Urban Agriculture as a

Green Stormwater Management Strategy

The Freshwater Society

In partnership with

The Mississippi Watershed Management Organization

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Executive Summary

This white paper is the result of a planning grant awarded by the Mississippi Watershed Management Organization. The report will describe the need that drives interest in green infrastructure, investigate major issues related to using urban agriculture as a green infrastructure strategy, identify gaps in current research, summarize actions other cities have taken on urban agriculture and green infrastructure, and frame a series of recommendations for next steps. As described by the MWMO, major issues to explore include:

- Soil moisture
- Run-off levels
- Erosion and sediment loss
- Practices that can be transferred from the agricultural sector
- Information gaps and needed research
- Water holding potential of urban farm sites
- Guidelines for using stormwater on crops
- Urban soil contaminants
- Stormwater for growing food crops
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- Opportunities and barriers for using stormwater BMPs as community garden and urban agriculture sites to help meet NPDES permit requirements
- Community gardening and urban agriculture as a community engagement strategy under the NPDES permit program

Rainfall amounts are increasing in both amount and frequency. Stormwater infrastructure has a fixed and finite volume capacity, and may be insufficient to meet future demands. Green infrastructure offers a promising new approach to managing stormwater by reducing the volume of water that would otherwise flow to traditional stormwater systems. While there are a number of widely-used green infrastructure strategies and structures available to cities, urban agriculture and community gardens are not typically among them.

In planning for healthy cities of the future, land use planners are looking beyond the single benefit of urban agriculture's potential as a stormwater management strategy, and evaluating the full range of benefits that derive from urban agriculture as a land use activity. Urban farms and gardens can improve the visual quality of neighborhoods, provide opportunities to socialize and cooperate with friends and family, connect urban residents to food systems, improve access to fresh, nutritious food, help in combating childhood obesity, diabetes, and poor nutrition, provide access to rare foods that support the cultural heritage of citizens, create opportunities for interracial and intercultural interactions, decrease crime, offer opportunities for recreation and relaxation when gardening outdoors, improve the food security of households, and help gardeners and urban farmers gain new knowledge and technical skills.

Before urban agriculture can move from being an interesting idea for managing stormwater to a technology cities can deploy as part of a holistic green infrastructure plan, its stormwater benefit must be quantified. That will involve resolving a set of issues, questions, and concerns about urban farming and gardening practices.

The nature of urban soils in particular are are not well-assessed, and data for water-holding capacity, infiltration rates, or other general characteristics are rare. In essence, there is no single, identifiable category with a consistent set of characteristics to which all urban soils belong.

Erosion is not currently a significant issue in urban farming or community gardening, as it is in production agriculture. However, an anticipated increase in the number and size of urban farms sites could drive an increase in erosion from urban lots. Urban agriculture is an emerging land use that has minimal history in modern cities, but is uniquely positioned to take advantage of lessons learned by both production agriculture and construction to reduce its impact on stormwater systems and the health of local waters. Commonly used gardening practices can contribute additional strategies to reduce erosion.

Many urban soils are highly compacted, and frequently contaminated, the result of years of industrial and development activities. Given time and patient, intentional management, compacted urban soils can be improved by deep tillage and the addition of compost and cover cropping to dramatically increase infiltration and water-holding capacity.

There is no clear consensus on whether it is safe or advisable to use stormwater on food gardens. Much of the world uses harvested rainwater to grow food, especially in arid and drought-prone regions of the world. Many organizations advise filtering harvested stormwater before using it in drip irrigation or other watering systems that reduce surface contact with edible plants.

Urban soils are presumed to have high levels of contaminants, and often do. There are systems in place to test soils, evaluate contaminant levels, and fairly simple measures exist to remediate contaminants, make them less mobile in soils, and to avoid their harmful effects. Washing leafy crops will generally remove most surface contaminants and make produce safe for consumption. Amending soil with compost in a 2:1 ratio by volume makes metals such as lead, or cadmium less mobile in soils, and reduces uptake by plants.

According to the City of Minneapolis, no licensing is required to install and/or operate an urban farm, nor does the City require soil testing for either urban farms or community gardens. Rather than create an overlapping set of regulatory parameters, the City adheres to statewide policies for food-related business. Neither the MN Department of Health nor the MN Department of Agriculture has licensing requirements for urban farms.

It is the recommendation of this report that the Mississippi Watershed Management Organization support the convening of a stakeholder group to further investigate a broad range of planning and policy issues related to urban agriculture as a green infrastructure strategy**.** Bringing together representatives from a variety of public and private agencies, organizations and commercial interests to engage in a comprehensive conversation about urban agriculture as a green stormwater control strategy would “de-silo” urban agriculture. It is time to bring together decision makers to comprehensively analyze options for urban land use to create better solutions for addressing the changing demands of managing stormwater in ways that benefit residents, communities and water resources in Minnesota.

Introduction

Recent trends in precipitation caused by a changing climate have made managing rainwater in Minnesota an increasingly complex challenge. In June of 2012, Duluth, MN experienced the wettest two-day period on record, overwhelming stormwater pipes, causing flooding, road washouts, raw sewage releases, and dangerous sinkholes. Conversely, by the end of July 2012, severe to extreme drought affected approximately 38 percent of the contiguous United States, and approximately 57 percent of the contiguous U.S. fell in the moderate to severe drought category.[1] Drought has continued to spread across the country throughout the fall. According to a study being undertaken by the Minnehaha Creek Watershed District in partnership with the National Oceanic and Atmospheric Administration (NOAA),

> Climate research, current weather patterns and projected trends show a significant increase in both the frequency and severity of rain events across Minnesota. Existing stormwater management systems designed to control runoff and protect property when it rains may no longer function as intended. The infrastructure in these systems may prove inadequate, resulting in increased flooding, damage to property, public safety concerns, and impacts to the quality of our lakes, streams and wetlands. [2]

As a participant in the study, the City of Minneapolis is already considering the stormwater management implications of changing rainfall patterns, asking whether, "citizens want bigger, more expensive sewer pipes, porous pavements, surface ponds, more wetlands and rain gardens, or none or all of the above?" According to Lois Eberhart, "There might have to be changes in behavior, such as accepting more standing water in our streets and yards."[3] Few cities will have the resources, or the inclination, to tear up miles of streets and replace stormwater pipes with others of larger capacity. Communities are looking for innovative ways to reduce the volume of stormwater flowing through the streets. These new and emerging strategies are grouped into what the EPA calls green infrastructure. According to the EPA[4],

> Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up and storing water.

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[1] http://www.ncdc.noaa.gov/sotc/drought/
[2] http://www.minnehahacreek.org/sites/minnehahacreek.org/files/pdfs/studies/NOAAExtremeTrendsFactsheet_FINAL.pdf
[3] http://www.startribune.com/local/152232355.html?refer=y
[4] http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm

The list of green stormwater infrastructure strategies promoted by the EPA includes downspout disconnection, rainwater harvesting, rain gardens, planter boxes, bio-swales, permeable pavements, green streets and alleys, green roofs, urban tree canopy, and land conservation. Typically excluded is urban agriculture.

There is a tremendous amount of interest in urban farming and community gardening across the country. Urban agriculture is commonly defined as, "the growing, processing, and distributing of food and other products through intensive plant cultivation and animal husbandry in and around cities."[5] The benefits of growing local foods are widely accepted:

- Increases surrounding property values, beautifies vacant properties, increases a sense of community, and provides recreational and cultural uses.
- Increases infiltration of rainwater, reducing stormwater overflows and flooding, decreases erosion and topsoil removal, improves air quality, and reduces waste by the reuse of food and garden wastes as organic material and compost.
- Increases physical activity and educates new gardeners on the many facets of food production from food security to nutrition and preparation of fresh foods.[6]

There are many anecdotal examples of projects that promote the stormwater infiltration and runoff volume reduction benefits of urban farms and gardens, but to-date no rigorous studies have been conducted to quantify those benefits.

This white paper is the result of a planning grant awarded by the Mississippi Watershed Management Organization to investigate major issues related to using urban agriculture as a green infrastructure strategy, gaps in research, and recommendations for next steps. Each of these issues will be explored in detail in sections that follow. As described by the MWMO, major issues to explore include:

- Soil moisture
- Run-off levels
- Erosion and sediment loss
- Practices that can be transferred from the agricultural sector
- Information gaps and needed research
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- Urban soil contaminants
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- Opportunities and barriers for using stormwater BMPs at community garden and urban agriculture sites to help meet NPDES permit requirements

[5] http://www.foodsecurity.org/uploads/BrownfieldsArticle-CFSNewsFallWinter1999.pdf

[6] http://www.epa.gov/swerosps/bf/urbanag/pdf/bf_urban_ag.pdf

- Community gardening and urban agriculture as a community engagement strategy under the NPDES permit program

The Need

Stormwater systems in urban and suburban environments are designed to move rainwater off of city streets quickly and efficiently. Large areas of impervious surfaces (e.g., buildings, pavement) that replace natural pervious surfaces (e.g., soil, wetlands) mean that lands in urban areas have a reduced capacity to infiltrate and absorb storm precipitation. It is estimated that a typical city block generates over five times the amount of surface runoff as a wooded area of the same size.[7]

Cities are required by law to create a stormwater management plan as directed by the National Pollutant Discharge Elimination System (NPDES). The National Pollutant Discharge Elimination System (NPDES) permit program requires cities to accurately measure their efforts to reduce pollutants in stormwater flowing into local waters.

Minneapolis began construction of its sewer system in approximately 1870. At that time, sewer system combined wastewater and sanitary sewers. Beginning in the 1920s the city shifted construction to sewers that separated stormwater and sanitary sewers. In 1960 the City banned rainwater drainage to the sanitary sewer, and has done extensive upgrades to older installations to further separate the two systems. Currently, it is estimated that only 68.8 acres of land in the city drain to combined sewers.[8]

During a typical year, 35 to 50 rain events occur in Minnesota. 90% of these rain events generate a rainfall depth of 1.05” or less.[9] As climate changes, a warmer atmosphere holds more water, meaning precipitation trends point to rainfall amounts increasing in both amount and frequency. In a recent presentation for the Minnehaha Creek Watershed District, Dr. Mark Seeley reported a 20% increase in annual precipitation “normals” between 1941 and 1970.[10] Rainfall amounts per storm event are increasing, and rain events are shifting to the margins of spring and winter seasons, with drier summers predicted.[11]

[7] United States Environmental Protection Agency, “Protecting Water Quality from Urban Runoff,” 841-F-03-003, February 2003.

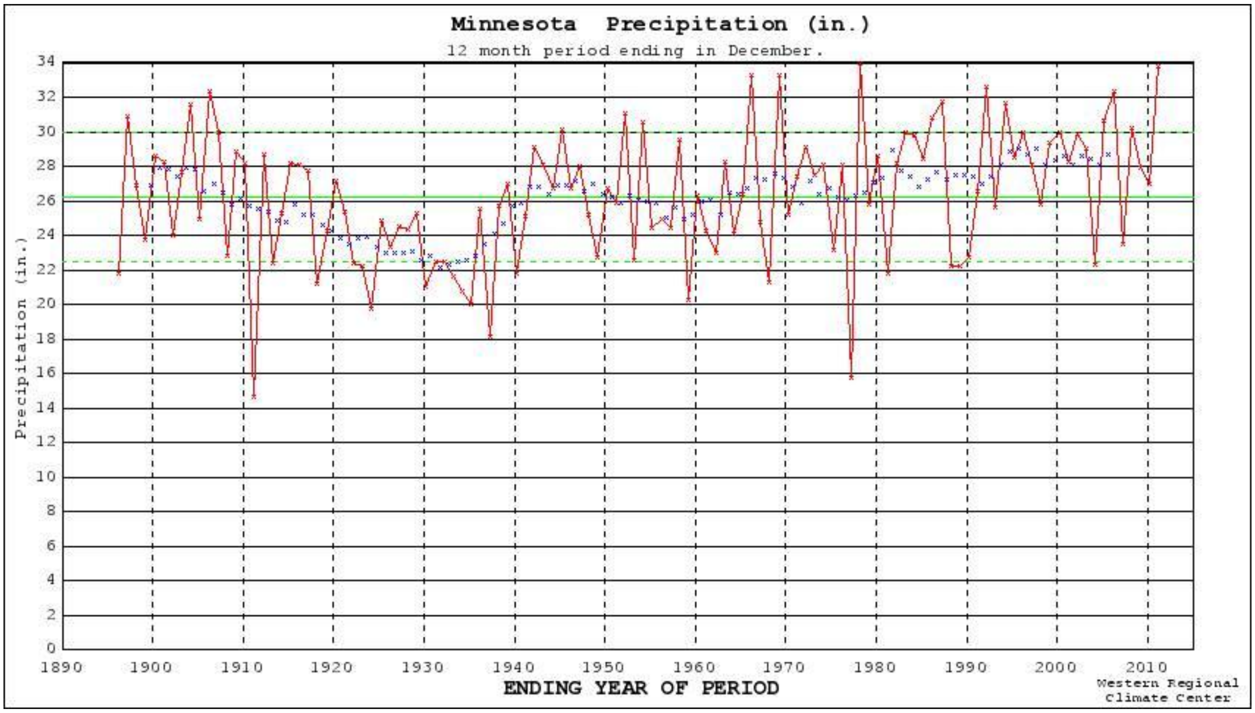
[8] http://www.minneapolismn.gov/www/groups/public/@publicworks/documents/webcontent/convert_254627.pdf

[9] Stormwater Reuse Guide: A guide for city planners, engineers, homeowners and green thinkers, 2011, http://www.google.com/url?sa=t&rct=j&q=metropolitan%20council%20stormwater%20reuse%20guide&source=web&cd=2&cad=rja&ved=0CCoQFjAB&url=http%3A%2F%2Frfcd.pima.gov%2Fpdd%2Flid%2Fpdfs%2F31-mn-metropolitan-council-stormwater-reuse-guide-2011.pdf&ei=4tY8ULzdOfGWyAHwmoHIBQ&usg=AFQjCNHKMQOEAQFyyM26o42_Guh0aMob2Q

[10] http://www.minnehahacreek.org/sites/minnehahacreek.org/files/events/minnehaha_creek_2012.pdf

[11] http://www.ucsusa.org/assets/documents/global_warming/climate-change-minnesota.pdf

The Minnesota Department of Health (MDH) confirms the changes in both quantity and character of precipitation in Minnesota. In the following chart, it is clear the overall trend is an increase in annual rainfall amounts.



The MDH web site explains the changing trends:

> Annual precipitation is expected to continue to increase. Additionally, Minnesota is starting to experience increases in localized, heavy precipitation events. The new precipitation trends have the potential to cause both increased flooding and drought, based on the localized nature of storms and their intensity, leaving some areas of the state drenched and other areas without any precipitation. For example, in August 2007, 24 counties throughout Minnesota were included in a US Department of Agriculture (USDA) drought disaster declaration while at the same time seven southeastern counties were declared a federal flood disaster by the Federal Emergency Management Agency (FEMA).[12]

Hennepin County also warns of more extreme weather events caused by a warming atmosphere, with increasing overall frequency of both floods and droughts. The impact of those changes will affect stormwater infrastructure, with the county warning specifically that, "Infrastructure for runoff and water management, such as storm sewers, is likely undersized and will need updates to deal with increases in heavy rainfall and flash flooding.[13]

[12] http://www.health.state.mn.us/divs/climatechange/climate101.html
[13] http://hennepin.us/portal/site/HennepinUS/menuitem.b1ab75471750e40fa01dfb47ccf06498/?vgnextoid=f48141036ae64210VgnVCM10000049114689RCRD

The Case for Urban Agriculture as Green Infrastructure

While climate may be changing, stormwater systems in long-established metropolitan areas such as Minneapolis have a fixed and finite capacity to manage stormwater volumes. A report from the Metropolitan Council[14] describes the challenge of increasing amounts of urban stormwater:

> Two water problems are emerging in urban areas, including the Twin Cities: excessive stormwater runoff is degrading our surface waters, and water treatment plants are undergoing costly expansions. These may seem to be unrelated problems, yet there is a common solution.

That common solution, says the report, is to require cities and other Municipal Separate Storm Sewer entities regulated by NPDES to include alternative methods to harvest, infiltrate, store and treat stormwater, thereby reducing the volume, and improving the quality, of stormwater running into stormwater systems. These stormwater management plans also encourage land users and developers to reuse stormwater in appropriate, effective, safe ways. This approach to abstracting and managing stormwater uses technologies collectively called, "green infrastructure."

According to a 2007 study by The Civic Federation for The Center for Neighborhood Technology,

> "Green infrastructure" is a term used to refer to a number of strategies for handling storm precipitation at its source rather than after it has entered a sewer system. Green infrastructure is thus understood as an alternative to conventional stormwater management approaches, which typically involve building containment and treatment facilities for collecting and cleaning stormwater before releasing effluent into natural waterways. Green infrastructure employs natural systems such as vegetation, wetlands, and open space to handle stormwater in populated areas. It can also involve manufactured solutions such as rain barrels or permeable pavement. [15]

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[14] Stormwater Reuse Guide: A guide for city planners, engineers, homeowners and green thinkers, 2011, http://www.google.com/url?sa=t&rct=j&q=metropolitan%20council%20stormwater%20reuse%20guide&source=web&cd=2&cad=rja&ved=0CCoQFjAB&url=http%3A%2F%2Frfcd.pima.gov%2Fpdd%2Flid%2Fpdfs%2F31-mn-metropolitan-council-stormwater-reuse-guide-2011.pdf&ei=4tY8ULzdOfGWyAHwmoHIBQ&usg=AFQjCNHKMQOEAQFyyM26o42_Guh0aMob2Q

[15] Managing Urban Stormwater with Green Infrastructure: Case Studies of Five U.S. Local Governments, July 30, 2007 Prepared by The Civic Federation for The Center for Neighborhood Technology

As noted earlier, the EPA promotes the use of green stormwater infrastructure as both a stormwater management approach and a key strategy in their Land Revitalization Program.[16] More and more cities are exploring the use of green strategies to collect and store stormwater, keeping it out of stormwater pipes. Green infrastructure strategies include a list of practices that have been studied and quantified, making their engineering and performance outcomes predictable and reliable. Lacking such rigorous quantification, or carefully researched sets of best management practices, urban agriculture is not a commonly promoted green infrastructure strategy. As Dunn (2010) argues, "Being able to quantify the effectiveness of green infrastructure on a small scale is one way to promote regulatory and enforcement acceptance, which thereby enhances its appeal to city officials."[17]

In early 2012, the City of Minneapolis, at the urging of urban farming, gardening, social justice, and food justice advocates, changed local zoning codes to reduce regulatory barriers to establishing urban agriculture land uses[18]. The City of St. Paul is currently studying a similar set of zoning amendments.[19] The newly-formed Twin Cities Agricultural Land Trust was created to increase the amount of, and ensure permanent access to, land in urban areas used for growing food[20]. It is anticipated by local food advocates that these regulatory changes and organizational developments will markedly increase the number of urban farms operating in the Twin Cities. How these changing land uses will affect the health of local waters is not known. The issues related to the impact of urban agriculture on stormwater management and water quality will be explored in the following sections.

Urban Agriculture as Green Infrastructure Project

In early spring 2012, The Freshwater Society (FWS), in partnership with and supported by a Planning Grant from the Mississippi Watershed Management Organization (MWMO)began an investigation into issues and concerns related to how cities might use urban agriculture as a green stormwater strategy. Issues to be explored were outlined by the Citizen Advisory Committee of the MWMO in order to better understand what is known and not known about urban agriculture and how these issues might affect the practical value of using urban agriculture as part of a suite of green stormwater strategies.

An Advisory Board of key experts and stakeholders involved in urban agriculture and community gardening was convened to offer insights into these issues. The Board consisted of:

Paula	Westmoreland	Permaculture Research Institute- Cold Climate
Kirsten	Saylor	Gardening Matters Executive Director

[16] http://www.epa.gov/LANDREVITALIZATION/
[17] Dunn, Alexandra Dapolito, "Siting Green Infrastructure: Legal and Policy Solutions to Alleviate Urban Poverty and Promote Healthy Communities" (2010). *Pace Law Faculty Publications.* Paper 559. http://digitalcommons.pace.edu/lawfaculty/559
[18] http://www.ci.minneapolis.mn.us/cped/projects/cped_urban_ag_zoning
[19] http://stpaul.gov/DocumentCenter/Home/View/20482
[20] http://www.gardeningmatters.org/sites/default/files/TCALT_StrategicPlan_030512.pdf

Eric	Larson	Stone's Throw Urban Farms
Carl	Rosen	U of MN, Head of Department of Soil, Water, and Climate
John	Gulliver	St. Anthony Falls Laboratory, Professor of Civil Engineering
Dan	Kalmon	MWMO, Planner & Program Manager
Anna	Cioffi	Land Stewardship Project, Community Based Food Systems Program Organizer

Additional advisors consulted during the planning phase included:

Jane	Shey	City of Minneapolis, HomeGrown Minneapolis Coordinator
Bertrand	Weber	Mpls. Public Schools Nutrition Services
Megan	O'Hara	Megan O'Hara Communications, founder and supporter of HomeGrown Minneapolis
Lois	Eberhart	City of Minneapolis, Stormwater Management
Gayle	Prest	City of Minneapolis, Sustainability Coordinator
Bill	Shuster	EPA Office of Research and Development soil scientist
Geri	Unger	Director of Education and Research, Cleveland Botanical Gardens
Susan	Schmidt	Trust for Public Land
Robert	Newport	USEPA, Land Revitalization program
Katherine	Kelly	Executive Director, Cultivate Kansas City
Jon	Grosshans	US EPA Region 5

Soil Moisture and Runoff – Rebalancing the Urban Water Cycle

It is difficult to generalize soil moisture and runoff levels, the water-holding capacity, infiltration rates, or other general characteristics of urban soils. In reality, there is no single, identifiable category with a consistent set of characteristics to which all urban soils belong. Unlike farm fields that have much less history of human disruption, urban soils have a mixed, often untraceable, history. As the EPA describes,

> An *urban soil* on a parcel in a metropolitan area has typically been moved, graded, and/or compacted over time, often as a result of construction and demolition activity at the site. Movement of soil and addition of non-native soils is relatively common in developed areas. As low areas are filled and hills are graded, soils are shifted and relocated, resulting in mixing of the soil profile or placement in a different order. Fill is often brought on-site from nearby areas and frequently has characteristics different from the native soils on site. Because of the ways soils have been altered, there can be great variation in the characteristics of soils within an urban land parcel. [21]

[21] Evaluation of Urban Soils: Suitability for Green Infrastructure or Urban Agriculture, EPA Publication No. 905R1103

The lack of reliable data on the infiltration and water-holding capacity of urban soils at the parcel level hampers stormwater managers' ability to implement green infrastructure. According to Shuster, et al, (2011), "There is a critical need to determine whether the type and storage capacity provided by green infrastructure techniques is adequate to mitigate CSO [Combined Sewer Overflows] and contribute to the restoration of degraded urban ecosystems. At the foundation of this issue is the nature of soils that underlay urban areas." Though Minneapolis has separated its stormwater and sanitary sewer systems, the city continues to face the challenge of managing peak flows of stormwater generated by increases in the frequency and severity of rain events. Runoff levels at the parcel level depend entirely on the specific characteristics of the site in question.

Erosion and Sediment Loss

Erosion is not currently a significant issue in urban farming or community gardening, as it is in production agriculture. However, an anticipated increase in the number and size of urban farm sites could drive an increase in erosion from urban lots. Urban agriculture is an emerging land use that has minimal history in modern cities, but is uniquely positioned to take advantage of lessons learned by both production agriculture and construction to reduce its impact on stormwater systems and the health of local waters. Commonly used gardening practices can contribute additional strategies to reduce erosion.

One study of erosion on community garden sites has been conducted in the Twin Cities Metro area. The major findings of this somewhat inconclusive study were:

> When compared to construction site erosion, erosion from community gardens is miniscule. However, for those working with the gardens, or living in the neighborhood, even a minor amount of soil on the sidewalk or in the street can be a concern, both from a loss of soil from the garden as well as a potential hazard, aesthetic problem, and pollutant issue. ..The main issues found with community gardens were minor soil loss onto the sidewalks. Much of this was a result of a lack of edging where the garden borders the sidewalk, or other means of sediment control. Some of the community gardeners used wood chips rather than shredded wood mulch. The wood chips are more likely to move with the soil and end up on the sidewalk and beyond.[22]

Conversely, erosion is a major issue in two other land use activities that cause landscape changes similar to urban agriculture: production agriculture and construction activities. Both land uses contribute significant amounts of sediments to waterways in Minnesota. Both have a wide variety of best management practices suggested or required to reduce erosion and sediment loss.

Production agriculture uses conservation tillage as the primary strategy to control erosion caused by wind and water. Conservation tillage practices include:

- mulch tillage

[22] Assessing Erosion and Sediment Control in Community Gardens, Minnesota Erosion Control Association, prepared by Dindorf, C. for Mississippi Watershed Management Organization. 2012

- strip tillage
- ridge tillage
- no-till

Each of these practices results in an increase in crop residue left on the land, which in turn holds soil in place, and with proper management of soil structure, can increase the water-holding capacity of soil. Any of these practices can and should be used in urban agriculture settings to reduce erosion to stormwater systems. Production agriculture also makes extensive use of cover crops to reduce erosion in the spring, when rains can damage and erode soils before crops are planted or emerge. This practice could, and often is, easily adapted to the smaller scale of urban farms. Vegetative buffers, a practice commonly used along waterways by production agriculture operations to reduce erosion, could address the issues identified by Dindorf.[23]

Because of the small scale of most urban farm plots, urban farmers can make extensive use of mulches to further reduce erosion, a common practice in backyard and community gardens. The use of organic materials as mulch, including straw and compost, significantly improves the infiltration and water-holding capacity of soils. This benefit will be explored in more detail in the following section.

Practices that reduce the impact of soil loss and erosion from construction activities can also be adapted for use in urban agriculture. The Minnesota Pollution Control Agency has a comprehensive guide for stormwater management on construction sites that includes guidelines for site preparation, flow control, vegetative stabilization, and treatment measures that could be adapted and implemented when and where appropriate by urban farmers.[24]

Information gaps in soil moisture, runoff levels, erosion and soil loss

What is not known is the possible cumulative effect of a significant increase in the number of urban farms operating on vacant land in urban areas. If more parcels are converted from other uses to agricultural use, would soils become more prone to erosion? Urban farms are typically placed on vacant land, often adjacent to impermeable urban surfaces like parking lots, sidewalks and streets, all connected directly to surface waters by stormwater pipes. What practices would best protect bare urban farm soils from spring rains before crops emerge, seedlings are transplanted, and mulches spread?

Vacant sites will need to be studied, and a soil characteristics profile generated, including soil moisture, runoff generated, and infiltration capacity of urban sites in Minneapolis that are appropriate for agricultural uses. City Public Works departments, watershed districts, watershed management organizations and programs offered by non-profit organizations such as the Permaculture Research

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[23] Assessing Erosion and Sediment Control in Community Gardens, Minnesota Erosion Control Association, prepared by Dindorf, C. for Mississippi Watershed Management Organization. 2012
[24] http://www.pca.state.mn.us/index.php/view-document.html?gid=7157

Institute- Cold Climate's Urban Farmer Certification program and the Land Stewardship Project's Community Based Food Systems initiative could all become important players in creating guidelines for urban farm construction, offering urban farmers advice and support on best practices to manage sediment loss and erosion.

Infiltration and water-holding capacity of soils

Soil compaction is one of the most common limitations to the movement of water through urban soils[25]. A study of compacted soil types in Florida found that, "Although there was wide variability in infiltration rates across both compacted and non-compacted sites, construction activity or compaction treatments reduced infiltration rates 70 to 99 percent."[26]

Many urban soils are highly compacted and frequently contaminated, the result of a long series of development activities. In a 2011 report from the EPA, researchers noted that, "Soil studies in urban areas have found that soil compaction, low organic matter content and low levels of contamination, usually from air deposition or from historical uses on site, are common attributes of urban soils."[27] Soil contaminants will be explored in detail in a subsequent section.

The University of MN Extension report, "Soil Compaction: Causes, Effects, and Control," notes that in the world of production agriculture, soil compaction affects

- Water availability (through increased runoff and decreased water storage)
- N [Nitrogen] and K [Phosphorus] uptake (disadvantageous nutrient cycling)
- Plant growth and yield (constricted root growth, limited water availability)
- Delayed planting and other field operations due to colder and wetter soils[28]

In urban areas, development and construction activities and the resulting compaction of soils, have a significant impact on both run-off volume and soil infiltration capacity.

> The role of urban soils in stormwater management cannot be under-estimated. Although landscaped areas typically produce relatively small fractions of the annual runoff volumes (and pollutant discharges) in most areas, they need to be considered as part of most control scenarios. In stormwater quality management, the simplest approach is to attempt to maintain the relative values of the hydrologic cycle components after development compared to pre-

[25] http://landrehab.org/UserFiles/DataItems/3034764F7459304F4F67673D/Daniels,%202011%20Managing%20urban%20soils.pdf
[26] Effect of urban soil compaction on infiltration rate. Gregory, J., Dukes, M., Jones, P., and Miller, G. Journal of Soil and Water Conservation Volume 61, Number 3
[27] Evaluation of Urban Soils: Suitability for Green Infrastructure or Urban Agriculture, EPA Publication No. 905R1103
[28] http://www.extension.umn.edu/distribution/cropsystems/components/3115s02.html

development conditions. This usually implies the use of infiltration controls to compensate for the increased pavement and roof areas.[29]

The volume reduction, infiltration and water storage capacities of many green stormwater control measures have been thoroughly researched, and the National Resource Conservation Service has a reliable procedure to "calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs"[30] in their Technical Release 55 (TR-55). TR-55 does not include urban farms or gardens in the menu of land cover conditions used to calculate runoff, making it of limited use in predicting the stormwater management potential of urban agricultural land uses.

Fortunately, compacted urban soils can be managed to increase infiltration, water-holding, and evapotranspiration capacities. Several studies point to the increased infiltration benefits of amending compacted urban soils with compost. Olson and Gulliver (2011) note that, "a substantial increase in infiltration rates in compact soil can be achieved by tilling the soil and adding compost." [31] These same soil remediation activities also increase soil fertility, a key issue in the economic viability of urban farm sites.

According to the web site, Urban Design Tools: Low Impact Design, a combination of tillage and composting yielded the following results:

- Within the test plots the water holding capacity of the soil was doubled with a 2:1 compost to soil amendment.
- Total storage for compost amended soils increased by about 65% from those of unamended soil values.
- Rainwater runoff rates were moderated with the compost amended soils. The amended soils showed a greater lag time to peak flow at the initiation of a rainfall event and attributed to an overall greater baseflow.

In short, the results of the study exhibited that compost amended soils consistently had longer lag times to response, longer times to peak flow, higher base flow, higher total storage, and smaller total runoff than unamended soils.

Relative to unamended soils, water conveyed through compost amended soils had

- 70% less total Phosphorous
- 58% less soluble reactive Phosphorous
- 7% less total nitrate. [32]

[29] Compacted Urban Soils Effects on Infiltration and Bioretention Stormwater Control Designs, Pitt, R., Chen, S., Clark, S. Presented at the 9th International Conference on Urban Drainage. Portland, Oregon, September 8-13, 2002, downloaded on 8/1/12 from http://bit.ly/SUwoka

[30] http://www.hydrocad.net/pdf/TR-55%20Manual.pdf

[31] Remediating Compacted Urban Soils with Tillage and Compost. Olson, N., Gulliver, J. CURA Reporter, Fall/Winter, 2011

[32] http://www.lid-stormwater.net/soilamend_benefits.htm

Increasing the organic materials in soils has emerged as a key strategy in building healthy urban soils, and makes a strong case for using soils as a strategy to better manage urban stormwater. The City of Seattle has published a report on the role of healthy soils in restoring and protecting aquatic habitat for salmon. The report promotes the role of compost in improving managing soil structure, supplying slow-release nutrients to plants, holding moisture, reducing erosion, and immobilizing and degrading pollutants.[33]

Information gaps in water-holding capacity of urban farm sites

These studies and others confirm the value of compost amendments as a strategy to increase infiltration, but raise a note of concern. Analyses of the nutrient content of runoff from test sites amended with the recommended 2:1 ration of soil to compost initially contained elevated levels of nutrients, particularly nitrogen. A 1999 study by Pitt, Lantrip and Harrison notes that,

> Adding large amounts of compost to marginal soils enhances many desirable soil properties, including improved water infiltration (and attendant reduced surface runoff), increased fertility, and significantly enhanced aesthetics of the turf. Unfortunately, the compost also increased the concentrations of many nutrients in the runoff, especially when the site was newly developed, but with the increased infiltration of the soil, the nutrient mass runoff was likely significantly decreased.

The studies by Urban Design Tools: Low Impact Design and Pitt, Lantrip and Harrison point up an apparent contradiction in the nutrient reduction potential of amending marginal urban soils. While the Urban Design study showed a decrease in soluble phosphorus in water conveyed through composted soils, the study by Pitt, Lantrip and Harrison warn that compost increases nutrient concentrations in runoff. That contradiction may be the result of the depth, and timing, of infiltration and subsequent runoff. Long-term sustainable agricultural management techniques could mitigate that apparent contradiction. Additional study is required to better understand this aspect of soil revitalization.

Given the relatively small size of urban farm plots, scale is another issue that will need to be explored. It will be important to determine what percentage of urban agricultural land use, using which sets of appropriate management practices on a variety of soils, would infiltrate and capture enough rainwater to reduce stormwater flows to a sufficient degree that land owners and and developers could reasonably use urban farms as a part of an integrated green stormwater pre-treatment plan.

A land capacity analysis of the City of Minneapolis done in 2010 indicates there are currently 1229 acres of vacant land, excess land on developed lots, and land that ranks high for redevelopment. Factoring in project growth over the next 20 years still leaves between 661 and 914 acres of land available for use as green infrastructure. While some raingardens and green roofs can absorb 15-90% of rainfall, and store

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[33] The Relationship Between Soil and Water: How Soil Amendments and Compost Can Aid in Salmon Recovery, Fall 1999, downloaded on 7/24/12 from depts.washington.edu/cuwrm/publictn/s4s.pdf

.5- 3 gallons per square foot[34], there is currently no reliable estimate of the water holding capacity of urban farm soils.

Stormwater for growing crops

There is no clear consensus on whether it is safe or advisable to use stormwater on food gardens. Much of the world uses harvested rainwater to grow food, especially in arid and drought-prone regions of the world. Many studies have been done on safety issues involved in growing food using harvested rainwater, but few have been done in the United States. Differences in roofing materials among nations in the developed and developing worlds make these studies of limited use in considering the safety of using harvested rainwater on urban farm crops.

Testing the quality of harvested rainwater is expensive to do and highly situational depending on where you live, frequency of rainfall, temperature, roofing materials, how long the water is stored and what kind of filtering is done. Testing rainwater immediately after a rain event will yield different results than testing the same water hours or days later. The many variables make it difficult to determine definitive answers on whether harvested rainwater is appropriate for use as irrigation water on food crops. Of the few US-based studies that have been conducted on contaminants in rainwater, most focus primarily on the use of harvested rainwater as a potable water source, comparing levels of contaminants to EPA drinking water standards rather than the lower standards for irrigation water.

Where rainwater is an option for use as irrigation water, it is necessary to consider a wide range of possible contaminants. The North Carolina Cooperative Extension Service notes,

> Primary substances of concern in roof runoff include heavy metals, polycyclic aromatic hydrocarbons (PAHs), microbes, pathogens, and pesticides. Birds, insects, and small mammals deposit fecal matter on rooftops and in gutters, contributing bacteria and pathogens to runoff. On metal roofs, water can react with the roof surface and adsorb metals, such as zinc, copper, and aluminum, especially where acid rain is prevalent. Roofs with wooden or asphalt shingles can increase concentrations of chemicals used for waterproofing and weathering treatments.[35]

However, the same report also notes that,

> Most of the metals (Cu, Cr, Cd, Pb) [Copper, Chromium, Cadmium, Lead] detected in rooftop runoff are also detected in rainwater that has yet to contact the rooftop. As such, these contaminants are unlikely to result in intolerable residues in edible plants, fruits, and vegetables, especially when they bind with soil particles and organic matter on the ground.

[34] http://www.lid-stormwater.net/greenroofs_benefits.htm

[35] Water quality of rooftop runoff: Implications for residential water harvesting systems, University of North Carolina Cooperative Extension Service, downloaded on 7/13/12 from http://www.bae.ncsu.edu/stormwater/PublicationFiles/RooftopRunoff2009.pdf

The Metropolitan Council recently published a Stormwater Reuse Guide that identifies irrigation of food gardens as a reasonable use of stormwater, but has yet to set water quality standards or treatment guidelines for the water crops would receive.[36] The issue of standards is one of many topics of discussion in the Minimal Impact Design Standards work group, under the direction of the MN Pollution Control Agency to "develop performance standards, design standards or other tools to enable and promote the implementation of low impact development and other stormwater management techniques."[37]

The MN Department of Health (MDH) is regularly quoted as advising against using harvested rainwater on food crops, as in this example taken from the HomeGrown Minneapolis web site,

> **Is water from a rain barrel safe for my garden and lawn?**
>
> Absolutely! Rainwater collected in your rain barrel is ideal for flowers, native gardens and lawns. However, the Minnesota Department of Health recommends that it **not** be used for vegetable gardens or food crops.[38]

However, based on conversations with MDH staff and a review of policies published on the MDH web site, the agency has no official written policy on the issue of whether or not to use rainwater on food crops. Warnings quoting MDH advice against using rainwater on food crops are precautionary, but anecdotal, and not based on an official Department policy. The Minnesota Stormwater Manual recommends rainbarrels as a valuable strategy for reducing runoff volumes, but has no recommendations for how to use, or not use, the water collected.[39] The City of Roseville takes the middle ground and urges residents to "exercise caution when using on food crops."[40]

There are numerous examples of city- sponsored and/or -affiliated food gardens in the Unites States that use harvested rainwater to reduce stormwater volumes and reduce gardeners' dependence on treated, drinking quality water to grow edibles. A one square block food garden in downtown Kansas City's Crossroads District uses rainwater harvested through a system of biofiltration swales collected and stored in a 40,000-gallon underground cistern.[41]

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[36] Stormwater Reuse Guide: A guide for city planners, engineers, homeowners and green thinkers, 2011, http://www.google.com/url?sa=t&rct=j&q=metropolitan%20council%20stormwater%20reuse%20guide&source=web&cd=2&cad=rja&ved=0CCoQFjAB&url=http%3A%2F%2Frfcd.pima.gov%2Fpdd%2Flid%2Fpdfs%2F31-mn-metropolitan-council-stormwater-reuse-guide-2011.pdf&ei=4tY8ULzdOfGWyAHwmoHIBQ&usg=AFQjCNHKMQOEAQFyyM26o42_Guh0aMob2Q

[37] http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-minimal-impact-design-standards-mids.html

[38] http://www.minneapolismn.gov/publicworks/stormwater/green/stormwater_green-initiatives_rain-barrel

[39] http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/minnesota-s-stormwater-manual.html

[40] http://www.ci.roseville.mn.us/index.aspx?NID=1597

[41] http://www.18broadway.com/index.html

New York City makes extensive use of rainwater harvesting systems in community gardens throughout the city. "The 35 rain water harvesting systems working in NYC's community gardens collect 422,900 gallons of water every year."[42] A 2009 study of rainwater harvesting systems in community gardens in the Hollenback neighborhood in Brooklyn, New York tested the quality of harvested rainwater at three points in the collection system- roof top washer, first flush diverter (a device that diverts and stores initial rainfall amounts that rinse contaminants from rooftop surfaces), and in the storage tank, using standard water quality parameters (bacteria, solids, nutrients, metals), comparing the water to both drinking water and irrigation standards. According to their findings, water in rainwater collection systems would be very difficult to treat and use as drinking quality potable water. If used for irrigation, water would need to be treated only for coliform bacteria, contingent upon proper use and maintenance of the roof top washer and first flush diverter.[43]

A 2011 study by the Texas Water Development Board (TWDB) tested five sites for pH, conductivity, turbidity, total suspended solids (TSS), total coliform (TC), fecal coliform (FC), nitrate, nitrite, dissolved organic carbon (DOC), and selected metals, as well as the diversity of the microbial communities from rainwater harvested from the pilot-scale roofs. Levels of these substances were compared to EPA drinking water standards. According to the report,

> Harvested rainwater quality generally increases with roof flushing, indicating the importance of an effective first-flush diverter. However, the rainwater harvested after the first-flush from all of the pilot-scale roofs did contain some contaminants at levels above EPA drinking water standards (i.e., turbidity, TC, FC, Fe3, and Al).

It should be noted that the TWDB study tests water only for potable use, and the report does not compare the quality of harvested rainwater to EPA standards for irrigation water.

Many organizations advise filtering harvested stormwater before using it in drip irrigation or other watering systems that reduce surface contact with edible plants.

Information gaps in using stormwater for growing crops

The suitability of harvested rainwater as a source for irrigation water on food crops is an unanswered question. While it is prudent to err on the side of caution, the predicted changes to precipitation patterns caused by a warming atmosphere may well impel cities to reconsider which is the more prudent course. Is it more prudent to develop safe and efficient rainwater harvesting, filtration and treatment technologies and encourage more rainwater harvesting, or continue to discourage the use of rainwater on food crops? Urban farming will likely increase, as indicated by the recent public demand for more locally grown food, and policy changes in local zoning codes. There is an increased likelihood

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[42] Rainwater Harvesting101, 2008, GROWNYC, by Leung, J. Downloaded on 5/12/12 from www.grownyc.org/files/osg/RWH.how.to.pdf

[43] Hollenback Community Garden Rainwater Harvesting System: Water Quality Findings. (2009) DiGiovanni, K., Montalto, F. Presentation at: Water Resources Group (WRG) Meeting New York, New York, January 15, 2009

of both droughts and flooding becoming more severe and more frequent. Planning for a future that includes these scenarios makes it prudent to develop a range of tools to harvest and properly treat and store rainwater as a volume reduction strategy, and use that resource on urban food crops.

Soil Contaminants

Urban soils are presumed to have high levels of contaminants, and typically do. There are systems in place to test soils, evaluate contaminant levels, and fairly simple measures exist to remediate contaminants, make them less mobile in soils, and to avoid their harmful effects.

The EPA describes a long list of potential contaminants in urban soils:

> In industrial areas, historical contaminates might include heavy metals, hydrocarbons, or chemicals used during the manufacturing process. In residential areas built before the early 1980s, contaminants generally include lead paint residues, and may have asbestos, coal and wood ash deposits, fuel oil, used motor oil residues, or pesticides. Remnants of abandoned septic systems, cisterns, and wells are also often uncovered during redevelopment of residential sites.[44]

A Minnesota Institute for Sustainable Agriculture publication notes that,

> Lead, arsenic, cadmium and PAHs may also be found in higher than usual concentrations around industrial locations… It is quite likely that the soil in any urban setting will contain detectable quantities of lead, arsenic, PAHs, and possibly cadmium. In most cases, especially in areas that have been residential for a long time, these contaminants will be at low concentrations that don't pose a health risk, unless pesticides or fertilizers that contain heavy metals were used.[45]

Measures to minimize risks to human health from the effects of soil contaminants require farmers to have some understanding of best management practices for gardening in an urban environment. Fruiting crops like tomatoes, peppers, and eggplants absorb fewer contaminants than leafy crops such as lettuce, spinach, or root crops such as potatoes and carrots. With leafy crops, contaminants are generally air-borne. Washing leafy crops will generally remove most surface contaminants and make produce safe for consumption. Amending soil with compost in a 2:1 ratio makes metals such as lead, or cadmium less mobile in soils, and reduces uptake by plants. Maintaining a soil pH of 6.5 or more (decreasing the acidity of soil) also makes metals less mobile and reduces uptake by plants.[46] Lead is of particular concern in urban farm and garden lots. Plants generally take up very little lead, with little absorption or accumulation. Locating gardens away from busy streets or creating berms of other

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[44] Evaluation of Urban Soils: Suitability for Green Infrastructure or Urban Agriculture, EPA Publication No. 905R1103

[45] Urban gardens and soil contaminants: A gardener's guide to healthy soils. Minnesota Institute for Sustainable Agriculture, downloaded from http://www.misa.umn.edu/prod/groups/cfans/@pub/@cfans/@misa/documents/asset/cfans_asset_287228.pdf on 4/30/12

[46] Urban gardens and soil contaminants: A gardener's guide to healthy soils. Minnesota Institute for Sustainable Agriculture, downloaded from http://www.misa.umn.edu/prod/groups/cfans/@pub/@cfans/@misa/documents/asset/cfans_asset_287228.pdf on 4/30/12

barriers between gardens and roads can also reduce the incidence of air-borne deposition of contaminants.[47]

Licensing requirements, Soil Testing Policies

According to the City of Minneapolis, no licensing is required to install and/or operate an urban farm, nor does the City require soil testing for either urban farms or community gardens. Rather than create an overlapping set of regulatory parameters, the City adheres to statewide policies for food-related business. Neither the MN Department of Health nor the MN Department of Agriculture has licensing requirements for urban farms. Farmers are explicitly exempted from licensing requirement both by State Constitution, Article 13, Section 7. "Any person may sell or peddle the products of the farm or garden occupied and cultivated by him without obtaining a license therefor," and by MN State Statute:

> 28A.15 EXCLUSIONS
> Subdivision 1.Licensing provisions applicability.
> The licensing provisions of sections 28A.01 to 28A.16 shall not apply to the following:
>
> Subd. 2. Sales by farmers; others not in food business.
>
> Persons selling the products of the farm or garden occupied and cultivated by them, or to persons not regularly engaged in the business of manufacturing and selling food and who prepare food only on order of and for sale directly to the ultimate consumer, or to educational, charitable or religious organizations not regularly engaged in the business of manufacturing, processing, or selling food at their established educational, charitable or religious institutions.

Information gaps for soil contaminants, licensing and testing requirements

As a precautionary measure, it is prudent for urban farmers to test the soil of any lot being converted to agricultural uses. There is an abundance of resources available for farmers to submit soils samples. Much research has been done on the uptake of contaminants by food crops, and best practices have been developed to minimize the risks of consuming food crops grown on urban soils.

Opportunities and Barriers

There are a number of remaining questions that represent real and significant barriers to using urban agriculture as a stormwater management strategy. Chief among them are issues of permanence and soil stability.

[47] http://www.extension.umn.edu/distribution/horticulture/DG2543.html

A major barrier to the implementation of urban agriculture projects as a stormwater control measure is the ephemeral nature of urban farm sites. Cities invest in stormwater pipes as a way to reliably will be manage stormwater over very long timelines. In Minneapolis, the city code has an extensive list of stormwater management requirements for land development projects. New development and re-development plans that disturb over one acre of land must develop stormwater management plans that maximize abstraction, or the interception of stormwater from the municipal stormwater system. According to Minneapolis ordinance, "Land use and building permits will not be issued until a Storm Water Management Plan has been approved. On-site devices are subject to annual site registration, annual inspection, and adherence to maintenance rules prescribed in the design manual.[48] Stormwater Management plans are intended to be long-lived, dependable and predictable.

Typically, urban farm sites are located on vacant urban lots. Property owners and urban farmers negotiate land use agreement that can last years, but are more often short-term, interim land use agreements. When a property owner is offered a more lucrative deal for land use, such as redevelopment for a commercial or residential building, land use agreements with urban farmers can be terminated. Lots can be redeveloped, and any stormwater benefit offered by the urban farm is lost. Unless farm sites can be established with more permanence, it would be difficult or impossible for cities to include these land use activities as BMPs in a stormwater management plan.

The issue of soil stability in urban farms poses additional challenges for watershed managers and stormwater planners. While erosion is not generally regarded as a significant problem in community gardens, sediment loss is a major pollution source in production agriculture and on construction sites. In general, urban farm sites are located on vacant lots adjacent to impermeable surfaces connected directly to stormwater pipes. As urban agriculture expands in response to the growing public demand for local foods, better access to foods, and entrepreneurial opportunities in urban areas, erosion from wind and water could become more of a concern.

The economic viability of urban farms could present a barrier for the proliferation of urban farming operations. Urban farms are labor intensive undertakings, and for most farmers, only marginally profitable. Urban food distribution systems are not fully developed. The question of how to make urban farming profitable enough to attract entrepreneurs to open more farms remains to be explored. For example, if urban farms have a quantified stormwater benefit, would that open up funding opportunities for farmers to develop land parcels as urban farm sites? Would there be opportunities to use stormwater funding to install rainwater catchment systems to further harvest rainwater volumes and reduce runoff? Would the City of Minneapolis offer tax credits to farmers who develop land for urban farm sites and install best practices for stormwater management?

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48 http://library.municode.com/HTML/11490/level3/COOR_TIT3AIPOENPR_CH54STWAMA.html#COOR_TIT3AIPOENPR_CH54STWAMA_54.70REPRCO

What is clear is that the widespread interest and growing interest in urban farming creates an opportunity to link urban farming and water quality practices. Guidelines can be developed that help farmers maximize the stormwater benefits of urban farm sites. Funding and cost share dollars could be tied to best management practices that maximize infiltration and rainwater capture, reduce erosion, reduce runoff, and minimize nutrient loss.

What Cities are Doing

It is important to note that urban agriculture brings with it many benefits that raingardens, bioswales, retention ponds and other green infrastructure strategies do not. In planning for healthy cities of the future, land use planners are looking beyond the single benefit of urban agriculture's potential as a stormwater management strategy, and evaluating the full range of benefits that derive from urban agriculture as a land use activity. In addition to helping manage stormwater, urban farming has been demonstrated to improve the visual quality of neighborhoods; provide opportunities to socialize and cooperate with friends and family; improve the environmental awareness that comes from a connection to food systems; improve access to fresh, nutritious food; help in combating childhood obesity, diabetes, and poor nutrition; offer residents healthier diets that include more fruits and vegetables; provide access to rare foods that support residents' cultural heritage, particularly for immigrant communities; improve interracial relationships; decrease crime; offer opportunities for recreation and relaxation when gardening outdoors; improve the food security of households and help gardeners and urban farmers gain new knowledge and technical skills. It is the multiple layers of benefits to cities, neighborhoods and residents that make urban farming such an intriguing green infrastructure strategy.

For these and many other reasons, cities across the nation and around the world are beginning to look at the inclusion of urban agriculture in green infrastructure planning:

Cleveland, OH

Cleveland, OH has created an Urban Agriculture Overlay District in its zoning codes, established for the following principal purposes:

- to provide appropriately located and sized land for urban agriculture use;
- to facilitate local food production and improve community health;
- to provide local opportunities for agriculture-based entrepreneurship and employment;
- to enhance the environment and improve stormwater management;
- to ensure safe and sanitary conditions for urban agriculture uses;
- to protect nearby residential areas from any adverse impacts of agricultural use; and
- to ensure that land best suited for non-agricultural use remains available for such use.[49]

[49] http://planning.city.cleveland.oh.us/zoning/pdf/urbanAgOverlayDraft.pdf

Cleveland has also incorporated urban agriculture into its vision for rehabilitating vacant lands on a subwatershed-wide geographic basis. The "[Greater] Cleveland Action Plan for Vacant Land Reclamation" plan calls for the creation of green redevelopment corridors that integrate urban farms with other green infrastructure and land revitalization projects, and economic development zones.[50]

Land use planners in Cleveland have evaluated potential return on land use activities using the triple bottom line of economic, social and environmental benefits to community. Vacant land converted to urban agricultural uses provided $103,185 per acre in benefits to local residents, with profits from raising food providing 33% of direct monetary estimates, and ecological benefits comprising approximately 65% of direct monetary estimates. Every garden within 400 meters of a house in the study area increased the sale price of that house by 3.22%.[51]

Boston, MA

The city of Boston is currently revising its zoning codes to include an Urban Agriculture Overlay District.[52] To provide incentives to increase urban agriculture, the State of Massachusetts authorized cities and counties in the state to offer a property tax credit, "a tax credit against the county or municipal corporation property tax imposed on urban agricultural property. The text of the law explicitly includes stormwater management and groundwater protection as acceptable "agricultural uses."

> (2) "Urban agricultural property" means real property that is:
>
> > (i) at least one–eighth of an acre and not more than 2 acres;
> > (ii) located in a priority funding area, as defined in § 5–7b–02 of the state finance and procurement article; and
> > (iii) used exclusively for urban agricultural purposes.
>
> (3) "urban agricultural purposes" means:
>
> > (i) crop production activities, including the use of mulch or cover crops to ensure maximum productivity and minimize runoff and weed production;
> > (ii) environmental mitigation activities, including stormwater abatement and groundwater protection"[53]

The Conservation Law Foundation recently completed a study of the benefits of urban agriculture in Boston, estimating that placing fifty acres of Boston's urban land in agricultural production would:

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[50] http://www.gcbl.org/system/files/reimag+action+plan_8-24-10.pdf

[51] Generalized Ecological Economics Framework for Evaluating Green Infrastructure in Great Lakes Cities: A case study of urban agriculture as a green infrastructure solution for vacant lands in Cleveland. A presentation by Shammin, R., Auch, T. from a study funded by the Great Lakes Protection Fund through a grant to the Cleveland Botanical Garden with additional support for student research assistants from Oberlin College.

[52] http://www.bostonredevelopmentauthority.org/Planning/PlanningInitsIndividual.asp?action=ViewInit&InitID=152

[53] http://www.farmlandinfo.org/documents/38192/MD_HB_1062.pdf

- Create between two and five direct, on-farm jobs per acre, or 130-220 total jobs;
- Create additional jobs in the agricultural services sector (equipment sales, composting and soil inputs, and food processing);
- Sequester about 114 tons of CO_2 in well-maintained soil per year;
- Support the development of compost markets that statewide would yield an additional 4,700 tons of avoided CO_2 emissions annually while helping Massachusetts achieve a 35% organic waste diversion goal; and
- Generate approximately 1.5 million pounds of fresh produce for sale into local markets, providing local communities with a nearby source of healthy food.[54]

New York, NY

The New York Department of Environmental Protection recently awarded $3.8 million in grants to four urban agriculture projects that have stormwater management functions and goals:

- 61 Bergen Street
  Amount: $41,975
  Location: 61 Bergen Street, Cobble Hill, Brooklyn
  Description: The property owner and Highview Creations LLC will construct a green roof on a building that houses 61 Local, a local bar and restaurant. The green roof will manage over 60,000 gallons of stormwater per year and will reduce CSOs to the Gowanus Canal. The owner and staff intend to grow a few varieties of drought-tolerant herbs on the green roof that can be used in the food and drinks served at the bar.
- Brooklyn Navy Yard
  Amount: $592,730
  Location: 63 Flushing Avenue, Building No. 3, Brooklyn Navy Yard
  Description: In partnership with Brooklyn Grange, the Brooklyn Navy Yard will construct a 40,000-square-foot commercial rooftop farm. The rooftop farm will manage over one million gallons of stormwater per year and reduce CSOs to the East River. The production of fresh local produce will create opportunities for urban agriculture jobs training and volunteerism, education and advocacy.
- Lenox Hill Neighborhood House
  Amount: $40,000
  Location: 331 East 70th Street, Lenox Hill, Manhattan
  Description: The Lenox Hill Neighborhood House will build two rooftop gardens that will manage up to 63,000 gallons of stormwater per year and provide its clients with fresh vegetables. The rooftop gardens will capture the rain water and will reduce CSOs to the East River. This project includes multiple community development factors such as educational programs.

[54] Growing Green: Measuring Benefits, Overcoming Barriers, and Nurturing Opportunities for Urban Agriculture in Boston, The Conservation Law Foundation and CLF Ventures, Inc. July 2012

- New York Restoration Project (NYRP) — Carroll Street Community Garden
  Amount: $244,920
  Location: Denton Place and Carroll Street, Park Slope, Brooklyn
  Description: NYRP will install a right-of-way bioswale that will divert stormwater flow from the street into a rain garden that features native plants and trees. The project will manage approximately 130,000 gallons of stormwater per year and will reduce CSOs to the Gowanus Canal. The design also includes a small Education Station that will function as a remote weather monitoring station and outdoor classroom hub.[55]

San Francisco, CA

In San Francisco, the San Francisco Planning and Urban Research (SPUR) Association commissioned an extensive study of urban agriculture. Among their findings was that, "at least seven city agencies provide monetary support and 11 agencies provide land to city gardeners and farmers. Though well-intentioned, their support is largely uncoordinated, understaffed and, as a result, inefficient… For San Francisco to reap the many benefits of urban agriculture, SPUR recommends that the city expand and coordinate its institutional support, increase funding and improve funding efficiency, and provide more access to public land." Among the recommendations was "The Public Utilities Commission should include urban agriculture as a stormwater management strategy."[56]

Seattle, WA

The city of Seattle has a long history of supporting urban farms and community gardens, and has analyzed the policy barriers that limit the growth of urban agriculture. The resulting report lists stormwater management as a recognized benefit of urban agriculture. The report also cites the State of Washington Growth Management Act's requirement that counties and cities set aside land for the specific purpose of managing stormwater, suggesting these two land uses overlap in their functions. In Seattle, as in the case of San Francisco, the rules and regulations that govern urban agriculture and quantify its benefits are spread across a variety of agencies and departments, making it difficult for the city to meet the growing demand for land, water and means of distribution of locally grown food, and to accurately assess the environmental impacts of an increase in open space.[57]

Portland, OR

In June of 2012, Portland amended its zoning code to allow market gardens (gardens or orchards where food is grown to be sold) "in all zones while ensuring that any negative impacts of the gardening on neighbors are minimized." Portland, like Cleveland, evaluated the benefits of urban agriculture to the community using the triple bottom line of social, economic and environmental benefits, noting that

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[55] http://www.urbanfoodpolicy.com/2011/06/urban-agriculture-as-stormwater.html
[56] http://www.spur.org/publications/library/report/public-harvest
[57] http://www.seattle.gov/neighborhoods/ppatch/pubs/Urban%20Agriculture%20in%20Seattle%20Policy%20and%20Barriers.pdf

"Urban vegetation effectively absorbs and filters rainwater, which reduces the impact on municipal storm water systems and delays storm water runoff that can pollute waterways and harm fish populations."[58]

A supplemental report of the benefits of urban agriculture in Portland notes that "greenroofs—and other urban gardens that host vegetation—effectively serve as a tool to reduce impact of urban development on municipal storm water systems. Ultimately, this helps to reduce pollution in surrounding watersheds and supports fish habitat."[59] The report notes that stormwater abstraction has been calculated for green roofs, but cites no studies that measure the stormwater abstraction of more common in-ground urban farm sites.

Minneapolis and St. Paul, MN

In a break with traditional views of what city parks look like and are for, Park and Recreation departments in both Minneapolis and St. Paul are currently considering urban agriculture in their planning for a 30-50 year vision for the future of city parks.[60] St. Paul is working with community groups and The Trust For Public Land to create Frogtown Farms, a 13-acre farm/park that will serve as a community resource center, offer education and demonstration programs, entrepreneurial opportunities, as well as more traditional recreational activities.

Working on a near-parallel track, a small group of individuals and organizations, including Gardening Matters, the Land Stewardship Project, and several Farmers' Markets began looking for solutions to the challenge of permanent land access for urban farmers. After nearly two years of work, the group formed the Twin Cities Agricultural Land Trust.

> "The Twin Cities Agricultural Land Trust is a community driven network that provides advocacy, holds land, facilitates and advocates for affordable ownership and/or leasing of agricultural land by growers, and connects stakeholders to resources and education for people seeking long term, affordable land access to grow food."

Though the organization does not explicitly include stormwater-related goals, the group expresses a commitment to "Healthy soil, air and water and the use of agricultural and land use practices that sustain this well-being" and "Use of land for sustainable, local food production, which benefits the environment and provides critical green space across communities." Their strategic priorities include policy and planning, organizational coordination and partnership development. [61]

Recommendations & Next Steps

[58] http://www.portlandoregon.gov/bps/article/402598
[59] http://www.portlandoregon.gov/bps/article/357756
[60] http://www.minnpost.com/line/2012/09/creating-public-parks-30-new-demographics-new-needs
[61] http://www.gardeningmatters.org/sites/default/files/TCALT_StrategicPlan_030512.pdf

Increased urban runoff volume is the primary driver of green infrastructure development. Cities are required to meet regulatory limits on pollutants flowing to surface waters. As development increases the amount of impervious surfaces, cities need a broad range of strategies to meet permit requirements and reduce the volume of water running through stormwater pipes into receiving waters.

Raingardens, commonly used and widely supported as a localized green infrastructure project, have evolved through research and engineering from a good idea to a technology that has reliable standards that can accurately predict the capacity necessary to hold, store and infiltrate stormwater from a defined area of impermeable surface. Raingardens are a known quantity, and are generally considered to be a "permanent" commitment. In Minneapolis for example, if part of an approved stormwater management plan, a raingarden must be maintained and must remain functional, unless an alternative stormwater management strategy is approved, generally due to redevelopment. Land developers can confidently deploy raingardens as one strategy in a site-based, integrated stormwater management plan. Urban farms are typically less permanent, and will require a well-tested understanding of their capacity- an understanding required by planners and policy makers if urban agriculture is to become part of a city's future.

If urban agriculture is to become a reliable, long-term stormwater control strategy that can be used by land developers, watershed planners and others to meet development standards, and ultimately for cities and other MS4s to meet permitting requirements, urban agriculture must be studied in several aspects. It seems less productive to embark on a piecemeal effort to study a single aspect of urban agriculture as a stormwater control strategy, such as the infiltration and water-holding capacity of urban farm sites. Instead, forethought and coordinated planning could lead to a more thoughtful series of studies that result in best management practices and guidelines for profitable, environmentally beneficial urban farms that help cities meet stormwater goals, as part of an effective and sustainable system of green infrastructure investments.

Though Minneapolis lags other cities' efforts to integrate urban agriculture into green infrastructure planning, the city has an opportunity to make use of lessons learned by others. The cross-cutting issues of stormwater management, green infrastructure, urban farming and urban food policy call for a deeper conversation among city planners, stormwater managers, urban food advocates, land use planners, stormwater researchers, public health professionals and others.

In the course of writing this report, the authors have interviewed or otherwise communicated with representatives from a wide variety of organizations already involved in looking at urban agriculture for its social, economic and environmental benefits, including:

National organizations:

- Office of Research and Development, US EPA
- Land Revitalization Program, EPA Region 5
- The Institute for Agriculture and Trade Policy
- The Lab at St. Anthony Falls, University of Minnesota

Regional and statewide organizations:

- Department of Soil, Water, and Climate, University of Minnesota
- The University of Minnesota Landscape Arboretum
- The Trust For Public Land
- The Permaculture Research Institute- Cold Climate
- Cleveland Botanical Gardens
- Cultivate Kansas City
- New York Department of Environmental Protection
- City Farmer
- The Land Stewardship Project

Local organizations:

- The City of Minneapolis, Public Works
- HomeGrown Minneapolis
- Stone's Throw Farms
- Gardening Matters
- Twin Cities Agricultural Land Trust

The many state, regional, and local organizations contacted by the authors have indicated a strong interest in a deeper conversation about a long-term vision for urban land use that yields multiple benefits to the watershed, city and its residents. It is clear that demand for permanent access to urban land for agricultural purposes is growing and will continue to grow. It is critical to consider how to best nurture and grow urban agriculture in ways that benefit water quality, rather than allow it to develop without considering the impact of urban agricultural land use on stormwater, and risk replicating practices from production agriculture that have had negative effects on Minnesota's waters.

It is the recommendation of this report that the Mississippi Watershed Management Organization support the convening of a stakeholder group to further investigate a broad range of planning and policy issues related to urban agriculture as a green infrastructure strategy. Participants should be drawn from the overlapping range of organizations already involved in urban agriculture and stormwater management, including representatives of city Public Works and Stormwater departments, urban land use planners, stormwater managers, watershed districts and management organizations, urban farmers, land trusts, community garden organizations, urban farmers and water advocacy organizations. This collaborative approach to creating a decentralized stormwater management approach is critical to building community engagement, according to researchers Green, Shuster, Rhea, Garmestani and Thurston.

> The ability to influence human behavior, a benefit of social capital, may not be readily available to sewer and sanitation districts with weak relationships with the community development groups that have expertise in citizen engagement and urban land redevelopment. While social capital may not be readily available to sewer districts, other forms of capital are not equally available to community groups, namely financial capitals. Thus, large-scale application of GI [green infrastructure] for CSO [combined sewer overflows] -related stormwater management is

steeped in social capital issues whereby we must utilize bridging organizations and social networks to form bonds between agencies with the necessary expertise, resources, and interpersonal relationships to solve a collective, municipal problem. Through collaboration, sewer districts under legal mandate to invest heavily in stormwater infrastructure and community organizations with access to stocks of volunteers could leverage alternate forms of capital for actualization of the full suite of GI co-benefits. Such partnerships may prove vital to the long-term success of GI, in terms of both stormwater abatement and community benefits as well as a paradigm shift whereby citizen engagement in decentralized stormwater management becomes the predominant culture.[62]

The stakeholder group should:

- Investigate the potential for the creation of green corridors for stormwater management, identifying sites appropriate for urban farming, and most effective for stormwater management, as well as other green infrastructure practices
- Identify basic science research opportunities that could be investigated on one or more vacant lots as they are converted to urban farm sites, including questions related to the following issues:
    - Cataloguing urban soils on a number of sites, to characterize local soils
    - How best to verify and encourage deep infiltration of water, ensuring water is not moving into adjacent parcels and their basements
    - Best practices for preparing urban farm sites and creating healthy soils as the foundation of healthy water when urban land is converted to agricultural purposes
    - Best practices for managing or remediating contaminants in urban soils, the potential for plant uptake of soil contaminants, or leaching into groundwater with increased infiltration
    - Best practices to minimize nutrient runoff or leeching into groundwater resulting from adding compost and other amendments to soils
    - Best practices for stabilizing soils and preventing erosion on urban agricultural sites
    - Development of a partnership to generate funding for research and community capacity building
    - Development of land use planning and policies that support permanent agricultural land uses on appropriate urban sites as a source of social, economic and environmental benefits
- Consider policies and land use agreement options that reduce policy barriers to using urban agriculture as green infrastructure to manage stormwater, and ensure the permanence of urban farms sites.
- Analyze the economic model of urban farming, to determine how integrating urban agriculture into green stormwater infrastructure brings benefit to the farmer.

[62] Identification and Induction of Human, Social, and Cultural Capitals through an Experimental Approach to Stormwater Management. (2012) Green, O., Shuster, W., Rhea, L., Garmestani, A., & Thurston, H. Sustainability, 2012, (4) pg. 1669-1682

Bringing together representatives from a variety of public and private agencies, organizations and commercial interests to engage in a comprehensive conversation about urban agriculture as a green stormwater control strategy would integrate urban agriculture into comprehensive land use planning. It is time to bring together decision makers to comprehensively analyze options for multifunctional urban land use to create better solutions for addressing the changing demands of managing stormwater in ways that benefit residents, communities and water resources in Minnesota.