Health Benefits of Forests Bibliography October 5, 2019

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October 5, 2019

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Web resources

Healthy Trees, Healthy Lives
Southern Group of State Foresters
https://www.southernforests.org/urban/healthy-trees-healthy-lives

This website provides an infographic to illustrate how urban forests can improve our physical and mental health and promote healing. Users can click on embedded icons to learn how their health can be connected to the trees in their communities. Icons display plain language summaries of research papers with links to pdf files of the reports.

Vibrant Cities Lab
How trees improve human health: https://www.vibrantcitieslab.com/human-health/

Urban forests can affect a variety of health issues, such as respiratory diseases and skin cancer, and promote an active lifestyle, which can reduce obesity. The site presents case studies and links to research papers describing how urban forests improve human health.

Monographs

U.S. Department of Agriculture, Forest Service. 2018.
Urban nature for human health and well-being: a research summary for communicating the health benefits of urban trees and green space. FS-1096. Washington, DC. 24 p.
https://www.fs.fed.us/sites/default/files/fs_media/fs_document/urbannatureforhumanhealthandwellbeing_508_01_30_18.pdf

This monograph is a comprehensive review of research studies that demonstrate the impact of urban forests and green space on human physical and mental health.   It summarizes recent research related to nature and public health to highlight the health benefits of urban nature. The intended audience is urban natural resource professionals, urban planners, architects, educators, health professionals, and community groups. The authors note this overview of the current literature offers a compelling case for maintaining and expanding nature-based outdoor environments in cities.   They describe the limitations

of this research and maintain that there are many opportunities to use this scientific knowledge to help improve individual and community health.

Hanson P, Frank M, Bowyer J, Bratkovich S, Fernholz K, Howe J, Groot H, Pepke. 2016.
The human health and social benefits of urban forests.
Dovetail Partners, Minneapolis MN. 13 p.
http://www.dovetailinc.org/dovetailurbanhealth0916.pdf

This report summarized recent research on the social and human health benefits of urban forests. Research findings are presented to illustrate how urban forests can improve human mental and physical health, increase social cohesion, and contribute to a reduction in crime.   The social benefits of urban forests often are unevenly distributed. They can be related to socioeconomic status and education level, as open space and urban tree cover are frequently less common in lower-income neighborhoods. The authors conclude that urban forests play an important role in maintaining and improving the economic and environmental conditions of cities and also the health of their inhabitants.

Journal articles, by publication date.

Respiratory and cardiovascular effects

Eisenman TS, Jariwala SP, Lovasi GS.
Urban trees and asthma: a call for epidemiological research.
Lancet Respir Med. 2019 Jul;7(7):e19-e20. doi: 10.1016/S2213-2600(19)30193-6.
https://www.thelancet.com/action/showPdf?pii=S2213-2600%2819%2930193-6

In this letter, authors are issuing a call for epidemiological research on urban trees, air quality, and respiratory health to inform landscape and urban planning. This supports similar calls for interdisciplinary research on the human health effects of spending time in or near green spaces, and it also addresses a policy issued by the American Public Health Association entitled, "Improving Health and Wellness through Access to Nature."

Eisenman TS, Churkina G, Jariwala SP, Kumar P, Lovasi GS, Pataki DE, Weinberger KR, WhitlowTH.
Urban trees, air quality, and asthma: An interdisciplinary review
Landscape and Urban Planning. 2019;187:47–59.
https://www.sciencedirect.com/science/article/pii/S0169204618301191

A "call to action" has been issued by scholars in landscape and urban planning, natural science, and public health to conduct interdisciplinary research on the human health effects of spending time in or near green spaces. This report provides an interdisciplinary review of urban trees, air quality, and asthma. The authors assess the scientific literature on the biophysical processes through which urban trees affect air quality, as well as associated models that extend estimates to asthma outcomes. Their review finds no scientific consensus that urban trees reduce asthma by improving air quality and, in some circumstances, can degrade air quality and increase asthma. Because causal pathways between urban trees, air quality, and asthma are very complex, and natural science and epidemiology approach

this issue differently, authors propose future research on this topic should be conducted through interdisciplinary teamwork.

Soyiri IN Alcock I.
Green spaces could reduce asthma admissions.
Lancet Respir Med. 2018; 6: e1
https://www.thelancet.com/action/showPdf?pii=S2213-2600%2817%2930441-1

In this letter, the authors propose that policymakers develop a strategy to promote respiratory health for urban populations by requiring tree planting as part of urban development in highly polluted residential areas.

Donovan GH, Gatziolis D, Longley I, Douwes J.
Vegetation diversity protects against childhood asthma: results from a large New Zealand birth cohort.
Nat Plants. 2018 Jun;4(6):358-364. doi: 10.1038/s41477-018-0151-8. Epub 2018 May 7.
https://www.fs.fed.us/pnw/pubs/journals/pnw_2018_donovan001.pdf

The authors assessed the association between the natural environment and asthma in 49,956 New Zealand children born in 1998 and followed up until 2016 using routinely collected data. Children who lived in greener areas, as measured by the normalized difference vegetation index (NDVI), were less likely to be asthmatic. In essence, an increase in NDVI was associated with a lower risk of asthma. Vegetation diversity was also protective. However, not all land-cover types were protective. An increase in the area covered by gorse (*Ulex europaeus*) or exotic conifers was associated with an increased risk of asthma. The authors conclude that exposure to greenness and vegetation diversity may be protective of asthma.

Alcock I, White M, Cherrie M, Wheeler B, Taylor J, McInnes R, im Kampe EO, Vardoulakis S, Sarran C, Soyiri I, Fleming L.
Land cover and air pollution are associated with asthma hospitalizations: A cross-sectional study.
Environ Int. 2017 Dec;109:29-41. doi: 10.1016/j.envint.2017.08.009. Epub 2017 Sep 27.
https://www.sciencedirect.com/science/article/pii/S0160412017304026?via%3Dihub

The authors assessed the relationships between tree and green space density and asthma-related hospitalizations, and how these varied with exposure to background air pollution concentrations. They used population standardized asthma hospitalization rates (1997-2012) for 26,455 urban residential areas of England and merged these with area-level data on vegetation and background air pollutant concentrations. They found green space/gardens were associated with less asthma when NO2/PM2.5 was lower, and urban trees were associated with less asthma when NO2/PM2.5 was higher. They recommend these findings can provide evidence for urban planning decisions to leverage health co-benefits from environmental improvements.

James P, Hart JE, Banay RF, Laden F.
Exposure to Greenness and Mortality in a Nationwide Prospective Cohort Study of Women.
Environ Health Perspect. 2016 Sep;124(9):1344-52. doi: 10.1289/ehp.1510363. Epub 2016 Apr 14.
https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.1510363

This study examined the prospective association between residential greenness and mortality using data from the U.S.-based Nurses' Health Study prospective cohort for health outcomes and satellite imagery using Normalized Difference Vegetation Index NDVI.   The authors followed 108,630 women and observed 8,604 deaths between 2000 and 2008. Women living in the highest quintile of cumulative average greenness in the 250-m area around their home had a 12% lower rate of all-cause nonaccidental mortality than those in the lowest quintile. These associations were strongest for respiratory disease and cancer mortality. The association between greenness and mortality may be mediated by physical activity, particulate matter < 2.5 µm, social engagement, and depression. The authors concluded higher levels of green vegetation were associated with decreased mortality. They suggest that policies to increase vegetation may provide opportunities for physical activity, reduce harmful exposures, increase social engagement, and improve mental health.

Nowak DJ, Hirabayashi S, Bodine A, Greenfield E.
Tree and forest effects on air quality and human health in the United States.
Environ Pollut. 2014;193:119-129. doi: 10.1016/j.envpol.2014.05.028. Epub 2014 Jul 10.
https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1282&=&context=usdafsfacpub&=&sei-redir=1&referer=https%253A%252F%252Fscholar.google.com%252Fscholar%253Fhl%253Den%2526as_sdt%253D0%25252C11%2526q%253DTree%252Band%252Bforest%252Beffects%252Bon%252Bair%2526Bquality%252Band%252Bhuman%252Bhealth%252Bin%252Bthe%252BUnited%252BStates.%252B%2526btnG%253D#search=%22Tree%20forest%20effects%20air%20quality%20human%20health%20United%20States.%22

The authors present an estimate of the magnitude and value of the effects of trees and forests on air quality and human health across the United States.   They conducted computer simulations with local environmental data that suggest that trees and forests in the conterminous United States removed 17.4 million tons of air pollution in 2010, with avoided human health effects valued at 6.8 billion U.S. dollars. Health impacts included the avoidance of more than 850 incidences of human mortality and 670,000 incidences of acute respiratory symptoms. Authors conclude that trees remove substantial amounts of pollution and can produce substantial health benefits and monetary values across the nation, with most of the health values derived from urban trees.

Rao M George LA Rosenstiel TN Shandas V Dinno A.
Assessing the relationship among urban trees, nitrogen dioxide, and respiratory health.
Environ Pollut. 2014;194:96-104.
http://www.whatsinourair.org/wp-content/uploads/2014/10/mrao-env-pollution-2014.pdf

This study examined the relationship between the presence of urban trees and childhood asthma in Portland, OR. The authors used NO2 measurements from 144 sites in Portland OR, and a land-use regression model to estimate how tree canopy could reduce NO2 levels. They then used BenMAP, a benefits mapping program from EPA, and estimated that the NO2 reduction associated with trees in Portland could result in significantly fewer incidences of respiratory problems, providing a $6.6 million USD benefit annually. They report that because of the city's existing tree canopy:

> children age 4-12 avoided missing 7,380 school days due to asthma attacks;
> people of all ages avoided 54 asthma-related emergency room visits;
> there were 46 fewer hospital stays for people older than 65 because of respiratory illness;
> health benefits equaled $6.6 million in savings.

Authors study concluded that trees are so important when it comes to removing nitrogen dioxide from the air; city planners should find ways to incorporate trees into their designs better.

Donovan GH, Butry DT, Michael YL, Prestemon JP, Liebhold AM, Gatziolis D, Mao MY.
The relationship between trees and human health: evidence from the spread of the emerald ash borer.
Am J Prev Med. 2013 Feb;44(2):139-45. doi: 10.1016/j.amepre.2012.09.066.
https://www.srs.fs.usda.gov/pubs/ja/2013/ja_2013_donovan_001.pdf

This report describes a natural experiment to test whether the loss of 100 million trees to the emerald ash borer has influenced human mortality related to cardiovascular and lower-respiratory diseases. The authors used regression models to estimate the relationship between emerald ash borer presence and county-level mortality from 1990 to 2007 in 15 U.S. states while controlling for a wide range of demographic covariates. They report an increase in mortality related to cardiovascular and lower-respiratory-tract illness in counties infested with the emerald ash borer. This effect was greater as infestation progressed, and in counties with above-average median household income. They estimated for the 15 states in the study area; the borer was associated with an additional 6113 deaths related to illness of the lower respiratory system and 15,080 cardiovascular-related deaths. They concluded that loss of trees to the emerald ash borer increased mortality related to cardiovascular and lower-respiratory-tract illness.

Lovasi GS, O'Neil-Dunne JP, Lu JW, Sheehan D, Perzanowski MS, Macfaden SW, King KL, Matte T, Miller RL, Hoepner LA, Perera FP, Rundle A.
Urban tree canopy and asthma, wheeze, rhinitis, and allergic sensitization to tree pollen in a New York City birth cohort.
Environ Health Perspect. 2013; 121: 494-500
https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.1205513

The authors investigated the association of tree canopy cover with subsequent development of childhood asthma, wheeze, rhinitis, and allergic sensitization. They used birth cohort study data linked to detailed geographic information systems data characterizing 2001 tree canopy coverage based on LiDAR (light detection and ranging) and multispectral imagery within 0.25 km of the prenatal address. A

total of 549 Dominican or African-American children born in 1998-2006 had outcome data assessed by validated questionnaire or based on IgE antibody response to specific allergens, including a tree pollen mix. Tree canopy coverage did not predict outcomes at five years of age but was positively associated with asthma and allergic sensitization at seven years. The authors concluded that tree canopy cover near the prenatal address was associated with a higher prevalence of allergic sensitization to tree pollen.

Nowak DJ Hirabayashi S Bodine A Hoehn R.
Modeled PM2.5 removal by trees in ten US cities and associated health effects.
Environ Pollut. 2013; 178: 395-402
https://www.fs.fed.us/nrs/pubs/jrnl/2013/nrs_2013_nowak_002.pdf

In this report, the authors present modeled estimates of tree effects on PM2.5 concentrations and human health for 10 U.S. cities. Estimated PM2.5 reductions varied from 4.7 tons in Syracuse NY to 64.5 tons for Atlanta, GA. The annual value of the reductions varied from $1.1 million in Syracuse to $60.1 in New York City, with most valuation from the effects of reducing human mortality. Authors note this report provides the first broad-scale estimates of city-wide tree impacts on PM2.5 and human health.

Lovasi S, Quinn JW, Neckerman KM, Perzanowski MS, and Rundle A.
Children living in areas with more street trees have a lower prevalence of asthma.
J Epidemiol Community Health. 2008 Jul; 62(7): 647–649. Published online 2008 May 1. doi: 10.1136/jech.2007.071894
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3415223/pdf/nihms394846.pdf

This report examines the prevalence of asthma among children aged 4–5 years and hospitalizations for asthma among children less than 15 years old in 42 health service catchment areas within New York City. Health outcome data were linked to data on the density of street trees, proximity to pollution sources, sociodemographic characteristics, and population density. Authors found an increase in tree density was associated with a lower prevalence of asthma but not with hospitalizations for asthma. They note that the PlaNYC sustainability initiative, which includes a commitment to plant one million trees by the year 2017, offers an opportunity for a large prospective evaluation.

Well-being and mental health effects

Song C, Ikei H, Park BJ, Lee J, Kagawa T, Miyazaki Y.
Psychological Benefits of Walking through Forest Areas.
Int J Environ Res Public Health. 2018 Dec 10;15(12). pii: E2804. doi: 10.3390/ijerph15122804.
https://www.mdpi.com/1660-4601/15/12/2804

The authors assessed the psychological benefits of brief walks through forest areas in a study of 585 adult participants who were asked to walk predetermined courses through forest (test) and city (control) areas for 15 min. Participants' psychological responses and trait anxiety levels were assessed using the Profile of Mood State (POMS) questionnaire and State-Trait Anxiety Inventory. Authors report that walking through forest areas decreased the negative moods of "depression-dejection," "tension-anxiety," "anger-hostility," "fatigue," and "confusion" and improved the participants' positive mood of "vigor" compared with walking through city areas. Authors conclude there are positive psychological benefits of walking through forest areas.

Oh B, Lee KJ, Zaslawski C, Yeung A, Rosenthal D, Larkey L, Back M.
Health and well-being benefits of spending time in forests: systematic review.
Environ Health Prev Med. 2017 Oct 18;22(1):71. doi: 10.1186/s12199-017-0677-9.
https://environhealthprevmed.biomedcentral.com/track/pdf/10.1186/s12199-017-0677-9

In this review, the authors evaluated literature on the physical and psychological benefits of a specific type of exposure to nature, forest therapy (also called Shinrin-Yoku or forest bathing). They identified and evaluated six reports of randomized clinical trials. Trial participants' ages ranged from 20 to 79 years. The sample size ranged from 18 to 99. Populations studied varied from young, healthy university students to elderly people with chronic disease. Studies reported the positive impact of forest therapy on hypertension, cardiac and pulmonary function, immune function, inflammation, oxidative stress, stress, stress hormone, anxiety, depression, and emotional response.   Authors conclude forest therapy may play an important role in health promotion and disease prevention

Reid CE, Clougherty JE, Shmool JLC, Kubzansky LD.
Is All Urban Green Space the Same? A Comparison of the Health Benefits of Trees and Grass in New York City.
Int J Environ Res Public Health. 2017 Nov 18;14(11). pii: E1411. doi: 10.3390/ijerph14111411.
https://www.mdpi.com/1660-4601/14/11/1411

Authors offer the hypothesis that the two key components of urban vegetation, trees, and grass, may differentially affect health. They estimated the association between near-residence trees, grass, and total vegetation (from the 2010 High-Resolution Land Cover dataset for New York City (NYC)) with self-reported health from a survey of 1281 NYC adults. They found higher reporting of "very good" or "excellent" health for respondents with the highest, compared to the lowest, quartiles of tree but not grass density within 1000 m buffers. Significant positive associations between trees and self-reported health remained after adjustment for grass; associations with grass remained non-significant. Adjustment for air pollutants increased beneficial associations between trees and self-reported health; adjustment for parks only partially attenuated these effects. Authors conclude that higher exposure to vegetation, particularly trees outside of parks, may be associated with better health. They suggest that urban street tree planting may improve population health.

Ulmer JM, Wolf KL, Backman DR, Tretheway RL, Blain CJ, O'Neil-Dunne JP, Frank LD.
Multiple health benefits of urban tree canopy: The mounting evidence for a green prescription.
Health Place. 2016 Nov;42:54-62. doi: 10.1016/j.healthplace.2016.08.011. Epub 2016 Sep 14.
https://www.fs.fed.us/pnw/pubs/journals/pnw_2016_ulmer001.pdf

The authors' purpose in this study was to enhance the understanding of the health-promoting potential of trees in an urbanized region of the United States. They used high-resolution LiDAR and imagery data to quantify tree cover within 250m of the residence of 7910 adult participants in the California Health Interview Survey, and then assessed associations between tree cover and multiple health measures. Authors report that more neighborhood tree cover, independent from green space access, was related to better overall health, primarily mediated by lower overweight/obesity and better social cohesion, and to a lesser extent by less type 2 diabetes, high blood pressure, and asthma. They conclude these findings suggest an important role for trees and nature in improving holistic population health in urban areas.

Wolf KL, Robbins AS.
Metro nature, environmental health, and economic value.
Environ Health Perspect. 2015;123(5):390–398. doi:10.1289/ehp.1408216
https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.1408216

The authors reviewed the literature on urban nature-based health and well-being benefits. They provide a classification schematic and propose potential economic values associated with metro nature services. Urban trees, parks, gardens, open spaces, and other nearby nature elements—collectively termed metro nature—have been largely overlooked in urban economics and policy. Authors present a range of health benefits, including benefit context and beneficiaries.   The authors conclude that metro nature provides diverse and substantial benefits to human populations in cities. They address the need for the development of valuation methodologies and new approaches to understanding the potential economic outcomes of these benefits.

Beyer KM, Kaltenbach A, Szabo A, Bogar S, Nieto FJ, Malecki KM.
Exposure to neighborhood green space and mental health: evidence from the survey of the health of Wisconsin.
Int J Environ Res Public Health. 2014 Mar 21;11(3):3453-72. doi: 10.3390/ijerph110303453.
https://www.mdpi.com/1660-4601/11/3/3453

Authors note that green space is now widely viewed as a health-promoting characteristic of residential environments, and has been linked to mental health benefits such as recovery from mental fatigue and reduced stress, particularly through experimental work in environmental psychology. With this study, the authors describe a population-level perspective to examine the relationship between environmental green space and mental health outcomes in a study area that includes a spectrum of urban to rural environments. Using regression analyses, authors examine the association between green space and mental health using the unique, population-based Survey of the Health of Wisconsin database. Higher levels of neighborhood green space were associated with significantly lower levels of symptoms for

depression, anxiety, and stress, after controlling for a wide range of confounding factors. Results suggest that "greening" could be a potential population mental health improvement strategy in the United States.

O'Brien L, Morris J.
Well-being for all? The social distribution of benefits gained from woodlands and forests in Britain.
Local Environment, 2014;19:356-383, DOI: 10.1080/13549839.2013.790354
https://www.tandfonline.com/doi/abs/10.1080/13549839.2013.790354

This review presents a summary of 31 studies undertaken since 2001 in Britain that research the well-being benefits gained by different sections of society through viewing, engaging with, and accessing woodlands and forests in Britain. The authors present a typology of well-being benefits for woodlands in Britain. They summarize well-being benefits into a number of categories: improved physical and mental health, nature/landscape connections, education and learning, economy, social development and connections, and symbolic/cultural significance. They note that evidence illustrates how carefully designed and targeted interventions can be particularly effective in enabling and encouraging people to visit woodland sites, to participate or get involved in new activities and, therefore, to realize a range of well-being benefits.

Nutsford D, Pearson, AL, Kingham S.
An ecological study investigating the association between access to urban green space and mental health.
Public Health Journal. November, 2013; 127(11):1005-1011.
https://www.sciencedirect.com/science/article/abs/pii/S0033350613002862

This study assesses whether proximity to urban green spaces is associated with human mental health. The authors examined the relationship between access to urban green spaces and counts of anxiety/mood disorder treatments among residents (aged 15 years and over) in Auckland City, New Zealand. Anxiety/mood disorder treatment counts by three age groups were aggregated to 3149 small area units in Auckland. Six measures of green space access were derived using geographic information system (GIS) techniques involving total green spaces and useable green spaces. Statistical models were used to test the relationship between access to green space and area-level anxiety/mood disorder treatment counts, adjusted for age, and area-level deprivation. Authors report that decreased distance to useable green space and an increased proportion of green space within the larger neighborhood were associated with decreased anxiety/mood disorder treatment counts in an urban environment.

Thompson CW, Roe J, Aspinall P, Mitchell R, Clow A, Miller D.
More Green Space Is Linked to Less Stress in Deprived Communities: Evidence from Salivary Cortisol Patterns.
Landscape and Urban Planning 2012;105:221-29. Elsevier. Web. 14 January 2016.
https://www.sciencedirect.com/science/article/pii/S0169204611003665

The authors describe an exploratory study of 25 participants to establish whether salivary cortisol can act as a biomarker for variation in stress levels, which may be associated with varying levels of exposure to green spaces. Results indicate significant relationships between self-reported stress, diurnal patterns of cortisol secretion, and quantity of green space in the living environment. The percentage of green space in the living environment is a significant and independent predictor of the circadian cortisol cycle. Authors conclude that salivary cortisol measurement offers considerable potential for exploring relationships between wellbeing and green space. They discuss how this methodology could be developed for use in future studies on how near-home green space could enhance health.

Abraham A, Sommerhalder K, Abel T.
Landscape and well-being: a scoping study on the health-promoting impact of outdoor environments.
Int J Public Health 2010;55:59–69.
https://boris.unibe.ch/21/8/38_2009_Article_69.pdf

The authors present the findings of a scoping study that represents a qualitative literature review. They examined 120 studies using a five-step-procedure. They present a set of pathways that link landscape and health. Landscapes have the potential to promote mental well-being through attention restoration, stress reduction, and the evocation of positive emotions; physical well-being through the promotion of physical activity in daily life as well as leisure time and through walkable environments; and social well-being through social integration, social engagement and participation, and through social support and security.

Bowler DE, Buyung-Ali LM, Knight TM, Pullin AS.
A systematic review of evidence for the added benefits to health of exposure to natural environments.
BMC Public Health. 2010 Aug 4;10:456. doi: 10.1186/1471-2458-10-456.
https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-10-456

In this article, the authors report on a systematic review of 25 studies that compare measurements of health or well-being in natural and synthetic environments. Effect sizes of the differences between environments were calculated, and meta-analysis used to synthesize data from studies measuring similar outcomes. Studies investigated the effects of short-term exposure to each environment during a walk or run. This included 'natural' environments, such as public parks and green university campuses, and synthetic environments, such as indoor and outdoor built environments. The most common outcome measures were scores of different self-reported emotions. A meta-analysis provided some evidence of a positive benefit of a walk or run in a natural environment in comparison to a synthetic environment. Authors conclude that the studies suggest that natural environments may have direct and positive impacts on well-being, but support the need for investment in further research on this question to understand the general significance for public health.

Karjalainen E, Sarjala T, Raitio H.
Promoting human health through forests: overview and major challenges.

In this review, the authors give a short overview of the most important health benefits that forests provide to humans and the risks that forests may pose to human health. They then discuss future challenges for the research on the links between forests and human health. Research shows that forest visits promote both physical and mental health by reducing stress. Forests represent natural pharmacies by being sources of plant and microbial material with known or potential medicinal or nutritional value. The authors note that the main challenges to delivering health through forests are ecosystem and biodiversity degradation, deforestation, and climate change. They argue that a barrier to implementation of research results into practice is the lack of policy-makers' and practitioners' awareness of the potential of forests for improving human health. They conclude by issuing a call for strong cooperation among researchers, policy-makers, and health and environmental professionals.

Birth weight

Dzhambov AM, Dimitrova DD, and Dimitrakova ED.
Association Between Residential Greenness and Birth Weight: Systematic Review and Meta-analysis.
Urban Forestry & Urban Greening. 2014;13:621-29. Elsevier. Web. 12 January 2016.
https://www.researchgate.net/profile/Angel_Dzhambov/publication/265913924_Association_between
_residential_greenness_and_birth_weight_Systematic_review_and_meta-
analysis/links/5af561a3aca2720af9c60ecb/Association-between-residential-greenness-and-birth-
weight-Systematic-review-and-meta-analysis.pdf

In this review, the authors examined whether greenspaces and generally greenery in the living environment of pregnant women are associated with the birth weight of their infants. They identified eight studies with a combined total of 214940 births. A meta-analysis of the eight studies identified neighborhood greenness within a 100-m buffer positively associated with birth weight. The authors conclude urban trees promote higher birth weights and better good health in newborn babies. They suggest the mechanism may be that urban tree canopy has a positive effect on maternal neuroendocrine and placental response.

Immune function

Li Q.
Effect of forest bathing trips on human immune function.
Environ Health Prev Med. 2010 Jan; 15(1): 9–17.
https://environhealthprevmed.biomedcentral.com/articles/10.1007/s12199-008-0068-3

This review focuses on the effects of "Shinrinyoku," or forest bathing (a short, leisurely visit to a forest) trips on human immune function. Study subjects experienced a 3-day/2-night trip to forest areas, and blood and urine were sampled and tested for immune function markers. The same measurements were made before the trips on a typical working day as a control. Markers of immune function on forest bathing days were significantly higher than those on the control days and remained elevated for 30 days after trips.

<u>Crime reduction</u>

Schusler T, Weiss L, Treering D, Balderama E.
Research note: Examining the association between tree canopy, parks, and crime in Chicago.
Landscape and Urban Planning 2018;170:309-313.
https://www.researchgate.net/profile/Earvin_Balderama/publication/318771547_Research_note_Exam
ining_the_association_between_tree_canopy_parks_and_crime_in_Chicago/links/5adc94f2458515c60f
5e80af/Research-note-Examining-the-association-between-tree-canopy-parks-and-crime-in-Chicago.pdf

Authors examined whether an association exists between two forms of green space–tree canopy and
public parks–and crime rates in the city of Chicago. They used publicly available data to calculate
percent tree canopy, percent acreage parks, and crime rate for assault, battery, burglary, homicide,
narcotics, and robbery between years 2009–2013 for each of Chicago's 801 census tracts. Authors
report that a higher percentage of tree canopy was associated with lower crime rates for assault,
battery, robbery, and narcotics. They conclude that understanding the relationship between green space
and crime can inform urban planning to improve human safety and well-being.

Kondo MC, South EC, Branas CC, Richmond TS, Wiebe DJ.
The Association Between Urban Tree Cover and Gun Assault: A Case-Control and Case-Crossover Study.
Am J Epidemiol. 2017 Aug 1;186(3):289-296. doi: 10.1093/aje/kwx096
https://academic.oup.com/aje/article/186/3/289/3800003

The authors investigated whether being near urban tree cover during outdoor activities was related to
being assaulted with a gun. They conducted geographic information systems-assisted interviews with
boys and men aged 10-24 years in Philadelphia, Pennsylvania. Each subject reported a step-by-step
mapped account of where and with whom they traveled over a full day from waking until being
assaulted or going to bed. Geocoded path points were overlaid on mapped layers representing tree
locations and place-specific characteristics. Statistical analysis compared case subjects with controls and
with case subjects at the time of injury versus times earlier that day. When comparing cases at the time
of the assault to controls matched at the same time of day, being under tree cover was associated with
a lower risk from gunshot assault, especially in low-income areas. Authors conclude that urban greening
and tree cover may hold promise as proactive strategies to decrease urban violence.

Gilstad-Hayden K, Wallace LR, Carroll-Scott A, Meyer SR, Barbo S, Murphy-Dunning C, and. Ickovics JR.
Research Note: Greater Tree Canopy Cover Is Associated with Lower Rates of Both Violent and Property
Crime in New Haven, CT.
Landscape and Urban Planning 2015;143:248-53. Elsevier. Web. 13 January 2016.
https://www.sciencedirect.com/science/article/pii/S0169204615001607

Authors examine the relationship between vegetation and crime in New Haven, CT, a midsized city with
high crime rates. They analyzed relationships between tree canopy coverage, measured through high-
resolution aerial imagery, with rates of violent (murder, rape, robbery, and assault), property (burglary,

theft, motor vehicle theft, and arson) and total (violent + property) crimes. Authors report that tree canopy cover was inversely associated with crime: a 10% increase in tree canopy was associated with a 15% decrease in violent crime; a 10% increase in tree canopy was associated with a 14% decrease in property crime.

Troy A, Grove JM, and O'Neil-Dunne J.
The Relationship Between Tree Canopy and Crime Rates Across an Urban-rural Gradient in the Greater Baltimore Region.
Landscape and Urban Planning. 2012;106:262-270. Elsevier. Web. 13 January 2016.
https://www.nrs.fs.fed.us/pubs/jrnl/2012/nrs_2012_troy_001.pdf

The authors assessed how tree cover might influence crime rates by examining geocoded crime point data and high-resolution tree canopy data to address this question in Baltimore City and County, MD. They found a strong inverse relationship between tree canopy and an index of robbery, burglary, theft, and shooting. A 10% increase in tree canopy was associated with a roughly 12% decrease in crime. When analyzing tree cover by public and private ownership, the magnitude of effect was 40% greater for public than for private lands. Authors conclude their findings support a relationship between crime and tree cover. They note that the results do not establish causality but suggest a need for more research on the role of vegetation in mediating crime.