

Delivering Technology to Assess and Promote Nature Exposure



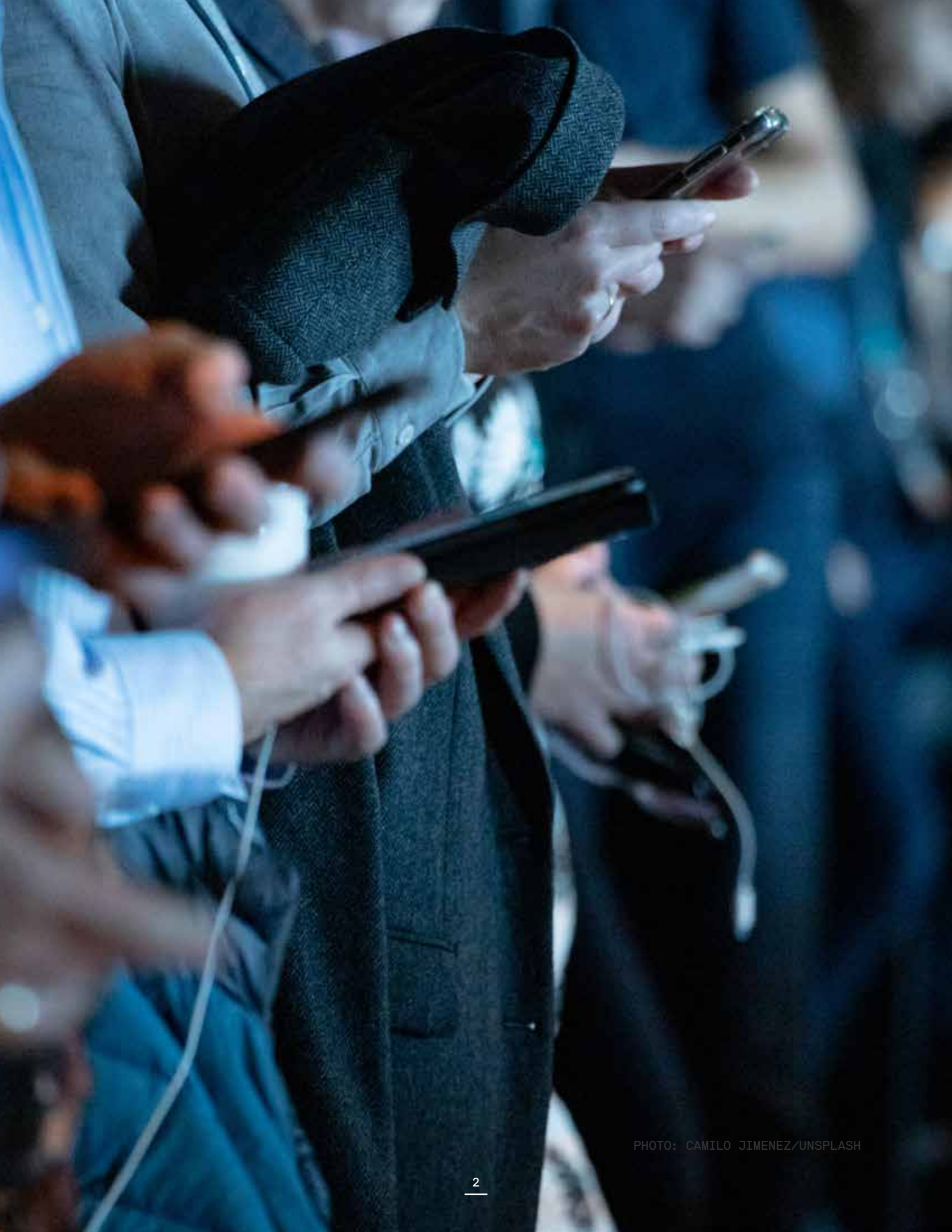


PHOTO: CAMILO JIMENEZ/UNSPLASH

Humanity is undergoing
a monumental shift,
rapidly moving from
a largely natural,
outdoor existence to
life in a more built,
urban surrounding.



Introduction

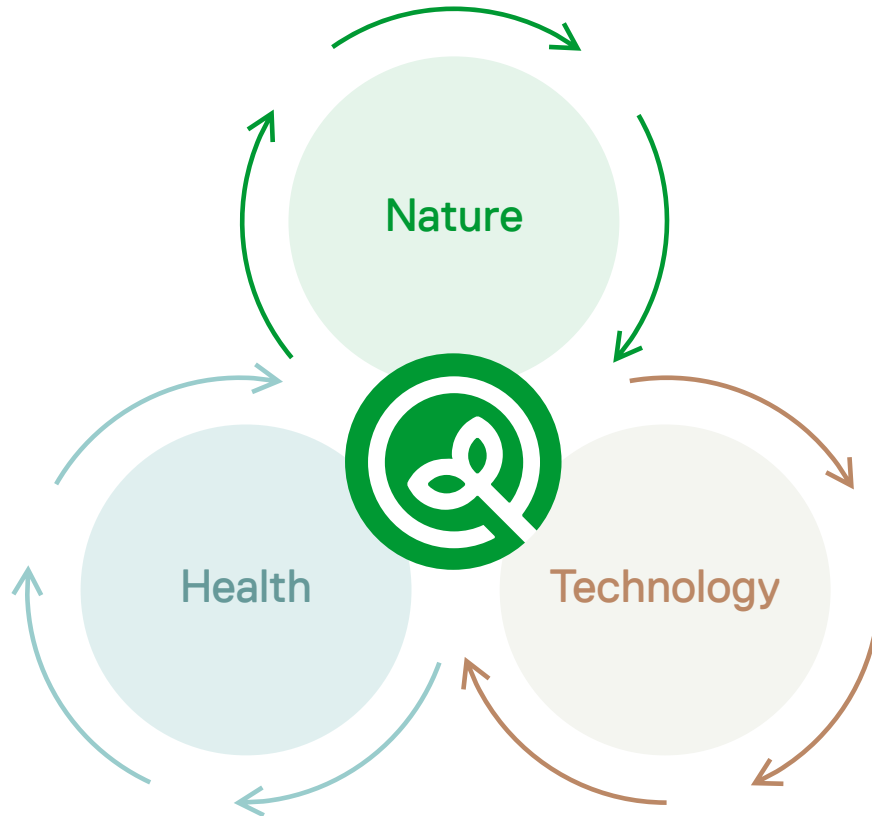
Humanity is undergoing a monumental shift, rapidly moving from a largely natural, outdoor existence to life in a more built, urban surrounding.

Our current “built environment” is dramatically different from the one we occupied for 99% of human history, as it physically separates us from the natural world. Most people—over half globally, and approximately four in five in the United States—live in urban areas, where nature exposure tends to be limited. This means that humans are increasingly disconnected from nature. In short, there is a growing nature deficit. As we have begun systematically studying the impact of this fundamental change, links between declining nature exposure and increasing depression, anxiety, heart disease, and obesity over the last five decades are becoming clear.

A large and growing body of scientific literature demonstrates that contact with nature (broadly defined as green space, trees, parks, forests, bodies of water, etc.) can lead to measurable psychological and physiological health benefits. Natural areas also have been linked to other positive effects, like improved property values, lower pollu-

tion, reduced crime rates, strengthened communities, and slowed viral and bacterial disease transmissions. On par with changes in exercise or diet, nature contact offers promise both as prevention and as treatment of many serious diseases. Additionally, potential advantages of nature exposure include almost zero-cost (relative to conventional medical interventions), safety, and practicality (not requiring individualized attention from highly trained professionals). Few, if any, medications or other interventions can boast these attributes.

However, few practical tools are available in areas like nature quantification, exposure assessment and tracking, integration of innovative data sources, and otherwise time-consuming analytical techniques. Additionally, we lack consensus around a standard measurement of nature or nature exposure. Finally, at least in the United States, there is limited public promotion or understanding of the benefits of nature.



Our Mission

NatureQuant, LLC was formed to create a suite of technologies that enhance the health impact of nature on humanity. Specifically, NatureQuant’s innovative tools quantify the natural elements for a static location (yielding a “NatureScore™”) and track an individual’s nature exposure over time (providing a “NatureDose™”).

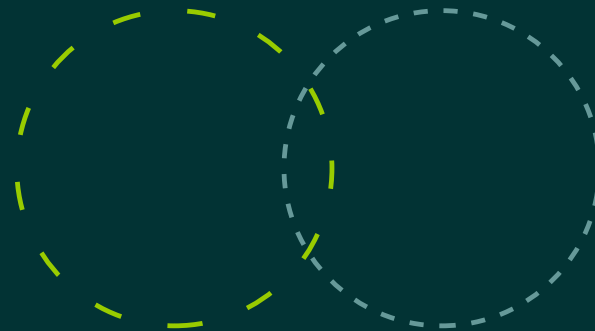
These tools will help us refine our understanding of the benefits of nature and promote the use of nature as a public health tool. The results of rich data will guide interventions across a wide range of settings, populations, spatial scales, and forms of nature. Individuals, health professionals, ecologists, landscape architects, parks staff, educators, governments, real estate owners, and many others will in turn be able to apply these results to improve health and well-being on a large scale.

The aim of NatureQuant is, therefore, to simplify and streamline how spatial scale, datasets, methods, and analytics regarding natural elements are currently applied.

As detailed later, NatureQuant’s techniques have proven to predict profound differences in longevity, obesity, high blood pressure, cardiovascular disease, cancers, and frequent mental distress simply by calculating nearby nature elements.



The Science Behind Nature Exposure and Health



GREENSPACE AND BLUESPACE

“Greenspace” is typically defined as undeveloped land with natural vegetation, although it also exists in many other forms, like urban parks, public open spaces, street trees, and landscaped plant-life. “Bluespace” is typically defined as the sea and ocean coasts, rivers, lakes, canals, waterfalls, and even some human-made water features. Much of the scientific literature lumps together exposure to both of these two categories, but there is also distinct research for the two types of natural spaces. To keep things simple, we have summarized the research, and we use “nature exposure” to refer to exposure to either greenspace or bluespace. Note, however, that in some disciplines the research is distinct.

Overwhelming evidence in the scientific literature links nature exposure to improvements in physiological and psychological human health. Over 150 observational studies and 100 interventional studies, tracking over 300 million individuals from 20 countries investigating 100 unique health outcomes, have convincingly demonstrated that greater nature exposure results in improvements in health span and longevity¹. In short, these studies prove that nature exposure can result in a longer, healthier, and even happier life.



HOW DOES NATURE HAVE SUCH A PROFOUND INFLUENCE ON HUMAN HEALTH?

We don't yet have the whole answer, but a number of associations and direct links are becoming clear. Part of the answer is that humans have become more separated from nature than ever before, with a dramatic shift worldwide to more people living in urban environments^{2,3}. This shift coincides with increases in the primary causes of death. According to the National Center for Health Statistics, in the United States the primary causes of death include heart and vascular disease, cancer, chronic respiratory disease, cerebrovascular disease (i.e., stroke), Alzheimer's and related dementias, and diabetes. While many of the underlying causes of these diseases are well known (for instance, sedentary lifestyle, poor eating habits, and chronic psychological stress), there are contributing or mediating factors as well, many of which are associated with a lack of nature exposure. Figure 1, displays data from a meta-analysis

demonstrating the strong relationship between nature exposure (specifically, greenspace) and improvements in all-cause mortality. A meta-analysis is an evidence-based study with a greater ability to extrapolate outcomes to the greater population than individual studies. What this meta-analysis demonstrates is that, consistently across a number of independent studies collectively investigating over 8 million people, a greater level of greenness surrounding a person's home was associated with living longer. Importantly, these epidemiological studies control for many potential alternative explanations (such as socio-economic status), definitively demonstrating the health benefits of nature exposure. As displayed in the graph, all studies and the combined data are shifted towards the level of greenness favoring all-cause mortality prevention.

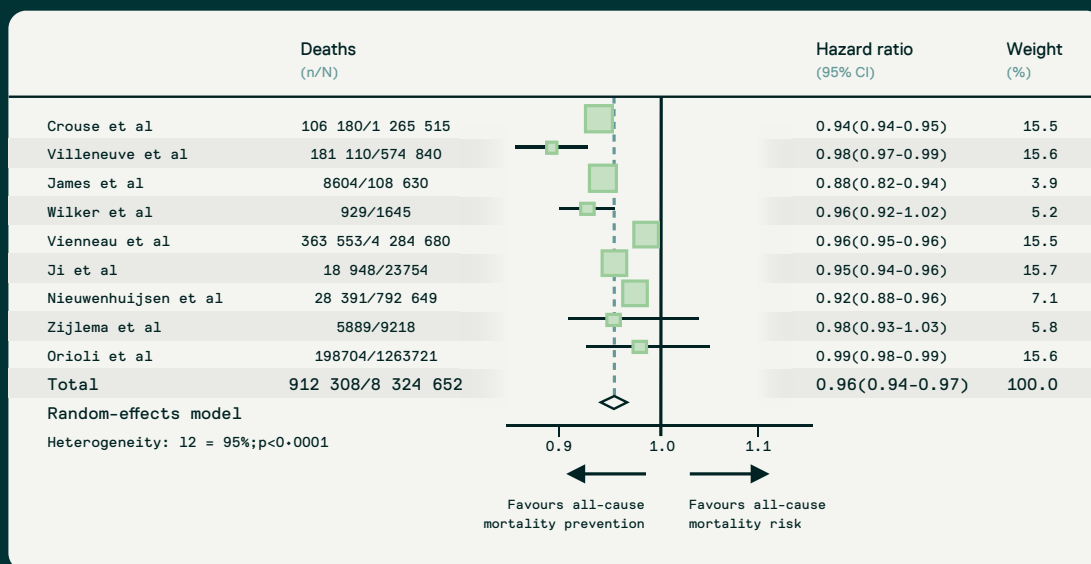


Figure 1.

Data from the meta analysis by Rojas-Rueda et al, 2019⁴. Association between greenness and all-cause mortality for each 0.1 increment of normalized difference vegetation index (NDVI) in less than 500 m from the participant's residence. The size of the square for each estimated hazard ratio in the plot is proportional to the weight of the study, which indicates its relative impact on the calculations of the common effect.

The relationships that underpin the health and longevity benefits of nature exposure are complex and multifaceted, and a number of psychophysiological and social pathways have been proposed that generally link the benefits of nature to health through improved air quality, increased physical activity, more frequent social

contacts, and decreased stress, to name just a few⁵. In an effort to simplify the empirical literature from distinct disciplines, four domains that emphasize different functions of nature have been proposed by Markevych et al(2017).⁶

1. Environmental Quality, 2. Physical Activity, 3. Social Contacts, and 4. Stress Reduction discussed (on the next page), and graphically represented in Figure 2 (below).

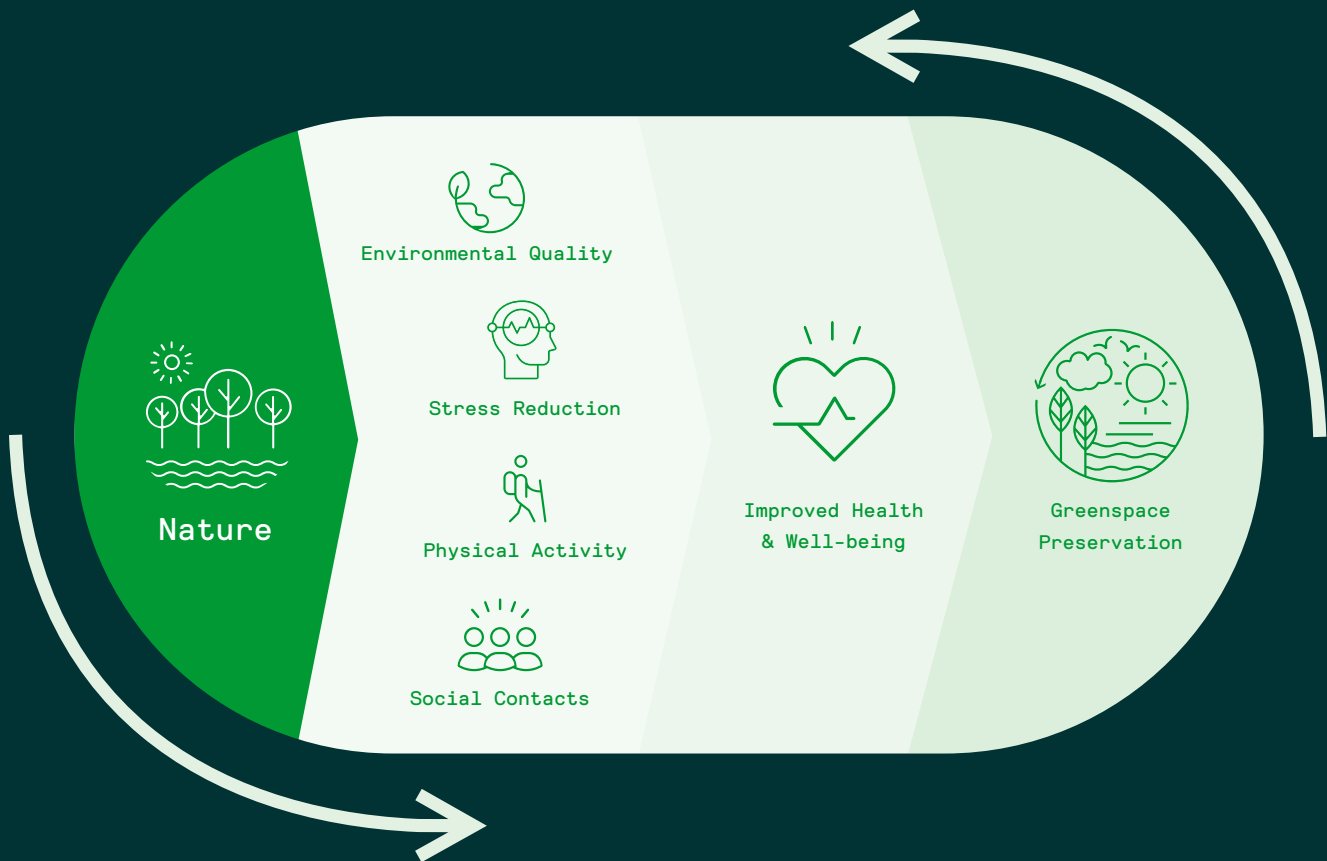


Figure 2. Domains linking Nature Exposure on the left side of the figure (including both greenspace and bluespace) to improved health and well-being.⁹

Access and exposure to natural environments impacts health and well-being within each of these domains through numerous physiological pathways, including lowering concentrations of cortisol, lowering heart rate and blood pressure, and decreasing sympathetic nerve activity and increasing parasympathetic activity^{23,24}. A growing body of evidence suggests this relationship is especially strong for low-income and nature deprived urban populations^{25,26}. Lower exposure to green space in these populations has been associated with a number of

lifestyle diseases such as obesity, Type II diabetes, osteoporosis, and stress-related illnesses such as depression, heart diseases, and mental fatigue^{22,25}.

Importantly, improved health and well-being supports the preservation or restoration of nature, allowing for a cycle of health and nature improvements. This comes from the perceived value of the natural environment in cities, pride in community, and improved property values.



ENVIRONMENTAL QUALITY

In this paradigm, Environmental Quality captures the benefits of the urban natural environment through the effects on air quality, noise reduction, reducing urban “heat island effects”, lowering building energy costs⁷, and improving microbial biodiversity. In terms of improving microbial biodiversity, use of greenspace in cities increases exposure to a range of micro-organisms, including bacteria, protozoa, and helminths, which are abundant in nature and may be important for the development of the immune system and the regulation of

inflammatory responses. This “old friends,” hypothesis proposes that lack of exposure to immunoregulatory microorganisms in modern urban societies is resulting in an epidemic of inflammatory disease, as well as psychiatric disorders in which chronic, low-level inflammation is a risk factor. Recent studies indicate that treatment with a specific soil bacterium, *Mycobacterium vaccae*, may alleviate depression and PTSD⁸. Lastly, nature promotes sustainability through habitats for urban wildlife and reducing flood risk by decreasing impervious surface area⁹.



STRESS REDUCTION

Stress Reduction encompasses the mental and physiological aspects of human health through reduction in stress. Given the links between mental and physical health, the importance of the natural environment on psychological health cannot be over emphasized^{10,11}. A number of studies link exposure to the natural environ-

ment with mental health benefits through mechanisms such as visibility of urban green spaces for rest and restoration¹²⁻¹⁵. Factors such as improved mood, self-esteem, reduced cognitive fatigue, greater attentional capacity and well-being, promoted emotional recovery, and reduced inflammation have all been reported^{12,16}.



INCREASING PHYSICAL ACTIVITY

Increasing Physical Activity occurs through having accessible, safe, and pleasing place to exercise and experience the natural environment. The benefit of exercise on health are very well known, and go beyond improvements in typical biomarkers such as blood pressure reduction, improved blood chemistry, and greater strength

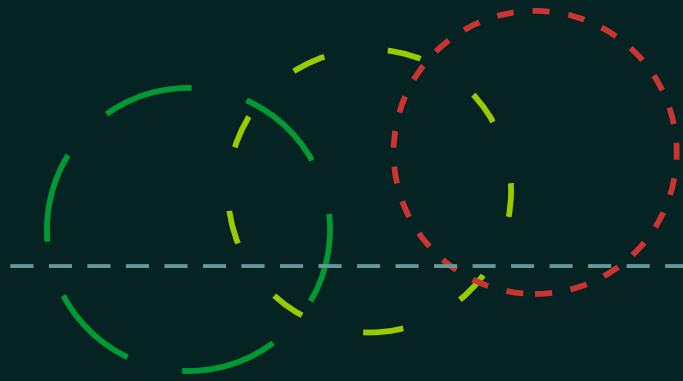
and endurance¹⁷. In this context, nature also plays an important role in creating a “culture of health,” defined as a culture that supports health improvement by fostering healthy, equitable communities that enable everyone to make healthy lifestyle choices.¹⁸



SOCIAL CONTACTS

Social Contacts describes the benefits of urban natural environments through improved social interactions among people¹⁹ and facilitating greater social cohesion²⁰. Nature contributes to improved social contacts through sense of community, with a focus on trust, shared norms and values, positive and friendly relation-

ships, and feelings of being accepted and belonging²¹. Residents in neighbourhoods with more and/or higher quality streetscape greenery experience less stress, more social cohesion, and spend more time on physical activity²².



INFLAMMATION AND HEALTH, COVID-19, AND NATURE EXPOSURE

One major contributing physiological factor linking many modern diseases through each of the domains is chronic low-grade inflammation, a well-described consequence of chronic psychological stress, poor eating habits, lack of sleep or recovery, exposure to pollutants, lack of physical activity, and social stress. Chronic low-grade inflammation is now recognized as a strong link between diabetes and cardiovascular disease²⁷.

Additionally, chronic low-grade inflammation disrupts overall immune function, including the ability to combat bacterial and viral infections²⁷. An example of the complex interplay between nature exposure and health outcomes through dysregulated immune function is depicted in Figure 3, modified from the review by Kuo²⁹:

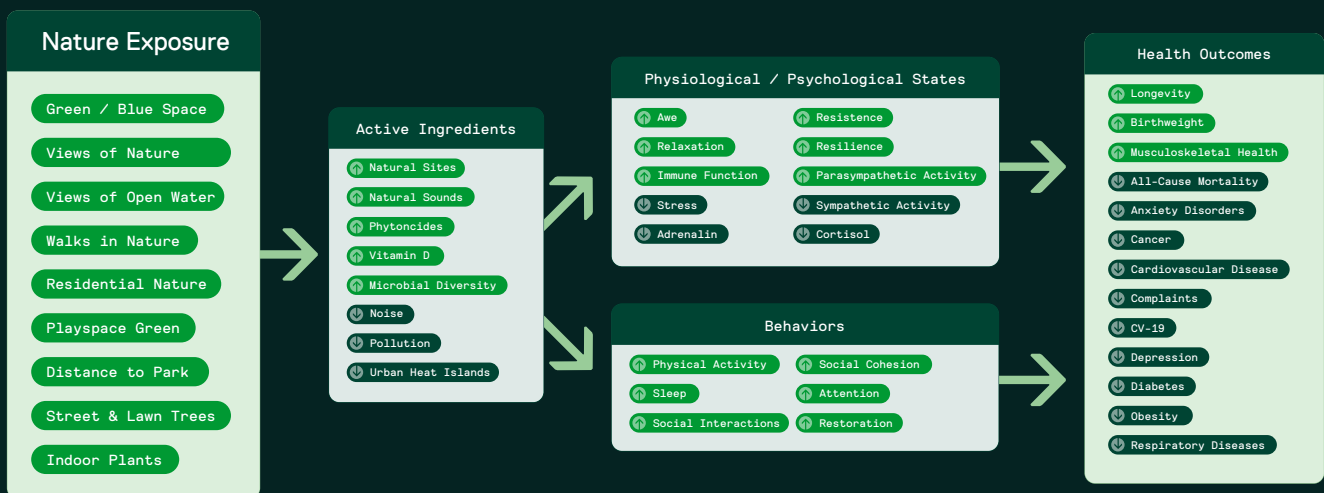


Figure 3.

Links between nature exposure and improved health outcomes. Multiple aspects of nature exposure from each of the domains work through key “ingredients” to improve physiological/psychological states and human behavior; in turn, that improves immune function, which has been linked to improved health outcomes.

By way of example, phytoncide exposure was found to significantly increase nature killer (NK) cell activity and significantly decrease concentrations of the stress hormones adrenaline and noradrenaline³⁰. Phytoncides are antimicrobial organic compounds released from plants and trees. NK cells are part of the innate immune system and contain viral infections until the adaptive immune response generates additional immune cells to clear an infection. Thus, NK cells play an important role in prevention of infections and chronic disease, whereas the stress hormones, when chronically elevated, can suppress overall immune function. The findings in this study indicate that phytoncide exposure and decreased chronic levels of stress hormone contribute to an overall improved immune function profile through multiple pathways.

While COVID-19 is too new to allow extensive information on associations between nature exposure and severity of the disease or mortality, strong associations have been reported between chronic respiratory disease, inflammation, and severity of symptoms and death rates from COVID-19. One study from the Harvard T.H. Chan School of Public Health found that an increase of only 1 μ g/m³ in air pollution is associated with an 8% increase in the COVID-19 death rate³¹. This suggests that someone who lives in an area with high levels of fine particulate pollution is significantly more likely to die from COVID-19 than someone who lives in a region with just one unit of pollution less. Additional recent data from China has determined that nearly every known infection (over 99.99%) initiated from contact in an indoor environment. Similarly, there is evidence that adequate Vitamin D levels are necessary for an effective vaccination response³². Sunlight is an essential aspect of Vitamin D synthesis within the body, and having nature close and available helps to encourage sun exposure.

Studies will likely demonstrate that those living with less access to natural environments are at heightened risk for exposure and severe symptoms or death from COVID-19.

While more time and precise location data is needed, as of July 2020, higher NatureScores™ appear to be linked to a slower spread of the coronavirus. NatureQuant™ analyzed data from the 500 largest U.S. counties by population and found that lower amounts of Nature, as determined by an average NatureScore™ for the area, was predictive of higher levels of cumulative COVID-19 cases on a per-capita basis.

While population density was the strongest predictor of cases per capita found, after controlling for population density, NatureScore™ had a statistically significant association with infection rates - (the multiple-R of population density and NatureScore™ with infection rates was 0.44).

The Nature Movement

The profound benefits of nature, in the U.S. at least, have received remarkably little public attention. However, this is rapidly changing.



Amazon's Nature Spheres
Photo: Patrick Schneider/Unsplash

A powerful movement is brewing among governments, health care providers, businesses, media, and social organizations whose mission is to improve public health through nature.

Our hospitals, clinics, and outpatient treatment centers are increasingly prescribing time in nature to help patients avoid growing heavier, sadder, or sicker. Research institutes for nature and health are opening at major medical centers, and now electronic health-record systems have begun to incorporate nature prescriptions just as they do pharmacological ones.

Recognizing nature as a potential low-cost intervention, health insurers (including Kaiser-Permanente, Aetna, and Blue Cross Blue Shield) have begun offering incentives for “nature prescriptions” and community nature programs.

Further, governments around the world fund nature programs and build parks to improve the health of their citizens. The USDA has published numerous reports on [Urban Nature for Human Health and Wellbeing](#). In the United States, city planners and public health officials are increasingly considering access to nature as a core component of urban planning.

Businesses are increasingly aware of their employees’ desire for access to green-space. To boost employee mental well-being and productivity, leading corporate campuses are incorporating “nature spaces” like Amazon’s “Nature Spheres.”

As embodiments of the “nature movement” have materialized and the science has solidified, more media outlets are advocating for the benefits of time in nature.



Forbes

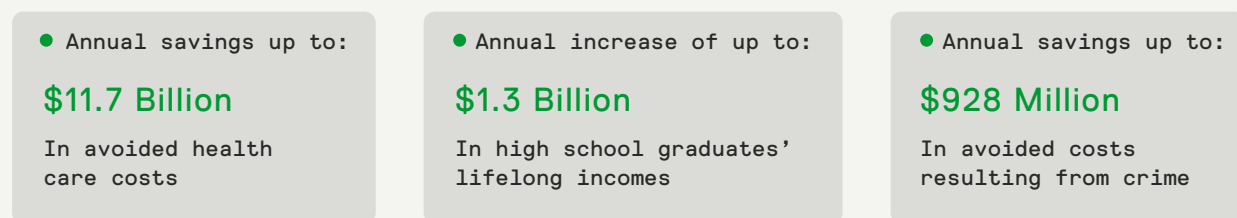
Yale



From a practical standpoint, quantifying the monetary value of things is important in our society. Anything not counted does not contribute to public decision making and becomes invisible. City trees are not grown and managed like products that can be bought and sold on markets, but they do provide many valuable services and benefits. Parks, gardens, and green spaces also provide intangible, but measurable, values. Economists, now understanding another layer of the benefits of nature exposure, have begun to incorporate nature into their models. Social scientists are gradually devising reliable nonmarket valuation methods to represent natural assets in communities' decision-making calculus.

A recent report ([Nature's Riches](#)) outlined the annual savings to society through a greater investment in nature near urban areas, including a few of the outcomes displayed below.

GREATER INVESTMENT IN THE NATION'S NEARBY NATURE COULD RETURN:



The report describes how community planners and leaders should plan and design with nature to improve wellness and quality of life, including how greater nearby-nature can have profound impacts on human physiological and cognitive health^{33,34}.

Additionally, several reports indicate that the presence of larger trees in yards and along streets can add from 3% to 15% to home values throughout neighborhoods. As noted later, NatureQuant's "NatureScore" has shown an average of a 15% price difference between the top and bottom scoring quintiles. Averaging the market effect of street trees on all house values across a major urban population can yield a total value increase of billions, which translates into potentially higher property tax revenues for the cities managing the trees. Homes that are adjacent to naturalistic parks and open spaces are valued at 8-20% higher than comparable properties, with the positive price effect declining to near zero about ½ mile away. One study found 7% higher rental rates for commercial offices having high-quality landscapes³⁵.

Nature may also reduce crime. In a study of public housing developments in Chicago, researchers found 52% fewer crimes reported near buildings surrounded by trees and other vegetation. Similar relationships between green space and crime have been observed in Baltimore, Chicago, Philadelphia, and Portland, as well as in cities outside the United States³⁶⁻³⁸.

A widespread, systematic, and evidence-based movement is now undeniably under way in recognition of these findings. The idea that a primary-care physician, psychiatrist, psychologist, or cardiologist might prescribe a park before a pill is quite new and disruptive. Determining property values by counting the trees on the street is a new approach. A company telling its employees to find greenspace for mental health is not yet a standard practice, but it is happening. Insurance companies offering a reduction in premiums if a person spends five hours a month outside is unconventional, but it is on the way.

We are at a tipping point. Health experts, researchers, and government officials are now proposing widespread changes aimed at bringing nature, and more nature, into people's everyday lives and surroundings.



The NatureQuant Advantage

Even with the strength of the existing science, there is a need for more cohort studies with better covariate data and improved nature assessments ^{39,40}.

Specifically, multiple exposure assessment methods would achieve a comprehensive evaluation of the association between nature and health⁴⁰. Additionally, we know relatively little about the optimal ‘dosage’ of nature for maximum possible improvements in health, well-being, social, and environmental benefits⁴¹. While 120 minutes of nature exposure per week will confer benefits⁴², the concept of dosage refers not only to time in nature, but also to the quantity, visibility, accessibility, and quality of that nature exposure. Also, the daily, weekly, or monthly nature exposure an individual receives from at home, during daily commutes, in work spaces, and through leisure time activities is unknown.

We need more comprehensive and detailed analytics of nature exposure. The comprehensive analytics of NatureQuant can substantially improve nature quantification, as well as track an individual’s daily exposure.



The NatureQuant Solution

PROCESS

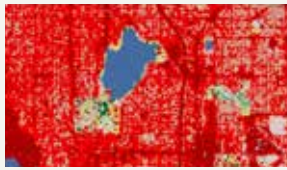
NatureQuant uses an evolving combination of inputs ranging from the immediate surroundings of the human body (10-100 meter), to the neighborhood scale (up to 500 meter), to the regional scale (1,000m+).

NatureQuant achieves this by merging various inputs, including land cover types, vegetation densities, vegetation seasonality, built city elements, and parks and open areas. This data is collected from various inputs, including aerial photography, NDVI values (the normalized difference vegetation index “NDVI” is a simple graphical indicator from a space platform used to assess whether the observed target contains live green vegetation), various GIS databases and open street maps, and various object based imagery analysis tools allowing review of aerial and street-level views.

Additionally, NatureQuant considers built environmental pollutions, like air quality, noise pollution, “urban heat islands”, and light pollution.

Green Lake, Seattle

47.6777895, -122.3510136



National Land Classification Database



Open Street Maps



Tree Canopy



Normalized Difference Vegetation Index (NDVI)



Light Pollution Map



Air Pollution Map



Sound Pollution



Computer Vision Street & Satellite Imagery

Figure 4.

Illustrative Data Sources. NatureQuant synthesizes this data to create a “NatureScore™ ” for any given location (see Figure 5) and to track an individual’s “NatureDose™,” the person’s exposure to nature over time and location. By applying evolving techniques to an ever-increasing body of health, location, and natural element databases, NatureQuant teases out the critical elements of exposure to optimize the health and monetary impacts of the tracking tools.

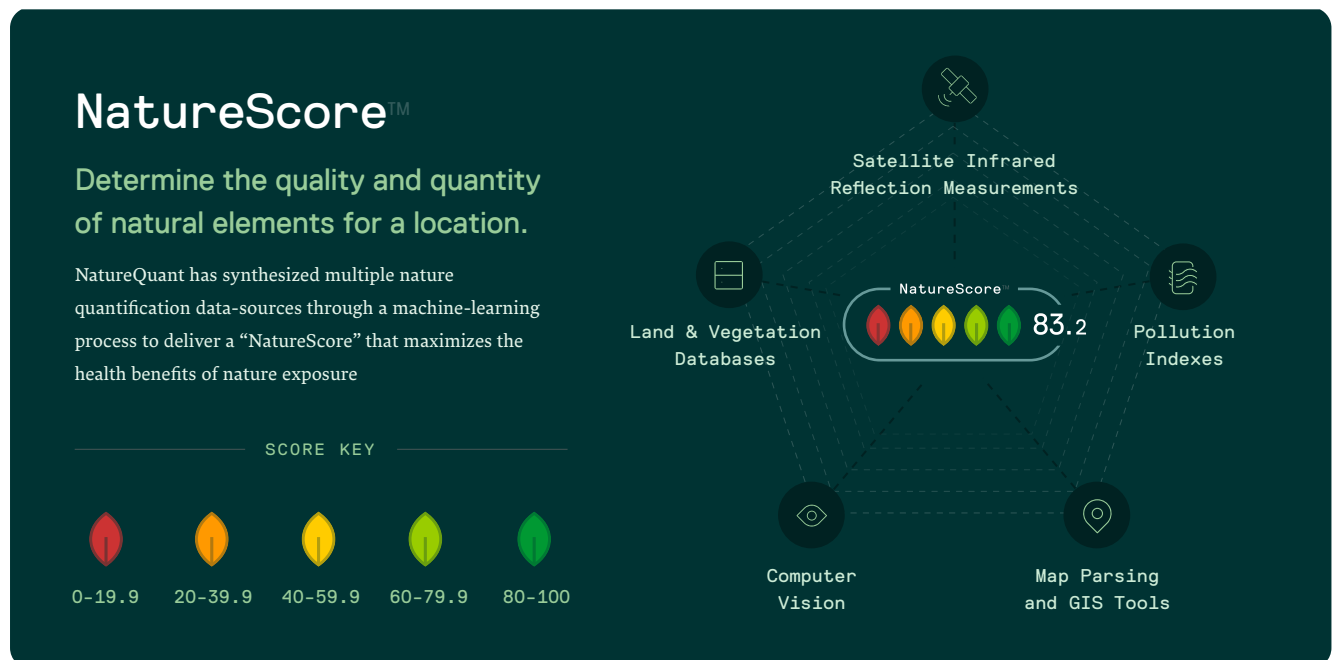


Figure 5.

The NatureScore™ for a given location is synthesized via machine-learning using multiple nature quantification data-sources as displayed that maximizes the health benefits of nature exposure to provide a numerical score between 0-100 and quintiles of one- to five-color-coded “leaves”.

Using dynamic, iterative technologies and machine learning, NatureQuant applied the NatureScore™ to national health data for over 30,000 census tracts and for the top 500 cities. As seen below, the NatureScore yielded powerful positive associations with longevity

and negative associations with poor health outcomes (cancer, diabetes, cardiovascular disease, etc.). In short, living in an area with a high NatureScore is strongly associated with enjoying a longer, healthier life.

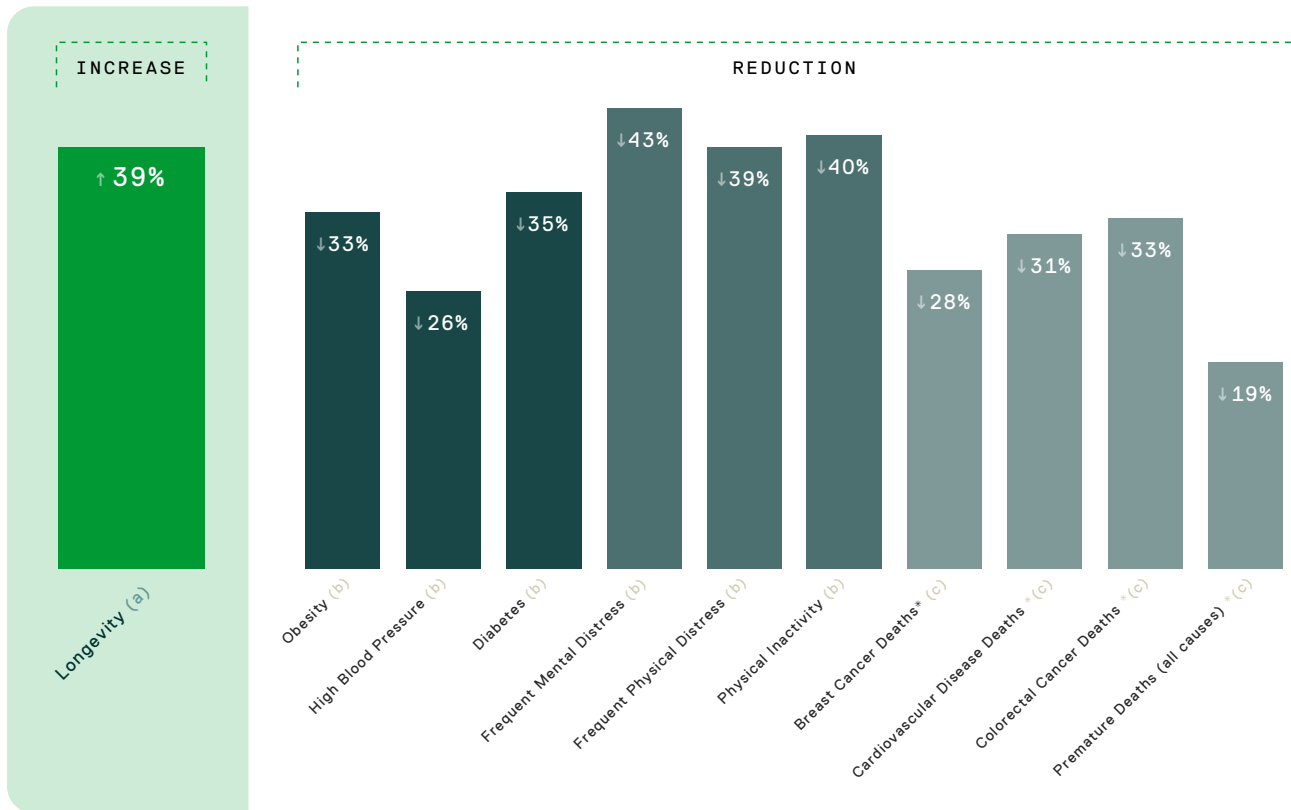


Figure 6.

NatureScore™ measurements derived from 29,296 census tracts and the 500 largest U.S. cities(*). Effect size represents the standardized mean difference between upper and lower quintiles divided by the standard deviation. NatureScore™ yielded powerful positive associations with longevity and negative associations with poor health outcomes (cancer, diabetes, cardiovascular disease, etc.). In short, living in an area with a high NatureScore™ is strongly associated with enjoying a longer, healthier life.

(a) U.S. Small-area Life Expectancy Estimates Project (USALEEP):

Life Expectancy Estimates File, National Center for Health Statistics. 2010-2017

(b) 500 Cities Project Data, Centers for Disease Control and Prevention. 2017

(c) Multiple Cause of Death Data, National Vital Statistics System, National Center for Health Statistics. Years of Collection: 2015-2017

APPLICATIONS

There are many promising applications for enhanced conformity in and access to quantified nature exposure. The technology could be used as a stand-alone product or as an added feature for existing applications and practices.



HEALTHCARE

While many health practitioners are already prescribing “time in nature,” tracking that nature exposure is limited to efforts like counting park visits. As previously noted, numerous studies have shown that simply living near nature improves health outcomes. Additionally, insurance companies are promoting time in nature but are not monitoring members’ exposure or providing incentives related to such exposure (like existing 10,000-step incentives). NatureQuant will enable real-time monitoring of nature exposure; it will also determine the amount of nature near a residence. By partnering with NatureQuant, health care providers and insurance companies can leverage and analyze nature’s positive effects on health and reduce overall health expenses.



DIRECT TO CONSUMER

A user’s ability to monitor her own time in nature will be helpful for personal fitness and medical goal setting and monitoring as well as the “gamification” of time outside. The applications will also provide educational and motivational features, for example via “daily tips” and “scoring/ranking systems.” Other elements, like maps/guidance to nearby natural areas, UV-exposure tracking, and vegetation guides, could be included. Note that, based on numerous studies, 120 minutes per week is a recommended minimum dose, with positive associations peaking at 200-300 minutes per week of nature exposure.



RESEARCH

NatureQuant and leading researchers will be able to determine the most impactful components of nature exposure through more robust and consistent data collection. NatureQuant’s AI-driven techniques may allow for more standardized protocols and methods for the evaluation of the impact of green-bluespace on health. NatureQuant will thus enhance the already widespread use of spatial data in greenspace/bluespace and health-related studies, offering valuable data to both

scholars and urban planners regarding the impact of urban design on health and wellbeing.

NatureQuant is already in discussions with numerous leading research institutions, including Harvard’s T.H. Chan School of Public Health, University of Washington’s EarthLab, the University of Oregon, and the Barcelona Institute for Public Health for the purposes of applying NatureQuant’s technologies to pioneering research.



FINANCIAL ANALYSIS

Given the strong associations NatureScore has shown with longevity and real estate prices, financial analysts could use NatureScore to improve their forecasting models. For example, total pension plan or annuity liability projections could be improved based on an understanding of the amount of nature near members’ homes. In a similar fashion, life or health insurance premiums could be adjusted. Real estate portfolios or mortgage-backed securities could also be analyzed based on the current or anticipated proximity to nature.



GOVERNMENT

Governments will be able to use NatureQuant’s tools for city planning, public health initiatives, tax assessment, and natural resource tracking/quantification.



NatureQuant will identify and assess the natural elements around any given real estate parcel for valuation and comparison purposes. Living in greener urban areas is associated with lower probabilities of cardiovascular disease, obesity, diabetes, asthma hospitalization, mental distress, and ultimately mortality among adults, and with lower risks of obesity and myopia in children. Nature-rich neighborhoods are also associated with better self-reported health and subjective well-being in

adults, and with improved birth outcomes and cognitive development in children. Nature spaces may also reduce the transmission rate of contagious diseases. Specifically, a recent meta-study involving eight-million people and seven countries found that for every 10% increase in vegetation within 1,600 feet of one's home, the probability of death drops by 4%⁴. As these results shape the public mindset, natural areas will increasingly affect real estate value.

NatureScore™ should be a basic component of any real estate assessment.

Furthermore, trees and other vegetation around a home add not only aesthetic appeal but also can provide shade during the summer and wind protection in the winter. And they can offer visual privacy and mitigate sound. Beyond the health benefits, all these additional factors translate into increased property values. By way of example, a study in Toronto, Canada⁴³ concluded that living in a home with ten or more trees in a city block, on average, **improves health perception as much as earning \$10,000 more per year or being seven years younger.**

Proprietary research using the NatureScore techniques and home sales in 2019 has shown up to 50% increases in property values for some regions when comparing the upper and lower quintile of scores. This correlation between property value and NatureScore could be used to assess real estate portfolios, mortgage-backed securities, lender risks, and tax assessor projections. Furthermore, for those seeking a healthy environment for their family, the NatureScore tool can provide unique data and screening abilities.

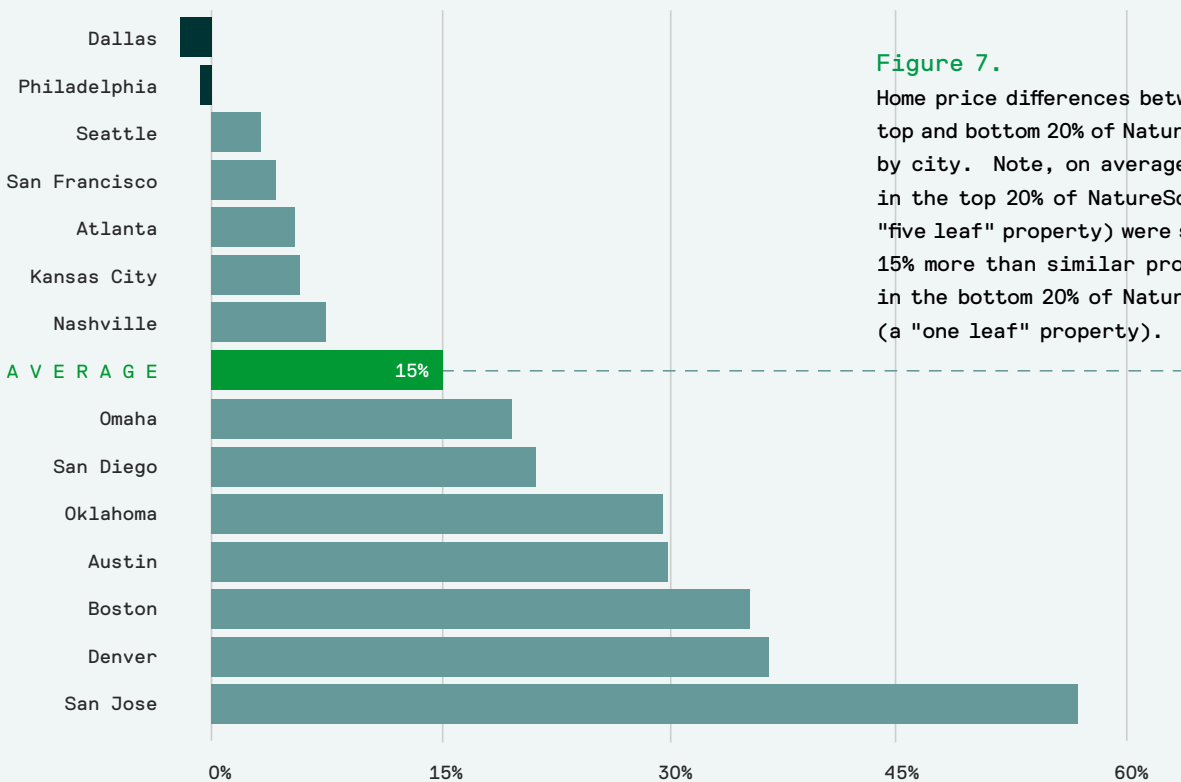


Figure 7. Home price differences between the top and bottom 20% of NatureScores by city. Note, on average, homes in the top 20% of NatureScores (a "five leaf" property) were sold for 15% more than similar properties in the bottom 20% of NatureScores (a "one leaf" property).

Data represent relative home price sales between the top and bottom quintiles of NatureScores by city. Over 80k transactions analyzed in aggregate.



BUSINESS

NatureQuant’s ability to track an individual’s nature exposure will complement many other physical health, mental health, and fitness apps, like activity trackers, meditation apps, psychiatry apps, and therapy apps.

NatureQuant will also be able to partner with corporations seeking to broadly enhance worker health and productivity through nature.

Many businesses are recognizing that health is material to the bottom line: Research shows that when organizations support the health of their most valuable assets (the people), they often experience lower turnover and burnout as well as greater productivity and employee engagement.

Furthermore, health is currently underrepresented in the capital markets. While the investment community has historically failed to acknowledge the materiality of health to organizations, it is increasingly becoming recognized as an important component of sustainable investing frameworks like ESG.

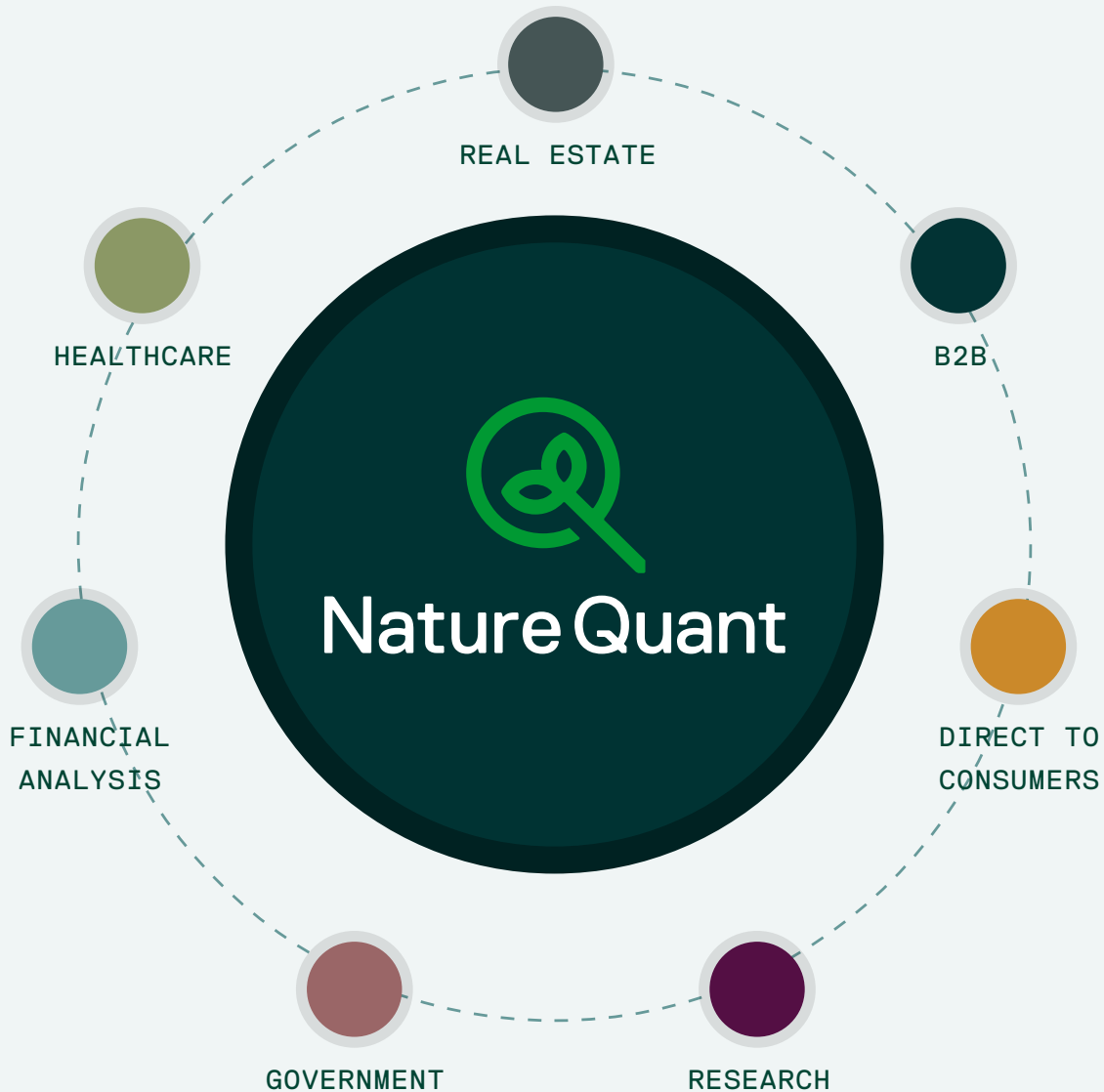


Figure 8. This diagram symbolizes the various disciplines in which NatureQuant can play a role in behavioral and economic applications.

IT IS CLEAR:

Nature exposure is not a luxury. It is a necessity.

NatureQuant analyzes nature's impact to help improve health and well-being on a large scale. Great advances in public health do not always come from the healthcare industry. They often come from the recognition of elements of our environment that are detrimental or beneficial to our well-being, like smoking, exercise, or diet. Nature exposure is next, and NatureQuant will help guide the way to a healthier future.

Humanity's shift to an indoor life spent predominately in cities is dramatic. The sudden loss of interaction with nature is affecting our physiology and psychology in ways that we are just starting to comprehend. Given the burgeoning recognition of the value of exposure to nature, NatureQuant seeks to further the development of strategies and interventions for the use of natural spaces through innovative technology. NatureQuant's tools should encourage practitioners, policymakers, businesses, and individuals to consider how they can create, maintain, use, promote, and improve access to nature.

NatureQuant's mission is to help solve humanity's increasing nature deficit through a suite of technologies that enhances the health-promoting impacts of nature.



Partnerships & Contact

NatureQuant seeks to partner with leading businesses, governments, and research institutions to explore ways to leverage new software, mobile apps, and data sources.

info@naturequant.com

www.naturequant.com

References

1. Twohig-Bennett, C. & Jones, A. The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environ. Res.* 166, 628–637 (2018).
2. Nieuwenhuijsen, M. J. Urban and transport planning, environmental exposures and health-new concepts, methods and tools to improve health in cities. *Environmental Health: A Global Access Science Source* vol. 15 S38 (2016).
3. World Cities Report 2016: Urbanization and Development - Emerging Futures | UN-Habitat. <https://unhabitat.org/world-cities-report>.
4. Rojas-Rueda, D., Nieuwenhuijsen, M. J., Gascon, M., Perez-Leon, D. & Mudu, P. Green spaces and mortality: a systematic review and meta-analysis of cohort studies. *Lancet Planet. Heal.* 3, e469–e477 (2019).
5. Hartig, T., Mitchell, R., de Vries, S. & Frumkin, H. Nature and Health. *Annu. Rev. Public Health* 35, 207–228 (2014).
6. Markevych, I. et al. Exploring pathways linking greenspace to health: Theoretical and methodological guidance. *Environmental Research* vol. 158 301–317 (2017).
7. Bowler, D. E., Buyung-Ali, L. M., Knight, T. M. & Pullin, A. S. A systematic review of evidence for the added benefits to health of exposure to natural environments. <http://www.biomedcentral.com/1471-2458/10/456> (2010).
8. Reber, S. O. et al. Immunization with a heat-killed preparation of the environmental bacterium *Mycobacterium vaccae* promotes stress resilience in mice. *Proc. Natl. Acad. Sci. U. S. A.* 113, E3130–E3139 (2016).
9. Approaches to Water Sensitive Urban Design: Potential, Design, Ecological ... - Google Books. <https://bit.ly/3feFebe>
10. Gascon, M. et al. Mental health benefits of long-term exposure to residential green and blue spaces: A systematic review. *International Journal of Environmental Research and Public Health* vol. 12 4354–4379 (2015).
11. Alcock, I., White, M. P., Wheeler, B. W., Fleming, L. E. & Depledge, M. H. Longitudinal effects on mental health of moving to greener and less green urban areas. *Environ. Sci. Technol.* 48, 1247–1255 (2014).
12. Nielsen, H. & Bronwen Player, K. M. Urban Green Space Interventions and Health. <http://www.euro.who.int/pubrequest> (2009).
13. Peschardt, K. K. & Stigsdotter, U. K. Evidence for designing health promoting pocket parks. *Archnet-IJAR* 8, 149–164 (2014).
14. Bratman, G. N. et al. Nature and mental health: An ecosystem service perspective. *Science Advances* vol. 5 (2019).
15. Dillen, S. van, Vries, S. de, Groenewegen, P. & Spreeuwenberg, P. Greenspace in urban neighbourhoods and residents' health: Adding quality to quantity. (2011).
16. Astell-Burt, T., Mitchell, R. & Hartig, T. The association between green space and mental health varies across the lifecourse. a longitudinal study. *J. Epidemiol. Community Health* 68, 578–583 (2014).
17. Joyner, M. J. & Green, D. J. Exercise protects the cardiovascular system: Effects beyond traditional risk factors. *Journal of Physiology* vol. 587 5551–5558 (2009).
18. Building a Culture of Health - RWJF. <https://www.rwjf.org/en/how-we-work/building-a-culture-of-health.html>.

19. Sturm, R. & Cohen, D. Proximity to urban parks and mental health. *J. Ment. Health Policy Econ.* 17, 19 (2014).
20. Jennings, V. & Bamkole, O. The relationship between social cohesion and urban green space: An avenue for health promotion. *Int. J. Environ. Res. Public Health* 16, (2019).
21. orrest, R. & Kearns, A. Social Cohesion, Social Capital and the Neighbourhood. *Urban Studies* vol. 38 2125–2143.
22. Gladwell, V. F., Brown, D. K., Wood, C., Sandercock, G. R. & Barton, J. L. The great outdoors: How a green exercise environment can benefit all. *Extreme Physiology and Medicine* vol. 2 3 (2013).
23. Jo, H., Song, C. & Miyazaki, Y. Physiological benefits of viewing nature: A systematic review of indoor experiments. *International Journal of Environmental Research and Public Health* vol. 16 (2019).
24. Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T. & Miyazaki, Y. The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventive Medicine* vol. 15 18–26 (2010).
25. Mitchell, R. & Popham, F. Effect of exposure to natural environment on health inequalities: an observational population study. *Lancet* 372, 1655–1660 (2008).
26. Maas, J. et al. Morbidity is related to a green living environment. *J. Epidemiol. Community Health* 63, 967–973 (2009).
27. Lopez-Candales, A., Hernández Burgos, P. M., Hernandez-Suarez, D. F. & Harris, D. Linking Chronic Inflammation with Cardiovascular Disease: From Normal Aging to the Metabolic Syndrome. *J. Nat. Sci.* 3, (2017).
28. Kaspersen, K. A. et al. Low-Grade Inflammation Is Associated with Susceptibility to Infection in Healthy Men: Results from the Danish Blood Donor Study (DBDS). *PLoS One* 11, e0164220 (2016).
29. Berman, M. G., Mukherjee, S., Horton, T. H. & Kuo, M. How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Front. Psychol* 6, 1093 (2015).
30. Li, Q. et al. Effect of phytoncide from trees on human natural killer cell function. *Int. J. Immunopathol. Pharmacol.* 22, 951–959 (2009).
31. Wu, X. et al. Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study. doi:10.1101/2020.04.05.20054502.
32. Kashi, D. S. et al. Vitamin D and the hepatitis B vaccine response: a prospective cohort study and a randomized, placebo-controlled oral vitamin D3 and simulated sunlight supplementation trial in healthy adults. *Eur. J. Nutr.* 1–17 (2020) doi:10.1007/s00394-020-02261-w.
33. Wolf, K. L. Nature's Riches: The Health and Financial Benefits of Nearby Nature.
34. Wolf, K. L., Measells, M. K., Grado, S. C. & Robbins, A. S. T. Economic values of metro nature health benefits: A life course approach. *Urban For. Urban Green.* 14, 694–701 (2015).
35. A variety of benefits and costs associated with urban forests and landscape trees have been explored (Dwyer et al.
36. Garvin, E. C., Cannuscio, C. C. & Branas, C. C. Greening vacant lots to reduce violent crime: A randomised controlled trial. *Inj. Prev.* 19, 198–203 (2013).
37. Troy, A., Morgan Grove, J. & O'Neil-Dunne, J. The relationship between tree canopy and crime rates across an urban-rural gradient in the greater Baltimore region. *Landsc. Urban Plan.* 106, 262–270 (2012).
38. Donovan, G. H. & Prestemon, J. P. The Effect of Trees on Crime in Portland, Oregon. *Environ. Behav.* 44, 3–30 (2012).

39. Dadvand, P. et al. Green spaces and General Health: Roles of mental health status, social support, and physical activity. *Environ. Int.* 91, 161–167 (2016).
40. Labib, S. M., Lindley, S. & Huck, J. J. Spatial dimensions of the influence of urban green-blue spaces on human health: A systematic review. *Environmental Research* vol. 180 (2020).
41. Ward Thompson, C. et al. More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landscape Urban Plan.* 105, 221–229 (2012).
42. White, M. P. et al. Spending at least 120 minutes a week in nature is associated with good health and wellbeing. *Sci. Rep.* 9, (2019).
43. Kardan, O. et al. Neighborhood greenspace and health in a large urban center. *Sci. Rep.* 5, (2015).

