomers to the area learned about yard waste disposal sites and methods from family, neighbors, and/or mailings. As one new resident mentioned, “I think when I moved in…my neighbors definitely let me know about the compost site and how close it is.” Fifth, challenges in yard waste removal include lack of time, tools, and/or ability. Distinct homeowners mentioned the following, “It's kinda discouraging that there isn't somewhere closer or like that service with the garbage doesn't run a little bit longer knowing that you know middle of November people still aren't done picking up leaves kind of thing.” And from another “well, frankly at our stage in life I think there may be a time where it would be more beneficial for us if someone would pick [our compost] up.”

In summary, from a programming standpoint, drivers of change in yard waste removal include convenience, cost, and relationships. Social diffusion theory supports this and encourages finding ways to make sustainable yard waste disposal systems more visible in the community (McKenzie-Mohr & Schultz, 2014). Strengthening and reaching out to neighborhood networks and developing educational programs at compost sites may be important first steps in encouraging new environmental stewardship practices. The next steps in the analysis are to estimate the role that homeowner yard waste management decisions play in urban water quality. In addition, spatial and demographic analysis of yard waste disposal methods (on-site vs off-site) will shed light on factors that influence the likelihood of participation in sustainable yard care practices.

Objective 2: What are the sources of nutrients to urban watersheds and what are the major pathways by which nutrients move from land to water?

Towards addressing Objective 2, our project has focused on several efforts related to understanding (1) the role of land cover, including tree cover, on nutrient flows to urban ground and surface water, 2) the role of hydrology and land cover in influencing nutrient loading of storm water conveyances, 3) the role of winter time processes and spring snowmelt in influencing nutrient export to stormwater, and 4) the role of hydrology and land cover in influencing water quality in urban small ponds. In addition (5), we used the results from this project along with other previous studies to construct whole watershed nutrient (nitrogen and phosphorus) budgets for seven subwatersheds of the Mississippi River in the Capitol Region Watershed. Following, we summarize our significant activities and findings related to this objective.

1) Considerable amounts of nitrogen (N) and phosphorus (P) leach to groundwater in the Twin Cities, even in unfertilized areas (Janke et al 2014), likely due to the region's coarse-textured soils. We examined whether or not urban trees can reduce nutrient leaching to groundwater, an important nutrient export pathway that has received less attention than stormwater. We characterized leaching beneath thirty-three trees of fourteen species, and seven open turfgrass areas, across three city parks in Saint Paul, Minnesota. We installed lysimeters at 60 cm depth to collect soil water approximately biweekly from July 2011 through October 2013, except during winter and drought periods, measured dissolved organic carbon (C), N, and P in soil water, and modeled water fluxes using the BROOK90 hydrologic model. We also measured soil nutrient pools (bulk C and N, KCl-extractable inorganic N, Brays-P), tree tissue nutrient concentrations (C, N, and P of green leaves, leaf litter, and roots), and canopy size parameters (leaf biomass, leaf area index) to explore correlations with nutrient leaching. Trees had similar or lower N leaching than turfgrass in 2012 but higher N leaching in 2013 (Fig. 1); trees reduced P leaching compared with turfgrass in both 2012 and 2013, with lower leaching under deciduous than evergreen trees. Scaling up our measurements to the Capitol Region Watershed, a subwatershed of the Mississippi River (~17,400 ha, containing roughly 1.5 million trees), we estimated that trees reduced P leaching to groundwater by 533 kg in 2012 (0.031 kg/ha or 3.1 kg/kma^2) and 1201 kg in 2013 (0.069 kg/ha or 6.9 kg/km^2). Removing the same amounts of P

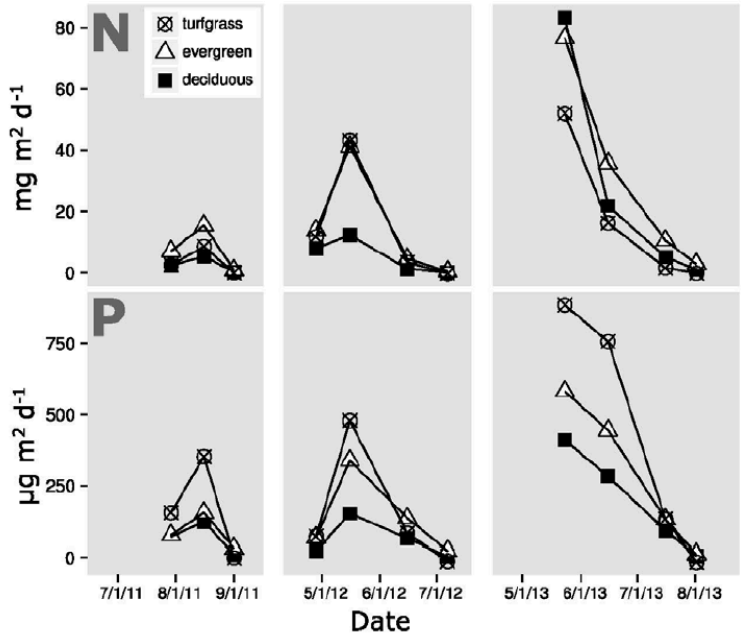

Fig. 1. Average daily N and P leaching fluxes for each calendar month, averaged by vegetation type (turfgrass, evergreen trees, deciduous trees) in city parks, St. Paul, MN. From Nidzgorski and Hobbie 2016.

with stormwater infrastructure would cost $2.2 million and $5.0 million per year, respectively.

2) However, trees are an important source of nutrients to stormwater. At the watershed scale, trees influence both the amount and timing of nutrient inputs to stormwater: watersheds with greater canopy cover over streets contributed more nitrogen and phosphorus to stormwater (Fig. 2), and concentrations of dissolved organic forms of nutrients (which are generally not monitored in storm water programs) are relatively high in storm drains, further evidence of the importance of trees as sources of nutrients to streets. The highest N and P concentrations in stormwater were observed during leaf out in late spring and leaf drop in autumn. The timing of these periods of high nutrient flux were highly variable from year to year due to climate influence on phenology, its timing relative to city street sweeping, and timing of rain events that move nutrients from streets into storm drains. These results suggest that increased street sweeping frequency, targeting areas with high canopy cover, could be an effective means of mitigating urban water pollution.

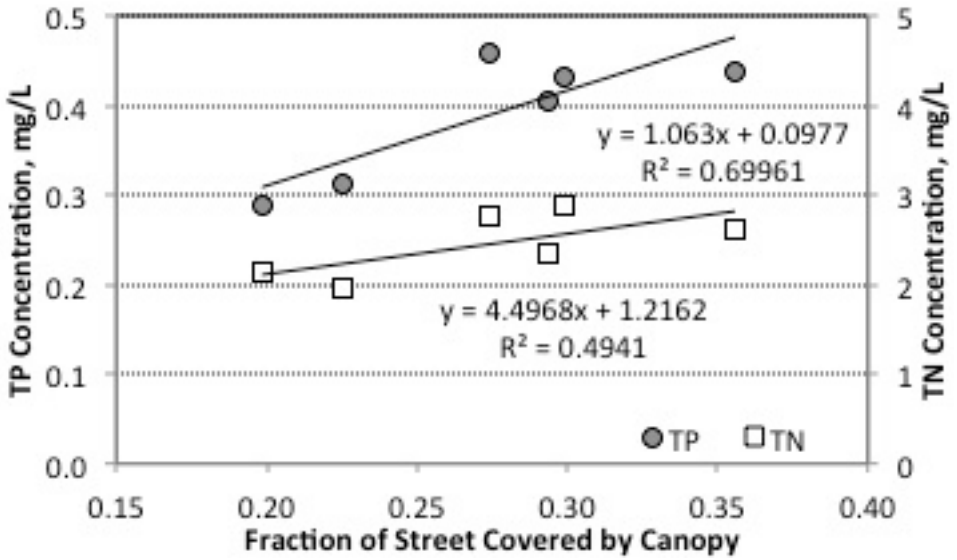

Figure 2. Mean Stormwater Total Nitrogen (TN) and Total Phosphorus (TP) Concentrations at 6 St. Paul, MN Storm Drains vs. Fraction of Street Covered by Tree Canopy in the Watershed. Data collected by the Capitol Region Watershed District during its monitoring seasons from 2005 – 2011 (Janke et al. in prep.).

3) Snowmelt during late winter and early spring is also a period of high nutrient export that is typically not captured by stormwater monitoring programs or management practices. However, winter contributions and sources of annual N and P loads from urban watersheds are poorly characterized in northern cities because most monitoring programs are limited to warm weather periods. To determine winter export of N and P, we monitored storm water outflow in a residential watershed in Saint Paul, Minnesota during 2012-2014 (Arlington-Hamline Underground). Our data demonstrate that winter melt events contribute a disproportionately high percentage of annual N and P export (50%) relatively to runoff (40%) (Fig. 3, Bratt et al.

submitted). We hypothesized that over-wintering leaf litter that is not removed by fall street sweeping could be an important source to winter loads of N and P. We estimated contributions of this source by studying decomposition in lawns, street gutters, and catch basins during two winters. Rates of decomposition and N loss were negligible during both winters. However, P was quickly solubilized from decomposing leaves. Using mass balances and estimates of P leaching losses, we estimated that leaf litter contributed 80% of winter total dissolved P (TDP) loading in this watershed (~40% of total TDP loading). Our work indicates that urban trees adjacent to streets likely represent a major source of P pollution in northern cities. Management that targets important winter sources such as tree leaves will be essential toward reducing P loading and may mitigate eutrophication in urban lakes and streams in developed cities.

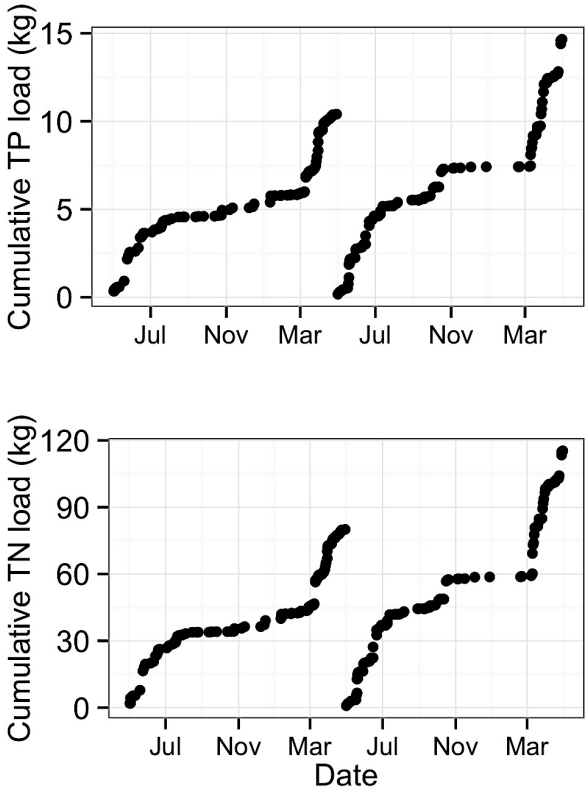

Figure 3. Annual cumulative nutrient loads (May-April) of total phosphorus (A, TP) and total nitrogen (B, TN) from May 2012 through April 2014 from data collected at the outflow of AHUG watershed. Arrows indicate May to April interval that cumulative loads were derived from (From Bratt et al. submitted).

4) At larger spatial scales in the Twin Cities (e.g. of entire watersheds), variation in stormwater quality is unrelated to broad land cover classes (Janke et al. 2014). Rather, stormwater nutrients vary across the city as a function of street density and resultant effects on hydrology.

5) Baseflow is a significant contributor to annual nutrient export in Twin Cities storm drains (Fig. 4, Janke et al. 2014), especially where groundwater is shallow, likely because of ground water inputs to stormwater networks. Sampling of water from a variety of sources (e.g. lakes, ponds, streams, and springs) around the Twin Cities during baseflow periods shows differentiation in nutrient chemistry among surface and sub-surface water sources. These data suggest that the large storm drains in St. Paul are primarily influenced by groundwater during baseflow periods, but also that upstream surface waters such as lakes and ponds that flow into the drains play an important role in water and nutrient loading by the drainage network. These results call into question the efficacy of stormwater best management practices that focus primarily on stormwater.

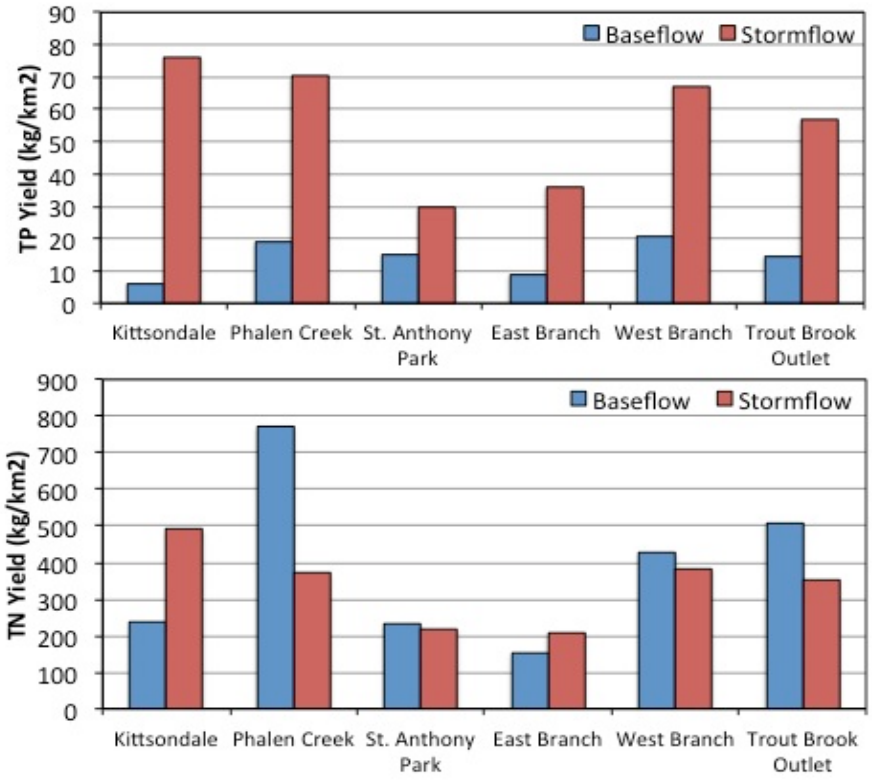

Figure 4. Mean Seasonal (May – Oct) Nutrient Yields (kg/km^2) from 2006-2011 at the main monitoring sites of the Capitol Region Watershed District. Baseflow and stormflow yields are shown separately for each site; total phosphorus yields are shown in the top graph and total nitrogen yields are shown in the bottom graph. From Janke et al. 2014.

6) Volunteers were successful in collecting water quality samples from 31 urban ponds. The samples were analyzed for total P, total dissolved N, dissolved organic carbon and conductivity. There was considerable variability in nutrient dynamics in both time and space in small urban

ponds; however this variability was not directly related to the predominant land cover surrounding the ponds as identified by the volunteer sampler.

7) We used a whole-watershed mass balance to compare watershed inputs and their retention for N and P in seven subwatersheds of the Mississippi River, in the Capitol Region Watershed (Hobbie et al. submitted). We used past research conducted as part of the Twin Cities Household Ecosystems Project (TCHEP) to estimate watershed inputs of N from residential fertilizer and inputs of N and P from pet waste. We obtained estimates of atmospheric deposition using models and published measurements. We estimated non-residential fertilizer inputs of N and P from interviews with land managers of golf courses, cemeteries, campuses, etc. Yard waste exports of N and P were estimated using TCHEP data. We found that lawn fertilizer and pet waste dominated N and P inputs, respectively, underscoring the importance of managing household actions to improve urban waters. Watersheds exhibited contrasting patterns of P and N retention. Despite low P inputs because of a statewide restriction on lawn P fertilizer, watersheds were net exporters of P on average. Stormwater P runoff, promoted by high impervious cover that mobilized P-rich materials to streets, along with P removal in yard waste, established P deficits in some watersheds. By contrast, watersheds were highly retentive of N (retaining 58-92% of net N inputs). However, N budgets were poorly constrained, and comparisons of the N:P stoichiometry of net inputs (inputs minus biomass removal) versus storm drain exports indicated that unmeasured leaching to groundwater and denitrification likely were significant losses of "retained" N. In summary, these urban watersheds exported high quantities of N and P, but via contrasting pathways: P was lost primarily via stormwater runoff where it likely degrades surface waters, while watershed N losses remain poorly characterized, but likely contribute to air, surface water, and groundwater pollution. These contrasting dynamics suggest that N management should emphasize reducing watershed inputs, while P management should focus on reducing P inputs and fluxes to streets.

Objective 3: How do current governance structures and institutions respond to perturbations in vegetation cover and water quality in urban systems in ways that either promote or hinder the development of human-environment feedbacks that improve human wellbeing?

Toward addressing Objective 3, we conducted an assessment of relevant local-scale zoning and related ordinances that have direct and indirect impacts on vegetation cover and water quality. In addition, we analyzed the use of data and the presence of goals related to vegetation and water quality in local-scale comprehensive plan and water resource management plans. Both the plan and policy analyses have been conducted for local governments within the Rice Creek and Capitol Region Watershed district boundaries. In addition, a similar assessment of data use and goal analysis has been conducted for the relevant watershed scale plans. In preparation for a survey of local government land use planning, water quality practitioners, and other relevant experts, a database of key contacts was attempted. Implementation of the survey was not pursued after it was determined the vast majority of the primary contacts for the land use and water-related plans no longer retained their earlier affiliation and could not be effectively targeted for data collection. Overall, the extensive content analysis of plans and the assessment of data use and goal analysis revealed significant disconnects between land use planning, which includes efforts that relate to vegetation cover and water quality, and water-

related planning. Even with a relatively consistent framework for planning offered by the Metropolitan Council, there seems to be a disconnect in terms of the personnel writing the land use and water-related content, as well as variations in language and approach. Much of the focus of land use planning language is focused on private sector development, while water-related planning is focused on public infrastructure.