RUAF Foundation
RESOURCE CENTRES ON URBAN AGRICULTURE & FOOD SECURITY

Urban Horticulture[1]

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Introduction

Urban and periurban horticulture (UPH) includes all horticultural crops grown for human consumption and ornamental use within and in the immediate surroundings of cities. Although crops have always been grown inside the city, the practice is expanding and gaining more attention. The products of UPH include a large variety of vegetables, cereals, flowers, ornamental trees, aromatic vegetables and mushrooms. Table 1 presents the main species cultivated in periurban horticultural systems and more specifically those presented in this paper. The case study from Yaoundé, Cameroon, later in this paper, is a good illustration of the large variety of species cultivated in UPH.
Generally, the types of crops cultivated vary according to the area, influenced by culture and tradition. In cities, short-cycle crops are preferred, while in the surroundings of the city crops with longer cycles are cultivated, for example in orchards.
Crops are grown in small gardens or larger fields, using traditional or high-tech and innovative practices. The major production systems and practices of UPH are described in this paper, together with the major constraints. Some new techniques that have been adapted to the urban situation and tackle the main city restrictions are also documented. These include horticultural production on built-up land using various types of substrates (e.g. roof top, organic production and hydroponic production), water saving in highly populated areas, the production of pesticide-free vegetables year-round with a low content of heavy metals and human pathogens, and control of wastes and leaching (fertilisers, pesticides, organic matter, water) in the urban environment. Urban and periurban cultivation systems differ from rural systems by their proximity to cities and by the constraints of space, which often lead to greater intensification of production.

Through the large variety of crops that are produced, urban horticulture makes a major contribution to food and economic security. It also contributes to strengthening social sustainability and increasing ecological sustainability by transforming wastes, conserving natural resources, preventing soil erosion, and reducing pollution. UPH, like UA in general, has multiple functions. The main function is supplying fresh food, but emerging functions that are becoming more and more essential are economic (income generation), social (labour), cultural, living environment (open spaces and greening), environmental (recycling) and security (food and natural risks).

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An update of this paper (and the whole book) is under preparation (publication expected August 2014).

Table 1 Horticultural plants cultivated in urban areas

<u>Vegetables</u>	**<u>Aromatic and flowering plants</u>**
Amaranth, Genius ***Amaranthus***	Agati, ***Sesbania grandiflora,***
Beans, ***Vigna radiata*** & ***Phaseolus vulgaris***	Basil, ***Ocimum basilicum***
Broccoli, ***Brassica oleracea* var. *italica***	Chives, ***Allium schoenoprasum***
Cabbage, ***Brassica oleracea* var. *capitata***	Horseradish tree, ***Armoracia rusticana***
Cassava leaves, ***Manihot esculenta***	Indian borage, ***Plectranthus amboinicus***
Cauliflower, ***Brassica oleracea***	Kohlrabi, ***Brassica oleracea* var. *gongylodes***
Chinese cabbage, ***Brassica rapa* var. *pekinensis***	Lemon grass, ***Cymbopogon citratus***
Chinese mustard, ***Brassica juncea* var. rugosa**	Mustard, ***Brassica compestris***
Choy sum, ***Brassica rapa* var. *parachinensis***	Pakchoy, ***Brassica camperstris* var *chinensis***
Cucumber, ***Cucumis sativus***	Peppers, Genius ***Schinus***
Eggplant, ***Solanum melongena***	Perilla, ***Perilla frutescens***
French bean, ***Phaseolus Aureus***	Roselle, ***Hibiscus sabdariffa***
Garlic, ***Allium sativum***	Tuberose, ***Polianthes tuberosa***
Gourd, Genius ***Cucurbita***	
Indian grass, ***Brassica juncea***	
Indian mustard, ***Brassica juncea***	**<u>Fruits</u>**
Jaxatu, ***Solanum aethiopicum***	Banana, Genius ***Musa***
Kangkong (water convolvulus), ***Ipomoea aquatica***	Melon, ***Cucumis melo***
Leek, ***Allium ampeloprasum***	Orange, ***Citrus sinensis***
Lettuce, ***Lactuca sativa***	Papaya, ***Carica papaya***
Lotus, ***Nelumbo nucifera***	Peach, ***Prunus persica***
Melindjo***, Gnetum gnemon***	Pineapple, ***Ananas comosus***
Mungo bean, ***Phaseolus Aureus***	Strawberry, Genius ***Fragaria***
Okra, ***Hibiscus esculentus***	
Onion, ***Allium cepa***	**<u>Ornamental plants</u>**
Palak, ***Beta vulgaris***	***Bougainvillea (Genius)***
Pea, ***Pisum sativum***	***Chrysanthemum (Genius)***
Potato, ***Solanum tuberosum***	Kumquat, Genius ***Fortunella***
Squash, ***Cucurbita maxima***	Rose, Genius ***Rosa***
Sweet pea, ***Lathyrus odoratus***	
Sweet pepper, ***Capsicum annuum***	
Snow pea, ***Pisum sativum***	
Tomato, ***Lycopersicon esculentum***	
Water morning glory, ***Ipomea aquatica***	
Wheat, ***Triticum aestivum***	
Yardlong bean, ***Vigna unguiculata sesquipedalis***	

Although most of these species are not specific to periurban horticultural systems and can also be grown elsewhere, horticulture in urban areas minimises the transportation time for the supply of fresh produce to city dwellers. The cropping system in urban and periurban areas is usually adapted to the specific circumstances. Many traditional crops have been adapted to better respond to the needs of city consumers. Horticulture is practised for home-consumption but very often also for the market as high-value cash crops. In such a competitive environment, a focus on profitability may lead to improper management such as the intensive use of water, land and other (chemical) inputs, and thereby pose threats to humans and the environment. This issue will be discussed later in this paper.

Policymakers around the world are showing an increased interest in urban horticulture, although their major focus is still on the temporary use of periurban lands. Periurban agriculture is encouraged in poor countries, mainly because it improves food security of poor households and the urban population's nutritional status (freshness of products and better access to fruit and vegetables, considered as a major source of vitamins and micronutrients), especially in view of the inefficient transportation and storage facilities in these countries. Policymakers also encourage UPH because it provides jobs and incomes to poor and landless urban dwellers and because it is well adapted to the urban environment where water and land are scarce.

Urban demands for horticulture

The proximity to urban markets often defines the production of specific fruits or vegetables, while there are also seasonal differences between rural and urban areas in terms of supply to the urban market. The case study from Hanoi, Vietnam, is an interesting example of how the horticultural market has evolved dynamically over the years in relation to social, climatic and cultural factors.

Fruits and vegetables for city markets are supplied from different areas: rural, periurban and urban, from within the country or from foreign countries. There is complementarity between the supply flows from the various origins, which may change over time. Products from UPH make up a very large part of the supply of vegetables to urban markets, such as in the capital city Hanoi (2.7 million inhabitants). Here, 80% of the vegetables (118,628 tonnes), come from the Province of Hanoi, an area of 7095 ha of urban gardens (Mai Thi Phuong Anh 2000). In Brazzaville, 65% of the marketed vegetables come from its urban gardens (Moustier 1999).

Factors such as climate, soil, access to water, insects and diseases, costs of production and, most importantly, the shelf life of the crop itself, influences the location of vegetable production. The last factor explains why, for most urban markets, leafy vegetables are produced in urban and periurban areas. In Brazzaville, the urban gardens provide 80% of the leafy vegetables for the urban market; in Bangui, 100%; in Bissau and Antananarivo, 90% (Moustier & David 1997); in Dar-es-Salaam, 90% (Sabel-Koschella *et al*. 1998). Some leafy vegetables are well adapted to a hot wet season. The very short shelf life of cut flowers such as roses and chrysanthemums explains the development of these horticultural crops around Hanoi, where they are grown on 1000 ha.

The season also influences the distribution of supply to the urban market from rural/ urban areas. In Bangui, the share of tomatoes from rural areas increases from 40% to 50% in the wet season. In Bissau, the share of tomatoes from urban areas increases from 10% to 20% in the wet season. Urban horticultural areas may also supply the urban market more regularly than the rural areas. In Nouakchott, UPH supplies the urban market during nine months of the year, whereas the rural areas provide vegetables to the city only during three months (Margiotta 1997). Around Hanoi, choysum and leafy mustard are grown year-round. In Dar-es-Salaam, amaranth is grown throughout the year. This tendency to crop year-round is increased by the UPH producers’ need to derive an income from various high-value crops throughout the year. This bias towards UPH may also be due to production constraints and access to transportation infrastructure during the rainy seasons or to socio-economic causes. In some countries, however, where flooding of urban areas expand every year, it is easier to find suitable spaces to grow vegetables in rural areas (Phnom Penh, Dacca).

Even if the consumption of vegetables per person is relatively low, consumer demand remains the major driving force behind UPH. In developing countries, the consumption of vegetables is generally lower than the FAO recommendation of 75 kg/year/inhabitant (205 g/day/capita). The importance of vegetable consumption depends on the population group. Over the period 1994–1998, consumption in Vietnam was higher in urban areas (182 g/capita/day) than in rural areas (122 g/capita/day), but lower than in mountainous areas (196 g/capita/day) (Nguyen Thi Lam & Ha Huy Khoi 1999). As is shown in Table 2, the consumption of vegetables in Bangladesh was higher in urban areas than in rural areas (Ali 2000).

Table 2 Monthly per capita consumption of vegetables (kg) in Bangladesh

Household	Total vegetables	Leafy vegetables	Potato	Banana, papaya & eggplant	Other vegetables
Urban	6.20	1.42	1.67	0.82	2.29
Rural	5.13	1.08	1.13	0.80	2.12

Source: Ali (2000).

Urban consumption is related to the size of households, income and socio-cultural characteristics (Bicas 1998). In Africa, the most popular vegetables are tomato, onion and leafy vegetables, but there are location-specific variations. In Brazzaville, for instance, the importance of vegetables varies from one socio-economic group to another (Moustier 1999).

Table 3 Most frequently eaten vegetables per socio-economic group in Brazzaville (Congo) (ranked in order of importance)

Socioeconomic groups	Vegetables eaten most frequently
Congolese households	Cassava leaves, cherry tomato, pakchoy, roselle, melinjo, dry kidney bean
Non-Congolese African households	Potato, cassava leaves, cherry tomato, dry kidney bean, amaranth, lettuce
Expatriates	Potato, "European-type" vegetables

Source: Moustier (1999).

Culture and festivals also has a very strong influence on consumer demand for specific products. In many countries, the main demand for flowers occurs on Mother's Day, Valentine's Day and during the Christmas period. In Vietnam, the Tet celebration is the opportunity to offer two ornamental trees: kumquats bearing mature orange fruits and peach trees in blossom. In urban and periurban areas in Hanoi, ornamental fruit-tree specialists have set up production to meet this demand, which means that they nurture young trees for a period of one year to prepare them for sale.

Factors influencing urban horticulture

The development of horticultural systems in urban and periurban areas is determined by specific opportunities and constraints in the city. The constraints are mainly related to resource scarcity (water, land, labour and access to other inputs) and pollution.

Access to natural resources and labour

Access to suitable land is a key factor in urban agricultural development. Land ownership and tenure arrangements are important. In the large and fast-growing cities of developing countries, land pressure is great and often leads to rising prices. In this context, access to land by urban or periurban producers is difficult and poses a major constraint to their activities. As they are usually not landowners, they are obliged to rent from others or to squat on public land in order to have a small plot to cultivate. This uncertainty of land tenure has a strong influence on land-use strategy and maintenance. Producers may select fast-growing plants (such as leafy vegetables) rather than perennials (such as fruit trees); and may use places regarded as unsuitable for dwellings (such as swamps), which limits the range of crops that can be grown.

Insecurity of land tenure is a major problem that often leads to two types of responses by producers, who do not always take the long-term effects of agricultural practices into account. As a result they might choose inputs with strong and quick effects, such as chemical fertilisers and pesticides, rather than improving the soil using long-acting fertilisers and integrated production techniques. Producers may even turn to soil-less production systems on diverse substrata.

The size of plots is also a constraint. In the inner cities or periurban areas, horticultural crops are grown on very small parcels of land. This leads to the development of specific systems: intensive, high-yielding and year-round with the same or different crops. High yields require high use of inputs – water and fertiliser – combined with good light. The role of substrates to grow the crops is essential. As will be discussed later, different techniques have been developed for cases of little land or poor soil quality, such as hydroponics or organoponics.

Different sources of water are available in urban and periurban areas: potable water, wastewater, rivers, lakes and ponds. The specificity of horticultural systems is their adaptability in using these different sources, particularly the use of wastewater. In all cases, this scarce source needs to be used efficiently and with precaution. Drip irrigation with different systems of micro-irrigation is possible. Use of a watering tank is more popular and is also one of the most efficient systems. The advantage of wastewater is that it provides nutrients together with the water. This saves the cost of fertilisers and labour to apply the fertiliser.

In urban areas, there is fierce competition for the use of land and water between horticultural activities and other economic activities. In a context of high economical competition, horticulture can be maintained if it generates more benefits than any other use of the resources. Yet, even without intensification of production and even if it is less profitable, horticulture continues to exist, if its other functions (i.e. cultural) are valued by city stakeholders.

Another aspect of this competition comes from the many other human economic activities that occupy urban producers. In Hanoi, for instance, periurban gardeners seek jobs in industry, business and administration. Most often urban horticulture is a part-time job in this city, and different activities are combined in order to maintain livelihoods. The household members also divide their activities between production, sales and employment. The multiple economic activities of most urban gardeners may lead to a lack of sufficient labour during certain cropping periods such as planting or harvesting or for irrigation. The urban economy and its dynamics assign different responsibilities to women and men: women are often more involved in the cultivation and marketing (West Africa) activities than in rural and traditional horticultural systems.

Environmental pollution

Industry, services, traffic and high population density in urban areas are known to cause pollution to water, soil and air and reduce light intensity. A major challenge for urban agriculture, and especially for horticulture, is to supply safe products in this often polluted environment. In urban or periurban areas, the main pollutants of horticultural crops are heavy metals, pesticide residues, and biological contaminants. Such pollution presents a risk not only to the consumers, but also to the producers who come in contact with contaminated materials, for instance in wastewater. Additionally, these forms of pollution can be major factors in limiting crop growth. The problems occur mainly in areas close to active or old industrial sites, on urban waste disposal sites, when irrigating is done with water that contains heavy metals, fertilisers or organic matter, or when contaminated soils are used for cultivation. The source of human parasites are wastewater or animal wastes that are not composted.

Heavy metals

The main causes of soil pollution from heavy metals (including lead, cadmium, chromium, zinc, copper, nickel, mercury, manganese, selenium and arsenic) are irrigation with water from streams and wastewater contaminated by industry, the application of contaminated solid wastes and the use of former industrial land contaminated by spilled oil and industrial wastes. Toxicity from heavy metals can directly affect plant physiology and growth and many cases of toxicity from heavy metals have been reported. For example, Jørgensen *et al*. (2005) show that intensive horticultural systems (particularly in greenhouses) in urban areas may be threatened by soil toxicity through trace elements such Zn, Cu, As and Pb. The soils in many cities in developing countries have very high heavy metal contents. If the concentration of these elements in human food increases, it may cause toxic symptoms and cause damage to health (carcinogenic and mutagenic effects).

The health effects and the heavy metal threshold concentration under which it is possible to practise safe agriculture have been subjects of much discussion. Puschenreiter *et al*. (1999) conclude that, having considered the several available pathways to reduce the transfer of heavy metals to the human food chain, urban soils with slight contamination by heavy metals can be used safely for gardening and agriculture if proper precautions are taken. However, Birley and Lock (2000) argue that little is known of the chronic health effects of consuming tiny amounts of heavy metals over long periods of time and that further research is needed. Mapanda *et al*. (2005) show that, in vegetable gardens of Harare (Zimbabwe), irrigation by wastewater may lead to significant heavy metal (Cu, Zn, Cd, Ni, Cr and Pb) enrichment in the soils. On the other hand, studies have shown that production in urban and periurban areas does not produce lower-quality vegetables than in rural areas (Midmore 1998). Depending on the species and the plant parts, accumulation of heavy metals varies. Leaves can reach a high level while seeds are often less affected. It is possible to adapt the choice of crops in relation to the degree and type of contamination. Some horticultural crops such as beans, peas, melons, tomatoes and peppers show very low uptake of heavy metals.

The risk of pollution depends directly on the location of the fields. The rate of absorption of heavy metals by vegetables seems to be linked with their levels in the soil. Lead is taken up by the plant roots and is then transported to the leaves. Lead from traffic fumes in the air settles on the leaves. It can be washed away by watering the leaves, especially when the leaf surface is waxy (cruciferous plants, Alliums). Cadmium can be taken up by plants through roots and leaves. For these two very poisonous heavy metals with no positive biological functions, their presence in plants is controlled by respecting the soil standards. The location of vegetable production, with regard to roads and polluting industries, should be selected carefully. Bio-remediation of the soil by plants and installation of mycorrizae limiting heavy metal uptake are long-term projects that might help in management of heavy metals in the future.

In addition to heavy metals, air pollution too can contribute to crop toxicity. For instance, Agrawal *et al*. (2003) show that, in the polluted environment of Varnasi, India, some physiological characteristics of bean, palak, wheat and mustard are significantly affected by the SO_2, NO_2 and O_3 concentration. These gases are very common in large cities in developing countries, especially with the fast growth of personal transport.

Pesticide residues and fertilisers

As in many forms of crop production, horticulture is confronted with pesticide residues in the plants and pesticide exportation to the environment. This can lead to major health problems for producers and/or consumers. The residues of pesticides and fertilisers originate not only from agricultural inputs used by the producers. Cultivation in contaminated areas or irrigation with contaminated wastewater, also contribute to increasing the residual levels in plants above the allowed limit.

These contaminants are adsorbed on soil and are characterised by a very long half-life. Most belong to families of products that are banned worldwide. The crops containing these pesticide residues are mostly tubers and root vegetables. For instance, in the periurban cropping system in the French West Indies (more specifically home-gardens), root vegetables (manioc, yam) grown on plots where organo-chrlorine has been used, even many years ago, contain some residues and may constitute a risk to consumers' health. In this case the risk is further enhanced due to the improper management of land.

Biological contaminants
The contamination of crops with pathogenic organisms by re-use of urban wastewater and organic solid wastes is an important issue associated with food safety, especially in the context of UPH. These diseases may affect the producers who handle the contaminated material, as well as the consumers who may eat contaminated fruits or vegetables.

In horticultural systems, solid wastes are mainly used to improve the soil (household wastes, market refuse, sewerage, night soil, manure, fish wastes and agro-industrial wastes). Urban organic wastes are mainly composted; this process significantly reduces health risks.

If the compost is not properly prepared (at a too low temperature), the organic wastes can still contain pathogens (bacteria, helminth eggs etc). The risk is greatly enhanced if organic materials are mixed with human excreta from latrines, manure or hospital waste, causing pathogens to breed. The use of domestic sewage for irrigating and fertilising field crops, perennials and trees is widespread. A large part of the wastewater used is untreated or poorly treated and contains various bacteria, protozoan parasites, enteric viruses and helminths. Coliform bacteria are mainly transmitted to humans from wastewater via the contamination of crops irrigated with wastewater or through consumption of contaminated meat from domestic animals that have ingested tapeworm eggs from faeces in untreated sewage.

Pollution by horticultural practices
Horticultural systems may also pose a risk to their environments, and especially so in an urban context because of the proximity to people. Additional conflicts may arise between urban gardeners and city dwellers, especially when horticultural systems cause odours or, improperly, use large amounts of pesticides or fertilisers – artificial or otherwise – that urban dwellers fear may cause pollution. Although it is a general rule that inputs that affect human and environmental health must be used with care, this is more so in urban areas. The intensive use of agrochemicals (fertilisers, pesticides, fungicides) may lead to residues in crops, surface water or groundwater and cause negative effects to the health of agricultural workers.

Pesticides
All levels of cropping intensity are encountered in urban areas, from the most extensive (traditional) in developing countries and in allotment gardens, to the very intensive agriculture using high amounts of agrochemicals. Logically, the levels of pollution risk vary depending on the intensity of production.

Vegetables containing pesticide residues above the maximum residue limit have been identified in markets (Moustier 2000, Midmore 1998, Fatou Diop Gueye & Sy 2001). In Accra, for example, a survey in 1998 of common cabbages collected from the retail market showed high residues of methamidophos, with two out of 20 samples exceeding the maximum residue limit (Sonou 2001). This occurs often, in spite of the fact that regulations for the use of pesticides and recommendations for health safety are in place. The application of pesticides on crops also endangers workers if little information is available on how to use them and when no protective measures are taken. This mainly affects low-income gardeners who cannot afford to buy proper protective clothing and equipment or are not aware of the importance of doing so.

Awareness of the risks caused by excessive use of chemical pesticides exists among all stakeholders, ranging from producers, consumers and public authorities to agrochemical companies. The UPH sector is more sensitive to this problem because of the proximity of consumer and producer. At this point in time, the penalties are not high enough to drastically reduce the over-use of pesticides. More negotiation between all players in the commodity chain might be one solution. In any case, there will be a cost, implying that the consumer must be ready to pay more to have a better-quality product and a safer environment. The development of new technologies such as integrated pest management and biological control can help in reducing pesticide use.

Nitrates

Nitrates deserve mention in pollution related to agriculture inputs. They can cause health problems in very young babies and pregnant women. Nitrates are also an indicator of good or bad agricultural practices. Nitrates cause eutrophication of water in combination with phosphorus. In Europe there are standards regulating the nitrate content in crops and water. In UPH systems, nitrates stem from fertilisation and from irrigation water. Some quick tests, such as Nitracheck®, appear to help producers manage nitrogen. Still, many of the methods available need to be validated for the specific urban and periurban leafy vegetables grown in developing countries. Moreover, with the aim of making better use of organic matter obtained from urban wastes in mind, specific tools need to be developed that take into account the problem of the irregular and slow release of nitrogen. If the source of pollution is close to the water resource, as is often the case with UPH, the risk of pollution of water by nitrates is enhanced. This is particularly true in developing countries that do not have a good network of water supply and where many people depend on the local water resources for their supply.

Recommendations for safe urban horticulture

De Zeeuw and Lock (2000) suggest a number of prevention and control measures that can be applied in UPH systems to help produce safe and healthy products. Such measures should help reduce risk of pollution of crops by heavy metals, agrochemical residues, pathogens and diseases. The general principle of these ‘good practices’ is often based on good communication between health sector actors and urban farmers, ensuring the latter is educated to respect rules to limit/ stop contamination of the horticultural products. A summary of the major recommendations are presented below (see Box 1).

Box 1 Major recommendations for reducing risks

<u>Heavy metals</u>

- Define norms regarding crop restrictions according to type and level of contamination of agricultural soils; test agricultural soils and irrigation water for heavy metals;
- Establish minimum distance between fields and main roads and/or boundary crops to be planted beside them;
- Treat soil to immobilise heavy metals: application of lime increases pH and thus decreases the availability of metals, except for selenium; application of farmyard manure reduces the heavy metal content of nickel, zinc and copper (but may increase cadmium levels); iron oxides (like red mud) and zeolites are also known to absorb heavy metals such as cadmium and arsenic;
- Wash and process contaminated crops to effectively reduce heavy metal content;
- Use plants such as Indian grass for biological remediation of polluted soils or streams (when planted in hydroponic beds).

<u>Agrochemical residues</u>

- Train of gardeners in proper management of agrochemicals;
- Promote ecological farming practices and replacement of chemical control of pests and diseases by integrated pest and disease management techniques;
- Establish better control on sales of banned pesticides;
- Introduce cheap protective clothing and equipment;
- Monitor residues of agrochemicals in groundwater.

Irrigation

- Improve inter-sectoral linkages between health, agriculture, waste and environmental management;
- Separate waste at source; collect organic refuse regularly;
- Establish decentralised composting sites; ensure the application of proper composting methods (temperature, duration) to kill pathogens;
- Identify quality standards for municipal waste streams and composts produced from them; monitor quality of soils, irrigation water from rivers and wastewater outlets, and composts; certify safe production areas; restrict of crop choice in areas where wastewater is used but water quality cannot be guaranteed;
- Establish adequate wastewater-treatment facilities with appropriate technologies;
- Train gardeners in managing health risks (for workers and consumers) associated with re-use of waste in agriculture;
- Educate consumers (scraping and washing of fresh salads; eating only well-cooked food).

Diseases

- Maintain cooperation between the health sector and the natural resource management sector (solid waste management, water storage, sewerage, agriculture and irrigation);
- Ensure water tanks and irrigation systems (especially in periurban areas) properly designed to prevent malaria;
- Apply slow-release floating formulations to control the malarial vector; use expanded polystyrene balls to effectively control mosquito breeding in latrines and stagnant polluted water.

Agronomic techniques

Horticulture in urban areas will continue to be adapted to specific circumstances, as determined by the opportunities and constraints, and specific techniques will be developed, including combinations of practices from traditional horticulture and more modern, innovative practices (see later).

Horticulture is practised in various agro-ecological and climatic zones, from dry areas to tropical and equatorial climates, in areas with cold seasons and in those without. Urban producers strive to grow crops year-round, to be able to better regulate delivery. However, in different parts of the world, certain periods of the year are too cold or too hot to produce crops. Or the producer faces drought in arid zones and excess of water in wet tropical areas, mainly in the rainy season. Temperatures can be regulated by using greenhouses and plastic covers. In developed countries, vegetables are grown in greenhouses with a cooling system to decrease air temperature. In developing countries, the two main difficulties faced are excess of water or lack of water.

In tropical areas, the distribution of rainfall often varies greatly between the dry season, which is usually colder, and the wet season, which is usually warmer. In the wet season, heavy rains may stop horticultural activities even though the consumer demand is high. In solving this problem, producers in some areas, such as Martinique (French West Indies) and Mayotte, use shelters as “umbrellas” to prevent an excess of water for the crops. In some areas, despite the tropical location (e.g. Réunion or Vietnam), heated shelters have to be used during winter when the temperatures are low. In some other cases, an insect-proof greenhouse has to be used to protect the crops (at least in its early stage of growth) from a virus frequently transmitted by insects. This is the case of tomatoes which can be infected by PYMV (Potato Yellow Mosaic Virus) and TYLCV (Tomato Yellow Leaf Curl Virus) through the white fly (*Bemisia tabaci*). These shelters help increase yields but require significant investment and may lead to side effects, such as the soil becoming too poor to further sustain production. Producers may need to turn to new techniques as described in the next section (organoponics or hydroponics). Producers, whether rural or urban, are always willing to adapt and improve their practices based on their own experiences and new information. Most of the new techniques however require access to capital for investments and access to specific knowledge.

Irrigation systems

Water is essential for the growth of plants. Water requirements are related to climatic conditions and plant species. In most capital cities of developing countries located in tropical and subtropical areas, the quantities needed vary from 0,1 to 1 l / m²/day in very dry and hot weather. For a crop of 30 days, the quantity of water needed by a leafy vegetable during the dry season is around 15 l/m². The case study of Dakar, Senegal (see the Dakar case) emphasises the issue of water management in a context of limited availability.

Generally, water availability in cities has been showing a decreasing trend and the forecasts predict it will continue at least in the next 30 years. Water is a necessity for crop production. Depending on the climate and the yields, producing 1 kg of a crop such as tomato requires 60–140 litres of water. Table 4 presents the approximate rates of water consumption of some horticultural crops.

Table 4 Water consumption of some horticultural crops

Vegetables	**Cycle length (without nursery) days**	**Yield kg/m²**	**Water needs litre/m² (tropical)**
Tomato	120	6	400 – 800
Non-leafy Chinese cabbage	40	2	150- 300

Different techniques are used for irrigation. Water is applied by overhead irrigation using watering cans, and also through sprinklers or perforated pipes from wells, ponds or the sewer.
Vegetables, especially leafy ones such as lettuce and cabbage, need to be watered twice a day, every day or at least every other day to obtain a good quality (freshness, tenderness) for marketing. There are two steps in watering: 1) lifting the water or bringing it to the plots, and 2) applying the water to the plants. These two steps may be merged or kept separate. For UPH in developing countries, the watering can is the most commonly used system. Each can holds 8–15 litres; one worker usually carries two cans. The water is taken from shallow wells, deep wells, “céanes” in Senegal (which are wells fed by groundwater and often located at the bottom of slopes and strongly polluted by nitrates), small cement reservoirs, drums (Ghana) etc. Reservoirs are filled by hand using small buckets, or with treadle, electric or motorised pumps. In Vietnam, people irrigate by submersing the crop or by using small hand buckets to lift water from canals to fields. The manual system is efficient because, most of the time, the gardener applies exactly the quantity of water needed by the crop. It is labour intensive, and in Senegal, this operation takes 60% of the total labour requirement for vegetable production.

Drip or trickle irrigation is another irrigation technique that has been promoted for nearly twenty years. It saves water by 10–20% compared with overhead irrigation, but requires clean water in order to avoid blocking of the emitters. The fully-fledged system includes filters, pumps and a pressure regulator, which low-income vegetable growers cannot usually afford. The advantage of this technique is that water is not in contact with the fruits and leaves. It will not, however, avoid contamination of the soil and roots of vegetables with biological pathogens. Underground irrigation provides water to the plant by capillary action. Such an underground system can limit the transmission of pathogens to the vegetables thanks to the filtrating effect of the soil. But installation (flat soil) and operation (control of the flow to the plants) are rather difficult. Some simple drip-irrigation systems have been developed, e.g. in South Africa. This system consists of a 210-litre drum, which is connected via a tap to a set of five polyethylene dripper lines, each with a length of 6 m. The drippers are constructed by perforating the polyethylene pipe with a heated nail. A piece of string is threaded through these perforations by means of a bag-needle. Knots on both ends of the string prevent it from slipping out of the pipe. When the perforations get clogged, pulling the string from side to side usually unblocks the openings. Clogging of the drippers is reduced by placing a stone and sand filter at the bottom of the drum. The filter prevents coarse particles, which may be present in the irrigation water, from entering the pipes and blocking the drippers (Khosa *et al*. 2003). Such a system of micro-irrigation is particularly suitable for small farms in urban areas, because it does not a high capital investment and because it uses rainwater collected from roofs.

Fertilisation

Crops require nutrients: macro-elements such as nitrogen, phosphorus, potassium, calcium and potassium; and micro-elements such as manganese, copper etc. Intensive cropping systems on very small areas, using only solid and liquid urban wastes, are not always optimal for crops.

Two main groups of fertilisers are used: organic fertilisers and chemical (or inorganic) fertilisers. There has always been a heavy use of organic fertilisers in intensive production such as vegetables and ornamental flowers. The quantity varies from a few tons/ha to 50 or even 100 tons per year. Organic fertilisers provide most of the micro-nutrients and in addition improve the structure of the soil. Organic fertilisers can be manure from livestock or poultry, compost from vegetable wastes or wastes from urban activities: sewage sludge, night soils, household wastes etc. Over many centuries, periurban and urban farmers have managed and recycled urban wastes (Fleury and Moustier 1999). In South-East Asia, use of fresh night soil is a common practice even though it disseminates human pathogens. These practices may cause some risks to the environment – pollution of soils with heavy metals from sewage sludge, pollution of water with nitrates due to large quantities of organic manure – and also to the health of the consumer.

Solid organic fertilisers have the disadvantage that they release nutrients, especially nitrogen, slowly. Liquid fertilisers act more quickly. This explains why liquid organic fertilisers are often used on short-cycle leafy vegetables like amaranth and mustard. In Hanoi (Vietnam), liquid organic fertiliser, e.g. pig urine, is used to supply nitrogen during crop growth. Research has often focused combining organic and inorganic fertilisers to enhance their efficacy. AVRDC (World Vegetable Center) is working on producing an organic liquid fertiliser that does not endanger consumer health (AVRDC 2000). The use of organic wastes as fertiliser can lead to different form of pollution as discussed earlier. This problem is strongly linked to recycling in the cities.

Inorganic fertilisers are easier to use and allow for application of the right dose of nutrients. However, there are risks of over-application and contamination of soils and water by nitrates and phosphates, which is especially relevant in the city. Also, they could be a source of heavy metals. In Thailand, it has been shown that ammonium phosphate can release cadmium, zinc and chrome into the environment in excessive quantities (Tran Khac Thi 1999). Urea is the main inorganic fertiliser used in horticulture, especially for vegetables. There is often a lack of phosphorus and potash, and this can lead to an imbalance in the proportion of nutrients in the soil. However, the access to fertilisers in general and inorganic fertilisers in particular still requires a fairly high investment by farmers in most developing countries.

Pesticides

Chemical pesticides have contributed to yield increases in agriculture in general for more than fifty years. Especially in periurban horticulture, easy access to pesticides (via national and international companies, retailers and wholesalers) and technical information has increased its use. However, this has also increased the negative perception of agricultural production in and around the cities. There are three major risks involved: i) health risks for consumers; ii) risks of polluting the environment (mainly water sources); and iii) risks for users. Surveys have been conducted regularly on the use of chemicals, their rate of application and the period between the last application and the harvest for marketing.

In Vietnam, low-cost pesticides (organo-phosphates, pyrethroids, carbamates) with high toxicity (classes I and II) are very commonly used with little information about how to use them. Surveys shows that application rates are much higher than the recommended rates for most of the pesticides used. This and the high spraying frequency are the causes for high pesticide residues in the marketed vegetables.

Pesticides in the city’s surface and waste water does not necessary come from urban horticultural production. Still when this water is used for urban crop irrigation, it constitutes a high risk. In Bangkok, a survey has shown residues of organo-chlorine and organo-phosphate in irrigation water (Eiumnoh & Parkpian 1998).

Urban horticultural systems

Rural horticulture adapted to urban situations

Horticulture in urban areas requires some specific adaptations, as discussed in the previous section. In this section we present some discussion on general cropping systems and their adaptation to the urban context.

Kessler (2003) describes the different farming systems in four West Africa capitals (Lome, Cotonou, Bamako and Ouagadougou). In this study, the farming systems are characterised by the crops grown by farmers. The study reveals that differences in crops and inputs of the different farming systems are due to different economic strategies adopted by the farmers. Mixed vegetable farming with watering cans and/or with pumps to cultivate short- and long-cycle vegetables like lettuce, cabbage, carrots, onions, etc. is an example.

Similar systems are also described in Asia. Farming systems in the peri-urban areas of Hubli-Dharward (India) comprise vegetable production, agroforestry systems, Napier grass (fodder) production and small-scale livestock production (Bradford et al., 2002). In Hyderabad (India), the predominant system is paragrass production, which like Napier grass is used as folder. Green leafy vegetables are grown here on small sections for subsistence needs and for sale. Other crops include rice, fruit trees and flowers. There is also coconut and banana as well as livestock (water buffalo) keeping (Buechler et al., 2002). In Cagayan de Oro (Philippines), urban types of agriculture are characterised by home gardens as well as aquaculture and other specialised food crops (banana, cereals, vegetables etc.,usually as mono-crops). Production can be for home consumption as well as for market sale. Peri-urban agriculture is often dominated by irrigated vegetable production, as is the case in Vietnam or Malaysia. Other systems that can be counted are commercial and domestic livestock production, flowers and seldom agroforestry (Potutan et al., 2000; own observations).

Major systems mentioned for Shanghai are cereals, vegetable and livestock production (Yi-Zhang and Zhangen, 2000).

Many additional types could be named using the major crops grown or animals raised as a criterion. A study under the Urban Harvest Programme (www.cipotato.org/urbanharvest/home.htm) in Cameroon identified three major types of cropping systems:
(1) mixed crop systems dominated by open-pollinated varieties (OPVs) of improved maize in the upland areas (vacant lots, unused municipal lands);
(2) mono-cropping systems of OPVs of improved maize grown in valley bottoms; and
(3) intensive horticultural systems in valley bottoms, primarily for the production of traditional leafy vegetables (TLVs).

In addition, they observed that there is widespread use of small home garden plots for growing leafy vegetables and stands of banana, plantain, avocado, African plum and other fruit trees around homesteads. Within these cropping systems, the research identified two types of agricultural units: “commercial” and “household food” producers based on the criterion of producing for sale, at least, half of the output from one of their products. The study found that women are the main producers both household food and for sale, accounting for 87% of the total sample (see also the case of Yaounde).

Moustier summarises the different descriptions found in literature of cropping and farming systems in 5 major types of urban agriculture:

-Subsistence home intra-urban farmers (intra-urban and peri-urban areas)
-Family-type commercial farmers (intra-urban and peri-urban areas)
-Urban and peri-urban agricultural entrepreneurs (intra-urban and peri-urban areas)
-Multi-cropping peri-urban farmers (peri-urban areas)
-Urban residents with speculative strategies (intra-urban and peri-urban areas)

Although quantitative data on the importance of each of these types are scarce, available figures for West and Central Africa suggest the dominance of family commercial farmers in terms of number and of importance in urban food supply (Moustier, this book). In Dakar, out of 5025 urban farmers, 70% were family commercial farmers, 25% were entrepreneurs and 5% were subsistence farmers (Mbaye and Moustier, 2000). Households may move from one category to another, for instance when products are being sold in the market. The (semi) commercial households’ main aim is to have a regular income and a regular food supply for securing their livelihoods. Therefore the cropping system is based on crops that add high value and that are less risky to grow, on small parcels of land. Leafy vegetables with short cropping cycles that enable regular cash generation are a typical example.

New urban horticultural systems

New horticultural practices have been developed to maximise the use of space, to optimise the use of inputs and to minimise impacts of horticulture on human and environmental health. Some of the new techniques described here are: growing horticultural crops on urban built-up land with various types of urban substrates (e.g. on roof tops, organic farming and hydroponic production), to save water in highly populated areas, to produce pesticide-free vegetables year-round with a low content of heavy metals and human pathogens, and to control wastage and leaching (fertilisers, pesticides, organic matter, water) into the urban environment.

These techniques take into account the specific constraints of UPH systems, but are more demanding than traditional or conventional techniques in terms of new knowledge and/or investments.

Hydroponics

Hydroponics is a technology characterised by the absence of soil. It needs less space, labour, external inputs and time, but needs proper management and often higher investments. As mentioned earlier, it is often difficult to control or quantify nutrient availability in the soil. Hydroponic systems provide a convenient means to control plant uptake of nutrients. An additional advantage of water culture is its secondary effects such as accumulation of soil toxins are likely to be reduced (Lissner *et al*. 2003). Another advantage of growing without soil is that it reduces some soil-borne diseases.

The basic concept of hydroponics is that roots suspended in moving water absorb food and oxygen rapidly. Of special concern is the availability of oxygen, in that when oxygen is insufficient, plant growth will be retarded. The grower's task is to balance the combination of water, nutrients and oxygen with the plants' needs in order to maximise yield and quality. The use of water and inputs is optimised: the exact amount needed by the plants is provided. For the best results, a few important parameters need to be taken into account: temperature, humidity and CO_2 levels, light intensity, ventilation and the plant's genetic make-up. In order to fix the crop roots in the required position, some inert substrata may be used (sponges, artificial mineral marbles, rock wool etc).

Water quantity and quality are key factors in hydroponic systems. Water quality depends mainly on the source used. Growers use water from different sources, such as surface water (lakes, natural and artificial ponds), groundwater (wells), municipal tap water, rainwater and combinations of these. Rainwater has a low ionic strength and usually low micro-organism and algal densities; it conforms to water quality guidelines and is often better than other sources. A common practice is to collect rainwater from greenhouse roofs into ponds. However, as these ponds are fed by atmospheric precipitation, they are vulnerable to changes in the environment, e.g. eutrophication and acidification. Rainwater is not always available for use in irrigation because of technical problems in collection and storage. Therefore, the grower must find other water sources, e.g. rivers or lakes, but, in many cases, such sources are polluted (Schwarz *et al*. 2005).

Hydroponics allows production in abundance of healthy fresh vegetables, ornamentals, aromatic and medicinal plants and suits the requirements of poor urban farmers. When the technique is well controlled, the productivity generated by hydroponic systems is greater than that from traditional gardening systems. It is a perfect technology for urban or periurban areas where the soil is poor or polluted. In many countries of South America, hydroponics is a technique that is fast gaining importance (Tabares 2003, Rios 2003).

Small hydroponic units can be operated by families. This may help in meeting their food needs and in getting an additional income. Some special hydroponic techniques have been developed, especially for limited spaces and to suit people in developing countries. Such simplified hydroponic systems often use recycled materials and are easier to understand, learn and implement (Caldeyro-Stajano 2004). Simplified hydroponics is a technology incorporating soil-less culture techniques without using mechanical devices or testing equipment. This technology was developed in the early 1980s in Colombia and is propagated by FAO. It is accessible to people with limited resources and is optimised to use minimal inputs of land space, water, nutrients and grower infrastructure (See Box 2). A Family Economical Unit (FEU) of 20 bed-growers of 2 m^2 each (40 m^2) is designed to produce crops that bring an income estimated at USD 3.33 per day in Colombia (year 2000 figures). Simplified hydroponics is well suited to fresh vegetables and fruits (with a high water content) such as lettuces, tomato, bell pepper, basil, celery and radish.

Another interesting process is hydroponics with floaters, where plants are fixed on polystyrene beds that float over a tank. The water surface is completely covered by the floating bed which permits a very limited growth of algae. The tank's nutritive solution is oxygenated, e.g. by a pump.

Box 2 Cost estimation of a simplified hydroponic system

In data gathered from the Colombia project, the results of garden productivity were averaged and the commercial values were estimated. The cost of building 20 bed-growers for the FEU from recycled wood is estimated to be USD 12.84 (6.42 m^2). The annual costs for operating a garden, using the same crops as in the Colombia project, will average about USD 355. This includes costs for medium replacement, seeds, nutrients and water. The annual net income from this garden is estimated to be about USD 1210.00 (USD 101/month). Water is applied to the bed-growers and the excess water is collected underneath them and recycled to the growers the next day. The average water use for a grower is 2–4 litres/day/m^2 or at most 160 litres per day. The annual water requirement for each garden is estimated to be 60,000–120,000 litres.

This hydroponic system is characterised by a large volume of nutritive solution, no losses of water, minimal evaporation and the possibility to use the solution for many crop cycles. It is a low-cost method needing little maintenance. It is used in Martinique (French West Indies), an island with high constraints of space in periurban areas, for production of lettuce or onion (Langlais, CIRAD, pers. comm.). Hydroponic systems also present interesting solutions in combination with the recycling of water, and has been studied in water hyacinth, reed and flower (roses) production systems. Another possible future development of hydroponics is the production of bio-energy crops using wastewater as a nutrient solution (Mavrogianopoulos *et al*. 2002).

The use of wastewater in hydroponic systems requires monitoring of the water quality. The Gravel Bed Hydroponic system (GBH) developed by the University of Portsmouth, UK, includes a rock filter in gabions for primary treatment, GBH beds for secondary treatment and a pond for tertiary treatment. It reduced the biochemical oxygen demand (from 350 to less than 20 mg/l) of the output water in a bed planted with narrowleaf cattail (*Typha angustifolia)* in Colombia (Stott *et al*. 1999). Williams *et al*. (1999) also show that the use of GBH in Egypt permitted a significant removal of parasite eggs from domestic wastewater.

Box 3 Allotment Gardens in Cagayan de Oro, Philippines
By R. J. Holmer

Cagayan de Oro, a city of about 600,000 people, is located on the central coast of Northern Mindanao in the Southern Philippines. It is representative for the numerous secondary cities that have rapidly emerged all over Asia in the shadow of the so-called megacities such as Manila, Jakarta or Bangkok. Out of its total land area of 48,885 ha, about 2300 ha are under agricultural production, mainly for production of corn, fruits, root crops, rice and vegetables with eggplant, squash, string beans, bell pepper, horse radish tree leaves and bitter gourd as the most popular ones (Potutan *et al*. 1997). Apart form of these commercial farms, other forms of urban horticulture also exist. The City Agricultural Office estimates that about 40% of all households (94,672 in 1997) maintain backyard gardens and produce mainly leafy vegetables, fruits and ornamental plants. Ninety-six percent (75 out of 78) of public elementary schools in Cagayan de Oro maintain a school garden. This activity is pursued by pupils as part of the school curriculum and supervised by the principals and teachers. The size of these gardens ranges from 500-1000 m^2. The pupils usually plant leafy vegetables, fruits, ornamental and herbal plants. In some schools, parents are involved in maintaining and safeguarding these gardens. School administrators have adopted bio-intensive gardening, designed for pupils to learn urban agriculture through both formal and informal approaches to education (Potutan *et al*. 2000).

Since 2003, a special type of community gardens, so-called allotment gardens, was established in four highly urbanised areas of Cagayan de Oro, particularly to benefit urban poor families.

Allotment gardens are characterised by a concentration in one place of several small land parcels of about 200 to 400 m^2 that are assigned to individual families, who are organised in an association. In allotment gardens, the parcels are cultivated individually, differing from other types of community gardens where the entire area is tended to collectively by a group of people (Holmer *et al*. 2003). The production practices for vegetables in allotment gardens are similar to those in rural areas, but differ mostly in the choice of suitable cultivars and the reduced application of agrochemicals due to the proximity to populated areas (Guanzon *et al*. 2003). The perceived benefits of the allotment gardens in Cagayan de Oro are many (Urbina *et al*. 2005). While 25% of the vegetables produced is consumed by the family or given away to friends, 75 % is sold to neighbours or walk-in clients who come directly to the gardens as they appreciate the freshness of the produce, the convenience of proximity as well as the lower price compared to the public markets. The gardening activities, a secondary occupation for all its members, have augmented the available income by about 20 % while the vegetable consumption has doubled for 75% of its members. This is especially notable since the average vegetable consumption in Cagayan de Oro is only 36 kg per capita and year, which is a half of the minimum recommended intake of FAO (Agbayani *et al*. 2001). In addition to these benefits, the gardeners particularly appreciate the strengthening of community values, which they have experiences by engaging in allotment gardening. The gardens are also essential for the successful implementation of the city's integrated solid waste management programme. The segregated bio-degradable waste from the neighbouring households is delivered to the allotment gardens where it is converted into compost. The amount of residual waste delivered to the landfill site from these areas has thereby been reduced by more than one third. The city government of Cagayan de Oro is presently mainstreaming this concept into its overall city planning and development, which will also use participatory GIS-based approaches to identify suitable areas for future allotment garden sites.

Conclusion

In many expanding cities in developing countries, UPH is already a large contributor in supplying fresh produce to city markets and is expected to remain so in the near future. On the one hand, the available land will decrease because of the need for industrial development and urban housing. On the other, the demand for fruit, vegetables and flowers will increase with rising standards of living and growing populations. Horticultural production units will evolve and adapt to new environments as cities continue to develop. In the future, vegetable production will remain essential as a source of high income and healthy food for growing cities.

Vegetable production provides regular and high incomes to the various actors in the commodity chain and provides food to urban dwellers. For instance, in 1999 in Jakarta (Indonesia), UPH fruit production supplied almost 20% of the city's demand. Worldwide, about one quarter to two thirds of urban and periurban households are involved in agriculture. In the coming decades, fruit and vegetable production will continue to play a key role in feeding cities and providing activities and incomes to farmers. To answer consumers' demand and to produce healthy fruits and vegetable in a manner that respects the environment and producers, it will be necessary to combine agro-technical solutions with urban planning. Many specific techniques have been developed or adapted specifically for urban areas but there is still some research needed in order to better understand these complex anthropised agro-systems. Systems such as permaculture that combine various forms of production can be very complex ecologically. It is therefore important to undertake agro-technical studies that could provide more in-depth on the conditions required for obtaining good-quality vegetables. Urban planning should help to provide optimal conditions for urban gardeners.

So, with a view to current and future technology transfer, all stakeholders in the commodity chains have to be involved in developing better conditions for integrating fruits, vegetables and flowers as part of UPH. Supply of inputs and materials, management of crop residues and linkage between activities are key points that need to be taken into account early in the urban planning process. It involves all aspects of a city's organisation and requires commitment to provide goods and services to agricultural activities and people (Pinderhughes 2004). The case of PROVE also shows that additional income can be gained by (poor) urban producers if less intermediaries are involved in getting their products to the consumers.

Various functions of UPH have been mentioned in this paper. The food supply function remains the most important, even though economical, social (labour), cultural, living environment, environmental (recycling) and security (food and natural risks) functions appear to be essential too. More than any other agricultural system, UPH has a multifunctional role that should be taken into account by researchers and policy makers. Implementation of an urban planning policy that includes the sustainability of this form of agriculture is a necessity for well-balanced urban development. UPH plays a substantial role in the development of local (micro)enterprises, including input supply, processing and marketing. It also reduces the distance that fresh food needs to travel from producer to consumer.

If well managed, urban horticulture can play an important role in reducing socio-economic and environmental problems in cities. Planners and policymakers should develop and support community-wide plans to improve poor people's incomes using urban organic waste, to improve urban food safety and to create sustainable food systems.

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