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Chapter 5
Producing Food and Fuel in Urban Areas

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Producing Food and Fuel in Urban Areas

Urban agriculture includes many diverse production systems, each with multiple processing methods and marketing procedures. These systems often link to each other, with the waste from one typically feeding another. In greater Mexico City, for example, sewage is used to irrigate and fertilize alfalfa, which is sold as fodder to small-scale producers of guinea pigs and rabbits, as well as to cattle growers. The small-scale livestock producers barter their manure to vegetable and flower growers, who mix it with compost made from household and street waste. They also sell it to the *nopal* (cactus) producers in the peri-urban area.[1] Thus the waste stream is transformed into food, beauty, and biodiversity while supporting six different farming systems: fodder, cattle, small livestock, vegetables, flowers, and cactus.

Although urban agriculture practices vary widely from continent to continent, from country to country, and even from town to town, for purposes of discussion, this form of agriculture can be divided into five broadly defined farming systems:

- horticulture,
- aquaculture,
- animal husbandry,
- forestry, and
- other urban farming production systems

The categories used in this chapter do not correspond precisely to any classification of farming systems taught in agricultural schools, but rather reflect the authors' field observations (Table 5.1).

The patterns described in this chapter are not exclusively urban — many of the farming methods also show up in rural areas, but all are especially appropriate to urban situations. When growing vegetables, for example, product freshness is critical, so rapid access to an urban market combined with intense cultivation makes horticulture an especially important part of urban agriculture.

Data are persuasive that urban agriculture contributes to cultivation and conservation of diverse crops. In the Washington, D.C. area, the number of tomato varieties available on the market rose from 12 to 72 in the period 1982 to 1996.[2] The explanation may lie in the greater need for the city farmer to cultivate for daily market demand.[3] Many high-value specialty ('niche') products are also grown or raised close to their urban consumers. These two phenomena (diversity within and across crops) can have a significant impact on the variety of plants (and, to a lesser degree, animals) found in an urban area. Some of these are generally native species.

Table 5.1 Farming systems common to urban areas

Farming system	Products	Where and how
Aquaculture	Fish, other seafood, vegetables, seaweed, fodder	Ponds, streams, cages, estuaries, sewage, lagoons, wetlands
Horticulture	Vegetables, fruit, compost	Home sites, parks, rights-of-way, rooftops, containers, hydroponics, wetlands, greenhouses
Livestock	Milk, eggs, meat, manure, hides, fur	Zero-grazing, rights-of-way, hillsides, coops, peri-urban, open spaces
Agroforestry	Fuel, fruit, nuts, compost, building and handicraft materials	Street trees, home sites, steep slopes, vineyards, greenbelts, wetlands, orchards, forests, parks, hedgerows
Miscellaneous	Houseplants, medicine, beverages, herbs, flowers, insecticides, mushrooms	Ornamental horticulture, rooftops, containers, sheds, beehives, cages, greenhouses, rights-of-way, urban forests

Source: Compiled by The Urban Agriculture Network from various sources

In the past couple of decades, there has been a resurgence of small-scale private research into urban farming methods such as biointensive raised-bed gardening, shallow-bed gardening, vermi-composting, zero-grazing, small-scale wastewater-based aquaculture, and hydroponics. Only a few subsystems of urban agriculture, such as chicken and egg production, have benefited from long-term public and private research and development. In most sectors, the special requirements of urban cultivation have received little attention. Agricultural research centers and extension services can play an important role in increasing the appropriateness of the varieties, farming systems, and techniques to the specific context of each city.

Urban agriculture produces fuel and other products in addition to food. For instance, fuel briquettes are produced from wood, cow dung, and other agricultural by-products such as the husks of cashew nuts (in East Africa) and coconuts (in eastern India).

There appear to be patterns in the scale at which various kinds of farming are practiced. Roadside cattle grazing and vegetable farming systems are predominantly small operations. Urban aquaculture, poultry farming, and orchards are dominated in most countries by medium- to large-scale operators.

The health hazards of producing food in urban areas must be recognized when looking at farming systems in the city. Pollution levels of soil, water, air, and wastes tend to be higher in the city than in rural areas. The presence of a large human population that potentially could be affected by its proximity to urban farms is another inherent characteristic. These two factors increase concerns about the potential health effects of farming in the city, and make selection of product and method especially vital in urban areas.

Certain parts of cities are too polluted for farming (at least directly in the soil), because plants and animals can transfer poisonous chemicals, heavy metals, or disease-carrying pathogens to farmers and consumers. Pathogens from irrigation in horticulture may represent a particular danger for spreading communicable diseases. Farmers themselves may face additional health risks by coming in direct contact with the heavy metals or pathogens. In certain cases, farming activity may increase the habitat for disease vectors, such as ponds in fields that may allow malaria-carrying mosquitoes to breed. Chapter 8 discusses health and urban farming, and ways to manage risks. Health risks always need to be balanced with the nutritional gains that fresh fruits and vegetables yield (as detailed in Chapter 7) to obtain a full picture of the health dimensions of urban horticulture.

Some aspects of intra- and peri-urban agriculture may be inherently more sustainable than those of rural agriculture. The former typically consume less land per unit of production because of higher land prices and greater competition for use of land. Given the greater availability of waste from human habitation, there is greater potential in urban farming to use waste as an input, thus reducing pollution and enriching the soil. Furthermore, urban farming is often less likely to include large-scale commercial practices that degrade the environment. Intensive urban practices generally use less water per unit of production.

A word of caution — some of the most unsustainable agricultural practices can also be found in urban areas. Concentrated livestock farms are sometimes located in peri-urban areas, threatening both local health and the environment, as does the use of unsorted waste as fertilizer. In some rich countries, low-intensity grain cultivation (e.g., in France) or rearing horses (in the U.S.) may be maintained around metropolitan areas through special land-use regulations and subsidies. Within an urbanizing setting, these are inefficient, unsustainable uses that can accelerate the sprawl of a metropolis. These few examples give a sense of the complex relationship between urban agriculture and sustainable agriculture.

Horticulture

Intensive production of vegetables and fruits (including market gardening or truck farming) is the most common and varied form of urban agriculture. Urban horticultural production takes place on all continents. Farmers range from the poorest slum dwellers growing a few tomatoes on some space around the hut to large agribusinesses.

Urban horticulture includes a vast variety of crops, depending on local tastes. A growing trend is the use of plastic-sheltered cultivation, which provides protection from cold, rain, wind, sun, birds, and insects. Urban crops are generally perishable, high-value, or specialty crops, including culinary and medicinal herbs. Some special horticultural crops are discussed at the end of this chapter.

The dominant image of horticulture today is a field with a single crop, whether tomatoes or artichokes. Unlike contemporary mechanized horticulture, urban agriculture is both labor and land intensive rather than extensive, and is typically multicropped. Thus urban horticulture is a candidate to increase biodiversity in horticultural systems, and

possibly in cities. If public policy favors urban biodiversity and sustainable agricultural practices, this increase becomes more likely.

The International Plant Genetic Resources Institute found in Africa that because "market gardening in urban areas [has] a narrow base in species and varieties", it can result in a "loss of access to plant diversity".[4] On the other hand, studies by ICRAF, UNU, and FAO have found remarkably diverse crops being grown in rural and urban household gardens. A recent UNU study found that seeing 50-75 varieties in a single garden was not unusual.[5]

The urban horticulturist has a much greater opportunity to compost organic waste than the rural one, in some cases mixed with appropriate inorganic material. The Mid-Peninsula Institute in California, long a leader in biointensive horticulture, claims that it can 'make soil' up to 40 times faster than Mother Nature.[6]

At the same time, urban horticultural practices are sometimes environmentally less friendly. Monocropping and the heavy use of chemical fertilizers and insecticides are especially common in market gardening, both of which can contaminate the soil and lower fertility, and perhaps produce unsafe food. Hence, urban horticulture can either enhance or degrade the environment and biodiversity, depending on its particular context and practices.

Household gardening is the most common form of urban horticulture (on-site at lower residential densities and off-site at higher densities). Its incidence varies from city to city and country to country. Evaluations of household gardens in the Philippines by the International Institute of Rural Redevelopment found that a family could feed itself from an 80-square-meter plot in a tropical climate using intensive horticultural techniques such as those developed by the Asian Vegetable Research and Development Center and other institutes.[7] In some cases high-value crops fulfilled a minimum living standard for a family on 160 square meters, providing food and other essentials.

A study in Java by FAO found that intense multicropped household gardens produce three times the monetary value per unit of land as three-crop rice farming.[8] The multicrop model generates crops every week of the year. In part, this is accomplished by operating on four layers — high trees, low trees and bushes, ground level, and root level. Crops include vegetables, fruit, culinary herbs, medicinal herbs, and flowers. This 'layered horticulture' used in Java and other Pacific islands is also found in West Africa.

Streiffeler notes that "mixed cropping can be an effective use of limited space, especially if the plants have different nutritive requirements." It also spreads "the risks of climate and attacks by insects, fungi and so on"[9] (Case 5.1).

Case 5.1 VAC yard horticulture in Viet Nam

Farmers in Viet Nam are increasing the productivity and sustainability of their backyard farms with help from the Vietnamese Gardeners Association. The association is promoting VAC — a process of mixed cropping that provides crops with improved nutrition, nourishes the soil, and provides cash crops. The VAC program is partly sponsored by UNICEF and promotes integrated farming of vegetables, pigs, and fish.

A farmer in Xuan Phuong outside Hanoi is growing vegetables in his 720-square-meter front yard for direct marketing in the several open markets in Hanoi. The yard grows grapefruit, oranges, bananas, papayas, sapodilla, mint, squash, onions, amaranth, protein-rich sauropus, and sweet potatoes. The plants grow at different levels and heights, providing shelter, shade, and nutrition to each other. The leaves of some plants are fed to pigs, while other parts — such as sweet potatoes — are for human consumption. The yard is fertilized with pig manure and human waste.

The farm includes a small fishpond that has about 1,500 fish. Species are carefully chosen to be symbiotic. Tench tend to feed near the top of the pond, carp in the middle, and tilapia at the bottom, feeding on waste from the two species living above it. The pond is covered with water hyacinth, which provides oxygen for the fish, protects them from the sun, and is fed to the pigs. The yard also has a pigsty with a sow that produces up to 20 piglets a year. Yard greens and fish-laced meal are fed to the sow.

In 1992, one farmer using the VAC system made about US$ 450 from his yard. (The average Vietnamese annual income is US$ 240.) UNICEF estimates the income of VAC farmers to be from three to ten times higher than that of rice farmers.

VAC gardens are also established by schools, churches, orphanages, old-age centers, and factories in Viet Nam, providing their users with free or subsidized nutritious food. The gardeners association has a corps of extension workers who are experts in the various technologies and farming systems, and provide extensive and regular advice to the VAC farmers.

Contact: Vu Quyet Thang (see Appendix F for complete address).

Household horticulture is primarily for consumption by family and barter within the community, but it can also be expressly for the formal market. Families in Thailand generate thousands of dollars by growing orchids on their verandas. Housewives in Latin America produce chilies and market homemade salsa. Lettuce grown on home rooftops is sold directly to supermarkets in Bogotá.

Families that do not have a yard at their home practice horticulture in allotments and community gardens or on plots located at the city's edge. The best known example is the Russian *dacha,* or small plot of land, within a couple of hours of the city center. *Dachas* have evolved from being primarily a form of recreation to an essential for the well-being of millions of urban Russians since the Gorbachev liberalization beginning in the 1980s.

In some places, types of farming differ depending on location within the metropolitan area. In Lusaka, Zambia, for instance, there are two distinct horticultural practices — vegetable cultivation around the home or inside the community, often using irrigation; and cultivation of staple foods at distant sites in the peri-urban areas, only in the rainy season.[10] Income tends to vary between these two practices because the lowest income groups generally do not have the resources necessary to practice dry-season cultivation.[11]

To previous generations in Europe and North America, urban horticulture may have been synonymous with *market gardening,* and in some places, it still is. Intensive production of fruits and vegetables in peri-urban areas by medium- and large-scale growers is common where transport costs are high and governments recognize its value. Thus market gardening is common along the rail lines at the edge of cities — congested Bombay (with no government support) and Tokyo (with government subsidy). New Jersey, where most of the population is urban or suburban, is still referred to today as the

Garden State, and produces fresh vegetables and chickens for the New York and Philadelphia metropolitan areas.

Market garden crops differ from rural crops — they are planted in response to estimated weekly market prices, and are produced because the farmer is located near a market, not because the climate and soil are necessarily best suited for the particular crop. Market gardening can be distinguished from community-based, consumption-oriented horticulture in that it is larger in scale, predominantly monocropping, and solely market oriented.

Small-scale low-income market gardeners form a significant population with a large productive capacity in poorer cities such as Bamako, Mali and La Paz, Bolivia. Market gardeners are usually among the wealthier farmers and sometimes are corporate. They rely more on hired staff, and many have professional managers.

Market gardeners often organize to enhance their pre-production, production, and post-production capacities. In some locales, for example, Taiwan (province of China), market gardeners have an information and technical assistance system established in cooperation with government. Farmer cooperatives provide extension services, inputs, credit, and marketing assistance.

Some horticultural practices, such as container horticulture and soilless horticulture, are particularly relevant in the urban context. Plants need only light, water, and a medium in which to take root. This medium may or may not be soil transported to urban settings. We will discuss next a range of such alternative horticultural practices.

Container Horticulture

Plants can be cultivated in a variety of containers — boxes, rain gutters, pots, used tires, even plastic bags — that can be placed in a variety of locations, including patios, balconies, open stairwells, and flat roofs. While container horticulture tends to be soil-based, the next sub-section will introduce several approaches that do not rely on the use of soil.

Restricted space in high-density quarters encourages container farming. In Mexico City, a typical field crop such as potatoes is grown in stacked used truck tires, producing a vertical cylinder of potatoes. In Santiago, Chile, the Centre for Education and Technology has a 20-square-meter demonstration city garden plot. The researchers make the most of the small space by planting crops in containers stacked in pyramids **(Photo 5.5)**. Plants grow on the walls and the same vines that provide a ceiling of shade also provide crops. By using containers, walls, and even air space, 20 square meters provides twice that much productive farm space.

Container farming has both the usual concerns related to agriculture (access to water, credit, and marketing) and its own special technical requirements. During the 1980s, container agriculture became a sustainable source of food security and income for an increasing number of low-income farmers. In the area of ornamental horticulture, it has also become a viable middle- and high-income farming system. The use of plastics for all kinds of containers has expanded dramatically, making them more readily available than traditional pots made from clay or expensive cloth.

Container farming is popular worldwide. Growing houseplants in plastic pots on the roadside and cactus in a box on balconies was mentioned earlier. In Hong Kong, vegetables are grown in containers that rest on top of the floating cages used for raising fish. In Old Delhi, silkworms live in boxes on verandas.

Soilless Horticulture

Another urban horticultural practice is soilless farming. Several forms of horticulture do not use, or at least do not require, soil. Some of them do include a small amount of soil to start plant growth, but the main medium may be any other organic matter. Crops may be grown in compost without soil, or even directly on solid waste. Two forms of soilless horticulture need to be highlighted — shallow-bed gardening and hydroponics.

Shallow-Bed Gardening

Shallow-bed gardening (sometimes called 'lazy-bed') is a technique that can be used to grow crops intensively on rooftops and other non-fertile surfaces (parking lots, paved schoolyards). It is useful for people who do not have land space on which to grow crops and for those dealing with contaminated urban soils. In this process, organic waste can be spread directly on a barren surface. Crops are seeded or set as seedlings in small amounts of soil (a bucket full) and the plants claim nutrition from the uncomposted waste.

Shallow-bed gardens need more frequent watering than plants grown on land. If the gardens are kept well-watered, the roots do not need soil. Many crops that send their roots deep on land can be grown in shallow beds.

Educational Concerns for Hunger Organization (ECHO), a U.S. non-profit organization, promotes rooftop shallow-bed cultivation among low-income residents in several locations, including Russia (Case 5.2). In Port-au-Prince, Haiti, the method has been particularly successful on the roof of a hospital and on paved patio surfaces. The shallow-bed garden is made up of a 3-6-inch bed of compost, 4-5 feet wide and several feet long. Fresh organic matter — such as wood chips, grass clippings, rice hulls, corn husks, or bagasse — is used where compost is not available. (Bagasse is plant residue left after a product has been extracted, such as juice from sugarcane or grapes.)

Case 5.2 Shallow-bed gardening on inner-city rooftops in Russian cities

ECHO's activities may have been most remarkable and enduring in Russian cities. It has been working in Saint Petersburg since the early 1990s on rooftop gardening in shallow beds. Along with a number of high-rise apartment buildings, a prison presents an outstanding case.

Local peat is used. The individual seedling is planted in a liter or two of soil set into the organic waste growth medium. Soil is not added to the bed — the compost has all the nutrients required, and soil would add weight that could cause structural problems on rooftops. The beds do not usually need a base or sides — the bags of peat are simply opened and used as containers. Several gardeners improved their 'soil' with compost from kitchen waste. One farmer set up a vermiculture operation in the basement to generate worms to make the cultivation more effective.

Environmental pollution of the food is one of the fears that constrain the expansion of shallow-bed farming in town. Tests carried out by the Russian State Committee on Standards showed almost identical results to those of Cornell University in New York — produce grown on rooftops contained up to ten times fewer contaminants than produce bought at local markets or grown on suburban plots.

After its initial success in the Saint Petersburg apartment buildings, the roof of a center for invalids (mostly soldiers who returned injured from Chechnya) was put in use in 1996. ECHO has been working with another U.S.-based organization, the Center for Citizen Initiatives, to expand rooftop gardening, starting with Moscow in 1996. They trained local trainers to improve practices, targeting the disadvantaged. The first site in Moscow was the roof of an orphanage.

Contact: Martin Price and Will Easton (see Appendix F for complete address).

Market crops can be grown in rooftop shallow beds in the heart of the city. Plants that can be grown include broccoli, cabbage, peas, beans, onions, tomatoes, herbs, maize, eggplant, and flowers. Pumpkin and watermelon can also be grown, with the vines flowing out of the beds. Root crops are not suitable for shallow beds.

UNICEF used shallow-bed horticulture successfully in Ethiopia during the 1980s. In Texas, tomatoes are 'traditionally' grown at home in a bale of straw. In the south Bronx in New York City, shallow beds were built on plastic placed over contaminated soils, and vegetables grown in the beds were judged safe by New York state inspectors.

Hydroponics

Hydroponics is the most important form of soilless horticulture, a plant-feeding technology in which plants are grown in sand, gravel, cinders, volcanic ash, or float in water with minerals and nutrients, as required. Hydroponic farming is highly resource efficient, using one-tenth or less water than field crops. Crops can be fed by hand or through a pump. Its low water usage makes this technology especially useful in areas with water shortages.

The importance of this decades-old technique expanded significantly in the 1980s. Developed in Europe and North America as a capital-intensive farming system, hydroponics has been modified in a few developing countries to be a low-capital, high-labor 'popular' system (Case 5.3).

Case 5.3 Farming without soil — women's hydroponic cooperative, Jerusalem, Bogotá

A cooperative of more than 100 low-income women in Jerusalem on the outskirts of Bogotá produces hydroponic vegetables (up to 30 different varieties) on contract to a supermarket chain that supplies the metropolitan area. Production on rooftops and other household surfaces began in 1985. Technical assistance has been provided by Centro Las Gaviotas, which developed the technology in Bogotá with funding from the UNDP office in Colombia and later through the supermarket chains.

The women in the APROHIJE cooperative (Asociacion de Productoras de Hidroverduras de Jerusalem) earn as much as their husbands earn in semi-skilled jobs (if one can even be found).

They produce all their own inputs except seeds (which are imported), including nutrient solution, which they also sell to other growers. The crops are of a good quality, but overripe or less-than-perfect crops are consumed by the farming family or fed to microlivestock.

The technology of hydroponics has received much attention. From Bogotá, it was transferred to the Dominican Republic, Venezuela, Nicaragua, and Chile. In Bogotá, however, the project has suffered since assistance ended, which demonstrates the necessity for locally manufactured nutrient solutions.

Contacts: Dr. Jorge Zapp and Cesar Marulanda (see Appendix F for complete addresses).

Hydroponics has two great advantages in low-income urban situations. First, it is virtually safe from water and land pollutants. Second, since the production is soilless and in some form of container, it does not depend on land space — plants can be grown anywhere, including the market roof. Consumers benefit from a fresher product.

Hydroponic horticulture requires a great deal of organization to be established as a viable commercial farming system. Some inputs (for example, seeds and fertilizers) may need to be imported, or a new local production system may need to be set up. And because each crop requires careful tailoring to the local climate, good collaboration among farmers, technical experts, and marketers is needed.

A variant is aeroponic horticulture, a newer system with great potential. One of its advantages is the ability to manipulate root zone temperatures, which allows crops to be grown far from their climatic region.[12] Aeroponic horticulture, however, requires advanced growing techniques in controlled environments, and is thus far from being adaptable to ordinary settings and ordinary farmers. Training courses in hydroponics and aeroponics techniques began in 2000 in Singapore, perhaps the leading nation in this cultivation method.

Aquaculture

Aquaculture is the fastest growing sector of agriculture.[13] It includes fish crops of all types as well as many vegetable crops. It takes place in man-made tanks or in ponds, lakes, rivers, estuaries, and bays from tropical to temperate climates. Calcutta raises over one-fifth of its fish demand in sewage-fed lagoons.[14]

Urban aquaculture includes a diverse range of production methods. The most evident split may be between saltwater and freshwater aquaculture. As water shortages become increasingly prevalent in one region after another, the former is becoming more important, especially to coastal cities. The potential of urban aquaculture remains substantially untapped. Obvious candidates such as the Gaza Strip in Palestine remain devoid of saltwater farming.

Aquaculture has the capacity to increase biodiversity or diminish it, to enhance the urban environment or harm it. Instead of a mechanical-chemical-polluting sanitation process, beneficial aquaculture can convert a substantial portion of a city's wastewater (and some of its solid waste as well) into food, greenery, and biodiversity. Fish and water vegetables can be raised in wastewater that is purified less completely than that needed

for direct human consumption. In many cases, the process of raising these crops purifies the wastewater to a cleaner state than some current sources of potable water.

On the other hand, however, aquaculture that uses high levels of external inputs can pollute surface and groundwater and reduce biodiversity. The fastest growing aquaculture crops of the 1980s and 1990s have been monocropped, particularly shrimp and seaweed. These technologies have had substantial negative environmental impacts, both by destroying other species in the farm area and by adding chemicals to the downstream watershed. Lagoon shrimp production requires eliminating other aquatic life, and use of antibiotics interferes with nature's biotic patterns. In the Philippines and elsewhere, the sea bottom is sanitized to monocrop seaweed on trellises. Hybrid fish raised in cages can escape and cross-breed with indigenous species, potentially causing widespread ecological problems.

Multicrop aquaculture has not had the large investments of monocrop, but research is showing very good results.[15] The multicrop methods will show greater secondary benefits for towns and cities — greater biodiversity, better links to land-based aquaculture, and capturing the synergy between crops without the risks of monocropping.

Aquaculture is sometimes a significant contributor to the urban ecology in a symbiotic relationship with other forms of urban agriculture. Thailand is known for raising poultry over fish tanks, and periodically the bottoms of the tanks are dredged and used for biointensive raised-bed vegetable production. Another aspect of this synergy is slaughtering chickens near fish farm tanks, with the offal going directly to feed the fish.

Urban aquaculture can be undertaken in bodies of water not in current productive use, many of which are publicly owned. It is also compatible with many recreational uses. Raising fish and crustaceans in urban and peri-urban water can be an economical complement to ocean fish and rangeland meat, conserving the global ecosystem as well as reducing consumption of energy for refrigeration, transport, and storage.

The production of aquatic plants and animals is not restricted solely to bodies of water. Aquaculture is found on a rooftop in Brisbane and Heifer Project International raises Nile perch in 50-gallon drums in basements in Chicago.[16] IIRR in Manila introduced raising eels in metal drums, which allows garbage to be used as food and supplies an excellent source of protein. Eels require little care because they can go without food for two weeks.

Aquatic Plants

Water spinach, water cress, water chestnuts, lotus stems, and various so-called seaweeds are common low-cost foods in Asia and Africa. Water spinach is a leafy plant grown in marshy areas and on streamsides in India, southeast Asia, Taiwan (province of China), and southern China. It is consumed as a vegetable and used as feed for livestock and fish. It takes root easily, requires little weeding, and can be harvested at any time. With heavy applications of treated night soil, water spinach yielded up to 90,000 kilograms per hectare in Hong Kong.[17]

Floating aquatic plants such as duckweed and water hyacinth have considerable potential as livestock feed and as a base for compost and fuel. When raised on

wastewater, they offer a biologically sustainable solution to the problem of urban water pollution. These plants purify wastewater by rapidly breaking down and consuming nutrients from sewage, especially nitrogen and phosphorus. The plants can then be fed to livestock or fish in a pond, and the nutrients are thus recovered. The purified water can be recycled into other uses, including irrigation and groundwater recharge (Case 5.4).

Case 5.4 Wastewater purification using duckweed in Bangladesh

While not a common activity in Bangladesh, wastewater reuse in aquaculture did have a small presence there. What little activity existed was in decline because some ponds were disappearing due to rapid urbanization, and the remaining ones were overloaded with organic matter. The best hope for wastewater reuse may lie in the introduction of duckweed into the system.

In experiments conducted in Bangladesh by the Prism Group (a U.S. non-profit organization) and the UN Capital Development Fund, wastewater from the Kumudini Welfare Trust Complex was channeled into duckweed farms. It was completely purified in 20 days, with less than 0.5 milligrams of nitrogen and phosphorus per liter.

Other aquatic plants such as water hyacinth have water purification properties similar to duckweed, but the latter has the advantage of being a much more valuable commercial crop. In the Bangladesh experiments, duckweed farmers are harvesting about 1 ton per hectare per day, making more than US$ 2,000 per year by selling the crop as a high-protein animal feed that is cheaper than its alternatives.

As fish feed, duckweed can triple the yield of fish over unfed ponds. The Prism Group experiments with feeding duckweed to fish yielded an average of 10 tons of fish per hectare per year (the Bangladesh average is 400 kilograms), generating a gross profit of US$ 16,000 per year.

Based on these experiments, Prism has begun to spread the technology. At Mirzapur, it operates duckweed treatment systems using wastewater from a hospital, and at Khulna using municipal sewage. Prism has also introduced a household, latrine-fed pond system to about 50 villages in Bangladesh, with duckweed cultivated to improve sanitation and feed fish in nearby ponds.

Contact: William Journey and Peter Edwards (see Appendix F for complete addresses).

In the United States, the Lemna Corporation has nine facilities purifying wastewater with duckweed, a process that offers savings of 50-75 percent over competing technologies. Lemna is also treating waste in Torreon, Mexico, and plans to do so in Egypt as well.

Duckweed grows quickly in many climates in temperatures ranging from 15 to 30 °C **(Photo 5.1)**. It doubles its wet weight in 2-4 days with per acre yields as much as 10 times those of soya bean. Dried duckweed has about the same amount of protein (35-50 percent) as soya bean. Israel exports the weed as a salad crop to European health food stores.

Fish and Other Seafood

In addition to fishing in open public waters, urban residents engage in urban pisciculture, breeding and producing fish and other seafood in controlled environments in ponds or

cages in rivers or lakes within metropolitan areas. In Jakarta, for instance, the city's reservoir is leased to fish farmers, and 1 hectare of water produces the same income as 1 hectare of land.[18] In Panama, one small-scale farmer who has four one-quarter-hectare ponds raises tilapia, carp, shrimp, and native fish for separate urban markets, all fed by waste from pigs and poultry **(Photo 5.2).**

In West Bengal, including greater Calcutta and several smaller cities, fish yields increased six-fold during the 1980s, primarily in man-made tanks and wastewater-fed lagoons.[19] In Hong Kong, fish are raised in small tanks with fences around them (providing open space in the center of high-density residential areas), and in cages in bays and lagoons. Some of the floats suspending the cages are used as the foundation for vegetable and chicken production.

In some cities surrounded by water, particularly in Asia, the contribution of pisciculture can be truly significant. Around metropolitan Manila, total fish production from within the city and off-shore was 226,000 tons in 1998, covering about two-thirds of the area's total fish demand. About 2 percent of the area of metropolitan Manila is covered with fishponds.[20]

It appears that fishing is by custom a male occupation around the globe, even in countries where women are traditionally accountable for food production. Urban pisciculture may be an exception, however, particularly for small-scale operations. Pisciculture typically demands a large amount of capital, thus poor farmers are generally precluded from participating, although there are some exceptions. For example, the Jakarta reservoir and the fishermen's cooperative at the sewage lagoons in Calcutta offer opportunities for lower-income farmers (see Case 3.5).

Fish from waterways that have high levels of heavy metals or pathogens may be hazardous to human health and lead to chemical poisoning or communicable diseases. Aquaculture that uses waste can also be a health hazard if proper control is not maintained to ensure that pathogen activity is below the relevant threshold. Pathogens that are not removed in the treatment can be passed from fish to consumers or to workers in the ponds. Aquatic snails can also serve as host for the schistosoma pathogen that causes schistosomiasis or bilharzia, which has been identified in some aquaculture ponds that use sewage.[21]

Standards from the World Health Organization (WHO) issued in 1989, or other stricter international standards such as those of the U.S. Environmental Protection Agency, can be used. Use of wastewater for aquaculture is safe if the wastewater is treated in stabilization ponds before being discharged into the fishponds.[22] One of the sustainable and safe solutions being promoted is a two-stage process in which aquatic macrophytes like duckweed, or 'trash' fish like tilapia, are raised in the sewage for use as feed for fresh fish in treated sewage.

Fish fed on sewage are commercially produced in China, India, Viet Nam, Germany, Hungary, and elsewhere. In most of these places, this farming activity is long established. Currently, there may be two parallel trends:

- a decline in the pioneering large cities, particularly in Asia, because sewage is contaminated with toxic industrial waste as urban areas expand; and

- new systems in a number of smaller cities. The best prospect may lie in semi-arid and arid countries such as Egypt and Peru (Case 5.5). The production of fish meal for animal feed may be another growth area.[23]

Case 5.5 Sewage-fed aquaculture in San Juan, Lima

Reuse of wastewater is especially important in arid Peru. The San Juan de Miraflores complex in Lima was created as an experimental facility to optimize reuse and recovery of wastewater. Stabilization ponds have been processing wastewater drawn from the neighboring communities of about 150,000 residents since 1969. The complex processes sewage to provide communities with treated effluent for use in horticulture and silviculture. The communities use the wastewater (legally and illegally) to irrigate crops such as maize, alfalfa, fruit and nut trees, and vegetables. The water is also used to water livestock and woodlands.

In 1983, aquaculture was initiated by the Pan American Centre for Sanitary Engineering and Environmental Sciences (CEPIS) as a demonstration project to test the possibility of producing fish in mature wastewater stabilization ponds. With World Bank support, CEPIS undertook research to examine both the productivity of the fish culture and any associated economic and public health aspects.

Nutrients in wastewater are beneficial for fish growth, however, fish rarely survive in untreated wastewater. Even when fish do survive they may contain pathogens, chemicals, or heavy metals that make them unsuitable for human consumption. The CEPIS/World Bank-funded experiments confirmed that tilapia and carp grown in partially treated (tertiary) city wastewater are suitable for human consumption. The self-purification capacity of tilapia was also observed, and its limits established through testing. The productivity of the waste ponds (4,400 kilograms per hectare of tilapia per summer season, with an average weight of 0.25 kilograms) compares well to tropical fishponds using expensive feeds.

Thus commercialization of aquaculture was shown as a possibility. CEPIS is also conducting socioeconomic studies to establish the size of the market for the fish. The sale of wastewater-fed tilapia was acceptable to Lima consumers even though they were aware of the origin of the fish. City authorities hope to replicate the San Juan experiment in other parts of Lima.

Contact: Carl Bartone and Julio Moscoso Z. (see Appendix F for complete addresses).

Animal Husbandry

Animal husbandry, including raising birds, is a common type of city farming. It dominates in some very large cities such as Cairo and Mexico City, where it is more common than vegetable cultivation. Scant research has examined this common practice as distinct from raising animals in rural areas. Low-income urban livestock farmers, receive little advice or assistance, including veterinary services, that is attuned to their special problems.

Urban livestock rearing is practiced by both large- and small-scale producers as well as high-income and low-income farmers. The large-scale producer may be a poultry farmer with thousands of birds, cold storage facilities, purchasing agreements for large amounts of feed, and specialists on staff. The small-scale producer might have a small herd of goats or a few pigs and some agreements about access to grazing land and access to restaurant waste.

The range of livestock raised in cities includes chickens, quail, pigs, cows, goats, guinea pigs, rabbits, ducks, geese, pigeons, worms, and hybrid members of the rat family. Exotic fauna such as antelope, ostrich, and emu are also raised close to urban customers. The larger and more diverse market and the smaller production facilities allow the urban producer to offer a wider range of products. Sometimes the animals' presence is not apparent since they are fed and raised in backyards.

The greatest presence of livestock within a metropolitan area is in the peri-urban area. Table 5.2 illustrates the distribution of livestock in Mexico City. Distribution is not uniform because some types of livestock tend to be found in significant numbers in inner areas, while others are overwhelmingly peri-urban.

Table 5.2 Distribution of selected livestock across the Mexico City metropolitan area in 1990

	Intra-urban	Suburban	Peri-urban
Cattle	2,931	6,597	13,591
Pigs	1,541	12,992	43,807
Hens	132,902	411,191	189,842
Turkeys	310	4,010	15,500
Rabbits	4,271	9,780	15,101
Beehives	200	2,789	3,738

Note: Many of these numbers may be underreported, due to fear of prosecution (particularly in intra-urban areas).

Source: H. Losada et al. 1998. Urban Agriculture in the Metropolitan Zone of Mexico City: Changes over Time in Urban, Suburban, and Peri-Urban Areas. *Environment and Urbanization* 10(2):46, Oct.

Animal husbandry generally has a main product (meat) and a number of useful by-products, including milk, eggs, fur, hides, feathers, and dung. In Hindu and Buddhist countries, and for many poor families elsewhere, some of these by-products are more important than the meat. The animals are often treated by the poorest as insurance — they can be sold in an emergency as a source of quick cash.

From sheep grazing in a park to pigeons flying over rooftops to guinea pigs squealing in cages on shelves, rearing animals offers multiple benefits to many in the city. First, family nutrition is improved through fresher, higher quality protein. Animal husbandry is an efficient way for a poor family to obtain expensive meat protein and fresh dairy products. Second, refrigerated shipping is not needed, reducing energy use, pollution, and traffic. Third, grazing livestock along roadsides and on public park grasslands can be an environmentally sound method of maintaining urban open spaces that reduces or eliminates costs. Finally, although livestock in the city may initially seem dirty, in fact

animals are efficient recyclers, and with some management, can improve the soil and thereby the environment.

While the blanket prohibition against urban livestock commonly found in many cities all over the world goes too far, some concerns of those who resist urban livestock are valid. Raising animals in congested quarters in proximity to (or in the midst of) a dense concentration of homes and workplaces can cause a variety of genuine problems — disease, overgrazing, unpleasantness (dung on the sidewalk), contamination of water sources, and a range of other health hazards.

Livestock waste can be a source of disease, as can unsanitary conditions in livestock holding pens. Intensive production of animals can pollute the soil and water table through leaching of animal excreta. Livestock feeding on untreated waste may pick up pathogens, and roaming animals can spread diseases they may carry. Potential health hazards also exist for workers through improper handling of livestock. Hazards are highest with larger livestock, relative to poultry and small livestock. They are also magnified when poultry or large livestock are concentrated in industrial-scale facilities housing thousands of animals or birds.

Stringent regulations and precise monitoring are vital to ensure appropriate animal husbandry practices in urbanized areas. More details on the potential health and environmental hazards of animal husbandry and ways to limit their effects are discussed in Chapter 8.

Poultry

Urban poultry production has an important role to play in the future food supply of the world's cities. It is growing fast and varies considerably among countries. In Asia, poultry production is shifting to large-scale 'factory' systems. In Africa, it is becoming a middle-income farming system, with indigenous breeds being replaced by American lines (Case 5.6). In Latin America, there is a closer balance than in Asia between large-scale, modern producers and the use of improved technology by small-scale farmers. In richer countries, massive units of production within and adjacent to metropolitan areas are very common, generating a range of problems.[24]

Case 5.6 Backyard poultry farms in Morogoro

For several years, professors living at Sokoine University of Agriculture in Morogoro, Tanzania have been raising chickens in backyard coops, with some having as many as 100 birds. Two-thirds of faculty families raise chickens or grow fruits and vegetables in the backyard.

The chicks and the technology are imported from Zambia, yields are good, and they run quality operations. The chicken farmers get free piped water and electricity from the government, and the household plots are rent-free. Extension help is available from staff at the university. (There has been a debate in Tanzania about the appropriateness of government staff using free resources and university expertise for personal profit.)

The efficiency of the poultry farms is high due to good in-house technology, and research and extension capacity. Considerable expertise in poultry production has emerged, and the university

staff could easily transfer the technology to low-income farmers, and provide them with extension support, thus making their efforts even more productive for the city.

Contact: Zebadato S.K. Mvena (see Appendix F for complete address).

An intermediate technology exists between chickens scratching in the backyard for scraps and offal and the chicken factories so common to the fringes of large cities in industrial countries. This intermediate technology is exemplified by the bookcase-style, stacked, small-livestock cages at the Centre for Education and Technology in Santiago, Chile **(Photo 5.7).** In this farming system, shelves with cages for chickens and rabbits are attached to a wall or fence. If there are four shelves in a typical set-up, then layers, broilers, chicks, and rabbits may each occupy one shelf. Their feed consists not only of household and vegetable garden scraps, but also worms and maggots that have fed on offal. Such systems incorporate recycling waste from local businesses (restaurants and green grocers) and waste from other urban farming systems.

Ducks, geese, pigeons, and other poultry each have an appropriate place in urban agriculture. In India, raising ducks is an important agricultural activity in urban areas. One government official said that "duck eggs are in great demand in urban markets and contribute much to the food requirements of the vegetarian [unfertilized eggs] and non-vegetarian communities."[25]

Quail, which are between pigeons and chickens in size, are growing in popularity for urban or cage production, particularly in Latin America.[26] One bird is a main course for both wealthy and moderate-income adults. Bright colored and articulate tropical forest birds such as the parrot and parakeet are being more widely grown in many cities for local and export markets. Sparrows and other small birds are produced for religious and cultural uses.

Poultry production provides fertilizer to horticultural crops and food to aquatic crops. The farmer in Bangkok, for example, feeds bird droppings to his fish and uses sludge from the bottom of the pond as a manure on his vegetable plot. Pigeons are an efficient rooftop farming system. Ducks and geese fit particularly well with some pisciculture systems because they eat grasses and weeds on land and in the water, and their offal provides the fish with nutrients.

Small Livestock

Microlivetock are widely raised by low- and middle-income farmers. They are now seen by many as an important technology for sustainable development. Small animals are generally more efficient converters of feed to meat than large animals. In many cities, microlivestock are a particularly common form of urban agriculture — especially rabbits and guinea pigs in Latin America and Africa (Case 5.7).

Rabbits in particular are ideal animals to raise in the city. They do not take up much space, are cheap to feed, and are prolific breeders. Rabbits can be fed grass, leaves, food scraps from the kitchen, alfalfa or other forage crops, commercial chicken or pig feed, or greens thrown out by stores, markets, and restaurants. For some, the rabbits they raise

may be their only source of meat. Fur and skin from rabbits and other microlivestock can be sold in the local market, and their dung can be used as garden fertilizer.

Rabbits made the pages of newspapers because of their contribution to the survival of the besieged population of Sarajevo, Bosnia in the mid-1990s. In the Washington, D.C. area, agricultural extension agents were having trouble keeping up with requests for information on rabbit raising in 1999, due to a burgeoning local demand led by restaurants.[27]

The biggest constraint to raising microlivestock is health regulations about both production and marketing. In addition, farmers often use inefficient practices, and improvements in extension services may be needed. Small producers would benefit from marketing cooperatives.

Case 5.7 Raising guinea pigs in Cameroon

Although guinea pigs originated in the Andes, over time they have established a foothold as a domesticated animal in a number of African countries. Because there was little information about guinea pigs as a food source, a joint Italian-local research team decided to assess their contribution to the household diet in Cameroon.

The study found two very different agroecological regions where guinea pigs are commonly raised in homes (both urban and rural) — the western savannah plateaux and the equatorial forest zones of the center and south (which include the capital Yaounde). Raising these little animals was found to be primarily an activity of lower-income women and children that occurred inside the home, specifically in the kitchen.

While raising them is primarily for food security, half the breeders also use them as a source of revenue and financial reserve. Guinea pigs are also used frequently for ritual purposes in the forested region. As a high-value animal (the most expensive local meat product in Cameroun), they are sold primarily around holiday periods.

Guinea pigs were found to be well-integrated with other livestock, roaming freely between them (although this does lead to some mortality from predators and from being stepped on). On average, households keep 17 Guinea pigs each. They are fed both fodder gathered nearby, as well as kitchen refuse and crop residue. Their own waste is used as fertilizer. The study found the animal to have great potential for expansion into new households.

Contact: See source listed in Appendix C.

Large Livestock

The significance and form of large livestock production in the city varies considerably from country to country. In Africa, where built-up areas in many cities still have low density, the practice of raising livestock for milk and meat is now widespread (Case 5.8). A recent survey in Kenya, however, found that low-income Nairobi cattle farmers lost more cattle to disease than they brought to market. In Latin America, where raising livestock has been a way of life in many locations, it is now being pushed out of the cities.

Case 5.8 Milk production in the Oyster Bay district of Dar es Salaam

Influential upper-income families in Oyster Bay — a rich residential area of Dar es Salaam, Tanzania — raise imported cross-bred cows in backyard stables for milk production. The cows are herded by hired help and graze on roadside verges, stream banks, parks, and private yards. Grazing helps maintain the roadsides and parks, but the beachside park may have been overgrazed.

Oyster Bay is a former colonial residential neighborhood with expanses of open space. The farming activity in Oyster Bay started with some residents perceiving a market need. Milk is in short supply and sells at a high price in Dar es Salaam, thus good profits can be made with just a few cows kept at home.

According to a survey reported by Sokoine University, at least 90 percent of officials residing in government houses in Oyster Bay raise several head of cattle and goats. (The Dar es Salaam City Council officially permits each household to have four animals.) That upper-income farmers are raising cattle shows the range of the industry.

This farming activity is controversial and criticized as unsanitary and unsuitable for urban areas. Livestock rearing in the city had been illegal, but gained acceptance under policy changes enacted in the 1980s, although grazing native cows on public land at the city fringes has always been practiced in Dar es Salaam. Rearing livestock in a wealthy neighborhood, and other similar farming activities, may lead to increased acceptance and policy support for urban farming in Africa.

Contact: Zebedato S.K. Mvena and Camillo Sawio (see Appendix F for complete addresses).

Sheep and goats in the city are making a return. These animals have trimmed the street sides of Rome since before Julius Caesar, and the great central Maidan of Calcutta since 1800. Indeed, in much of Asia, grazing on public land and milk production in urban locations are still common. Urban land-use regulations, based on Hindu and Moslem traditions, often do not contain the blanket ban on raising livestock in cities that is prevalent in European and American cities.[28]

In southern Europe, livestock grazing in public parks and other open spaces continues wherever there is continuity of Roman law. Today goats are transported by truck 1,000 miles up and down the megalopolis from Georgia to Maine on the Atlantic seaboard of the United States.[29] They are hired by municipalities and institutions to ecologically trim grass, weeds, and shrubbery.

Large and small livestock can be produced at high densities in ‘zero-grazing’ (stable- or cage-fed) farming systems, where fodder is brought to the animal instead of the animal being taken to graze.[30] Zero-grazing has many benefits as a symbiotic link in the cycle of urban agriculture. It also requires stringent quality control, necessitating cooperation among public entities and private farmers and processors. Research is needed to bring the benefits of zero-grazing now enjoyed by large-scale producers to small-scale producers.

Serious problems can arise from urban rearing of large livestock. As one analyst states, some “urban agriculture activities are not as benign as others”.[31] This observation may apply more to keeping large livestock than to any other agricultural activity, thus this activity must be assessed not just by itself, but also in comparison to alternative activities. Risks encountered in the practice of urban animal husbandry include health

problems such as bovine tuberculosis, environmental problems, and overgrazing (see Chapter 8).

Forestry

In much of the developing world, wood is the primary fuel for cooking and heating. As cities grow and demand increases, access to fuelwood becomes more difficult, exacerbating desertification and erosion.[32] Residential construction is often dominated by timber, a commodity that is becoming more scarce and expensive as urbanization increases. Managua, Nicaragua was a particularly tragic example after a decade of war and economic sanctions. When petroleum imports were cut off, the forests around the city disappeared. A similar situation has occurred more slowly around Addis Ababa, Ethiopia.

Urban agroforestry can help mitigate these problems and contribute other benefits. Urban forests have the potential to be managed for social, economic, environmental, and recreational benefits (Case 5.9). Managed forests that produce fuelwood and construction materials can also produce fruit and other food through intercropping with vegetables and grasses. There is a huge untapped potential to combine urban forests and urban waste management. Furthermore, large peri-urban forests, of which there still are many around the world, have a unique role in maintaining biologically diverse domains close to urbanized centers. In the long term, urban agroforestry may also be important to reduce the indirect impacts of cities on surrounding and more distant ecosystems. All these functions complement the special contributions that woodlands provide to the physical and mental well-being of urban residents — trees reduce noise and pollution, and are aesthetically pleasing.

Case 5.9 The Bountiful City Project, Asheville, North Carolina

Asheville's Bountiful City Project is being established as the USA's first edible public park system (although Boston's park system has some similar elements). Such an endeavor involves multiple elements — a community-oriented approach to urban ecological health and economic sustainability, community recreational space that raises awareness of urban food security issues, and an educational forum for neighborhood residents, students of all ages, and visitors to Asheville. Each park is a combination of an edible forest ecosystem and safe city park.

The Bountiful City Project is modeled after permaculture forest gardening principles that mimic the design of natural forest ecosystems by incorporating the seven layers of a forest ecosystem — canopy trees, dwarf fruit trees, shrubs, vines, herbaceous plants, groundcover, and root layers. By facilitating and accelerating the first stages of natural forest succession, the volunteers of CitySeeds, a grassroots, nonprofit organization based in Asheville, are able to create a system that is self-sustaining, highly productive, environmentally sound, and beneficial to the local economy and community. The parks are conceived, designed, and built through a process of public design charettes and public workdays scheduled throughout the seasons.

The first 1-acre park was built adjacent to the Stephens-Lee Community Center, behind City Hall. The City of Asheville Parks and Recreation Department allocated the land for the project. The next park is being implemented in the historic Montford community. Both existing Bountiful City Parks are located adjacent to community centers that run after-school and summer camp programs for children. Both Centers are collaborating with CitySeeds to serve children. Interns, volunteers,

and various student groups from colleges and universities around the region, as well as at-risk youth, have been extremely active in the Bountiful City Project.

The Bountiful City sites are public parks open to everyone. The trees require less work than annual vegetable gardening, with nearly 90 percent of the financial investment occurring within the first year. Because they are perennial, they will continue to produce nutritional benefits, park space, and environmental benefits for years or decades. The parks are partially funded by the citizens of Asheville, several private foundations, and local businesses.

Contact: Jonathan Brown (see Appendix F for complete address).

In most places, street trees help to modify the climate serve aesthetic purposes. In a few places, they play a more significant role. Bangalore, India uses a substantial share of its street trees for fruit production. In Hungary, the harvest from street-side plum trees is auctioned. In Argentina and Chile, oranges are grown on streets for hospitals, schools, and orphanages. Fruit trees provide shade over sidewalks from one side of the Mediterranean basin to the other **(Photo 5.?)**.

In Greece, olives are grown in cemeteries, while Adelaide, Australia promotes olive planting for use by the population. In Beijing, persimmon and walnut trees are grown in parks. Singapore's Housing Authority plants fruit trees in housing areas.[33] Foods like baobab leaf, tamarind, and processed parkia seeds are very popular in large towns in the African Sahel. Trees are also important for medicinal purposes and as sources of animal fodder. In China, 17 percent of the trees in Beijing (and as much as 42 percent in some other areas) are estimated to be fruit trees.[34]

Urban forestry generates a large variety of economic enterprises. In particular, urban trees offer the poorest urban residents a means of generating income. Activities include collecting nuts; recovering fallen trees for use as fuelwood, construction material, or wood for handicrafts; and gathering fodder, herbs, or shrubbery. In Panama, agricultural shantytowns produce forest and vegetable crops just across the Panama Canal from downtown Panama City. In peri-urban Nairobi, urban agroforestry produces coffee, vegetables, and fruit. Leaves are collected throughout the Sahel for marketing as food and as medicine. Indian peri-urban areas have numerous nurseries for small palm trees that are grown for nutritional as well as decorative purposes.

An early example of a managed food and fuel production program was started in Lae, Papua New Guinea. It helped meet the needs of the city while rehabilitating the surrounding hilly area. The peri-urban Aztera Hills region had suffered severe deforestation and degradation as a result of city residents stripping fuelwood or farming it for short-term use. The program created zones for ecological rehabilitation and conservation, fuelwood cropping and agroforestry, and other farming. The agroforestry program granted access to plots averaging one-tenth hectare to farmers for symbiotic planting of trees and vegetables. The city also planted fruit and nut trees in public areas and provided free seedlings to city residents for planting at their homes.[35]

Relative to the other categories of urban agriculture described here, urban agroforestry has exceptional advantages that add to whatever productive functions (food, fuel, herbs, etc.) it may also have. In other words, a farmer may plant a tree for its fruits or profits, but she may also gain a range of environmental assets. The environmental

contributions of urban forests and other treed surfaces are indeed vast. The capacity of woodland to absorb wastewater for irrigation is just beginning to be tapped, for example, in Lima and Cairo.[36] Kuwait, Almaty (Kazakhstan), and Aden (Yemen) also recycle their wastewater into urban forests, flowers, and food.[37] In addition to the treatment of wastewater, important aquifers lie under many metropolitan forests. The maintenance of these forests thus plays a role in the supply of drinking water to the city.

Urban forests act as natural filters and are central to combating urban air pollution, especially carbon dioxide, ozone, and particulate matter. They effect considerable modifications in the microclimate, consequently conserving energy by reducing the need to heat and cool buildings. A pioneering study sponsored by the U.S. Environmental Protection Agency and the Chicago Urban Forest Climate Project has quantified the impact of forest vegetation on local climate, energy use, and air quality.[38]

For some cities like Dakar (Senegal), Beijing (China), and Ismailia (Egypt), tree cover provides crucial protection against the encroachment of sand and dust from nearby arid or desert areas. The capacity of shrubs and trees to preserve the soil, protect against erosion, and maintain steep slopes and wetlands has been underrated by most urban administrations. At Mont Ngafulla in Kinshasa, low-income farmers, with help from a horticulturist and the forestry department, created orchards and nurseries to control soil erosion through a productive use. In the floodplains of the Nairobi River, slum dwellers planted fruit trees and other crops to save themselves from river floods.

The benefits of green space and forestry in urban areas (as detailed in Chapter 7) are coming under increased attention in both developed and developing countries.[39] The European Forest Institute (EFI) of Finland is presently conducting a comparative study of urban forests in Europe — with emphasis on forest policies — in 30 cities in 16 European countries. FAO has a global program on urban and peri-urban forestry. The Tree City Initiative in Germany focuses on urban greening, especially resource-poor citizens and trees in developing countries, and provides technical assistance.[40]

Urban forestry has some special constraints and problems in addition to those that are common to all forms of urban agriculture, as described in Chapter 9. In particular, the length of time required to grow a tree is longer than for any other crop. Consequently, security of tenure or license is especially important for the longer-term investment in tree planting. In dense urban areas, the roots of larger trees or their falling branches can cause structural damage to buildings. Damage can be minimized through species choice and maintenance.[41]

Further, the harsh conditions in an urban ecosystem mean that the urban tree is more vulnerable to a variety of environmental stresses, including disease, pollution, poor soils, and vandalism, than its rural counterpart.[42] The survival rate for planted trees can be low — in Mexico City, for example, fewer than one-half the trees planted survive to maturity.[43] Research to continue to develop or identify trees that can adapt to the urban environment, as well as diffusion of what is known about the benefits of urban forestry, are crucial to surmount these special hindrances.

Urban forests have long been an intricate part of the life in many cities. In many European examples, urban forests have become part of the city's identity — Fontainebleau near Paris, Epping forest in London, Grünewald in Berlin, and the Zonienwoud near Brussels. While the historical purpose of these urban forests was for

food and fuel, they have become mainly recreational and environmental enhancement areas that are critical to the character and 'liveability' of the cities.

Forested reserves, sometimes in the form of greenbelts around settlements, can be found in some parts of the developing world. While the potential role of sustainably managed greenbelts around urban areas for food, fuelwood, and timber supply has long been recognized, few cities have included protected green space by design. Lilongwe (Malawi) is designed to intersperse housing areas with forestry areas, yet the forestry areas are not managed to supply either food or fuelwood to residents. The same is also true in Rabat (Morocco).

Urban forestry projects in greenbelt-type zones were funded by FAO and GTZ in Ouagadougou (Burkina Faso), Kinshasa (Democratic Republic of the Congo, formerly Zaire), N'Djamena (Chad), Nouakchott (Mauritania), and Maputo (Mozambique). They did not all meet with success, however, due to a blanket design and species approach, and lack of dialogue and involvement with communities.[44] With some notable exceptions such as Ethiopia, to date such plantations (usually of exotic species) have not improved the fuelwood supply. This is either because higher-priced building materials were produced instead of fuel, or because poor people could not afford the fuelwood. Solutions recommended by Kuchelmeister include forestry that allows co-existence of agriculture and trees, and the provision of incentives for community involvement.[45] Urban forest reserves need to be rethought in terms of multiple functions — in a way, the concept needs to revert closer to its original form.

Other Urban Farming Systems

Urban agriculture fills additional market niches beyond food and fuel. Some of these might be labeled 'exotica', but they are economically significant. Snails are raised indoors and in yards. Ornamental fish for living room tanks are an important crop in some cultures. Straw and small branches (rattan, willow) are a common crop for basket weaving.

Singapore illustrates the potential of exotica as a major farming activity. Despite the limited surface available for cultivation, it has become a leader in the worldwide export of tropical ornamentals, orchids, specialty fish, exotic birds, and even crocodiles raised in Singapore's 'agrotechnology parks'.[46]

The various 'minor' urban agricultural crops may be the most important for urban biodiversity. Bees are essential for both agricultural and natural ecosystems, and worm production is essential for composting, fishing, and silk production. Countless medicinal plants for humans and animals are produced in small urban spaces.

Medicinal plants are part of an important subsector of urban agriculture — 'biopharming'. This includes edible vaccines, medicinal herbs and insects, and sources for vitamins. Biopharming holds promise of reducing the cost of new medicines and keeping traditional medicines available to low-income families.[47] It is particularly suited to small-scale production (rooftop, window box, greenhouse) and needs precise policy interventions.

Three forms of cultivation should be noted in particular — apiculture (bees), vermiculture (worms), and mycoculture (mushrooms). In addition, some specialized forms of horticulture not discussed earlier deserve mention — beverage crops, medicinal crops, and most notably, ornamental horticulture.

Fauna

Apiculture involves specialized techniques for beekeeping. A labor-intensive activity, apiculture can be a significant employment generator or a sideline for small farms **(Photo 5.?)**. Wax obtained as a by-product has much commercial utility, particularly as a source of lighting material.[48] Finally, the role of bees as pollinators is clearly vital to promote biodiversity.

An emerging form of intensive culture is raising snails. Long common in European countries, this crop is now increasingly found in developing countries with traditions of eating snails. In a number of Central African countries, for example, giant African snails had traditionally been gathered from the bush for consumption and sale. Depletion of this resource has led to development of production techniques to keep up with rising demand from consumers, particularly restaurants. 'Achatiniculture' has thus become a common activity for urban residents from Guinea to Angola.[49] (*Achatina* is a genus of land snails that are often large and common in the warm parts of Africa.)

Vermiculture has diverse uses in the urban context. Silk is spun by worms in boxes on verandas — the worms eat mulberry leaves that are delivered daily from urban forests. Worm larvae are also raised as fodder, especially for chickens. Worms greatly increase the effectiveness of composting, and their excreta have a high value as a soil additive.[50]

Flora

Mushrooms

Many cultures around the world include mushrooms in their diet. As the world has become more urbanized, mushrooms that once were collected in fields and forests are now mostly grown in cellars and sheds, making mycoculture a primarily urban form of production. The technology is being transferred from Asia and Europe to Latin America and Africa, usually first to corporate ventures and well-to-do farmers (Case 5.10).

Case 5.10 Asian roots of mushroom cultivation in Ghana

In an exciting project supported by UNDP and the International Trade Center, a Thai mushroom expert working in Sri Lanka taught Ghanaians how to grow mushrooms in sheds behind their houses. Mushrooms have always grown wild in Ghana, and Ghanians have for centuries used them as a meat substitute. Traditionally, the mushrooms common to Ghanaian cuisine had been collected in the forest and at the edge of roads. Eventually, however, demand came to exceed the supply, which led to importing large quantities of mushrooms.

In 1987, Kwesi Ahwoi, Executive Secretary of the Ghana Export Promotion Council, visited the UNDP-supported National Mushroom Project in Sri Lanka and talked with its main consultant, Prof. Anon Auetragul, a leading Thai mushroom expert. Consequently, the National Mushroom

Development Project (NMDP) was launched under the auspices of Ghana's Food Research Institute.

The NMDP's success depended on reciprocal visits by Prof. Auetragul to Ghana and by Leslie Sawyeer, a young local mushroom expert who came to head the project. NMDP's activities included establishing a laboratory to produce mushroom spawn, studying propagation techniques, and training cultivators. Mushroom species were also collected and evaluated.

The country's favorable climate for mycoculture and the great demand for mushrooms as a source of protein has meant that Ghanaians have taken enthusiastically to mushroom cultivation. One Ghanaian who has become a part-time mushroom farmer is Cudjoe Tsegah, a civil servant. He uses some of the mushrooms for his family's consumption (in salads, with rice, or even as sandwiches). The rest of the mushrooms are sold for extra income. Starting with an investment of US$ 760, he now has more clients (including restaurants) than he can supply.

The high domestic demand, the high value of the product, and the small space requirement thus make the mushroom production an industry with significant growth potential in and around Ghana's cities. The surplus is also marketed easily by GEPC, which is still maintaining its support for this activity.

Contact: See source listed in Appendix C.

This crop has multiple advantages over other food sources because mushrooms:

- have a higher protein content than any other vegetable product, as well as a higher concentration of essential vitamins and minerals;
- can be grown on a variety of agricultural waste products which can then be used as compost for other plants;
- require a very small amount of land for cultivation; and
- require a minimum of water and sunlight.

Transnational agribusinesses are producing mushrooms in several developing countries, frequently in urban areas. At the same time, small growers are producing for the local market. Like hydroponics, mushroom farming requires less access to land and water than horticulture and livestock rearing.

Restaurants in London and other UK cities are serving Irish mushrooms, made possible by a combination of small-scale urban farming and high-speed ferry service. A corporation produces and distributes mushroom growth medium and spore to small growers with heated plastic greenhouses. All production is done in plastic bags. The individual grower keeps the 'farm' at the right temperature and humidity for six or so weeks, and the corporation then picks up the mushrooms at a prearranged price. The product is delivered to the UK the same day.[51] In the United States, a suburban area adjacent to Wilmington, Delaware, is in fact the 'capital of mushrooms' in the country. In Philadelphia, Kaolin Mushroom Farms Inc. is planning to replicate the Irish system in an abandoned 40,000 square foot warehouse.[52]

Beverage Crops

Beverage crops include grapes, hibiscus, palm, tea, coffee, sugar cane, and matte (an herbal tea). A number of these are grown intensively in urban areas. Grapevines, for instance, are planted on slopes that are too steep for buildings in the very heart of

European cities such as Freiburg and Würzburg **(Photo 5.11).** Post-production processes — in particular, the processing necessary to turn the crop into a beverage — are crucial, and provide important downstream entrepreneurial activities. Street and door-to-door sales of 'homemade' beverages are common in cities of the developing world.

One study of the rural-urban interface in Tanzania found that two out of five farmers in and around the town of Biharamulo included alcoholic beverage crops in their product mix.[53] The income generated by these crops ranged from 46-78 percent of the farmers' total income. The most common type of beverage was beer made from bananas; the second was distilled spirits. Production was strictly divided by gender — all beer was made and sold by women, while all spirits were produced by men. Most significantly, the households that combined alcohol production and sale with other agricultural crops had a constant cash flow to meet the household budget.

Medicinal Crops

Medicinal crops are another important urban agricultural crop. Along with culinary herbs, which require similar management, they provide an important cash supplement for small urban farmers. As medical care turns more and more to herbal over synthetic medications, the urban grower of medicinal plants is gaining market share and recognition, as the case of Durban illustrates clearly (Case 5.11).

Case 5.11 Production and sale of medicinal herbs in Durban, South Africa

Growing out of ancient Zulu traditions, the production and sale of medicinal herbs has long been a major activity in Durban and its surrounding region. Herb growers and gatherers scattered in the growing metropolitan area led to an innovative project in the 1980s. More recently, the proliferation of traders selling herbal cures has resulted in a creative intervention by the post-apartheid municipality.

The Silverglen Medicinal Plant Project started in 1983 as a low-key operation at the experimental plant nurseries at the Silverglen Nature Reserve near Durban. In 1986, the nursery operation that provided thousands of groundcover plants for parks in Durban moved closer to the city to save on transportation costs. The relatively few Zulu medicinal plants that were cultivated were given more room in the reserve and allowed to grow to their full potential.

With the influx of people into the metropolitan area, the Health Department as well as the Urban Foundation requested help with upgrading programs in the settlements. The task at Silverglen became to provide the expertise and plants to people for the sustainable production and marketing of medicinal plants, alleviating the problem of supplying medicinal plants to a growing urban population from a diminishing wild stock in the natural areas of the city.

The principal point for marketing the herbs from Durban is Warwick Junction, a major transport hub that emerged at the point where busses carrying blacks and Indians were prohibited from entering the inner city. This junction became the largest herbal medicine market in southern Africa. The conditions at the site where an estimated 500 informal traders gathered raised environmental, health, and planning concerns. The city council helped the herb traders organize themselves into a traders' street committee, and in cooperation with the traders, converted a nearby warehouse into a market structure. The success of the project gave the city council credibility and access to a larger trading community.

Contact: See source listed in Appendix C.

In Cuba, every pre-school has a medicinal garden, exposing each child to the lessons of Mother Nature's cures for illness. This national program is supported by impressive research, and underlines the importance of bringing nutritionists and health care specialists into urban agriculture studies to define opportunities and risks.

Cactus

Cactus cultivation for salads is well established as a cash crop in countless small-scale family enterprises in suburban Mexico City, and has recently been rediscovered by the well-off population of Mexico. Half of the crop is consumed within Mexico City itself. Some of the cactus is also exported to the western United States and Japan. As a result, cactus cultivation has greatly expanded in Mexico City's peri-urban areas, increasing from 1,600 hectares in 1980 to over 7,000 hectares by the late 1990s. It has emerged as the most important economic activity in the city's agriculture.[54]

Cactus can have other functions too. All over Gaza, hedges made from cactus bushes as the most common form of barrier (Photo 5.?). In addition to the impenetrability they offer, they have the added benefit of bearing fruit for the property owner. Cacti are also a very popular form of ornamentals that are typically grown within the space of metropolitan areas — as are numerous other ornamental plants.

Ornamental Horticulture

Ornamental horticulture is predominantly an urban farming system because the market exists almost entirely in cities, and flowers and other ornamentals are highly perishable **(Photo 5.12)**. Moreover, the urban producer has the advantage over the rural grower of being better able to target the crop to feast days (Easter, Christmas, etc.). In most cities, we found large numbers of ornamental plant farmers and floriculturists. Most often, this was as a peri-urban phenomenon, but it has been moving toward downtown, roadside verges, and plastic containers.

Ornamental horticulture has the twin distinctions of being aesthetically pleasing and in demand by the elite. These plants are therefore found in areas of the city where vegetable or livestock farmers may not be welcome. The crops can be grown at a temporary site for as little as one season. It is most commonly a middle-income farming system (Case 5.12). Large growers and corporations tend toward flower markets more than production of trees, house plants, and shrubbery.

Case 5.12 Growing ornamental crops at home in Lusaka

A middle-income family in Lusaka, Zambia produces a second income by growing potted house plants in their front and back yards. The family produces its own pots, makes soil from neighborhood waste, and markets the plants directly to homeowners. The husband is the principal farmer, but the wife holds a government job and is the expert horticulturist and market specialist. She works on the business in her spare time, and the children help as well.

This successful ornamental horticulture enterprise is supported by a farmers' association that provides both technical advice and some credit. There is a large market for houseplants in most cities worldwide, and several low- to middle-income farmers are supplying each local market.

Contact: Lyson Phiri (see Appendix F for complete address).

Access to water and credit are particularly important issues for ornamental horticulture. Production in greenhouses can have negative environmental effects from intense monocropping with heavy applications of fertilizers and insecticides. When not grown in greenhouses using intensive chemical inputs, the product itself can be friendly to the environment, helping to clean the air. Depending how it is practiced, ornamental horticulture can be an aesthetic amenity, twinning perfectly with 'agro-tourism', which may be exemplified in the *chinampas* of Mexico City.

There is a trend in some countries to return ornamentals to native rather than exotic plants, which contributes to biodiversity of other species. Indeed, ornamental horticulture can be one of the more biodiverse sectors of urban agriculture.

Each of the urban farming systems discussed in this chapter has the potential to contribute to sustainable development and sustainable cities. Bringing agriculture — with its capacity to transform waste into crops — into cities can move them toward sustainability. It can also reduce pressure on rural areas that are frequently subjected to unsustainable farming systems. While both urban and rural areas have a great need for sustainable agriculture, its benefits are greater in urban settings.

Notes

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