Participatory Technology Development for Sustainable Intensification of Urban Agriculture[1]

Gordon Prain[1]

[1] CIP, Peru

Introduction

The production of food, feed, fuel and construction material in and around cities has almost as long a history as human settlements themselves. The earliest cities in the Fertile Crescent, in China and in South and Central America report the presence of local food production, which was an essential component of urban food security in times of conflict and military insecurity (Southall 2001). The urban setting offers special advantages for food and animal production, but also presents particular challenges. Cities accumulate nutrients through the concentration of human population and their organic waste products, whether in solid or liquid form. These nutrients can often be acquired free or at low cost and can be converted into edible plant parts or animal products. On the other hand, as cities develop, there is increasing demand for residential and business accommodation which competes with agricultural space. Producers must adapt to these more constrained conditions, whilst still trying to maintain productivity through intensifying production techniques.

Producers' adaptation of agriculture to urban realities also occurs within a policy environment which is much more challenging than the rural context. This is partly because of the density of the population and intense competition for natural, physical and financial resources in urban settings which municipal governments try to arbitrate. It is also because of the density of competing economic and political interests present in the city, in which the local council is only one player.

---

1 This paper was first published as Chapter 10 of the RUAF publication "Cities Farming for the Future; Urban Agriculture for Green and Productive Cities" by René van Veenhuizen (ed.), RUAF Foundation, the Netherlands, IDRC, Canada and IIRR publishers, the Philippines, 2006 (460 pages).

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

Another feature of cities is their dynamic nature: a constant flux of growth, decay and transformation which puts a very high value on continuous technological innovation to maintain or enhance productivity and sustainability. As part of their livelihood strategies, urban producers are already engaged in innovative adaptation to new circumstances. This paper argues that to support them, we need to employ participatory methods, for the same reasons as they have been essential for working with complex rural agriculture systems – mixed upland systems for example - the need to combine local knowledge and innovation skills with new technical opportunities.

This is the context for participatory technology development in urban agriculture systems which will be explored in the following sections.

Agricultural technology development

Why has agricultural research been so little concerned with urban agriculture (CGIAR 1998). The answer is related to the sectoral separation of "urban" and "rural", a separation that has its roots in the Industrial Revolution and its subsequent transfer through colonial expansion to the developing world.

In northern Europe, the industrial revolution came to be seen as an urban revolution, associated with cities such as Manchester, Liverpool and Birmingham in the north and midlands of England. The workers who were employed in the new factories came from agricultural communities. Cities became part of what was seen as a movement away from an agrarian society towards industrialisation and the creation of wealth through capital investment. Rapid urban growth occurred around manufacturing and service industries and included dense, low-cost residential housing for the new industrial workforce – the future inner city slums – together with elite suburban settlements, occupied by the "captains of industry" and the professional classes who supported them (Fishman 1987). Yet this division was more ideological than real. Because transport systems failed to keep pace with urban growth, food supply to cities remained a problem. In England and other European countries, municipal authorities were obliged to "allot" small plots to workers' families for food production (Burchardt 1997). These allotment gardens have been reduced in size or have changed location, but they never left the cities in Europe.

The colonial expansion of northern European economies, driven by the search for new sources of raw materials as well as for new consumer markets, exported the sectoral divide between "rural" and "urban" to the developing world, with efforts made to keep "rural" agricultural local populations out of the colonial urban centres, except for the provision of services to the colonists (Tibaijuka 2004).

This divide has come also to characterise the investment by public sector agencies in technology generation. Agricultural technology development has been almost exclusively oriented towards rural needs, whereas research on manufacturing processes, product transformation, infrastructure and sanitation has been focused mainly on urban needs.

Early investments in research and development for rural agriculture were primarily associated with fertiliser development (an off-shoot of military research into munitions and one of the few examples where weapons really have been turned into ploughshares), pesticide development and more recently, especially in the second part of the 20th century, plant genetics and breeding (Simmonds 1979). Plant breeding began to be applied to the developing world's main food security crops of rice, wheat and maize during the 1960s, seeking to increase the fertiliser responsiveness and harvest index of the crops (ratio of grains to other parts of the plant biomass) and therefore their food productivity.

The methodological background to this technology development process, which became known as the Green Revolution, was the notion of a central source of innovation (Biggs, 1990; Biggs and Farrington, 1991). This notion proposes that agricultural innovations are generated in centres of excellence by scientists, are then pushed out to national agricultural programmes which may conduct some local adaptive research before transferring the technology to extension services and thence to early-adopting farmers, who then abandon traditional practices. Although this "pipeline" or top-down approach succeeded in greatly increasing the production of rice, wheat and maize in the relatively simple farming systems in breadbasket regions of the developing world – the Indo-Gangetic plain, the irrigated lowland valleys and plains of Southeast Asia, the maize-producing valleys of central Mexico – it made little impact on ecologically, agronomically and socio-economically more complex upland farming systems. These systems have to adapt to difficult, risk-prone environments and this demands local farmer innovation in crop-livestock management in multiple micro-environments. A quite different, participatory approach to agricultural research is required to enhance the capacity of these systems to ensure year-long food and income security for households.

In these more complex situations it is necessary that researchers and agricultural producers first conduct situation analysis (Martin et al 2001) to analyse the existing strengths and weaknesses of local farming systems, regional agro-enterprise and marketing systems (Bernet et al 2005) and the body of available indigenous and incorporated knowledge. Farmer-led experimentation can then evaluate alternative options for change, drawn from both local experience and national and international scientific resources. This is the essence of participatory technology development (PTD), an on-going process of innovation that blends new and tested principles and practices to changing local realities (Chambers et al 1990; Havercort et al 1991; Douthwaite 2002).

This brief review of the background to participatory agricultural research is relevant because urban and peri-urban agricultural systems exhibit even higher levels of complexity than rural upland systems and call for a wider range of participatory methods (Veenhuizen et al 2001). As well as the need for situation analysis of the diverse mixed farming systems in a range of (urban) micro-ecologies, there are specific interactions with the urban environment that must be analysed. These concern the opportunities and risks of accessing and recycling accumulated urban nutrients (Dubbeling et al 2005); the need to adapt and intensify production in space-constrained conditions (Veenhuizen 2003); the risks of exposure to urban contaminants (Cole et al 2004); the opportunities of agro-enterprises and accessing diverse nearby markets (Holmer 2001; Peters et al 2002); and the need to engage with a dense and often intrusive regulatory, policy and planning environment, which impinges on agriculture in multiple ways and makes demands on the types of technologies that can be used (Dubbeling 2001).

Finally, agricultural production in urban areas is rarely the only or even the major livelihood activity of households. It is combined and sometimes integrated with part- or fulltime activities in other urban sectors, such as the construction, manufacturing and service industries. This creates intricate decision-making processes within households regarding the deployment of household resources in livelihood strategies. Gender and inter-generational relations and sustainability considerations are part of these processes and a more comprehensive framework is required for their analysis and for the design of interventions (Rakodi and Lloyd-Jones 2002).

In the next section the sustainable urban livelihoods framework will be introduced, to better characterise the multi-sectoral, institutional and policy aspects of urban agriculture and identify appropriate interventions. After that, several specific participatory methods to help urban producers adapt agriculture to urban realities will be reviewed.

Farming systems and livelihood systems in the urban environment

The concept of "farming system" was developed during the 1970s to capture the multiple, integrated components and large-scale continuities in rural agriculture and to identify points of technology intervention for particular types of systems (Norman et al 1995). It also has value to understand the situation of urban agriculture, which exhibits a similarly high degree of biological and agronomic diversity at one level but also the potential for identifying continuities, common features and broadly applicable interventions. Farming systems research seeks to understand the integration of agricultural production involving crops, animals and the use of natural resources, the deployment of household and hired labour and linkages with markets. Its weakness has been its agro-centrism - seeing everything through the agricultural lens and often the lens of the individual farmer – and also a difficulty to characterise adequately the feedback loops linking the farm and farm household with other local and regional systems, whether ecological systems such as watersheds or socio-political systems such as local political structures, food systems and different kinds of markets.

The more recent emergence of livelihood systems approaches has enriched action research and development work with agrarian societies, by adopting a broader perspective that analyses households dynamically, in terms of the deployment of their accumulated assets through livelihood strategies that are constrained both by external stresses and shocks and by the need to engage with local and national institutions, policies and processes (Farrington et al. 1999). Although developed to better analyse rural realities, this approach has proved to be very fruitful for understanding households in urban settings, including those engaged in different kinds of agricultural production (Radoki and Lloyd-Jones 2002).

Increasingly in rural settings, and very much so in complex urban contexts, poor households depend on multiple income sources, credit, physical resources such as equipment and technology, access to natural resources, and a range of non-material assets such as local knowledge, formal education, health and social support structures to ensure their livelihood. Inadequate assets can leave households vulnerable to economic, environmental, health, and political stresses and shocks, which is referred to as the vulnerability context.

Household-based assets have been classified into five types or capitals.

Natural capital involves the quantity and quality of accessible land, water and biodiversity. The basic ingredients for both crop and livestock agriculture are water and nutrients. Nutrients for crops are delivered mostly through soils, though their delivery in water in hydroponics systems is also important in urban settings (see below). Conditions and management of soils differ widely in urban settings and across different types of urban and peri-urban agriculture, though frequent, common problems include the presence of inorganic materials – especially heavy metals and trash – and a high level of compaction (Evans et al 2000). Because small urban plots are often intensively used, soil fertility is a constant challenge as will be discussed further below, and the incorporation of urban nutrients via vegetative or co-composting is a key area for PTD in urban agriculture. Nutrients for livestock production involve access to forage and other feed sources and their efficient use in livestock nutrition. These feed sources are often scarce in urban and peri-urban areas and this leads frequently to complex nutrient exchanges along rural to urban transects, for the benefit of both animal and crop production (Njenga et al forthcoming).

Water is also often a scarce natural resource in urban areas, and there is frequently intense competition between agriculture and domestic and industrial uses. “Resource recognition” is important in this context (Furedy 1992; Smit and Nasr 2001). “Hidden” natural resources can be accessed, such as unused water surfaces and nutrient-rich wastewater. The notion of resource recognition is also important for accessing land, through use of vacant lots, unused public lands, and the composting potential of urban solid wastes.

Biodiversity is a key natural resource that supports agriculture. Population pressure, presence of contaminants and the fragmentation of green spaces in urban areas can severely reduce the resilience of plant and animal populations and their capacity for survival and for symbiotic interactions in ecological systems. PTD involves not only the identification of native species and varieties of plants and animals that are well adapted to urban soils and other conditions, but also the application of practices that enhance species resilience and symbiosis, for example, through biological pest control.

It is not always easy to differentiate natural and physical capital in the urban environment. Water, for example, is usually considered part of natural capital. Yet when it is cleaned and piped to the homes of urbanites, it becomes "adequate water supply and sanitation, which is part of physical capital according to DfID's literature on livelihoods. Organic wastes can also be considered part of the natural capital of the urban environment which is available for composting, yet when chemical fertilizer is packaged and purchased by households; it is usually considered part of physical capital. The important point here is not about trying to create watertight boundaries, but about the access of poor households to these different types of capital.

Physical capital includes the buildings, equipment, tools and physical inputs to agriculture and other activities, such as seeds, fertilisers, pesticides, animals, a small kiosk for trading, a sowing machine etc. PTD can have a direct impact on physical capital through improving the quality and fit of assets such as seed and equipment with the urban environment.

Financial capital refers primarily to the income available to the household from different sources, but also to loans and credit. As already mentioned, households in urban and peri-urban areas are rarely dependent on a single income source. Different household members access different sources of income, and the same individual may also manage different occupations simultaneously. A common example would be a woman who is responsible for household food preparation and child-rearing, contributes to raising crops and animals and engages in petty trading (Arce et al 2004).

Human capital includes labour, knowledge and the health status of family members and the ways these are deployed – or impaired – in livelihoods strategies. The local technical knowledge which household members utilise in agricultural activities is an important example of human capital. The depth of this knowledge, which is so critical in the management of complex rural farming systems, may be less obvious among migrants from totally different agricultural environments, or among non-agricultural households seeking ways to better secure family food security. Evidence from research with horticulturalists in Hanoi, Vietnam, indicates a reduction of use of toxic pesticides with greater time spent farming in a given environment, suggesting a growth in local knowledge of how to manage horticultural pests (de Bon et al 2004).

Human health is another key aspect of human capital that needs special attention in urban areas. Conditions in low-income areas of developing world cities often create health risks for the urban poor (Hardoy et al 1990). Participation in agriculture can intensify negative health impacts on human health, through human and food exposure to contaminants and other illness-producing hazards in water, soils and animals (Birley and Lock 1999). Health impacts can also be positive through nutritional and other health benefits of farming and farming products (Armar-Klemesu, 2000).

Social capital includes the access to and membership in social networks, groups and associations of different kinds, through which households gain access to other assets, such as knowledge, financial loans, labour and different kinds of support and security. Social capital also involves the trust that exists with others, which facilitates access to resources and enhances the sense of well-being and psycho-social health. Social capital is strongly gendered, in that social networks, trust, sharing and social support tend to be forged within the sexes rather than between, though important exceptions to this generalisation exist, including religious organisations. Relatively little work has been done so far on social capital in relation to urban agriculture, but there are examples of its contribution to community building, especially in the USA and Europe, and to improvements for HIV/AIDS affected communities. Research findings in both Latin America and Africa suggest that women play a major part in harnessing and maintaining social capital in support of crop and animal production (Maldonado 2005; Maxwell 1992).The deployment of assets in household strategies, the influences and impediments which household members experience when they deal with urban institutions such as municipal regulations and policies or local marketing practices, and the livelihood outcomes which they achieve, are all part of urban livelihood processes. These processes in turn exert positive and/or negative ecosystem feedback on the livelihood assets and on the vulnerability context (see Figure 10.1). This means that efforts to develop physical and human capital through PTD need to take into consideration the effects of the technology on other household assets. For example, a technology involving high financial investment, such as drip irrigation, would reduce household financial assets that may be needed for other investments such as education or health care. PTD also needs to monitor the implications of alternative technologies for urban institutions and processes. For example, technologies for improving feed efficiency and thus profitability of pig-raising in locations where the municipal authority prohibits keeping animals (see the Hanoi case, Peters et al, 2002).

Whereas PTD in rural contexts has typically involved farmers and technicians jointly evaluating technology options in terms of their fit with the local farming and food system, the addition of an urban livelihoods systems framework locates the assessment of technologies in a more cross-sectoral, policy-sensitive setting. The rest of this paper will explore a range of experiences evaluating technologies for urban use and highlight the way they have tried to adapt to different dimensions of livelihoods in the city

Participatory technology development: intensification and livelihoods

The wide range of farming systems found in urban areas can be differentiated in terms of types of intensification and their potential for positive and negative impacts on livelihoods. The urban setting encourages intensification and evidence suggests that the productivity of these systems is systematically higher than in rural areas (Yeung 1987). Technology development needs to be focused on ensuring that intensification of both crop and animal production and processing offers maximum benefits to urban livelihoods and minimum negative impacts on the health of producer and consumer families, their neighbours and on the urban environment.

Agricultural intensification has usually been associated with the increase of output per unit of land area, through technical changes in crop management, especially the use of modern varieties and animal races, increased use of fertilisers and pesticides for crops, prepared feed, antibiotics and vaccines in livestock production, and improved water efficiency, especially via irrigation (Matson et al 1997). Intensification in urban and peri-urban settings can be described as maximising output from minimal space. This also involves input technologies such as crop varieties and their combinations, seed management, animal nutrition, soil nutrition and water management. Pest and disease management is of major importance in some urban systems and almost ignored in others. Two aspects of intensification in the urban context which are less common or non-existent in rural agriculture (which will be considered later) involve the manipulation of vertical space and the recycling of domestic and commercial organic wastes as sources of soil or animal nutrition. This concerns technologies of composting or co-composting and the large-scale collection and preparation of restaurant and other food residues for animal feed, sometimes in combination with available forage. Although use of small quantities of domestic food residues is very commonly fed to animals also in rural areas, this urban feed system is unique in its scale and contribution to total feed input.

There are enormous differences in the way urban agriculture systems are classified, as is demonstrated in this volume. Classifications differ based on space (intra-urban/peri-urban), based on production objectives (subsistence/semi-commercial/entrepreneurial) and on predominance of crops or livestock and based on size of holdings. Most classifications capture a part of the reality but suffer from overlapping boundaries and geographical variability. In thinking about methods for technology development, it is important to think about the ways that different types of urban agriculture impinge on household livelihoods.

It is helpful to group together systems which mainly contribute in a positive way to household human resources through subsistence and enhanced nutrition, which also contribute in a limited way to the income of the family through small sales, or indirectly, through savings on purchased food. This contrasts with intensive semi-commercial or entrepreneurial systems which contribute an important, though not necessarily the major, part of household income, but because of the urban setting and the intensive methods can have negative health impacts on producer families and on neighbours and consumers. This is also an imperfect division, but it helps to organise thinking about key PTD issues in the urban context. In particular, it focuses attention on substantive differences in the manipulation of space and inputs.

Because of the somewhat different methodological experiences between crop and livestock production, these will be considered separately, even though mixed crop-livestock systems in cities are common and important for maximising recycling opportunities of crop and livestock wastes as fodder or manure.

The extent to which the policy and planning environment interacts with technology development also tends to vary between crop and livestock systems and between these two types of production system. Livestock-raising is subject to greater regulation and policy issues than crop production, and income-focused systems tend to be more policy sensitive than small-scale, “health and income support” systems. Policy factors are considered in a separate section.

Box 1 Main stages of PTD

Participatory situation analysis
The first stage of PTD involves different kinds of interactions between “outsider” PTD practitioners and local people in an area which has been targeted for development interventions. This initial stage includes a wide variety of acronyms and approaches (Survey, Sondeo, RRA, PRA, PLA, situation analysis etc) with the level of participation of local people differing considerably. A PTD workshop undertaken by ILEIA (Center for Information on Low External Input and Sustainable Agriculture) in the late 1980s assessed over 200 methods and characterised the first two stages as “Getting started” and “Looking for things to try” (Reijntjes et al 1992). The key elements of this first phase are: creating favourable conditions; establishing rapport and trust; jointly understanding the local context; identifying key local needs; listing and prioritising the collaborative opportunities that exist for experimentally testing solutions for those needs.

Participatory Experimentation
Once the research opportunities are selected, the process moves to the stage of experimentation, including participatory monitoring. The different degrees of local participation typical of situation analysis also characterise experimentation and joint research. These differences have been formalized into a typology of participation in research (Biggs 1989): <u>Contractual</u> in which researchers contract with farmers for land or services such as labour or use of equipment. This is typically associated with “off-station

research", experimentation which seeks to scientifically test technologies under different environments, but with minimal interest in the views and opinions of farmers. Consultative This is agricultural research as a doctor-patient relationship, in which consultation with farmers about problems is part of a structured process determined by researchers, in which decisions about responses to needs and opportunities are also researcher led. Collaborative is a partnership arrangement between scientists and local individuals and groups. Two way learning, in which local expertise is combined with positive lessons and best practices derived from comparative experiences of researchers. Collegial This type of participation actively encourages and seeks to strengthen local-led research and development (R&D), in which experimenting farmers (often informally) take the lead. Because of the very common situations in which migrant households need to adapt to new production contexts in urban and peri-urban areas or new market opportunities, these types of innovative producers are likely to be very common in urban and peri-urban areas, and this type of collegial mode would therefore be very appropriate.

Going to scale: technology and policy innovation at regional and national level
PTD is not just about technology innovation among a small number of farmers who participate in situation diagnosis and participatory experimentation. It incorporates methods to facilitate the sharing of innovations among a broader group of stakeholders. These include field days, cross-visits, extension messages and replications in other localities. In urban and peri-urban areas, there is a special importance attached to influencing policy, through the involvement of policy makers in PTD activities.

Intensification and sustainability of urban horticulture

A key technology development issue for urban horticultural production systems, especially on larger urban or peri-urban plots, concerns the sustainability of intensification strategies that farmers adopt, especially the extent to which these strategies impact on urban environmental health. Intensification of larger-scale urban horticultural systems occurs in at least three different ways with different associated health and environmental risks:

1) Through cultivating high value crops during the off-season, to capture higher prices, through a combination of adapted varieties, increased use of pesticides and/or the use of physical barriers to control or avoid higher pest pressure. Risk factors are pesticide contamination and high cash investment.

2) Through productivity increases on the same land area in the same time period through modern varieties and/or increased use of agro-chemicals. Risk factors are pesticide contamination and nitrate leaching.

3) By maximising the use of available natural resources where these had not previously been used for agriculture, including use of wastewater, as a source of water but also as a source of nutrients (Cornish and Lawrence 2001), composted urban organic solid wastes and the use of abandoned or marginal lands, such as old factory or workshop areas, riverbanks or wetlands. Risk factors in this strategy are exposure to pathogens, parasites and heavy metals.

Technology innovation in these kinds of systems needs to adopt a broader urban systems approach to ensure that intensification contributes positively to individual household livelihoods – does not, for example, undermine human capital through pesticide poisoning – and also contributes to a more sustainable urban environment.

Intensified use of limited space

Some of the highest urban population densities are in developing world cities. For example, Manila City, part of Metro Manila, capital of the Philippines, has a population density of 41,000 people per square kilometre, almost ten times that of London. Very often the poorest families live in the most congested neighbourhoods and experience associated problems, such as health and difficulties in securing adequate food and nutrition for the household, because of high food costs. The poorest urban households spend as much as 80% of their income on food, up to 30% more than is spent by rural families (Argenti 2000). With urban income frequently based on uncertain, intermittent employment, the possibility of utilising even the smallest spaces for intensive production of vegetables or small livestock can make a major contribution to the overall food security of these households.

Options and methods to maximise the agricultural productivity of minimal space vary along the urban-rural transect, with the greatest challenge existing in the most crowded intra-urban areas of cities where earth itself is lacking. In this situation, evaluation and innovation surrounds the conversion of under-utilised surfaces of the dwelling into mini-gardens.

This is the basis of container gardening, also referred to in the Philippines as "receptacle farming" (Undan et al 2002). Rooftop gardening, as practised in many parts of the world from Manila to Russia to Senegal incorporates container gardening. This production method can provide an accessible and dependable source of leaves, stems, fruits, flowers and occasionally roots to supplement purchased food and to add micro-nutrients to starch-based diets. It takes advantage of patios, window sills, crevices and rooftops to locate any of a wide range of recycled domestic and industrial containers as recipients for soil and plants. Old tyres, tin cans, plastic bottles with the tops cut off, old water buckets, basins, baths, refrigerators and air-conditioning casings, biscuit boxes, fruit crates, bamboo poles, jute or plastic sacks with holes in the sides - the list goes on. As always with urban food production, human health risks need to be monitored in this method. Metal containers or paint cans can be a source of heavy metal contamination affecting humans and in some cases such as zinc, also plants. Metal containers can also absorb too much heat preventing good root growth. Two key technologies influence successful container gardening and need to be carefully evaluated: the type and quality of the planting materials and the quality of the planting medium. The economic benefits of container gardens are usually derived from the saved income from not purchasing vegetables in the market rather than from direct sales (Villamayor 1991).

For these very low cost systems, accessing low- or zero-cost planting material is of major importance. A key strategy in PTD for facilitating access to planting material is through local seed networks, involving neighbouring households, schools, civil society organisations, agricultural extension services, city health centres and/or other local and national government offices. Social networks, especially linking women neighbours, do exist in urban settings (Arce et al 2004) and seed transactions, if they don't exist already, can relatively easily become absorbed as a type of exchange in these informal networks. In some cities, such as Dar es Salaam in Tanzania, Dhaka in Bangladesh, Manila and Baguio in the Philippines and Havana in Cuba, formal community or local government seed systems exist which supply seedlings at low prices to container and other types of urban gardeners (Jacobi et al 2000; Gayao et al 1997;Hellen Keller International 1994; Cruz and Medina 2003).

Box 2 Choice of crops

The choice of crops to plant in containers depends on the preference of the household agronomic constraints of the system and availability of seed. Tree species are generally too demanding of space and soil depth to be successfully grown in containers. Root crops can be grown in sacks, known as "gardens in the air" technology (Gayao et al 1997:100), but many containers are too shallow for good storage root development. The most common plants for container gardening are vegetables, both erect or compact types such as lettuce, kale, celery, fruiting vegetables such as aubergine and peppers, aromatic plants like parsley, basil, mint etc., and spreading types which can be supported on trellises, such as gourds, climbing beans, chayote (Sechium edule), zucchini etc. These species are both well adapted to containers and offer culinary, nutritional and economic benefits for low income inner city households. In terms of human health, vegetables are important sources of micro-nutrients, including minerals and vitamins known to be essential for good health. They are also sources of a range of "phytochemicals" such as anthrocyanins and lycopenes, which are thought to have important health benefits but for which less evidence has so far been accumulated (Johns 1999; Deveza and Holmer 2002).

Indigenous species can more easily be replanted than exotic species, since the saved seed is mostly viable. Among African traditional leafy vegetables (TLVs), Amaranthus, Corchorus and Vernonia spp produce easily harvestable seeds which can be stored and reused, though the period of viability may be limited to as little as six months, and storage practices are sometimes problematic (Poubom 1999). The production of seed of exotic, temperate vegetables is mostly a specialised activity in limited agro-ecosystems in tropical and sub-tropical regions, and seed must be purchased. Because seed of these species is usually sold in volumes much larger than is needed to plant containers in a small area, these are less commonly found in container gardens and usually linked to a community or local government seed system. Although there is much evidence about informal, reciprocal seed exchanges taking place between small rural households in the literature (eg Tripp 2001) there is limited information about exchanges among container and other kinds of urban producer. An early study in Kenya found that this type of exchange exists among different types of urban producers, but more commonly in the larger towns and cities (Lee-Smith and Memon, 1994). A recent study in Lima among small producers growing mainly for the market found that only about1% of producers obtain their seed this way, 18% reproduce their own seeds, primarily for local species, whilst the main seed source – especially for exotic and/or commercial species and varieties - is the commercial seed sector. Participatory technology development has been actively applied to the field of local seed systems (Scheidegger and Prain 2000) and could contribute to enhancing access to and management of seeds in urban container gardening and other kinds of urban production systems.

The main factors of concern in managing container media are fertility, moisture control and aeration. A variety of techniques are available, and some examples are described in Table 1.

Table 1 Management issues in Container Gardening

	Fertility	Moisture	Aeration
Container gardening, Mexico (Erdmann 2004)	Urine (N), worm castings and rotting leaves (P,K)	Containers with side drains for bottom reservoir without water-logging. Central stick to test moisture	Use of leaves, grass-cuttings under layer of soil
Container gardening, Philippines (Deveza and Holmer, 2002)	Mixed substrate (2 x loam soil, 1 x compost and 1 x rice hull). Top dressing of composted manure every 2 weeks or rice or meat washing water	Porous structure of the substrate due to rice hull provides good drainage. Regular morning watering	Structure of the substrate with rice hull provides good aeration
Barrel garden, Ethiopia (Getachew)	Mixed substrate (2 x soil, 1 x composted manure, 1 x sand. Weekly application of "manure tea" (5)	Slow moisture delivery through central, sand-filled corrugated iron roll; perforated base and standing on gravel	Structure of the substrate with sand and manure providing better aeration

Although container gardens are adapted to densely populated spaces lacking plots of cultivable land, those same spaces are dense in usable nutrients: those deriving from the organic wastes and residues of the local population. Urine was identified as the most effective nutrient in Mexico, and it also emerged as the winner in participatory evaluations in the slums of Tacloban in central Philippines (Villamayor 1991). Other sources of nutrients include food wastes, leaves collected from city trees and animal wastes from urban livestock keepers who sometimes find problems with disposal of these wastes (Njenga et al 2005). Evaluations of different nutrient options depend on local availability of organic residues of different types and the interest and resources of the container owner. Often there is either no space or no time for composting of household wastes, so urine is an attractive alternative. Where manure is easily available, as in Addis Ababa, maintenance of a stock of manure tea may be quite feasible.

Whether for container gardens or in less dense settlements where people have access to small backyard gardens or to off-site plots such as roadsides, riversides, wetland margins or unused public lands such as railway embankments and under power lines, opportunities exist for intensifying production. Intensification is dependent, as has been mentioned, on the interest and resources of the producer family, but it is also dependent on the regulatory environment. Even with sufficient resources, large investments in hydroponic or organoponic technologies is likely to occur only if there is security of tenure and supportive local policies. These issues are discussed in more detail in the final section of this paper. In this section, alternative methods are briefly introduced which offer minimalist, low-cost solutions to intensification under constrained space conditions and often in an uncertain regulatory climate and informal social organisation.

Bio-intensive gardening seeks to intensify and diversify production through low-cost improvements in crop, seed and variety selection and sequencing, plant nutrition, soil management and pest management (Getachew 2002). The approach has a long history as a strategy for rural food and nutrition security (IIRR 1991), but more recently it is being applied to the urban context. Bio-intensive urban gardens, in addition to the emphasis on enhanced nutritional quality of the food produced, adds a concern with food safety, given the increasing commercialisation of vegetables from high input peri-urban and truck farming systems. There is a strong emphasis on crop management and especially soil management, through simple techniques such as “basket gardens” and more labour intensive “double digging” of the garden bed with a mixture of 50 – 100% compost, for enhanced productivity.

The “pyramid” gardens introduced in Kampala and other cities are examples of the importance of manipulating vertical as well as horizontal space as a means of bio-intensification of small urban plots (cf. Niñez 1984). Through collaboration between the Kampala City Agriculture Office and local women gardeners, pyramid-shaped structures have been constructed, using compost-enriched earth held in place by chicken wire and sacking. Holes are made in the sacking both horizontally, around the structure, and vertically, with the top part left open for additional planting. Such an arrangement allows the growth of many more plants than could be grown in a flat bed.

These practices are simple adaptations of two livelihoods realities present in many poor households in Addis, Kampala and in other cities in the developing world. On the one hand it is the common practice of planting horticultural crops in any available planting space, to supplement household food supplies and reduce cash expenditures on food, however modest. On the other, it is the existence of “hidden” household physical or natural capital – vegetative and animal organic wastes – which instead of being perceived as a nuisance and a burden, can be co-composted for use as soil nutrients to improve horticultural productivity. In Ethiopia, this simple connection has been made through hands-on practical training courses in bio-intensive gardening and through incorporating this and other types of bio-intensive technologies into NGO activities in and around Addis. In the case of intensive gardening in Kampala, although their introduction and use has been a result of close cooperation between the City Agriculture Office and women gardeners, the ambiguous status of cultivation in the city, with several by-laws prohibiting aspects of agriculture still in existence into the 21st century, the large-scale diffusion of these approaches has been inhibited, at least until a recent participatory review of the by-laws and ordinances and their revision by the City Council (DFID, 2006).

Urban horticulture as an income source and health risk: Intensification and sustainability

A second, broad category of crop production systems in urban and peri-urban areas are those that seek to take advantage of close by, diverse markets through shorter growing seasons, higher yields and the production of the most profitable commodities. In this commercial intensification, these systems can interact in a number of negative ways with the urban environment, creating health risks to both producers and consumers and therefore becoming unsustainable. Risks include pesticide contamination, nitrate leaching, exposure to pathogens and parasites and contamination from heavy metals.

Technology innovation in these kinds of systems needs to adopt a broader urban systems approach to ensure that intensification contributes positively to individual household livelihoods – does not, for example, undermine human capital through pesticide poisoning – and also contributes to a more sustainable urban environment.

Farmer Field Schools, an approach which was developed for rural agriculture, has attempted to focus on eco-system learning and sustainable production systems, especially through integrated crop management.. It seems very appropriate for adaptation for use in urban conditions.

The Farmer Field School (FFS) method applies adult education thinking and experience to agricultural learning and change. Adult education has grown in importance as educators have recognised that the accelerating pace of technological change means that the tools one acquires in formal pedagogic education (6) become quickly obsolete in adult life (Minnick 1989). FFS was developed initially to facilitate farmer understanding and application of integrated pest management principles in rice farming, for which conventional technology transfer training approaches were found to be inadequate (Röling and van de Fliert 1998) and it was successfully introduced into rice farming in Indonesia and other Asian countries (ibid).

FFS has been applied to a broader range of crops, such as vegetables and has become less specifically focused on IPM, especially in cases where it is applied to crops with less stable demand and less clear agronomic constraints, such as sweetpotatoes in Indonesia (Braun et al 1997). This has led to considerable adaptation of the original production-side, crop constraint focus, with more attention to soils, markets, local learning and organization and farmer empowerment (Röling 2003; Züger 2005). In particular, it is possible to see how FFS is becoming more closely aligned with a livelihoods perspective, and less strongly tied to crop protection. In the words of Niels Röling, FFS is "a form of agricultural education that develops 'human and social capital' while conserving 'natural capital'" (ibid). This evolution of FFS seemed to align it very well with the livelihoods framework which is being increasingly used in urban agriculture research (Urban Harvest 2004).

The basic principles of the Farmer Field School, distilled from 10 years of Asian and other experience are listed in box 3 (adapted from Pretty 1995)

Box 3 Basic principles of a Farmer Field School

What is relevant and meaningful is decided by the learner and must be discovered by the learner.

Learning flourishes when teaching is seen as a facilitating process that assists people to explore and discover

Learning is a consequence of experience ("learning by doing"). The field is the best learning site

Cooperative approaches are enabling. They can strengthen learning (social learning, farmer-to-farmer learning) and as people invest in collaborative group approaches, they develop a better sense of their own worth

Learning is an evolutionary process and is characterized by free and open communications, confrontation, acceptance, respect and the right to make mistakes

Each person's experience of reality is unique. As they become more aware of how they learn and solve problems, they can refine and modify their own styles of learning and action

FFSs provide the setting and the materials for farmers to explore and discover for themselves new knowledge about agricultural production on the presumption that knowledge actively and repeatedly obtained in this way will be more easily internalised, retained and applied after completion of the training. Repetition is important for retention, which is one reason why FFSs are repeated, usually on a weekly or fortnightly basis, with the same structure, throughout the growing season.

Though some of these elements are as relevant and important for urban agriculture as they are for agriculture in rural conditions, some have special resonance in urban conditions. The approach requires a major time commitment by FFS participants which can be problematic in urban conditions where agriculture may be only one of several livelihoods activities.

Until recently the application of this method to urban conditions was largely untested (Prain 2001). Yet it appears to offer the possibility of mitigating the negative consequences of intensification referred to above through safely and sustainably increasing the use of organic wastes for soil conditioning and plant nutrition and improving the management of pests and diseases through integrated approaches, leading to improved crop quality and food safety which are increasingly contentious issues in urban agriculture. It also offers the means to relate crop production to the broader socio-economic, institutional and policy arenas.

The CIP-Urban Harvest project in Lima, Peru was launched in 2004 and involved multilateral, national public sector, NGO's and community participation to mitigate urban poverty in the low-income eastern shanty towns of Lima through agriculture. Lima. The general objective of the project was to contribute to reduced urban poverty, improved food and nutrition security and a more sustainable urban environment through participatory, urban-adapted innovation in crop and livestock technologies and capacity building of the local population in sustainable and healthy urban food production. The

experience of Farmer Field Schools within the CGIAR and especially within the International Potato Center, which convenes Urban Harvest, offered a model to address both urban-adapted innovation and farmer capacity building.
The project showed that time is more of a constraint in urban settings and commitment is perhaps more closely linked to commercial opportunities offered by participation in the school. FFS also places strong emphasis on social interaction and learning, involving group activities. This can present difficulties in urban contexts where limited trust and social capital exist among urban cultivators (Arce et al 2004). The project also made clear, though weak social linkages and other, urban-specific factors necessitate special attention at the beginning of the FFS process, the process itself provides a positive means to establish and strengthen social and communal ties within cities.

Urban and peri-urban livestock raising: methods for addressing needs and mitigating risks

Throughout the developing world, and especially in Africa, animals are an important physical and financial capital for many urban and peri-urban households. They may be a regular or periodic source of income through sale of milk, eggs or off-spring, and they represent a form of savings which can be cashed-in if a crisis occurs. Animals also generate additional physical capital in the form of manure, either for sale or for improving the household's crop production system. Livestock are thus key components of livelihoods for many families and improvements in growth rate, health status and meat quality and/or reduction in costs of production through alternative diets using locally available ingredients can contribute directly and significantly to livelihoods (ILRI 2005). On the other hand, keeping animals in the often cramped conditions faced by many peri-urban and especially urban producers is a potential health risk, not only to the producer's family, but also to neighbours and consumers (Birley and Lock 1999).

Yet in both rural and urban contexts, PTD for livestock has a much shorter history than for crops. A search on the internet for PTD in relation to crops and crop varieties, seed, soils, pests and diseases returns 5.5 million pages as opposed to 94,000 for PTD and animals, livestock and/or specific types of animals. Although situation diagnosis and analysis often includes livestock-raising and crop-livestock interactions, and looks at economic risks of the business, it less commonly incorporates environmental or health risk assessment associated with integrated systems. There are also far fewer cases of participatory experimentation for technology development. This is partly due to the fact that livestock research is still very much scientist-led and experiment-station based (DfID 2005; Conroy 2004), more so than crops research. Conroy also comments on another tendency within livestock research – to address the problems of, and work with, large-scale, commercial animal production and product enterprises, rather than addressing the often very different problems and needs of small-scale livestock keepers.

However, there are also methodological difficulties with participatory research with animals. Situation analysis may require different kinds of sampling, to capture different sizes of enterprises involving different kinds of animals and the variability of herd size over time, as well as including non-livestock keepers. This tends to favour the use of modelling, which allows the possibility of including these multiple variables, at lower cost. Where health risks are part of the diagnosis, minimal data on exposure to risk may require diverse sampling of animal substances and products. Although these difficulties also apply to situation analysis involving health risks in crop production, these are far fewer, and the more limited physical contact between human and crop reduces the exposure risk. The importance of exposure risk in livestock keeping suggests that there is more of a need for complementarity between participatory and non-participatory methods. In many cases, laboratory assessments, for example, need to be considered a component of the PTD process. Some of these issues are listed below.

- Experimental comparison of different technology options, such as animal cohorts undergoing alternative feed regimes, is complicated by several factors not present in the case of crops;
- Space constraints on-farm, limiting number of technology options or number of animals per option, which weakens the conclusions that can be drawn;
- Livestock management limitations, such as ensuring that “technology options” do not walk into each other’s pens, thus confusing the conclusions that farmers and researchers can draw;
- High value to households of individual animals, leading sometimes to sales ahead of the completion of the trial;
- Practical difficulties and costs of periodic weighing on farm;
- Negative attitudes of local authorities or neighbours to the participant in research;

Many of these methodological problems are even more severe for urban livestock-keepers, where space is often more limited and the separation of technology options or treatments more complicated and where potential health risks from close animal-human interactions and the difficulties of disposing of animal wastes are greater. This tends to place greater importance on the use of statistical techniques to overcome these constraints.

The policy and regulatory context is often more difficult in urban settings, with controls or prohibitions frequently applied to livestock raising, leading to insecurity. Nevertheless, there have been some recent developments in introducing PTD into smallholder livestock research and at the same time reviewing the policy context in which technical improvement is taking place (7). The rest of the section illustrates these developments in Vietnam, Uganda and Lima.

Participatory experimentation: pig nutrition in Hanoi, Vietnam.

Feed is the main direct expense for pig-raising households in Hanoi, after the cost of piglets. Thus farmers seek ways to reduce their costs whilst maintaining or improving the health and growth rates of their animals. Situation diagnosis in a rural-urban transect linking Hanoi with its rural hinterland found three distinct pig production systems: mostly rural production of piglets, with sows fed on available agricultural residues, especially sweet potato vines; commercial fattening of pigs over about 30 kilos, mostly in the urban and peri-urban areas, and increasingly dependent on use of restaurant and other food residues from the city; in between these two systems, there is the specialised raising of young pigs (got) from about 7 kilos to about 30 kilos. This is the most entrepreneurial system, in that it carries higher risks from disease, but also higher potential profits. Profitability is related to growth rate, as well as the healthy, chubby appearance of the animals at sale, and these factors are highly influenced by diet. The original diet was based on purchased rice, rice bran, concentrates and a small amount of forage, mainly sweet potato tops. These inputs, most of which are enmeshed in a complex credit system, suffer significant price fluctuations, making the pig-raising family vulnerable to losses.

Furthermore, the rice needs to be cooked, thus increasing the costs and the labour investment. The PTD intervention in this context consisted in evaluating alternative, local feed sources, both for energy and for protein. In a series of three rounds of trials, two or three options or treatments, discussed and developed with the farmers, were compared with the current feed combination. Once again, as occurred in the example of Kampala, there is need to help construct a strong social network among farmer participants to establish a trusting environment within which to pool existing knowledge and experience and to ensure continued interest in participation. This was achieved through orientation and consultation meetings, sensitisation workshops, group evaluations of interim results and the encouragement of regular interactions among those involved in the trials. In Vietnam, there is a very strong local government system which supports to some extent the organisation of this kind of intervention, but there is also a need to create legitimacy for the intervention among the local cadres. An effective means to achieve this is through regular presentation of results to the local authorities and involvement of local authority representatives in knowledge exchange visits to other sites. This is important in any PTD intervention, but in political contexts where the local authorities control outsider access to households, it is essential. (Peters et al 2002; Tinh 2004).

Building capacity, institutional dialogue and policy support: Livestock groups in Lima and Nairobi

Within an urban livelihood framework, participatory technology development cannot be separated from PID: participatory institutional development. This is especially important for livestock-related PTD which is the target of much local regulatory attention. PID includes the need for capacity building, both to enhance efficiencies and to build awareness about safety and health issues. In Lima, a key component of capacity building for livestock production involves familiarisation with key indicators of animal health, development and feed needs and the maintenance of livestock registers, using the indicators to monitor growth and improve performance. This monitoring process is also being used by the R&D team to identify tendencies, in terms of feed use, health status or growth rate to propose technology intervention options. At the same time, this hands-on capacity building provides the basis for group formation around particular livestock and eventually formation of legal associations. This is part of a strategy to strengthen the capacity of local livestock keepers to link to new markets. Group formation can be a new process, working with independent households, or can build on existing structures, for example schools, churches or, as in the case of Lima, community kitchen-based women's groups. This group formation is closely linked in turn with institutional analysis, learning and change at the level of the local government, involving elected and appointed officials and representatives of other sectors (Arce 2006).

In Nairobi, where urban and peri-urban livestock keepers make a major contribution to satisfying the city's demand for milk (Staal et al 2002), they are also rather isolated from government services and vulnerable to regulation and harassment. In 2004, the Nairobi and Environs Food Security, Agriculture and Livestock Forum (NEFSALF) was established to: "drive the sectoral mix and interactions" among producer communities, government agencies, local government, the agricultural research community and the market, thereby improving institutional recognition and supporting commercial opportunities; acquire and target relevant knowledge; and monitor process and monitor outcomes.

NEFSALF provides a platform to facilitate access by the community to provincial and municipal services and to open a dialogue with the City Council. It also provides the space for capacity building in key technical, health and policy areas, provided by public sector specialists. Currently the forum brings together 15 community groups mostly involved in mixed crop-livestock farming, government ministries, NGOs and local government representation (NEFSALF 2005).

Integrated urban management of local agricultural development

In the urban setting, agriculture is one strand in a complicated web of activities in which households are engaged in pursuit of their livelihoods. Participatory technology development needs to assess the direct impact of innovations on household capitals and potential feedbacks to the urban ecosystem, affecting the capitals of other families. As the livelihoods framework makes clear, these innovations are also filtered through local institutions and policies which are more pervasive and invasive in urban areas than in the countryside. Urban PTD has a better chance of success if agriculture forms part of an integrated approach to urban development, with a supportive and enabling institutional and policy environment.

A useful example to consider, in which PTD has proceeded within an enabling policy environment, is Cuba. The growth of urban agriculture in Cuba and the uptake of innovative UA technologies have been dramatic and impressive. In just over ten years, between 1989 and 2000, it moved from a marginal component in urban food systems to a major category of land use in Havana and other cities, a major employer of urban labour and an important source of micro-nutrients for the urban population. It has also greatly reduced the accumulation of organic wastes in urban dumpsites.

Among the many instances of technical innovation which have accompanied this agricultural transformation, "organoponics" – the large-scale construction of raised beds for vegetable production using an enriched substrate of soil and organic matter – is a particularly important illustration of how institutional and policy integration facilitates technical change. Organoponics involves spatial intensification through the utilization vacant lots – frequently the concrete surfaces of demolished buildings. Facilitating this intensification are a series of policy changes about access to land, marketing of products and the structuring of the employment market. Bio-intensification, through an adaptation of the raised bed and double-digging techniques and the application of high levels of organic matter is again supported through institutional and policy mechanisms involving access to waste building materials to construct the beds and the provision of transport services to bring the large quantities of organic matter from the rural to urban areas.

Technologies do not stand alone. They need to be adapted not only to local ecological and socio-economic realities, they also need to be compatible with and supported by the local institutions and policies.

Concluding remarks

Two important lessons emerge from the experiences discussed in this paper. For urban agriculture to be viable and sustainable, innovation needs to occur in the context of urban livelihoods, in which agriculture usually complements other employment and where agriculture contributes to and draws on the diverse set of capitals making up the household asset base.

Innovation also needs to occur at technical, institutional and at policy levels and to involve households, communal organisations and city authorities. It is this need for multiple innovation which seems to be more essential for urban than for rural agriculture. Cuba exemplifies not only the contribution of the city authorities to technical innovation in the organoponic gardens, but also the provision of a facilitating policy environment, in the form of relaxed restrictions on private access to and exploitation of land, new marketing systems and support for establishment of local level organisations.

Less successful aspects of the Cuban experience highlight other key elements of urban agriculture that need to be fostered. Technical, institutional and policy innovation need to result from participatory dialogue and negotiation, rather than being imposed by a single actor in the process. For instance, in Cuba there has been a tendency to impose a uniform use of high-yielding varieties, through a centrally-organised seed production system, even though experimentation with local land races or mixed varietal plantings could lead to benefits in some systems. Furthermore, there are indications that though urban agriculture has successfully produced food for several cities, it has not always become a well-integrated part of those cities. In the words of two Cuban writers, there is a lack of "harmony between the productive space and the constructed space" (Cruz and Medina 2003). These observations raise an increasingly important theme in the urban agriculture discourse in both the North and the South. This concerns the multi-functionality of urban space and the opportunity for agriculture in the urban setting to fulfil multiple roles for the urban community. The environmental contribution of agriculture has been widely documented. Already there is evidence that the psycho-social space which agriculture provides to poor households and communities in the city, and especially to women, can sometimes be as important as its food security or income role (Slater 2001). Experiences cited in this paper suggest that through the medium of field schools, urban agriculture can be a means for social organisation. There are also opportunities for agriculture to function as a source of child and youth education about natural processes and resources, as a locus for family recreation, and a major contributor to the sustainability of cities.

References

Altieri, M., P. Rosset and C. Nicholls. 1997. Biological control and agriculture modernization: Towards resolution of some contradictions. In Agriculture and Human Values. 14:303-310.

Arce, Blanca, Gordon Prain and Luis Maldonado, 2004. Urban Agriculture and Gender in Latin America: A case study of Carapongo, Lima, Peru. Paper presented at the workshop, “Woman Feeding Cities: Gender mainstreaming in urban food production and food security” 20th -23rd September, 2004, Accra, Ghana. RUAF/Urban Harvest http://www.ruaf.org/files/gender_arce_et_al_peru.pdf

Argenti, Olivio, 2000. Food for the cities: food supply and distribution policies to reduce urban food insecurity. FAO, Rome.

Armar-Klemesu, Margaret. 2000. Urban agriculture and food security, nutrition and health. In Bakker, Nico, Marielle Dubbeling, Sabine Gundel, Ulrich Sabel-Koschela and Henk de Zeeuw (editors). Growing Cities, Growing Food: Urban Agriculture on the Policy Agenda. A Reader on Urban Agriculture. Deutsche Stiftung fur internationale Entwicklung (DSE). Germany

AVRDC 2002. Quality assurance of agricultural products in peri-urban Hanoi. Final Report to SIUPA. AVRDC-CIRAD-RIFAV component. CIP, Lima.

Bernet T., A. Devaux, O. Ortiz and G. Thiele. Participatory Market Chain Approach. In: UPWARD. 2005. ‘Participatory Research and Development for Sustainable Agriculture and Natural Resource Management: A Sourcebook’. Los Baños, Philippines.

Biggs, Stephen D., 1989. Resource-Poor Farmer Participation in Research: A Synthesis of Experiences from Nine National Agricultural Research Systems. OFCOR – Comparative Study Paper No. 3. ISNAR, The Hague, Netherlands.

Biggs, S. 1990. A multiple source of innovation model of agricultural research and technology promotion. World Development 18(11), 1481.1499.

Biggs, S. and J. Farrington. 1991. Agricultural Research and the Rural Poor. A Review of Social Science Analysis. International Development Research Centre (IDRC), Ottawa, Canada, 139pp.

Birley, Martin and Karen Lock, 1999. The Health Impacts of Peri-urban Natural Resource Management. Liverpool School of Tropical Medicine, Liverpool, UK.

Burchardt J (1997) Rural social relations, 1830-50: Opposition to allotments for labourers. Journal of Agricultural and Rural History 45 (part II): 165-175

Caldeyro-Stajano, M. 2004. Simplified Hydroponics as an Appropiate Technology to Implement Food Security in Urban Agriculture. Practical Hydroponics and Greenhouses. 76: 6.

CGIAR System Review Secretariat, 1998. Third System Review of the Consultative Group on International Agricultural Research: The International Research Partnership for Food Security and Sustainable Agriculture. CGIAR, Washington.

Chambers, Robert, Arnold Pacey and Lori Ann Thrupp, 1990. Farmer First. Itermediate Technology Publications, London

Cole, Donald C., Kate Bassil, Heather Jones-Otazo, Miriam Diamond, 2004. Health Risks and Benefits Associated with UPA: impact assessment, risk mitigation and healthy public policy. Workshop on Health Risks and Benefits of Urban & Peri-Urban Agriculture (UPA) including Livestock Production in Sub-Saharan Africa, ILRI, Nairobi, June 9-12, 2003.

Conroy, Czech, 2004. Livestock Sector Growth and Poverty, with particular reference to India. DfID Consultation Paper, Natural Resources Institute, Greenwich. http://dfid-agriculture-consultation.nri.org/theme1/keypapers/livestockrevolution.pdf. Last consulted March 25, 2006.

Cornish, G.A. and P.Lawrence, 2001. Informal irrigation in peri-urban areas: a summary of findings and recommendations. Report OD 144, HR. Wallingford/DfID, Oxford.

Cruz, María Caridad and Roberto Sánchez Medina, 2003. Agricultura in the City. A Key to Sustainability in Havana, Cuba. Ian Randell, IDRC, Kingston, Jamaica.

Deveza, Kilian and R. Holmer. 2002. Container Gardening: A Way of Growing Vegetables in the City. 2002 http://www.puvep.com/publications/container_gardening.pdf accessed 30/10/05

DfID 2005. Annual Reports for 2003-2004, Livestock Production Program. DfID, London.

DfID 2006. User Friendly Guidelines for Food Security. DfID Livestock Production Program, 2004-2005, Highlight 1: pp21-22. DfID, London.

Douthwaite, Boru, 2002. Enabling Innovation. A practical guide to understanding and fostering technological change. Zed Books, London.

Dubbeling, Marielle, Gordon Prain, Maarten Warnaars and Thomas Zschocke (eds), 2005. Feeding Cities in Anglophone Africa with urban agriculture. Concepts, tools and cse studies for practitioners, planners and policy makers. CD-ROM. International Potato Center-Urban Harvest, Lima, Peru.

Ellis, Frank, 2000. Rural Livelihoods and Diversity. Cambridge University Press, Cambridge, UK.

Erdmann, Rodrigo A. Medellín, 2004. Container Gardening. Organic food production in the slums of Mexico City. Handmade Projects. http://journeytoforever.org/garden_con-mexico.html Last accessed 12-12-05

Evans et al. 2000. Human-Influenced Soils. In Brown, R., J.H. Huddleston and J. L. Anderson (Co-eds) Managing Soils in an Urban Environment. Agronomy No. 39. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America, Inc., Madison, Wisconsin, USA

Farrington, J., D. Carney, et al. 1999. "Sustainable Livelihoods in Practice: Early applications of concepts in rural areas." ODI - Natural Resource Perspectives 42: 13.

Fishman, Robert. 1987. Bourgeois Utopias: The Rise and Fall of Suburbia. New York: Basic Books.

Furedy, Christine. 1992. "Garbage: exploring non-conventional options in Asian cities," in Environment and Urbanization, vol. 4, n. 2, pp. 42-61.

Gayao, B.T., J.M. Sim, and A.T. Sabado. 1997. Sustaining home gardens in the city: institutions and institutionalization in Baguio. In UPWARD, 1997. Local R&D: Institutionalizing Innovations in Rootcrop Agriculture. UPWARD, Los Banos, Laguna, Philippines.

Getachew, Y, 2002. The Living Garden : a Bio-intensive Approach to Urban Agriculture in Ethiopia. Urban Agriculture Magazine No. 6. RUAF, Leusden, Netherlands

Getachew, Y., 2003. Micro-technologies for Congested Urban Centers in Ethiopia Urban Agriculture Magazine No 10, RUAF, Leusden, Netherlands

Hardoy, Jorge E., Sandy Cairncross and David Satterthwaite. 1990. The Poor Die Young: Housing and Health in Third World Cities. Earthscan Publications Ltd. London.

Havercort, B., J. van der Kamp and A. Waters-Bayer (eds.). 1991. "Joining Farmers' Experiments. Experiences in Participatory Technology Development". ILEIA Readings in Sustainable Agriculture, Intermediate Technology Publications, London.

Helen Keller International, 1994. Promotion of Home Gardening Through Training: A DAE-NGO Collaboration. Helen Keller, Dakar, Bangladesh.

Holmer, R. 2001. Appropriate Methods for Micro-enterprise Development in Urban Agriculture. In Urban Agriculture Magazine, number 5, December 2001. 51-53p.

IIRR 1991. The Biointensive Approach to Small-scale Household Food Production. International Institute for Rural Reconstruction (IIRR), Silang, Cavite, Philippines.

ILRI 2005. Invest in Humanity. ILRI Website http://www.ilri.cgiar.org – INVEST IN HUMANITY – Last visited 20/3/06.

Jacobi, Petra, Jorg Amend and Suzan Kiango. 2000. Urban agriculture in Dar es Salaam: providing for an indispensable part of the diet. In Bakker, Nico, Marielle Dubbeling, Sabine Gundel, Ulrich Sabel-Koschela and Henk de Zeeuw (editors). Growing Cities, Growing Food: Urban Agriculture on the Policy Agenda. A Reader on Urban Agriculture. Deutsche Stiftung fur internationale Entwicklung (DSE). Germany.

Johns, T. 1999. The Chemical Ecology of Human Ingestive Behaviors. Annual Review of Anthropology, October 1999, Vol. 28, Pages 27-50

Lee-Smith, Diana and Pyar Ali Memon. 1994. Urban Agriculture in Kenya. In Egziabher, A., D. Lee-Smith, D. Maxwell, P.A.Memon, L. Mougeot and C. Sawio (eds) Cities Feeding People. An Examination of Urban Agriculture in East Africa. International Development Centre. Canada, Ottawa. pp. 67-84.

Maldonado, Luis, 2005. La agricultura urbana en Lima: estrategia familiar y política de gestión municipal. AGROPOLIS AWARD Report. CIP, Lima.

Martin, A., N. Oudwater and S. Gündel. 2001. Methodologies for Situation Analysis. In Urban Agriculture Magazine, Number 5, 10-12p. Leusden, Netherlands.

Marulanda, C.and J.Izquierdo 2003. "LA HUERTA HIDROPONICA POPULAR". Manual Técnico . Regional Office of the FAO for Latin America and the Caribbean. 3rd edition. Santiago, Chile.

Matson, P.A., W.J. Parton, A.G. Power and M.J. Swift. 1997. Agricultural Intensification and Ecosystem Properties. Science, vol. 277: 504-509.

Maxwell, Daniel, 1994. Internal Struggles over Resources, External Struggles for Survival: Urban Women and Subsistence Household Production. http://www.cityfarmer.org/danmax.html

Midmore D. and W. Deng-lin. 1999. Work that water! Hydroponics made easy. Waterlines. ITDG Publishing, London, volume 17(4).

Minnick, Dan R., 1989. A Guide to Creating Self-Learning Materials. IRRI, Los Banos, Philippines

Moselle, Boaz, 1995. Allotments, Enclosure, and Proletarianization in Early Nineteenth-Century Southern England. Economic History Review, New Series, Vol. 48, No. 3 (Aug., 1995) , pp. 482-500

NEFSALF. 2005. Nairobi and environs food security, agriculture and livestock forum. Bulletin, Issue No.2. Mazingira Institute, Nairobi, Kenya.

Niñez, V., 1984. Household Gardens: Theoretical considerations on an old survival strategy. Potatoes in Food Systems Research Series Report No.1:41p. CIP, Lima-Peru.

Norman et al. 1995. The farming systems approach to development and appropriate technology generation. Rome: FAO.

Njenga (forthcoming) A Livelihood Strategy for the Urban Poor in Nairobi: Organic Waste Recovery for Reuse in Urban Agriculture. Urban Harvest Working Paper 5, CIP, Lima.

Novo, Mario Gonzalez and Catherine Murphy, 2000. Urban agriculture in the City of Havana: a popular response to a crisis. In de Zeeuw, H. N. Bakker, M. Dubbeling, S. Gundel & U. Sabel-Koschella, eds. Growing cities, growing food. p. 329-347. Feldafing, German Foundation for International Development (DSE).

Peters, D., Wheatley, C., Prain, G., Slaats, J., and Best, R. (2002) Improving agroenterprise clusters: Root crop processing and piglet production clusters in peri-urban Hanoi. In CIRAD, Local Agrifood Systems: Products, Enterprises and Local Dynamics.CIRAD, Montpellier, France.

Poubom, Christine F. Ngundam, 1999. Cameroon. In Chweya, J..A. and P.B. Eyzaguirre (eds.) The Biodiveristy of Traditional Leafy Vegetables. International Plant Genetic Resources Institute, Rome, Italy

Premat, Adriana. 2005. Moving between the Plan and the Ground: Shifting Perspectives on Urban Agriculture in Havana, Cuba. In Mougeot, Luc J.A. (ed.), AGROPOLIS: The Social, Political, and Environmental Dimensions of Urban Agriculture. IDRC and Earthscan, Ottawa and London.

Rakodi, C. and T. Lloyd-Jones.(eds.) 2002. Urban Livelihoods. A people-centred approach to reducing poverty. 306pp.Earthscan, London.

Reijntjes, Coen, Bertus Haverkort and Ann Waters-Bayer, 1992. Farming for the Future: An introduction to low-external-input and sustainable agriculture. MacMillan Press, London

Rosset, Peter M., 2002. Posted: May 7, 2002Agricultura Alternativa Durante La Crisis Cubana. Food First, Berkely. http://www.foodfirst.org/cuba/agalternativa.html Last viewed 1 December 2005

Roling, Niels, G. and Elske van de Fliert, 1998. Introducing integrated pest management in rice in Indonesia: a pioneering attempt to facilitate large-scale change. In Roling, N.G., and M.A.E. Wagemakers, (eds.), Facilitating Sustainable Agriculture. Cambridge University Press, Cambridge, UK.

Scheidegger, Urs and Gordon Prain. 2000. Support to diversity in potato seed supply. In Almekinders, Conny and Walter De Boef (Editors). Encouraging Diversity: The Conservation and Development of Plant Genetic Resources. Intermediate Technology Publications. London.

Thiele, Graham. 1999. Informal Potato Seed Systems in the Andes: Why are they important and what should we do with them?. World Development Vol.27. Issue 1.

Simmonds, N.W.1979. Principles of crop improvement. Longman Scientific & Technical. UK.

Slater, Rachel. 2001. Urban agriculture, gender and empowerment: an alternative view. Development Southern Africa. Volume 18. Issue 5.

Smit, J and J. Nasr. 2001. Agriculture – Urban Agriculture for Sustainable Cities: Using Wastes and Idle Land and Water Bodies as Resources. In Satterthwaite, David (ed), Sustainable Cities. Earthscan, London.

Southall, Aidan, 1998. The City in Time and Space. Cambridge University Press, Cambridge, UK.

Staal, S.J. 2002. The competitiveness of smallholder dairy production: evidence from sub-Saharan Africa, Asia and Latin America. In Rangnekar, D. (ed.); Thorpe, W. (ed.). National Dairy Development Board, Anand, Gujarat (India); Australian Center for International Agricultural Research, Canberra; ILRI, Nairobi (Kenya). Smallholder dairy production and marketing - opportunities and constraints. Proceedings of a South-South workshop. p. 250-264. Anand, Gujarat (India): NDDB.

Staal, S.J.; Baltenweck, I.; Waithaka, M.M.; Wolff, T. de; Njoroge, L. 2002. Location and uptake: integrated household and GIS analysis of technology adoption and land use, with application to smallholder dairy farms in Kenya. Agricultural Economics (The Netherlands). v. 27(3). p. 295-315.

Stren, Richard, Barney Cohen, Holly E. Reed, Mark R. Montgomery (Eds), 2003. Cities Transformed: Demographic Change and Its Implications in the Developing World. National Academies Press, Washington, DC.

Tibaijuka,AnnaKajumulo, 2004. Africa on the move: an urban crisis in the making. A submission to the Commission for Africa. Commission for Africa, Nairobi.

Tinh, Nguyen Thi, Gordon Prain and Dai Peters, 2004. Effect of different feed compositions on post-weaning piglets basing on local available feed resources in Cat Que village of Ha Tay province. Technical Report, Urban Harvest, Lima, Peru.

Tripp, R. 2001. Seed Provision and Agricultural Development: The Institutions of Rural Change. 192pp. June 2001. ODI, London

Undan, R., S. Pedriot, A. Nitural, S. Roque and D. Liban. 2002. Urban Agriculture - A Step-By-Step Guide To Successful Container Gardening in the City. Published by "Foresight Book Publishing & Distribution Co., Inc., Philippines.

Urban Harvest, 2004. Urban Harvest, CGIAR System-wide Initiative on Urban and Peri-urban Agriculture. Brochure, 19pp. CIP, Lima, Peru

Veenhuizen, René van, Gordon Prain and Henk de Zeeuw, 2001. Editorial: Appropriate Methods for Urban Agriculture: research, planning, implementation and evaluation. Urban Agriculture Magazine No. 5. Luesden Netherlands.

Veenhuizen, René van, 2003. Editorial: Micro-Technologies for Urban Agriculture. Urban Agriculture Magazine No. 10, Luesden, Netherlands.

Villamayor Jr. and G. Frederico. 1991. Camote Tops Pot Gardens for Slum Dwellers in Tacloban. In UPWARD, Sweetpotato Cultures of Asia and the South Pacific. UPWARD, Los Banos, Laguna, Philippines

Yeung, Yue-man, 1987. Examples of urban agriculture in Asia. Food and Nutrition Bulletin Volume 9, Number 2. The United Nations University Press.