Chapter 31
Horticultural Science's Role in Meeting the Need of Urban Populations

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Abstract Horticultural products and services impact the health and well-being of urban populations. This is an extremely important group for horticultural scientists and researchers to serve: more than half of all people worldwide already live in urban areas, and more than two-thirds will do so by 2050. In this chapter we address the past, current, and future roles that horticultural science plays in the major issues of concern to public welfare: public health, environmental health, food security, and economic stability. Urban horticulture has important impacts on the health of the individual and the community, two concerns of public health. Documented individual health benefits include less depression and improved pregnancy outcomes from walking in or living near urban green spaces. Community gardens, parks, and other urban vegetation enhance community health by improving social interactions, such as family dynamics, and public safety, such as protection from crimes. Uses of plants to improve the urban environment include temperature modification, air pollution reduction, and water quality improvement. Impacts on biological diversity are mixed. Other negative impacts include the introduction of invasive species. Urban food security requires food in sufficient, nutritious, and affordable quantities. Providing this for all people is one of the greatest challenges for horticultural science. Potential solutions include increasing small-scale food production in urban areas by providing more community gardens or converting vacant lots. Horticulture contributes directly to urban economics through the production and sales of horticultural products by urban businesses. Indirect contributions from plants include higher property values and more productive employees. The increasing urbanization and aging of the human population is happening in conjunction with rising environmental destruction from global warming and climate change. Combining the traditional horticultural concern of feeding the world with an expanded understanding of the additional functions provided by horticultural products, the needs of urban people, and the opportunities to partner with professionals in other disciplines will be essential in the unpredictable future.

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Introduction

In this chapter we address the impacts of horticulture on urban populations and their physical and psychosocial needs. We use the word, *urban*, in a broad sense, including related, human-dominated landscapes, such as suburban and peri-urban areas. We also address the applications of horticultural science in urban agriculture. For the purpose of the discussion, we draw on the broad definition of *urban agriculture* given by the Council for Agricultural Science and Technology: "Urban agriculture is a complex system encompassing a spectrum of interests, from a traditional core of activities associated with the production, processing, marketing, distribution, and consumption, to a multiplicity of other benefits and services that are less widely acknowledged and documented. These include recreation and leisure; economic vitality and business entrepreneurship, individual health and well-being; community health and well-being; landscape beautification; and environmental restoration and remediation" (Butler and Maronek 2002). Horticulture is clearly included in this definition of urban agriculture, and for the purposes of this chapter we focus on that aspect by using the term urban horticulture.

In this chapter, we will consider the impact on urban populations on the full range of horticultural plants, including but certainly not limited to trees, shrubs, flowers, turf, indoor plants, fruits, vegetables, native and introduced species, cut and potted flowers, and medicinal plants. These products of horticulture are essential for a healthy urban population. At the same time, topics related to horticultural services are considered. These include meeting the needs of human beings and addressing their quality of life through contact with plants, utilization or consumption of plant parts, or involvement in the cultivation of plants. The information explored by horticultural science that is included in this concept ranges from ecosystems to green-care farms, from landscape design to healthcare gardens, from economics and marketing to school gardens, and multitudes of other human concerns. Opportunities to grow plants, to nurture the life of the plant, and to feel personal responsibility for caring for life in urban environments are also essential for the health and well-being of urban populations. While our focus is primarily on the benefits from horticultural crops and services, we also present some detrimental aspects, including environmental destruction from the introduction of invasive species and property damage from poorly sited or maintained vegetation.

Many of the items in this chapter are addressed in other chapters, but we include them here to emphasize that their role has a strong urban aspect and that professionals responsible for the management of urban areas need to be aware of the importance of horticulture and horticultural science as a part of the urban complex. Among the urban professionals that we, as horticulturists, need to address are: urban planners, engineers, public health officials, business leaders, politicians,

educators, non-profit staff, and volunteers. In addition, our focus is on the role that horticultural science and horticultural scientists play in the urban natural environment in partnership with urban foresters, agronomists, landscape architects, urban ecologists, and others concerned with linking people and nature.

As the world continues its rapid urbanization, with projections that 67% of the human population will be concentrated in cities and their surroundings by 2050 (United Nations 2012) and as the negative impacts of climate change become increasingly apparent (Lelieveld et al. 2012), the importance of horticultural science in conducting research and disseminating information to address world issues effectively becomes more evident. In this chapter we address the role of horticultural science in the major issues of concern to public welfare: public health, environmental health, food security, and economic stability. Needless to say, these are tightly interrelated, but for the purpose of this chapter we will consider specific elements of each separately.

Horticultural Science's Role in Public Health

Public health is a major social and economic issue that will continue to grow as the human population expands and ages. It is also an environmental issue: practitioners in public health have long focused on the reduction of health problems by remediation of causal factors including degraded environments (see section on: Urban Environmental Health). Certainly urban horticulture has important impacts on the health of the individual, the community, and the environment, the three areas that constitute public health concerns. Health of the individual and health of the community are discussed in this section with an emphasis on the role of horticulture in both.

To meet the needs of healthcare and public health practitioners and develop strong utilization of horticulture in public health, to meet the needs of the rapidly growing and aging population and the professionals that serve this group, and to provide knowledge and skills to help build healthy communities, we need to develop a long-term plan for research and outreach. Among the tasks to be completed in cooperation with researchers from other universities, colleges, and departments is to identify the most critical issues to be researched. Long-term cooperative research will demand external funds from sources not usually approached by researchers in Colleges of Agriculture. This cross disciplinary work with researchers in medicine, education, social sciences, urban planning, and others will open doors to different private foundations, corporate foundations, and government organizations that must be identified and communicated with in terms that clearly address their goals.

Health of the Individual

Horticulture has important impacts on the health of individuals through direct interaction with plants and the natural environment. Horticulture promotes individual health through exercise, stress reduction, social interaction, and mental stimula-

tion. Gardening is recommended by such groups as the American Heart Association (2013) as a technique to improve general physical health and thus prevent many human diseases. In addition urban horticulture can plan a role in improved health through access to high quality fresh produce either locally produced or self-produced (see discussion below on *Food Security*).

How we use plants in our cities, whether indoors or out, can have strong influences on health and well-being (Lohr 2010, 2011). Increasing research is identifying strong links between plants in our surroundings and positive health outcomes. In fact, documentation of such links have become so strong that the medical and public health communities are promoting the expansion of green spaces, parks, green roofs, and community gardens and the planting trees to reduce the incidence of human diseases, including heat-related deaths, respiratory illnesses, and cardiovascular diseases (Younger et al. 2008; O'Neill et al. 2009; Cheng and Berry 2012). Some examples of connections between human health and the use of plants in our surroundings are presented below, focused on areas that have significant potential for further involvement by horticultural scientists. Additional examples are presented in other chapters. Such information can be useful in promoting the need for municipalities to spend money on establishing and maintaining plants in urban areas.

Trees, walkable communities, *and human health*. According to the World Health Organization, obesity has more than doubled worldwide since 1980 and being overweight is the fifth leading risk factor for deaths worldwide (World Health Organization 2012). Common health problems associated with being overweight or obese include heart disease and cancer. The Centers for Disease Control and Prevention (2012) attribute the lack of physical activity in the United States of America (U.S.), in part, to current patterns of land use and transportation. Studies have shown that walkable outdoor spaces with trees (Fig. 31.1) are correlated with lower rates of obesity (Lachowycz and Jones 2011). Lovasi et al. (2012) found that residents in New York City who lived in areas with more walkable streets with trees had lower body mass indices than people living in areas without street trees. In Tokyo, five-year survival rates for citizens in their 70s and 80s were greater if they had space for walking near their residences and if there were parks and street trees near them (Takano et al. 2002). Even children's health can be improved through appropriate incorporation of plants in urban areas. One study showed that children had better body mass index scores if they lived in communities with more vegetation nearby compared to children in areas with low amounts of green (Bell et al. 2008). As a result of such studies, public health professionals and even the American Planning Association are emphasizing the need to plant more trees and build more parks (Younger et al. 2008; Ricklin et al. 2012). Communities are also responding. For example, Fort Worth, Texas has a plan to increase neighborhood and community park space by more than 1 acre per 1,000 people by 2025 (Ricklin et al. 2012).

Other documented health benefits from walking in parks and green spaces include reduced stress and less depression. In the 1980's, researchers began to document evidence of reduced human stress when passively viewing plants or nature (Moore 1981; Ulrich and Simon 1986). Benefits from actively walking among trees or in gardens were documented in subsequent studies. Cimprich (1993) studied

Fig. 31.1 Walkable street with trees in Madrid, Spain. Streets with shade trees increase the likelihood that people will walk along them and gain health benefits, including reduced obesity. (Photo by V. I. Lohr)

women undergoing surgery for breast cancer. They typically suffer from mental fatigue and show signs of depression. Half of the subjects were given only routine treatment, while the others were also asked to perform a mentally restorative activity. Most women decided to walk in a garden. Depression began to lift within 3 months of surgery for those who walked in gardens, while depression worsened for those in the control group. A more recent study, using medical records from people in The Netherlands, found that rates of anxiety disorders and depression were lower when the amount of green space within 1 km of people's residences were greater (Maas et al. 2009). In another study, Berman et al. (2010) worked with people with major depressive disorder. The moods and mental capacities of the subjects were better on days when they walked in an arboretum than on days when they walked in an urban area. Gardening has similar benefits to walking in nature: gardeners who performed a stressful, non-gardening task and then gardened for 30 min had lower levels of salivary cortisol, a hormone associated with human stress, than those who read absorbing material for 30 min following the task (Van den Berg and Custers 2011).

Green areas and human health. A range of positive and perhaps surprising health outcomes have been documented in urban areas with increasing amounts of green space. One study, looked at mortality rates for people in England based on income

deprivation and found that overall mortality rates dropped as the amount of vegetation near their residence increased (Mitchell and Popham 2008). Two recent studies have shown a positive link between pregnancy outcomes and green space near the mother's home. One conducted in Barcelona, Spain, documented an increase in birth weight from mothers in the lowest educational group as the amount of vegetation within 500 m their residences increased or as the distance to a major green open space shortened (Dadvand et al. 2012). A study in Portland, Oregon, U.S. documented a reduction in the number of babies who were small for their gestational age as tree canopy cover within 50 m of the mother's residence increased (Donovan et al. 2011).

Other studies have looked at the effects of nature on exercise and sports. Barton and Pretty (2010) showed that activities performed in areas with plants, such as walking, cycling, or gardening in urban green areas, could improve mood and self-esteem within just 5 min. A recent study found that track and field athletes received their best performance marks at sites with more green landscaping and their worst scores at venues with the least amount of vegetation (DeWolfe et al. 2011).

A wide range of health benefits that accrue from being in urban areas with high amounts of vegetation are known, and some researchers are now examining the level of access to vegetation for different populations. Environmental inequities are wide-spread. In Montreal, Canada, disparities based on income have been found, with lower income people having less green in their neighborhoods than more affluent people (Pham et al. 2012). Similar relationships have been documented in many places, including six cities in Australia (Kirkpatrick et al. 2011), the urban and peri-urban area of Phoenix, Arizona, U.S. (Hope et al. 2003), and the municipality of Campos Dos Goytacazes in the state of Rio de Janeiro, Brazil (Pedlowski et al. 2002). This relationship was not found in Paris, France (Cohen et al. 2012a). Mitchell and Popham (2008) showed how critical green areas for low income people could be: they documented that the increase in mortality associated with income deprivation in urban areas could be overcome with more exposure to vegetation. This knowledge is critical to incorporate in urban and peri-urban planning (Frumkin and McMichael 2008; Rydin et al. 2012).

The role of horticultural science in contributing to walkable communities and green health includes selection and testing of plants for the specific areas and intent; development of maintenance techniques to withstand the environmental stresses placed on urban trees; cooperative research with other professionals to determine the sustainability of plants in the research that is conducted (for example, are the trees healthy and appropriate for their location and does that matter as far as the effect on humans); and appropriate plant materials to withstand stresses related to efforts to rectify environmental inequality. Ideally these roles involve horticultural scientists working with public health professionals and other social scientists to conduct research and provide educational materials to the urban officials who make the decisions regarding funding.

Horticulture and healthcare. Horticulture has a long history of use as a treatment for individuals within the healthcare system (Warner and Baron 1993). As part of the professional area of healing landscapes, horticulture and plants play roles in

providing an atmosphere that is conducive to recovery (Relf 2005). In the professional areas of social horticulture and therapeutic horticulture and as part of green-care farming (Hassink and van Dijk 2006), horticulture is valued as an activity to stimulate, motivate, and rehabilitate the gardener with health issues whether or not they are in a structured, goal directed program (Relf 2006). In the profession of horticultural therapy, horticulture has use and significant potential as a structured treatment tool for individuals with diagnosed health issues in defined treatment programs with specific achievable goals utilizing living plants under the direction of a trained professional therapist (Relf 2005).

Extensive information is available on the design and use of healing landscapes for the positive ambiences they provide. Research focused on post-occupancy surveys of hospital and other healthcare landscapes have been conducted and reported (Marcus and Barnes 1999). There is access to links and descriptions of healing landscapes sites on-line (Anon 2012b). Therapeutic gardens, as sites for the implementation of therapeutic horticulture and horticultural therapy programs, are less well researched, as they require the integration of therapist, patients, and programs to test their efficacy.

The majority of the research on the utilization of horticulture as an activity in the healthcare area has looked at social and therapeutic horticulture, with particular focus on aging (Gigliotti et al. 2004; Wichrowski et al. 2005; Collins and O'Callaghan 2008). Activities with children have also been studied (Kim et al. 2012). Theoretical models have been put forth to serve as guides for research and to stimulate query (Relf 2006; Shoemaker and Lin 2008) and methods for research have been discussed (Shoemaker et al. 2000), but the limited number of potential researchers within academic horticulture has resulted in a lack of adequate studies that look at the efficacy of horticultural therapy as a treatment regime eligible for third party reimbursement. Anecdotal evidence and growth of horticultural practices among activity therapists and other healthcare professionals justifies an expanded role for horticultural scientists working cooperatively with healthcare professionals to conduct the research and teaching to ensure this professional area reaches its potential.

It is widely recognized that a rapidly aging population worldwide has significant implications for health issues. Horticulture has an important role to play in enhancing and/or ameliorating health factors (Rappe and Kivelä 2005). In recent years connections have been found between gardening and a delay in Alzheimer's disease (Simons et al. 2006). Two major causes of health problems among the elderly are lack of exercise and loneliness. Horticulture addresses both of the issues for many people. However, many people unnecessarily stop gardening as they age due to impacts of arthritis, back problems, heart disease, and other ailments often associated with aging. This translates into landscapes in both private and public areas lying idle, which, if properly designed, could serve to meet recreational and health needs of this large population. Despite the widely accepted value of gardening, only limited research has been done to understand how gardening affects elderly individuals socially, psychologically, physically or intellectually (Park et al. 2011). The research that has been conducted provides important indicators of the value of continued work in this area. In two separate studies of intergenerational programming

in horticulture with adults who still lived at home either independently or with care givers, researchers (Kerrigan and Stevenson 1997; Predny and Relf 2000) found that horticultural activities that focused on growing plants resulted in greater interaction than those activities that involved craft-type work. For seniors in intermediate care, Mooney (1994), using three different psychological measuring tools, found a pattern of improvement after the treatment was implemented and decline when the therapy was withdrawn to be a "classic" pattern for the experimental group. For elderly adults with cognitive impairment such as Alzheimer's disease, studies indicated that a properly designed outdoor environment reduced incidents of aggressive behavior (Mooney and Nicell 1992) and agitation (Detweiler et al. 2008).

This type of research data is important in justifying the expenditure of dollars for gardening facilities in public parks and gardens, retirement communities, public housing, and hospitals as well as residential and healthcare sites for elderly. Research in this area would also have implications for making gardening easier and more rewarding for the well-elderly and for the expansion of horticulture in the recreation and tourist industry.

Health of Communities

A third significant area in which horticulture impacts public health is through the interaction and dynamics of a healthy community. Research has indicated that community gardens, street trees, parks, and other urban vegetation play a role in reduction of crime, including child abuse, and that gardens can be a central focus for community development and neighborhood partnerships (Kuo et al. 1998; Kuo and Sullivan 2001a). Charles Lewis (1996) wrote that if an area is dilapidated or vandalized, has trash-filled vacant lots, or is sterile steel and concrete, it sends messages that those in charge (the city government, the owner, the employers) do not place value on the area or the people there. It implies that the people have no intrinsic worth and no control over their environment. It tells outsiders that this is not a good place to be. The opposite is also true; for example, as a consequence of businesses and neighborhoods beautifying their surroundings as part of the Philadelphia Garden Blocks program, other areas followed suit, a phenomena reported as early as the 1960's.

The daily contact with nature that takes place in the landscapes around homes is important to people's welfare. For example, in a National Gardening Survey in the U.S., 37% of respondents said gardening gave a sense of peace and tranquility (Relf et al. 1992). Forty percent reported that being around plants helped them feel calmer and more relaxed, and 46% said that nature was essential to their well-being. In Uruguay, people in urban areas with trees were more likely to report being happy and having an improved social life than people in areas without trees (Gandelman et al. 2012). In this section we look at the impact of horticulture by expanding on two factors critical to healthy communities: social functioning, including neighbor cohesion and family dynamics, and public safety, including reduced crime.

Social Functioning. Positive connections between plants and social functioning have been documented for decades. An early study by Brogan and Douglas

(1980) in Atlanta, Georgia, U.S. examined the association between the psychosocial health of the community and the physical environment (e.g., landscaping and nearby land use) and sociocultural environment (e.g. population density and income). They found that the characteristics of physical and sociocultural environments were about equally important in explaining the variations in the psychosocial health of the community.

A wide range of positive connections between plants and social functioning have been revealed by researchers comparing residents in randomly assigned Chicago, Illinois, U.S. public housing units with differing amounts of vegetation. They found that greener landscapes led to stronger social integration and a stronger sense of community for older adults (Kweon et al. 1998), better parental functioning (Taylor et al. 1998), and less verbal aggression (Kuo and Sullivan 2001a). Their work also indicated that green outdoor spaces were associated with a lower incidence of "incivilities" including litter and graffiti (Kuo and Sullivan 2001b). One study, particularly relevant to community cohesion, examined the role of plants in the formation of neighborhood social ties in neighborhood common spaces and found that levels of vegetation predicted both the use of common space and the strengths of the ties (Kuo et al. 1998).

Studies of the impact of community gardens and gardening on community cohesion have also shown positive trends. Kidd and Brascamp (2004) surveyed gardeners in New Zealand who reported that gardening was peaceful and almost never frustrating. Female gardeners were especially likely to value stress reduction from gardening, while men were more likely to value gardening as a shared activity with others. In another study, community garden project leaders reported positive social impacts from community gardens, including the promotion of neighborhood cohesion and trust and an increase in civic participation and diversity in neighborhood associations (Feenstra et al. 1999). The potential for community gardens to address social, cultural, and educational needs was revealed by a gardening program started in an immigrant center in Germany in 1995 (Müller 2007). The intercultural garden involved immigrants from many countries with the initial goals of providing meaningful work and healthful food for the families. It was recognized for its impact on intercultural communication and integration into the German community on the basis of a resource-oriented approach that built on the knowledge base of participants.

Public safety. Positive impacts of urban nature on public safety can be readily seen in two areas: reduced traffic related injuries and reduced property and violent crimes. Examples of the magnitude of the improvement to public safety in these two areas are presented below.

Traffic calming is widely accepted as a technique by which landscaped circles and chicanes and other environmental designs slow traffic and increase pedestrian and neighborhood safety (Fig. 31.2). In Seattle, Washington, U.S., the city's traffic calming program has reduced accidents by more than 90% (Mundell and Grigsby 1997). Lockwood and Stillings (2001) reported that traffic calming and streetscaping techniques installed in West Palm Beach, Florida, U.S., managed traffic effectively by altering driver behavior, thereby reducing car speeds and reducing collision frequency and severity.

Mok et al. (2006) analyzed crashes along stretches of urban roads ranging from highways to cities streets in 8 cities in Texas, U.S., before and after landscape im-

Fig. 31.2 A traffic island in Aix-en-Provence, France. Trees and flowers planted within the traffic island help calm drivers and focus their attention. (Photo by V. I. Lohr)

provements were installed. They documented significant reductions in crash rates, speculating that trees affected driver behavior by improving driver alertness. It is important to note that, while the rate of accidents on roads with trees may be lower than on roads without trees and the actual number of crashes with trees is low, when crashes with trees occur, they are more likely to be fatal than crashes with other vehicles (Wolf and Bratton 2006). Fatal accidents with trees are much less likely in urban areas than in rural areas (Wolf and Bratton 2006). Given the trade-off between the benefits and hazards of trees along roadways, the general consensus is that trees should be used, but with reasonable setbacks along high-speed roadways. In cities, traffic calming landscapes give a psychological indications that drivers should proceed at lower speeds (Ewing and Dumbaugh 2009).

Lockwood and Stillings (2001) reported that one of the results of the traffic calming efforts in West Palm Beach was a reduction in some crimes. Arrests for prostitution dropped 80 % as the streets became safer and more useable. In the same area, incidences involving drugs went down 60 % over the same period. The authors speculated that increases in pedestrian and bicycle traffic lead to better surveillance of the neighborhood contributing to reductions in other crimes. They suggested that, as these elements change, more residents and businesses would improve their property inducing others to move to the community and further reduce crime. Results such as these have been generalized. In a paper co-authored from the U.S., Australia, and the United Kingdom, large-scale evaluations of crime prevention through

environmental design were reviewed to compile current knowledge on the evidence of crime prevention through environmental design. It identified a large and growing body of research supporting the claim that crime prevention through environmental design is effective in reducing both crime and fear of crime in communities (Cozens et al. 2005).

Many people believe that vegetation is positively linked to crime, however, findings in urban residential areas indicate that the opposite may be true. Kuo and Sullivan (2001b) examined crime reports in Chicago, Illinois, U.S. and found that fewer property crimes, such as theft, and fewer violent crimes, such as homicides, were reported in public housing with trees than without. Donovan and Prestemon (2012) examined the relationship between trees and crime at single-family homes in Portland, Oregon, U.S. and found similar connections. Property crime rates, such as burglary and car theft, were lower at houses with larger tree canopies on the lot or on the street. Having more, smaller, view-obstructing trees was associated with increased property crime, but was not associated with violent crimes, such as simple assault. The only significant relationship between trees and violent crime was a decrease in violent crimes at homes with larger canopies trees on the lot. In Baltimore, MD, U.S., increases in canopy cover were associated with reductions in outdoor crime, especially on public land (Troy et al. 2012).

In addition to the impact of traffic calming landscapes and trees in urban areas, community gardening has been reported to have a positive impact on community safety. In one Philadelphia, PA, U.S., neighborhood, resident involvement in community greening was the catalyst for a 90% reduction in neighborhood crime (Macpherson 1993). In the Mission District of San Francisco, CA, U.S., residents noted a 28% drop in crime after the first year of their garden project (Malakoff 1995). Feenstra et al. (1999) reported a decrease in vandalism near garden sites. A San Francisco County Sheriff reported that the recidivism rate was cut in half (from 55 to 24%) among prisoners who participated in the prison gardening project in the San Francisco County Jail (Gilbert 2012).

School and youth gardening education. There has been a national movement over the last 10 years, encouraged by the National Gardening Association, the American Horticultural Society, and numerous botanical gardens, to integrate gardening into the school curriculum, as evidence of the benefits of such programs grows. Researchers at Texas A&M, for example, have been conducting research in this area for many years (Waliczek and Zajicek 1996; Waliczek et al. 2001; Aguilar et al. 2008).

Studies are determining the efficacy of specific resource materials and to understand what makes a school gardening program effective (Dobbs et al. 1998). In an early survey of teachers who received National Gardening Association gardening grants, DeMarco et al. (1999) found that the most important factor in the successful integration of gardening into the school curriculum was ownership of the concepts and goals by the teachers and students. They also found that the teachers did not use the garden simply to teach gardening, plant science, or environmental attitudes. They also used it to teach language arts, art, and ethics. They reported that their goals when using school gardens were academic, social, recreational, and therapeutic.

Juvenile offenders are a unique subset of youth, and the application of gardening with these individuals often has goals that are different than in the classroom. The

Green Brigade is a community-based program started by the Bexar County Agriculture Extension Service (Finch 1995). Cammack et al. (2002a) reported about a 10% increase in both horticultural knowledge and environmental attitude scores among offenders in this program. They also found that the Green Brigade program was as effective as traditional probationary programming at reducing the rate and severity of crimes by juvenile offenders (Cammack et al. 2002b). Findings reported by Flagler (1995) on the Rutgers Careers in the Green Industry program, where over 70% of the youth indicated an increase in experience, skills, contacts with people that could help them, and ideas about future education, indicated that an organized vocational based education program is an effective curriculum for this population. In a study conducted at an alternative education program for youth on probation, McGuinn and Relf (2001) noted that among the small group that they studied, there was strengthening in the delinquent individual's bond with society and the youth were motivated to think more practically about their future and career possibilities. Five of the six students in the study were hired for summer positions by horticulture establishments. These findings further reinforce Flagler's conclusions that horticulture is an effective curriculum focus for vocational training of juveniles on probation and other youth at risk.

Horticultural Science's Role in Urban Environmental Health

Urban environmental health directly impacts quality of life, public health, economic stability, and food security (see related sections of this chapter). The use of plants to improve the urban environment has been well documented. Plants provide valuable ecosystem services, including air quality improvement, storm water runoff management, carbon sequestration, and temperature modification. McPherson et al. (2005) calculated the annual net benefits from the economic return of trees in cities to be US$ 21 to US$ 38 per tree. Public domain software for individual communities to assess these benefits (i-Tree 2013) is now in use in more than 100 countries (i-Tree 2012). The connections of urban environmental issues to global warming and to plant diversity are so strong that we are focusing on these elements for this chapter.

Urban Environmental Issues and Climate Change

As the world is getting hotter and the climate more extreme, it is especially important for horticulturists to understand a range of the environmental impacts they may cause and the actions needed to ameliorate these impacts. Land management practices rooted in horticultural science can play a role in landscape design and plant selection for temperature and water management, pollution abatement and remediation, and management of health hazards associated with urban plants stressed

by global warming and climate change. Some of the services, values, and negative impacts are presented below; others, such as carbon sequestration, are covered in other chapters.

Green roofs and green walls are examples of ways that horticulturists can contribute to ameliorating the issues discussed below. These horticultural uses of plants are increasingly valued as ways to create more places for vegetation in cities. They contribute to improved air quality, reduced city temperatures, and improved water quality (Alexandri and Jones 2008; Yang et al. 2008; Berndtsson 2010). They can also provide healthy space for wildlife and people. Rain gardens and bioswales are also becoming popular ways to improve water quality (Dietz and Clausen 2005; Xiao and McPherson 2011). The role of horticulturists in planning, designing, and selecting plant material for these is essential (Dylewski et al. 2011). Too many rain gardens, for example, are created by well-meaning ecologists who do not consider design aesthetics or maintenance requirements when selecting plants for such urban environments. They may have no idea how the plants in these will grow in urban landscapes over time and select plants that are native, but look like weeds to the neighbors. This can encourage negative attitudes toward the use of non-traditional landscape designs (Morzaria-Luna et al. 2004). For full acceptance of horticultural solutions to urban problems, the solutions must serve their ecological functions, be viable for long-term survival and maintenance, and appeal to people. In a similar manner xeriscaping, as means of limiting use of water in dry periods, must be approached from a horticultural science perspective to insure sustainability from a socio-cultural as well as ecological perspective.

Cooling. Horticultural science contributes to an understanding of the role of vegetation in affecting temperatures and energy use in cities and the selection and maintenance of plant systems that reduce the demands for energy in cities. Trees and other vegetation can be used to reduce temperatures indirectly though evaporative cooling and directly through shading and directing wind. The need for cooling in urban areas is increasing (Fig. 31.3). Average temperatures and high temperature extremes are rising around the world as a result of global warming (Lüdecke et al. 2011; Lelieveld et al. 2012). The temperatures are exacerbated in cities, where the urban heat island effects from the excess of hardscape compared to surrounding vegetated areas can magnify temperatures by 10° C (Kim 1992; Akbari et al. 2001). As cities grow in size and population, the number of people affected by these often-fatal heat waves increases (O'Neill et al. 2009; Egondi et al. 2012). The potential to provide cooling through plantings in cities has been documented around the globe. In Manchester, UK, planting new trees has the potential to reduce maximum surface temperatures between 0.5° C and 2.3° C (Hall et al. 2012). In Tel Aviv, Israel, urban parks can be up to 3.8° C cooler than urban street canyons (Cohen et al. 2012b). In Washington, D.C., models showed that decreasing the width of urban streets to increase planting space and add 50% tree canopy coverage would drop temperatures of the air, building walls, and road surfaces by 4.1° C, 8.9° C, and 15.4° C, respectively (Loughner et al. 2012). In Hong Kong, models predicted that planting trees or grass on the roofs of tall buildings could reduce temperatures at pedestrian level by 0.2° C to 0.6° C (Ng et al. 2012); they also showed that trees were more effective than grass.

Fig. 31.3 Urban area of Hiroshima Japan. Hardscape, such as buildings and roads, contribute to the urban heat island effect, while the addition of trees and grass help counteract that by reducing temperatures on hot days. (Photo by V. I. Lohr)

A direct benefit of using vegetation to reduce temperatures is the effect on energy usage. If energy usage drops and if the energy source is carbon-based, such as coal is, then greenhouse gas emissions are also reduced (Akbari 2002). Huang et al. (1987) predicted that increasing tree cover around a home by 25 % could save 25 % in energy for cooling in Phoenix, Arizona, and 40 % in Sacramento, California, U.S. They showed that there were additional benefits in lowering the peak energy loads. McPherson and Rowntree (1993) used computer simulations to show that planting a single, small deciduous tree could reduce annual heating and cooling costs for a typical residence by 8 to 12 %.

Air Quality. Planting trees, establishing green roofs and wall plantings, and creating community gardens are ways that horticulturists can contribute to improved air quality and human health. Air pollution in urban areas is a problem worldwide

(Fenger 1999; Duh et al. 2008). Trees improve air quality through the physical removal of chemical and particulate air pollutants, such as ozone, carbon monoxide, sulfur dioxide, and dust (Nowak et al. 2006; Popek et al. 2013). McDonald et al. (2007) used modeling to show that trees could contribute to the reduction of particulate matter of < 10 μm in diameter, which are associated with adverse human health effects. By understanding the results of scientific studies in this area, horticulturists can increase the quantity of pollutants removed from the air by selecting specific trees and planting systems. For example, trees with smaller leaves, such as conifers, and hairier leaves are more effective than other trees at removing particulate matter (Beckett et al. 2000; Xie et al. 2011). Horticultural scientists can also be involved in such research, using their extensive knowledge of plants to suggest and study other features for their effectiveness (Xie et al. 2011; Popek et al. 2013), including the use of vines, shrubs, and green walls of herbaceous plants for faster, short-term impacts.

Water quality. Clean water in cities for human and ecosystem health are critical, yet water quality in cities is often compromised by the traditional handling of storm water (Whitehead et al. 2009). Many cities have relied on concrete culverts and ditches to drain storm water away from developed areas (Roy et al. 2008). As cities become more urbanized, the amount of impervious surface area increases. Climate change is bringing more and heavier rain events to some cities (Whitehead et al. 2009). Together, these are exacerbating flooding and reducing water quality. Plantings contribute to improved water quality by slowing water run-off and reducing soil erosion (Xiao et al. 1998). They also filter sediments and chemical pollutants from the run-off (Davis et al. 2006). There is an important role for horticultural science to play in understanding what can be done and what plants and planting systems are most effective for improving water quality. This may prove to be particularly important in developing countries as urban populations continue to grow faster than the infrastructure to provide water or remove excesses. Integration of water quality projects into multifunction uses including green roofs, green walls, community gardens, market gardens, parks, and recreational and tourism sites will maximize their sustainability and the potential for implementation where the urban planner, politicians, and taxpayers can better understand and appreciate the planted areas.

Hazards and safety issues presented by plants. All interactions between humans and plants in cities are not positive. Weak limbs can break and damage vehicles or injure people. Utility wires can come down with fallen trees. Trees with invasive root systems can seriously damage sidewalks. Improperly selected or managed urban vegetation can become a serious liability. Trained horticultural professionals are essential to address these hazards and safety issues. Climate change means greater wind speeds, more intense rainstorms, and more flooding, so we need to have trees that are pruned properly and transplanted correctly. Improper pruning leads to poorly attached branches and decay (Shigo 1985; Dahle et al. 2006). Improper transplanting leads to girdling roots and tree failure (Gouin 1983; Maleike and Hummel 1992).

In the U.S., courts of law have recognized that land managers and owners have a legal obligation to maintain vegetation in a healthy and safe condition. A 1978 court case, Husovsky vs. United States (described in detail in Anderson and Eaton 1986),

involved a driver who suffered permanent paralysis when a limb dropped onto his vehicle in a park in Washington, D.C. The defendants (in this case the District of Columbia and the National Park Service) were found negligent for not inspecting for defects and, therefore, liable for damages of nearly US$ 1 million. This case demonstrates the serious legal ramifications of poor urban landscape management.

Urban Environmental Issues and Biodiversity and Genetic Diversity

As the world has become more and more urbanized, both biodiversity (here used to mean diversity of different species, species richness, or the number of different species) and genetic diversity (diversity within a single species) are being affected. Urbanization can create highly degraded landscapes that are unsuitable for most species, thus negatively impacting diversity. There are also positive aspects related to urbanization and diversity. Understanding what is happening to diversity in urban areas is of significant concern to horticultural science in order to develop methods to address the actual problems.

Enhanced biodiversity in urban areas. When properly managed, urban parks and forests can afford landscape diversity and rich habitats for many different organisms (Alvey 2006). Residential gardens can also provide a rich diversity of species (Kendall et al. 2012). While the dense urban cores of most cities have little space for plants of any sort, other urban areas can have greater biodiversity than surroundings non-urban areas; this has been documented in both developed and developing countries (Kühn et al. 2004; Alvey 2006). This may be due to the introduction of different plants by people from around the world and the intense cultivation of land where plants will be grown. Many urban areas include parks, zoological gardens, botanic gardens, and similar sites dedicated to collection of different species. In addition, a number of local native species find appropriate habitat in cities. For example, in northern Belgium, 30% of the local wild plant species and even greater percentages of wild birds, butterflies, and amphibians can be found within city parks (Cornelis and Hermy 2004). Larger parks, not surprisingly, had greater biodiversity due to greater diversity of habitats, such as forests, ornamental gardens, and hedges. Small parks still have value for biodiversity and can be critical for wildlife in increasingly urban areas. Ikin et al. (2013) showed that small parks can provide needed habitat for bird species, especially when there is green space in the surrounding urban blocks. Tree size also has an impact: larger trees have increased bird species richness (number of different species), abundance, and breeding (Stagoll et al. 2012).

Reduced biodiversity and genetic diversity in urban areas. Many urban areas currently have greater biodiversity than surrounding areas (Kühn et al. 2004; Alvey 2006), however they may have less biodiversity than they did historically. Gregor et al. (2012) looked at changes in the number of plant species in Frankfurt, Germany, over 200 years: from 1800 to 1900, the number dropped by 2.6%, while from 1900 to 2000, it dropped an additional 7.75%. On degraded urban landscapes, highly

adapted, early succession species are often required for successful establishment (McKinney 2006). To survive these conditions, plants must grow under high light and temperatures and in droughty soils with high pH (Wittig and Becker 2010). There are a limited number of such species, which contributes to reduced biodiversity in such areas. Selecting and cloning cultivars of landscape plants, such as street trees that are well-adapted for urban conditions and human preferences, lead to reduced genetic diversity (Morton and Gruszka 2008). In a similar fashion, seed companies throughout the world distribute the same cultivars of flowers and vegetables.

At a time when global warming and climate change are subjecting urban plants to more environmental extremes and increased pest problems, the risks from greatly reduced diversity are growing (Lohr 2013). Elm trees (*Ulmus* spp.) provide an example of the problems that can arise from reduced diversity. They were widely planted as street trees in cities in Europe and America more than a century ago. Then Dutch elm disease (*Ophiostoma ulmi*), first reported in 1921, began to decimate the elms and cities where they had been planted (Wilson 1975). There was a problem from over-reliance on a few species of elms (little biodiversity), all of which had some susceptibility to the disease. The close proximity of the trees made the spread of the disease, once it was introduced, common. Within cities on both continents, many avenues with large, continuous canopies of cool shade became barren as the elms died. The spread of the disease continues today, but a handful of resistant American elms and hybrids created by crossing with resistant Asian species are now available for planting (Santini et al. 2002; Townsend et al. 2005). As plant breeders were searching for resistant trees, the disease was evolving. In 1972, a new more virulent strain of the disease (*Ophiostoma novo-ulmi*) was found (Potter et al. 2011). It is only a matter of time until other strains of the disease or other problems impact the new, currently resistant cultivars. In fact, Dutch elm disease has recently been found in trees in Japan on species that had been considered resistant (Masuya et al. 2010).

If we continue to overplant a few species and a limited numbers of cultivars in cities, other catastrophes like those from Dutch elm disease will continue to occur. In fact, similar catastrophes are readily evident today. Ash trees (*Fraxinus* spp.) were frequently planted (over-planted) to replace the decimated elms. Now emerald ash borer (*Agrilus planipennis*) in the U.S. and ash dieback (*Hymenoscyphus pseudoalbidus*) in Europe are wreaking havoc on urban areas at a similar scale to Dutch elm disease, but at an alarmingly faster pace (Poland and McCullough 2006; Bakys et al. 2009). Horticultural scientists need to understand the problems and risks from the worldwide homogenization of species in urban areas and work with the nursery industry to diversify their crops while maintaining market and profit if we are to maintain healthy green spaces in cities in the decades to come (Lohr 2013).

Invasive species. A weed is a plant that is growing in a place where it is not wanted. Historically, weeds have often been native plants, such as ragweed (*Ambrosia artemisiifolia*) in North America and dandelion (*Taraxacum officinale*) in Europe and Asia, that have invaded cultivated gardens. Today, non-native plants, such as African boxthorn (*Lycium ferocissimum*) in North America and Australia, common rhododendron of southern Europe and southwest Asia (*Rhododendron ponticum*)

in Great Britain and New Zealand, neem from India (*Azadirachta indica*) in West Africa, and yarrow from the northern hemisphere (*Achillea millefolium) in Australia*, invade native ecosystems and have become weeds of increasing concern. These are considered invasive species. According to U.S. Federal law, an invasive species is: "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (NISIC 2012). These plants may be introduced accidentally or intentionally. In the U.S., about 5,000 alien plant species have become established outside of cultivation (Pimentel et al. 2005). Not all non-natives become problems. For example, in Florida, only about 1 in 25 alien introductions have become invasive (Pimentel et al. 2005). While the percent may seem small, the amount damage to ecosystems and the economy may not be. The estimated annual cost in the U.S. for European purple loosestrife (*Lythrum salicaria*) (Fig. 31.4) alone is estimated at US$ 45 million (Pimentel et al. 2005). Ecosystem damage from the same plant includes loss of native plant species, increased wetland evapotranspiration rates, and reduced bird habitat (Blossey et al. 2001).

Increasingly, the horticultural industry and gardeners are being seen as a major source of the problem (Niemiera and Von Holle 2009; Barbier et al. 2011). There are a number of different responses to this within and outside of the horticultural industry. Some groups organize parties to remove invasive plants (WNPS 2012), while others recommend avoiding invasives and using alternatives (Coats et al. 2011). Bans on the sales of particular plants occur (Dehnen-Schmutz and Touza 2008). Some breed low fertility versions of otherwise desirable invasive species (Ranney et al. 2006). Some people work to predict invasive potential and recommend avoiding particular plants (Kueffer and Loope 2009). Some have recommended concentrating on natives (Missouri Prairie Foundation 2013). Others propose the implementation of regulation and taxes (Barbier et al. 2011). Disturbed, unnatural conditions in human dominated landscapes make urban areas inhospitable to many native plant species. Global warming and climate change contribute to the inhospitability. Some researchers are now suggesting that alien plants must be brought into cities to maintain green space (Hitchmough 2008). But we must maintain a balance between those that can tolerate the urban conditions and those that would dominate and exclude other species.

Horticultural Science's Role in Urban Food Security

Food security is a complex concept with complex causes and no simple solutions. According to the Food and Agriculture Organization (FAO) of the United Nations, food security is defined as existing: "…when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO 2013). This is exceedingly difficult to obtain at a time when the human population of our planet exceeds 7 billion people (U.S. Census Bureau 2013). The concern for world food security is not simply related to the size of the population, but also to the concentration in urban locations, where the problems causing food insecurity are

Fig. 31.4 European purple loosestrife (*Lythrum salicaria*). This beautiful plant, which had been available in nurseries, has invaded vast areas of North America, causing the loss of native plant species and increased evapotranspiration in wetlands. (Photo by V. I. Lohr)

compounded. More than half of the world's people live in urban areas (United Nations 2012). In 1970, there were two megacities (more than 10 million inhabitants) in the world, Tokyo and New York City; in 2011, there were 23 megacities (United Nations 2012). Rates of urbanization are not uniform worldwide. Africa's urban population is growing faster than that of any other region, while Asia is close behind (United Nations 2012). This has the potential to further exacerbate food insecurity in those areas.

Causes of Food Insecurity

Most causes for food insecurity ultimately translate into three key factors: lack of available nutritious food, lack of money to purchase food, and lack of the ability to grow food. The quantity of food is impacted by issues including climate change, sustainability, and affluent consumption of food products (e.g. corn for meat and

ethanol). Availability of food is impacted by the political will to provide for all citizens; the use of agricultural commodities in developed and developing countries; the impact of war and climate change related disasters; infrastructure for storage, transport, and delivery; and household resources for transportation, preparation, and storage. Even if food is available, if the quality is insufficient, then food security will not been achieved. Particularly among the urban poor, there is a significant need, for example, for sources of fresh food, which is beyond their limited purchasing power. Funds for the purchase of food is embroiled in all of the causes of poverty including health, education, gender freedoms, and other societal factors. Inability to grow food for the family is related to the urbanization of the world's population and the lack of policy and procedure to enable people who are food insecure to access urban land for cultivation.

Role of Industrial Food Production

The insurance of safe and nutritionally adequate food for all people is perhaps the greatest challenge for horticultural science worldwide. This issue is being addressed extensively from many directions—political, economic, social, environmental, and medical. But at the core of these discussions is still the optimum production techniques for horticultural crops to contribute to meeting the nutritional needs of populations lacking in food security, both in developed and developing countries that can be implemented within the constraints of the social, environmental, economic, and political realties of the population. This brings into question the other possible applications of horticulture and higher education to find sustainable solutions to intractable problems, particularly in the light of climate change and increased risk of natural disasters.

It is argued that commercial production of horticultural crops as currently practiced in the U.S. and other developed countries is not suitable for supplying the bulk of the human population with the fresh fruits and vegetables needed to provide a nutritionally adequate diet. Looking at food security from a public health perspective, Dixon et al. (2009) argue that "functional foods", one area of high interest and involvement for horticultural science, are produced by an industrialized agricultural model that will not be able to address the needs of the urban poor and are counter to long term sustainability. While functional foods are an efficient means to supply essential micronutrients, they have several problems on a worldwide basis. Involving large agrifood and pharmaceutical corporations, it is a highly profitable sector that is outside the financial reach of most of the world's population, it fails to recognize and address the realities of production with climate change, it fails to provide the nutritional balance in a culturally acceptable way that the World Health Organization (2012) recognizes as essential, and it reduces biodiversity at the same time as altering genomes. The authors point out that it is often overlooked that the green revolution contributed to marked rural inequalities and despoiled traditional agricultural environments (Dixon et al. 2009).

An additional problem with industrial-scale food production as the sole source of nutritious diets for the urban poor is that the method for getting the food to the populous is costly and wasteful, with large amounts of packaging, transportation, and fossil fuels involved. Despite this, with urban growth and increasing demand for prepared or easily prepared and storable foods, there has been a significant emergence of supermarkets and fast food chains worldwide (Kennedy et al. 2004). The demand for large quantities of uniform product has contributed to erosion of food culture and reduction in biodiversity, as well as the loss of a major sector of employment in agriculture and horticulture. Furthermore, packaged products in the supermarket contain large quantities of salt and sugar, and fast food is often very high in fat, salt, and sugar, all contributing to the worldwide health epidemic. All of these factors increase the cost of the food, often beyond the finances of the poor.

Potential Solutions

It was not until 1996 at the International Conference on Human Settlements, that the United Nations formally recognized gardening and urban agriculture for their potential contribution to the health and welfare of urban populations worldwide (United Nations 1996). In 1999, the FAO pointed out that when done in a safe and secure manner, the local production of food in urban and peri-urban regions can be successful for several reasons: increased quantity of food available, increased quality of food, and increased income from jobs or from successful marketing (FAO 1999b). According to FAO this source of food proves to be important during times of crisis and severe scarcity (civil war, widespread drought, currency devaluations, inability to import) as well as personal upheaval (illness, health, sudden unemployment).

The FAO reports case study data indicating that both food availability and incomes in poor farming households are significantly higher compared to households of non-farmers (FAO 1999b). However, it is important to note that urban gardeners are not typically the poorest residents, but rather those families that have lived long enough in the city to secure land and water and become familiar with the market channels for selling. The quality of the perishable food produced near the consumer, whether at home or in peri-urban farms, is often higher as it is fresher than when it travels long distances along the supply chain often lacking cooling in storage or transport thus quality and nutritional value deteriorates rapidly (Fig. 31.5).

As a source of income, food production offers few barriers to employment. The FAO estimates that worldwide, 800 million urban residents are involved in food producing/income earning activities with one-quarter to two-thirds of urban and peri-urban households involved in agriculture and horticulture, depending on location (FAO 1999b). In many cases, women are the primary food producer as they combine gardening with childcare and other home based responsibilities.

To overcome some of the limitations of previous anecdotal and qualitative data, a recently created dataset bringing together comparable, nationally representative

Fig. 31.5 Produce stand at the Green Market in Almaty, Kazakhstan.Locally produced, fresh crops, which are available for sale to urban populations, is not transported long distances along a supply chain. (Photo by V. I. Lohr)

household survey data for 15 developing or transition countries, was used by Zezza and Tasciotti (2010) to analyze the importance of urban agriculture for the urban poor and food insecure and provide a comparative international perspective. This study pointed out that "the potential for urban agriculture to play a substantial role in urban poverty and food insecurity reduction should not be over-emphasized, as its share in income and overall agricultural production is often quite limited." However its value cannot be dismissed as a source of income for the urban poor. And there was evidence of a positive statistical association between participation in urban agriculture and positive indicators of dietary adequacy.

The greatest growth of urban farming has been in the developing countries, but in recent years it has also become a factor of importance in the developed world as more affluent individuals choose to produce their own food to address quality rather than quantity, desiring greater freshness and control over pesticides and other inputs. The bulk of the information on-line regarding urban farming in developed countries is presented by advocates and may be biased regarding the projected efficacy in meeting significant nutritional requirements of urban populations. However the total positive impact of urban horticulture must be taken into the discussion of food security. Food grown in home and community gardens supplements other food sources and provides excess for trade or informal markets. Even with little or no

land, high valued vegetables can be produced in containers on floors or walls. Other gardening sites include parks, utility rights-of-way, bodies of water, rooftops, walls and fences, balconies, basements, and courtyards (Brown et al. 2003).

Through their web-pages and numerous books, conferences and papers the FAO (Anon 2013b) and the Resource Centres on Urban Agriculture and Food Security (Anon 2012a) provide a tremendous amount of information regarding urban population growth, food security needs, and urban agriculture practice and policy development, accompanied by a significant amount of anecdotal and qualitative research to document its efficacy (FAO 1995, 1999a; Drescher et al. 2000; FAO 2001, 2008, 2012; FAO et al. 2012). In addition, an interesting source of information is Mission 2014: Feeding the World (Anon 2013d), which provides current data and recommendations addressing world food needs developed by Terrascope, a student-run class offered to MIT freshmen that focuses on solving complex world problems through the collaboration of students, faculty, and alumni. This outstanding teaching model is indicative of the views of future generations of problem solvers and how they learn.

Additional Benefits of Urban Food Production

Health professionals are recognizing the value of farm- and garden-scale urban agriculture (Baumgartner and Belevi 2001; Bellows et al. 2004). Numerous reasons are discussed for growing food and non-food crops in and near cities. Urban food production contributes to healthy communities by engaging residents in work and recreation that improves individual and public well-being, providing exercise, enhancing mental health, as well as improving social and physical urban environments.

Based on surveys and case studies from 31 countries, the FAO (2012) recommended that African policymakers act now to refocus urbanization toward a greener, healthier environment. The current path is unsustainable as the urban populations continue rapid growth. The FAO highlights a key component of sustainable urban development: that peri-urban and urban horticulture needs to ensure food and nutrition security, decent work and income, and a clean environment for all their citizens. Studies of urban agriculture in South Africa found it is important to women of low-income households in ways less directly related to monetary gain (Slater 2001); for women, urban agriculture promotes empowerment, establishes social networks, symbolizes a sense of security, and encourages community development.

Urban food production has multiple functions, playing a role in urban poverty alleviation, social inclusion, urban food security, urban waste management, and urban greening (Hoekstra 2006). Smit and Nasr (1992) discussed the potential for transforming urban centers from consumers of agricultural products to centers that conserve resources, improve health, and produce foods in a sustainable fashion with particular emphasis on conversion of urban wastes, use of vacant areas, and other improvements of the environment. According to Bon et al. (2010), challenges for

urban agriculture include obtaining inputs, such as fertilizers, and growing fresh and nutritious food in polluted environments. They advocate the reuse of city wastes to help alleviate these challenges, but recognize that those alone will not be sufficient to achieve needed yields.

Urban food production has strong proponents worldwide who feel that it contributes to mitigating the two most intractable problems facing Third World cities – poverty and waste management (Baumgartner and Belevi 2001). They recognize that urban food production is simply one of several food security options for individuals and family groups. Urban agriculture and horticulture complement, rather than supplant, rural supplies and imports of food and will continue to do so. Cities will continue to depend largely on rural food production for bulkier, less perishable foodstuffs (Mougeot 2000). Similarly, it is only one of many tools for making productive use of urban open spaces, treating urban waste, saving or generating income and employment, and managing freshwater resources more effectively. Many professionals in the field also highlight its importance public health and sustainable resource management.

Challenges for Urban Food Security

There are a number of significant issues that challenge the success of peri-urban and urban food production to provide food security. They include:

- safety of the soils in which crops might be grown, particularly in brown fields and other reclaimed industrial sites;
- utilization of scarce resources such as water and heat for protected spaces;
- potential for health hazards including attracting rats and other pests; pesticides; polluted flood water;
- difficulty of obtaining resources such as seeds and fertilizer;
- problems in finding and keeping land for gardening;
- impact that food production for personal consumption and marketing has on family and community dynamics; and
- lack of training and skills to implement urban horticulture issues.

Research issues for horticultural science include:

- the identification of the best crops to grow given the environmental and sociocultural demands of an area to optimize the nutrition value of the resources utilized;
- affordable techniques for producing crops under the environmental and economic constrains of urban poverty, both for market and personal consumption;
- use of horticultural crops to ameliorate some of the problems such as soil reclamation, revegetation, and other bio-system issues;
- food gardening for health to include psychosocial, and physical benefits as well as nutrition as presented in other chapters in this book;

- food gardening for community development, economic opportunity, and personal growth; and
- development of educational tools and techniques particularly using computers and smartphones to improve communication and technology especially in poorer, developing countries.

Horticultural Science's Role in Urban Economics

Ultimately much of the application of horticulture to the urban environment comes down to economics and the basic concept of cost/benefit analysis. One question is: "Does the use of urban land and the installation and maintenance of plants cost more than the resulting 'profit'?" This profit may take many forms such as the savings from a reduced cost of energy or less flood damage; actual profit from increased worker productivity or property values; financial savings to individuals from improved nutrition and health; or, less tangible, thus more difficult to measure, profits from the perception of improved quality of life. In this section we will look briefly at the following areas related to economic issues: urban businesses based on horticultural crops and services; non-horticultural businesses that utilize plants as part of their business plan; and potential savings from cost of environmental issues being ameliorated by plants.

Urban Businesses Based on Horticultural Crops and Services

A majority of urban and peri-urban horticultural commodities in both developed and developing countries include vegetables, fruits, herbs, potted and cut flowers, commercial turfgrass, and horticultural crops cultivated for indoor and outdoor landscapes. In addition to production, horticultural businesses are part of the retail and service industries. Urban farm and garden enterprises employ a variety of marketing models in urban settings including: direct sales to grocery outlets, restaurants, schools, hospitals, and other institutions; community supported agriculture; cooperatives; value-added processing and sales; and sale at farmers markets and farm-stands in a neighborhood (Feenstra et al. 1999). Environmental horticulture crops are sold through nurseries, garden centers, landscape contractors, and mass marketers (Hayes et al. 2007). Flowers and related floral products are commonly found in grocery stores, quick-stop stores, roadside stalls, and corner flower stands as well as full service florists. Horticultural service businesses, including interior and exterior landscape design, construction, and maintenance, continue to grow as the urban population expands and the demand for public and private landscape increases, particularly at recreational and tourism sites. The expansion of rooftop and wall gardens offers significant opportunity for growth of the industry in ur-

ban settings. Potential for specialized small scale and essentially self-maintaining landscapes are presented by the increase in apartment dwellers with neither space for landscapes nor skills and time for maintenance. At the same time, in peri-urban settings, demands for well-designed small-scale gardens for intense caring and cultivating are increasing in demand for retired hobbyists.

Horticultural businesses provide entry level and unskilled jobs in both the production area of the industry and sales and service, which rely heavily on individuals with relatively little education or experience, thus providing jobs for population such as disenfranchised youth and immigrants. This in turn opens opportunities for training programs (Justen et al. 2009). Further demand for education among consumers opens opportunities for writers and media professionals, education consultants, and other entrepreneurs to profit from urban horticulture. In addition, urban farmers markets provide opportunities for entrepreneurial businesses for people who manage the site as well as small-scale farmers, home gardeners, producers of specialty crops such as mushrooms, and organic farmers who profit from the direct sales.

To give a glimpse of the money involved for just a small percent of the worldwide market, one study estimated that the economic impacts of the U.S. environmental horticulture industry were about US$ 148 billion in output, 2 million in jobs, US$ 95 billion in value added, US$ 64 billion in labor income, and US$ 7 billion in indirect business taxes (Hall et al. 2006). In addition, the study evaluated the value and role of urban forest trees (woody ornamental trees); the total output of tree production and care services was valued at US$ 15 billion, which translated into US$ 21 billion in total output impacts, 260,000 jobs, and US$ 4 billion in value added. Another example comes from the small country of The Netherlands, which in 2010 alone accounted for 24% of global trade in horticultural products, 50% in world trade of floricultural products, 80% of the world market in flower bulbs (Anon 2011). In 2011, their total horticultural production amounted to € 8.6 billion, and in 2010, they exported € 4.2 billion worth of vegetables. Exports and re-exports of Dutch horticultural crops amounted to € 16.2 billion in 2011 (Anon 2011). FloraHolland is the world's largest auctioneer for cut flowers and plants. In 2011, it employed 4,000 people and sold 12.5 billion cut flowers and plants for € 4.2 billion (Anon 2013a).

Non-Horticultural Organizations Utilizing Plants as Part of Their Business Plan

From tourist sites to shopping malls to corporate offices, horticultural crops and services play an important role in the profitability of many urban businesses. According to Wolf (2003) the character of a place is important to business communities as it influences consumer choices and ultimately the profitability of retail business. Among benefits were an increase in return visits, a message of care, and a perception of higher quality merchandise; negative aspects included reduced usable parking space, increased waste from tree debris. There were also higher positive

Fig. 31.6 A bridge in Frederiksberg Have in Copenhagen, Denmark. This popular urban park provides opportunities for nature-based recreational experiences, such as walking along paths among mature trees. (Photo by V. I. Lohr)

perceptions of business districts and a willingness to pay more for merchandise at businesses that had street trees and other landscape improvements (Wolf 2009).

Plants are an essential part of the urban tourism experience. Half of the respondents to a U.S. survey conducted by the Gallup Organization indicated that plants and flowers at theme parks, historic sites, golf courses, and restaurants were important enjoyment of visiting there (Relf et al. 1992). At Opryland in Nashville, TN the "greatscapes" contributed to higher occupancy and room rates for those rooms overlooking the gardens, which yielded US$ 7 million in additional room revenue annually (Evans and Malone 1992). Tyrväinen (2001) found that people want green nature-based recreation areas in their cities (Fig. 31.6), and 82 % of users were willing to pay for the recreational experiences these sites provide. A cost-benefit analysis revealed that revenues could be as much as 25 times more than the costs. A Canadian study suggested that tourist locations that feature plants attract an older, wealthier, and better-educated clientele (Lang Research 2001).This group of tourists has the interest and resources to visit public and private gardens and related tourist sites such as historical sites, natural wonders, museums, art galleries, zoos, aquariums, and planetariums and to take scenic bus tours.

Demand for recreational activities dependent upon the products and services of environmental horticulture (e.g. athletic fields, parks, golf courses) continue to in-

Fig. 31.7 Floriade in Canberra, Australia. This annual spring event is an example of a festival celebrating horticultural products that brings tourists to an area and generates income for businesses nearby. (Photo by V. I. Lohr)

crease as population increases. In Europe, new forests are also being established with public recreation and tourism very much in mind, often close to large centers of urban population (Bell et al. 2007). Tourism based on natural environments is an increasing international industry with major economic, social, and environmental consequences at both local and global scales (Buckley 2003). Festivals celebrating horticultural products are another popular form of horticultural tourism (Gen-Song et al. 2012). There are large events, such as the Flower Festival in Chiang Mai, Thailand, the Infiorata Flower Festival in Genzano, Italy, La Tomatina in Buñol, Spain, Leboku (New Yam Festival) in Ugep, Nigeria, and the Cherry Blossom Festivals in Washington D.C. and across Japan, and small ones, such as the Dogwood Festival in Lewiston, Idaho, U.S., and the Fête du Melon in Cavaillon, France. An example of the impact of such an event comes from Floriade a month-long festival held every year to celebrate spring in Canberra, Australia (Fig. 31.7). In 2012, nearly ½ million people visited Floriade (Barr 2013). More than 1/4 of the visitors were national or international travelers who came to Canberra because of Floriade and spent nearly AU$ 30 million. The City estimated that news stories about the event reached almost 34 million people, and they estimated that to be worth more than AU$ 5 million.

Employees are the single greatest expense for any business. Even small increases in job satisfaction, productivity, and health can have significant impact on the net profit of a business. Plants contribute to all of these. Workers with views of nature, such as trees and flowers, have been shown to experience less job pressure, be more satisfied with their jobs, and have fewer ailments than those who could only see built elements from their windows (Kaplan et al. 1988). Productivity on a computer task was shown to be higher in a room with interior foliage plants compared to one without plants (Lohr et al. 1996). Subsequent studies have further explored the potential impact on employees and anecdotal evidence from corporations utilizing plants further substantiates their value (Thomsen et al. 2011). Workers in an office with foliage plants reported fewer physical symptoms including coughing, hoarse throat, and fatigue than when no plants were present, translating into more productive workers (Fjeld 2000). A major cost to employers is employee's sick time. Additional studies showed improvements in indoor air quality through reductions in air pollution (Burchett et al. 2005) and dust (Lohr and Pearson-Mims 1996) and an increase in relative humidity (Lohr 1992), all of which could have a positive impact on health of employees. Employees appear to understand the need for plants, as those who work in windowless offices have been found to be 5 times more likely to have brought plants in their offices than those with windows (Bringslimark et al. 2011).

Value of Plants to Real Estate

The real estate industry is impacted both by the quality of the landscape of the property on the market and the proximity to parks, botanic gardens, and other urban green. Crompton (2001) reports positive impact of parks, open spaces, and water features on residential property values. Behe et al. (2005) reported that landscape plant material, size, and design sophistication increase the perceived home value from 5 to 11% for homes with good landscaping. In another study comparing homes with the same square footage and other characteristics, Stigarll and Elam (2009) reported that homes that improved landscaping from average quality to good or excellent quality increased selling price by 5.7% and 10.8%, respectively. HomeGain (Anon 2013c) surveyed nearly 600 real estate agents nationwide to determine the top 10 low cost, do-it-yourself home improvements for people getting their home ready to sell. They reported an average investment in landscaping of US$ 540 gave an average US$ 1,932 price increase for a 258% return on investment. Culp (2008) reported a study of on-site inspections of 3,088 home sites that showed that time on market is reduced and price is increased by a variety of green features, such as trees, landscaping, open spaces, and parks.

Another way in which plants have significant impact on real estate value and the economics of real estate to urban governments is as an alternative method of dealing with vacant properties. In Baltimore MD U.S., where it is estimated that it can cost city services between US$ 2,000 and US$ 4,000 per year to clean a problem lot, the city established a new program "Vacants to Value" (Sernovitz 2011) aimed at

reducing the estimated 40,000 vacant lots or abandoned row homes through sale to homeowners for planting gardens and lawns. Converting vacant lots to community gardens is another approach to significant sanitation savings. In Sacramento, California (CA) researchers compared community gardens to city-managed parks and found that the community garden was 20 times cheaper to create and 27 times cheaper to maintain each year (Francis 1987). Urban green spaces from rooftop plantings to community gardens to parks and greenways reduce storm water runoff and improve water quality and thus the related service costs. Reduced noise, glare, and wind and temperature moderation all have impact on energy costs, human stress and health, and other factors that translate into dollar savings for the urban governments and businesses.

Personal Perspectives on the Urbanization of Horticultural Science and Conclusions

The role of horticultural science in the urban environment is an issue of definition and perception by researchers, academics, and others who shape the knowledge and attitudes about a scientific arena and the profession that it supports. The transition in attitude over the last 50 years has been significant and promises to accelerate as the human population continues to urbanize. In 1963, co-author Relf, as a Horticulture Science freshman in a land-grant university in the U.S., was told that horticulture was the intensive production of crops and encompassed the skills and knowledge for growing fruits, vegetables, cut and potted flowers, and woody plants. The commonly held definition of horticulture as an art as well as a science was acknowledged via studies in landscape design and construction. While insects, diseases, and weeds were essential parts of the science of horticulture; related topics such as extension, marketing, and education were peripheral subjects to be studied by non-horticulturists. Environmental impact was not discussed, and organic gardening was heresy and a return to the mythology and ignorance of the past. Women and urban students were an anomaly. As the top graduating senior in horticulture in 1967, Relf was told by a noted horticultural production firm that they would hire a man who was classified 1A by the draft board and on his way to Vietnam before they would hire a woman. In 1975, co-author Lohr was told that it was great to have women in horticulture departments, because they were good at flowering arranging due to their manual dexterity.

In the 1970's the environmental movement began to influence people's thinking. In the U.S., the demand for information from the public and the influx of urban students wishing to change the world by growing a garden forced horticulture departments to become aware of the urban population and to expand their course offerings to a wider non-production audience, thus indoor plants and home horticulture were offered to non-majors. As more urban students joined horticulture departments, they become more diversified in race and gender. The changes in size and diversity of the students forced open doors for additional course work to be included in horticultural

science degrees. Kansas State University established a degree in Horticultural Therapy and shortly thereafter Michigan State University began a program. John Carew, their department head, fully demonstrated the challenges in attitude to be faced in redefining horticultural science while at the same time indicating a willingness to try to adapt to new paradigms when he commented to Relf, "I am glad you invented this horticultural therapy. It will give my little girls something to do."

By the late 70's and early 80's the academic acceptance of human-oriented, non-traditional horticulture increased (Cotter et al. 1978; Relf 1982). *Home Gardening* had become *Consumer Horticulture* and the formation of HortTechnology as a refereed journal by the American Society for Horticultural Science (ASHS) opened more doors for an expanded definition of horticultural sciences. The specific needs of urban communities came to the forefront in the U.S. with the establishment of the Urban Horticulture Institute at Cornell in 1980 and the Center for Urban Horticulture at University of Washington in 1983.

As horticultural science moved closer to the 21st Century, researchers including Relf, Lohr, Shoemaker, and others called for greater recognition of the relationship between horticultural science and the urban environment with a greater focus in horticultural science on the psychosocial aspects being researched by urban forestry, environmental psychology, landscape architecture, social ecology, anthropology, sociology, geography, communications, and other fields (Relf 1990; Relf 1992b; Lohr and Relf 1993). Relf also proposed a more complete definition of horticulture (Relf 1992a).

> Horticulture—the art and science of growing flowers, fruits, vegetables, trees and shrubs resulting in the development of the minds and emotions of individuals, the enrichment and health of communities and the integration of the 'garden' in the breadth of modern civilization. By this definition, horticulture encompasses PLANTS, including the multitude of products (food, medicine, O2) essential for human survival; and PEOPLE, whose active and passive involvement with 'the garden' brings about benefits to them as individuals and to the communities and cultures they comprise.

Today, this broader understanding of horticulture is widely embraced. The International Society for Horticultural Science has had a Commission on Landscape and Urban Horticulture for many years. The broader understanding of horticulture became the theme of the XXVIth International Horticultural Congress held in Toronto, Canada in 2002: Horticulture—Art and Science for Life. The opening plenary colloquium of that Congress focused on human issues in horticulture, recognizing "…that the horticultural arts and sciences exist to nourish and enrich the human body and the human soul" (Lohr et al. 2004). It is widely evident in the chapters in this book.

With the increasing urbanization of the world and the daunting global environmental changes instigated by human activity and related global warming and climate change, it is essential that horticulturists focus on the needs of urban populations. We have illustrated some of the issues and opportunities for horticulture. For example, environmental justice demands that all individuals have access to a healthy environment. This is a particular problem for disadvantaged and disenfranchised individuals with strong racial and income implications that can be addressed

through properly researched and designed horticultural initiatives. Howard Frumkin, from the Centers for Disease Control and Prevention in the U.S., and Anthony McMichael, from the National Centre for Epidemiology and Population Health in Australia, called on readers to recognize the value of designing and maintaining a healthy natural environment as a essential preventative measure integral to public health (Frumkin and McMichael 2008). By combining awareness of traditional horticultural issues, i.e. feeding the world, with expanded awareness of functions and services provided by additional horticultural crops and awareness of the needs of people, horticulturists should become indispensable members of teams addressing urban populations.

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