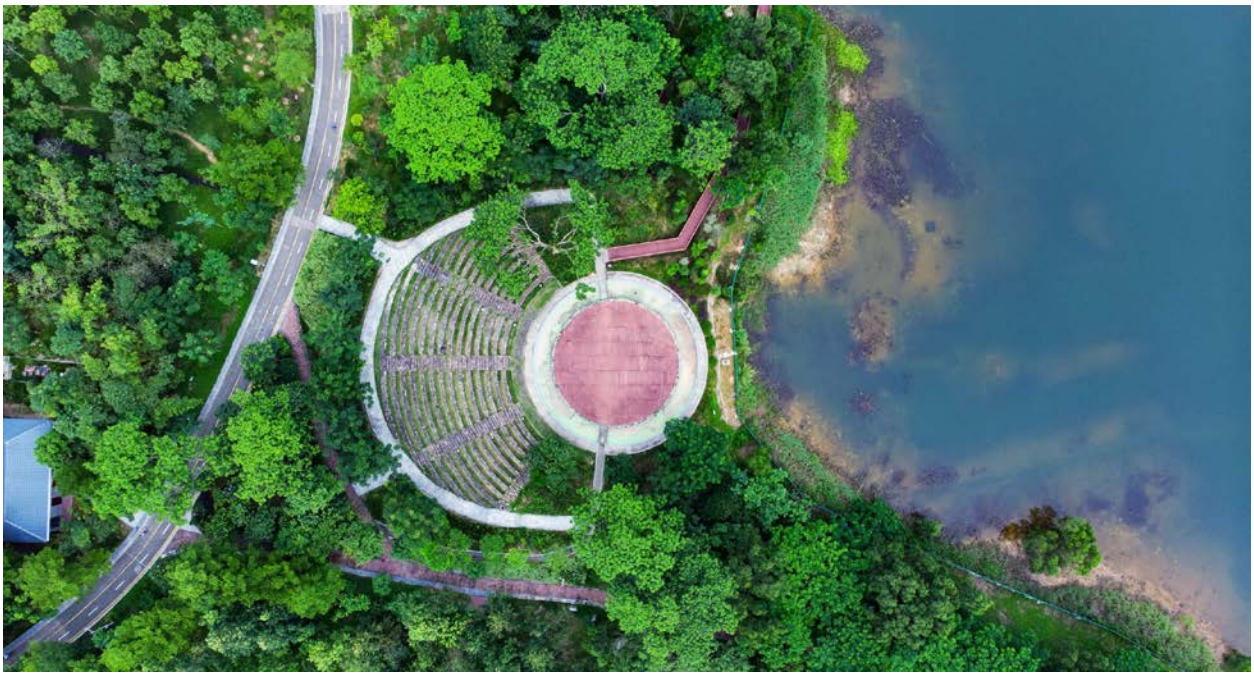
Green Infrastructure and Health

A Literature Review



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July 2019

Photo by Park Pride

June 2019 was the hottest month in recorded history across the planet. January - May of 2019 was the wettest period on record in the US and caused severe, record flooding for much of the midwest and southeast. The arctic is experiencing more wildfires in 2019 than ever before. These drastic events affect more than the natural world—they have consequences for the human communities whose health outcomes are affected because of flooding, smoke, and increased summer temperatures. These consequences disproportionately impact the most vulnerable communities, including low-income communities and communities of color. At the same time, these communities often lack access to quality parks and green spaces that function as places to capture and slow stormwater, get physically active, provide workforce development opportunities and gather with other community members.

As climate change continues to affect weather patterns across the world, cities will need to adapt to changing weather and precipitation patterns to mitigate the human health impacts. Managing stormwater runoff caused by increased rainfall in historically atypical patterns will continue to present challenges around the world. Communities will need to make fundamental changes in the way they view stormwater runoff as both a nuisance and a potential health resource in the face of a changing climate.

The purpose of this literature review was to determine what evidence exists linking green infrastructure to health. Using the Green Infrastructure Evaluation Framework developed by the National Recreation and Park Association (NRPA) that broadly encompasses the social determinants of health, we've identified health benefits findings in four major categories: human health, environmental health, economic health, and social health.

Before we explore the findings, it is important to define some key terms used throughout the document:

What is Green Infrastructure (GI)?

Our working definition of green infrastructure is "the natural and built green spaces that use nature and natural processes to manage a variety of challenges, including water quality, reducing flood risk, providing wildlife habitat, improving air quality, and now, improving human health."[1]

Green infrastructure is often seen as an alternative to traditional "gray" stormwater infrastructure, which would include features like sewer pipes, wastewater treatment facilities, and outflow tunnels. Some cities have combined sewage systems, which carries stormwater runoff and wastewater both to a treatment facility. The alternative is a separate sewage system, which simply directs stormwater runoff back into natural waterways without treatment. In both combined and separate sewage systems, green infrastructure can play an important role in enhancing water quality and decreasing costs for communities.

Analogous terms to green infrastructure include: green stormwater infrastructure (GSI), low impact development (LID), water-sensitive urban design, and sustainable urban drainage systems.[2]

What is Health?

"Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."[3] Healthy communities are more than a place where people aren't sick—they are communities where people are thriving.

Social Determinants of Health

"The social determinants of health are the conditions in which people are born, grow, live, work and age. These circumstances are shaped by the distribution of money, power and resources at global, national and local levels."[4] Put simply, the social, economic, and physical environment in which you live plays a large role in determining your health outcomes. If you face social discrimination because of your race, gender or sexuality, this negatively impacts your health. If you live next to a busy road where air pollutants are unavoidable, this negatively impacts your health. And if you don't have access to a job that pays a fair and living wage in your community, this negatively impacts your health.

These social determinants of health are all contributing factors to *health equity*. Health equity means that everyone in a community has a fair and just opportunity to be as healthy as possible. This requires removing obstacles to health for vulnerable populations, including poverty, discrimination, racism, and pollution. While easy to conceptualize, achieving health equity is a daunting challenge.
Recognizing that human health is impacted by more than just explicit physical and mental health benefits, our framework for this literature review also includes sections on the environmental, social, and economic benefits of green infrastructure. Because these are all social determinants of health (though not an exhaustive list), any benefits in these areas correlate with increased community health benefits.

A note on green space, nature, and parks:

There is a thorough and robust body of evidence linking green space and nature to human health benefits. In urban settings, parks play a hugely important role in delivering these benefits to their surrounding communities and have been shown over time to substantially increase moderate-to-vigorous activity levels[5] and provide a whole host of significant mental and physical health benefits.[6]

The physical and mental health benefits of nature and green space can reasonably be assumed to apply to green infrastructure features inasmuch as the green infrastructure increases the level of green space in a surrounding area, even if the feature is only looked at by passersby.[7] However, the findings presented in this literature review include only those that mentioned specific green infrastructure features, not broader nature or green space. It does not mean that those nature benefits do not apply to green infrastructure, only that we sought to identify the *specific* health benefits of *specific* green infrastructure features.

Because parks are already often green spaces that provide health benefits to communities, they are in a unique position to enhance their net-positive impact of community quality of life by intentionally integrating green infrastructure features. Our hope is that this literature review offers casemaking tools to show how green infrastructure features can make parks an even more integral part of their communities by helping curb some of the largest threats facing cities: climate change, health inequity, etc.

Photo by Dan Gold

Methodology:

Our literature review focused mainly on peer-reviewed academic articles published in the last 20 years (1999 - 2019). To find articles that connected green infrastructure features to health benefits, we performed combined keyword searches in two large medical and science databases (PubMed and Web of Science).

The search terms used to represent green infrastructure were:

- Green infrastructure
- Trees
- Street trees
- Green stormwater infrastructure
- Green spaces
- Open spaces
- Green views
- Views of nature
- Parks
- Bioretention
- Rain gardens
- Bioswales
- Green roofs
- Flowers
- Native plants
- Wetland
- Biodiversity
- Permeable pavement
- Low-impact development
- Dispersed development

The search terms used to represent health and related benefits were:

- Human health
- Well-being
- Attention restoration
- Stress recovery
- Social cohesion
- Pro-social behavior
- Mental health
- Crime
- Social capital
- Feelings
- Preference
- Perception
- Happiness index
- Health equity

The combined keyword search was performed by including one term from the green infrastructure list and one term from the health and related benefits list.

Our initial search identified 90 articles that fit our inclusion criteria, including some previous literature reviews that identified connections between health and green infrastructure. From this initial list, we looked through the identified literature reviews to draw out additional relevant articles. We also searched other smaller database sites that collect evidence connecting green space and health benefits.

To be included in this literature review, identified articles must have A) an explicit green infrastructure feature (urban trees, bioswales, permeable pavement, etc.), and B) an explicit benefit associated with that feature (increased physical/mental health, reduced water pollutants, improved social cohesion, etc.). Articles that found benefits associated with general nature/green space, not specifically green infrastructure features, were not included.

Additional supporting articles, gray literature, and white papers included in this literature review were identified by NRPA in a previous research document compiled for this project.

Photo by Alaric Sim

Evidence/Findings

Health Benefits:

Nature is good for your health, and green infrastructure that increase greenery in a space increase physical and mental health benefits in the surrounding area.

Physical Health

Increased physical activity

Increased greenery in an area positively correlates to increased physical activity and improved physical health outcomes,[8] even in small-scale project like pocket parks.[9] What's more, physical activity in these green spaces is shown to be more beneficial to physical health indicators like blood pressure, obesity, and risk of heart disease than the same physical activity performed indoors.[10]

Urban trees help reduce surrounding air temperature, making spaces more comfortable and encouraging increased physical activity.[11] In fact, several studies show a positive correlation between the number of urban trees and physical activity.[12] [13] High-density treed environments

increase the amount of walking in a given area, and large bodies of water (which would include engineered wetlands or lakes) have been shown to have the same effect.[14]

Physical health improvements

Closely correlated with increased physical activity is decreased rates of obesity and obesity-related illnesses. Studies show that proximity to urban green space and trees significantly decreased rates of obesity and lowered BMI in children.[15] [16] Others show that proximity to urban engineered green space decreases obesity rates and BMI in adults.[17] [18]

The mere sight of green space, including green infrastructure, improves cardiovascular health by lowering blood pressure[19] and improving heart rate variability,[20] an effect that is magnified as biodiversity increases[21] and is measurable on ECGs.[22] These heart rate and blood pressure benefits associated with views of green infrastructure and green space are evidenced in children as well,[23] who also show rates of decreased blood pressure after spending time in urban green space.[24]

Urban trees are linked to any number of physical health improvements in surrounding communities, including lowered rates of obesity,[25] diabetes,[26] and cardiovascular disease,[27] decreased instances of high blood pressure,[28] and increased self-reports of good physical health.[29] [30] When linked together, “green corridors” of urban trees and other natural features (like green infrastructure) increase self-reported good physical health within communities.[31]

Another health benefit associated with green infrastructure and urban greenery is improved birth outcomes.[32] Proximity to city parks and other “engineered” green spaces in urban settings are shown to positively correlate with higher birth weights and lowered rates of infant mortality,[33] [34] [35] along with improved blood pressure measurements in expecting mothers.[36]

Mental Health

Reductions in stress/anxiety

Time spent in natural environments, including those created by green infrastructure features like urban trees, correlates with decreased cortisol levels[37] [38] [39] and other physical stress indicators.[40] Communities with high levels of urban greenery are also less likely to seek treatment and medication for depression, anxiety and mood disorders.[41] [42]

Urban trees have been shown to decrease levels of depression and anxiety, and increase feelings of tranquility.[43] By positively corresponding to increased social connectivity, they also reduce counts of psychological distress and generally poor self-perceptions of mental health.[44] Even just viewing pictures of urban trees is enough to measurably reduce stress and anxiety in laboratory settings.[45]

In traffic, street trees can reduce feelings of road rage and increase overall frustration tolerance of drivers,[46] and are largely shown to have positive mental health benefits.[47] However, it should also be noted that street trees can prove driving hazards and can be fatal when hit by cars.[48] [49] [50]

Attention/restoration

Green infrastructure can provide attention restoration by increasing the amount of green space in a given environment. One study showed that office workers who took short breaks on green roofs had improved focus and mental restoration than those in a control group.[51] Students who attend schools with high levels of greenery and urban trees show increased test scores and attention levels.[52]

Urban trees have been shown to have restorative effects, too.[53] [54]This effect is magnified when urban trees are coupled with more biodiverse environments, including a variety of plants and animals.[55]

Other mental health benefits

Evidence shows that urban trees generally correlate with improved mental health,[56] and increased tree canopy coverage in a neighborhood corresponds with increased sleeping hours for residents in that neighborhood.[57] Time spent near urban trees and greenery also positively correlates with improvements in memory,[58] [59] emotional resilience[60] and overall mood,[61] and is shown to decrease impulsive behavior.[62] [63] In a case study of the Huckleberry Trail and Heritage Community Park and Natural Area, increased visitor frequency and nearer distance to the community green infrastructure (including urban trees) increased the overall mental health benefits of community members.[64]

Specific to children, time in urban green space positively correlates with improved cognitive development.[65] Children who visit urban green space and natural features in parks demonstrate increased emotional resilience and self-regulation,[66] and mothers reported better behavior in their children after spending time in urban parks and near tree canopy coverage.[67] Even adults are more likely to display helpful social behaviors[68] [69] and less likely to display aggressive behaviors[67] after spending time in urban green environments.

A few studies linked non-tree green infrastructure features to specific mental health benefits. One we identified showed that spending time near constructed urban lakes improved self-reported physical and mental health,[71] while another reported similar self-reported improvements for people who spent time near constructed wetlands.[72]

Photo by Parks and People Foundation

Economic Benefits:

In addition to reducing the costs of gray stormwater infrastructure, green infrastructure has specific economic impacts through both workforce development and broader community economic development.

Workforce Development

Job creation

From the beginning planning phase all the way through upkeep and maintenance, green infrastructure has the potential to create new jobs. One paper estimates that:

- Converting 1% of urban roofs in the United States to green roofs would create 190,000 jobs.
- Investing $10 billion in water efficiency projects across the United States would create 150,000-220,000 jobs.[73]

A $166 million investment in green infrastructure in Los Angeles created more than 2,000 new jobs; in Portland, OR, green infrastructure-related projects employed over 10,000 people in 2015.[74] Worth noting is that almost three quarters of these new jobs go to local residents,[75] creating a direct economic investment back into the community.

Job skills

Green infrastructure jobs also provide workers with specialized training and skills,[76] and the job market is growing. The green infrastructure-related job market—including implementation, maintenance, and inspection—was estimated to grow by 5% from 2015 to 2020.[77]

Economic Development

Increased property values

Studies have shown that land value for properties around green infrastructure projects can increase anywhere from 8 to 20 percent.[78] In New York City, buildings with green roofs had rent prices 16 percent higher than the neighborhood average.[79] These increased property values can also lead to increased property taxes, which can lead to increased revenue for municipalities as well.[80]

Spurred economic development

Green infrastructure features are good for retail spaces, too. Several studies have shown that retail property values near green infrastructure features increase in similar fashion to residential areas.[81] And not only are these properties more valuable, consumers are willing to spend 8 to 12 percent more in retail spaces with tree canopies and other green infrastructure features than in spaces without green infrastructure.[82]

Cost savings related to flooding

Perhaps the most obvious economic benefit related to green infrastructure is its reduction of costs associated with flood damage.[83] At its most basic level, green infrastructure's function is to treat stormwater on-site and slow the rate of stormwater runoff, which inevitably has an impact on local and watershed-level flooding events. It shouldn't be surprising to learn that a University of Vermont study showed property owners were more likely to adopt or install green infrastructure features if they had recently experienced flooding or erosion on their property.[84]

"Between 2007 and 2017, The National Flood Insurance Program (NFIP) paid an average of $2.9 billion per year to cover flood-related losses."[85] Historic flooding events, such as Hurricane Sandy in 2012 or Hurricane Harvey in 2017, can cost as much as $8.8 billion in flood-related damages in a single event.[86] As climate change increases the intensity and likelihood of these events, the economic case for green infrastructure should become a more and more convincing argument.

Some green infrastructure features quantifiably store and treat more water than others, thus potentially increasing their overall cost benefit. A study from Illinois looked at which trees were most effective at cycling water in bioswales via transpiration, concluding that some species of

trees are more cost-effective as green infrastructure because of the amount of water they are able to retain.[87]

Cost savings as compared to gray infrastructure

Green infrastructure also helps protect water sources by filtering out harmful chemicals and heavy metals from stormwater runoff, which can have huge impacts on the costs of treating water. One study showed that "every $1 spent on source-water protection saved $27 in water treatment costs."[88]

Green infrastructure can also save communities millions of dollars in expenses that would typically go to installing and maintaining gray infrastructure with an analogous treatment capacity. Engineering wetlands to treat plant wastewater in Seadrift, TX was 96 percent cheaper than installing a gray wastewater treatment center, saving the community nearly $40 million in capital costs alone. The wetlands are also significantly cheaper to maintain and require none of the full-time staff that would be needed to run a new wastewater treatment center.[89] Similar projects save ongoing costs related to energy consumption and significantly reduce the carbon output of water treatment facilities.[90]

Other costs savings

Green infrastructure features save costs in other ways, too. Green roofs benefit buildings through reduced energy needs for heating and cooling. A 21,000 square foot green roof can save almost $200,000 in energy savings over its lifetime.[91] Green roofs also protect basic roof infrastructure from weathering and UV rays, which can extend their life to 2-3 times that of traditional roofs.[92]

Permeable pavement is also generally cheaper to install and maintain over time than traditional impermeable surfaces, which can lead to savings of tens of thousands of dollars over the lifetime of a parking lot.[93]

Photo by Robert Bye

Social Benefits:

Social benefits matter in health.[94] As a broad concept, "social cohesion" folds in several aspects related to how humans interact and work together in community. When clarified into distinct concepts, such as feelings of safety, wellbeing, and connection with the people around us, it's obvious that how we relate and fit in with other people has broad effects on our mental and emotional health.[95]

Social Cohesion

"Social cohesion is defined as the willingness of members of a society to cooperate with each other in order to survive and prosper."[96] Put simply, it's how individuals in a community work together to make their community a better place. Unsurprisingly, feelings related to trust, safety, and belonging among community members are indicators of improved health outcomes.[97] Green infrastructure can provide a handful of benefits to communities that help increase the bonds between community members, strengthen relationships, and promote healthy lifestyles at a neighborhood-level. This happens primarily by providing communities more green, inviting spaces to congregate, socialize, and exercise together.

Enhanced neighborhood socialization

Green infrastructure offers a space for communities to come together and increases opportunities for socialization (in and of itself a social benefit),[98] which can lead to increased

trust and cooperation between neighbors.[99] Several green infrastructure features also promote increased community physical activity, which further increases social bonds as neighbors recreate together.[100]

Trees and urban tree canopy in particular have a wide range of social benefits, including improving general feelings of social cohesion[101] and inspiring prosocial behavior after study participants spent time in urban forests.[102] Edible trees and plants in urban areas have the added benefit of drawing people together while also providing nutrition, compounding their community benefit.[103]

Community satisfaction w/project

Green infrastructure provides more opportunities for trust between people and government, too. Well-managed public spaces, including parks and other green infrastructure features, also increase trust and satisfaction among community members toward their local governments, and this trust grows over time as the assets stay well-managed.[104]

Public Safety

Reductions in crime

Perhaps the most studied social benefit associated with green infrastructure and urban trees is its inverse correlation to street crime. Studies from urban areas across the world have shows that crime rates are lower in areas with increased tree coverage.[105] [106] Even planting smaller trees in neighborhoods has been shown to decrease crime levels in following years, an effect that grows more evident in neighborhoods with lower median incomes.[107] Green infrastructure in urban areas has also been shown to correlate with decreased narcotics possession in the surrounding neighborhood by anywhere from 18 percent to 27 percent.[108]

Specific to parks, a study from Chicago found that increasing the tree canopy in a park by just 10 percent decreased the battery rate in the park by 10 percent, and decreased robbery, assault, and narcotics usage by more than 11 percent.[109]

In addition to decreasing violent crime, green infrastructure can also positively impact how safe a neighborhood feels to its residents. A randomized control trial from Philadelphia showed that residents who lived near urban lots covered with impermeable pavement felt significantly safer once the surface was replaced with grass and trees.[110] The follow-up study demonstrated that not only do greened lots make residents feel safer, but they also have significant impacts on a community's overall mental health, significantly decreasing rates of self-reported depression and worthlessness.[111]

Project Reach

Community Engagement

Community engagement, when done properly, leads to increased social benefits merely through the process itself. Increasing a community's social capital and giving them power in the decision-making process can be a powerful change agent in communities experiencing health inequities,[112] and is particularly important when working with communities who have been historically excluded and underserved in planning processes.

Green infrastructure Knowledge + Use

Offering educational opportunities about green infrastructure to communities is another effective means of increasing the social benefits of green infrastructure. Communities that receive green infrastructure education show increased rates of community trust[113] and are more likely to engage in social and volunteer opportunities around the neighborhood.[114]

Another benefit of community education around green infrastructure is its likelihood to increase the development of private green infrastructure projects, increasing support for your efforts while also increasing the community benefits as green infrastructure projects spread.[115] For example, installing a rain garden and holding community training clinics and demonstrations empowered a community in American Somoa to install rain gardens on their own property.[116]

Photo by Philadelphia Water Dept.

Environmental Benefits:

Human health is intricately linked to the health of the surrounding environment. Improvements to the natural world are one of the main ways that green infrastructure features benefit surrounding communities.

Water Benefits

Reduced flooding

Green infrastructure is designed to capture and treat stormwater on site, reducing the flow and volume of stormwater runoff. This has an inherent effect on the flooding potential of surrounding areas, and so it is not surprising that several articles identified reduced flooding and runoff volume as a major environmental benefit of green infrastructure.[117] In particular, rain gardens were identified as impacting the likelihood of flooding in urban areas by collecting and diverting runoff from otherwise impermeable surfaces.[118] Permeable pavement and green roofs are also shown to not only decrease the intensity of flooding events, but also mitigate the negative health impacts of flooding.[119]

Enhanced water quality

Not only is runoff volume decreased, but green infrastructure has a significant impact on the quality of the runoff that is discharged. Bioretention cells help remove heavy metals and other dissolved pollutants through their filtration systems, which prevent those pollutants from reaching waterways.[120] [121] Green sorption materials,[122] bioswales,[123] grasswales,[124] urban

trees,[125] [126] and other forms of green infrastructure also remove pollutants from runoff and improve water quality in surrounding communities.[127]

Most green infrastructure features combine these benefits, reducing the rate and volume of runoff while also filtering dissolved pollutants. Permeable pavement can actually trap airborne pollutants like CO2 and SO2 from vehicles,[128] benefiting both air quality and water quality.[129] Urban trees also perform both functions, and one studied identified evaluated which species of tree were most cost effective for water treatment in bioswales.[130]

Habitat Benefits

Expanded and restored habitat

Certain green infrastructure features provide more habitat space than others. For example, engineered wetlands are a common practice for treating water discharge, and provide extensive habitat space for flora and fauna in addition to recreational space for humans.[131]

Air Benefits

Decreased air temperature

Urban greenery, in particular tree canopy coverage, lowers ground temperature in nearby areas, combating the "urban heat island" effect and encouraging increased physical activity because of lower temperatures.[132] This also leads to "reductions in heat- and pollution-related mortality rates and hospital visitations." [133]

Enhanced air quality

Green infrastructure can have significant impacts on urban air quality. Green roofs help filter out any number of pollutants from the air, including NOx,[134] CO2,[135] ozone, SO2, and NO2.[136]

Urban trees have significant and well-studied impacts on surrounding air quality. They remove any number of pollutants from the air, including vehicle exhaust[137] and ozone.[138] Urban trees also serve to sequester huge amounts of carbon, and even affect the soil underneath them so that the soil sequesters more carbon than regular soil.[139]

Studies are mixed on the effects of urban trees and asthma in surrounding populations. One study showed decreased rates of asthma in people living in areas with increased tree canopy coverage,[140] while another showed increased in asthma and allergy rates for children living in more forested urban areas.[141] More studies are needed to determine how urban trees affect asthma rates in surrounding populations.

Photo by Cassie Gallegos

Key Themes and Findings:

1. While the health benefits of green space and nature have been rigorously studied for decades, it is difficult to differentiate the health benefits gleaned specifically from green infrastructure.

One explanation for this is that green infrastructure, by definition, is “green” or nature-based. Thus when community health benefits are studied, it’s hard to see where the green space benefits end and the green infrastructure-specific benefits begin. This becomes particularly challenging when discussing green infrastructure in the context of parks, which already provide green space and their own host of benefits.

This unclear distinction between green infrastructure and green space benefits is particularly evident in the number of academic articles identified that are associated with urban trees. A majority of the articles that explicitly connect human health benefits to green infrastructure features were focused on urban trees, whereas other green infrastructure features (permeable pavement, bioswales, green roofs, etc.) in studies were mostly linked to explicit environmental benefits. These environmental benefits (ex. decreased CO2 emissions, decreased heavy metal pollution in runoff, etc.) obviously impact human health, but require a further step in determining just what the exact health benefits are. Further study would be useful in connecting non-tree, specific green infrastructure features to specific human health outcomes.

2. Just by virtue of being green infrastructure, all features have some effect on the likelihood of flooding events, which affect all four benefit categories when you consider

the effects that flooding has on human health, local economies, the environment, and community social connectedness.

When deployed effectively, it's safe to assume that *all* green infrastructure has some positive affect in these areas. Since all four framework categories are social determinants of health, they're all linked together in how their benefits impact overall community health.

On a similar note, several of the papers we found showed benefits in multiple framework categories. While the framework of health/environmental/economic/social is helpful to breakdown the findings, there's lots of overlap and connection between all these areas. If people are healthy, they're more likely to work and connect with their peers. When well-paying jobs are plentiful, communities are able to invest in environmental improvements, etc. While each benefit category can be used to highlight the specific benefits of green infrastructure, we shouldn't lose the view of all four impact areas braided together in a way that broadly improves quality of life for communities.

3. Green infrastructure can have important impacts on community health equity, but the potential negative effects of green infrastructure on community equity also need understanding.

In some studies we identified, the introduction of green infrastructure features (green space/urban trees) in a neighborhood were shown to have the greatest net positive impact on people who were experiencing the greatest health disparities.[142] [143] However, several studies we identified also highlighted that urban green space is distributed inequitably across urban areas, generally favoring white, high-income communities and potentially leading to community displacement through gentrification.[144] [145]

None of the literature we identified focused on how specific green infrastructure projects (and not broader urban tree or greening projects) affect issues of community health equity within the context of the social determinants of health. This would be an excellent area of further study, and cities looking to install green infrastructure should carefully consider how to mitigate potential negative impacts of development in the communities who stand to benefit most from improved health equity.

NRPA recognizes the need to encourage the park and recreation field to adopt green infrastructure practices into their planning efforts, with special emphasis on prioritizing projects that seek to understand and incorporate the needs of underrepresented populations. This literature review will inform the creation of a communications toolkit that will provide park and recreation professionals with powerful messages to bolster support for GI projects in parks that improve health equity and community resilience outcomes.

Sources:

1. Cochran, B., Henke, E. & Robison, B. (2018). Green Infrastructure & Health Guide. http://willamettepartnership.org/wp-content/uploads/2018/07/Green-Infrastructure_final_7_12_18_sm.pdf
2. Marsalek, J., & Chocat, B. (2002). International report: stormwater management. *Water Science & Technology*, *46,* 6-7. https://www.ncbi.nlm.nih.gov/pubmed/12380969
3. WHO Constitution. (n.d.). Retrieved July 29, 2019, from https://www.who.int/about/who-we-are/constitution
4. WHO Constitution. (n.d.). Retrieved July 29, 2019, from https://www.who.int/about/who-we-are/constitution
5. Han, B., Cohen, D. A., Derose, K. P., Marsh, T., Williamson, S., & Raaen, L. (2014). How much neighborhood parks contribute to local residents' physical activity in the City of Los Angeles: a meta-analysis. *Preventive Medicine*, *69 Suppl 1*, S106-110. https://doi.org/10.1016/j.ypmed.2014.08.033
6. de Vries, S., Verheij, R., Groenewegen, P., & Spreeuwenberg, P. (2003). Natural environments - Healthy environments? An exploratory analysis of the relationship between greenspace and health. *Environment and Planning A*, *35*, 1717–1731. https://doi.org/10.1068/a35111
7. Planning, Nature and the Environment. Nature and Health. (2004). *The influence of nature on social, psychological and physical well-being. https://www.healthcouncil.nl/documents/advisory-reports/2004/06/09/nature-and-health.-the-influence-of-nature-on-social-psychological-and-physical-well-being*
8. Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. BMC public health, 10(1), 456. https://doi.org/10.3390/ijerph110303453
9. Cohen, D. A., Marsh, T., Williamson, S., Han, B., Derose, K. P., Golinelli, D., & McKenzie, T. L. (2014). The potential for pocket parks to increase physical activity. *American Journal of Health Promotion: AJHP*, *28*(3 Suppl), S19-26. https://doi.org/10.4278/ajhp.130430-QUAN-213
10. Pretty, J., Peacock, J., Sellens, M., & Griffin, M. (2005). The mental and physical health outcomes of green exercise. *International Journal of Environmental Health Research*, *15*(5), 319–337. https://doi.org/10.1080/09603120500155963
11. Young-Jae, K., Lee, C., & Jun-Hyun, K. (2018). Sidewalk Landscape Structure and Thermal Conditions for Child and Adult Pedestrians. *International Journal of Environmental Research and Public Health; Basel*, *15*(1), 148. http://dx.doi.org/10.3390/ijerph15010148
12. Eichinger, M., Titze, S., Haditsch, B., Dorner, T. E., & Stronegger, W. J. (2015). How are physical activity behaviors and cardiovascular risk factors associated with characteristics of the built and social residential environment? *PloS One*, *10*(6), e0126010. https://doi.org/10.1371/journal.pone.0126010
13. Lovasi, G. S., Jacobson, J. S., Quinn, J. W., Neckerman, K. M., Ashby-Thompson, M. N., & Rundle, A. (2011). Is the environment near home and school associated with physical activity and adiposity of urban preschool children? *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, *88*(6), 1143–1157. https://doi.org/10.1007/s11524-011-9604-3
14. Vich, G., Marquet, O., & Miralles-Guasch, C. (2019). Green streetscape and walking: Exploring active mobility patterns in dense and compact cities. *Journal of Transport & Health*, *12*, 50–59. https://doi.org/10.1016/j.jth.2018.11.003
15. Kim, J.-H., Lee, C., & Sohn, W. (2016). Urban Natural Environments, Obesity, and Health-Related Quality of Life among Hispanic Children Living in Inner-City Neighborhoods. *International Journal of Environmental Research and Public Health*, *13*(1). https://doi.org/10.3390/ijerph13010121
16. Wolch, J., Jerrett, M., Reynolds, K., McConnell, R., Chang, R., Dahmann, N., … Berhane, K. (2011). Childhood obesity and proximity to urban parks and recreational resources: a longitudinal cohort study. *Health & Place*, *17*(1), 207–214. https://doi.org/10.1016/j.healthplace.2010.10.001

17. Villeneuve, P. J., Jerrett, M., Su, J. G., Burnett, R. T., Chen, H., Wheeler, A. J., & Goldberg, M. S. (2012). A cohort study relating urban green space with mortality in Ontario, Canada. *Environmental Research*, *115*, 51–58. https://doi.org/10.1016/j.envres.2012.03.003
18. Kim, J.-H., Lee, C., & Sohn, W. (2016). Urban Natural Environments, Obesity, and Health-Related Quality of Life among Hispanic Children Living in Inner-City Neighborhoods. *International Journal of Environmental Research and Public Health*, *13*(1). https://doi.org/10.3390/ijerph13010121
19. Pilotti, M., Klein, E., Golem, D., Piepenbrink, E., & Kaplan, K. (2014). Is Viewing a Nature Video After Work Restorative? Effects on Blood Pressure, Task Performance, and Long-Term Memory. *Environment and Behavior*, *47*. https://doi.org/10.1177/0013916514533187
20. Brown, D. K., Barton, J. L., & Gladwell, V. F. (2013). Viewing Nature Scenes Positively Affects Recovery of Autonomic Function Following Acute-Mental Stress. *Environmental Science & Technology*, *47*(11), 5562–5569. https://doi.org/10.1021/es305019p
21. Chang, K. G., Sullivan, W. C., Lin, Y.-H., Su, W., & Chang, C.-Y. (2016). The Effect of Biodiversity on Green Space Users' Wellbeing—An Empirical Investigation Using Physiological Evidence. *Sustainability*, *8*(10), 1049. https://doi.org/10.3390/su8101049
22. Wang, X., Rodiek, S., Chengzhao, W., Chen, Y., & Li, Y. (2016). Stress Recovery and Restorative Effects of Viewing Different Urban park Scenes in Shanghai, China. *Urban Forestry & Urban Greening*, *15*, 112–122. https://doi.org/10.1016/j.ufug.2015.12.003
23. Li, D., & Sullivan, W. C. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning*, *148*, 149–158. https://doi.org/10.1016/j.landurbplan.2015.12.015
24. Markevych, I., Thiering, E., Fuertes, E., Sugiri, D., Berdel, D., Koletzko, S., … Heinrich, J. (2014). A cross-sectional analysis of the effects of residential greenness on blood pressure in 10-year old children: results from the GINIplus and LISAplus studies. *BMC Public Health*, *14*, 477. https://doi.org/10.1186/1471-2458-14-477
25. Lovasi, G. S., Schwartz-Soicher, O., Quinn, J. W., Berger, D. K., Neckerman, K. M., Jaslow, R., … Rundle, A. (2013). Neighborhood safety and green space as predictors of obesity among preschool children from low-income families in New York City. *Preventive Medicine*, *57*(3), 189–193. https://doi.org/10.1016/j.ypmed.2013.05.012
26. Ulmer, J. M., Wolf, K. L., Backman, D. R., Tretheway, R. L., Blain, C. J., O'Neil-Dunne, J. P., & Frank, L. D. (2016). Multiple health benefits of urban tree canopy: The mounting evidence for a green prescription. *Health & Place*, *42*, 54–62. https://doi.org/10.1016/j.healthplace.2016.08.011
27. Donovan, G. H., Butry, D. T., Michael, Y. L., Prestemon, J. P., Liebhold, A. M., Gatziolis, D., & Mao, M. Y. (2013). The relationship between trees and human health: evidence from the spread of the emerald ash borer. *American Journal of Preventive Medicine*, *44*(2), 139–145. https://doi.org/10.1016/j.amepre.2012.09.066
28. Ulmer et al (2016)
29. Mansor, M., Zakariya, K., & Harun, N. Z. (2017). Does Neighborhood Green Infrastructure (NGI) Affect Residents' Self-Perceived Health? *Advanced Science Letters*, *23*(4), 2770–2773. https://doi.org/10.1166/asl.2017.7626
30. Tsurumi, T., Imauji, A., & Managi, S. (2018). Greenery and Subjective Well-being: Assessing the Monetary Value of Greenery by Type. *Ecological Economics*, *148*, 152–169. https://doi.org/10.1016/j.ecolecon.2018.02.014
31. Mansor et al (2017)
32. Dadvand, P., Sunyer, J., Basagaña, X., Ballester, F., Lertxundi, A., Fernández-Somoano, A., … Nieuwenhuijsen, M. J. (2012). Surrounding greenness and pregnancy outcomes in four Spanish birth cohorts. *Environmental Health Perspectives*, *120*(10), 1481–1487. https://doi.org/10.1289/ehp.1205244
33. Grazuleviciene, R., Danileviciute, A., Dedele, A., Vencloviene, J., Andrusaityte, S., Uždanaviciute, I., & Nieuwenhuijsen, M. J. (2015). Surrounding greenness, proximity to city parks and pregnancy outcomes in

Kaunas cohort study. *International Journal of Hygiene and Environmental Health*, *218*(3), 358–365. https://doi.org/10.1016/j.ijheh.2015.02.004

34. Hystad, P., Davies, H. W., Frank, L., Van Loon, J., Gehring, U., Tamburic, L., & Brauer, M. (2014). Residential greenness and birth outcomes: evaluating the influence of spatially correlated built-environment factors. *Environmental Health Perspectives*, *122*(10), 1095–1102. https://doi.org/10.1289/ehp.1308049
35. Donovan et al (2013)
36. Grazuleviciene, R., Dedele, A., Danileviciute, A., Vencloviene, J., Grazulevicius, T., Andrusaityte, S., … Nieuwenhuijsen, M. J. (2014). The influence of proximity to city parks on blood pressure in early pregnancy. *International Journal of Environmental Research and Public Health*, *11*(3), 2958–2972. https://doi.org/10.3390/ijerph110302958
37. Gidlow, C. J., Randall, J., Gillman, J., Smith, G. R., & Jones, M. V. (2016). Natural environments and chronic stress measured by hair cortisol. *Landscape and Urban Planning*, *148*, 61–67. https://doi.org/10.1016/j.landurbplan.2015.12.009
38. Roe, J. J., Thompson, C. W., Aspinall, P. A., Brewer, M. J., Duff, E. I., Miller, D., … Clow, A. (2013). Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban Communities. *International Journal of Environmental Research and Public Health*, *10*(9), 4086–4103. https://doi.org/10.3390/ijerph10094086
39. Thompson et al (2012)
40. Jiang, B., Li, D., Larsen, L., & Sullivan, W. (2014). A Dose-Response Curve Describing the Relationship Between Urban Tree Cover Density and Self-Reported Stress Recovery. *Environment and Behavior*, *48*. https://doi.org/10.1177/0013916514552321
41. Nutsford, D., Pearson, A. L., & Kingham, S. (2013). An ecological study investigating the association between access to urban green space and mental health. *Public Health*, *127*(11), 1005–1011. https://doi.org/10.1016/j.puhe.2013.08.016
42. Taylor et al (2015)
43. Watts, G. (2017). The effects of “greening” urban areas on the perceptions of tranquillity. *Urban Forestry & Urban Greening*, *26*, 11–17. https://doi.org/10.1016/j.ufug.2017.05.010
44. Rugel, E. J., Carpiano, R. M., Henderson, S. B., & Brauer, M. (2019). Exposure to natural space, sense of community belonging, and adverse mental health outcomes across an urban region. *Environmental Research*, *171*, 365–377. https://doi.org/10.1016/j.envres.2019.01.034
45. Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7
46. Cackowski, J. M., & Nasar, J. L. (2003). The Restorative Effects of Roadside Vegetation: Implications for Automobile Driver Anger and Frustration. *Environment and Behavior*, *35*(6), 736–751. https://doi.org/10.1177/0013916503256267
47. Fernandes, C. O., da Silva, I. M., Teixeira, C. P., & Costa, L. (2019). Between tree lovers and tree haters. Drivers of public perception regarding street trees and its implications on the urban green infrastructure planning. *Urban Forestry & Urban Greening*, *37*, 97–108. https://doi.org/10.1016/j.ufug.2018.03.014
48. Sullivan, E. C., & Daly, J. C. (2005). Investigation of Median Trees and Collisions on Urban and Suburban Conventional Highways in California. *Transportation Research Record*, *1908*(1), 114–120. https://doi.org/10.1177/0361198105190800114
49. Wolf, K. L., & Bratton, N. (2006). *Urban Trees and Traffic Safety: Considering U.S. Roadside Policy and Crash Data*. 10.
50. Bratton, N. J., & Wolf, K. L. (2005). *Trees and Roadside Safety in U.S. Urban Settings*. 21.
51. Lee, K. E., Williams, K. J. H., Sargent, L. D., Williams, N. S. G., & Johnson, K. A. (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. *Journal of Environmental Psychology*, *42*, 182–189. https://doi.org/10.1016/j.jenvp.2015.04.003
52. Wu, C.-D., McNeely, E., Cedeño-Laurent, J. G., Pan, W.-C., Adamkiewicz, G., Dominici, F., … Spengler, J. D. (2014). Linking student performance in Massachusetts elementary schools with the “greenness” of

school surroundings using remote sensing. *PloS One*, *9*(10), e108548. https://doi.org/10.1371/journal.pone.0108548

53. Chang et al (2014)
54. Lin, Y.-H., Tsai, C.-C., Sullivan, W. C., Chang, P.-J., & Chang, C.-Y. (2014). Does awareness effect the restorative function and perception of street trees? *Frontiers in Psychology*, *5*, 906. https://doi.org/10.3389/fpsyg.2014.00906
55. Wood, E., Harsant, A., Dallimer, M., Cronin de Chavez, A., McEachan, R. R. C., & Hassall, C. (2018). Not All Green Space Is Created Equal: Biodiversity Predicts Psychological Restorative Benefits From Urban Green Space. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.02320
56. Mansor et al (2017)
57. Beyer, K. M. M., Kaltenbach, A., Szabo, A., Bogar, S., Nieto, F. J., & Malecki, K. M. (2014). Exposure to neighborhood green space and mental health: evidence from the survey of the health of Wisconsin. *International Journal of Environmental Research and Public Health*, *11*(3), 3453–3472. https://doi.org/10.3390/ijerph110303453
58. Bratman, G. N., Daily, G. C., Levy, B. J., & Gross, J. J. (2015). The benefits of nature experience: Improved affect and cognition. *Landscape and Urban Planning*, *138*, 41–50. https://doi.org/10.1016/j.landurbplan.2015.02.005
59. Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., … Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. *Journal of Affective Disorders*, *140*(3), 300–305. https://doi.org/10.1016/j.jad.2012.03.012
60. Balseviciene, B., Sinkariova, L., Grazuleviciene, R., Andrusaityte, S., Uzdanaviciute, I., Dedele, A., & Nieuwenhuijsen, M. J. (2014). Impact of residential greenness on preschool children's emotional and behavioral problems. *International Journal of Environmental Research and Public Health*, *11*(7), 6757–6770. https://doi.org/10.3390/ijerph110706757
61. Berman et al (2012)
62. Berry, M. S., Sweeney, M. M., Morath, J., Odum, A. L., & Jordan, K. E. (2014). The nature of impulsivity: visual exposure to natural environments decreases impulsive decision-making in a delay discounting task. *PloS One*, *9*(5), e97915. https://doi.org/10.1371/journal.pone.0097915
63. Beute, F., & De Kort, Y. (2014). Natural resistance: Exposure to nature and self-regulation, mood, and physiology after ego-depletion. *Journal of Environmental Psychology*, *40*. https://doi.org/10.1016/j.jenvp.2014.06.004
64. Kim, G., & Miller, P. (2019). The impact of green infrastructure on human health and wellbeing: The example of the Huckleberry Trail and the Heritage Community Park and Natural Area in Blacksburg, Virginia. *Sustainable Cities and Society, 46*. https://www.sciencedirect.com/science/article/pii/S221067071830831X
65. Dadvand, P., Nieuwenhuijsen, M. J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., … Sunyer, J. (2015). Green spaces and cognitive development in primary schoolchildren. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(26), 7937–7942. https://doi.org/10.1073/pnas.1503402112
66. Flouri, E., Midouhas, E., & Joshi, H. (2014). The Role of Urban Neighbourhood Green Space in Children's Emotional and Behavioural Resilience. *Journal of Environmental Psychology*, *40*. https://doi.org/10.1016/j.jenvp.2014.06.007
67. Balseviciene et al (2014)
68. Guéguen, N., & Stefan, J. (2016). "Green Altruism": Short Immersion in Natural Green Environments and Helping Behavior. *Environment and Behavior*, *48*(2), 324–342. https://doi.org/10.1177/0013916514536576
69. Piff, P. K., Dietze, P., Feinberg, M., Stancato, D. M., & Keltner, D. (2015). Awe, the small self, and prosocial behavior. *Journal of Personality and Social Psychology*, *108*(6), 883–899. https://doi.org/10.1037/pspi0000018
70. Ng, H. K. S., & Chow, T. S. (2017). The effects of environmental resource and security on aggressive behavior. *Aggressive Behavior*, *43*(3), 304–314. https://doi.org/10.1002/ab.21690

71. Natarajan, S. K., Hagare, D., & Maheshwari, B. (2018). Understanding socio-economic benefits of stormwater management system through urban lakes in Western Sydney, Australia. *Ecohydrology & Hydrobiology*, *18*(4), 412–419. https://doi.org/10.1016/j.ecohyd.2018.11.003
72. Pedersen, E., Weisner, S. E. B., & Johansson, M. (2019). Wetland areas' direct contributions to residents' well-being entitle them to high cultural ecosystem values. *The Science of the Total Environment*, *646*, 1315–1326. https://doi.org/10.1016/j.scitotenv.2018.07.236
73. Hewes, W. (2008). Creating Jobs and Stimulating the Economy through Investment in Green Stormwater Infrastructure. Retrieved July 29, 2019, from http://www.allianceforwaterefficiency.org/uploadedFiles/News/NewsArticles/NewsArticleResources/American_Rivers_and_AWE-Green_Infrastructure_Stimulus_White_Paper_Final_2008.pdf
74. Jobs for the Future. 2017. Exploring the Green Infrastructure Workforce. Boston, MA: Author.
75. Green Infrastructure Projects Create Jobs | CLF. (2014, March 13). Retrieved July 25, 2019, from Conservation Law Foundation website: https://www.clf.org/blog/green-infrastructure-projects/
76. Hawkins & Prickett (2014)
77. Jobs for the future (2017)
78. Cicea, C. & Pirlogea, C. (2011). Green spaces and public health in urban areas. *Theoretical and Empirical Researches in Urban Management, 6.1*, 83-92. https://econpapers.repec.org/article/romterumm/v_3a6_3ay_3a2011_3ai_3a1_3ap_3a83-92.htm
79. Ichihara, K., & Cohen, J. P. (2011). New York City property values: what is the impact of green roofs on rental pricing?. *Letters in spatial and resource sciences*, *4*(1), 21-30. https://doi.org/10.1007/s12076-010-0046-4
80. Cicea & Pirlogea (2011)
81. Wolf, K. L. (2007). City trees and property values. *Arborist News*, *16*(4), 34-36.
82. Wolf, K. L. (2004). Nature in the retail environment: Comparing consumer and business response to urban forest conditions. *Landscape Journal*, *23*(1), 40-51. https://doi.org/10.3368/lj.23.1.40
83. Morsy Mohamed M., Goodall Jonathan L., Shatnawi Fadi M., & Meadows Michael E. (2016). Distributed Stormwater Controls for Flood Mitigation within Urbanized Watersheds: Case Study of Rocky Branch Watershed in Columbia, South Carolina. *Journal of Hydrologic Engineering*, *21*(11), 05016025. https://doi.org/10.1061/(ASCE)HE.1943-5584.0001430
84. Coleman, S., Hurley, S., Rizzo., D. Koliba, C., & Zia, A. (2018). From the household to the watershed: A cross-scale analysis of residential intention to adopt green stormwater infrastructure. *Landscape and Urban Planning*, Vol. 180, 195-206.
85. Denchak, M. (2019, April 10). Flooding and Climate Change: Everything You Need to Know. Retrieved July 29, 2019, from https://www.nrdc.org/stories/flooding-and-climate-change-everything-you-need-know
86. Denchak, M. (2019)
87. Scharenbroch, B. C., Morgenroth, J., & Maule, B. (2016). Tree Species Suitability to Bioswales and Impact on the Urban Water Budget. *Journal of Environmental Quality*, *45*(1), 199–206. https://doi.org/10.2134/jeq2015.01.0060
88. Chesapeake Bay Foundation (2014). The economic benefits of implementing the blueprint in Delaware. Accessed June 14, 2019. Retrieved from https://www.cbf.org/document-library/cbf-reports/0929-Final-DE-fact-sheet9b9e.pdf
89. Hawkins, N. C., & Prickett, G. (2014). The case for green infrastructure. In R. Kupers (Ed.), *Turbulence* (pp. 87–100). Retrieved from http://www.jstor.org/stable/j.ctt128781v.11
90. Hawkins & Prickett (2014
91. US EPA, O. (2014, June 17). Using Green Roofs to Reduce Heat Islands [Overviews and Factsheets]. Retrieved July 24, 2019, from US EPA website: https://www.epa.gov/heat-islands/using-green-roofs-reduce-heat-islands
92. Frequently Asked Questions (FAQs) about Green Roof Consulting/Design. (n.d.). Retrieved July 24, 2019, from http://www.greenrooftechnology.com/green-roofs-explained#roof-last-green-roof
93. Terhell, S.-L., Cai, K., Chiu, D., & Murphy, J. (n.d.). *Cost and Benefit Analysis of Permeable Pavements in Water Sustainability*. 8.
94. Chuang, Y. C., Chuang, K. Y., & Yang, T. H. (2013). Social cohesion matters in health. International journal for equity in health, 12(1), 87. https://doi.org/10.1186/1475-9276-12-87

95. Chuang et al (2013)
96. Stanley, D. (2003). What Do We Know about Social Cohesion: The Research Perspective of the Federal Government's Social Cohesion Research Network. *The Canadian Journal of Sociology / Cahiers Canadiens De Sociologie, 28*(1), 5-17. doi:10.2307/3341872
97. Forrest, R., & Kearns, A. (2001). Social cohesion, social capital and the neighbourhood. *Urban studies*, *38*(12), 2125-2143. https://doi.org/10.1080/00420980120087081
98. Hartig T, Mitchell R, de Vries S, Frumkin H: Nature and health. Ann Rev Public Health. 2014, 35: 207-228.
99. Green, O. O., Shuster, W. D., Rhea, L. K., Garmestani, A. S., & Thurston, H. W. (2012). Identification and Induction of Human, Social, and Cultural Capitals through an Experimental Approach to Stormwater Management. *Sustainability*, *4*(8), 1669–1682. https://doi.org/10.3390/su4081669
100. McCormack, G. R., Rock, M., Toohey, A. M., & Hignell, D. (2010). Characteristics of urban parks associated with park use and physical activity: A review of qualitative research. *Health & place*, *16*(4), 712-726. https://doi.org/10.1016/j.healthplace.2010.03.003
101. Ulmer et al (2016
102. Guéguen & Stephan (2016)
103. Stoltz, J., & Schaffer, C. (2018). Salutogenic Affordances and Sustainability: Multiple Benefits With Edible Forest Gardens in Urban Green Spaces. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.02344
104. Center for Active Design. (2018). The Assembly Civic Engagement Survey. Retrieved July 29, 2019, from https://centerforactivedesign.org/assembly-civic-engagement-survey
105. Escobedo, F. J., & Nowak, D. J. (2009). Spatial heterogeneity and air pollution removal by an urban forest. *Landscape and urban planning*, *90*(3-4), 102-110. https://doi.org/10.1016/j.landurbplan.2008.10.021
106. Kuo, F. E., & Sullivan, W. C. (2001). Environment and Crime in the Inner City: Does Vegetation Reduce Crime? *Environment and Behavior*, *33*(3), 343–367. https://doi.org/10.1177/0013916501333002
107. Burley, B. A. (2018). Green infrastructure and violence: Do new street trees mitigate violent crime? *Health & Place*, *54*, 43–49. https://doi.org/10.1016/j.healthplace.2018.08.015
108. Kondo, M. C., Low, S. C., Henning, J., & Branas, C. C. (2015). The Impact of Green Stormwater Infrastructure Installation on Surrounding Health and Safety. *American Journal of Public Health; Washington*, *105*(3), E114–E121.
109. Schusler, T., Weiss, L., Treering, D., & Balderama, E. (2018). Research note: Examining the association between tree canopy, parks and crime in Chicago. *Landscape and Urban Planning*, *170*, 309–313. https://doi.org/10.1016/j.landurbplan.2017.07.012
110. Garvin, E. C., Cannuscio, C. C., & Branas, C. C. (2013). Greening vacant lots to reduce violent crime: a randomised controlled trial. *Injury Prevention: Journal of the International Society for Child and Adolescent Injury Prevention*, *19*(3), 198–203. https://doi.org/10.1136/injuryprev-2012-040439
111. South EC, Hohl BC, Kondo MC, MacDonald JM, Branas CC. Effect of Greening Vacant Land on Mental Health of Community-Dwelling Adults: A Cluster Randomized Trial. *JAMA Netw Open.* Published online July 20, 2018 1(3):e180298. doi:10.1001/jamanetworkopen.2018.0298
112. Eriksson, M. (2011). Social capital and health—implications for health promotion. *Global Health Action, 4.* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3036711/
113. Green et al (2012)
114. Sullivan, W. C., Kuo, F. E., & Depooter, S. F. (2004). The Fruit of Urban Nature: Vital Neighborhood Spaces. *Environment and Behavior*, *36*(5), 678–700. https://doi.org/10.1177/0193841X04264945
115. Cochran et al (2018)
116. Curtis, M. Community Rain Gardens are a Great Environmental Outreach Tool. Retrieved July 29, 2019, from https://coast.noaa.gov/digitalcoast/training/american-samoa.html
117. Scharenbroch et al (2016)
118. Morsy et al (2016)
119. Pappalardo, V., La Rosa, D., Campisano, A., & La Greca, P. (2017). The potential of green infrastructure application in urban runoff control for land use planning: A preliminary evaluation from a southern Italy case study. *Ecosystem Services*, *26*, 345–354. https://doi.org/10.1016/j.ecoser.2017.04.015

120. Al-Ameri, M., Hatt, B., Le Coustumer, S., Fletcher, T., Payne, E., & Deletic, A. (2018). Accumulation of heavy metals in stormwater bioretention media: A field study of temporal and spatial variation. *Journal of Hydrology*, *567*, 721–731. https://doi.org/10.1016/j.jhydrol.2018.03.027
121. LeFevre Gregory H., Paus Kim H., Natarajan Poornima, Gulliver John S., Novak Paige J., & Hozalski Raymond M. (2015). Review of Dissolved Pollutants in Urban Storm Water and Their Removal and Fate in Bioretention Cells. *Journal of Environmental Engineering*, *141*(1), 04014050. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000876
122. Valencia, A., Kilner, J., Chang, N.-B., & Wanielista, M. P. (2019). Chemophysical Evaluation of Green Sorption Media for Copper Removal in Stormwater Runoff for Improving Ecosystem and Human Health. *Water Air and Soil Pollution*, *230*(1), 2. https://doi.org/10.1007/s11270-018-4047-z
123. Scharenbroch et al (2016)
124. Stagge, J. H., & Davis, A. P. (2006). Water Quality Benefits of Grass Swales in Managing Highway Runoff. *Proceedings of the Water Environment Federation*, *2006*(6), 5518–5527. https://doi.org/10.2175/193864706783775702
125. Kondo, M., Han, S., Donovan, G., & M. MacDonald, J. (2016). The Association Between Urban Trees on Crime: Evidence from the Spread of the Emerald Ash Borer in Cincinnati. *Landscape and Urban Planning*, *157*, 193–199. https://doi.org/10.1016/j.landurbplan.2016.07.003
126. Denman, E. C., May, P. B., & Moore, G. M. (2016). The Potential Role of Urban Forests in Removing Nutrients from Stormwater. *Journal of Environmental Quality*, *45*(1), 207–214. https://doi.org/10.2134/jeq2015.01.0047
127. Pennino, M. J., McDonald, R. I., & Jaffe, P. R. (2016). Watershed-scale impacts of stormwater green infrastructure on hydrology, nutrient fluxes, and combined sewer overflows in the mid-Atlantic region. *Science of The Total Environment*, *565*, 1044–1053. https://doi.org/10.1016/j.scitotenv.2016.05.101
128. Liu, C.-M., Chen, J.-W., Tsai, J.-H., Lin, W.-S., Yen, M.-T., & Chen, T.-H. (2012). Experimental studies of the dilution of vehicle exhaust pollutants by environment-protecting pervious pavement. *Journal of the Air & Waste Management Association (1995)*, *62*(1), 92–102. https://doi.org/10.1080/10473289.2011.630628
129. Jaber F. H. (n.d.). Bioretention and Permeable Pavement Performance in Clay Soil. *International Low Impact Development Conference 2015*, 151–160. https://doi.org/10.1061/9780784479025.015
130. Xiao, Q., & McPherson, E. G. (2016). Surface Water Storage Capacity of Twenty Tree Species in Davis, California. *Journal of Environment Quality*, *45*(1), 188. https://doi.org/10.2134/jeq2015.02.0092
131. Semeraro, T., Aretano, R., & Pomes, A. (2017). Green Infrastructure to Improve Ecosystem Services in the Landscape Urban Regeneration. *IOP Conference Series: Materials Science and Engineering*, *245*, 082044. https://doi.org/10.1088/1757-899X/245/8/082044
132. Young-Jae et al (2018)
133. National Recreation & Parks Association (2019). Green Infrastructure in Parks: Resource Guide for Planning, Designing and Implementing. https://www.nrpa.org/contentassets/0e196db99af544bbba4f63f480c1316b/gupc-resource-guide.pdf
134. Clark, C., Adriaens, P., & Talbot, F. B. (2008). Green roof valuation: a probabilistic economic analysis of environmental benefits. Environmental science & technology, 42(6), 2155-2161. https://doi.org/10.1021/es0706652
135. Baraldi, R., Neri, L., Costa, F., Facini, O., Rapparini, F., & Carriero, G. (2019). Ecophysiological and micromorphological characterization of green roof vegetation for urban mitigation. *Urban Forestry & Urban Greening*, *37*, 24–32. https://doi.org/10.1016/j.ufug.2018.03.002
136. Yang, J., Yu, Q., & Gong, P. (2008). Quantifying air pollution removal by green roofs in Chicago. *Atmospheric Environment*, *42*(31), 7266–7273. https://doi.org/10.1016/j.atmosenv.2008.07.003
137. Tong, Z., Baldauf, R. W., Isakov, V., Deshmukh, P., & Max Zhang, K. (2016). Roadside vegetation barrier designs to mitigate near-road air pollution impacts. *The Science of the Total Environment*, *541*, 920–927. https://doi.org/10.1016/j.scitotenv.2015.09.067

138. Sicard, P., Agathokleous, E., Araminiene, V., Carrari, E., Hoshika, Y., De Marco, A., & Paoletti, E. (2018). Should we see urban trees as effective solutions to reduce increasing ozone levels in cities? *Environmental Pollution (Barking, Essex: 1987)*, *243*(Pt A), 163–176. https://doi.org/10.1016/j.envpol.2018.08.049
139. Livesley, S. J., Ossola, A., Threlfall, C. G., Hahs, A. K., & Williams, N. S. G. (2016). Soil Carbon and Carbon/Nitrogen Ratio Change under Tree Canopy, Tall Grass, and Turf Grass Areas of Urban Green Space. *Journal of Environmental Quality*, *45*(1), 215–223. https://doi.org/10.2134/jeq2015.03.0121
140. Ulmer et al (2016)
141. Lovasi, G. S., O'Neil-Dunne, J. P. M., Lu, J. W. T., Sheehan, D., Perzanowski, M. S., Macfaden, S. W., … Rundle, A. (2013). Urban tree canopy and asthma, wheeze, rhinitis, and allergic sensitization to tree pollen in a New York City birth cohort. *Environmental Health Perspectives*, *121*(4), 494–500. https://doi.org/10.1289/ehp.1205513
142. Garvin et al (2013)
143. South EC, Hohl BC, Kondo MC, MacDonald JM, Branas CC. Effect of Greening Vacant Land on Mental Health of Community-Dwelling Adults: A Cluster Randomized Trial. *JAMA Netw Open.* Published online July 20, 2018 1(3):e180298. doi:10.1001/jamanetworkopen.2018.0298
144. Cronin-de-Chavez, A., Islam, S., & McEachan, R. R. C. (2019). Not a level playing field: A qualitative study exploring structural, community and individual determinants of greenspace use amongst low-income multi-ethnic families. *Health & Place*, *56*, 118–126. https://doi.org/10.1016/j.healthplace.2019.01.018
145. Jennings, V., Floyd, M. F., Shanahan, D., Coutts, C., & Sinykin, A. (2017). Emerging issues in urban ecology: implications for research, social justice, human health, and well-being. *Population and Environment*, *39*(1), 69–86. https://doi.org/10.1007/s11111-017-0276-0

Additional Resources:

Beckett, K. P., Freer-Smith, P. H., & Taylor, G. (1998). Urban woodlands: their role in reducing the effects of particulate pollution. Environmental pollution, 99(3), 347-360. https://doi.org/10.1016/S0269-7491(98)00016-5

Branas, C. C., Cheney, R. A., MacDonald, J. M., Tam, V. W., Jackson, T. D., & Ten Have, T. R. (2011). A Difference-in-Differences Analysis of Health, Safety, and Greening Vacant Urban Space. *American Journal of Epidemiology*, *174*(11), 1296–1306. https://doi.org/10.1093/aje/kwr273

Buijs, A. E., Mattijssen, T. J. M., Van der Jagt, A. P. N., Ambrose-Oji, B., Andersson, E., Elands, B. H. M., & Moller, M. S. (2016). Active citizenship for urban green infrastructure: fostering the diversity and dynamics of citizen contributions through mosaic governance. *Current Opinion in Environmental Sustainability*, *22*, 1–6. https://doi.org/10.1016/j.cosust.2017.01.002

Center for Neighborhood Technology. (2011). The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits.

Coutts, C., & Hahn, M. (2015). Green Infrastructure, Ecosystem Services, and Human Health. *International Journal of Environmental Research and Public Health*, *12*(8), 9768–9798. https://doi.org/10.3390/ijerph120809768

Donovan, G., & Prestemon, J. (2012). The Effect of Trees on Crime in Portland, Oregon. *Environment and Behavior - ENVIRON BEHAV*, *44*, 3–30. https://doi.org/10.1177/0013916510383238

Donovan, G. H., Michael, Y. L., Butry, D. T., Sullivan, A. D., & Chase, J. M. (2011). Urban trees and the risk of poor birth outcomes. *Health & Place*, *17*(1), 390–393. https://doi.org/10.1016/j.healthplace.2010.11.004

Du, Y., & Law, J. (2016). How Do Vegetation Density and Transportation Network Density Affect Crime across an Urban Central-Peripheral Gradient? A Case Study in Kitchener—Waterloo, Ontario. *ISPRS International Journal of Geo-Information*, *5*, 118. https://doi.org/10.3390/ijgi5070118

Escobedo, F. J., Clerici, N., Staudhammer, C. L., Feged-Rivadeneira, A., Bohorquez, J. C., & Tovar, G. (2018). Trees and Crime in Bogota, Colombia: Is the link an ecosystem disservice or service? *Land Use Policy*, *78*, 583–592. https://doi.org/10.1016/j.landusepol.2018.07.029

Flores, A., Pickett, S. T., Zipperer, W. C., Pouyat, R. V., & Pirani, R. (1998). Adopting a modern ecological view of the metropolitan landscape: the case of a greenspace system for the New York City region. *Landscape and urban planning*, *39*(4), 295-308. https://doi.org/10.1016/S0169-2046(97)00084-4

Fuertes, E., Markevych, I., von Berg, A., Bauer, C.-P., Berdel, D., Koletzko, S., … Heinrich, J. (2014). Greenness and allergies: evidence of differential associations in two areas in Germany. *Journal of Epidemiology and Community Health*, *68*(8), 787–790. https://doi.org/10.1136/jech-2014-203903

Hall, D. M., Camilo, G. R., Tonietto, R. K., Ollerton, J., Ahrné, K., Arduser, M., ... & Goulson, D. (2017). The city as a refuge for insect pollinators. *Conservation Biology*, *31*(1), 24-29. https://doi.org/10.1111/cobi.12840

Jennings, V., Baptiste, A. K., Osborne Jelks, N., & Skeete, R. (2017). Urban Green Space and the Pursuit of Health Equity in Parts of the United States. *International Journal of Environmental Research and Public Health*, *14*(11). https://doi.org/10.3390/ijerph14111432

Jennings, V., Floyd, M. F., Shanahan, D., Coutts, C., & Sinykin, A. (2017). Emerging issues in urban ecology: implications for research, social justice, human health, and well-being. *Population and Environment*, *39*(1), 69–86. https://doi.org/10.1007/s11111-017-0276-0

Kondo, M., Hohl, B., Han, S., & Branas, C. (2016). Effects of greening and community reuse of vacant lots on crime. *Urban Studies (Edinburgh, Scotland)*, *53*(15), 3279–3295. https://doi.org/10.1177/0042098015608058

Kondo, M. C., Sharma, R., Plante, A. F., Yang, Y., & Burstyn, I. (2016). Elemental Concentrations in Urban Green Stormwater Infrastructure Soils. *Journal of Environmental Quality*, *45*(1), 107–118. https://doi.org/10.2134/jeq2014.10.0421

Loreau, M., Naeem, S., & Inchausti, P. (Eds.). (2002). *Biodiversity and ecosystem functioning: synthesis and perspectives*. Oxford University Press on Demand.

Ma, Y., Gong, M., Zhao, H., & Li, X. (2018). Influence of low impact development construction on pollutant process of road-deposited sediments and associated heavy metals. *Science of the Total Environment*, *613*, 1130-1139. https://doi.org/10.1016/j.scitotenv.2017.09.174

Macdonald, E., Harper, A., Williams, J., & Hayter, J. A. (n.d.). *Street Trees and Intersection Safety*. 105.

McPherson, E. G. (1994). Cooling urban heat islands with sustainable landscapes. *In: Platt, Rutherford H.; Rowntree, Rowan A.; Muick, Pamela C.; eds. The ecological city: preserving and restoring urban biodiversity. Amherst, MA: University of Massachusetts Press: 151-171*, 151-171.

Rigolon, A., Browning, M., & Jennings, V. (2018). Inequities in the quality of urban park systems: An environmental justice investigation of cities in the United States. *Landscape and Urban Planning*, *178*, 156–169. https://doi.org/10.1016/j.landurbplan.2018.05.026

S. Taylor, M., Wheeler, B., P. White, M., Economou, T., & Osborne, N. (2015). Research note: Urban street tree density and antidepressant prescription rates—A cross-sectional study in London, UK. *Landscape and Urban Planning*, *136*. https://doi.org/10.1016/j.landurbplan.2014.12.005

Salmond, J. A., Tadaki, M., Vardoulakis, S., Arbuthnott, K., Coutts, A., Demuzere, M., … Wheeler, B. W. (2016). Health and climate related ecosystem services provided by street trees in the urban environment. *Environmental Health: A Global Access Science Source*, *15 Suppl 1*, 36. https://doi.org/10.1186/s12940-016-0103-6

Shin, W., Seob Shin, C., Sik Yeoun, P., & Joon Kim, J. (2011). The influence of interaction with forest on cognitive function. *Scandinavian Journal of Forest Research*, *26*, 595–598. https://doi.org/10.1080/02827581.2011.585996

Suppakittpaisarn, P., Jiang, X., & Sullivan, W. (2017). Green Infrastructure, Green Stormwater Infrastructure, and Human Health: A Review. *Current Landscape Ecology Reports*. https://doi.org/10.1007/s40823-017-0028-y

Terhell, S.-L., Cai, K., Chiu, D., & Murphy, J. (2015). *Cost and Benefit Analysis of Permeable Pavements in Water Sustainability*. 8.

Troy, A., Morgan Grove, J., & O'Neil-Dunne, J. (2012). The relationship between tree canopy and crime rates across an urban–rural gradient in the greater Baltimore region. *Landscape and Urban Planning*, *106*(3), 262–270. https://doi.org/10.1016/j.landurbplan.2012.03.010

Troy, A., Nunery, A., & Grove, M. (2016). The relationship between residential yard management and neighborhood crime: An analysis from Baltimore City and County. *Landscape and Urban Planning. 147: 78-87.*, *147*, 78–87. https://doi.org/10.1016/j.landurbplan.2015.11.004

Ward Thompson, C., Roe, J., Aspinall, P., Mitchell, R., Clow, A., & Miller, D. (2012). More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landscape and Urban Planning*, *105*(3), 221–229. https://doi.org/10.1016/j.landurbplan.2011.12.015

Wolfe, M. K., & Mennis, J. (2012). Does vegetation encourage or suppress urban crime? Evidence from Philadelphia, PA. *Landscape and Urban Planning*, *108*(2), 112–122. https://doi.org/10.1016/j.landurbplan.2012.08.006