The Value of Planting Trees in the Urban Setting

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Contents

Introduction

There is currently a rapid rate of urbanization taking place across the world. It is estimated that by the year 2050, 34 percent of the world's population will be living in rural environments and 66 percent will be living in urban environments (UN 2014).

With urbanization comes an increase of industry, burning of fossil fuels, manmade infrastructure, and human-generated waste. These activities as well as other environmental changes that come with urbanization create a unique living space that can often be detrimental to human health (Bolund et al. 1999). For example, due to the increase of industry and automobile use, urban air carries more particulate pollution than rural air. The concentrated presence of particulate air pollution has been linked to respiratory problems (Gomez-Baggethun and Barton 2013).

With the increasing rate of urbanization the ecosystem services provided by nature are needed more than ever. Ecosystem services provided by urban trees, such as mitigating air pollution, moderating urban microclimates, combating global warming, and improving urban hydrology are important in mitigating the environmental effects of urbanization (Armson et al. 2013, Beckett et al 1998, Bolund and Hunhammar 1999, Dwyer et al. 1991, Georgi et al. 2006, Gomez-Baggethun and Barton 2013).

This paper aims to explore the benefits of ecosystem services provided by trees in the urban environment, including street trees, parks, lawn trees in residential areas, as well as urban forests and woodlands. The cultural benefits of urban trees will also be described.

Mitigating Air Pollution

In comparison to rural air, the quality of urban air is diminished by pollutants in the atmosphere (Gomez-Baggethun and Barton 2013). The pollutants result from human processes that become concentrated and exacerbated as an effect of urbanization, primarily transportation, industry, domestic heating, and waste incineration (Gomez-Baggethun and Barton 2013). Urban air pollutants include ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter (Nowak et al. 2006).

In recent years, concerns about particulate air pollution have grown due to the negative effects they have on human health. Particulate matter has been shown to exacerbate illnesses affecting the cardiovascular and respiratory systems (Beckett et al. 1999). The majority of particulate matter found in the atmosphere has an aerodynamic diameter of less than 10 µm and is referred to as PM_{10} (Beckett et al. 1998). The classification of PM_{10} can be further broken down into two fractions, the coarse fraction and the fine fraction. The coarse fraction is any suspended particle with a diameter between 10 µm and 2.5 µm, the fine fraction is any suspended particle with a diameter less than 2.5 µm. Particles of the fine fraction are often referred to as $PM_{2.5}$ (Beckett et al. 2000). Both the coarse and fine fraction of PM_{10} have been linked to negative health effects but it is the fine fraction that seems to have greater effects on human health. The smaller size of these particles allows them to migrate deeper into the lungs (Beckett et al. 2000). The concentrated presence of PM_{10} has been linked to increasing asthma morbidity and mortality (Beckett et al. 1998).

Many studies have found that urban trees play a significant role in removing harmful air pollutants from the atmosphere (Beckett et al. 2000, Gomez-Baggethun and Barton 2013, McPherson 1992, and Nowak 2006). Trees remove pollutants through dry deposition, which occurs when particles or gasses land on a surface (Beckett et al. 1998). When gaseous pollutants land on the surfaces of trees as well as other vegetation, they can be absorbed into plant tissues through the stomata and assimilated into the inner leaf cells (Jim and Chen 2008). If there is a high concentration of pollutants this assimilation can sometimes damage the tree. These negative impacts are variable among species (Jim and Chen 2008). PM_{10} is removed from the atmosphere when particles land on and adhere to tree surfaces.

The ability of trees to absorb these particles varies across species due to roughness of leaf surface, amount of leaf area, and the growing angles of leaves. A study of five tree species found that coniferous species capture more particles than broad leaf species. Coniferous species are additionally more productive in this sense because they retain their leaves in the winter, when particulate concentration is reportedly highest. In broad-leaf species, species with rough, hairy leaves are better able to remove particulate particles than those without (Beckett et al. 2000). Not only is species consideration important, but where urban trees are planted affects their productivity in cleaning the air. Trees planted close to streets are able to better intercept particulate generated by car exhaust. However, if the tree canopy is too dense at the street level pollutants can be trapped at a level that increases exposure to humans (Morani et al. 2011).

The ability of trees to remove air pollutants is an important and valuable ecosystem service. A study of the coterminous United States estimated that urban trees remove a total of 711,000 metric tons of air pollution annually, with an estimated value of $3.8 billion (Nowak et al. 2006). The effectiveness of urban trees in mitigating air pollution has been recognized in countless cities across the globe. Cities in China especially, where air pollution is an epidemic, have turned to large-scale tree plantings as a way to combat air pollution (Jim and Chen 2008).

Moderating Urban Microclimate

An important urbanization phenomenon observed in cities due is the urban heat island (UHI) effect: air temperature in cities is higher than in surrounding rural areas. There are many causes of UHI including absorption of radiation by low albedo (solar reflectance) building materials, heat produced by cars and industry, and tall buildings reducing the escape of heat at night (Kleerekoper et al. 2012). Increased urban air temperature can produce uncomfortable living environments. Excessive heat can also pose as a serious health threat to residents. Healthy adults are able to efficiently deal with high levels of heat but young children and older seniors are more susceptible to heat stroke and heat exhaustion (Kovats and Hajat 2007).

The presence of vegetation, particularly in parks and urban woodlands, helps cool cities and improve resident comfort. Trees are able to directly cool their surrounding environments in two ways: the first occurs when tree canopies intercept light radiation and leaves either absorb or reflect that energy, thus shading the area below the canopy. The second cooling mode occurs via evapotranspiration, a combined process of evaporation and transpiration. Evaporation is the loss of water from surfaces on the Earth to the air and transpiration is the loss of water vapor from inside plants through the stomata. Heat from the air evaporates water in these processes, cooling the surrounding environments (Georgi and Dimitrou 2006). There have been many studies of the cooling effects of urban parks and green spaces on microclimate (the climate of a small area that differs form the surrounding areas). Within one city there may be several microclimates, which has been illustrated by the park cooling island (PCI) phenomenon. The PCI is similar to UHI and is a phenomenon in which areas around vegetated urban parks are reportedly cooler than those without vegetation. In a study in Lisbon, Portugal, air temperature in the park studied was reported to be 6.9° C cooler than surrounding areas during the summer months (Oliveria et al. 2011). This study was done on a relatively small urban park (95 x 61 m), supporting the notion that even small vegetated areas in urban areas are better than nothing. In another study of a larger park (~500 ha) in Mexico City, PCI was reported to be 2–3°C cooler. These effects reached beyond the park's boundaries by about 2 km (Jauregui 1990).

Not only do the cooling effects of trees benefit human health and comfort but they can also help decrease in the consumption of energy for air conditioning. Trees can cool buildings in the summer by direct and indirect means. Direct effects are due to the shading of buildings from solar radiation. Indirect effects come from evapotranspiration cooling air temperatures and by decreasing the entrance of outside air to the inside by reducing wind speeds (Akbari 2002).

Global Climate Change

Global climate change is one of the greatest environmental concerns facing our planet. The presence of greenhouse gasses—carbon dioxide, methane, nitrous oxide, chlorofluorocarbons and tropospheric ozone—in the atmosphere are believed to contribute to the rise in atmospheric temperatures by trapping certain wavelengths of radiation in the atmosphere instead of allowing them to be reflected back into space (Nowak and Crane 2002). The concentration of these gasses has increased with the rise of industrialization and urbanization (Jo 2002). Carbon dioxide is one of the most abundant greenhouse gasses. The majority of carbon dioxide in the atmosphere comes from the combustion of fossil fuels and deforestation.

Trees play an important role in reducing the amount of carbon dioxide released into the atmosphere, an especially important role in urban settings where a highly concentrated level of fossil fuels are burnt (Nowak and Crane 2002). Trees reduce the amount of carbon dioxide in the atmosphere in two ways. The first is a direct effect of photosynthesis as trees (and all plants) take up carbon dioxide from the atmosphere to carry out photosynthesis. This carbon is either used for metabolic processes such as the Calvin cycle or stored as biomass allowing the plant to grow. In a study of carbon sequestration by urban trees in the coterminous United States it was reported that urban trees store an estimated 700 billion kilograms of carbon. This storage was valued at about $14,300 million (Nowak and Crane 2002). The same study estimated that urban trees sequester about 22.8 million tC (tons of carbon) per year. This service has an estimated value of about $460 million per year (Nowak and Crane 2002).

Trees also indirectly reduce the amount of carbon dioxide in the atmosphere by cooling buildings, and decreasing the amount of energy needed to cool buildings, thus reducing the amount of carbon dioxide produced by burning fossil fuels in energy plants (Akbari 2002).

Improving Urban Hydrology

The cycling of water in urban environments is vastly different than in undeveloped areas mainly due to the replacement of vegetated ground cover with impermeable surfaces and the vast pipe systems of urbanized areas. Underground pipe systems redirect large volumes of wastewater and stormwater away from infrastructure (Welty 2009). The combination of impermeable surfaces and underground pipe systems increases the volume and speed of stormwater runoff, the water from rain events that flows over the Earth's surface rather than infiltrating into the soil. An increase in the runoff's volume and speed can increase flooding, which can be both dangerous and costly for homeowners (Welty 2009).

Urban trees improve the hydrology of cities by decreasing the rate of runoff. The presence of trees increases both the rate and volume of stormwater infiltration (Armson et al. 2013). Trees create channels in the soil by their root growth (Armson et al. 2013) and tree canopies intercept rain water, preventing it from reaching the ground. Instead of this water adding to the runoff volume, it is held on leaf surfaces to be evaporated back into the atmosphere (Armson et al. 2013).

A study in Dayton, Ohio fond that the existing tree canopy decreased potential runoff volume by seven percent. This study accounted for trees across the city including residential areas, office and commercial areas, as well as urban forests, parks, and open spaces (Sanders 1986). Street trees have been found to reduce runoff as well. They are important contributors to natural stormwater management because they are located in urban areas with the most impermeable surfaces; generally, street trees are completely surrounded by sidewalks and roads. A

Manchester, UK study of street trees reported that street trees can reduce runoff from asphalt by as much as 62 percent (Armson 2013).

Cultural Benefits of Urban Woodlands

In addition to the ecological benefits of trees, urban woodlands and public green spaces have a wide range of social benefits that impact a city's quality of life and cultural environment. One of the most obvious benefits of urban woodlands and parks is recreation. Park access is important for urban quality of life. They are appealing places for urban dwellers to spend leisure time and escape the stresses of urban living (Ulrich et al. 1991, Dwyer et al. 1991). Park trees and vegetation also attract wildlife such as birds and butterflies that may also make parks more appealing and pleasing to visitors. Parks enhance the quality of urban life by promoting exercise providing bike trails, walking paths, and sports fields (Bolund and Hunhammar 1999).

The psychological implications of green spaces are also important. The high concentration of people living in the city can create a stressful living environment. A study by Ulrich et al. (1991) found that people in a state of high stress, their stress levels were maintained when exposed to the urban environment but in natural environments there was a rapid decrease in stress level. A study aimed at the sociological benefits of trees found that Chicago area residents highly value access to urban trees for several different reasons including religious reasons and calming effects (Dwyer et al. 1991). The paper concluded that access to "every day nature" within city limits is crucial to the emotional well-being of urban residents (Dwyer.al 1991). These studies imply that the non-ecological services provided by urban woodland are essential to comfortable living in an urban setting.

Conclusions

Urban trees offer ecological, economic, and social benefits that improve urban living. The improvements to the quality of life that trees bring to urban living are countless and invaluable to the future development of sustainable cities.

Although this paper divided these benefits into separate topics, everything in nature is connected. "When one tugs at a single thing in nature, he finds it attached to the rest of the world," (John

Muir). In the case of urban woodlands, the benefits described above intermingle and magnify each other. For example, the cooling effects of trees reduce the consumption of fossil fuels, thus further reducing air pollution. Also, hydrology benefits means less soil is carried away by runoff and thus the visual appeal of recreational parks is maintained for visitors.

In Columbia, the interconnected benefits of trees can be used to promote tree planting. These benefits only further increase the value and importance of planting, properly managing, and caring for urban trees.

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Gomez-Baggethun, Erik and David N. Barton. “Classifying and Valuing Ecosystem Services for Urban Planning.” Ecological Economics 86(2013): 235-245.

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Annotated Resource List

1. Akbari H. "Shade Trees Reduce Building Energy Use and CO2 Emissions From Power Plants" Environmental Pollution. 116 (2002): S119-S126.

   This study looks at the effects that a large-scale urban tree planting program can have, specifically shading benefits that include reduced heating and cooling costs as well as reduced CO_2 emissions from power plants. It found that trees can reduce air-conditioning demand as well as improve air quality, with savings reported to be as high as $200 per tree. The study also looks at the cost of maintaining shade trees and whether the benefits outweigh the costs.

2. Armson, D., P. Stringer and A.R. Ennos. "The Effect of Street Trees and Amenity Grass on Urban Surface Water Runoff in Manchester, UK." Urban Forestry & Urban Greening 12(2013): 282-286.

   This study assesses the effects street trees and grass on the volume of stormwater runoff. Trees reduce runoff by intercepting rainfall in the canopy and increasing infiltration rates. The authors examined three treatments in 9 m^2 plots, which were covered with asphalt alone, asphalt with a tree planted in the center, or just grass. The study reported that grass almost completely eliminated surface runoff. The asphalt with a tree planted in the center also reduced surface runoff by as much as 62 percent.

3. Beckett, K. Paul, Peter Freer-Smith and Gail Taylor. "Effective Tree Species For Local Air-Quality Management." Journal of Aboriculture 26(2000): 12-19.

   This UK study looked at five different tree species and their effect on local air quality. The tree species examined were *Sorbus aria, Acer campestre, Populus deltoids, Pinus nigra*, and *Cupressocyparis leylandii*. Two sites were used to compare a relatively clean background site and one that was heavily polluted. It was found that all the studied trees captured large quantities of PM_{10}. In comparison with broad-leaved species, coniferous species captured more particulate matter due to an increase in leaf surface area. It was also observed that the trees in the heavily polluted site captured significantly more material than those in the relatively clean background site.

4. Beckett, K. Paul, Peter Freer- Smith and Gail Taylor. " Urban Woodlands: Their Role In Reducing the Effects of Particulate Pollution." Environmental Pollution 99(1998): 347-360.

This paper provides an extensive review of literature regarding particulate air pollution and the role urban woodlands play in mitigating the effects of this pollution. Particulate air pollution is an important area of research due to the negative health effects that have been linked to PM_{10}, that is, those particles found in the atmosphere with an aerodynamic diameter of less than 10 µm. Negative health effects include increased asthma morbidity and mortality as well as alveolar inflammation. Urban trees play a significant role in reducing the amount of particulate matter in the air by removing these particles from the air when particles stick to the vegetation surface.

5. Bolund, Per, and Sven Hunhammar. " Ecosystem Services in Urban Areas." Ecological Economics 29 (1999): 293-301.

This study analyzes the ecosystem services of seven different urban ecosystems including street trees and urban forests, particularly at study sites in Stockholm. It reports benefits from urban trees that include air filtration, micro-climate regulation, noise reduction, rainwater drainage, and recreation and cultural values.

6. Dwyer, John F., Herbert W. Schroeder, and Paul H. Gobster. "The Significance of Urban Trees and Forests: Toward a Deeper Understanding of Values." Journal of Aboriculture 17 (1991): 276-284.

This study takes a different approach to the value of urban trees than the other sources. It looks at the value of trees from a sociological standpoint rather than ecological one. The authors find that many urban dwellers have strong ties to urban forests and trees and list the many psychological, social and cultural needs that urban trees fulfill. The study comes out of the USDA Forest Service.

7. Georgi, Julia N. and Dimos Dimitrou. " The Contribution of Urban Green Spaces to the Improvement of Environment in Cities: Case Study of Chania, Greece." Building and Environment 45(2006): 1401-1414.

This paper examines the effects of vegetation on microclimates in Chania, Greece, mainly looking at cooling effects due to evapotranspiration. Evapotranspiration cools the air by using energy to evaporate water so this energy is no longer available to heat the surrounding area. From the study's results it was clear that evapotranspiration effects the microclimate by increasing humidity in dry summer atmospheric conditions, creating a more pleasant thermal environment. It was found that Ficus species had the highest amount of evapotranspiration followed by fig, pine, palm, bitter orange, and olive trees.

8. Gomez-Baggethun, Erik and David N. Barton. "Classifying and Valuing Ecosystem Services for Urban Planning." Ecological Economics 86(2013): 235-245.
   This is a review paper looking at the many ecosystem services of the natural environment within urban settings. The paper first identifies and groups ecosystem services and disservices. Ecosystem services recognized included recreation, moderation of environmental extremes, climate regulation, air purification, and waste treatment. The paper also examined the economic valuation of these services and their social and cultural value.

9. Jauregui E. "Influence of a Large Urban Park on Temperature and Convective Precipitation in a Tropical City." Energy and Buildings 15(1990): 457-463.

   This study is examined the cooling effects of large green spaces have in a tropical climate.

10. Jim, C.Y. and Wendy Y. Chen. "Assessing the Ecosystem Service of Air Pollutant Removal By Urban Trees in Guangzhou (China)." Journal of Environmental Management 88 (2008): 665-676.

    This study analyzed ecosystem services provided by trees in Guangzhou, China, a city, like most urban areas in China, plagued by air pollution. However, this particular area is considered to be the 'greenest city' in China due to its high percentage of tree cover. The authors analyzed the role of trees in removing air pollutants as well as valuing this service. With the data collected they also make suggestions for planning future urban green spaces. This study was sponsored by the University of Hong Kong.

11. Jo, Hyun-Kil. “Impacts of Urban Greenspace on Offsetting Carbon Emissions for Middle Korea” Journal of Environmental Management 64(2002): 115-116.
Carbon dioxide is an important greenhouse gas and agent of climate change. This study investigated the relationship between urban green space and carbon emissions in three central Korean cities. The study estimated carbon emissions using carbon emission coefficients for the fossil fuels consumed. Carbon storage in woody plants was then calculated using biomass equations and radial growth rates. Carbon storage in soils was directly determined using core samples. The study’s observations supported the hypothesis that urban green space has a significant effect on offsetting carbon emissions in the urban setting. This effect was more pronounced in some cities, which leads to implications for further management techniques. Some study recommendations include increasing planting area by moving parking structures and power lines underground, and multilayered planting schemes in urban areas where herbs, shrubs, and trees overlap.

12. Kleerekoper, Laura, Marjolein van Esch, and Tadeo Baldiri Salcedo. “How to Make a City Climate-Proof, Addressing the Urban Heat Island Effect.” Resources, Conservation and Recycling. 64(2012): 30-38.
This paper examined both the effects of the urban heat island as well as urban planning approaches that can help reduce some harmful effects of UHI. UHI not only creates physical discomfort but can also be a serious health issue for urban dwellers. Some approaches include increasing vegetation, implementing water bodies, and using permeable materials in new buildings and development. The paper concluded with a case study of an area in the Netherlands where several of these suggestions could be implemented. The case study includes design plans as well as policy approaches to actually implement the designs.

13. Kovats, R. Sariand Shakoor Hajat. “Heat Stress and Public Health: A Critical Review.” Annual Review of Public Health 29(2007): 41-55.
This paper is a review of heat stress and public health from the Public and Environmental Health Research Unit of the London School of Hygiene and Tropical Medicine. The review examined heat as a public health issue. Humans naturally have some tolerance for temperature fluctuations. However, there is a limit the human body can handle. A main point

of this review is that populations vary in their tolerance based on climate, culture, infrastructure, and age. The review specifically looked at UHI effect and states that mortality is more sensitive to heat in urban areas in comparison with rural and suburban areas, a difference that varies based on region.

14. McPherson, Gregory E. "Accounting for Benefits and Costs of Urban Greenspace." Landscape and Urban Planning 22(1992): 41-51.
    This paper described a benefits-cost analysis for a proposed tree-planting initiative in Tucson, Arizona. This analysis is useful to policy-makers and planners because it applies specific costs and benefits of tree planting. The combined analysis of these dollar amounts allows for the examination of the net economic benefits of investments in urban forests. Cost prices included maintenance, planting, pruning, removal, and irrigation. A dollar amount was also estimated for benefits that come along with planting such as cooling energy savings, interception of particulates, and stormwater runoff reduction.

15. Morani, Arianna, David J. Nowak, Satoshi Hirabayashi and Carlo Calfapietra. "How to Select the Best Tree Planting Locations to Enhance Air Pollution Removal in the MillionTreesNYC Initiative."

    The main goal of this study was to select high priority zones for the planting of trees in the MillionTreesNYC initiative. These high priority zones were determined using three main factors. These factors were pollution concentration, population density and low canopy cover. The study also estimates the annual and cumulative amount of carbon storage and air pollution removed by the one million trees in a 100 year period. The paper also discusses potential limitations in using urban trees to improve air quality and store carbon.

16. Nowak, David J., Daniel E. Crane, Jack C. Stevens. "Air Pollution Removal By Urban Trees and Shrubs in the United States." Urban Forestry and Urban Greening 4(2006): 115-123.

    Using modeling, meteorological data, pollution concentration, and urban tree cover data this study finds that urban trees in the coterminous United States can reduce air pollution and improve air quality in urban areas. The study estimated that approximately 711,000 metric

tons of air pollution is removed annually by urban trees across the country. Factors found to influence the removal value for pollutants include amount of tree cover, pollution concentration, length of in-leaf season, and precipitation. This paper's data may be underestimates because they do not account for the removal of pollutants from the ground and only account for a one-year period.

17. Nowak, David J., and Daniel E. Crane. "Carbon Storage and Sequestration by Urban Trees in the USA." Environmental Pollution 116(2002): 381-389.

    This study looked at the role of urban forests in reducing carbon dioxide levels. Through photosynthesis, trees naturally act as a carbon sink and thus help lower carbon dioxide levels in the atmosphere. This study analyzed urban tree cover data in 10 major U.S. cities and found that urban trees in the coterminous U.S. store about 700 million tons of carbon, valued to be worth $14,300 million. The study also found that urban forests probably have a greater impact based on area of tree canopy cover than rural forests due to growth rates. This study was sponsored by the USDA Forest Service and SUNY-ESF.

18. Oliveira, Sandra, Henrique Andrade and Teresa Vaz. " The Cooling Effect of Green Spaces as a Contribution to the Mitigation of Urban Heat: A Case Study in Lisbon." Building and Environment 46(2011): 2186-2194.

    This study examined the cooling effects of green spaces in urban areas and how successful they are in mitigating Urban Heat Island. The study specifically looks at the thermal performance of a small green space in Lisbon, Portugal. Measurements were made along a transect, starting from inside the park and ending nearly 570m away in the surrounding areas. The study found that areas inside the garden were cooler than surrounding areas, when comparing both sunny and shaded areas. The largest temperature difference observed was that the air temperature of the park was 6.9° C cooler than surrounding areas during the summer months.

19. Sanders, Ralph A. "Urban Vegetation Impacts on the Hydrology of Dayton, Ohio." Urban Ecology 9(1986): 361-376.

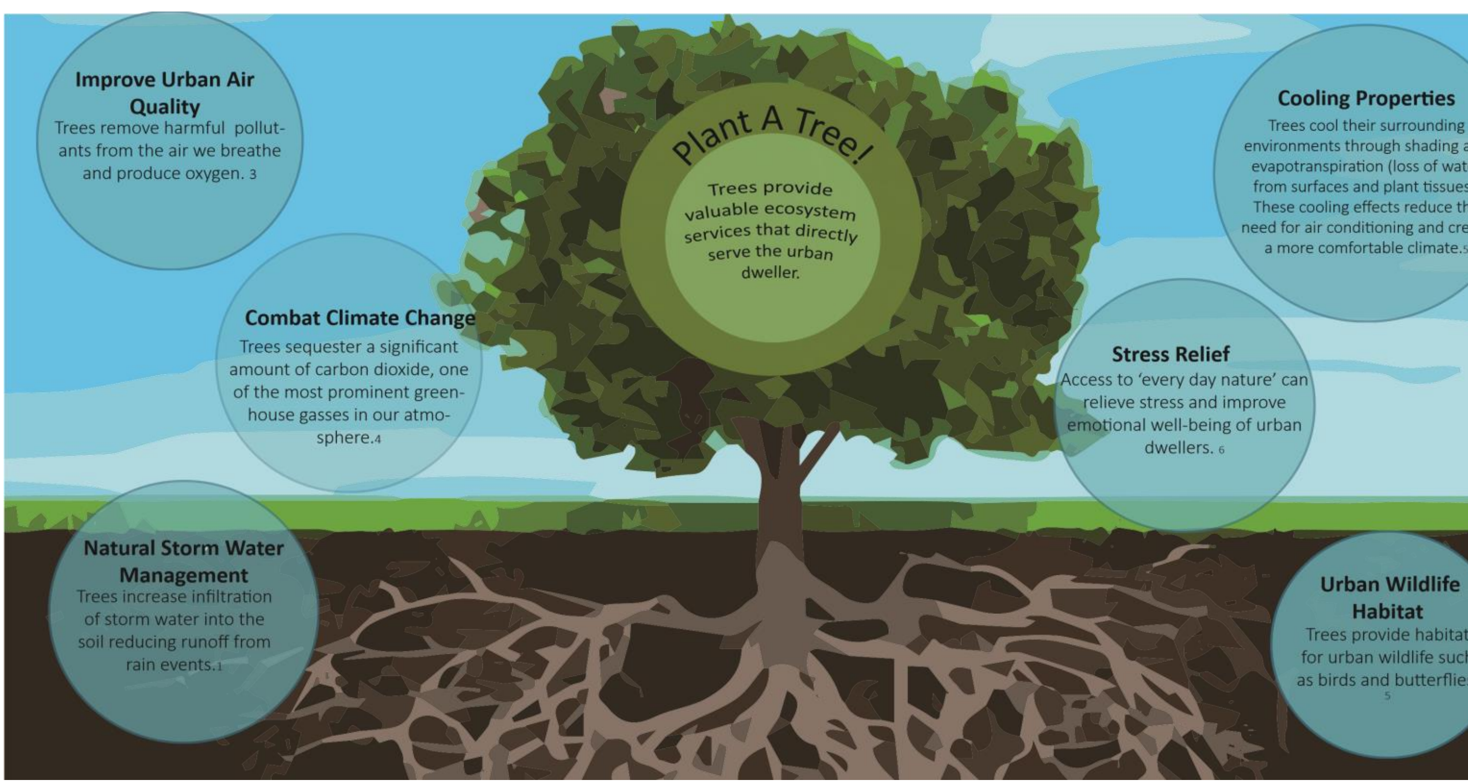
This study quantified the specific effects of vegetation in lessening runoff in the urban setting, specifically in Dayton, Ohio. The study recorded the abundance of four different types of land cover in 79 Dayton neighborhoods—artificial surfaces, exposed soil, herbaceous cover, and tree crown coverage. Using a modeling approach, runoff volumes were estimated in a one-year, six-hectare storm. The study compared Dayton's hydrologic pattern as affected by current land cover, its hydrologic pattern if all tree canopy were removed, and the hydrologic pattern if all exposed soil was replaced with tree coverage. A major finding was that the existing tree canopy of Daytona reduces runoff by seven percent and that by modestly increasing this tree canopy this runoff reduction benefit could be increased by nearly 12 percent.

20. Ulrich, R.S., R.F. Simons, B.D. Losito, E. Fiorito, M.A. Miles and M. Zelson. "Stress Recovery During Exposure to Natural and Urban Environments." Journal of Environmental Psychology 11(1991): 201-203.
This study hypothesized that exposure to an unthreatening natural environment can have calming effects on a stressed individual. To test this hypothesis, the author subjected 120 individuals to a stressful movie. Subjects were then exposed to videos of one of six different natural and urban settings. Physiological measures of stress were taken such as heart rate, muscle tension and skin conductance. There was physiological evidence that exposure to natural environments had a calming effect; such evidence was not present for the urban environment.

21. United Nations. "World Urbanization Prospects The 2014 Revision: Highlights." United Nations (2014)
This U.N. report highlighted important growth patterns of the urban environment. The amount of people living in urban environments has been rapidly growing since 1950. The rate of urbanization is only expected to increase in the coming years. In 2014, when the report was published, it was estimated that about 54 percent of the world's population lived in an urban environment. According to U.N. estimates, by the year 2050 about 2.5 billion people will be added to the world's urban population, resulting in about 66 percent of the world's population living in an urban environment.

22. Welty, Claire. “The Urban Water Budget” in *The Water Environment* (New York: Springer Science and Business Media, LLC 2009)

This paper described water flow in the urban environment with concentration on runoff. Water flow in the urban environment is totally different than the ‘natural’ water flow in surrounding rural environments. Impermeable surfaces such as asphalt roads and concrete sidewalks prevent the infiltration of rainwater into the soil and increase both the volume and velocity of storm water runoff. To redirect runoff from heavily populated areas, pipes are installed in urban areas. Pipes are also used to redirect sewage water, which can be problematic if there are any cracks in the pipes.



To create the figure above, an image was sourced from www.123rf.com and altered in Adobe Illustrator.

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Trees Reduce Building Energy Use and CO2 Emissions From Power Plants” Environmental Pollution. 116 (2002): S119-S126. 3. Nowak, David J., Daniel E. Crane, Jack C. Stevens. “Air Pollution Removal By Urban Trees and
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