Urban and periurban horticulture in Africa and Asia: characterisation of the systems and issues of sustainability

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1. Definitions

Urban and periurban horticulture (UPH) in his article refers to: (i) the production of a range of vegetables, aromatic plants, medicinal plants, flowers, ornamental plants, fruit trees and mushrooms, (ii) grown mainly in intensive production systems with high levels of inputs, (iii) located in the city or at its close periphery where there is competition for access to land between agricultural and other human activities, (iv) the products of which are consumed in the city (Moustier, 1999). This paper will focus on two aspects of the horticultural sector: production, essentially of vegetables, and marketing, and is mainly based on data from Africa and South-East Asia.

2. Farming systems

Most of the farming systems in the big cities of developing countries do not require much starting capital. Use of labour, however, is far higher than in cereal crop production. In northern Vietnam, for instance, AVRDC has shown that vegetables require twice as much labour per unit of land (456 days/ha) as rice (223 days/ha).

The classification of agricultural production systems proposed by Moustier is well suited to horticultural systems (Moustier,2000):
(i) subsistence home production,
(ii) farm-type commercial production systems,
(iii)entrepreneurial production systems,
(iv) multicropped 'rurban' production systems.
Within each group, different kinds of technical systems are used: roof top production, open space in the city, hydroponics, organoponics, high-level input production systems, protected cultivation, standard cultivation.

Most of the time, horticultural farming is a full-time job. In some locations, however, it becomes a part-time activity for employees, workers, shopkeepers, craftsman, etc. In Dakar, for instance, such persons are called Sunday farmers. They are urban civil servants or employees of private companies who buy land for producing fruit trees and vegetables. Traditional farmers consider that these newcomers are robbing them of their lands and market opportunities.

Land is one of the main constraints in the horticultural system. The average garden surface area for vegetable farmers is rather low: 700m² in Brazzaville, 1,500 m² in Bangui, 760 to 900 m² in Bissau, 700 m² in Antananarivo, 6,750 m² in periurban areas and 500 m² in intra-urban areas in Dar-es-Salaam, 1,490 m² in Hanoi. The harvest is either used for auto-consumption (mainly in the case of intra-urban subsistence-oriented home gardening) and/or for sale.

There are two groups of horticultural farmers:
(i) farmers who deal only with horticultural products (medicinal plants, ornamental plants, flowers, vegetables, and fruit trees), and
(ii) those who also produce cereals or breed animals. In Hanoi province, for instance, 78% of the cultivated area is covered with rice and maize: most of the horticultural farmers also produce food crops and some animals.

Whatever the level of specialisation, horticultural activity faces similar urban conditions:
(i) problems of quality of natural resources (water, air, soil, light) and inputs (water, fertilizers) needed for production,
(ii) high population density that may limit the use of inputs and the management of horticultural waste products.

3. Cropping systems and crop management

The crops

Vegetables usually include between 60 to 100 species. The range of the ornamental crops is larger. Classification may be based on length of cycle, inputs requirements, and risks related to climate and pests. In Central Africa, vegetables are divided into four groups:

- Short-cycle indigenous leafy vegetables (less than one month): amaranth, petsay, local sorrel, etc. that grow with very few disease problems. They are used very commonly, but generated incomes are low due to low prices.
- Long-cycle indigenous leafy vegetables (one – two months) with few risks for production and marketing: glossy nightshade, cabbage, chives, Malabar spinach, which provide higher revenues.
- Short-cycle temperate origin vegetables (less than two months): e.g. lettuce and parsley, with risks at production and marketing levels situated between those of leafy vegetables and long-cycle temperate vegetables.
- Long cycle temperate vegetables (more than two months) such as tomato, carrot, purple eggplant, and cucumber that present some risk in production and marketing. They provide the highest revenues, but also present the highest risks.

Another classification is based on internal characteristics including taste, shape, size, colour, origin and shelf life. Vegetables can be ranked in five groups according to their shelf lives:

- very short (1-2 days): day lily and leafy vegetables, leafy mustard, lettuce, amaranth, choysum, jute, spinach, Malabar spinach, pumpkin leaves, sweet potato leaves, cassava leaves, Ethiopian kale, chinese kale
- short (3-7 days): pakchoi, okra, radish, green pea, asparagus
- medium (1-2 weeks): mushroom, sweet pepper, tomato, watermelon, musk melon, cucumber, yard long bean, squash, broccoli
- medium-long (3-4 weeks): common cabbage, cauliflower, eggplant, Chinese cabbage, chilli pepper
- long (more than 4 weeks): onion, garlic, pumpkin, shallot

Year-round vegetable production system or seasonality

The objective of periurban farmers is to produce horticultural products for as long as possible during the year in order to obtain a regular income. They face a number of constraints, through: (i) adverse climatic conditions such as excess of water, lack of water, high temperature; (ii) lack of technical know-how; (iii) lack of on-farm and public infrastructures; (iv) competition between suppliers. Seasonality in supply of vegetables is observed in all vegetable markets in the world. The development of urban and periurban horticulture may decrease the variation of the markets' supply during the year, because of easier access to new off-season technologies.

For year-round production, crops may be cultivated on the same fields or on different fields throughout the year. If horticultural crops are grown continually on the same fields, the length of the period between crops has to be very short. This favours the permanent presence of pests in the soils and the decrease of soil fertility. One solution is hydroponics, to be described in chapter two of this publication.

Production during hot and wet season

Some vegetable species do not adapt to high temperatures and a rainy season. Lettuce yields are still rather low during this season from June to October in the northern inter-tropical and tropical zone. Many breeding programmes have been conducted since 1950 in tropical areas of Japan, the United States, Europe, and Taiwan.
Many new varieties have been successfully obtained for resistance to disease (tomato, eggplant, cucumber, melon, sweet pepper, cabbage, etc.) or for better adaptation to high temperatures (tomato, common cabbage). Still, climatic variables (heat, low irradiance) limit the development of the plant. Tomato yield during the hot and rainy season, for instance, is half of the cool season yield. There are still a number of limits to production in the hot and rainy season, especially in the intensive urban and periurban systems.

To avoid the direct physical damaging effects of the rain, it is recommended that vegetables be grown under plastic shelter houses with good static ventilation to avoid the negative effect of temperature increase due to the plastic cover. Growing tomato, cucumber, and lettuce under shelter protects the plants from heavy rains. In the hot and wet season, high temperature and high humidity are factors favouring the development of plant pathogens such as fungi (anthracnose due to *Collectotrichum spp*., fruit rots, downy mildew, Southern blight due to *Sclerotium rolfsii*) and bacteria (bacterial wilt due to *Ralstonia solanacearum*, soft rot caused by *Erwinia spp.*). For solanaceous crops (tomato, pepper, eggplant), frequent cropping also leads to the development of bacterial wilt. Three solutions may limit the damaging effect of this disease: long-term rotations with crops that are not sensitive to the bacteria; growing resistant varieties; growing tomato –the most sensitive plant to this diseasegrafted on bacterial wilt resistant solanaceous crops.

On the other hand, periurban production may have to face the problem of lack of water in particular conditions, for instance in Accra. There, the main production occurs during the rainy season and at the beginning of the dry season with the associated risk of disease development.
The development of permanent vegetable crops on a restricted location increases the risk of insect pest development. The absence of adequate rotations leads to problems in controlling pest development. This is one of the causes of the excessive use of pesticides.

Use of pesticides

Chemical pesticides have played an important role in yield increases for more than fifty years. Periurban horticulture has increased this phenomenon due to easy access to the products (via national and international companies, retailers, and wholesalers), technical information, high value of the crops, and the effectiveness of the chemicals. There are three major risks, however: (i) the health risk for consumer, (ii) the risk of polluting the environment (mainly water sources), and (iii) the user risk. 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 Hanoi, low-cost pesticides (organophosphates, pyrethroids, carbamates) with high toxicity (classes I and II) are very commonly used, with little information provided about how to use them. Application rates are much higher than the recommended rates (table 3) for most of the insecticides used. This and the high spraying frequency are the causes of high pesticide residues in the marketed vegetables.

Table 1. Pesticide application rates on Cruciferae (kg a.i./ha/time) in Thanh Tri and Tu Liem districts (1995) *(From, Tran Khac Thi 1999)*

Pesticides	Tu Liem	Thanh Tri	Recommended rate
Wofatox 50 EC (methyl parathion)	1.25	1.50	0.50
Monitor 70 SC (methamidophos)	1.05	1.80	0.70
Dipterex 90 WP (trichlorfon)	1.50	0.50	0.90
Sherpa 25 EC (cypermethrin)	0.20	0.20	0.12
Sumicidin 20 EC (fenvalerate)	0.20	0.20	0.12

Pesticide presence in the city's surface water and wastewater for crop irrigation constitutes a high risk for urban and periurban horticulture, even though this presence is not due solely to urban and periurban horticulture. In Bangkok, a survey has shown residues of organochlorine and organophosphate in the irrigating water (Eiumnoh.& Parkpian, 1998).

Fertilizer management

Two main groups are distinguished: organic fertilizers and chemical (or inorganic) fertilizers. Intensive production of vegetables and ornamental flowers has always made heavy use of organic fertilizers. The quantity used varies from a few tons/ha to fifty or even a hundred tons per year. The organic fertilizers provide most of the micronutrients and improve the structure of the soil. Organic fertilizers have various origins: manure from livestock or poultry; compost from vegetable waste; waste from urban activities: sewage sludge, night soil, household waste, etc.

For many centuries, periurban and urban agriculture have managed and recycled the urban waste products (Fleury & Moustier, 1999). These practices cause some risks to the environment: pollution of soils with heavy metals from sewage sludge, pollution of water with nitrates due to huge quantities of organic manure; but also to the health of the consumer (see below). In South-east Asia, use of fresh night soil is a common practice even though it disseminates human pathogens. The disadvantage of these solid organic sources for vegetable production is that they release nutrients (especially nitrogen) slowly. Liquid fertilizers act faster. This is why these liquid organic fertilizers are often used on the short-cycle leafy vegetables such as amaranth, choysum, and mustard.

Often, research has been on combining organic fertilizers and inorganic ones to enhance their efficacy (AVRDC, 2000). In Hanoi, liquid organic fertilizer, such as pig urine, is used to supply nitrogen during crop growth. AVRDC is working on producing an organic liquid fertilizer that does not endanger consumer health. Inorganic fertilizers are easier to use, especially as regards providing the right dose in relation to plant uptake. The risks concern application and contamination of soils and water by nitrates and phosphates. Also, they might be the source of heavy metals. In Thailand, it has been shown that ammonium phosphate can bring cadmium, zinc, chrome into the environment in excessive quantity[14].

Irrigation

Water is essential to the growth of the plants. Water requirements are related to climatic conditions and the plant species. In most of the capital cities of developing countries, located in tropical and subtropical areas, quantities required vary from 0.1 to 1 l / m²/day in very dry and hot areas. For a crop of 30 days, the quantity of water needed by a leafy vegetable during the dry season will be around 15 l/m².

Different techniques are used for irrigation. Water is supplied through overhead irrigation by tanks, sprinklers or perforated pipes from wells, ponds, or the sewer. Drip or trickle irrigation has been promoted for twenty years now. This technique saves water by 10 to 20% compared with overhead irrigation, but requires clean water in order to avoid blocking the emitters. The full-fledged system includes filters, pumps and a pressure regulator that low income vegetable growers cannot afford. The advantage of this technique is that water is not in contact with fruits and leaves. It will not, however, avoid contamination of soil and roots of vegetables with biological pathogens. Underground irrigation provides water to the plant by capillarity. 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 flows to the plants) are rather difficult and tend to be inaccurate.

4. Quality of the production

Studies have shown that production in urban and periurban areas does not produce lower quality vegetables than in rural areas[13]. In the context of increasing consumer awareness, it is worthwhile, all the same, paying attention to major elements of the quality of the vegetables: nitrates, biological pathogens, heavy metals and pesticide residues.

Nitrates

Nitrates can cause health problems to very young babies and pregnant women. They are also an indicator of good or bad agricultural practices. Nitrates also cause eutrophication of water in combination with phosphorus. In Europe, there is standard for lettuce (see table 4). FAO and a Russian recommendation also provide extensive standards. In urban and periurban systems, nitrates stem from fertilizers and from irrigation water. Some quick tests, such as Nitracheck®, appear to help farmers in nitrogen management. In Germany, the “KNS system” based on Nmin measurement is commonly used in field vegetable production. Still, these methods need to be validated for the specific urban and periurban leafy vegetables. Moreover, with the objective of developing the use of organic matter obtained from urban waste products in mind, it appears that specific tools must be developed that take into account the problem of the irregular and slow release of nitrogen.

Table 2. Standards for nitrates in lettuce (CE 194/97)

Lettuce type	Nitrates content limit (mg/kg)
Greenhouse lettuce October – March	4,500 ppm
Greenhouse lettuce April – September	3,500 ppm
Open field lettuce	2,500 ppm

Biological contaminants

Biological contaminants are introduced through organic fertilizers, irrigation water and handling and storing of products. Tap water and wastewater are used for irrigating crops and for cleaning vegetables. In Accra, the common micro-organisms isolated form vegetable samples include *Escherichia coli*, *Pseudomonas spp., Salmonella arizonae* on white radish, green pepper, lettuce, and carrot. Helminths and protozoans have also been identified on vegetables collected on fields and markets (Sonou, 2001). In a recent study in Vietnam, 39 samples of choysum (*Brassica campestris spp. parachinensis*) from fields have not shown any presence of Salmonella, E. coli and Shigella, but have revealed the presence of some Ascaris eggs in four cases (10%). These Ascaris eggs probably originate from top dressing applications of liquid organic fertilizer (pig urine). Similar results have been obtained in various studies in Dakar (Ndeye Fatou Diop Gueye & Mouss Sy, 2001).

Regulations exist at production level on the quality of the water and organic fertilizers used. Also, there are standards for the quality of vegetables. According to FAO, water for irrigating vegetables should contain less than 1 egg per litre for intestinal nematodes and less than 1,000 / 100ml of coliform bacteria. For flowers and ornamental crops, less strict regulations have to be set up. In Vietnam, the maximum levels in fresh vegetables are: coliforms 10/1g and Salmonella 0/1g, but for *E. coli, Staphylococcus aureus* and *Clostridium perfringens*, control is done according to a guide of Good Agricultural Practices.
The main problem will be the implementation of the regulations. Numerous projects have been set up, implemented and completed with some success about composting organic matter, deep wells, waste stabilisation ponds and treatment batches. The adoption of safer technologies will have to include mechanisms for certification and the creation of small and medium enterprises specialised in these activities.

Heavy metals residues

Industrial activities, wastewater and vehicle traffic increase the levels of heavy metals in the air (lead from the vehicle), in the soil and in the water (cadmium, zinc from chemical and industrial activities). The presence of heavy metals in the environment reaches the plants through the air (roadside dust on the leaves), the underground and surface water, and the soil (deposit of dust and supply by organic and inorganic chemicals). The consequence is an increase of heavy metal content in vegetables for human consumption. In Bangkok, the presence of a permanent fog decreases the light intensity, reducing the photosynthesis activity of the plant. The presence of air pollutants such as sulphur dioxide and fluoride may reduce growth and yield through a reduction in chlorophyll content, and, hence, the inhibition of photosynthesis (Midmore, 1998).

In Hanoi, sampling at 25 locations near industrial factories (battery factory, chemical industry), revealed an excess of lead and cadmium on choysum, lettuce, kangkong at two locations (Tran Khac Thi, 1999). In other capital cities of developing countries such as Dar-es-Salaam, it appears, however, that the negative impact due to the urban polluting environment is not as important given the lack of industrial activities (Giza Muster, 1997). Table 5 gives the maximum level for a number of heavy metals.

Table 3. Maximum levels of heavy-metal content in vegetables (from FAO/WHO 1993)

Element	Arsenic	Lead	Mercury	Copper	Cadmium	Zinc	Boron	Antimony
Content mg/kg	0.2	0.5-1.0	0.005	5.0	0.02	10.0	1.8	200

The rate of absorption of heavy metals by vegetables seems linked to the levels present 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 biological functions, controlling their presence in plants must be done by respecting the soil standards. The locaation of vegetable production with regard to roads and polluting industry, should be looked at carefully. Bioremediation of the soil by plants, and installation of mycorrhizae that limit heavy metal uptake are long-term projects that might help solving the management of heavy metals in the future.

Pesticide residues
Pesticide residues above the maximum residue limit, have been observed several times in markets[12, 13, 18]. In Hanoia survey in 1998 of common cabbages collected on the retail market showed high residues of methamidophos on cabbage, 2 out of 20 samples exceeding the maximum residue limit[17]. More recently, 1 out of 8 samples taken on choysum at harvesting time showed excessive residues of cypermethrin. This in spite of the fact that regulations were already in place for the use of pesticides and in spite of existing recommendations for health safety. The application of pesticides to crops also endangers workers if protective measures are not taken. This is mainly the case for low-income farmers who cannot afford to buy proper clothing and equipment or are not aware of the importance of doing so.

Awareness of risks due to excessive use of chemical pesticides exists at all levels, ranging from farmers, consumers, and public authorities to agro-chemical companies. The urban and periurban horticulture sector is more sensitive to this problem due to the proximity of consumer and farmer. At this moment, penalties are normally 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 for having a better quality product and a safer environment. The development of new technology such as integrated pest management and biological control can help in reducing pesticide use.

Management of horticultural product quality
Most countries have already set up standards for improving the quality of vegetables and to reduce pollution to the environment and to limit the uptake of natural resources, especially water, mainly based on the improvement of farmers' practices as has been done in Vietnam (Decision 1208 KHCN/QD, July 15, 1996 Ministry of Agricultural and Rural Development; temporary regulation, April 9, 1999 by Ministry of Agriculture and Rural Development). Still, it is in many cases very difficult to set up good control mechanisms and to enforce the regulations. These problems increase in urban and periurban areas where there is easy access to the inputs. In addition, cropping areas are small, easily leading to input overdoses, coupled with the need of farmers to obtain high yields.
The first step will be to follow the existing standards. This requires certification and control mechanisms. To be effective these should be the result of inter-professional negotiations with the support of public authorities.
Some technical obstacles must be cleared for the control methods: basic analytical laboratories and quick on-field tests. New standards must be set for little known vegetables, such as African and Asian leafy vegetables. Also, new technology must be developed in order to reduce pesticide use: alternative technology to pesticide use, biological control, resistant cultivars and crop management.

At the production level, decision making-tools for better management of the crop, the cropping systems, the farming systems need to be established for the specific small size urban and periurban horticultural sector.
Techniques that may be developed for reducing levels of nitrate, pesticides and heavy metals must be based on decision-making tools that integrate all components of the urban-horticulture system: economic costs, sustainability of the horticultural farming system, regulation systems, costs of control. In the same way, the use of wastewater and water saving techniques such as drip irrigation and mulching must be validated in the context of urban and periurban horticulture.

5. Sustainability of urban and periurban horticultural systems

Two main hypotheses could be formulated:
- The urban and periurban horticulture sector is not profitable compared to other human activities and needs for urban infrastructure.

- The city would like to maintain urban and periurban horticultural activity in and around the city in order to benefit from its different advantages: links with nature, waste product recycling, job opportunities, greening of cities.

The sustainability of these systems must be of a different kind. In the first hypothesis, it will be related to the direct productive role of the commodity chain to provide horticultural products to the city; in the second one, the productive roles will be supplemented by more qualitative functions about city environment.

In the first case, the horticulture activity will follow the expansion of the city. This is a phenomenon that has been observed for centuries. Research should be more focused on the agricultural problems of horticulture: improving productivity but, at the same time, reducing the negative impacts on the environment (less pesticides, less waste products, recycling urban waste products), organisation of farmers, an innovative sector in terms of products, technologies with a quick and efficient response to consumer demands.

In the second case, more efforts will be directed towards environmental aspects, employment opportunities for a part of the urban population, greening of the city, technology for smallspace horticulture, diversification of horticulture towards leisure. In this case, horticulture needs the support of policy makers for securing access to land and natural resources - water, air and light - in the city environment.

In these two hypotheses, two problems remain essential: (i) the response of the horticulture industry to quality demand by consumers, and (ii) the relationship between horticulture and the urban environment.

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