

Benefits of Plants to Humans and Urban Ecosystems

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The link between horticulture and health and well-being has been scientifically documented for centuries. In 1812, psychiatrist, professor, and Declaration of Independence signer Dr. Benjamin Rush reported in his book *Medical Inquiries and Observations, Upon the Diseases of the Mind* (Rush 1812) that patients “digging in the dirt” fared better than their nongardener counterparts.

Since then, hundreds of peer-reviewed scientific studies have been published documenting benefits of active (e.g., gardening/landscaping) and passive (e.g., viewing nature through a window, taking a walk in a park) interactions between people and plants and the value of plants in urban ecosystems (fig. 1). We draw on many of those studies, from these literature reviews:

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Figure 1. Scientific studies have documented many benefits of interactions between people and plants, even passive interactions such as walking through a park or viewing nature. *Photo:* Janet Hartin.

- Howarth et al. 2020: An overview of seventy-seven peer-reviewed journal articles that identifies thirty-five positive outcomes linking physical and mental health and well-being to active and passive horticultural interactions
- Soga et al. 2017: A meta-analysis of twenty-two studies examining mental health outcomes related to gardening, including mood, group cohesiveness, cooperation, pride, and well-being
- Tillmann et al. 2018: A review of thirty-five published papers that link mental health benefits in youth to interactions with nature
- Coventry et al. 2021: A review and meta-analysis of fifty research papers connecting interactions with nature with improved mental and physical health in youth and adults, including older adults with chronic conditions
- Twohig-Bennett and Jones 2018: A review of 143 studies linking green space exposure to improved physical health outcomes
- Shepley et al. 2019: An overview of forty-five studies that identify links between well-designed and -maintained urban green spaces and reduced crime and enhanced cohesiveness in low-wealth urban neighborhoods
- Cruz-Piedrahita et al. 2020: A review of 120 papers that report public health benefits from urban horticulture activities, including activities with a specific focus on social cohesion or social capital
- Alizadeh and Hitchmough 2019: A synthesis of 106 research papers regarding the ecosystem services and benefits of trees and other plants to people and urban environments

Physical Health Benefits

Planting, trimming, raking, weeding, and participating in other gardening and landscaping activities expend calories through physical exertion. Adults burn between 220 and 500 calories per hour engaging in these horticultural activities (Harvard Health Publishing 2021). The actual amount of exercise and calories used varies by age, weight, metabolism, and other factors, as well as the specific type of activity.

Adopting an active lifestyle can reduce the incidence and risk of at least thirty-five chronic conditions, including diabetes, cardiovascular diseases and strokes, many forms of cancer, osteoporosis, and

Horticulture Therapy

Horticulture therapy involves active engagement in horticultural activities by clients facilitated by a registered horticultural therapist with specific rehabilitation or vocational goals (AHTA 2015). Often these activities are developed by a team of medical professionals working with the horticultural therapist, all of whom provide oversight. Results of research measuring the success of these efforts indicate that, in many cases, participants do recover more quickly and more fully from physical, emotional, and psychological conditions than people with the same conditions who do not participate in horticulture therapy (Diamant and Waterhouse 2010; Jarrott and Gigliotti 2010; Kamioka et al. 2014; Mizuno-Matsumoto et al. 2008; Söderback et al. 2004; Spring et al. 2011; Tu 2022). Adherence to recommended therapeutic horticulture regimes can also lead to greater independence and autonomy (Gonzalez et al. 2010; Kamioka et al. 2014).

osteoarthritis (Booth et al. 2012; Lubber and Lemery 2015). Gardening provides opportunities for exercise that are consistent with the U.S. Department of Health and Human Services physical activity recommendations of 150 minutes a week of moderate-intensity aerobic activity for adults and 60 minutes a day of moderate-intensity aerobic activity for children 6 to 18 years old (HHS 2018). Researchers have also linked active gardening to improved bone density, strength, and lower body mass indices (Alaimo et al. 2015; Park et al. 2019; Zick et al. 2013).

The presence of trees and other plants in urban areas can also reduce the risk of cardiovascular and respiratory diseases, heatstroke, and asthma due to cooler urban heat islands and lower concentrations of air pollutants (Alizadeh and Hitchmough 2019; Twohig-Bennett and Jones 2018; Tzoulas et al. 2007; Waring et al. 2020; Yeager et al. 2018). Consequences of a warming climate often disproportionately impact those living in cities, and particularly disadvantaged communities with dense living conditions and few trees shading and cooling urban heat islands (Bikomeye et al. 2021; Grove et al. 2014; IPCC 2018; Locke et al. 2021; Mearns and Norton 2009; Nadkarni et al. 2017; Schwarz et al. 2014). With deaths from heatstroke on the rise due to the impacts of climate change (Lubber and Lemery 2015), increasing tree

canopy cover is important since shade from mature trees can reduce the temperature of asphalt surfaces, by more than 60°F in inland and desert climates (Hartin 2021), and surrounding air temperatures by up to 15°F if the trees are well placed to avoid heat being trapped within interlinked canopies (Oke 2010; Pauleit et al. 2017).

Even passive interactions with nature have been found to improve health. A groundbreaking research study documenting the benefits of passive interaction between people and plants compared patients recovering from gall bladder surgery who had views of landscape plants with patients recovering from the same surgery in the same facility who had views of a brick wall (Ulrich 1984). Patients with landscape views had fewer surgical complications, shorter hospital stays, required fewer analgesics, were happier, and had fewer negative remarks entered in their daily medical records by hospital staff. Since then, hundreds of replicated studies building on this research and documenting the benefits of people/plant interactions have been summarized in literature reviews (Coventry et al. 2021; Howarth et al. 2020; Twohig-Bennett and Jones 2018).

Food gardeners reap many benefits. Eating three or more servings of fresh fruit and vegetables daily is an important part of a healthy diet. Consumption of fresh fruit and vegetables has been found to be higher among backyard, community, and school gardeners than among nongardeners (Alaimo et al. 2008; Alaimo et al. 2015). Youth who participate in gardening activities at school, in after-school programs, at home, or at community gardens are also more likely to eat a wider variety of produce than nongardening youth (Alaimo et al. 2008; Alaimo et al. 2015; Evans et al. 2012; McAleese and Rankin 2007; Morris and Zidenberg-Cherr 2002; Parmer et al. 2009; Wang et al. 2010). Household participation in a community garden is also linked to increased consumption of fresh produce among nongardening family members (Alaimo 2008; Wells et al. 2018).

Growing food or having access to fresh local produce increases food security. The definition of food security is that all members of a household “have consistent, dependable access to enough food for active, healthy living” (Coleman-Jensen et al. 2022). Nearly 10 percent of Californians report being low or very low food secure, with people of color disproportionately impacted (Coleman-Jensen et al. 2022). Many backyard and community gardeners donate some or

all of their produce to food banks, distribution centers, and homeless shelters and often choose to grow and share produce high in nutritive value and expensive to purchase or less available in local markets and grocery stores (Dyg et al. 2020).

LA Sprouts

LA Sprouts was a 12-week experiential after-school program in Los Angeles, offered for 90 minutes each week, that combined gardening, nutrition education, and cooking. Partners included University of Southern California, Los Angeles Unified School District, LA's BEST Afterschool Enrichment Program, and UC Master Gardener volunteers in Los Angeles County. One hundred and four fourth- and fifth-grade students participated in the program (fig. 2). In 2010, researchers found that participating students increased their dietary fiber intake and had lower diastolic blood pressure than nonparticipants. Participants with higher-than-desired body mass indices (BMI) at the beginning of the program reduced BMI and gained less weight by the program's conclusion than nonparticipants (Davis et al. 2011). Participants also had a greater preference for garden-grown produce than nonparticipants, including three target vegetables and fruit, and more often agreed with the statement that “vegetables from the garden taste better than vegetables from the store” than nonparticipants (Gatto et al. 2012).



Figure 2. Youth gardeners enjoyed participating in the LA Sprouts gardening, nutrition education, and cooking experiential after-school program in Los Angeles. *Photo:* LA Sprouts.

Curriculum for Elementary Students

Nutrition to Grow On (2nd edition) offers free integrated garden and nutrition lessons oriented to fourth- through sixth-grade students. Developed by Jennifer Morris and Sheri Zidenberg-Cherr, Department of Nutrition, UC Davis, it provides nine lessons linked to California academic content standards in science, mathematics, language arts, history, environmental studies, nutrition, and health. <https://cns.ucdavis.edu/sites/g/files/dgvnsk416/files/inline-files/ntgo2013.pdf>

Cognitive Functioning Benefits

Several studies link participation in landscaping and gardening activities to enhanced cognitive functioning (Bratman et al. 2012; Dadvand et al. 2015; Kuo et al. 2021; Ohly et al. 2016; Park et al. 2019; Stevenson et al. 2018). Research conducted by Kuo and Sullivan (2001) and Mayer et al. (2009) found that exposure to nature in urban settings can enhance attention span, working memory, and concentration. Both youth and adults who participate in landscaping and gardening projects were also found to have higher cognitive functioning in the areas of short- and long-term memory, focus, and concentration (Dadvand et al. 2015; Markevych et al. 2019; Matsuoka 2010; Meuwese et al. 2021; Park et al. 2019; Stevenson et al. 2018) and reported reduced symptoms of attention-deficit/hyperactivity disorder (ADHD) (Faber Taylor and Kuo 2011).

Other studies summarized in a literature review (Williams and Dixon 2013) found that kindergarten and middle-school students who participated in school gardening activities linked to classroom learning in biology, nutrition, mathematics, and other subjects earned higher grades and attained greater academic achievement than nonparticipants. A recent study linked high tree canopy coverage on school grounds with higher achievement scores in math and reading in middle-school students across a wide range of socioeconomic and ethnic backgrounds (Kuo et al. 2021).

Due to its multisensory nature, the experiential (hands-on) learning that occurs in school gardens can also bridge the achievement gap between traditional and nontraditional learners (Kolb and Kolb 2005). School gardens were found to play an especially

important academic role among elementary school youth from low-wealth communities who had not previously been given experiential learning opportunities (Dyg et al. 2020; Kuo et al. 2021; Ray et al. 2016; Williams and Dixon 2013). However, Hoover et al. (2021) found that successful, sustainable school gardens require strong administrative and district support in addition to enthusiasm and support from parents and teachers.

Community Health and Safety Benefits

Landscaping and gardening projects that remediate vacant land, landscape streets and neighborhoods, create community gardens, or improve the health of wetlands and undeveloped natural environments can build community cohesiveness, neighborhood bonding, and mutual community pride (Draper and Freedman 2010; Glover et al. 2005; Hartwig and Mason 2016; Kuo and Sullivan 2001; Moyer et al. 2019; Neo and Chua 2017; Saldivar-Tanaka and Krasny 2004). With unmaintained vacant lots comprising nearly 15 percent of the land area of U.S. cities (Branas et al. 2018), greening opportunities, including planting and caring for edibles and landscape plants, are substantial.

Results indicate that people from different cultural and ethnic backgrounds unite in gardening and urban greening projects, enjoying growing and sharing produce special to them (Agustina and Beilin 2012; Baker 2004; Cruz-Piedrahita et al. 2020; Dyg et al. 2020; Hartwig and Mason 2016; Teig 2009). Building a sense of community through social engagement, celebrations, and communal meals has been perceived as beneficial by both gardeners and nongardener participants (Allen and Alaimo 2008).

Well-designed and -maintained urban green spaces not only bring people together, but they can reduce crime and gun violence and enhance the safety and cohesiveness of urban neighborhoods, as summarized in several literature reviews (Bogar and Byer 2016; Mancus and Campbell 2018; Shepley et al. 2019). Some of the strongest links reported in the literature involve crime reduction in vegetated and well-maintained urban neighborhoods and walkways (Branas et al. 2018; Demotto and Davies 2006; Garvin et al. 2013; Locke et al. 2017) and a reduction in gun violence in neighborhoods with green spaces including trees (Branas et al. 2018; Kondo et al. 2017; Schertz et al. 2021; Wolfe et al. 2012). One study found that

community greening projects that vegetated vacant lots was an effective strategy to improve neighborhood safety, resulting in a nearly 40 percent decrease in violent crime (Heinze et al. 2018). However, other researchers (Groff and McCord 2012) found a greater incidence of opportunistic crime in areas with dense tree canopies, perhaps due to concealed illegal activities.

Another study found that participating in community greening projects from design through implementation and maintenance can result in a sense of accomplishment and satisfaction (Murphy-Dunning 2009). Neighbors caring for urban green spaces together also tend to spend more time conversing and building important social relationships than do nonparticipants (Peters et al. 2010).

Mental Health Benefits

Multiple literature reviews link interactions with nature to improved mental health in both youth and adults (Bowler et al. 2010; Clatworthy et al. 2013; Coventry et al. 2021; Cruz-Piedrahita et al. 2020; De Vries et al. 2003; Tillmann et al. 2018) in studies conducted in parks, gardens, urban green spaces, and even shopping malls. The restorative impact of simply viewing plants has also been widely studied. Walking through a park or seeing a natural scene through a window can lead to a sense of well-being, restfulness, reflection, and reduced mental fatigue (Shanahan et al. 2019). More recently, Dzhambov et al. (2021) found lower rates of depression in students homebound for long periods of time during the COVID-19 pandemic with views of plants (indoors and out) than in homebound students during the pandemic who lacked these views.

A literature review by Bowler et al. (2010) highlighted more self-reported positive emotions and lower levels of anger and sadness in people in natural settings than people in nonnatural settings. Interactions with nature can also reduce symptoms of depression and anxiety (Beyer et al. 2014; Gonzalez et al. 2010; Lee et al. 2015). Thompson Coon et al. (2011) reported that exercising outdoors in natural settings led to greater feelings of positivity and revitalization and less tension, anger, and depression than exercising for the same amount of time indoors. Other studies link gardening to feelings of peace and contentment (Meuwese et al. 2021; Shanahan et al. 2015; Shanahan et al. 2019).

MacKerron and Mourato (2013) reported that individuals who interacted with nature were often happier than those lacking this interaction. Ambrose et al. (2020) reported that home gardeners growing food crops experienced particularly high levels of happiness and meaningfulness. Bakolis et al. (2018) linked two elements of mental well-being (optimism and energy) to interactions with nature, while Van den Berg and Custers (2011) and Wood et al. (2016) found a link between engagement with nature and a reduction in stress. White et al. (2019) determined that these benefits are maximized when individuals spend 120 minutes a week or more interacting with nature, but a shorter period of exposure is also beneficial (Shanahan et al. 2015; Shanahan et al. 2019; White et al. 2019).

Other studies report a link between growing food and a deepened sense of purpose (Tzoulas et al. 2007; Wiesinger et al. 2006). Digging in the soil can be a welcome change from deadlines, traffic jams, and other everyday stressors. Focusing on the needs of plants, such as watering and fertilizing them, harvesting their fruit, flowers, leaves, or roots, or completing other garden tasks can prove pleasantly distracting and provide time for reflection and problem resolution (Capaldi et al. 2015; Meuwese et al. 2021; Stevenson et al. 2018).

Several research papers report important positive roles that plants are playing related to mental health as impacts of climate change increase (Cryder et al. 2006; Dillman-Hasso 2021; Doherty 2018; Fernandez et al. 2015). Those studies show decreases in post-traumatic stress disorder (PTSD), major depressive disorder, stress, anxiety, and other emotional problems.

Urban Ecosystem Services and Benefits

Plants in metropolitan areas produce many ecosystem services benefiting individuals, communities, and the environment. Plants provide the oxygen that sustains human life. Without them, life the way we know it would not exist. As pressures from climate change mount, plants will play an even larger environmental role. The benefits are not evenly distributed. Due to social inequities, low-wealth urban communities often gain fewer ecosystem benefits, because of smaller housing lots, less neighborhood vegetation, fewer parks and green spaces, and fewer trees and less canopy cover (Shannahan et al. 2019).

Tree Canopy Cover across Communities

Assessments conducted by McPherson et al. (2017), using models based on data from fifty California cities, determined that the ecosystem services value of California's 173 million urban trees is approximately \$8.3 billion. They also determined that trees cover, on average, 15 percent of California cities, resulting in the lowest canopy cover per capita (108 trees per square yard) in the United States. In response, many collaborations and partnerships have been established to increase the number of drought-, heat-, and pest-resistant trees in California cities. The projects are important to enhance tree canopy cover, cool urban heat islands, provide shade, and enhance species diversity, habitat, and other ecosystem and societal benefits. For example, a collaboration among the Inland Empire Resource Conservation District, UC

Cooperative Extension (UCCE) San Bernardino County, California Climate Action Corps, and municipal and nonprofit partners in 2021 and 2022 provided over six hundred trees free of charge that were planted in parks, schools, and residential neighborhoods with low tree canopy cover (fig. 3). The selected tree species withstand harsh urban conditions resulting from climate change and urban heat islands and include several species identified in research trials conducted by UC Agriculture and Natural Resources and USDA Forest Service academics. UC Master Gardener volunteers in San Bernardino County played a key role in the project, providing guidance on tree care to help ensure that the trees maximize their lifespan, and, therefore, their ecosystem and societal benefits (e.g., shade, cooling, carbon dioxide sequestration).



Figure 3. California Climate Action Corps members and UC Master Gardener volunteers provided a tree to a resident of a neighborhood with low tree canopy cover in San Bernardino County. *Photo:* Thomas McGovern.

While all plants cool the surrounding environment through transpiration, trees play a particularly important role in mitigating climate change by also shading urban heat islands (Bowler et al. 2010; McPherson et al. 2016; McPherson et al. 2017; Nowak et al. 2006; Shashua-Bar and Hoffman 2000; Teo et al. 2021; Tzoulas et al. 2007) (fig. 4). Strategically designed urban green spaces that include properly selected, placed, and maintained street trees are especially effective at improving thermal comfort (Jung et al. 2021; Oke 2010; Pataki et al. 2021; Pauleit et al. 2017). Dense shade can also reduce air-conditioning needs in buildings and vehicles (McPherson et al. 2016; McPherson et al. 2017; Tzoulas et al. 2007).

Mature trees sequester (capture and store) much more atmospheric carbon dioxide in their wood and roots than young trees. However, it is important to note that although planting trees and providing them optimal care throughout their lifespan can decrease atmospheric carbon dioxide, these efforts do not

negate the need to decrease fossil fuel emissions (Waring et al. 2020). In most cities, fossil fuel combustion far exceeds the ability of trees to mitigate the carbon dioxide emissions (Friggens et al. 2020; Pataki et al. 2021; Teo et al. 2021).

Many trees are effective interceptors of air pollutants such as particulate matter, carbon monoxide, ozone, nitrogen dioxide, sulfur dioxide, and certain classes of hydrocarbons (Hewitt 2020; Nowak et al. 2006; Nowak and Greenfield 2018; Teo et al. 2021). However, Eisenman et al. (2019) and Xing and Brimblecombe (2020) caution that because some tree species produce and release biogenic volatile organic compounds that result in pollution and because interlocking tree canopies may actually restrict release of pollutants into the air above, urban trees do not always decrease the net concentration of pollutants in dense urban environments.



Figure 4. Shade trees in urban parks cool heat islands and provide many other ecosystem benefits. *Photo:* Janet Hartin.

Additional urban ecosystem services that trees and other urban landscape and garden plants provide that benefit the environment include providing habitat for wildlife, birds, and pollinators (Anderson et al. 2019; Burghardt et al. 2008; Clucas et al. 2018; Lee and Maheswaran 2011; Liu and Russo 2021; Teo et al. 2021; Waring et al. 2020), enhancing biodiversity (Fragkias et al. 2013), stormwater/irrigation water runoff management (Backhaus and Fryd 2013), and noise buffering (Mullaney et al. 2015; Walsh et al. 2016). Plants also reduce soil erosion by reducing water runoff and enhancing infiltration (Berland et al. 2017) and improve water quality (Denman et al. 2016).

It is important that trees be well maintained over their lifespan to maximize their ecosystem benefits (Salmond et al. 2016). Urban street trees have considerably shorter lifespans than trees in natural forests due to poor site characteristics and care. Improper species selection, drought, soil compaction, improper pruning, and inadequate above- and belowground space are common reasons for low survival rates (Hilbert et al. 2018).

Medicinal Benefits

Plants have been used to treat physical conditions and to enhance psychological well-being since ancient times; written records date back 5,000 years (Leroi-Gourhan 1975). By 700 BC, the Charaka Samhita (one of two Sanskrit foundational texts on Indian traditional medicine) included over three hundred plants. Since the 1960s, hundreds of research papers have been published regarding the benefits of herbs for a wide variety of health concerns (Pan 2010). Plants are also used in mainstream medicines. Taxol, used to treat some types of cancer, contains paclitaxel derived from Japanese yew (*Taxus cuspidata*) bark.

Digitalis, derived from *Digitalis purpurea* (purple foxglove), is used to treat heart failure. There are also anti-inflammatory drugs, antidiabetic drugs, and other chemotherapeutic compounds derived from plants (Leavitt 1990).

The U.S. Department of Agriculture (USDA) is responsible for establishing regulations and maintaining strict standards for plant-based pharmaceuticals, from the research and development stage through trials and production. Proven and unproven plant remedies that are sold over the counter that do not have USDA approval may have been researched, produced, and sold with less, or no, regulation and scrutiny. Approval practices vary widely from country to country. Progress is being made on an international level to develop a uniform and stringent process for testing and approving over-the-counter products (Thakkar et al. 2020). At this time, a decision to use an unregulated plant-based product should be made in consultation with a medical professional.

Spiritual/Ritualistic Benefits

Psychoactive plant parts have been used in ceremonial rituals for thousands of years in many parts of the world (Crocq 2007; Guerra Doce 2015; Vetulani 2001). Anthropologists have linked the cultivation and use of opium poppies (*Papaver somniferum*) to Neolithic farmers in Italy; evidence of opium use has been found too in 4,000-year-old human remains. They have also documented the use of mescaline, an alkaloid with hallucinogenic properties produced by *Echinopsis pachanoi* (San Pedro cactus), in Peruvian rituals as far back as 8,600 BC. Peoples of many geographic backgrounds and ancestries identify their cultural history with specific plant families, and many rituals in use today mark the holistic benefits of air, water, and earth, and the life they support.

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