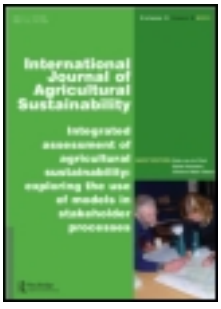

International Journal of Agricultural Sustainability

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tags20

Sustainable urban agriculture: stocktake and opportunities

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Published online: 08 Jun 2011.

To cite this article: Leonie J. Pearson , Linda Pearson & Craig J. Pearson (2010) Sustainable urban agriculture: stocktake and opportunities, International Journal of Agricultural Sustainability, 8:1-2, 7-19

To link to this article: http://dx.doi.org/10.3763/ijas.2009.0468

Sustainable urban agriculture: stocktake and opportunities

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This paper reviews research on urban agriculture which relates to the three dimensions of sustainability: social, economic and environmental. We propose that urban agriculture has three elements: urban agriculture in isolation; its interface with the people and environment within which it is situated; and its contribution to the design of built form. Additionally, we consider its scale: micro, meso and macro. The analysis draws attention to legal, social and economic constraints and opportunities. It suggests that future priorities for research should be directed towards (i) strategically identifying principles of sustainable urban agriculture that help policy makers to design resilient cities, e.g. using flood-prone areas for food and employment, and (ii) operationally trialling innovative institutional mechanisms, e.g. differential land taxes to support sustainable urban agriculture or payments for environmental services provided by urban agriculture such as carbon sequestration.

Keywords: economic, institutions, legal, resilience, scale, social

Introduction

Urban agriculture (UA) is the producer, processor and market for food, plant- and animal- sourced pharmaceuticals, fibre and fuel on land and water dispersed throughout the urban and peri-urban areas, usually applying intensive production methods (expanded from Smit *et al.*, 1996). It encompasses greenhouse cropping and intensive animal industries. 'The lead feature of UA which distinguishes it from rural agriculture is its integration into the urban economic and ecological system' (Mougeot, 2008, p. 9). UA includes horticultural crops (fruits, flowers), but it does not usually include amenity or landscape horticulture, either at the home-garden or parkland scale. This convention is retained in this article although we note that amenity horticulture provides an opportunity for UA – simply by changing to species of plants that produce food. In our review we have drawn on research in amenity horticulture where we did not find any in UA.

Food production in cities has a long tradition in many countries and the UNDP (1996) has estimated that UA produces between 15 and 20 per cent of the world's food. Urban agriculture, although practised in both developed and developing economies, often serves different purposes, e.g. recreation in the former and food security in the latter. We draw most of our analysis from the literature of the developed economies.

For this paper, and indeed this Special Issue, we focus on the production end of urban agriculture. We disaggregate it into three scales: micro, meso and macro, and categorize ownership as private, corporate or public entities (Table 1).

The paper is purposeful in that we ask the question: what are the priorities for research and public policy to assist UA's contribution in creating sustainable, resilient cities? We define resilient cities in line with Holling's (1973) definition of resilience as the capacity of the city (built infrastructure, material flows, social functioning, etc.) to undergo change while still maintaining the same structure, functions and feedbacks, and therefore identity.

The focus on the UA–city interface is relatively unique because the literature on sustainable cities, and the need for transformational change to the ecology of western cities, usually ignores the opportunities for UA to contribute to urban sustainability. For example,

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INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY 8 (1&2) 2010
PAGES 7–19, doi:10.3763/ijas.2009.0468 ISSN: 1473-5903 (print), 1747-762X (online). www.earthscan.co.uk/journals/ijas
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Table 1 | **Scale of urban agricultural production**

Scale	Examples of scale	Broad ownership categories of UA land and produce
Micro		
	• Green roofs, walls, courtyards	• Private, corporate
	• Backyards	• Private
	• Street verges	• Public
Meso		
	• Community gardens	• Private, on public land
	• Individual collective gardens (allotments)	• Private
	• Urban parks	• Public
Macro		
	• Commercial-scale farms, e.g. turf, dairy, orchard, grazing (e.g. horses)	• Private, corporate
	• Nurseries	• Private, corporate
	• Greenhouses: floriculture and vegetables	• Private, corporate

Note: Ownership is categorized as private when owned by individuals with fully assigned property rights; corporate when owned by shareholders so that decision making is collective or may be assigned to corporate officers; and public when owned by government and managed for social outcomes, e.g. schools.

four studies of initiatives to improve the sustainability of US cities identify the importance of green space but not agriculture or food production (Saha and Paterson, 2008), land-use controls to reduce carbon emissions omit UA (Brown *et al*., 2005) and actions to improve urban health do not mention the possible contribution of UA (Kjellstrom and Mercado, 2008).

The disconnection between UA and city ecology may be attributed equally to the focus of planners on the built environment, and the narrow focus of researchers into UA. In an excellent review, Mougeot (2008) characterizes the history of research in UA in three phases: first, geographical accounts; then isolated surveys and (in our words) 'success stories' or advocacy; then institutional projects led by multidisciplinary teams focused on the UA system rather than UA as part of a city system. However, it is self-evident that UA is part of the city ecosystem, with some statistics to indicate its importance: for example, employing 200 million people, engaging up to 80 per cent of urban households in some less developed countries (Vietnam, Nicaragua, Ghana, Cuba), contributing about 15 per cent of state vegetable and fruit production in some developed economies (Australia), and increasing dietary diversity of those who participate in UA in two-thirds of countries analysed (Zezza and Tascottiu, 2008). Additionally, the intensity of UA ensures it achieves high productivity: in Sydney, Australia UA accounts for 1 per cent of the land area and produces $1 billion in agricultural produce, accounting for some 12 per cent of the state's agricultural production (Sinclair *et al.*, 2004). In this paper we seek to enumerate these and a much wider range of outputs (both positive and negative) from UA in the context of the UA–city relationship; individual papers in this volume add richness and specificity to this analysis.

Context

We propose three elements to the UA–city relationship: urban agriculture in isolation; its interface with the people and environment within which it is situated; and its contribution to the design and construction of the built form of cities.

There are many external pressures that will cause changes in UA and the design of cities. First, there is growing acceptance that the structure and function of cities must change rapidly to respond to various drivers, e.g. resource scarcity, population pressure (urbanization) and climate change (van Ginkel, 2008). This implies an opportunity for UA, as a component of cities, to affect this change through the UA–built environment interface. Second, as cities become very large, issues such as the increasingly complex and costly food transport chains (in financial, infrastructure and energy terms), and the negative effects of the built environment, e.g. heat islands, cause researchers and policy makers to review the outputs from UA and perhaps place more emphasis on their benefits, or modify UA to minimize dis-benefits that arise from it. Third, there is a growing call for changes in the practice of agriculture itself to create systems that are integrated and deal with the by-products from food transformation and consumption (e.g. Pearson, 2007).

For UA to address these opportunities, there is a need to have two elements (i) knowledge, and (ii) institutional structures, e.g. policies, laws and incentives. When reviewing these elements it became clear to us that the context for UA is different in developed from developing economies; for example, the primary purpose may be

recreational or social in a developed, cash-based economy, but subsistence food production in a developing country. Further, city planning and legal jurisdictions are so different between countries, and especially between developed and developing countries, that global generalizations are unlikely to be helpful and are very possibly misleading. As a consequence, this article does not seek to compare and contrast UA in developed and developing countries and we draw most of our analysis from the literature of developed economies.

The aim of this paper is to identify what knowledge or research priorities are necessary to achieve sustainable urban agricultural systems that contribute to resilient cities. An overview of current knowledge, categorized into social, economic and environmental systems and their institutional environment (consistent with UA sustainability research, e.g. Ellis and Sumberg, 1998) is given in the next section. This leads to identification of knowledge gaps and priorities. The paper places emphasis on institutional arrangements, e.g. laws and incentives for creating sustainable systems.

Current knowledge of sustainable urban agriculture

This section summarizes the knowledge that is available about urban agriculture. There is no single approach to assessing the sustainability of UA; however, three approaches have informed our investigation: (i) the Food and Agricultural Organization's framework for the evaluation of sustainable land management to open-space UA (Drechsel *et al.*, 2008b); (ii) spatio-temporary dynamics of UA (Drechsel and Dongus, 2010); and (iii) a methodological assessment of UA (Nugent, 1999a). These approaches emphasize the elements of sustainability – environmental, social and economic – and the institutional environment to achieve sustainability. The current body of UA work can be broadly grouped into either case studies (e.g. Sawio, 1998; Larsen *et al.*, 2008) or descriptive accounts of concepts or theories associated with UA (e.g. McBey, 1985; van Veenhuizen and Danso, 2007). A sample of current knowledge and the contributions of articles in this special issue is given in Table 2.

Sustainability depends on the 'institutional environment' in which UA operates. The institutional environment includes social norms and rules as well as the formal laws and protocols for urban agriculture, summarized in Table 3. The categorization in Table 3 is adapted from Coggan and Whitten (2008) and includes economic and legal instruments for UA. Important for any investigation is the need to recognize that regulations and incentives need to reflect differences in context, i.e. legal frameworks and social norms. For example, implementation of a Purchase of Development Rights scheme requires that a landowner own 'rights' (e.g. water rights, mineral rights) that can be transferred separately from the title of land, so that the landholder can sell the right to develop to government or others. Ownership of land in the US includes a right to develop (Daniels and Bowers, 1997); however, there is no independent 'right to develop' in many countries, e.g. Australia (McKenzie, 1997). The jurisdiction-specific challenges for institutional and regulatory design need to be accommodated in a way that may not apply for economic incentives.

All instruments require a clear understanding of who 'owns' the productive capacity of land for UA. In Table 1 we simplistically divide ownership into private, corporate or public (government) and suggest that public ownership is most important at the macro and meso scales, although when aggregated these may amount to large areas within cities. Whereas all three ownership categories in Table 1 can initiate actions to make UA sustainable, all require government support and/or implementation, as shown in Table 3.

Knowledge gaps in urban agriculture

Knowledge gaps in UA occur in two areas. First in the social, economic and environmental attributes of UA (Table 4). Second, in the institutions which govern UA, which we address in the following text.

Information and research into the social, economic and environmental goods and services produced by UA is weakest where it relates to the opportunities for UA to impact on urban form (planning, design and construction), followed closely by the interface between UA and the built environment (Table 4). Noticeably, there was a lack of discussion about the dynamic aspects of cities and UA, i.e. their transformational and resilient qualities, such as the role UA might (or might not) play in the transformation to low-carbon economies.

With respect to knowledge gaps in institutional governance, we have identified five points that relate to opportunities for innovation and scale: innovative institutional frameworks for success. Development of institutional frameworks, regulatory requirements and economic incentives has recently occurred for the conservation of biodiversity in urban and rural contexts (Kelly and Stoianoff, 2009). In comparison, there has

Table 2 | **Key scientific knowledge surrounding the social, economic and environmental attributes of urban agriculture**

Urban agricultural goods and services		Comments/references	Contributions in this journal issue
Social	Food security, access	'Urban penalty' in access to sufficient and healthy (quality) food for urban poor, thought to be addressed by micro UA (Islam, 2004; Zezza and Tascottiu, 2008). Access to fresh food rated as highest benefit from micro UA by English allotment holders (Perez-Vazquez *et al.*, 2005). Contribution of urban vs. peri-urban vs. rural food supply (Drechsel *et al.*, 2007). Several location-specific quantitative studies of contribution of urban vs. peri-urban vs. rural food supply (e.g. Drechsel *et al.*, 2007).	Eriksen-Hamel and Danso, Karanja *et al.*, Mason and Knowd
	Diet and health	Reviews of city health usually omit consideration of UA (e.g. Harpham, 2009). UA should be able to address specific deficiencies in micronutrients and vitamins (now recognized as more important than gross dietary energy or protein, e.g. Gibney and Strain, 1999; Allen, 2003) which is particularly constrained in poor societies (Seinfeld, 2003). See also Personal well-being.	Karanja *et al.*
	Personal well-being/ psychological purpose, fitness	Agricultural activity may offset decline in physical activity with ageing after childhood, especially in women. Activity reduces health problems, e.g. obesity, type 2 diabetes, some cancers, clinical depression (Miles, 2007). Physical, intellectual and psychological benefits can occur from direct involvement in UA (micro–meso scale) related to issues of 'gardening' (McBey, 1985).	van Leeuwen *et al*.
	Sense of place	Farming protected in urban greenbelts of capital cities to preserve national rural image (Canada, Australia: Pearson *et al.*, in review); environmental values associated with person's place-experience (e.g. Brandenburg and Carroll, 1995).	van Leeuwen *et al*., Sumner *et al*.
	Aesthetics	Mixed appreciative responses: micro UA often viewed as nuisance, trivial, unsightly (Mbiba, 1994), abundant plants in offices as bizarre (Hansen and Machin, 2008), gardening as a 'harmonious human–nature interaction' (Brady, 2006), but meso UA, e.g. low-intensity farming, more aesthetically pleasing than intensive agriculture (Schupbeck *et al.*, 2008). Familiarity with agriculture 'should be included in all environmental education' (Van Bonsdorff, 2005).	Condon *et al.*, van Leeuwen *et al*.
	Social inter-actions/ community building	Particularly in low income areas with disadvantaged groups; organization through UA (micro and meso level) leads to enhanced development; i.e. information flow, neighbourhood watch, community cohesion (Mudimu, 1996; Armstrong, 2000; Brown and Jameton, 2000).	van Leeuwen *et al*., Sumner *et al*.
	Personal skills	Micro UA can develop horticultural and communication skills (Perez-Vazquez *et al.*, 2005)	Seymoar *et al*.
	Urban planning	Buffer zones, greenbelts, heritage values, social identity and economic infrastructure of UA influence urban planning as shown in Ile-de-France (Fleury, 2002).	Lydecker and Drechsel, Condon *et al*., Knight and Riggs, Mason and Knowd, Merson *et al*.
	Employment and income in production	Significant employment creation of the underemployed for both income (meso–macro level) and subsistence (micro level) livelihoods (van Veenhuizen and Danso, 2007). In developed economies, government estimates for Australian states are that UA contributes 12–18% of value of vegetable industry; Cuba 60% (Premat, 2005).	
	Gender equity	In developing countries, e.g. Zimbabwe, it is predominately women who undertake UA, ensuring they have greater input and self-determination of household resources (Mudimu, 1996).	Seymoar *et al.*
Economic	Highest productive use of land	Vacant and degraded sites are utilized for UA, ensuring that land has the highest 'value' potential (Madaleno, 2000) and UA on vacant sites can lead to increased surrounding house prices (van Veenhuizen and Danso, 2007)	Condon *et al*., Merson *et al*.
	Employment and income in UA value added (aggregate benefit to society)	Meso- and macro-scale UA has potential for commercial market value and significant employment opportunities, but little work has been done to quantify these aspects (Nugent, 1999b): some examples of benefits to society from West Africa (Drechsel *et al.*, 2007).	Karanja *et al*., Seymoar *et al*.
	Diversified industry base in cities	Micro and meso level UA (e.g. Sawio, 1998; Larsen *et al.*, 2008) can have significant enterprise development and value-adding potential to UA production, e.g. retail (local food markets), marketing and supply chain opportunities, although no scientific study of impacts has been estimated (Nugent, 2003).	Merson *et al*.
	Energy transport ('food miles')	Food may account for 40% of all road freight; fossil fuel used in food transport 'in most cases exceeds the energy consumed in (production)' (UK: Jones, 2002). Current rise in popularity of 'local' food, markets.	Knight and Riggs

Table 2 | **Continued**

Urban agricultural goods and services		Comments/references	Contributions in this journal issue
Environmental	Waste recycling	Food waste contributes 30–40% of municipal solid wastes (UK, Korea: Forkes, 2007; Lee *et al.*, 2007). Composting and recycling in agriculture, gardens reduces nutrient losses (e.g. Forkes, 2007), may lead to soil nutrient accumulation (Khai *et al.*, 2007), and reduces greenhouse gas emissions (e.g. Tsai, 2008). May cause problems, e.g. ammonia generation, acidic leachate (Lee *et al.*, 2007).	Lydecker and Drechsel, Eriksen-Hamel and Danso
	Urban heat and air quality	Urban heat island (UHI) and air pollution, e.g. ozone mitigated by vegetation. Micro (building/canopy) and meso (boundary layer) effects. UHI over vegetation/parks c. 4–5°C cooler than built environment (e.g. Taha, 1997; Wong and Yu, 2005; Strathopoulou and Cartalio, 2007). Benefit/cost of tree planting in Chicago 3:1 (McPherson *et al.*, 1994). Mitigating UHI generates savings of $5–10 billion p.a. cooling electricity, 20% reduction in ozone (US: Meier, 1997).	
	Carbon sequestration	Vegetation (crop UA) sequesters carbon; other agriculture may be net emitters due to methane emissions from livestock and manure. Total agricultural emissions decline with urbanization (e.g. Lebel *et al.*, 2007); sequestration by vegetation may be only 0.2% of city emissions (Manila: Lebel *et al.*, 2007); air mixing disperses possible low-CO_2 islands associated with parks (and crop-based UA) (Wentz *et al.*, 2002). Shade trees have approximately double the mitigative impact of reflective roofs (Akbari, 2002). Green roofs reduce building carbon emissions by 9% (Roehr and Laurenz, 2008).	Several at micro level: green walls (Dixon *et al.*), Eriksen-Hamel and Danso
	Wastewater recycling and health	Health risks of irrigated urban farming and options to address them (Cole *et al.*, 2008; Drechsel *et al.*, 2008a).	Lydecker and Drechsel, Eriksen-Hamel and Danso, Merson *et al*.
	Wastewater filtration	Vegetation filtering of nutrients and heavy metals from wastewater from industrial, farm or human sources (e.g. Verhoeven and Meuleman, 1999; Vymazal, 2005); less consideration of harvesting of vegetables for urban food or fibre.	Lydecker and Drechsel, Merson *et al*.
	Malaria	Green open spaces can be resting places for *Anopheles* but due to widespread use of polluted water, seldom breeding places (Afrane *et al.*, 2004; Klinkenberg *et al.*, 2005, 2008).	
	Noise	Abatement/absorption especially by trees (logarithmic reduction with height, width of vegetation); vegetation significant in attenuating city noise (Delhi: Kumar *et al.*, 2008). UA causes noise pollution related to farm operations; substantial research on noise from machinery in workplaces but no publications found on reception/perception of agriculturally emitted noise in urban areas, although legal thresholds for urban noise are commonplace.	
	Odour	Vast literature on emissions, detection and control of odour, including tainting of products, e.g. milk. Urban impacts, e.g. legislated separation distances between livestock and human residences.	
	Light	UA may create islands or buffers with low reflected light (e.g. cropping) or light pollution (greenhouses). Unable to find refereed papers on light pollution from greenhouses despite this being an issue for planning and location of greenhouses in urban areas.	
	Pesticides	Pesticides and faecal coliform in urban-produced vegetables in Ghanaian cities exceed health thresholds (Amoah *et al.*, 2006).	

been relatively little research and development of frameworks and incentives for sustainable UA. There is heavy debate regarding how effective these institutional frameworks are (Robinson, 2009), though this debate has also not spread to UA.

The institutional knowledge gaps that relate to scale include:

1. Issues of scale in UA are well recognised in the institutional environment. At the macro scale of production, the primary challenge is in preserving land for agricultural use in peri-urban areas while minimizing conflict between different land uses. There are two key points to note. In the absence of regulation or economic incentives, residential spread puts pressure on rural land for subdivision into smaller holdings, for rural residential use or for hobby farms. Even in cases where regulation is enacted it is not sufficient to protect land for UA without other supporting institutions, e.g. incentives, policy (Alterman, 1997). This fragmentation of land holdings both impacts on the capacity to support sustainable agriculture, and leads to an increase in the value of land used for non-agricultural uses, making farming uneconomic (Sinclair and Bunker, 2007). It is difficult for zoning and other planning controls to address this in the absence of economic incentives. For example, the NSW State Environmental Planning Policy (Rural Lands) 2008 was intended to encourage agricultural activity (e.g. by allowing subdivision for primary production into lots smaller than would otherwise be permissible provided there is no dwelling on the lot). However, it does not address how to identify the point below which agricultural activity is not sustainable or leaves insufficient separation from other uses, and, more importantly, it does not apply to any of the local government areas in the Sydney basin, where much of New South Wales' perishable vegetable production occurs (Sinclair and Bunker, 2007).
2. Managing conflict between inconsistent land uses is necessary at all scales but there is little systematic research into best scale-dependent practices. The impact of agricultural activities on neighbouring residential uses can generate claims of nuisance, such as interference caused by noise, smell, chemical sprays or dust; while non-farm activities can impact on agricultural uses, for example, dogs (Daniels and Bowers, 1997). Right to farm legislation is one response used in the USA, to give farmers a defence to civil claims for impacts on nearby land from noise, smell and other intrusions, as long as they are carrying out 'good management practices' (Daniels and Daniels, 2003). This is a limited response to the symptoms of conflict and does not address problems of planning and design of urban development that is sensitive to agricultural operations and appropriate modifications to farming practices on the edge (Sinclair and Bunker, 2007). An alternative approach, the provision of accessible mechanisms for resolution of disputes between landholders, has been attempted in Western Australia (Western Australia, 1995).
3. At the meso and micro scale UA is less regulated than macro UA and hence has its own issues. Agricultural activities incidental to a residential use in urban areas would generally be permissible subject to restrictions based on nuisance to neighbours. At the meso level economic incentives need to be carefully designed. For example, a differential tax or rating regime may tax commercial-scale agricultural land at a lower rate, leaving land used primarily for residential purposes and incidentally for agriculture to be taxed at a higher rate (Kelly and Stoianoff, 2009). At a community level governments can provide land for community gardens, which take one of two models: an allotment model in which gardeners have exclusive right to the use of an area of land, or shared gardens in which a garden is cultivated in common (Marrickville Council, 2007). Continued operation of a community garden may be vulnerable to changes in priorities for land use and perceptions of public liability associated with, for example, food poisoning from contaminated sites (Marrickville Council, 2007).
4. What are the best public policy instruments for each scale to optimize benefits? Broadly, there appears to be a link between scale of UA and type of instrument employed. Voluntary and information instruments are targeted towards micro and meso UA production. However, macro UA relies heavily on regulation for implementation. Many of the economic and social benefits of UA (from Table 3) arise from volunteerism at the smaller scales while regulatory, publicly owned activities may produce the greatest environmental benefits.
5. Lastly, there is a gap in institutional knowledge around how to 'scale-up' the findings from UA case studies. For example, UA has been designed into the roof infrastructure of Roppongi Hills, Tokyo, Japan; it includes a rice paddy and vegetable garden as well as aesthetic gardens. Its success has been measured in the reduction of the 'heat island' effect, workers' stress levels, etc. but there is a question of how realistic this 'case study' is for all buildings in a city. This has not been

Table 3 | **Current known institutional mechanisms and instruments for sustaining agriculture in urban areas**

Mechanism	Instruments	Examples
Regulations: required actions	Government zoning without compensation Zoning and planning controls, e.g. minimum subdivision sizes	Toronto greenbelt, to preserve agriculture (2005) New South Wales policies for identifying significant state agricultural land, and assessing land-use conflict (New South Wales, 2008)
	Government acquisition	Ottawa; land leased back to farmers (1965–1968)
	Support for efficient production, e.g. pesticide use, through regulations	Right-to-farm legislation in all US states except Iowa (Daniels and Daniels, 2003)
Economic incentives	Purchase of Development Rights (PDR)	Seattle USA, 24 states with PDR programs (Daniels and Daniels, 2003)
	Offset benefits: exchange for, e.g., increased building density elsewhere	USA: transfer of development rights (Daniels and Daniels, 2003)
	Differentiated agrarian taxes	NSW: 'farmland' usually rated at lower rate (Kelly and Stoianoff, 2009)
	Government payment for delivery of environmental goods and services (e.g. clean water)	USA: purchase of clean water by New York State through various catchment-wide approaches, e.g. planning, land acquisition (CGER, 2000)
	Rebates for farm inputs, e.g. diesel	Australia: income tax legislation (McKerchar and Coleman, 2003)
	Government grants for UA	USA: Community Food Security Competitive Grants Program (Feenstra, 2002)
	Subsidies to sustain production in difficult circumstances	Exceptional circumstances payments for broadacre agriculture, but not UA
Voluntary actions for enhanced security of UA	NGO-initiated land trust protected by legal covenant/perpetual conservation easement	Ontario Farmland Trust California, Vermont, Colorado (Daniels and Daniels, 2003)
	Government provision of land (and perhaps free services, e.g. water) for, e.g., community gardens	Australian city farms and community gardens: variety of forms/security of land tenure (Marrickville Council, 2007)
	Established industry structure for clear supply chain integration	Large-scale supply contracts by, e.g., supermarkets, not applying to UA
	Government maintenance of food-producing facility, e.g. fruit-bearing street trees	Canberra, since around 1935
Information, advice, support and moral suasion	Voluntary decision to use land for food production, e.g. household gardens	USDAs 'People's Garden' initiative to encourage and inform use of land for gardens Illawarra Biodiversity and Local Food Strategy for Climate Change
	Government and industry supported extension workers in rural and not UA	Extension officers (provided by government or NGOs) used in Harare (Drescher, 1996) and USA to improve UA yields
	Support for locally produced food, e.g. farmers markets	Friends of the Greenbelt (Toronto) Hawkesbury Harvest Farm Gate Trail (Sydney)

Table 4 | **Subjective assessment of the knowledge gaps in sustainable urban agriculture as related to: (i) urban agriculture; (ii) interface of UA with the people and environment in which it sits; and (iii) UA's contribution to the design of built form**

	Urban agriculture goods and services	Urban agriculture	UA interface with the people and environment within which it sits	UA contribution to built form
Social	Food security, access	2 (food security in developing countries); 1 but growing awareness in developed economies	1	1
	Diet and health	1	1	2
	Personal well-being/ psychological, purpose, fitness	1 Economic impacts, e.g. absenteeism reputed to be very large, but anecdotal	1	2
	Sense of place	2	1	2
	Aesthetics	1	1	1
	Social interactions/ community building	2	1 Unaddressed, whereas activity and community coherence seem increasingly important with ageing population, rising city crime	2
	Personal skills	1 Likely to be important for up-skilling in developing economies; more recreational in highly educated societies	n.a.	n.a.
Economic	Urban planning	1 Some awareness among planners but little literature/generalized lessons about benefits/dis-benefits of incorporation of UA into planning	2 Most of the work on conflict	1
	Employment and income in production	2	1	2
	Gender equity	2	2	1
	Economic value of land	3 highest value of agricultural or vacant land but same note as for urban planning	1	1 Little work done on the competing land uses, e.g. residential vs. UA vs. mining
	Employment and income in UA value added (aggregate benefit to society)	1 Most work is done at the micro scale and does not deal with the whole city	1	1
	Diversified industry base in cities	1	1	1
	Energy transport ('food miles')	2	1	2

Continued

Table 4 | **Continued**

	Urban agriculture goods and services	Urban agriculture	UA interface with the people and environment within which it sits	UA contribution to built form
Environmental	Waste recycling	1	1	1
	Urban heat	2	2	3
	Carbon sequestration	3 although research does not compare UA vs. green spaces, i.e. impact of harvesting	1	1
	Wastewater recycling and health	1	1	1
	Wastewater filtration	2	1	1
	Malaria	1	1	1
	Noise, odour	1 but substantial research in rural agriculture	1	1
	Light,	1	1	1
	Air quality	1	1	1
	Pesticides	1 as for noise etc.	1	1

Note: The ratings were provided by all three authors using a three-point scale, where 1 is little UA work undertaken and 3 represented a comprehensive research assessment of the issue from the UA perspective.

addressed within the literature. By contrast, there are participatory methods for scaling-up community development that is based on UA (Seymoar *et al.*, this volume).

Priorities for future research

Two directions for future research priorities emerge: strategic, to develop principles for implementing public policy for city design; and operational, to enhance UA's contribution to sustainable cities.

Strategic research may include:

1. Design and test policies and systems which will maintain UA (and its environmental benefits) as part of the urban system. This contrasts with the current situation where policies are primarily designed to manage conflict between UA and the built environment. These systems could be created through community consultation and trialled within local government areas, as with the introduction of on-farm nutrient management in the Netherlands (Neeteson *et al.*, 2002; Wiskerke *et al.*, 2003).
2. Research to assess the contribution of UA to large cities. Contributions which should be assessed include: (a) production of local food, as FAO and national statistics do not capture much of UA (e.g. UNDP, 1996); (b) employment in UA to reduce social inequity (Wilkinson and Pickett, 2009); and (c) the value of lower energy food chains. Other opportunities are: (d) contributions to adaptation to climate change, for example through sequestration of soil carbon; (e) shifting cultivation on underused (i.e. vacant) land between development opportunities and on flood-prone sites; and (f) using UA as a natural buffer against natural disasters, e.g. Hurricane Katrina.

While these strategic priorities encourage a move away from the current emphasis on case studies, we recognize that local developments or models are necessary to provide quantitative inputs for appropriate scaling-up to whole-city design. For example, taking the principle of the need to design the resilience of cities to pressures such as population and climate change by designing agriculture (in this case, urban agriculture) as semi-closed systems (Pearson, 2007), it is possible to

design integrated green space/built environments that totally recycle wastewater, re-use the vast majority of solid wastes, improve aesthetics, reduce heat, and improve personal well-being, reduce absenteeism and improve community (workplace or neighbourhood) cohesion. Estate developers have designed such systems but their implementation is, to date, partial (e.g. the London Docklands) because of municipal conservatism and/or insufficient independent evidence of their economic or social benefits. This calls for the need for partnerships between planners and developers and researchers to quantify operational issues.

Operational research may be prioritized according to the mechanisms identified in Table 3:

1. *Regulatory.* Research priorities for regulations fall into two categories: macro-scale land-use management, and micro- and meso-scale enterprise regulations. Greenbelts, green wedges and protected agricultural land within urban conurbations (e.g. London, Toronto, and Ottawa; Portland and Melbourne; and Vancouver, respectively) provide macro-scale examples of regulatory intervention to support agriculture with minimal research as to its effectiveness. City parklands, often on a similar scale (e.g. Adelaide, Canberra) provide parallel regulated spaces with no agricultural content. A research priority would be to study the societal and economic benefits arising from different legal constraints on land-use within the recreational and commercial continuum from passive parkland to UA. At smaller scales, a priority is to review legal requirements for the practice of UA. While it is common to impose additional constraints oriented to urban residents (e.g. restricting the use of herbicides, buffers against light pollution from greenhouses) other regulations applied to UA, such as separation distances from intensive livestock, relate to much larger scale rural enterprises.
2. *Economic*. The embracing of biodiversity by local, city and national governments has given rise to a mix of economic incentives and regulations. A research priority is to explore a parallel set of incentives (or, in places, disincentives) for UA. For example, in addition to private benefits of profit and well-being, local governments may obtain financial benefits through carbon trading, offsetting and differential rates that encourage UA, such as the planting of trees in allotments and rear laneways. These mechanisms, e.g. payments for environmental goods and services, would increase the economic rent obtained from maintained greenspaces rather than the current perception that they are vacant land awaiting building 'development' which (alone) generates economic return. At the micro level, mechanisms to respond to the Kyoto CDM would be augmented by economic returns from, for example, fruit produced for local restaurants. Other examples of economically oriented research in UA that would benefit effective land use within cities include analyses of economic costs and benefits associated with community (or commercial company) use of vacant land for UA during the development of new housing estates, and investigating the issue of separating ownership of UA land from UA produce, and how these two entities can provide multiple benefits to individuals and local communities. Green roofs and walls, increasingly encouraged by city planners, also lack underlying economic studies that quantify their benefits or provide a basis for differential land taxation.
3. *Voluntary or community engagement*. Peri-urban and rural communes and government-supported food production projects abound, whereas community-supported action research based on UA is rare or at least unpublished. Nonetheless, there are several opportunities (Table 3). Priority research would provide data on participants' well-being and other social issues (Table 4). For example, the making over of some gardens at Vancouver city hall to UA in 2009 provides a 'laboratory' to research community engagement, benefits and dis-benefits. Results would provide a basis for scaling-up to public policy (priority 1, above).
4. *Information*. While UA will be enhanced by information addressing technical issues and community organization for resource-poor city dwellers in developing countries (e.g. Seymoar *et al.*, this volume), in our view the information needs in developed cities relate to (i) supply chains, particularly niche or specialist marketing and local branding, and (ii) securing resources, e.g. land and water for urban gardens, from municipalities. These relate to scaling-up micro-scale UA for its long-term impact. Industry bodies, consultants and sometimes government departments provide this advice for rural farmers. Who will take responsibility for urban communities? (This relates also to economic structures to secure land and UA.)

In conclusion, in our view, research priorities for affluent societies are largely related to legal and economic issues although they need to be based on quantification of the environmental and social benefits generated by UA. The priorities include all scales, micro, meso and macro, but call for UA to be situated within the conceptual framework of the planned, built environment,

rather than as UA has been viewed historically, as a discrete and often competing use of urban land. While most other articles in this special issue necessarily deal with UA case studies, the research priorities arising from this paper reflect the growing need by policy makers to deliver integrated urban policies.

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