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Review article

Sustainable urban agriculture in developing countries. A review

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Abstract – The population living in cities is continuously increasing worldwide. In developing countries, this phenomenon is exacerbated by poverty, leading to tremendous problems of employment, immigration from the rural areas, transportation, food supply and environment protection. Simultaneously with the growth of cities, a new type of agriculture has emerged; namely, *urban agriculture*. Here, the main functions of urban agriculture are described: its social roles, the economic functions as part of its multi-functionality, the constraints, and the risks for human consumption and the living environment. We highlight the following major points. (1) Agricultural activity will continue to be a strong contributor to urban households. Currently, differences between rural and urban livelihood households appear to be decreasing. (2) Urban agricultural production includes aquaculture, livestock and plants. The commonest crops are perishable leafy vegetables, particularly in South-east Asia and Africa. These vegetable industries have short marketing chains with lower price differentials between farmers and consumers than longer chains. The city food supply function is one of the various roles and objectives of urban agriculture that leads to increasing dialogue between urban dwellers, city authorities and farmers. (3) One of the farmers' issues is to produce high quality products in highly populated areas and within a polluted environment. Agricultural production in cities faces the following challenges: access to the main agricultural inputs, fertilizers and water; production in a polluted environment; and limitation of its negative impact on the environment. Urban agriculture can reuse city wastes, but this will not be enough to achieve high yields, and there is still a risk of producing unsafe products. These are the main challenges for urban agriculture in keeping its multi-functional activities such as cleansing, opening up the urban space, and producing fresh and nutritious food.

urban and peri-urban agriculture / livelihoods / marketing chains / vegetables / freshness / multi-functional

1. INTRODUCTION

While urban agriculture occurs in all cities of the world, there are still many questions about whether and how to develop research and development activity for this particular type of agriculture. The tremendous and continuing urbanization process in Asia, Africa and Latin America raises questions about the employment of the new "urban" manpower, feeding the growing urban population, and the management of the continuously moving fringes of the cities of developing countries. Different definitions of urban agriculture have been developed that stress the relationships between agriculture and the city both in terms of resources and outputs (Lourenco-Lindell, 1995; Moustier and Mbaye, 1999; Moustier and Fall, 2004; Mougeot, 1995). In this paper, the words "urban agriculture" will be used as defined by the growing of plants and the raising of animals for food and other uses within and around cities and towns (from Van Veenhuizen, 2006).

The major question asked of agronomists, agro-economists and agro-sociologists is whether urban and peri-urban agriculture are genuinely distinct from rural agriculture and, if so, what are their main distinguishing characteristics? Does this type of agriculture then require specific research work? Literature on the subject is rather extensive, belonging both to the life sciences and the social sciences, and including also a large number of technical documents, technical bulletins and project reports. Since the end of the 1980s, CIRAD has developed research programs on urban agriculture in Africa and in South-east Asia (Parrot et al., 2008a, b; Moustier, 2007). This paper makes the following assertions about the future of urban agriculture: the continuing population growth of cities in developing countries will not decrease the economic and social importance of urban agriculture, if governments are made aware of its multi-functional role, and if the safety of its products and environment can be guaranteed.

To give answers to this hypothesis, three characteristics of urban agriculture in developing countries will be developed

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and commented on: (1) the social roles of urban agriculture in relation to the urban population growth; (2) the economic functions of urban agriculture and the emergence of its multifunctionality; (3) the constraints and the risks of developing an urban agriculture for human consumption. CIRAD's experiences in developing country projects will be presented and complemented by a review of the literature.

2. URBAN AGRICULTURE AND URBAN POPULATION GROWTH

Half of Africa's population already lives in cities, a proportion that will continue to increase (UN, 2006), though it is also recognized that agriculture still provides employment and income for the majority of the population (World Bank, 2007). If national data and predictions are correct, a significant part of the African population will live in cities, but will rely on agriculture for income. This situation may cause serious sanitary and environmental challenges for all agricultural activities conducted in an urban area (Cohen, 2004; Ruel and Haddad, 1999; Haggblade and Hazell, 1989).

2.1. Farmers will live in towns

According to The 2005 Revision of World Urbanization Prospects (UN, 2006), by 2030, more than 50 per cent of the African population is expected to live in cities. For example, in Cameroon today, 50 per cent of the population already lives in cities; by 2030, this number is expected to be more than 70 per cent. With the rise of mega-cities, secondary towns and small urban settlements will spread into rural areas, increasing population densities even in remote areas. The traditional distinctions between urban and rural lifestyles are becoming redundant, and we can reasonably expect a convergence in developing countries between these two lifestyles (Cohen, 2004).

The concept of urban agriculture involves the notion of both urban and rural areas, but the definition of what constitutes an urban or a rural area varies between countries. No clear consensus seems to prevail in the literature (Cohen, 2004; Tiffen, 2003; Frey and Zimmer, 2001). For example, in Cameroon, the 1976 and 1987 censuses considered as urban population anybody living in a locality with a district, a division, a department or a Province and/or having at least 5000 inhabitants and including a secondary or post-primary school, a healthcare center, a water conveyance and a daily market. A locality with less than 5000 inhabitants and without any of the cited infrastructures was considered as rural (INS, 2004). In Benin, localities with 10000 inhabitants or more are classified as urban in UN data, while in Angola, Argentina and Ethiopia, all localities with 2000 inhabitants or more are considered urban. Such disparities pose problems when making international comparisons.

Between 1960 and 2020, the number of West African cities, Cameroon included, with a population over 100 000 will rise from 17 to 200 (Cour, 1995, 2001). Most of the urban growth may in fact not occur in the larger towns, but in secondary towns or in the hinterlands. For example, the respective populations of Douala and Yaoundé in Cameroon are projected to increase from a little less than 2 million inhabitants in 2005 to a little more than 2 million inhabitants in 2030 (UN, 2006). These two cities will therefore have lower urban growth rates in the future than during previous decades: 5 to 6 per cent between 1990 and 1995 compared with 2.5 per cent projected between 2010 and 2015. The percentage of the urban population living in these two towns should stabilize at 20 per cent in 2015 after reaching a peak in 2005 of about 22 per cent (UN, 2006). The missing millions of the population will therefore be located in the hinterland, in secondary towns.

In 2030, over 70 per cent of the population of Cameroon is expected to live in cities. If we assume that 60 per cent of the population will still derive income from farming, this means that at least 30 per cent of farmers will live in towns. For instance, according to the UNDP, 80% of families in Libreville (Gabon), 68% of urban dwellers in six Tanzanian cities, 45% in Lusaka (Zambia), 37% in Maputo (Mozambique), 36% in Ouagadougou (Burkina Faso) and 35% in Yaounde (Cameroon) are involved in urban agriculture. In their study of Kampala (Uganda), Maxwell and Zziwa (1992) estimated that 36% of the population was involved in urban agriculture. The involvement of so many people in urban agriculture indicates its centrality in informal sector activities. There seems to be no signs in Sub-Saharan Africa today that the number of people involved in farming activities as a primary or as a secondary source of income will significantly decline in the near future (World Bank, 2007). But this trend will induce strong urban-rural linkages, as rural households progressively combine employment and incomes from the two sectors (Ruel and Haddad, 1999; Haggblade and Hazell, 1989). Therefore, an increasing share of farmers' income will derive from off-farm activities (Reardon, 1997; Ellis, 1998; Parrot et al., 2008c).

2.2. Urban agriculture will provide employment

The social impact of agriculture is still predominant in Africa. In the absence of formal employment opportunities from other sectors of the economy, industries and services, agriculture remains a necessary contributor to livelihoods (Ellis and Sumberg, 1998). However, the economic impact of agriculture at the country level is not always so significant. In Cameroon, the primary sector (food crops, livestock and fisheries) accounts for only 20 per cent of the gross domestic product (GDP) (MINADER, 2006).

Though agriculture in Cameroon accounts for less than 20 per cent of GDP, in 2004, it still provided income for almost 60 per cent of the population (MINADER, 2006). The social impact of agriculture is therefore very important, especially for small-scale farming. As much as 80 per cent of all farms are family farms, accounting for most rural employment. Following the rise in demand from cities for food, small-scale farming is gradually shifting from subsistence farming to a mix of subsistence and capitalistic farming (Cour, 2001). At household level, the social impact of agriculture is still predominant in terms of employment opportunities and survival

strategies (Corral and Reardon, 2001; Berdegue et al., 2001; Reardon et al., 2001; Parrot et al., 2006). The lack of employment opportunities in the industrial sector or in the service sector makes agriculture essential to the livelihoods of millions of people in developing countries (World Bank, 2007).

Trends in urban growth and the rise of urban farmers will affect productivity in agriculture by reducing the area of arable land, especially in regions of high population density. They will also influence environmental issues, such as reduced fallow time and multiple cropping cycles in one year (Keys and McConnel, 2005). Larger proportions of farmers will live in towns or in their peri-urban belts, using more chemical products than before and therefore increasing sanitary risks (Reardon et al., 1999).

2.3. Livelihoods and the informal sector

Rural-urban linkages are increasing and the distinction between the two sectors is already causing conceptual problems for national statistics institutes. Very little is known about local economic activities and livelihoods. Local economic activities are difficult to assess, because of: (i) underground production such as registered traders with deliberately concealed production; (ii) illegal production such as fuel smuggling; (iii) informal production, "unregistered traders" mostly at household level; and (iv) household production for auto-consumption, e.g. food. Investigations of livelihoods will prove to be necessary in order to cover all the dimensions of households and understand the continuing structural and social changes among them. Agricultural and non-agricultural activities will have to be analyzed simultaneously and not separately for a better understanding of household strategies and income portfolios.

The informal sector also needs to be taken into account, because it impacts most other sectors of an economy and the methodological frameworks for surveys. In 2004, the informal sector accounted for more than half of the gross domestic product (GDP) of Cameroon (Fig. 1). As much as 90 per cent of all workers in the country did not have a signed and formal contract with their employer (INS, 2005). As stated by Schneider and Enste (2000), "a prospering shadow economy may cause severe difficulties for politicians, because official indicators – on unemployment, labor force, income, consumption – are unreliable". The lack of proper information, or statistics between the macro- and the micro-level of analysis, in a decentralization process, can lead to dramatic policy implications (Bahiigwa et al., 2005; Ellis and Bahiigwa, 2003).

Urban agriculture is one of the traditional activities conducted by African households as a risk-sharing strategy, but also as a significant part of their culture and tradition of urban gardening. As stated by Page (2002) in the case of Cameroon: "Far from being a technical practice, urban agriculture has often been a culturally and politically important aspect of urbanism in Africa". Urban growth and the consecutive structural changes in landscape and livelihoods affect urban agriculture. In Africa, the institutional interactions between the ministries of Agriculture and the ministries of Urban Planning often turn into conflicts of interest as urban agriculture can be considered on one side as a necessary contributor to livelihoods or, on the other side, just as an illegal scheme for squatters. Urban agriculture is also practiced by the urban poor or newcomers, and partly in non-constructible areas of towns, in swamps and lowlands. The lack of property rights and the illicit nature of its practice make any investigation very difficult to implement. All in all, the traditional and cultural aspects of urban agriculture in Africa are confronted with the structural challenges faced by the towns in which they have been evolving for decades.

Figure 1. The informal sector accounted for more than half of the gross domestic product (GDP) of Cameroon. In agriculture industry, it includes agricultural production activities as well as marketing of agricultural products as in Muea next to Douala. Credit: Laurent Parrot/CIRAD.

A major feature of Urboa Agriculture (UA) is the diversity of the socio-economic profiles of the actors involved, and their varying income and livelihood strategies, a reflection of the diversity of the labor and capital basis in urban areas. A typology was established Gura in 1996 (Gura, 1996) and since that time some other research has provided some attempts at classification (Bakker et al., 2000; Temple and Moustier, 2004; Moustier and Danso, 2006) that are summarized in Table I. The first category, home subsistence farmers, refers to urban residents who farm on small plots around their homes, mostly for subsistence purposes. The second category also refers to farmers with predominant subsistence strategies, but whose location in peri-urban areas makes it possible to associate multiple food crops on large plots, without use of chemical inputs or irrigation. This type is especially observed in the rain-fed agricultural systems of Central Africa. The third type refers to commercial urban and peri-urban farmers who are involved in agriculture to earn a monetary income for basic family expenditures, while the "entrepreneurs" (fourth type) have diversified sources of income and are able to invest in a larger scale of production than farmers in the other categories. For these farmers, agriculture not only represents a source of income, but also a source of leisure. This dimension is also present in the other categories, although it may not be the major driver of the activity.

Table I. Summary of typology of urban agriculture socio-economic profiles.

	Home subsistence farmers	Multi-cropping peri-urban farmers	Family-type commercial farmers	Entrepreneurs
Location*	U	P	UP	P
Outlets	Home	Home + urban markets	Urban market	Urban market + export
Objective	Home consumption	Home consumption and income for subsistence	Income for subsistence	Additional income Leisure
Size	Usually < 100 m^2	Usually > 5000 m^2	Usually < 1000 m^2	Usually > 2000 m^2
Products	Leafy vegetables, cassava, plantain, maize, rice, goats and sheep, poultry, fruits,	Staple food crops, local vegetables	Leafy vegetables, temperate vegetables Poultry (Sheep) (Milk)	Temperate vegetables, fruits, poultry, livestock, fish
Intensification (inputs/ha)	2	1	2 to 3	4
Gender	F	F + M	F + M	M
Limiting factor	Size	Access to inputs Fertility	Size, land insecurity, access to inputs, water and services, marketing risks	Technical expertise, marketing risks

* U: within the urban districts of the city; P: in the peri-urban districts of the city. Source: Moustier and Danso (2006).

3. MARKETING AND MULTI-FUNCTIONALITY OF URBAN AND PERI-URBAN AGRICULTURE

3.1. The food-supplying role of urban agriculture

The contribution of urban agriculture (UA) to the livelihoods of the urban poor is obvious. In the second part of this review, the specificity of UA will be described in terms of marketing, products and multi-functionality. Urban agriculture is the subject of intense debate as regards its viability and the necessity for political support. In a challenging paper, Ellis and Sumberg (1998) provided a number of reasons why scarce public resources should not target urban agriculture: in particular, the high cost of land in urban areas and the pollution it can attract and generate. Nevertheless, more and more data is becoming available to demonstrate the unique advantages of urban agriculture that advocate for well-targeted public support.

Urban agriculture is a source of food for urban dwellers both in terms of self-consumption and in terms of purchased food. The share of self-consumption in urban agriculture ranges from 10% to 90% according to the availability of land in the city, the nature of the staples, and urban purchasing power. With increasing land pressure, home consumption tends to decrease and recourse to the market increases. Peri-urban areas play a central role in the supply of perishable products, especially vegetables.

The importance of urban agriculture in supplying fresh, perishable products, while rural areas supply more bulky and easier-to-store products, is in line with Von Thünen's predictions in the first analysis of agricultural land use according to location done in 1826. According to Von Thünen's model, land is allocated according to the use which brings the highest rent, and can be sketched as concentric circles relative to the city center. The rent is defined as the share of the output by area after deduction of production and transport costs. The most profitable and intensive land use by unit area, and commodities with high value relative to transport costs are found near the city center (Huriot, 1994). This is typically the case for perishable fruits and vegetables.

The available data in Asia and Africa confirm the importance of urban agriculture in the provision of perishable food commodities, including fresh vegetables, dairy products and plantain banana. Figures on the importance of urban agriculture in urban food markets using market surveys have been gathered by CIRAD in case studies conducted between 1990 and 1995 in Central Africa (Mbaye and Moustier, 2000; Moustier and Danso, 2006). The International Development Research Center (IDRC) supported similar studies in Ghana via the International Water Management Institute (IWMI) (Keraita and Drechsel, 2004). Other similar studies providing data on UA market share include Mai Thi Phuong Anh et al. (2004) for Hanoi; Yi-Zhanh and Zhang (2000) for Shanghai; and various sources quoted in the Urban Agriculture Magazine 2002 special edition for the World Food Summit. The CIRAD studies involved in-depth interviews with a sample of farmers and traders on the relationships between buyers and sellers, particularly the regular nature of the relationship and possible commitments in terms of quality.

Fresh vegetables supplied by urban agriculture are leafy vegetables such as amaranth (*Amaranthus hybridus*), water convolvulus (*Ipomea aquatica*), sorrel (*Hibiscus sabdariffa*), morel (*Solanum aethopicum* and *S. nigrum*), cabbages (various species of Brassicacea), lettuces and chives (*Allium fistulosum*) (Figs. 2, 3). These vegetables top the list of vegetables consumed in Africa and in Asia, along with onions and tomatoes. They are well known for their fragility (after one day they are no longer fresh) in countries where freshness is an important criterion for consumers who often do not have

Figure 2. The freshness of urban leafy vegetables, as water convolvulus (*I. aquatica*) in ponds in inner districts of Hanoi, is one the reason of their cultivation in urban area. Credit: Paule Moustier/CIRAD.

Figure 3. Amaranthus and cabbages are two worldwide leafy vegetables grown in tropical urban and periurban areas, mainly in developing countries due to the high adaptation of some varieties to high temperature and humidity. Credit: Hubert de Bon/CIRAD.

refrigerators. These leafy vegetables are mostly brought into town from distances of less than 30 kilometers from the city centers, be it in Africa or in Asia. The urban agriculture origin represents more than 70% of the contributions in all the cities investigated. In Hanoi in 2002, more than 70% of all leafy vegetables came from a production radius of 30 kilometers around the city. Ninety-five to 100% of all lettuce came from less than 20 kilometers away, while 73% to 100% of water convolvulus was harvested less than 10 kilometers from the city (Moustier et al., 2004). In Phnom Penh, urban areas, i.e., those located inside the municipality, supply all of the water convolvulus marketed in the city. This is a vegetable particularly important for consumption by the poor (Sokhen et al., 2004).

In the case of less perishable vegetables, such as tomato and cabbage, which can stay fresh for a few days, supply varies from peri-urban to rural production. Dry onion originates only from rural areas or from imports in the African cities investigated. As regards staple foods, such as rice, plantain banana and maize, the situation is highly variable according to the city. In Asia, the share of rice supplied by the city to urban residents ranges from 7% in Phnom Penh, to 100% in Vientiane, where pressure on land is low; Hanoi being an intermediate case with 58% (Mai Thi Phuong Anh et al., 2004; Ali et al., 2006), and a steady decrease in the production of rice in favor of vegetables.

3.2. The characteristics and advantages of proximity in market supply

Urban-produced commodities are distributed through short marketing chains relative to rural commodities. The extreme case is direct producer involvement in retail sales. This is the case for 30% of all transactions in Bangui (David, 1992) and 70% in Bissau, where private trade had recently been legalized at the time of surveys (David and Moustier, 1993). Generally, the producer sells to retailers. This transaction takes place in the field or at nighttime wholesale markets in, for example, Brazzaville, Bangui, Bissau, and in Hanoi, Phnom Penh and Vientiane. In Hanoi, more than 40% of all wholesale market sellers are also producers. This percentage increases to 100% for water convolvulus (Moustier et al., 2004).

In Phnom Penh, the marketing chains of kangkong, i.e. water convolvulus, are short, and 57% of retailers are directly supplied by farmers, who receive more than 50% of the final price. Hence, the water convolvulus-growing areas are important with respect to poverty for both farmers and consumers (Sokhen et al., 2004). On the other hand, tomato, which mostly originates from Vietnam, is traded through collectors and wholesalers for more than 60% of transactions.

Short marketing chains enable low price differentials between the farm and final consumption. Such differentials are 30% for leafy vegetables traded in Hanoi, 35% to 50% of cabbage, and 75 to 80% of tomato, while they are more than 100% for vegetables brought from Dalat or China, and more than 200% for vegetables traded from the Red River Delta to Ho Chi Minh City (Moustier et al., 2004). In Havana, Cuba, the prices of tomato, onion, pork and fruits fell threefold between 1994 and 1999, the period when the urban agricultural program was launched (Novo, 2002). The government provided free land access for more than 26000 gardeners, and technical training in organic and hydroponic cultivation methods (Moskow, 1999). Peri-urban areas have transport cost advantages compared with rural areas that translate into lower final prices. Rising oil prices will make local food supplies even more valuable than at present.

While food safety risks may be higher in urban production areas than in rural areas, because of various sources of pollution, e.g. heavy metals in water used for irrigation, and limited land area, forcing farmers to use excess fertilizers and pesticides, the proximity of production areas to consumers provides them with advantages for easier quality control. In Hanoi, supermarkets, shops and restaurants are mostly supplied by three cooperatives located in the peri-urban areas where production following Integrated Pest Management (IPM) or organic standards is certified by government bodies (Moustier et al., 2006). Proximity enables frequent contacts between farmers, traders and consumers, and monitoring of the production process. In

India, farmers located around Aurangabad sell their vegetables through urban organic bazaars organized on a fortnightly basis. Local certification is obtained through "eco-volunteers", people usually working in the vicinity of the vegetable farmers (Braber, 2006). The irregular nature of vegetable production is a major drawback of all direct sales by organic or IPM farmers, as they are tempted to buy from sources other than their own, which then creates further difficulties in guaranteeing product safety (Braber, 2006).

Factors other than distance also give specific advantages to urban agriculture. In certain cases the hinterlands of cities are especially favorable for agriculture, and there are cases when a city was established in a given location because of a rich agricultural hinterland. Furthermore, compared with rural areas, farmers are motivated to earn regular cash income year-round from small plots in order to be able to buy food and ensure a regular livelihood, while in rural areas some land can be reserved for subsistence food production. This explains why urban production tends to be less seasonal than rural production, which is an important factor for guaranteeing food security in urban areas (Moustier and Danso, 2006).

The possibility for citizens to exert control over the way food is produced can indeed be considered as a legitimate right (Koc et al., 1999). Yet the development of international trade, as well as the globalization of capital in food distribution, is now widely documented (McMichael, 1994; Reardon and Berdegué, 2002). This creates risks of growing distance between producers and consumers. Durability of food is developed at the expense of its sustainability (Friedmann, 1994). Growing distances between production and consumption areas reinforce consumers' anxieties about food safety, which some authors have called "anxiogenic distanciation" (Bricas and Seck, 2004).

3.3. The case for public support for multi-functional urban agriculture

In addition to its role in urban food supply, urban agriculture plays a number of environmental, social and economic functions that are still to be recognized by urban authorities. Multi-functionality, usually defined as the multiple roles or objectives that society assigns to agriculture, including economic, social and environmental roles, is a typical characteristic of urban agriculture (Vollet, 2002; Véron, 2004; Duvernoy et al., 2005; Ali et al., 2006). Urban agriculture creates landscape, i.e. a public good, in which users cannot be excluded. This makes land management of little interest to the private sector (Donadieu and Fleury, 1997). In both Southern and Northern countries, as well as with family gardens, urban agriculture produces other things of value to the public, such as food security, social insertion and employment. Within cities, other sectors create landscape, such as parks, to which urban agriculture can be compared. The advantage of urban agriculture over other 'landscape producers' is that its functioning is supported by market forces, even if these markets are imperfect. It is thus a less expensive landscape producer than a public park. It also provides jobs and social inclusion. Based on research in France, Russia and Brazil, it has been argued that urban agriculture is a key component of sustainable human development, including therapy, culture and identity (Boukharaeva et al., 2005; Boukharaeva and Marloie, 2006). The multi-functionality of urban agriculture makes it a 'cheap' producer of public good (Moustier and Danso, 2006).

Increasing distances between urban centers and agriculture is, however, irreversible, if market forces are given a free hand. This is due to the fact that it is more economically sound to develop land than farm it, other than for exceptions such as swamps. Access to land is always quoted among the first constraints by farmers, together with excess or deficient water, flooding and humidity, resulting in various diseases (Temple and Moustier, 2004; Midmore and Jansen, 2003; Prain, 2006). Hence, from a political economy viewpoint, it is legitimate for the public sector to support urban agriculture. In fact, for urban agriculture to be successfully maintained in the city, farmers and non-farmers should share some objectives: duties and rights to examine from the urban residents' side, landscape and environment, and from the farmers' side, protection from land development. Instead of claiming a specific space for urban agriculture, farmers have to negotiate sharing it with other users (Mbiba and Veenhuizen, 2001). In Delft, a city in the south of Holland, a farmer was able to negotiate a 12-year term lease for 35 hectares of land with the municipality, thanks to his commitment to producing organic vegetables and milk, and also the setting aside of 5 hectares of land for nature preservation (Deelstra et al., 2001).

Four areas are particularly relevant for public support of urban agriculture: (i) integration in urban planning; (ii) financial support; (iii) research and extension for more profitable and sustainable intensive commercial vegetable and animal systems (Midmore and Jansen, 2003); and (iv) innovative marketing, including quality labeling. The municipality has a crucial role to play in organizing such support in collaboration with national and international programs.

As for the provision of other urban services, in a context of scarce public resources and concern for long-term sustainability of employment, public-private partnerships are advocated by UN agencies as a promising strategy of public support. Cuba is a successful illustration. In return for providing the land, the government receives a proportion of the produce – usually about one-fifth of the harvest – to use at state-run daycare centers, schools and hospitals (Cruz and Medina, 2003).

Multi-stakeholder processes dealing with urban agriculture were amongst others developed by UN-Habitat city development strategies, especially in Ecuador, Argentina and Tanzania. In Quito, the local government, several NGOs, UN-Habitat and community representatives signed an interactor agreement for carrying out a participatory diagnosis and developing an action plan on urban agriculture. In Dar-es-Salaam, a multi-stakeholder consultation held in 1992 resulted in the protection of specific areas for agriculture (Dubbeling and Merzthal, 2006). Growing attention and increasingly positive attitudes towards urban agriculture are reflected in a number of "declarations on urban agriculture" in which local and national level policy-makers have stated their formal commitment to developing policies on urban

Figure 4. The cultivation of short-cycles leafy vegetables, from 25 to 40 days, as choysum (*Brassica rapa* cvg. *Choysum*) in Hanoi, is one of the main characteristics of the urban and peri-urban production. Credit: Hubert de Bon/CIRAD.

agriculture. These include the forum in Harare in 2003 attended by local governments from Kenya, Malawi, Swaziland, Tanzania and Zimbabwe, and the Quito declaration signed in 2000 by city mayors from 22 countries in Latin America and the Caribbean (Veenhuizen, 2006).

In Benin, talks between the government and the Cotonou communal producers' union resulted in the allocation of 400 hectares to market gardeners (Deguenon, 2008). In Uganda, the Mayor of Kampala passed by-laws in 2005 to allow urban dwellers to cultivate land and rear animals within the city (Cofie et al., 2003). In 2005, these various experiences prompted the Cameroonian farmers to set up a coalition for the promotion of urban and peri-urban agriculture in Africa, with the support of researchers. The coalition, named *Coalition pour la promotion de l'agriculture urbaine et périurbaine en Afrique* (CAUPA) intends to foster dialogue between farmers and town councils.

4. URBAN AGRICULTURAL PRODUCTION TECHNIQUES

The different products of urban agriculture include many different plant crops (vegetables, cereals, tree fruits, ornamentals, spices, seedlings and plants, and flowers) and animal products (dairy, pigs, poultry, livestock and aquacultural products). This review has focused on vegetables, as already mentioned, which are typical urban crops due to their short cycles, for example, 30 days for choysum in Hanoi, short shelf-life, high manpower needs and high value (Bon et al., 2002) (Fig. 4).

4.1. Technical agricultural requirements for production in urban and peri-urban areas

Urban agriculture faces severe competition with non-agricultural economic activities, habitat, transportation, etc. There is strong competition for access to manpower, but also

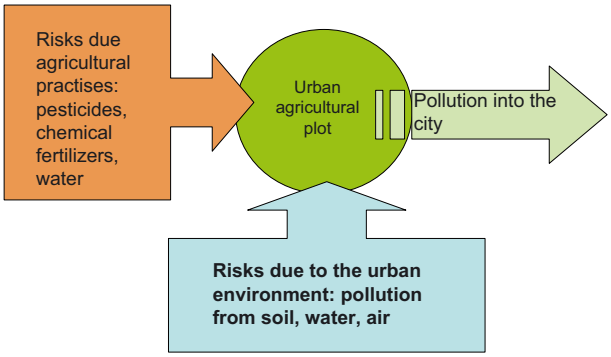

Figure 5. The risks in the relation between city and urban agricultural production are various and reciprocal. Evaluation has to be done for each couple city/crop.

to inputs (water, fertilizers) and land. In addition, urban and peri-urban environments are often highly polluted by industry, domestic activities such as domestic and office heating and cooling, for example, and transport. At the same time, agriculture is known to pollute the environment through the use of pesticides, and chemical and organic fertilizers. Thus, the challenge for urban agriculture is to demonstrate that it does not pollute the city environment, but rather that it produces safe food products despite a sometimes polluted urban environment (Fig. 5). One difficulty for the agronomist is that the "field" in peri-urban and urban areas can vary from one hectare for rice in Taiwan to one square meter for organoponic beds in buildings in La Habana; the "field" can also be a pond to grow aquatic vegetables, as in Hanoi. As Deffontaines (1991) has shown for rural areas, the field is increasingly a piece of the landscape that is located in an environment, the city in the case of urban and peri-urban agriculture, and is the center of multiple interests for the grower, and also for all the population living around the field. So the concept of sustainability as defined in rural areas (Meynard et al., 2001) must be used with all its social, economic and environmental dimensions to propose cropping systems adapted to the city environment.

4.2. What inputs are used in urban agriculture?

Despite many efforts to increase productivity, to provide disease- and pest-resistant varieties, and to develop techniques for small areas, water and fertilizers are the major inputs used in agricultural production (Bon, 2003). In addition, horticultural production requires pesticides, and livestock production needs animal feed. The proximity of cities may provide opportunities to get part of them by the uses of solid and liquid wastes of the cities, the available quantities of which increase with the growth of the cities.

The different sources of nutrients for urban crop production are chemical fertilizers, plant compost, animal manures and solid city wastes. Chemical fertilizers are used by all the urban farmers in all the cities and cases cited in this review. Solid wastes are also used for fish ponds. The use of organic matter, although very frequent, is not so widespread. Organic wastes

are used fresh or composted. In Hanoi, the different manures that are used include chicken dung, cow manure, pig manure and various mixes of these. The percentage of farmers using manure in Hanoi increases from 16% for the inner urban agriculture farms of the city to 75% for those at the district limits. The manures are produced on the farm or are bought. Average annual usage is 9.8 to 12.7 t/ha (Mai Thi Phuong Anh et al., 2004). Vagneron (2006) cites the use of 5 t/ha on vegetables in Bangkok. In Antananarivo, organic matter is provided by manure, which is sometimes on-farm compost, straw from uncultivated lands and compost from solid city wastes (N'Dienor, 2006). In Lomé, organic matter and chemical fertilizers are used in all the city gardens (Tallaki, 2005). In Dakar, it has been estimated that 25% of the nutrients for horticulture crops come from plant compost and another 25% from animal manure (Fall et al., 2002). The integration of livestock and horticulture with horticultural residues being used as livestock feed has been promoted (Akinbamijo et al., 2002). Most surveys of urban areas have shown links between horticulture and livestock production by the means of purchase of animal manure by farmers rather than by integration of the two activities. And the manure and crop residues are not sufficient for a complete urban nutrient cycle.

The use of solid waste in urban agriculture is common in the cities of developing countries. In these cities, kitchen wastes and paper are the major components of refuse, accounting for 42% and 19%, respectively, in Metro Manila (Ali and Porciuncula, 2001). The nutrient content of these wastes is rather low; for example, just 0.29% nitrogen and 0.16% phosphorus in organic waste in Ougadougou and Bamako (Eaton and Hilhorst, 2003). Numerous projects have been implemented to encourage the use of different wastes from municipality projects by establishing compost plants for community and individual growers in cities using specific compost chambers, containers, heaps, trench composting and vermiculture systems. In composting urban solid wastes, the risks to human health for both consumers and the farmers handling the compost must be considered. This includes the survival of pathogenic organisms (*Salmonella*, *Entamaeba coli*, *B. cereus*), zoonosis, disease vectors, and chemical pollution by heavy metals and persistent organic compounds. A sorting of wastes based on a house-to-house source-separated waste-collection system with a good composting process for the correct raw materials should be used to minimize these risks (Cofie et al., 2006).

The use of wastewater for crop production, e.g. ornamentals, vegetables, tree fruits and fodder, as well as for aquaculture, occurs in developing country cities and those of emerging countries such as China and Mexico. The generation and the use of wastewater is rising in peri-urban and urban areas together with increasing population. The IWMI estimates that 16 000 ha in Hyderabad are irrigated with wastewater (Buechler et al., 2006). In Kumasi (Ghana), the area irrigated with wastewater is about 11 900 ha in a catchment of 12 700 households, and in Nairobi (Kenya) 2220 ha and 3700 households (Cornish and Kielen, 2004). In arid and semi-arid areas, such as Nouakchott in Mauritania, this is the only source of water for crops. Wastewater provides nutrients for crops and for fish in aquaculture. The water needed to produce, for example, 1 kg of tomatoes can vary from 50 liters to 100 liters depending on the climatic conditions. Thus, as domestic and industrial demands for freshwater resources increase, it becomes unreasonable to consider irrigating crops with potable water. The use of wastewater brings benefits for growers. In Nairobi, the average annual revenue per hectare from irrigated plots is US $1770, but only US $544 in Kumasi during the dry season. So urban wastewater can contribute to the livelihoods of the irrigators using it (Cornish and Kielen, 2004), but the implications for public health of wastewater use are serious. Fecal coliforms and streptococcus as well as Ascaris, Giardia and *E. coli* parasites are present in wastewater. Lagoon sewage treatment with *Psitia stratiotes* can improve the quality of the water by reducing the presence of parasites, but not the fecal coliforms (Gaye and Niang, 2002).

The use of solid and liquid wastes is thus an opportunity for developing agricultural production and for cleansing the polluted urban environment. These wastes could supply a part or all of the nutrients needed for urban agriculture, but the human health concerns are still to be addressed.

4.3. Pollution of the environment

The soils, water resources and air of the urban environment are polluted. Analyses indicate that city soils are more polluted that those in rural areas. In one study, organic pollutant (benzo(a)pyrene) contents were more than 0.05 $mg.kg^{-1}$ in all of the urban soils sampled compared with only 15% of those sampled from rural areas (Konig, 1991, cited by Barriuso et al., 1996). Similar observations have been made in various studies on PCB and PAH contamination (PCB: polychlorobiphenyls, PAH: polycyclic aromatic hydrocarbons). The heavy metal contents of urban agriculture soils are frequently above allowable limits. Cu, Zn, Pb, Ni, Cd, Co, Mn and Cr were found in a survey of various cities in Eastern Europe. The largest sources of this contamination are heavy industry and run-off from highway drains (Lungu, 2002). This type of contamination is also often found in the irrigation water and water used for aquaculture in Asian cities.

Air pollution is due mainly to transportation, domestic heating and industry. In Hanoi, the average contents of NO_2, CO_2 and NO_3 in the air have reached levels of 0.04–0.09 $mg.m^{-3}$ and the level of CO 2–5 $mg.m^{-3}$.The concentrations of SO_2 and CO_2 in urban districts are higher than the permissible limits (Mai Thi Phuong Anh et al., 2004).

4.4. The use of pesticides

A major constraint to the development of agriculture in and around cities is the use of synthetic chemical pesticides. Technical protocols for vegetable, ornamental and flower crop production typically recommend frequent pesticide applications. Various active ingredients from all the principal chemical families – organophosphates, carbamates, pyrethroids and

Table II. Some characteristics of urban / peri-urban vs. rural agriculture in developing countries.

Characteristics	Urban agriculture	Rural agriculture
Employment	Agricultural labor is low related to non-farm employment in the city	Agriculture is the main employer in the rural area
Farmers' income	Agriculture may be a temporary or partial source of income	Agriculture is the main source of income
Farm profile	Informal and often illegal use of the land	Traditional access to land
Market supply	Urban markets and self-consumption	Self-consumption, urban and rural markets, exports
Product types	High value and perishable products	All types, mainly staple food
Commodity chain	Short marketing chain	Long marketing chains
Multi-functionality	High	Low
Access to inputs	Close to the sellers	Far from sellers
Food safety risks	Risky (polluted inputs and environment)	Low risk
Access to natural resources	Strong competition with other urban economic activities	Little competition with other uses
Public policy	Ambiguous. Generally in favor of other urban activities and land uses	Priority for policy-makers in charge of rural areas

organochlorines – are commonly used in urban vegetable production (Tallaki, 2005; Mai Thi Phuong Anh et al., 2004; Cissé et al., 2002) as well as the biological insecticide *Bacillus thuringiensis*. In Lomé, neem seed juice from *Azadarichta indica* is used by 70% of farmers alone or in combination with chemical insecticides (Tallaki, 2005). Pesticides are applied with small individual sprayers at rather high frequencies of up to once or twice a week throughout the year. These practices can have negative effects on the health of farmers and consumers, and on the environment. An extensive study on the contamination of the watershed in Niayes in Dakar showed chemical pesticide contamination of the 20 wells surveyed (Cissé et al., 2002). Different studies have shown toxicity symptoms due to pesticides in Dakar (Cissé et al., 2002) and Hanoi (Trong Khac Thi, unpublished). Despite numerous projects on Integrated Production Management in the urban agriculture of large cities around the world, there is still much to do in training farmers, extension workers, and chemical retailers and traders in the areas of pest and disease identification, correct use of pesticides and their application, and promotion of less toxic pesticides. Research on how to enhance the natural control of pests and diseases needs to be developed.

4.5. Is there a future for specific techniques in urban agriculture?

To avoid the problems of pollution due to chemical pesticide use, organic agriculture has been suggested and pushed in some cities of Germany, the Netherlands and Slovenia. This kind of production is seen as a way to reinforce the role of agriculture in maintaining biodiversity. Interesting initiatives have been encouraged in some Eastern European cities (e.g. Romania, Bulgaria and the Czech Republic) (Yoyeva et al., 2002). The integration of different agricultural production systems such as livestock, aquaculture, vegetables and tree fruits could be a way to reduce input costs. However, animal husbandry in the city is problematic because of its relation to unpleasant smells and noise, as well as health risks and need to manage manure. It must therefore be strictly regulated in relation to population density and distance to the city center in terms of animal numbers and types, the cleaning of stalls, disease control and water use. The risk due to heavy metal contamination in water, and solid wastes used for compost and soil can be decreased by phytoremediation or specific land uses (e.g. flowers, ornamentals and recreational areas). Nevertheless, the use of waste to produce agricultural products for human consumption must still be improved to assure consumer safety.

In Asia, the SUSPER project (AVRDC/CIRAD) has enabled cities (Hanoi, Ho Chi Minh City, Phnom Penh and Vientiane) to respond better to local demand for vegetables and to make the switch to commercial production. Technical solutions have been found in order to satisfy market demand and boost farmers' incomes, such as out-of-season production. New vegetable sanitary quality certification systems have been tested, and a system for gathering and disseminating daily price information has been developed to facilitate negotiations between producers and traders (Moustier, 2007).

5. CONCLUSION

In Table 2, the components of urban agriculture that have been analyzed in the paper are compared with rural agriculture. These specificities have to be taken into account in the development of research related to urban agriculture.

Urban growth in Africa and urban food requirements will induce significant changes in African agriculture. Two types of farmer already coexist on the continent and this trend will continue for the next few decades. At one extreme there is the traditional farmer, living in a rural or an urban context, with low

productivity, low income and off-farm incomes. At the other extreme is the capitalistic farmer, specialized in agriculture, with high productivity and strong market integration (Cour, 1995, 2001). In urban agriculture, the family-type, commercial farmer, is still widely represented, but his options for economic accumulation are still limited. Export crops and high added-value production, such as horticultural crops, are part of two strategies which will develop in the near future (Jayne et al., 2006; Oliver and Spencer, 2005). These structural changes will require specific analyses and specific policy actions. Urban agriculture is often tolerated by governments, but rarely encouraged despite its vital contribution to employment and livelihoods, although this is reported to be changing. The urban farmers must be more determined in promoting their agriculture and in proposing services to the urban dwellers and city authorities, including landscape preservation and social inclusion. The promotion of the multiple functions of urban agriculture is a major challenge for the future. Hence, there is a growing need for documentation of the successful integration of urban agriculture in urban development, and on the conditions necessary for its social, economic and environmental sustainability.

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