



The Scientific Benefit of Trees: A literature review

Jessica Turner-Skoff, PhD

Water

Interception of stormwater

Planting trees can reduce stormwater in urban environments. The permeability of vegetated areas, including urban forested areas, allows more water to be intercepted, especially compared to concrete. (Bolund and Hunhammer 1999)

Interception of stormwater

Large trees are valuable to prevent runoff and to clean water, since they intercept and slow precipitation. The urban forest of Canberra, Australia, including both street trees and trees in parks, contributes to this ecosystem service of amelioration of water runoff, which is valued at \$1,330,000 (\$US) a year. (Brack 2002)

Phytoremediation

Trees can be useful in phytoremediation because they can take up pollutants into their woody tissues. They may be useful in controlling heavy metals and other contaminants from sewage sludge. (French et al. 2006)

Interception of stormwater

A review of 14 studies across five continents showed that landscapes with trees are able to reduce rainwater runoff, improve the quality of the runoff water, and increase cooling by evapotranspiration from their leaves. (Livesley et al. 2016)

Interception of stormwater

When planted in bioswales, large trees with high stomatal conductance, allowing ample CO₂ and water vapor in and out of leaves, are valuable to reduce runoff and discharge of stormwater. Trees are an important component of green infrastructure design. (Scharenbroch et al. 2016)

Social/Cultural

Urban residents value trees

Urban residents valued trees because they provide shade, make people feel calmer, and reduce smog and dust. Any potential problems associated with trees, such as blocking

storefronts or causing allergies, were not considered sufficient reasons to avoid planting trees in cities. (Lohr et al. 2004)

Trees and well-maintained landscaping make people feel safer

In Chicago, an increased density of trees and maintained grass in a neighborhood made residents feel safer. If the outside shared areas were well-maintained, it encouraged social ties within the community. (Kuo et al. 1998)

More trees means more social capital

An increase in tree canopy cover in a neighborhood has been documented to increase social capital for individuals and encourage neighborhood connections. (Holtan et al. 2014)

Trees are associated with increased social ecology

A review paper suggests that green areas, defined as those with well-maintained trees and grass, are linked to increased social ecology of an area. Greenness is associated with lower crime rates, more play activity with children, and a greater sense of safety as compared to barren areas. (Kuo 2003)

Trees are associated with increased social capital

In an observational study, trees encouraged residents in a public housing development in Chicago to use the common outdoor space, thus increasing social capital. Areas that had trees, as compared to areas devoid of trees, encouraged larger gatherings of people of a variety of ages. (Coley et al. 1997)

Trees often evoke strong positive emotions and are anthropomorphized

While the intensity and the emotions vary among individuals, people often have a strong connection for trees. Trees are often anthropomorphized, and they are used as religious symbols. (Dwyer et al. 1991)

Humans evolved from nature and have an innate need to be around nature

Our love of nature is inherent (biologically based), part of our evolutionary history, part of our “fitness” and our evolutionary advantage. It helps us achieve personal meaning and demonstrates that there is self-interest in conservation. (Kellert and Wilson 1995)

Humans are drawn to living things and processes

Humans evolved from nature, and so there is an innate need for humans to be around nature. (Wilson 1984)

Trees can be vital tools to increase community development and social ties

Involving the community in tree planting can be a great way to develop community capacity. Urban foresters and arborists are valuable to the health and happiness of a community. (Elmendorf 2008)

Photos of natural environments were preferred to photos of urban environments
Undergraduate females preferred looking at pictures from an arboretum, as compared to more urban scenes. They were also more likely to label the natural scenes as less complex. (Kaplan et al. 1972)

Physical Health

Hospital patients heal faster and better

Patients in hospital rooms that overlooked trees, as compared to a wall, had shorter stays and marginally reduced complications, needed fewer intense painkillers, and had fewer negative comments from hospital staff. (Ulrich 1984)

Trees affect asthma rates **see notes**

Increased density of street trees in an urban area has been associated with a lower prevalence of asthma among children, regardless of sociodemographic and other variables. (Lovasi et al. 2008) However, in a later study, Lovasi et al. (2013) incorporated all trees in an urban area, not just street trees, and found that Dominican or African American children who had higher levels of tree canopy cover at their prenatal address had greater sensitivity to tree pollen when they were older.

Decline in diastolic blood pressure

Study participants who sat in a room after completing a drive or a task and were able to look out over trees had a greater decline in diastolic blood pressure than participants who looked out on a view without trees. (Hartig et al. 2003)

Trees make people feel younger and healthier

In a study that controlled for a variety of demographic factors, scientists found that participants who lived on a block with 10 or more street trees felt, on average, as healthy as someone seven years younger or \$10,000 a year richer and living in a wealthier neighborhood. Participants in areas with more trees also had reduced cardio-metabolic conditions. (Kardan et al. 2015)

Increase in physically activity, less likely to be overweight

Individuals who live in areas that are greener are much more likely to be physically active and 40 percent less likely to be overweight. (Ellaway et al. 2005) While this is not directly about trees, trees are often a large component of green space.

Children are less likely to be overweight

A study that controlled for a variety of demographic and socio-demographic variables found that children growing up in neighborhoods that are greener were less likely to increase their body mass index over two years, as compared to children who live in areas

that are not as green. (Bell et al. 2008) Greenness was determined through satellite images and the Normalized Difference Vegetation Index (NDVI).

Alzheimer patients are less violent and have fewer falls
Care centers for Alzheimer's patients that had garden environments with trees had lower violence and fewer falls among their residents, as compared to care centers without gardens. (Mooney and Nicell 1992)

Mortality

Living near green spaces associated with reduced mortality

A long-term cohort study that adjusted for a variety of social and environmental factors, though not all confounding variables, found that living near green spaces was associated with reduced mortality, especially from respiratory disease. (Villeneuve et al. 2012)
Greenness was determined through satellite images and the Normalized Difference Vegetation Index (NDVI).

Living near green spaces results in lower mortality in women

A cohort study that adjusted for factors including age, smoking, and socioeconomic status found that for women, living in areas with the densest vegetation, or "greenness," was associated with a lower rate of non-accident related mortality, such as lower rates of deaths related to respiratory disease, kidney disease, and cancer. (James et al. 2016)
Greenness was determined through satellite images and the Normalized Difference Vegetation Index (NDVI).

Reduction in tree cover results in increased mortality

An observational study reported that counties with widespread ash tree dieback due to emerald ash borer infestation had an increase in deaths related to cardiovascular issues or respiratory illness. The authors included covariates in the model. The impact was greatest in wealthier counties, likely because these counties had more ash trees, that died from the infestation. (Donovan et al. 2013)

Mental Health

Reduction in negative thoughts and activities in the brain associated with mental illness

After participants walked through a green space that had scattered native shrubs and oaks, they had less perseveration, or tendency to dwell, on negative thoughts of self, and less activity in a part of the brain associated with mental illness. (Bratman et al. 2015)

Increase in attention, positive emotions, and reflection

Taking a walk in an arboretum, as compared to a setting in a downtown city environment with fewer trees, has been documented to increase the attention capacity, positive emotions, and capability for reflection in students. (Mayer et al. 2009)

Increased memory in depressed people

Walking in an arboretum, as compared to a downtown city environment, has been shown to increase the memory span and mood of individuals diagnosed with major depressive disorder. (Berman et al. 2012)

Green spaces reduce stress in participants

Stress was reduced in study participants if they spent more time in urban green spaces, regardless of sex, age, or socio-economic background. (Grahn and Stigsdotter 2003). While this is not directly about trees, trees are often a large component of green space.

Increased memory and attention

After walking in an arboretum or even looking at pictures of nature, study participants had increased memory and greater directed-attention. Being in the arboretum increased the participants' positive mood as compared to a walk in a downtown city environment with fewer trees. (Berman et al. 2008)

Ability to recover from stress more easily

Participants who viewed streets with more trees were able to recover from stress more easily. This study showed a linear positive association for participants regardless of age, baseline stress, or gender. (Jiang et al. 2014)

Increased attention and focus

Trees in an urban environment have been documented to increase an adult's ability to focus and pay attention. (Lin et al. 2014)

Reduced symptoms of ADD/ADHD in children

Children with attention deficits (ADHD or ADD) had increased concentration after walking in a park. A walk in the park had an effect similar to taking attention deficit medication. (Taylor and Kuo 2009)

Reduced symptoms of ADD in children

Greener environments, such grassy areas or open spaces with big trees, have been linked to reduced symptoms of ADD in children. (Taylor et al. 2001)

Better attention and recovery from stress

Students who were able to look out a window onto trees and green spaces had higher attention levels and there was a trend that they were able to recover from stress quicker than students who did not have a view in their classroom. (Li and Sullivan 2016)

Increased discipline in young girls

Seven to 12-year-old inner-city girls who lived in apartments in Chicago that overlooked nature showed increased self-discipline (as measured by an index that combined

concentration, impulse inhibition, and delayed gratification) than girls who lived in apartments that looked over a scene with less greenery. (Taylor et al. 2002)

Increased ability in paying attention

If a student's dormitory window overlooked views of natural settings, including trees and/or a lake, as compared to a more built setting, the student had increased directed attention. (Tennessen and Cimprich 1995)

Increase in street trees results in a reduction in prescribed antidepressants

In one study that attempted to control for confounding variables, residents living on a street with an increased density of trees were prescribed fewer antidepressants than individuals on streets with fewer trees. (Taylor et al. 2015)

Tree images make people happier

Looking at an image of a scene with trees made study participants happier and less angry and sad than looking at the same image with the trees removed. Not only were scenes with trees deemed more attractive, but trees evoked a positive emotional response. (Lohr and Pearson-Mims 2006)

Increased tree diversity, increased reflection

An increasing level of tree and shrub diversity in different urban green spaces was associated with increased psychological benefits of reflection and identity in 312 self-selecting participants. (Fuller et al. 2007)

Increase in life satisfaction, decrease in mental distress

Living near a green space has been documented to increase life satisfaction and decrease mental distress. (White et al. 2013)

Financial

Positive return on investment in tree planting and maintenance

For every dollar invested annually in tree planting and maintenance in five major cities, there was a return of \$1.37 to \$3.09, based on the benefit of trees (i.e. energy savings, atmospheric CO₂ reductions, stormwater runoff reductions, etc.). (McPherson et al. 2005)

Positive rate of return on tree maintenance

In California, street trees provide \$1 billion in services annually, with a return of \$5.82 for each \$1 spent on tree management. (McPherson et al. 2016).

Trees are valuable structural assets

It is estimated that the compensatory value of the urban forest of the continental United States is more than \$2.4 trillion. The estimate is based on the benefits trees provide, such

as energy savings, atmospheric CO₂ reductions, and stormwater runoff reductions. (Nowak et al. 2002)

Trees can save money on road maintenance

The shade of trees can protect roadways, therefore reducing the amount of asphalt sealers needed over a 30-year period and saving money. (McPherson and Muchnick 2005)

Well-maintained trees and landscaping increase office rents

Quality landscaping including trees can increase rental rates for offices, as long as the trees do not block the building from view. (Laverne and Winson-Geideman 2003)

Trees can increase sales in a shopping area

The presence of quality trees encourages shoppers to spend more time at a business district, and they will travel a greater distance to visit that center. Further, shopping areas with trees were more likely to be ranked as being more comfortable and having better upkeep, friendlier staff, and higher quality products. (Wolf 2005)

Trees can increase the sale price of a house

There is an association that homes will have a 3.5 to 4.5 percent greater selling price if there are trees on the property. (Anderson and Cordell 1988)

Street trees can help sell houses

Street trees are beneficial in selling homes. The presence of trees on the street not only increases a home's sales price but reduces its time on the market. (Donovan and Butry 2010)

Trees can increase the sale price of a house

Tree cover increases the sale price of a home. (Sander et al. 2010)

Proximity to a forest can increase the sale price of a house

Living closer to a larger forested area, or having a view onto a forest, increased a home's value in Finland. (Tyrväinen and Miettinen 2000)

Energy Bills

Reduced summer energy use

Houses shaded by trees on the south or west exposure have a reduced summertime energy use of over 5 percent. (Donovan and Butry 2009)

Reduced summer energy use

Dense shade around a home can reduce residential energy usage, depending on the season. (Pandit and Laband 2010)

Reduced energy use

Planting trees in urban areas can reduce energy use associated with heating and cooling. This reduction can be 25 percent in an urban landscape. (Akbari 2002)

Reduced energy use

Trees substantially reduce air conditioning and heating costs of residential and commercial buildings in Sacramento County, Calif. (Simpson 1998)

Reduce urban heat islands

Trees, combined with high-albedo surfaces, can help reduce urban heat islands in major cities. This can reduce electricity needed to cool buildings. (Akbari et al. 2001)

Ecosystem services

Trees clean the air, regulate climate, reduce noise pollution, and add social value. Street trees, parks and lawns, and forested areas are beneficial as they can filter out pollution from the air, provide microclimate regulation, reduce noise pollution, and they provide social value. Parks, lawns, and forested areas can also provide the ecosystem service of rainwater drainage. (Bolund and Hunhammer 1999)

Green spaces increase ecosystem services

A literature review found numerous health benefits are associated with access to green space, due to the ecosystem services these areas provide. (Jenning and Gaither 2015)

Trees remove air pollution, creating huge economic value

Every year in the United States alone, urban trees are responsible for removing 711,000 metric tons of CO, NO₂, O₃, PM₁₀, and SO₂ from the air. This ecosystem service of removing air pollution is valued at over \$3.8 billion. (Nowak et al. 2006)

Carbon storage

Urban forests are beneficial for storing carbon, which has an effect on carbon's contribution to climate change. (Nowak 1993)

Carbon storage

Based on data from 10 urban centers, urban trees annually sequester 22.8 million tons of carbon. The total carbon storage of urban trees in the continental United States is 700 million tons. (Nowak and Crane 2002)

Food security/Non-timber forest products

Urban Forests can help provide additional food security or non-timber forest products to a neighborhood. (McLain et al. 2012)

Food security/Non-timber forest products

Urban Forests can help provide additional food security or non-timber forest products to a neighborhood. (Poe et al. 2013)

Trees remove air pollution, huge economic value

In 2010, urban trees in the continental United States were responsible for removing over 17 million metric tons of air pollution, which had a health benefit valued at almost \$7 billion. (Nowak et al. 2014)

Crime

Reduced crimes in a neighborhood

Controlling for other variables, mature street trees are related to reduced reports of crime in a neighborhood. On the other hand, trees that are smaller and closer to the house are related to increased crime reports. However, the authors caution that another explanation is possible: Neighborhoods with large trees may be more desirable areas where it would be more likely for a criminal to be spotted. (Donovan and Prestemon 2012)

Value of homes near parks relates to the crime rate in the park

Not all green spaces are desirable. In Baltimore, property values of homes close to parks are related to the amount of crime in an area. Higher levels of rape and robbery in a neighborhood reduce the value of a park to the community. (Troy and Grove 2008) This citation is important in relation to the others by Troy.

Well-maintained trees are related to lower crime rates

Controlling for a variety of factors, including income, population density, and type of housing, there is a strong relationship between well-maintained trees and lower crime rates in Baltimore. This could be an example of “cues to care”—the idea that a well-tended landscape communicates it is valued. Visibly maintained areas may have greater social capital. (Troy et al. 2016)

Higher crime areas typically have unmanaged trees *

There is a relationship between tree cover and crime rates in Baltimore, with more trees usually related to a reduced crime rate. In areas where there is a positive relationship between tree cover and crime rates, this is most likely due to those areas being unmanaged. (Troy et al. 2012)

Green view can lower aggression, violence, and mental fatigue

A study showed that women living in Chicago public housing reported less aggression and violence and lower mental fatigue, if their apartment overlooked a yard with grass and trees, as compared to a more barren landscape. (Kuo and Sullivan 2001a)

Vegetation reduces property crimes and violent crimes

Despite the fear that dense vegetation leads to greater crime rates, and controlling for other crime predictors, apartments in inner-city Chicago that had lower levels of

vegetation had higher levels of property crimes and violent crimes. (Kuo and Sullivan 2001b)

Negatives about Trees

Detriments from street trees

Street trees can be considered undesirable due to the potential for damage of municipal property, leaf litter, problems associated with visibility and security. (Lohr et al. 2004)

Fear of concealment

Trees and shrubs can offer places of concealment, which can make college students feel unsafe at night on college campuses. (Nasar & Fisher 1993)

Costs vs. benefits of trees

Communities in Florida were concerned about urban trees due to the potential of hurricane damage from the trees; falling branches and damage to property; the mess trees can create with falling leaves; and pollen and tree sap on cars. Despite this, these same communities favored an increase in urban tree planting, as trees increased shade, character, and the beauty of a community, as well as increasing property values to the area. (Wyman et al. 2012)

Storm damage costs

It can be expensive to clean up after urban trees after a storm. (Staudhammer et al. 2009)

Ecosystem disservices

Urban forests can produce many ecosystem disservices, which can be categorized as financial costs, social nuisances (including vectors for pests or disease), and environmental conditions (such as altered nutrient cycles). (Escobedo et al. 2011)

Disadvantages of trees

Trees can cause ecosystem disservices. Roots can break up concrete. Tree branches increase cover, which may increase crime. Branches can cause unnecessary shading or maintenance issues. Fallen leaves can decrease the ability of vehicles to break at appropriate speeds. (Lyytimäki and Sipilä 2009)

Limitations of these studies

Unequal distribution of trees

Trees are more likely to be found on public rights of ways in wealthy areas than in poorer areas. (Landry and Chakraborty 2009)

Income and tree distribution

While trees and nature clearly are beneficial for humans, there are many variables that could be confounded. For example, in one study that analyzed seven major cities, the authors found a strong relationship between urban tree cover and income: the lower the income, the fewer the trees. (Schwarz et al. 2015)

Tree research correlative

Some studies may not consider important variables in understanding the importance of trees. While there is strong evidence that nature benefits humans, it is important to note that much of the research that has been conducted is correlative. (Keniger et al. 2013)

Citations

- Akbari, H. 2002. Shade trees reduce building energy use and CO₂ emissions from power plants. *Environmental Pollution* 116:119–126.
- Akbari, H., M. Pomerantz, and H. Taha. 2001. Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy* 70:295–310.
- Anderson, L. M., and H. K. Cordell. 1988. Influence of trees on residential property values in Athens, Georgia (U.S.A.): A survey based on actual sales prices. *Landscape and Urban Planning* 15:153–164.
- Bell, J. F., J. S. Wilson, and G. C. Liu. 2008. Neighborhood greenness and 2-year changes in body mass index of children and youth. *American Journal of Preventive Medicine* 35:547–553.
- Berman, M. G., E. Kross, K. M. Krpan, M. K. Askren, A. Burson, P. J. Deldin, S. Kaplan, L. Sherdell, I. H. Gotlib, and J. Jonides. 2012. Interacting with nature improves cognition and affect for individuals with depression. *Journal of Affective Disorders* 140:300–305.
- Berman, M., J. Jonides, and S. Kaplan. 2008. The cognitive benefits of interacting with nature. *Psychological Science* 19:1207–1212.
- Bolund, P., and S. Hunhammer. 1999. Ecosystem services in urban areas. *Ecological Economics* 29:293–301.
- Brack, C. L. 2002. Pollution mitigation and carbon sequestration by an urban forest. *Environment Pollution* 116:195–200.
- Bratman, G. N., J. P. Hamilton, K. S. Hahn, G. C. Daily, and J. J. Gross. 2015. Nature experience reduces rumination and subgenual prefrontal cortex activation. *Proceedings of the National Academy of Sciences of the United States of America* 112:8567–72.

- Coley, R. L., W. C. Sullivan, and F. E. Kuo. 1997. Where does community grow?: The social context created by nature in urban public housing. *Environment and Behavior* 29:468–494.
- Donovan, G. H., and D. T. Butry. 2009. The value of shade: Estimating the effect of urban trees on summertime electricity use. *Energy and Buildings* 41:662–668.
- Donovan, G. H., and D. T. Butry. 2010. Trees in the city: Valuing street trees in Portland, Oregon. *Landscape and Urban Planning* 94:77–83.
- Donovan, G. H., and J. P. Prestemon. 2012. The effect of trees on crime in Portland, Oregon. *Environment and Behavior* 44:3–30.
- Donovan, G. H., D. T. Butry, Y. L. Michael, J. P. Prestemon, A. M. Liebhold, D. Gatzliolis, and M. Y. Mao. 2013. The relationship between trees and human health: Evidence from the spread of the emerald ash borer. *American Journal of Preventive Medicine* 44:139–145.
- Dwyer, J. F., E. G. McPherson, H. W. Schroeder, and R. A. Rowntree. 1992. Assessing the benefits and costs of the urban forest. *Journal of Arboriculture* 18:227–234.
- Ellaway, A., S. Macintyre, and X. Bonnefoy. 2005. Graffiti, greenery, and obesity in adults: secondary analysis of European cross sectional survey. *BMJ (Clinical research ed.)* 331:611–612.
- Elmendorf, W. 2008. The importance of trees and nature in community: A review of the relative literature. *Arboriculture and Urban Forestry* 34:152–156.
- Escobedo, F. J., C. J. Luley, J. Bond, C. Staudhammer, and C. Bartel. 2009. Hurricane debris and damage assessment for Florida urban forests. *Arboriculture and Urban Forestry* 35:100–106.
- Escobedo, F. J., T. Kroeger, and J. E. Wagner. 2011. Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental Pollution* 159:2078–2087.
- French, C. J., N. M. Dickinson, and P. D. Putwain. 2006. Woody biomass phytoremediation of contaminated brownfield land. *Environmental Pollution* 141:387–395.
- Fuller, R. A., K. N. Irvine, P. Devine-wright, P. H. Warren, and K. J. Gaston. 2007. Psychological benefits of greenspace increase with biodiversity:390–394.
- Grahn, P., and U. A. Stigsdotter. 2003. Landscape planning and stress. *Urban Forestry & Urban Greening* 2:1–18.
- Hartig, T., G. W. Evans, L. D. Jamner, D. S. Davis, and T. Gärling. 2003. Tracking restoration

- in natural and urban field settings. *Journal of Environmental Psychology* 23:109–123.
- Holtan, M. T., S. L. Dieterlen, and W. C. Sullivan. 2014. Social life under cover: Tree canopy and social capital in Baltimore, Maryland. *Environment and Behavior*:1–24.
- James, P., J. E. Hart, R. F. Banay, and F. Laden. 2016. Exposure to greenness and mortality in a nationwide prospective cohort study of women. *Environmental Health Perspectives*.
- Jennings, V., and C. J. Gaither. 2015. Approaching environmental health disparities and green spaces: An ecosystem services perspective. *International Journal of Environmental Research and Public Health* 12:1952–1968.
- Jiang, B., D. Li, L. Larsen, and W. C. Sullivan. 2014. A dose-response curve describing the relationship between urban tree cover density and self-reported stress recovery. *Environment and Behavior*:1–23.
- Kaplan, S., R. Kaplan, and J. S. Wendt. 1972. Rated preference and complexity for natural and urban visual material. *Perception & Psychophysics* 12:354–356.
- Kardan, O., P. Gozdyra, B. Misic, F. Moola, L. J. Palmer, T. Paus, and M. G. Berman. 2015. Neighborhood greenspace and health in a large urban center. *Scientific Reports* 5:11610.
- Kellert, S. R., and E. O. Wilson. 1995. *The Biophilia Hypothesis*. A Shearwater Book. Island Press.
- Keniger, L. E., K. J. Gaston, K. N. Irvine, and R. A. Fuller. 2013. What are the benefits of interacting with nature? *International Journal of Environmental Research and Public Health* 10:913–935.
- Kuo, F. E. 2003. The role of arboriculture in a healthy social ecology. *Journal of Arboriculture* 3:148–155.
- Kuo, F. E., and W. C. Sullivan. 2001a. Aggression and violence in the inner city: Effects of environment via mental fatigue. *Environment and Behavior* 33:543–571.
- Kuo, F. E., and W. C. Sullivan. 2001b. Environment and Crime in the Inner City. *Environment and Behavior* 33:343–367.
- Kuo, F. E., M. Bacaicoa, and W. C. Sullivan. 1998. Transforming Inner-City Landscapes: Trees, Sense of Safety, and Preference. *Page Environment and Behavior*.
- Landry, S. M., and J. Chakraborty. 2009. Street trees and equity: Evaluating the spatial distribution of an urban amenity. *Environment and Planning A* 41:2651–2670.

- Laverne, R. J., and K. Winson-Geideman. 2003. The influence of trees and landscaping on rental rates at office buildings. *Journal of Arboriculture* 29:281–290.
- Li, D., and W. C. Sullivan. 2016. Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning* 148:149–158.
- Lin, Y. H., C. C. Tsai, W. C. Sullivan, P. J. Chang, and C. Y. Chang. 2014. Does awareness effect the restorative function and perception of street trees? *Frontiers in Psychology* 5.
- Livesley, S. J., G. M. McPherson, and C. Calfapietra. 2016. The urban forest and ecosystem services: Impacts on urban water, heat, and pollution cycles at the tree, street, and city scale. *Journal of Environment Quality* 45:119–124.
- Lohr, V. I., and C. H. Pearson-Mims. 2006. Responses to scenes with spreading, rounded, and conical tree forms. *Environment and Behavior* 38:667–688.
- Lohr, V. I., C. H. Pearson-Mims, J. Tarnai, and D. A. Dillman. 2004. How urban residents rate and rank the benefits and problems associated with trees in cities. *Journal of Arboriculture* 30:28–35.
- Lovasi, G. S., J. W. Quinn, K. M. Neckerman, M. S. Perzanowski, and A. Rundle. 2008. Children living in areas with more street trees have lower prevalence of asthma. *Journal Epidemiology Community Health* 62:647–649.
- Lyytimäki, J., and M. Sipilä. 2009. Hopping on one leg - The challenge of ecosystem disservices for urban green management. *Urban Forestry and Urban Greening* 8:309–315.
- Mayer, F. S., C. M. Frantz, E. Bruehlman-Senecal, and K. Dolliver. 2009. Why is nature beneficial? The role of connectedness to nature. *Environment and Behavior* 41:607–643.
- McLain, R., M. Poe, P. T. Hurley, J. Lecompte-Mastenbrook, and M. R. Emery. 2012. Producing edible landscapes in Seattle’s urban forest. *Urban Forestry and Urban Greening* 11:187–194.
- McPherson, E. G., and J. Muchnick. 2005. Effect of street tree shade on asphalt concrete pavement performance. *Journal of Arboriculture* 31:303–310.
- McPherson, E. G., N. van Doorn, and J. de Goede. 2016. Structure, function and value of street trees in California, USA. *Urban Forestry & Urban Greening* 17:104–115.
- McPherson, G., J. R. Simpson, P. J. Peper, S. E. Maco, and Q. Xiao. 2005. Municipal forest benefits and costs in five US cities. *Journal of Forestry* 103:411–416.

- Mooney, P., and P. L. Nicell. 1992. The importance of exterior environment for Alzheimer residents: Effective care and risk management. *Gestion des soins de sant * 5:23–29.
- Nasar, J. L., B. Fisher, and M. Grannis. 1993. Proximate physical cues to fear of crime. *Landscape and Urban Planning* 26:161–178.
- Nowak, D. J. 1993. Atmospheric carbon reduction by urban trees. *Journal of Environmental Management* 37:207–217.
- Nowak, D. J., and D. E. Crane. 2002. Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution* 116:381–389.
- Nowak, D. J., D. E. Crane, and J. C. Stevens. 2006. Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry and Urban Greening* 4:115–123.
- Nowak, D. J., D. E. Crane, and J. F. Dwyer. 2002. Compensatory values of urban trees in the United States. *Journal of Arboriculture* 28: 194-199.
- Nowak, D. J., S. Hirabayashi, A. Bodine, and E. Greenfield. 2014. Tree and forest effects on air quality and human health in the United States. *Environmental Pollution* 193:119–129.
- Pandit, R., and D. N. Laband. 2010. Energy savings from tree shade. *Ecological Economics* 69:1324–1329.
- Poe, M. R., R. J. McLain, M. Emery, and P. T. Hurley. 2013. Urban forest justice and the rights to wild foods, medicines, and materials in the city. *Human Ecology* 41:409–422.
- Sander, H., S. Polasky, and R. G. Haight. 2010. The value of urban tree cover: A hedonic property price model in Ramsey and Dakota Counties, Minnesota, USA. *Ecological Economics* 69:1646–1656.
- Scharenbroch, B. C., J. Morgenroth, and B. Maule. 2016. Tree species suitability to bioswales and impact on the urban water budget. *Journal of Environmental Quality* 45:199–206.
- Schwarz, K., M. Fragkias, C. G. Boone, W. Zhou, M. McHale, J. M. Grove, J. O’Neil-Dunne, J. P. McFadden, G. L. Buckley, D. Childers, L. Ogden, S. Pincetl, D. Pataki, A. Whitmer, and M. L. Cadenasso. 2015. Trees grow on money: Urban tree canopy cover and environmental justice. *PLoS ONE* 10:1–17.
- Simpson, J. R. 1998. Urban forest impacts on regional cooling and heating energy use: Sacramento county case study. *Journal of Arboriculture* 24:201–214.
- Staudhammer, C. L., F. Escobedo, C. Luley, and J. Bond. 2009. Patterns of urban forest debris from the 2004 and 2005 Florida hurricane seasons. *Southern Journal of Applied*

Forestry 33:193–196.

- Taylor, A. F., and F. E. Kuo. 2009. Children with attention deficits concentrate better after walk in the park. *Journal of attention disorders* 12:402–409.
- Taylor, A. F., F. E. Kuo, and W. C. Sullivan. 2001. Coping with ADD: The surprising connection to green play settings. *Environment & Behavior* 33:54–77.
- Taylor, A. F., F. E. Kuo, and W. C. Sullivan. 2002. Views of nature and self-discipline: Evidence from inner city children. *Journal of Environmental Psychology* 22:49–63.
- Taylor, M. S., B. W. Wheeler, M. P. White, T. Economou, and N. J. Osborne. 2015. Research note: Urban street tree density and antidepressant prescription rates—A cross-sectional study in London, UK. *Landscape and Urban Planning* 136:174–179.
- Tennessen, C. M., and B. Cimprich. 1995. Views to nature: effects on attention. *Journal of Environmental Psychology* 15:77–85.
- Troy, A., A. Nunery, and J. M. Grove. 2016. The relationship between residential yard management and neighborhood crime: An analysis from Baltimore City and County. *Landscape and Urban Planning* 147:78–87.
- Troy, A., and J. M. Grove. 2008. Property values, parks, and crime: A hedonic analysis in Baltimore, MD. *Landscape and Urban Planning* 87:233–245.
- Troy, A., J. Morgan Grove, and J. O’Neil-Dunne. 2012. The relationship between tree canopy and crime rates across an urban–rural gradient in the greater Baltimore region. *Landscape and Urban Planning* 106:262–270.
- Tyrväinen, L., and A. Miettinen. 2000. Property prices and urban forest amenities. *Journal of Environmental Economics and Management* 39:205–223.
- Ulrich, R. S. 1984. View through a window may influence recovery from surgery. *Science* (New York, N.Y.) 224:420–421.
- Villeneuve, P. J., M. Jerrett, J. G. Su, R. T. Burnett, H. Chen, A. J. Wheeler, and M. S. Goldberg. 2012. A cohort study relating urban green space with mortality in Ontario, Canada. *Environmental Research* 115:51–58.
- White, M. P., I. Alcock, B. W. Wheeler, and M. H. Depledge. 2013. Would you be happier living in a greener urban area? A fixed-effects analysis of panel data. *Psychological science* 24:920–8.
- Wilson, E. O. 1984. *Biophilia*. Harvard University Press.

Wolf, K. L. 2005. Business district streetscapes, trees, and consumer response. *Journal of Forestry* 103:396–400.

Wyman, M., F. Escobedo, T. Stein, M. Orfanedes, and R. Northrop. 2012. Community leader perceptions and attitudes toward coastal urban forests and hurricanes in Florida. *Southern Journal of Applied Forestry* 36:152–158.