Human Health Benefits of City Trees & Forests:

Rapid Review of Research Publications with Practical Application

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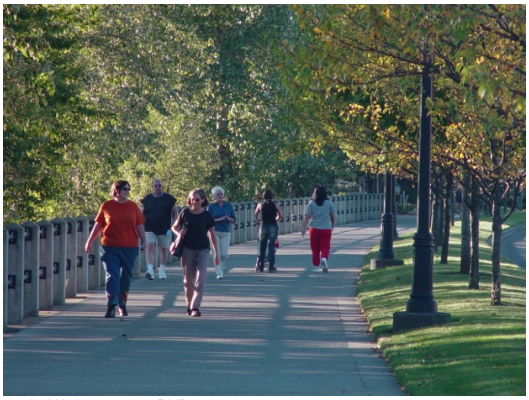

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credit: Washington state DNR

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Rapid Review of Research Publications with Practical Application

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1. BACKGROUND

This report provides an update on the research evidence concerning trees and forests in cities and their contributions to human health and wellness. Included is a compilation of research publications, and a translation of findings that can be incorporated into local government policy and programs.

A scoping review of peer-reviewed research focusing on city trees and human health response was published in 2020. A systematic search used keywords representing human health, environmental health, and urban forestry resulted in a collection of 3,358 studies. Following screening and science quality appraisal, 201 studies were conceptually sorted into a three-part framework. *Reducing Harm*, representing 41% of studies, includes topics such as air pollution, ultraviolet radiation, heat exposure, and pollen. *Restoring Capacities*, at 31%, includes attention restoration, mental health, stress reduction, and clinical outcomes. *Building Capacities*, at 28%, includes topics such as birth outcomes, active living, and weight status.

It's important to note that the various human and community responses are not equally represented by consistent results or depth of research. Appendix A is a summary from the review article. It visually represents the strength of evidence, with mental health and function being represented by both higher quantity and quality of research.

The published review article is free to download: Wolf, K. L., Lam, S. T., McKeen, J. K., Richardson, G. R. A., van den Bosch, M., & Bardekjian, A. C. (2020). Urban Trees and Human Health: A Scoping Review. *International Journal of Environmental Research and Public Health*, *17*(12), 4371. https://www.mdpi.com/1660-4601/17/12/4371

2. REVIEW APPROACH

The informal literature review reported here is an update, presenting studies dating from 2019 to mid-year 2024 as the article search for Wolf et al. ended in 2018. It is provided on request and with support from Health Canada and the Toronto and Region Conservation Authority. ‘Snowball sampling’ was done using informed keywords from the earlier published review as well as the author’s familiarity with the research. No effort was made to conduct a formal or comprehensive review. Studies derived from tropical/semi-tropical bio-geographies were not included. The author is confident that few substantially important or significant studies have been overlooked but bears no responsibility for omissions.

An Excel spreadsheet was populated with citations of the 106 located studies, and each was summarized with a brief statement. It should be noted that thousands of articles about urban green spaces and climate and/or human health imply the presence of trees, but only articles explicitly exploring trees, urban canopy or forest are included in this bibliographic review. An informal qualitative review of the article collection resulted in a thematic sorting of studies. The next section summarizes seven themes, and Appendix B presents recent studies, sorted by the themes.

3. THEMES AND STUDIES

The city trees and human health response research studies are represented by seven themes. This section provides a brief interpretive overview of the studies' results.

The entire study collection is provided in Appendix B. Studies are sorted by themes and each article is briefly summarized. Note that an article summation is but a sentence or two, representing typically thousands of words in the source publication. Source .pdfs can be provided on request if there is interest in learning more detail about any study.

3.A. IMPORTANCE OF PLANNING

Planning articles numbered 10. This tally had a smaller article count than the following themes but is important as the literature appears to be turning to translation of evidence to planning and management that goes beyond professional best practices of arboriculture and urban forestry. Systems thinking is often emphasized. Pursuit of community or city-wide tree programs is endorsed to achieve population-level physical activity, reduced human morbidity and mortality, achievement of multiple ecosystem services and tree longevity (which optimizes benefits). A recent planning guideline being promoted for biophilic cities is the 3-30-300 rule: having at least 3 well-established trees in view from every home, school, and place of work; no less than a 30% tree canopy in every neighbourhood; and no more than 300 meters distance to the nearest public green space from every residence.

3.B. URBAN HEAT ISLAND, TEMPERATURE AND THERMAL COMFORT

The articles in this theme numbered 20. Earlier studies in this dimension tended to evaluate the relationship of trees and heat rather simplistically (i.e., shade is good). The attention and research quality addressing this concern has expanded in response to climate change related extreme heat episodes in cities all around the world. Studies have used remote and *in situ* sensors, with research methods ranging from on-the-ground measures to remote sensing (for larger geographic areas). Generally, the studies indicate that heat reduction and thermal comfort advantages are probable with the presence of trees, addressing both pre-heat mitigation and extreme heat adaptation. Yet, there is variability in ground temperatures and perceptions of thermal comfort. Notably, the studies point to the importance of species selection, vegetation configuration, planting density and spacing of the trees, and microclimate influences (such as wind direction and speed). The modelling has also explored benefits associated with boosting canopy cover rates to the levels pursued by city policies. Some models have also analyzed heat-related mortality (finding older people are particularly susceptible) and avoided medical costs of reducing heat-related morbidities.

3.C. AIR QUALITY, ALLERGENS AND RESPIRATORY EFFECTS

The articles in this theme numbered 20. Earlier studies, using research approaches of clinical medicine, tended to isolate pollen and allergy associations from lived experience, concluding that 'pollen – thus trees – are bad'. Owing to big data analysis capabilities and increased understanding of ecosystem services benefits, speculation is that deeper understanding of pollen disservices is generating more interest in evidence-based mitigation and adaptation strategies rather than tree

exclusion. Studies include the complex process of sensitization to allergens (including early human age exposures), seasonality of pollen release and exposure, and species specificity in irritant potential.

This group of studies also addresses the air quality potential of trees, particularly fine particulates. Fine particulates are widely distributed across cities, though often concentrated near high traffic volume roads. Even short-term exposures of hours or days can aggravate lung disease, causing asthma attacks and acute bronchitis, and may also increase susceptibility to respiratory infections. In people with heart disease, short-term exposures to particulates have been linked to heart attacks. While early studies (such as those supporting i-Tree) called out the adherence potential leaf and bark surfaces of trees to remove particulates, more recent research again addresses greater specificity of species' leaf surface area and 'stickiness', microclimate dynamics (particularly wind) and proximity to particulate generators (such as high-volume roads). Current studies point out potential benefits to specific populations (such as pedestrian and cycling users of streetscapes), management strategies to optimize particulate capture, and the potential disservice of particulate concentration in urban canyons, that is, the possibility of tree canopy enclosing a street lined by tall buildings thus blocking the air movement that could clear the air.

3.D. MENTAL HEALTH AND FUNCTION

The articles in this theme numbered 16. This theme is less focused on physiological health response to physical conditions, but more on the experiential consequences of being in the midst of trees and urban forests. In earlier research, remote sensing of vegetation using satellite NDVI (Normalized Difference Vegetation Index) was a common green space and tree indicator. Providing only a coarse resolution of on-the-ground conditions, there have been concerns about the accuracy of this approach to vegetation classification and thus, health consequences. More recent research is using finer grain vegetation classification, such as tree inventories, street views and within-green mapping. Newer research addresses mental health promotion and general well-being, as well as tree and forest experiences as treatment for clinical concerns (such as depression). Across the studies there is greater attention to lived experience of nature. The consequences include reductions (but not elimination) in measures of stress, anxiety, and distress. Experiences of trees contribute to enhanced subjective well-being and psychological restoration. Studies have begun to focus on life cycle stages such as youth showing better school performance and elders showing better self-rated memory and reduced dementia risk.

3.E. FOREST BATHING & THERAPY

The articles in this theme numbered 11. Forest bathing and therapy, based on decades of rigorous research (particularly in Japan and South Korea), is emerging as a consequential practice for city residents and healthcare providers. Forest bathing and therapy is the practice of intentional, contemplative time outside, with sessions delivered by certified guides within tree-shaped environments that range from parks to naturalistic forests and include even very small greenspaces. Several review articles highlight the wide array of physiological and psychological benefits. The studies and reviews are evolving from early studies showing general beneficial health associations to more detailed investigations into the benefits for general urban residents, healthcare treatment (such as depression and cancer patients), and specific populations (such as elders and students). The importance of these findings relates to urban forest and city planning. A co-design for co-benefits planning outlook could consider how to plant and manage trees to adapt for thermal comfort and allergen or particulates reduction, and simultaneously address how to create the spaces (such as groves or streetscapes) that facilitate forest bathing on a routine, accessible basis.

3.F. PHYSICAL WELLNESS

The articles in this theme numbered 8. The relationship of nature and physical activity (walking and recreation) was an early focus in the health and nature research. Though the legacy research shows some variability, the presence of trees and green space in residential areas is associated with both intent to be more active and increased levels of physical activity for leisure.

Broader research questions about this topic were less prominent in this review of recent research but indicate important implications for preventing chronic disease. Recent studies capitalized on more widely available public health records of hospitalization, morbidity, and mortality. Like forest bathing, general forest exposure was associated with reduced hypertension, stress indicators and heart rate variability. Tree canopy (including a study of longitudinal trends) was a common urban forest measure and was associated with reduced cardiovascular risk, healthier weight, less non-accidental death, higher life expectancy and reduced risk of all-cause mortality. These studies often included socioeconomic disparities and tree distribution inequity as factors in the outcomes modelling.

3.G. EMERGENT BENEFITS, FUNCTIONS AND SERVICES

The articles in this theme numbered 21. As one looks over this article collection and the broader realm of nature and health research, the specificity and innovativeness of the research is expanding rapidly. Singular or even a handful of studies are suggestive of new lines of inquiry and novel research methods and will probably inform future expanded research designs. The breadth and variety of this work again suggests the importance of planning for ‘stacked’ or co-benefits and attention to the configuration of new or managed urban forests and greening to promote multiple community and individual benefits. Ecosystem and health services can be optimized with greater attention to the placement, density and biodiversity of vegetation. Some of the research findings overlap with prior themes but their intriguing outcomes merit ongoing attention to the strength and depth of evidence, further confirming urban forestry as a multi-dimensional adaptation for physical, mental, and social benefits. Highlights are:

- economics of pharmaceutical or treatment reductions
- experiences of trees (and green space) as intentional treatments for specific clinical conditions or diseases
- in addition to infant birth weight, mothers’ health pre- and post-term
- the food security and social cohesion potential of urban foraging and food forests
- reduced noise and improved sleep
- neuroscience and 'deep responses' such as phytoncides and other VOCs (volatile organic compounds) emitted by trees
- social engagement
- community safety perceptions, and incidence of crime and intentional deaths

APPENDIX A – URBAN TREES & HUMAN HEALTH: 2020 REVIEW RESULTS

Graphic summary of a scoping review of 201 studies about urban trees and human health, sorted by health outcomes domains and study methods. All references were provided as Supplementary Material in Wolf & Lam, et al. 2020.

Domain/Subdomain	Study Count	Experiment	Natural/Quasi-Experiment	Longitudinal/ Cohort	Cross Sectional	Modelling	Time Series
4.1. Reducing Harm	**82**						
4.1.1 Air Pollutants and Respiratory Condition	14				●●◐◐◐ ○	●●●●● ●●●	
4.1.2 Tree Pollen and VOCs	40	◐	◐	○○○	◐◐◐◐◐ ◐◐◐◐◐ ◐◐◐◐ ○○○○	○○○	◐◐◐◐ ○○○○○ ○○○○○
4.1.3 Ultraviolet Radiation	5		●●			●◐◐	
4.1.4 Excess Heat and Thermal Comfort	17		●●●●●	●●		●●●●● ●●●●◐	
4.1.5 Crime	6		●● ◐		●●◐		
4.2. Restoring Capacities	**63**						
4.2.1 Cognition and Attention Restoration	13	●●●●● ●◐◐	●●●◐		●		
4.2.2 Mental Health, Anxiety and Mood	15	●●●●● ●●●● ◐◐	●		●◐◐		
4.2.3 Psychophysiological Stress	25	●●●●● ●●●●● ●●●● ◐◐◐◐	●●	◐	●●●●		
4.2.4 Clinical Outcomes	10	●●● ◐	◐	●●	●●●		
4.3. Building Capacities	**56**						
4.3.1 Birth Outcomes	4			◐◐◐	●		
4.3.2 Immune System	6	●●●●● ●					
4.3.3 Active Living	19		●●		●●●●● ●●●●● ◐◐◐◐◐ ○○		
4.3.4 Weight Status	8				●●●●● ●●●		
4.3.5 Cardiovascular Function	16	●●●●● ●●◐◐	●●●◐		●◐◐		
4.3.6 Social Cohesion	3		●		●●		
Total Studies	**201**	**57**	**26**	**12**	**69**	**24**	**13**

APPENDIX B – STUDIES SORTED BY THEME

A. IMPORTANCE OF PLANNING

Finding		Reference
Street greenery (e.g. tree-lined streets) was positively associated with the odds of achieving 300 minutes or more of physical activity per week for older adults.	2020	He, H., Lin, X., Yang, Y., & Lu, Y. (2020). Association of street greenery and physical activity in older adults: A novel study using pedestrian-centered photographs. Urban Forestry & Urban Greening, 55, 126789. https://doi.org/10.1016/j.ufug.2020.126789
Trunk circumference is a very valuable indicator for estimating climate regulating ecosystem services; larger trees = more services.	2020	Helletsgruber, C., Gillner, S., Gulyás, Á., Junker, R. R., Tanács, E., & Hof, A. (2020). Identifying Tree Traits for Cooling Urban Heat Islands—A Cross-City Empirical Analysis. Forests, 11(10), 1064.
Higher neighbourhood concentrations of tree canopy are related to better physical health, overall health, and an increased capacity to control stress.	2020	Jiang, X., Larsen, L., & Sullivan, W. (2020). Connections-between Daily Greenness Exposure and Health Outcomes. International Journal of Environmental Research and Public Health, 17(11), 3965. https://doi.org/10.3390/ijerph17113965
Estimated prevention of annual adult premature deaths, particularly in areas of lower socioeconomic status, if Philadelphia were to meet 30% canopy goal.	2020	Kondo, M. C., Mueller, N., Locke, D. H., Roman, L. A., Rojas-Rueda, D., Schinasi, L. H., Gascon, M., & Nieuwenhuijsen, M. J. (2020). Health impact assessment of Philadelphia's 2025 tree canopy cover goals. The Lancet Planetary Health, 4(4), e149-157. https://doi.org/10.1016/s2542-5196(20)30058-9
Considering economics of street shading, costs of tree planting and maintenance were higher than the estimated benefits in the short term (20–30 years) but were lower when tree life expectancy increased (> 40 years).	2021	Horváthová, E., Badura, T., & Duchková, H. (2021). The Value of the Shading Function of Urban Trees: A Replacement Cost Approach. Urban Forestry & Urban Greening, 62, 127166. https://doi.org/10.1016/j.ufug.2021.127166
A review concluded that current evidence supports local cooling, stormwater absorption, and health benefits of urban trees for nearby residents. However, the potential for urban trees to appreciably mitigate greenhouse gas emissions and air pollution over a wide array of sites and environmental conditions is limited.	2021	Pataki, D. E., Alberti, M., Cadenasso, M. L., Felson, A. J., McDonnell, M. J., Pincetl, S., Pouyat, R. V., Setälä, H., & Whitlow, T. H. (2021). The Benefits and Limits of Urban Tree Planting for Environmental and Human Health. Frontiers in Ecology and Evolution, 9, 603757. https://doi.org/10.3389/fevo.2021.603757
Evaluating the 3-30-300 green space rule (with emphasis on trees), meeting the full surrogate rule was associated with better mental health, less medication use, and (strongest findings for) fewer psychologist or psychiatrist visits.	2022	Nieuwenhuijsen, M. J., Dadvand, P., Marquez, S., Bartoll, X., Barboza, E. P., Cirach, M., Borrell, C., & Zijlema, W. L. (2022). The evaluation of the 3-30-300 green space rule and mental health. Environmental Research, 215(Pt 2), 114387. https://doi.org/10.1016/j.envres.2022.114387
Need for systems thinking to promote urban forest planning and management to promote mental health, and other well-being outcomes.	2023	Alvarado, M., Lovell, R., Guell, C., Taylor, T., Fullam, J., Garside, R., Zandersen, M., & Wheeler, B. (2023). Street trees and mental health: developing systems thinking-informed hypotheses using causal loop diagraming. Ecology and Society, 28(2), 1. https://doi.org/10.5751/es-14013-280201

Finding		Reference
Based on research reviews concerning benefits of city trees regarding both human health and climate adaptation, the 3-30-300 planning guideline sets thresholds of having at least 3 well-established trees in view from every home, school, and place of work; no less than a 30% tree canopy in every neighbourhood; and no more than 300 meters to the nearest public green space from every residence.	2023	Konijnendijk, C. C. (2023). Evidence-based guidelines for greener, healthier, more resilient neighbourhoods: Introducing the 3-30-300 rule. Journal of Forestry Research, 34(3), 821-830. https://doi.org/10.1007/s11676-022-01523-z
The article offers implementation strategies and typology for 3-3-300 rule.	2024	Browning, M., Locke, D. H., Konijnendijk, C., Labib, S. M., Rigolon, A., Yeager, R., Bardhan, M., Berland, A., Dadvand, P., Helbich, M., Li, F., Li, H., James, P., Klompmaker, J., Reuben, A., Roman, L. A., Tsai, W. L., Patwary, M., O'Neil-Dunne, J., . . . Nieuwenhuijsen, M. (2024). Measuring the 3-30-300 rule to help cities meet nature access thresholds. Science of the Total Environment, 907, 167739. https://doi.org/10.1016/j.scitotenv.2023.167739

B. URBAN HEAT ISLAND, TEMPERATURE AND THERMAL COMFORT

Finding		Reference
Modelling indicated that increases to Vancouvers Street tree cover by 1% of plan area can substantially reduce mean radiant temperature during extreme hot weather.	2019	Aminipouri, M., Knudby, A. J., Krayenhoff, E. S., Zickfeld, K., & Middel, A. (2019). Modelling the impact of increased street tree cover on mean radiant temperature across Vancouver's local climate zones. Urban Forestry & Urban Greening, 39, 9-17.
Mean radiant temperature (MRT) for pedestrians was reduced linearly by large trees; with decreased planting interval MRT was increased by small trees. To reduce pedestrian exposure to radiation plant either larger trees or closely spaced smaller trees.	2019	Park, C. Y., Lee, D. K., Krayenhoff, E. S., Heo, H. K., Hyun, J. H., Oh, K., & Park, T. Y. (2019). Variations in pedestrian mean radiant temperature based on the spacing and size of street trees. Sustainable Cities and Society, 48, 101521.
Temperature decreased nonlinearly with increasing canopy cover, with the greatest cooling when canopy cover exceeded 40%. The magnitude of daytime cooling also increased with spatial scale and was greatest at the size of a typical city block (60-90 meters).	2019	Ziter, C. D., Pedersen, E. J., Kucharik, C. J., & Turner, M. G. (2019). Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. Proceedings of the National Academy of Sciences, 116(15), 7575-7580. https://doi.org/10.1073/pnas.1817561116
Rectangular planting of evergreen trees in the outer rows and deciduous trees in the inner rows in a direction perpendicular to the prevailing wind was optimal in improving outdoor thermal comfort.	2020	Abdi, B., Hami, A., & Zarehaghi, D. (2020). Impact of small-scale tree planting patterns on outdoor cooling and thermal comfort. Sustainable Cities and Society, 56. https://doi.org/10.1016/j.scs.2020.102085
An investigation of the role of vegetation in regulating land surface temperature found that composition, configuration, and vertical structure of tree canopy were all significantly related to both daytime and nighttime temperatures.	2020	Chen, J., Jin, S., & Du, P. (2020). Roles of horizontal and vertical tree canopy structure in mitigating daytime and nighttime urban heat island effects. International Journal of Applied Earth Observation and Geoinformation, 89, 102060.

Finding		Reference
Trees are the most effective at mitigating human heat stress on the S-facing sidewalk of a shallow E-W street canyon and increases with crown coverage, i.e. as the crown spacing decreases. On the N-facing sidewalk, shading by any S-bordering building masks the mitigation of human heat stress by tree crowns.	2020	Lee, H., Mayer, H., & Kuttler, W. (2020). Impact of the spacing between tree crowns on the mitigation of daytime heat stress for pedestrians inside E-W urban street canyons under Central European conditions. Urban Forestry & Urban Greening, 48, 126558. https://doi.org/10.1016/j.ufug.2019.126558
Consider human thermal comfort taller trees with low branching height and dense crowns had the largest effect on solar radiation reduction. Terrestrial radiation was most affected by leaf albedo and sky view factor.	2020	Liu, Z., Brown, R. D., Zheng, S., Jiang, Y., & Zhao, L. (2020). An in-depth analysis of the effect of trees on human energy fluxes. Urban Forestry & Urban Greening, 50, 126646.
Based on measured surface temperatures within the shade of trees, strategic planting of single trees can positively impact the absorption of solar radiation by ground surface materials thus reducing the heat storage that contributes to UHIs (urban heat island index).	2020	Speak, A., Montagnani, L., Wellstein, C., & Zerbe, S. (2020). The influence of tree traits on urban ground surface shade cooling. Landscape and Urban Planning, 197, 103748. https://doi.org/10.1016/j.landurbplan.2020.103748
A review shows that the development of mitigation measures using tree shading systems can reduce the pavement temperature during daytime and increase human thermal comfort.	2021	Cheela, V., John, M., Biswas, W., & Sarker, P. (2021). Combating Urban Heat Island Effect—A Review of Reflective Pavements and Tree Shading Strategies. Buildings, 11(3), 93.
Greater tree diversity results in lower land surface temperature at the city block scale, and poorer urban forest health showed higher surface temperatures.	2021	Chinchilla, J., Carbonnel, A., & Galleguillos, M. (2021). Effect of urban tree diversity and condition on surface temperature at the city block scale. Urban Forestry & Urban Greening, 60. https://doi.org/10.1016/j.ufug.2021.127069
Surface temperature decreases with canopy cover level, and magnitude of the canopy mitigation effects differs based on development level and current canopy cover.	2021	Jung, M. C., Dyson, K., & Alberti, M. (2021). Urban Landscape Heterogeneity Influences the Relationship between Tree Canopy and Land Surface Temperature. Urban Forestry & Urban Greening, 57, 126930. https://doi.org/10.1016/j.ufug.2020.126930
A consistent negative relationship between urban heat island intensity and large and medium sized trees.	2021	Rakoto, P. Y., Deilami, K., Hurley, J., Amati, M., & Sun, Q. (2021). Revisiting the cooling effects of urban greening: Planning implications of vegetation types and spatial configuration. Urban Forestry & Urban Greening, 64, 127266. https://doi.org/10.1016/j.ufug.2021.127266
Mean radiant temperature reduction by trees is found directly related to their canopy-size/cluster-density, and inversely to background wind-speed.	2021	Raman, V., Kumar, M., Sharma, A., Froehlich, D., & Matzarakis, A. (2021). Quantification of thermal stress abatement by trees, its dependence on morphology and wind: A case study at Patna, Bihar, India. Urban Forestry & Urban Greening, 63, 127213. https://doi.org/10.1016/j.ufug.2021.127213
Existing tree cover estimated to reduce annual mortality by 543 deaths as compared to a 0% tree cover scenario, and increasing the area of current tree cover by 10% reduced baseline annual mortality. Over half of the reduced mortality is for over 65-year age group, among the most vulnerable to extreme heat.	2021	Sinha, P., Coville, R. C., Hirabayashi, S., Lim, B., Endreny, T. A., & Nowak, D. J. (2021). Modeling lives saved from extreme heat by urban tree cover. Ecological Modelling, 449, 109553. https://doi.org/10.1016/j.ecolmodel.2021.109553
Optimizing the plant community structure (particularly tree diversity and crown widths) improves the cooling effect of greenspaces without increasing their size.	2021	Wang, X., Dallimer, M., Scott, C. E., Shi, W., & Gao, J. (2021). Tree species richness and diversity predicts the magnitude of urban heat island mitigation effects of greenspaces. Science of the Total Environment, 770, 145211.

Finding		Reference
Tree canopy reduces urban heat, and that widespread tree planting could offset the increases in heat-attributable deaths as climate warming progresses.	2022	Chaston, T. B., Broome, R. A., Cooper, N., Duck, G., Geromboux, C., Guo, Y., Ji, F., Perkins-Kirkpatrick, S., Zhang, Y., Dissanayake, G. S., Morgan, G. G., & Hanigan, I. C. (2022). Mortality Burden of Heatwaves in Sydney, Australia Is Exacerbated by the Urban Heat Island and Climate Change: Can Tree Cover Help Mitigate the Health Impacts? Atmosphere, 13, 714. https://doi.org/10.3390/atmos13050714
Modeling a 10% increase in tree cover in 10 U.S. cities, addressing moderately and extremely hot days, significant declines in heat mortality were found, with greater implications for older people.	2022	Sinha, P., Coville, R. C., Hirabayashi, S., Lim, B., Endreny, T. A., & Nowak, D. J. (2022). Variation in estimates of heat-related mortality reduction due to tree cover in U.S. cities. Journal of Environmental Management, 301, 113751. https://doi.org/10.1016/j.jenvman.2021.113751
Modeling indicated that increasing tree coverage to 30% would cool [European] cities by a mean of 0.4 degrees C, and thousands of premature deaths could be prevented by increasing city tree coverage to 30%, corresponding to 1.84% of all summer deaths.	2023	Iungman, T., Cirach, M., Marando, F., Pereira Barboza, E., Khomenko, S., Masselot, P., Quijal-Zamorano, M., Mueller, N., Gasparrini, A., Urquiza, J., Heris, M., Thondoo, M., & Nieuwenhuijsen, M. (2023). Cooling cities through urban green infrastructure: a health impact assessment of European cities. Lancet, 401, 577-589. https://doi.org/10.1016/S0140-6736(22)02585-5
Compact urban green spaces of 10-25 ha with dense trees have the most pronounced cooling effect in residential areas, providing a mean decrease in land surface temperature within 400 meters of 2.3 degrees C.	2023	Kirschner, V., Macku, K., Moravec, D., & Manas, J. (2023). Measuring the relationships between various urban green spaces and local climate zones. Science Reports, 13(1), 9799. https://doi.org/10.1038/s41598-023-36850-6
Probability of daytime temperatures on sidewalks exceeding regulated high temperature thresholds was up to five times greater in locations with no canopy cover within 10 meters compared to those with 100% cover, and air temperatures decreased linearly with increasing cover within 10 meters.	2024	Ettinger, A. K., Bratman, G. N., Carey, M., Hebert, R., Hill, O., Kett, H., Levin, P., Murphy-Williams, M., & Wyse, L. (2024). Street trees provide an opportunity to mitigate urban heat and reduce risk of high heat exposure. Science Reports, 14(1), 3266. https://doi.org/10.1038/s41598-024-51921-y

C. AIR QUALITY, ALLERGENS AND RESPIRATORY EFFECTS

Finding		Reference
This review finds no scientific consensus that urban trees reduce asthma by improving air quality. In some circumstances, urban trees can degrade air quality and increase asthma. Causal pathways between urban trees, air quality, and asthma are very complex.	2019	Eisenman, T. S., Churkina, G., Jariwala, S. P., Kumar, P., Lovasi, G. S., Pataki, D. E., Weinberger, K. R., & Whitlow, T. H. (2019). Urban trees, air quality, and asthma: An interdisciplinary review. Landscape and Urban Planning, 187, 47-59. https://doi.org/10.1016/j.landurbplan.2019.02.010
For each 10% increase in tree canopy coverage, slightly decreased odds were found for grass and tree pollen sensitization.	2019	Gernes, R., Brokamp, C., Rice, G. E., Wright, J. M., Kondo, M. C., Michael, Y. L., Donovan, G. H., Gatziolis, D., Bernstein, D., LeMasters, G. K., Lockey, J. E., Khurana Hershey, G. K., & Ryan, P. H. (2019). Using high-resolution residential greenspace measures in an urban environment to assess risks of allergy outcomes in children. Science of the Total Environment, 668, 760-767. https://doi.org/10.1016/j.scitotenv.2019.03.009

Finding		Reference
Percent canopy cover and leaf area index were inversely correlated to respiratory and cardiovascular outcomes, with leaf area index specifically related to respiratory conditions. Percent racial/ethnic minority residents was negatively related to median income and tree density.	2019	Jennings, V., Gragg III, R. S., Brown, C. P., Hartel, D., Kuehler, E., Sinykin, A., Johnson, E., & Kondo, M. (2019). Structural Characteristics of Tree Cover and the Association with Cardiovascular and Respiratory Health in Tampa, FL. Journal of Urban Health, 96, 669-681. https://doi.org/10.1007/s11524-019-00380-2
Tree pollen concentration values were not dependent on total canopy volume, but on tree species type and density.	2019	Kasprzyk, I., Ćwik, A., Kluska, K., Wójcik, T., & Cariñanos, P. (2019). Allergenic pollen concentrations in the air of urban parks in relation to their vegetation. Urban Forestry & Urban Greening, 46, 126486. https://doi.org/10.1016/j.ufug.2019.126486
Although a greater concentration of trees contributes to better local air quality, species with severe allergenicity can increase local asthma hospitalization rates in vulnerable populations.	2019	Lai, Y., & Kontokosta, C. E. (2019). The impact of urban street tree species on air quality and respiratory illness: A spatial analysis of large-scale, high-resolution urban data. Health & Place, 56, 80-87. https://doi.org/doi.org/10.1016/j.healthplace.2019.01.016
For adult tree pollen allergy patient,s residential green space had protective effects against short-term mental distress, but distress was higher in patients who reported perceived presence of allergenic trees near their residence.	2020	Aerts, R., Stas, M., Vanlessen, N., Hendrickx, M., Bruffaerts, N., Hoebeke, L., Dendoncker, N., Dujardin, S., Saenen, N. D., Van Nieuwenhuyse, A., Aerts, J. M., Van Orshoven, J., Nawrot, T. S., & Somers, B. (2020). Residential green space and seasonal distress in a cohort of tree pollen allergy patients. International Journal of Hygiene and Environmental Health, 223(1), 71-79. https://doi.org/10.1016/j.ijheh.2019.10.004
For children diagnosed with asthma, increased incidence was found in association with tree pollen, both for total tree pollen and most individual tree types, thus advisories of pollen levels are important.	2020	De Roos, A. J., Kenyon, C. C., Zhao, Y., Moore, K., Melly, S., Hubbard, R. A., Henrickson, S. E., Forrest, C. B., Diez Roux, A. V., Maltenfort, M., & Schinasi, L. H. (2020). Ambient daily pollen levels in association with asthma exacerbation among children in Philadelphia, Pennsylvania. Environment International, 145, 106138. https://doi.org/10.1016/j.envint.2020.106138
Review of particulate matter removal capacity of different vegetation types at different scales could not be simply deemed positive or negative, yet general effectiveness is in the following order: coniferous forest > evergreen forest > deciduous forest.	2020	Han, D., Shen, H., Duan, W., & Chen, L. (2020). A review on particulate matter removal capacity by urban forests at different scales. Urban Forestry & Urban Greening, 48, 126565. https://doi.org/10.1016/j.ufug.2019.126565
Street trees in a boulevard-type street canyon can lead to decreased pedestrian-level air quality with the effect being particularly strong for larger aerosol particles, yet with careful planning of the street vegetation, significant reductions in pedestrian-level aerosol particle concentrations are possible.	2020	Karttunen, S., Kurppa, M., Auvinen, M., Hellsten, A., & Järvi, L. (2020). Large-eddy simulation of the optimal street-tree layout for pedestrian-level aerosol particle concentrations – A case study from a city-boulevard. Atmospheric Environment: X, 6, 100073. https://doi.org/10.1016/j.aeaoa.2020.100073
Medium and high numbers of trees and allergenic-prone near birth addresses were associated with increased odds of allergic rhinitis up to 15 years regardless, and these exposures were also related to higher odds of sensitization to aeroallergens.	2020	Markevych, I., Ludwig, R., Baumbach, C., Standl, M., Heinrich, J., Herberth, G., de Hoogh, K., Pritsch, K., & Weikl, F. (2020). Residing near allergenic trees can increase risk of allergies later in life: LISA Leipzig study. Environmental Research, 191, 110132. https://doi.org/10.1016/j.envres.2020.110132
Effort to analyze the characteristics and assess the seasonally allergenic risk of street trees, found great variability across species and seasonality, and that increased allergenicity was observed with decreasing street width.	2020	Zong, H., Yao, M., Tang, Y., & Chen, H. (2020). Assessing the composition, diversity, and allergenic risk of street trees in Qingyang District of Chengdu City. Urban Forestry & Urban Greening, 54, 126747. https://doi.org/10.1016/j.ufug.2020.126747
An assessment of tree allergenicity resulted in removal of species (birch, hazel, and alder) bringing down allergy risk 13%.	2021	Aerts, R., Bruffaerts, N., Somers, B., Demoury, C., Plusquin, M., Nawrot, T. S., & Hendrickx, M. (2021). Tree pollen allergy risks and changes across scenarios in urban green spaces in Brussels, Belgium. Landscape and Urban Planning, 207, 104001. https://doi.org/10.1016/j.landurbplan.2020.104001

Finding		Reference
While inconsistent, vegetation combination of trees, shrubs, and herbs is effective for reducing the concentration of particulate matter in near-road settings, with secondary plantings of <2 meters providing better screening.	2021	Chen, X., Wang, X., Wu, X., Guo, J., & Zhou, Z. (2021). Influence of roadside vegetation barriers on air quality inside urban street canyons. Urban Forestry & Urban Greening, 63, 127219. https://doi.org/10.1016/j.ufug.2021.127219
Evaluating 5 tree species for roadside plantings as defense guard against vehicular emission, all were potential tree species for roadside plantation to mitigate air pollution.	2021	Kumar, A., Kumar, P., Singh, H., & Kumar, N. (2021). Adaptation and mitigation potential of roadside trees with bio-extraction of heavy metals under vehicular emissions and their impact on physiological traits during seasonal regimes. Urban Forestry & Urban Greening, 58, 126900. https://doi.org/10.1016/j.ufug.2020.126900
Review on the harmful health effects of air pollution in urban environments, and the potential of forested environments to promote health and disease prevention.	2021	Mei, P., Malik, V., Harper, R. W., & Jiménez, J. M. (2021). Air pollution, human health and the benefits of trees: a biomolecular and physiologic perspective. Arboricultural Journal, 3(1), 19-40. https://doi.org/10.1080/03071375.2020.1854995
Pollen production is essential for natural regeneration and potential seed/food production; limiting tree species with high allergenic potential in areas near people can help reduce tree-related allergies. Cities developed within areas having naturally occurring Pinaceae (pine, spruce, fir, cedar, Douglas fir, larch) forests and/or have more Pinaceae species tended to have the lowest pollen index scores.	2021	Nowak, D. J., & Ogren, T. L. (2021). Variations in urban forest allergy potential among cities and land uses. Urban Forestry & Urban Greening, 63, 127224. https://doi.org/10.1016/j.ufug.2021.127224
Estimates of pollen exposure risk range from 1 to 74% for trees considered to be highly allergenic in the same city; diverse urban forests offer a potentially safer strategy aimed at diluting sources of allergenic pollen.	2021	Sousa-Silva, R., Smargiassi, A., Kneeshaw, D., Dupras, J., Zinszer, K., & Paquette, A. (2021). Strong variations in urban allergenicity riskscapes due to poor knowledge of tree pollen allergenic potential. Scientific Reports, 11, 10196.
Types of vegetation may play a role in the association between greenness exposure and childhood asthma. Exposure to trees may reduce the odds of childhood asthma, whereas exposure to grass may increase the odds.	2021	Yu, H., Zhou, Y., Wang, R., Qian, Z., Knibbs, L. D., Jalaludin, B., Schootman, M., McMillin, S. E., Howard, S. W., Lin, L.-Z., Zhou, P., Hu, L.-W., Liu, R.-Q., Yang, B.-Y., Chen, G., Zeng, X.-W., Feng, W., Xiang, M., & Dong, G.-H. (2021). Associations between trees and grass presence with childhood asthma prevalence using deep learning image segmentation and a novel green view index. Environmental Pollution, 286, 117582. https://doi.org/10.1016/j.envpol.2021.117582
Results of a city-wide tree planting campaign found smog pollution reduction of 3.4% on average, with strengthened effect of 8.5% in the 10th year, with social programs as mediators.	2022	Xie, H., Tan, X., Yang, C., & Li, C. (2022). Does Urban Forest Control Smog Pollution? Evidence from National Forest City Project in China. Sustainability, 14(19), 12897. https://doi.org/10.3390/su141912897
Concerning bicyclists and pedestrians, medium spacing of trees was most effective in reducing air pollution particulates on bicycle lane and sidewalk areas in comparison to on-street traffic-lane measurements.	2023	Ren, F., Qiu, Z., Liu, Z., Bai, H., & Gao, H. O. (2023). Trees help reduce street-side air pollution: A focus on cyclist and pedestrian exposure risk. Building and Environment, 229, 109923. https://doi.org/10.1016/j.buildenv.2022.109923

D. MENTAL HEALTH AND FUNCTION

Finding		Reference
An inverse relationship was found between depressive symptoms and tree cover surrounding nursing home facilities.	2019	Browning, M. H. E. M., Lee, K., & Wolf, K. L. (2019). Tree cover shows an inverse relationship with depressive symptoms in elderly residents living in U.S. nursing homes. Urban Forestry & Urban Greening, 41, 23-32. https://doi.org/https://doi.org/10.1016/j.ufug.2019.03.002
A short walk along urban roads surrounded by trees reduced the negative psychological states of tension, fatigue, confusion, and anxiety compared to the control road. Also, restorative outcome and vitality were higher after walking along treed roads, and no differences were detected between male and female participants.	2019	Elsadek, M., Liu, B., Lian, Z., & Xie, J. (2019). The influence of urban roadside trees and their physical environment on stress relief measures: A field experiment in Shanghai. Urban Forestry & Urban Greening, 42, 51-60. https://doi.org/10.1016/j.ufug.2019.05.007
A brief virtual visual experience of campus street trees in autumn has stress recovery effects on graduate students, and the different levels of stress recovery are associated with different types of street trees.	2019	Guo, L.-N., Zhao, R.-L., Ren, A.-H., Niu, L.-X., & Zhang, Y.-L. (2019). Stress Recovery of Campus Street Trees as Visual Stimuli on Graduate Students in Autumn. International Journal of Environmental Research and Public Health, 17(1). https://doi.org/10.3390/ijerph17010148
Street view green and blue spaces are protective against depression for the elderly (in China).	2019	Helbich, M., Yao, Y., Liu, Y., Zhang, J., Liu, P., & Wang, R. (2019). Using deep learning to examine street view green and blue spaces and their associations with geriatric depression in Beijing, China. Environment International, 126, 107-117. https://doi.org/10.1016/j.envint.2019.02.013
Tree cover density within a 1-mile radius of high schools was positively associated with ACT* scores, college readiness, even after controlling for factors known to influence academic performance. However, tree cover density was not significantly correlated with four-year graduation rates. *ACT is an academic performance testing for college-bound students.	2019	Li, D., Chiang, Y.-C., Sang, H., & Sullivan, W. C. (2019). Beyond the school grounds: Links between density of tree cover in school surroundings and high school academic performance. Urban Forestry & Urban Greening, 38, 42-53.
Viewing forest landscapes resulted in physiological and psychological relaxations in young women. Scores of negative feelings, such as tension–anxiety, depression–dejection, anger–hostility, fatigue, and confusion, were significantly lower.	2019	Song, C., Ikei, H., Kagawa, T., & Miyazaki, Y. (2019). Physiological and Psychological Effects of Viewing Forests on Young Women. Forests, 10, 635. https://doi.org/doi:10.3390/f10080635
Neighbourhood street walkability in Beijing, as measured by visual enclosure, was negatively associated with geriatric depression and anxiety, especially for disadvantaged older adults.	2019	Wang, R., Lu, Y., Zhang, J., Liu, P., Yao, Y., & Liu, Y. (2019). The relationship between visual enclosure for neighbourhood street walkability and elders' mental health in China: Using street view images. Journal of Transport & Health, 13, 90-102. https://doi.org/10.1016/j.jth.2019.02.009
Adults having more tree canopy relative to open grass within 1.6 km had fewer subjective memory complaints and more favorable self-rated excellent memory at baseline.	2020	Astell-Burt, T., & Feng, X. (2020). Greener neighbourhoods, better memory? A longitudinal study. Health & Place, 65, 102393. https://doi.org/10.1016/j.healthplace.2020.102393
Dementia risk was lower with more tree canopy when the outcome was measured using hospital and death records, but diagnosis was less consistent for other diagnosis contexts.	2020	Astell-Burt, T., Navakatikyan, M. A., & Feng, X. (2020). Urban green space, tree canopy and 11-year risk of dementia in a cohort of 109,688 Australians. Environment International, 145, 106102. https://doi.org/10.1016/j.envint.2020.106102

Finding		Reference
Increases in tree cover within 200 meters of a child's home was associated with modest improved performance on math tests, and more so on reading tests.	2020	Donovan, G. H., Michael, Y. L., Gatziolis, D., & Hoyer, R. W. (2020). The Relationship Between the Natural Environment and Individual-Level Academic Performance in Portland, Oregon. Environment and Behavior, 52(2), 164-186.
A lower rate of antidepressant prescriptions was found for people living within 100 meters of higher density of street trees, though other health factors interacted, yet for individuals with low socio-economic status, high density of street trees at 100 meters around the home significantly reduced prescribed antidepressants.	2020	Marselle, M. R., Bowler, D. E., Watzema, J., Eichenberg, D., Kirsten, T., & Bonn, A. (2020). Urban street tree biodiversity and antidepressant prescriptions. Sci Rep, 10(1), 22445. https://doi.org/10.1038/s41598-020-79924-5
In urban areas, higher tree density correlated with lower odds of depression in older adults.	2020	Nishigaki, M., Hanazato, M., Koga, C., & Kondo, K. (2020). What Types of Greenspaces Are Associated with Depression in Urban and Rural Older Adults? A Multilevel Cross-Sectional Study from JAGES. International Journal of Environmental Research and Public Health, 17(24), 9276. https://doi.org/10.3390/ijerph17249276
Concerning park experiences, trees are the most important nature element contributing to subjective well- being and connectedness to nature.	2021	Maurer, M., Zaval, L., Orlove, B., Moraga, V., & Culligan, P. (2021). More than nature: Linkages between well-being and greenspace influenced by a combination of elements of nature and non-nature in a New York City urban park. Urban Forestry & Urban Greening, 61, 127081. https://doi.org/10.1016/j.ufug.2021.127081
Higher stem densities and higher crown volumes are both associated with lower medication sales for Mood Disorders and Cardiovascular Disease, though opposing associations emerged in multifactor models.	2022	Chi, D., Aerts, R., Van Nieuwenhuyse, A., Bauwelinck, M., Demoury, C., Plusquin, M., Nawrot, T. S., Casas, L., & Somers, B. (2022). Residential Exposure to Urban Trees and Medication Sales for Mood Disorders and Cardiovascular Disease in Brussels, Belgium: An Ecological Study. Environmental Health Perspectives, 130, 57003. https://doi.org/10.1289/EHP9924
Situations of COVID-19 epidemic harmed mental health, analysis indicated the positive effects of residential tree canopy on psychological distress - results that may generalize to other public health stress situations.	2022	Zhang, C., Wang, C., Chen, C., Tao, L., Jin, J., Wang, Z., & Jia, B. (2022). Effects of tree canopy on psychological distress: A repeated cross-sectional study before and during the COVID-19 epidemic. Environmental Research, 203, 111795. https://doi.org/10.1016/j.envres.2021.111795
Models indicated presence of 20% tree canopy lowered the odds of developing dementia by 14% over 11 years and was mediated by other health behaviour factors.	2023	Astell-Burt, T., Navakatikyan, M. A., & Feng, X. (2023). Why might urban tree canopy reduce dementia risk? A causal mediation analysis of 109,688 adults with 11 years of hospital and mortality records. Health & Place, 82, 103028. https://doi.org/10.1016/j.healthplace.2023.103028

E. FOREST BATHING & THERAPY

Finding		Reference
A meta-analysis indicated forest bathing can significantly influence cortisol levels on a short term in such a way as to reduce stress.	2019	Antonelli, M., Barbieri, G., & Donelli, D. (2019). Effects of forest bathing (shinrin-yoku) on levels of cortisol as a stress biomarker: a systematic review and meta-analysis. International Journal of Biometeorology, 63, 1117-1134. https://doi.org/10.1007/s00484-019-01717-x
A review forest bathing on heart rate variability (indicative of health problems including heart conditions and mental health issues), with studies indicating activation of the parasympathetic nervous system and reduced anxiety.	2019	Farrow, M. R., & Washburn, K. (2019). A Review of Field Experiments on the Effect of Forest Bathing on Anxiety and Heart Rate Variability. Global Advances in Health and Medicine, 8. https://doi.org/10.1177/2164956119848654
For adults having depression tendencies, all forest bathing participants showed decrease in systolic and diastolic blood pressure and less negative mood states.	2019	Furuyashiki, A., Tabuchi, K., Norikoshi, K., Kobayashi, T., & Oriyama, S. (2019). A comparative study of the physiological and psychological effects of forest bathing (Shinrin-yoku) on working age people with and without depressive tendencies. Environmental Health and Preventive Medicine, 24(1), 46. https://doi.org/10.1186/s12199-019-0800-1
Cancer patients participating in forest therapy experienced better sleep efficiency and increased total sleep time.	2019	Kim, H., Lee, Y. W., Ju, H. J., Jang, B. J., & Kim, Y. I. (2019). An Exploratory Study on the Effects of Forest Therapy on Sleep Quality in Patients with Gastrointestinal Tract Cancers. International Journal of Environmental Research and Public Health, 16, 2449. https://doi.org/10.3390/ijerph16142449
Walking in forest settings (by male study participants) decreased mean cortisol concentrations, indicating reduced physiological stress.	2019	Kobayashi, H., Song, C., Ikei, H., Park, B.-J., Kagawa, T., & Miyazaki, Y. (2019). Combined Effect of Walking and Forest Environment on Salivary Cortisol Concentration. Frontiers in Public Health, 7, 376. https://doi.org/10.3389/fpubh.2019.00376
Students in an 8-week forest therapy program showed significant positive outcomes in emotional stability and positive thinking.	2019	Lee, J.-E., & Shin, W.-S. (2019). The Effects of Campus Forest Therapy Program on University Students Emotional Stability and Positive Thinking. Korean Journal of Environment and Ecology, 33(6), 748-757. https://doi.org/10.13047/kjee.2019.33.6.748
A review finding that forest bathing provides significant benefit for human health in relation to cardiovascular, immune, and neuro-endocrine function, as well as significant psychological benefit.	2019	Payne, M. D., & Delphinus, E. (2019). A Review of the Current Evidence for the Health Benefits Derived from Forest Bathing. International Journal of Health, Wellness & Society, 9(1), 19-30. https://doi.org/10.18848/2156-8960/CGP/v09i01/19-30
A review of forest bathing suggests many merits including improving physiological functions (cardiovascular, hemodynamic, neuroendocrine, metabolic, immunity and inflammatory, antioxidant, and electrophysiological) and mental health outcomes (enhanced emotional state, attitude, adaptive behaviours, and alleviation of anxiety and depression).	2019	Wen, Y., Yan, Q., Pan, Y., Gu, X., & Liu, Y. (2019). Medical empirical research on forest bathing (Shinrin-yoku): a systematic review. Environmental Health and Preventive Medicine, 24(1), 1-21.
The review indicates that forest therapy plays an important role in preventive medicine and stress management for all age groups.	2020	Rajoo, K. S., Karam, D. S., & Abdullah, M. Z. (2020). The physiological and psychosocial effects of forest therapy: A systematic review. Urban Forestry & Urban Greening, 54, 126744. https://doi.org/10.1016/j.ufug.2020.126744

Finding		Reference
Relative to many more conventional alternatives, forest therapy is a more effective short-term intervention for the prevention and treatment of depression in adults.	2021	Rosa, C. D., Larson, L. R., Collado, S., & Profice, C. C. (2021). Forest therapy can prevent and treat depression: Evidence from meta-analyses. Urban Forestry & Urban Greening, 57, 126943. https://doi.org/10.1016/j.ufug.2020.126943
Adolescents participating in an urban forest bathing program showed improvements in anxiety (13% reduction); rumination (44% reduction); skepticism (17% reduction); nature connection (25% increase); and social connection (12% increase).	2022	McEwan, K., Potter, V., Kotera, Y., Jackson, J. E., & Greaves, S. (2022). 'This Is What the Colour Green Smells Like!': Urban Forest Bathing Improved Adolescent Nature Connection and Wellbeing. International Journal of Environmental Research and Public Health, 19(23). https://doi.org/10.3390/ijerph192315594

F. PHYSICAL WELLNESS

Finding		Reference
Street tree cover was consistently protective for healthy weight status; every 10% increase in street tree cover within 2000 meters was associated with 18% lower odds of being overweight or obese.	2019	Tsai, W.-L., Davis, A. J. S., & Jackson, L. E. (2019). Associations between types of greenery along neighborhood roads and weight status in different climates. Urban Forestry & Urban Greening, 41, 104-107. https://doi.org/10.1016/j.ufug.2019.03.011
In a study in Barcelona, street trees and the presence of both blue and traditional green spaces were significant factors of increased walking levels.	2019	Vich, G., Marquet, O., & Miralles-Guasch, C. (2019). Green streetscape and walking: Exploring active mobility patterns in dense and compact cities. Journal of Transport & Health, 12, 50-59. https://doi.org/10.1016/j.jth.2018.11.003
The review summarized how forest exposure was beneficial to health, such as reducing systolic blood pressure, diastolic blood pressure, heart rate, sympathetic nervous activity, salivary cortisol, and increasing parasympathetic nervous activity. Meanwhile lower levels of systolic blood pressure and sympathetic nervous activity, and higher levels of parasympathetic nervous activity were associated with duration exposure to the forest, while lower levels of heart rate and higher levels of parasympathetic nervous activity were associated with methods of intervention with forest environment.	2021	Cheng, X., Liu, J., Liu, H., & Lu, S. (2021). A systematic review of evidence of additional health benefits from forest exposure. Landscape and Urban Planning, 212, 104123. https://doi.org/10.1016/j.landurbplan.2021.104123
Percent tree canopy cover was protective against the cardiovascular risk factors, particularly in census tracts with low percentages of the population living in poverty and with low percent non-Hispanic Black populations.	2021	Knobel, P., Kondo, M., Maneja, R., Zhao, Y., Dadvand, P., & Schinasi, L. H. (2021). Associations of objective and perceived greenness measures with cardiovascular risk factors in Philadelphia, PA: A spatial analysis. Environmental Research, 197, 110990. https://doi.org/10.1016/j.envres.2021.110990
Tree cover, as one element of neighbourhood greenery, was consistently associated with decreased odds of women being overweight or obese.	2021	Tsai, W.-L., Nash, M. S., Rosenbaum, D. J., Prince, S. E., D'Aloisio, A. A., Neale, A. C., Sandler, D. P., Buckley, T. J., & Jackson, L. E. (2021). Types and spatial contexts of neighborhood greenery matter in associations with weight status in women across 28 U.S. communities. Environmental Research, 199, 111327. https://doi.org/10.1016/j.envres.2021.111327

Finding		Reference
Significant reductions in non-accidental death and cardiovascular mortality were associated with tree plantings across 15 years, and association between tree planting and non-accidental mortality increased in magnitude as trees aged and grew.	2022	Donovan, G. H., Prestemon, J. P., Gatziolis, D., Michael, Y. L., Kaminski, A. R., & Dadvand, P. (2022). The association between tree planting and mortality: A natural experiment and cost-benefit analysis. Environment International, 170, 107609. https://doi.org/10.1016/j.envint.2022.107609
Tree canopy and NDVI were both significantly associated with higher life expectancy (across diverse communities in Los Angeles), suggesting the importance of equitable green space access.	2023	Connolly, R., Lipsitt, J., Aboelata, M., Yanez, E., Bains, J., & Jerrett, M. (2023). The association of green space, tree canopy and parks with life expectancy in neighborhoods of Los Angeles. Environment International, 173, 107785. https://doi.org/10.1016/j.envint.2023.107785
10% increase in tree canopy cover was associated with reduced risks of all-cause mortality, cardiovascular disease mortality, and fatal or non-fatal acute myocardial infarction.	2023	Feng, X., Navakatikyan, M. A., Toms, R., & Astell-Burt, T. (2023). Leafier Communities, Healthier Hearts: An Australian Cohort Study of 104,725 Adults Tracking Cardiovascular Events and Mortality Across 10 Years of Linked Health Data. Heart, Lung and Circulation, 32(1), 105-113. https://doi.org/10.1016/j.hlc.2022.10.018

G. EMERGENT BENEFITS, FUNCTIONS AND SERVICES

Finding		Reference
Forest and shrub covers were significantly and inversely associated with median Medicare fee-for-service spending with small effect sizes. Counties with more forest and shrub land cover may hold both health and economic benefits for the elderly and disabled.	2019	Becker, D. A., Browning, M. H. E. M., & Kuo, M. (2019). Is green land cover associated with less health care spending? Promising findings from county-level Medicare spending in the continental United States. Urban Forestry & Urban Greening, 41, 39-47.
Including participatory and informational activities re: urban orchards appear to increase impacts on the social dimensions of social capital and place attachment, and food and environmental knowledge.	2019	Colinas, J., Bush, P., & Manaugh, K. (2019). The socio-environmental impacts of public urban fruit trees: A Montreal case-study. Urban Forestry & Urban Greening, 45, 126132.
Increased vegetation height is protective of SGA (small for gestational age) births, but the greatest protection comes from landscapes with both high vegetation and variation in vegetation height. In contrast, homogenous landscapes such as grass fields (low-low landscape) or dense forests (high-low landscape) were not protective.	2019	Donovan, G. H., Gatziolis, D., Jakstis, K., & Comess, S. (2019). The natural environment and birth outcomes: Comparting 3D exposure metrics derived from LiDAR to 2D metrics based on the normalized difference vegetation index. Health & Place, 57, 305-312. https://doi.org/10.1016/j.healthplace.2019.05.011
Reviewing urban forest management plans from 47 municipalities in Canada, inclusion of urban food forests and related terms was very uneven, with less than one-third of the plans containing considerations.	2019	Kowalski, J. M., & Conway, T. M. (2019). Branching out: The inclusion of urban food trees in Canadian urban forest management plans. Urban Forestry & Urban Greening, 45, 126142.
Neighbourhoods with higher tree cover are perceived as safer than those with lower tree cover, and when accounting for neighbourhood socio-demographic deprivation, high-density neighbourhoods are viewed as similarly safe as low-density neighbourhoods.	2019	Mouratidis, K. (2019). The impact of urban tree cover on perceived safety. Urban Forestry & Urban Greening, 44, 126434. https://doi.org/10.1016/j.ufug.2019.126434

Finding		Reference
In a 44-article review, urban food forests food production was mentioned prominently, but also primary function mentioned, recreation, education, connection to nature, good social relations, and habitat value.	2019	Park, H., Kramer, M., Rhemtulla, J. M., & Konijnendijk, C. C. (2019). Urban food systems that involve trees in Northern America and Europe: A scoping review. Urban Forestry & Urban Greening, 45, 126360.
Childhood experience was significant in determining frequency of forest visits at adulthood, influencing development of better recreational habits.	2019	Taye, F. A., Abildtrup, J., Mayer, M., Ščasný, M., Strange, N., & Lundhede, T. (2019). Childhood experience in forest recreation practices: Evidence from nine European countries. Urban Forestry & Urban Greening, 46, 126471. https://doi.org/10.1016/j.ufug.2019.126471
Participants with more tree canopy (>/=30%) had lower incidence of recurring insufficient sleep in middle-to-older aged adults.	2020	Astell-Burt, T., & Feng, X. (2020). Does sleep grow on trees? A longitudinal study to investigate potential prevention of insufficient sleep with different types of urban green space. SSM-Population Health, 10, 100497. https://doi.org/10.1016/j.ssmph.2019.100497
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Finding		Reference
Municipal initiatives designed to reduce urban noise should account for tree features (such as crown footprint and mean crown height), and not just the number of trees or the overall amount of vegetation.	2021	Zhao, N., Prieur, J.-F., Liu, Y., Kneeshaw, D., Lapointe, E. M., Paquette, A., Zinszer, K., Dupras, J., Villeneuve, P. J., & Rainham, D. G. (2021). Tree characteristics and environmental noise in complex urban settings–A case study from Montreal, Canada. Environmental Research, 202, 111887.
Estimated the alignment between city tree species composition and foraging to identify useful tree species, species likely of interest to foragers, and species actively foraged, and estimate the relative abundance of species in each category.	2022	Hurley, P. T., Becker, S., Emery, M. R., & Detweiler, J. (2022). Estimating the alignment of tree species composition with foraging practice in Philadelphia's urban forest: Toward a rapid assessment of provisioning services. Urban Forestry & Urban Greening, 68, 127456. https://doi.org/10.1016/j.ufug.2021.127456
Higher rates of existing tree cover were associated with a 9% reduction of firearm violence. Simulation of 40% tree cover was associated with reductions, with the largest reductions in highly deprived neighbourhoods.	2022	Jay, J., Kondo, M. C., Lyons, V. H., Gause, E., & South, E. C. (2022). Neighborhood segregation, tree cover and firearm violence in 6 U.S. cities, 2015-2020. Preventive Medicine, 165, 107256. https://doi.org/10.1016/j.ypmed.2022.107256
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Increased neighbourhood greenspace accessibility and tree canopy cover were associated with reduced intentional deaths (i.e., homicides and suicides).	2023	Ryan, S. C., Sugg, M. M., & Runkle, J. D. (2023). Association between urban greenspace, tree canopy cover and intentional deaths: An exploratory geospatial analysis. Urban Forestry & Urban Greening, 86, 128015. https://doi.org/10.1016/j.ufug.2023.128015