Urban Climate 12 (2015) 183–204

Contents lists available at ScienceDirect

Urban Climate

journal homepage: www.elsevier.com/locate/uclim

Managing change and building resilience: A multi-stressor analysis of urban and peri-urban agriculture in Africa and Asia

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ARTICLE INFO

Article history:
Received 24 October 2014
Revised 5 February 2015
Accepted 10 April 2015

Keywords:
Urban and peri-urban agriculture
Climate change
Adaptation
Africa
South Asia

ABSTRACT

Urban and peri-urban agriculture (UPA) is increasingly being promoted as a multi-focal strategy for enhancing urban food security and advancing climate change adaptation and mitigation efforts in cities. The extent to which this potential can be realized is circumscribed by access to adequate land and water resources, the degree of recognition of UPA within the urban policy domain, and the ability of producers to effectively navigate the myriad risks associated with food production in urban and peri-urban environments. This paper argues that UPA faces significant interlocking stresses stemming from marginalization of land and water resources, increasing exposure to climate risks, and ineffective policies and poor governance that undermine its long-term potential to address urban food security and climate change adaptation concerns. This paper examines key environmental and governance dimensions of UPA in the context of rapidly growing cities in Africa and Asia, and advances understanding of how increasing urban pressures on land and water resources, and intensifying climate risks, are undermining the resilience of UPA in the face of rapid change. The paper's findings are drawn from a series of assessments on UPA that were recently conducted in nine cities spanning West and East Africa, and South Asia.

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http://dx.doi.org/10.1016/j.uclim.2015.04.003
2212-0955/

1. Introduction

Rapid urbanization together with the extraordinary growth of cities is proceeding on a scale and at a rate that is unprecedented. Today, more than half the world's population resides in urban centers (UNDESA, 2013), and over the next several decades the pace of urbanization will accelerate. Much of this growth is expected to occur in urban centers of Africa and Asia (Montgomery, 2008; Revi et al., 2014; Taylor and Peter, 2014). These low and middle income regions face significant adjustment pressures, as poverty becomes increasingly urbanized, demand for urban services swells, and cities exert greater influence on peri-urban and rural livelihoods and environments (Forster and Escudero, 2014). For the poorer segments of society, the convergence of pressures brought about by the urban transition is exacerbating existing patterns of uneven development, informality, and deeply entrenched inequality. Thus, achieving international ambitions for sustainable development (eradicating poverty and hunger) will depend to a large extent on how developing-country cities are planned, managed and governed (Jabareen, 2013; Cohen, 2006; Allen, 2003).

The multiplicity of challenges and uncertainties associated with the growing urban footprint are accentuated by emerging risks from climate change. In developing countries, urban centers are particularly vulnerable to climatic extremes due to their strongly interlocking social and environmental stresses associated with rapid growth, systemic poverty, environmental degradation, and poor governance (Revi et al., 2014; Lwasa et al., 2014; Lwasa, 2014; World Bank, 2011a,b,c,d; De Bon et al., 2010; Zhao et al., 2010).

The concept of 'resilient cities', which is becoming increasingly prominent within the discourse on climate change adaptation, provides an important entry point for addressing urgent urban development needs while also considering longer-term implications of changes in the amplitude of risks that cities will face in the coming decades. Strategies for building urban resilience are most effective where they include a wide range of shocks and stresses, not just those attributed to climate change, and where they consider how resilience-building efforts can influence important equity issues associated with urban development (Kithiia, 2010; Leichenko, 2011; Moench et al., 2011; Satterthwaite and Dodman, 2013; Jabareen, 2013; Bahadur et al., 2013).

Concerns over urban food security are beginning to gain traction within the resilient cities and urban adaptation framework in large part because of the food price crisis that began in 2007 (Frayne et al., 2012; Revi et al., 2014). The consequences of the food price crisis continue to reverberate for the urban poor who typically devote more than half of their income to basic food purchases, and thus are highly sensitive to food price fluctuations (Cohen and Garrett, 2010; Crush and Frayne, 2010, 2011). In a number of developing-country cities, discrete episodes of social unrest, including violent protests and riots in 2008 and 2011 throughout Africa and the Middle East, coincided with large peaks in global food prices (Lagi et al., 2011; Holt Giménez and Shattuck, 2011).

Urban and peri-urban agriculture (UPA) resides within the current urban food security discourse, where it is viewed by some scholars as an important entry point for addressing both urban food security challenges as well as urban resiliency and adaptation goals (De Zeeuw et al., 2011; Dubbeling and De Zeeuw, 2011; FAO, 2012; Gerster-Bentaya, 2013; Lwasa et al., 2014). However, a central role for UPA in addressing urban food security is disputed by others who contend that UPA's importance to urban food security, especially that of the urban poor is overestimated (Battersby, 2013; Crush et al., 2010; Frayne et al., 2014; Mkwambisi et al., 2011; Webb, 2011). Recent, empirical studies on UPA's contribution to food security are few in number and therefore provide only a partial picture. One such study, of food security in 11 Southern African cities (Crush et al., 2012; Frayne et al., 2014), indicated that UPA had limited importance as a contributor to food security amongst poor households in these cities. Conversely, meta-analyses of UPA studies from across the developing world by Zezza and Tasciotti, 2008, 2010 described an equivocal link of UPA to urban food security whereby engagement in urban food production contributed significantly to household income and dietary diversity of the poorest quintile in some countries yet contributed very little in others. Both sets of studies warn against looking for universal success from UPA in helping the urban poor, but both also

acknowledge to varying degrees the reality and potential for UPA, embedded in a wider urban-development strategy, to contribute to more resilient urban food systems.

While the effectiveness of UPA as a means of reducing urban food insecurity remains an open question, recent empirical evidence suggests that the sector does play an important role in diversifying urban diets in cities where UPA is vibrant. This diversification is primarily achieved through the production of leafy green vegetables and other fresh produce, milk, poultry, eggs, and small livestock (Cofie et al., 2003; De Zeeuw and Dubbeling, 2009; Dossa et al., 2011; FAO, 2012; Lee-Smith, 2010; Simatele and Binns, 2008). In addition to its food provisioning attributes, UPA can potentially provide important ecosystem services related to use of urban organic waste as an input for food production, dampening of storm water runoff, biodiversity conservation, and aesthetic enhancement. Moreover, UPA has potential to shorten value chains that result in lower food costs in the informal economy and source diversity of nutrient rich foods, as well as reduced greenhouse gas emissions associated with food transport (De Bon et al., 2010; Orsini et al., 2013; Lwasa et al., 2014).

This suite of urban ecosystem services attributed to UPA has been used to advance the position that UPA can play a critical role in helping cities achieve climate change adaptation and mitigation goals as well as achieve greater overall resilience in the face of rapid social and physical changes (Dubbeling and de Zeeuw, 2011; Lwasa et al., 2014; Moglia, 2014; UN-Habitat, 2011). While UPA may indeed offer potential to strengthen urban resilience and advance adaptation efforts, the knowledge base to support this position is quite tenuous, and the sector itself faces serious threats to its sustainability that could undermine this potential.

The nature of these threats revolves around interacting drivers of population growth and rapid urbanization with the associated effects on land-use change, water resource management, environmental pollution, and climate change. Given the difficult choices and uncertainties facing long-term urban planning, promoting UPA as a resilience-building, adaptation strategy requires conclusive evidence of how UPA is faring under these intensified drivers of change and the degree to which the policy community is responding to these threats. In the developing world, and particularly Africa, UPA has been largely ignored or actively discouraged by municipal and national policy bodies (Simatele and Binns, 2008; Mkwambisi et al., 2011; Halloran and Magid, 2013). However, the historically antagonistic relationship between the urban policy community and urban agriculture is gradually shifting toward greater acceptance of UPA (Redwood, 2009a,b; Lwasa et al., 2014).

The knowledge base pertaining to the environmental dimensions of UPA is fragmented and largely outdated, particularly in considering the rapid changes underway in urban areas. This paper provides critical insights into these environmental change dimensions through synthesizing findings from a recent assessment of UPA undertaken in nine cities across Africa and South Asia, thus helping to address this important knowledge gap. The assessments aimed to better understand critical interactions at the land–water–climate nexus that influence resilience of UPA systems in the context of rapidly growing cities of the global south that are facing a changing climate. This paper highlights important points of intersection and convergence across the nine cities, describes critical knowledge gaps, and offers potential responses that could serve to enhance the resilience of UPA.

2. Description of the assessment

In 2011–12, integrated knowledge assessments[2] were undertaken in nine cities to examine the state of UPA through the lens of intensifying urban pressures and increasing climate risks. A key objective of these assessments was to better understand critical issues at the land–water–climate nexus that influence the productivity and viability of UPA systems in the context of rapidly growing developing-country cities. Assessments were carried in Addis Ababa (Ethiopia); Chennai (India) Dakar (Senegal); Dar es Salaam (Tanzania); Dhaka (Bangladesh); Ibadan (Nigeria); Kampala (Uganda); Kathmandu (Nepal); and Tamale (Ghana).

[2] Here, we define *knowledge assessments* as highly collaborative and deliberative processes for assembling, synthesizing, interpreting and organizing existing empirical information, knowledge and experience on complex set of issues in an integrated manner with a view toward informing policy and decision-making processes, as well as advancing the knowledge base.

A diversity of climates (humid to semi-arid) and locations (coastal to inland) were considered in selecting the cities. Additionally, consideration was given to cities where past work on UPA had been done and thus where expertise was available within the cities to carry out the assessments. The nine selected cities range from large to mega-city status with the exception of Tamale, in northern Ghana. This size bias may require some measure of caution in considering the applicability of findings from these assessments to small and medium-size urban areas. Also, the selection of cities where past work on UPA had been done implies an importance of the UPA sector that may not be applicable to cities where the UPA sector is less vibrant.

2.1. Methodological approach

The assessments examined the current state of knowledge and identified knowledge gaps, as well as critical entry points for devising responses intended to strengthen UPA. Specifically, the assessments explored: (1) the historical evolution and context of UPA in each city; (2) the predominant production systems; (3) the major stresses facing UPA related to urban encroachment, water allocation, and pollution; (4) climate stresses that potentially intersect with the non-climate stresses; (5) key policy, institutional, and governance factors that influence the viability and utility of UPA; and, (6) the development of recommendations for actions that could be taken at the city level to address sustainability concerns identified and described in the assessment reports. This paper builds on the information captured and aggregated from the nine assessments, which provides a basis upon which to consider the resilience of UPA systems, as described in Section 5 of this paper.

The composition of the nine assessment teams varied, with some of the teams being comprised predominately of researchers from universities and research institutes, and other teams comprised of a mix of researchers, city officials and NGO practitioners (Table 1). The researchers on these teams had ample experience interacting with policy and practice communities so even those teams comprised of only researchers had a strong orientation toward stakeholder engagement. There was diverse disciplinary expertise across the assessment teams that included geography, agriculture (including livestock), urban planning, water resource management, environmental science, development practice, and economics.

Information gathered for the assessments came from a variety of secondary data sources, including government reports and statistical bulletins, project reports, and academic articles, that were augmented with meteorological data, spatial mapping, focus group discussions, and expert interviews. The focus group discussions were held with farmers, and the interviews with a variety of sectoral experts and city officials with direct relevance to the assessment topic.

The development of the assessment topic and subsequent actions in carrying out the work, were consultative and highly participatory throughout. The process began with a scoping meeting at UNEP headquarters in Nairobi, Kenya in January 2011, which involved researchers working on various aspects of urban agriculture and food systems, and included representatives from the RUAF Foundation (Resource Center on Urban Agriculture), and the African Food Systems Urban Network. The Nairobi meeting resulted in further refinement of the assessment topic in preparation for regional consultative meetings held later in 2011 in West Africa, East Africa and South Asia.

The regional consultations engaged researchers, policy makers, urban planners and NGO representatives from the nine cities targeted for the assessment. The wide-ranging expertise and disciplinary perspectives of the participants was used to critically examine the assessment topic and sub-themes in the context of their respective cities. Each assessment team continued the consultative process by convening city inception meetings at the outset of their respective assessments to garner input from diverse stakeholder groups regarding relevant decision making priorities and knowledge deficits and to identify potential sources of information for the assessment. Several of the assessment teams convened subsequent meetings with city officials and others over the course of the assessment to update them on findings and to garner additional inputs.

The consultative process that the teams undertook in engaging city-based stakeholders produced reports that differed somewhat in their emphasis and direction, depending on decision making needs and priorities of relevant city-based stakeholder groups as well as on the availability of adequate information upon which to base the assessment. For example, while the overall assessment topic dealt with both urban and peri-urban agricultural systems the city teams emphasized these systems

Table 1
Composition of the nine city assessment teams.

City	Team composition
Addis Ababa	Researchers, city officials, NGOs
Kampala	Researchers, city officials
Dar es Salaam	Researchers
Ibadan	Researchers, city officials, NGOs
Dakar	Researchers, city officials, NGOs
Tamale	Researchers, NGOs
Dhaka	Researchers
Chennai	Researchers
Kathmandu	Researchers

differently; some cities gave considerable weight to both urban and peri-urban systems (e.g. Addis Ababa, Kampala, Dar es Salaam, Ibadan and Dhaka) while other cities primarily or exclusively emphasized peri-urban systems (i.e. Dakar, Tamale, Chennai and Kathmandu). The reports also emphasized different components of UPA, reflecting the relative importance of systems across the various cities. For example, urban livestock keeping featured prominently in the Kampala assessment, paddy rice and fisheries in Chennai, aquaculture in Dhaka, and irrigated vegetables in Dakar.

3. Key attributes of urban and peri-urban agriculture in the nine cities

3.1. Urban and peri-urban agriculture: Arriving at a common definition

In the context of today's demographic transition and the acceleration toward a predominantly 'urbanized' world, researchers continue to grapple with persistent definitional difficulties between urban, peri-urban and rural environments; not least, how these systems interact. The obvious challenge is that of temporal and spatial heterogeneity: where jurisdictional boundaries vary enormously across countries and over time (Montgomery, 2008). Moreover, a deeply-entrenched dichotomy between what in actuality is better conceived as a continuum (rather than detached zones) has given rise to mischaracterization of urban areas and a trivialization of the peri-urban transition space. As metropolitan areas continue to sprawl, there is an increasing perception that a deeper understanding of the peri-urban interface is critical for mitigating the multiplicity of stressors and uncertainties of the growing urban footprint (Simon, 2008).

Similar challenges are manifested in the agricultural context. Here, arriving at a meaningful and uniformly agreed distinction between urban and peri-urban spaces—which in large part determine the constraints and opportunities for agricultural production systems—has resulted in multiple characterizations of 'urban and peri-urban agriculture' (UPA). In the developing-country context, where informality, density, and types and patterns of land uses vary tremendously between and within metropolitan areas – the nature of peri-urban spaces are highly dynamic, both geographically and conceptually. As such, the concept of UPA has not been amenable to a single definition.

Despite inherent and persistent definitional ambiguities, at a basic level, the notion of UPA is generally acknowledged in the literature, as the production of crops, livestock agriculture, and cultivation of fish within and around metropolitan areas, for local sale and consumption (Hodgson et al., 2011). For the purposes of our analysis, the common characteristics of urban and peri-urban agriculture (UPA) include an emphasis on the production of fresh, nutrient-dense foods (leafy green vegetables, dairy, poultry, eggs, etc.) that is typically carried out on a small scale and is often opportunistic about accessing land, water, and other inputs. The UPA systems described in the nine city-level knowledge assessments fall well within this definition.

3.2. UPA's contribution to the urban food system

Table 2 describes important attributes of UPA production systems in the nine cities. These details were primarily obtained through peer-reviewed publications and city statistical reports and other

secondary literature. In the case of vegetables, dairy, and eggs, the UPA contribution in most of the African cities was quite high, confirming findings of previous reports on the extent to which UPA provides nutritionally important components to urban diets (e.g. De Zeeuw and Dubbeling, 2009; Lee-Smith, 2010; Simatele and Binns, 2008.) By contrast, evidence of UPA's contribution in the South Asian cities was considerably less. However, three cities is a small sample size, thus no broader inferences about UPA's contribution to the food supply in South Asian cities can be drawn from these findings. With a few exceptions, empirical examination and quantitative information on UPA's contribution to urban food systems is outdated and fragmented, indicating the need for robustly designed, quantitative studies to update the state of knowledge with respect to UPA's contribution.

One important finding across many of the cities concerned the highly dynamic nature of the urban livestock sector. Livestock rearing including poultry, dairy, cattle, and other ruminants, provides readily available market opportunities with quick returns and income stability from relatively little land area that can meet an increase in demand from the urban population (Guendel and Richards, 2002). Poultry production, in particular, is an important component of UPA in these cities, ranging from large-scale commercial operations to small-scale household production. Vertical chicken houses are an important response to space constraints. In two of the cities, Ibadan and Dakar, peri-urban poultry production serves as an important supply hub for their respective countries (Adelekan et al., 2014; Sy

Table 2
Description of UPA systems in the nine cities.

City	Main production systems	Contribution to urban food supplies
Addis Ababa	*Urban*: Vegetables, poultry, eggs, honey, dairy, livestock *Peri-urban*: Cereals, oil crops, vegetables, dairy, livestock	Based on 2007 estimate, 30% of vegetables (60–70% of leafy greens); 60–70% of milk; 40–60% of eggs
Kampala	*Urban*: Vegetables, cereals, dairy, livestock, poultry, eggs *Peri-urban*: Root crops, cereals, banana, vegetables, livestock	Precise estimates lacking. Large increase in urban livestock keeping over the past decade, especially poultry
Dar es Salaam	*Urban*: Vegetables, root crops and fruits, livestock, dairy *Peri-urban*: Fruits, cashew nuts, livestock, increasingly intensive farming practices	Based on estimates from 1997 and 2000, 90% of leafy vegetables and 60% of milk
Dakar	*Urban and peri-urban*: Intensive, commercial vegetable and fruit production, livestock	Dakar's peri-urban vegetable production provides 60% of total demand in Senegal. Based on 2000 estimate, 65% of national poultry demand supplied by peri-urban areas
Ibadan	*Urban:* Backyard vegetable and fruit production, livestock, aquaculture *Peri-urban*: Root crops and cereal plantations, livestock, vegetable plots, aquaculture	Estimates from 2001 indicate 54% of food crops to the city supplied by peri-urban areas. Based on 2012 estimates, urban horticulture accounts for 80% of the city's vegetable supply
Tamale	*Urban*: Vegetables, ornamental horticulture, livestock *Peri-urban*: Cereals, legumes, ornamental horticulture, livestock	No data available on UPA's contribution to the city's food supply
Chennai	*Peri-urban*: Paddy rice, marine-coastal fisheries, eggs, dairy cattle	No data available on UPA contribution. Most of UPA occurs in peri-urban areas where there has been a recent decline in cereal, vegetable and milk production
Dhaka	*Urban*: Backyard and garden cereal and vegetable crops, fruits, flowers, fish *Peri-urban*: Rice, cereals, sugarcane, vegetables, tobacco, oil seeds, fruits, flowers, fish	In 2010–2011, Dhaka metropolitan area produce 9.5% of the total rice demand for the city. Estimates from 2004 indicate 7–10% of fresh fish sold in Dhaka are from peri-urban areas
Kathmandu	*Peri-urban*: Cereals, vegetables, oilseeds, livestock	The Kathmandu Valley produces 8% of the highly perishable vegetables consumed in the city, according to a 2012 survey

Table references: Addis Ababa – Gebremichael et al. (2014), Kampala – Sabiiti et al. (2014), Dar es Salaam – Mlozi et al. (2014), Dakar – Sy et al. (2014), Tamale – Adelekan et al. (2014), Tamale – Gyasi et al. (2014), Chennai – Nambi et al. (2014), Dhaka – Rahman et al. (2014), Kathmandu – Dixit et al. (2014).

et al., 2014). In Ibadan production of chicks and eggs are traded throughout Nigeria and neighboring countries.

In many of the cities, dairy and other livestock producers are facing significant pressures from the escalating cost of animal feed, the increasing constriction of available grazing land, and the absence of government support for livestock keeping. In response to diminished and fragmented grazing lands and space constraints, dairy farmers, for example in Kampala and Dar es Salaam, have transitioned toward zero grazing, supported by 'cut-and-carry' fodder supplied from distant sources and sorted urban organic waste as a food source (Mlozi et al., 2014; Sabiiti et al., 2014). These trends are similar to what has been reported elsewhere for peri-urban livestock keepers facing diminished grazing areas (Duku et al., 2010). In three of the cities (Addis Ababa, Dar es Salaam, and Kampala), micro-credit schemes and other support from NGOs and government programs targeted to female-headed households, widows, and the elderly help mitigate some of the stresses facing urban livestock keepers, although these efforts have limited impact relative to the scope of the challenges (Gebremichael et al., 2014; Mlozi et al., 2014; Sabiiti et al., 2014).

3.3. UPA's contribution to livelihoods

The socio-economic status of UPA producers varies across the nine cities. High-income producers appear to be increasing in peri-urban areas of Dar es Salaam, Ibadan, and Kampala, likely in response to growing business opportunities, particularly for livestock keeping and fish rearing (Adelekan et al., 2014; Mlozi et al., 2014; Sabiiti et al., 2014). Vegetable producers generally tended to be of low- or middle-income status though there were exceptions; for example, Dakar's market-oriented vegetable production is an important economic activity for farmers across the income spectrum. In several of the cities, UPA farmers represent a broad spectrum of income classes, and a significant portion of the farmers are long-term residents who have obtained sufficient resources, networks, and other forms of social and physical capital to engage in UPA, and are not the poorest of the poor. This finding is consistent with previous studies by Dossa et al. (2011), Lee-Smith (2010), and Frayne et al. (2014). In Kampala, a series of economic and political crises in the 1970s and 1980s were an important precursor to the revitalization of UPA and it remains strongly embedded in the urban landscape today, with participation that spans income classes. This observation is consistent with other studies that have shown how urban agriculture exists partly in response to political and economic crises that spawn increased informalization of the economy (Babo, 2010; Gómez-Baggethun and Barton, 2013; Kutiwa et al., 2010; Maconachie et al., 2012).

4. Land and water resources for UPA

4.1. Policy and governance dimensions

Our analysis of the assessments reveals that diminishing access to land and water is a significant concern across all nine cities. The peri-urban dimension of UPA is under intensive pressure from urban encroachment and from increasing urban demand for water from peri-urban sources. High population growth rates in these cities are an important driver of encroachment onto peri-urban agricultural land. Additional factors exacerbating urban encroachment pressures identified across the nine assessments include the emergence of informal land markets that favor development in peri-urban areas, the erosion of traditional tenural arrangements that have safeguarded agricultural lands from development, the lack of policy frameworks for urban development and the promotion of urban renewal policies that relocate residents outward from core areas of the city (Table 3). Similar dynamics of urban pressures on peri-urban farmlands have been described by Lynch et al. (2001), Maconachie et al. (2012), Redwood (2009a,b), and Thuo (2013).

Urban encroachment is also exerting pressures on agriculture in the core urban areas of the nine cities. Within urban boundaries, vegetable producers and livestock keepers face increasing pressure to adopt space saving approaches to cope with increasingly crowded conditions. The assessments note that urban growth pressures on UPA also manifest in terms of waste hazards, as urban waste dumping

Table 3
Characteristics of land pressure on peri-urban agriculture in the nine cities.

City	Characteristics of peri-urban land conversion	Policy and governance dimensions
Addis Ababa	Informal and formal settlements outpacing infrastructure development. Buffer zones along rivers being developed counter to master plan. Peri-urban farmers displaced to marginal agricultural lands	Urban renewal policies resulting in relocation of farmers to increasingly marginal lands. Lack of harmonization between relevant land administration agencies. Corruption of political processes
Dar es Salaam	Liberalization of the transportation sector and housing subsidies for civil servants encourage settlement in peri-urban areas. Emergence of an informal land market; exponential increase in peri-urban land prices driven by housing needs	Mismatch of strong policy support for UPA at the state level with a lack of action on and antagonism of UPA at the municipal level (i.e. no official demarcation of land for UPA; eviction of farmers by municipal officials)
Kampala	High housing prices in the urban core driving a quest for affordable housing in peri-urban areas. Wetland areas converted for informal settlements and providing brick making materials. Emergence of informal land market as response to inefficient formal land market	Lack of an urban planning policy, and weakly enforced laws. Lack of qualified urban planners
Dakar	Peri-urban wetland areas and forests are under heavy encroachment pressures. Flood-prone areas traditionally used for agriculture are being developed for settlements. Exponential increase in peri-urban land prices driven by housing needs	Lack of clear delineation of roles and responsibilities between state and local authorities resulting in lack of enforcement of policy framework for protecting against development in the environmentally sensitive *Niayes* area
Ibadan	Loss of forest reserves and prime agricultural land including land adjacent to wetlands. High rate of illegal settlements along river corridors that exacerbate flooding. Industrial pollution. Increasing uncertainty over whether 'idle' land will remain so or be developed contributes to residents foregoing cultivation	Traditional communal land tenure system giving way to individual titles to land, which increases farmer uncertainties over land access. Deterioration of previously dependable infrastructure, including dams. Lack of urban land-use policy frameworks
Tamale	Changes in housing arrangements from traditional compound housing to self-contained dwellings, which require more land per capita. Selling of land to developers through informal land market. Prime agricultural land in valley bottoms under pressure for settlements	Traditional communal land tenure system giving way to arrangements whereby chiefs able to sell land to developers. High potential for corruption by traditional authorities
Chennai	Soil and water degradation, reduced profitability of farming, and industrial development and housing pressures driving land-use conversion. Farmers selling water to urban consumers rather than using on crops	Tripartite Agreement of 2000 created a lucrative market for selling water rights to industrial and urban users. Farmers not holding water rights are being marginalized
Dhaka	Infilling of water bodies through unplanned urban development has diminished natural drainage systems that are in turn negatively impacting on aquaculture	Weak enforcement of existing regulations, Lack of coordination between government agencies responsible for monitoring unplanned expansion/ encroachment
Kathmandu	Prime agricultural land being lost to industrial development, brickmaking and housing in peri-urban areas. Haphazard and unregulated development increasing the riskiness of agriculture as access to water resources becomes less dependable	Lack of urban policy frameworks and enforcement mechanisms for construction in peri-urban areas. The Kathmandu Valley Town Development Committee deemphasizes agriculture in its recent 5-year plans

Table references: Addis Ababa – Gebremichael et al. (2014), Kampala – Sabiiti et al. (2014), Dar es Salaam – Mlozi et al. (2014), Dakar – Sy et al. (2014), Tamale – Adelekan et al. (2014), Tamale – Gyasi et al. (2014), Chennai – Nambi et al. (2014), Dhaka – Rahman et al. (2014), Kathmandu – Dixit et al. (2014).

concentrates in low lying areas and utility and transport corridors—lands considered marginal for development but that are used opportunistically by urban farmers to produce vegetable crops. Population growth in the nine cities is projected to increase sharply over the next few decades, which will exert further pressures on the land and water base.

Attempts to develop proactive policy responses have begun to emerge in some of the nine cities. For example, policy frameworks that explicitly support UPA have recently been developed in Kampala, Dar es Salaam, and Tamale; a UPA policy framework is being developed in Addis Ababa, and existing environmental preservation policies in Dakar have direct potential to be supportive of UPA. Also, urban agriculture offices within city government have been established in Addis Ababa and Kampala.

While the creation of policies favorable to UPA in some of these cities represents progress, the existence of significant gaps between policy promulgation and actual implementation calls into question the effectiveness of current policy responses. For example, in Kampala, farmers are unaware of licensing requirements for UPA and view enforcement of new rules regulating UPA as arbitrary and punitive; moreover policies in Kampala that are ostensibly favorable for UPA are weakened when set against city efforts to crack down on informal food markets that are served by UPA (Sabiiti et al., 2014).

As noted in Table 3, our analysis of the nine assessments reveals that the lack of a coordinated response across different layers of authority is undermining efforts to protect lands used for UPA. For example, in Dar es Salaam, the assessment findings show that municipalities are not enforcing state laws meant to protect UPA and are reluctant to configure UPA into land-use planning, such as setting aside land for urban farming (Mlozi et al., 2014). In Dakar, vagueness in jurisdictional responsibilities between state level and municipal governments is hampering efforts to implement programs designed to preserve encroachment of urban settlements into environmentally sensitive areas where UPA is practiced (Sy et al., 2014); similarly in Tamale a lack of coherency between different policy bodies and government units with respect to land-use planning in peri-urban areas has led to diminished land security for farmers (Gyasi et al., 2014). In other cities, including Kathmandu, Chennai and Dhaka, the assessments found that there are no protections for agriculture in urban and peri-urban land use planning and existing land and water-use policies directly undermine peri-urban agriculture (Dixit et al., 2014; Nambi et al., 2014; Rahman et al., 2014).

These findings underscore the degree to which ambiguities in jurisdictions, policies, and legal codes in urban and, particularly, peri-urban areas exacerbate pressures on UPA. Other studies have shown how tensions associated with these governance failures lead to increased opposition between empowered and marginalized groups over productive resources, and fragmented landscapes with negative consequences for food production, water supply, waste regulation and flood risk management (Eakin et al., 2010; Garschagen et al., 2011; Makita et al., 2011; Mbiba and Huchzermeyer, 2002; UN Habitat, 2011).

4.2. Urban pressures and climate risks

The opportunistic use of marginal lands for urban farming, which is one of UPA's important characteristics, will likely become more difficult to the extent that urban growth pressures and climate change impacts converge. Examples of such convergence in the UPA context include insecure land tenure situations that prevent investments in irrigation to cope with moisture deficit periods, and the likelihood of more extreme rainfall, associated with climate change, superimposed upon more concretized land surfaces and haphazard urban growth patterns that create flood-conducive conditions (Kenyon et al., 2008; Wheater and Evans, 2009). The following examples from cities where the UPA assessment took place illustrate how urban development pressures are increasing farmer exposure to flooding and other climate risks.

- *Dar es Salaam*: Vegetable farmers report that flooding in river valleys has increased, attributable to development, which leaves fewer channels for water to disperse. Flooding interrupts production for months at a time; farmers cope by finding other income sources or temporarily migrating back to home villages or to other cities to grow vegetables for income while waiting for flood waters to abate. Vegetable farmers who lack land tenure security do not have the incentive, nor the means, to cap wells during floods to prevent contamination of wells and groundwater from urban wastes (McLees, 2011).

- *Addis Ababa*: Farmers report that flooding has intensified, which they attribute to increased siltation caused by upstream erosion and solid waste dumping from upstream urban areas (Gebremichael et al., 2014).
- *Ibadan*: Poultry and fish producers recently experienced high losses from flooding exacerbated by illegal building in stream setback corridors, blockage of the storm water drainage system by municipal solid waste dumping, and siltation of natural drainage waterways that reduces the rate of runoff discharge (Adelekan et al., 2014).
- *Dakar*: Urban development in the dunes surrounding the *Niayes* ecosystem has increased runoff volumes and flooding in lowland areas where intensive vegetable production takes place. Irrigation infrastructure is in poor condition (Sy et al., 2014).
- *Kampala*: Vegetable farming adjacent to wetlands, and mostly carried out by low-income households, faces consistent threat of washout by heavy rains and flooding. Projections of high settlements rates in these marginal land areas over the next few decades indicate potential that settlement patterns will amplify future flood risks (Sabiiti et al., 2014).
- *Kathmandu*: Quarrying, brick making, and extraction of sand and gravel from riverbeds, combined with poor planning, increase hazards of flooding, landslides, and debris flow that adversely affect agricultural lands. Deterioration of irrigation delivery systems is increasing peri-urban farmers' vulnerability to extended dry periods and drought (Dixit et al., 2014).
- *Tamale*: River valley bottoms that provide good land for agriculture and that drain the city of storm water runoff are experiencing increasing urban encroachment pressures (Gyasi et al., 2014).
- *Chennai*: Sale of water rights allocated for peri-urban rice production to urban consumption reduces irrigation water availability to those farmers who do not have water rights. Deterioration of irrigation delivery systems exacerbates the impact of diminished water rights during drought periods (Nambi et al., 2014).

The impacts of flooding in these cities are likely to intensify in the coming decades to the extent that extreme rainfall events become more prevalent with climate change. Analysis of long-term temperature trends indicated a decadal warming trend in most of the nine cities, and decadal analysis of extreme rainfall events indicated a slight increase in heavy rainfall events in two of the African cities, Addis Ababa and Dakar (Gebremichael et al., 2014; Sy et al., 2014).

Groundwater salinization was identified as a critical threat in the three coastal cities where high urban demand for groundwater is contributing to saltwater intrusion into freshwater aquifers. In Dakar, irrigation water used for intensive vegetable production is becoming increasingly saline, and the surrounding Cap Vert peninsula is highly vulnerable to sea level rise (Sy et al., 2014). In Dar es Salaam, vegetable farmers reported having to curtail production during periods when irrigation water salinity is high (Mlozi et al., 2014). In Chennai, the transfer of water rights from farmer to urban consumer has accelerated groundwater extraction thus increasing the potential for saltwater intrusion, a situation that will be increasingly aggravated by sea level rise (Nambi et al., 2014).

Several of the nine city assessments explored, through surveys and focus group discussions, how urban farmers observe and perceive climate change. These perceptions included increased temperatures, especially at night, more intense and unseasonable rainfall events, stronger winds, and increased cloud cover (Table 4). Farmers attributed hazards such as flooding to changes in both climatic and non-climatic stresses, the latter of which including blocked storm drainage systems, unregulated settlements in environmentally sensitive areas, and land degradation. The extent to which vulnerabilities are increasing due to climate change as opposed to changes in covariate stresses that increase vulnerability to climate is not clear.

A consistent finding from across the nine cities is that climate impacts are intensifying underlying vulnerabilities that UPA systems and related livelihoods are experiencing due to urban development pressures. Two recent studies describe situations comparable to our findings presented in this paper. Simatele et al. (2012) reported that UPA farmers in Lusaka, Zambia contend with significant flooding risks that are exacerbated by land degradation linked to illegal quarrying, and Aubry et al. (2012) described how rice cultivation in peri-urban Antananarivo, Madagascar has become increasingly risky once embankments were constructed in the floodplain to protect the city.

Table 4
Observations of climate change by UPA farmers.[a]

City	Observations of climate change	Impacts of concern to farmers
Addis Ababa	Increase in heavy and unseasonable rainfall; intensified flooding; increase in rust (fungal) diseases and insects; increase in livestock diseases during warm periods	Flooding losses and crop storage losses from heavy and unpredictable rains; flooding takes land out of production for prolonged periods
Dar es Salaam	Unseasonably high temperatures; unseasonable rains; intensified flooding; salinization of irrigation water; stronger winds; increased cloudiness, which farmers linked to increased fungal diseases	Vegetable producing season shortened due to higher temperatures, stronger winds, and increased salinity of irrigation water; flooding takes land out of production for prolonged periods
Kampala	Changes in the timing and distribution of rainfall; increase in unseasonable and heavy rainfall events; warmer temperatures, particularly at night; stronger winds; changes in cloud cover and increased hail	Soil erosion is increasing and soil water holding capacity is decreasing; heat stress of livestock is increasing, as is livestock disease prevalence; livestock shelters and crops damaged by heavy rains and hail
Dakar	Increasing salinity of irrigation water; increase in heavy rainfall; intensified flooding; unseasonably high temperatures	Floods, poor quality irrigation water, and high temperature stress results in increasingly risky vegetable production
Ibadan	Changing rainfall patterns including delayed onset of the rainy season and/or early cessation of rains; increase in heavy rainfall events and flooding; high temperatures	Two harvests of maize no longer possible, switching to cassava; reduced flowering of vegetable and pulse crops; crops and agricultural processing equipment washed away by floods; high livestock and aquaculture losses; food spoilage
Tamale	Rainfall increasingly erratic, unseasonably high temperatures, changing pattern of the *Harmattan* winds, increased windstorms	Drier conditions and shortened rainy season; high temperature stress at critical crop development stages
Kathmandu	Rainfall becoming increasingly erratic	Delays in the monsoon rains, which shift planting times and reduce maturation periods; weed management during low rainfall periods

Table references: Addis Ababa – Gebremichael et al. (2014), Kampala – Sabiiti et al. (2014), Dar es Salaam – Mlozi et al. (2014), Dakar – Sy et al. (2014), Tamale – Adelekan et al. (2014), Tamale – Gyasi et al. (2014), Kathmandu – Dixit et al. (2014).
[a] No surveys of farmer observations of climate change were obtained from Dhaka or Chennai.

In the Lusaka study, Simatele et al. found evidence that farmers are responding by making changes to their farming systems—switching to drought tolerant crops in some areas and cultivating rice in other areas where flooding episodes are becoming more common. Similar findings of changing production practices emerged from a number of the nine cities included in our analysis. Notable examples include Addis Ababa farmers in flood prone areas switching from leafy greens to more inundation-tolerant root crops in response to increased flooding risks, peri-urban farmers in Tamale and Dar es Salaam favoring more drought tolerant crops and varieties, and farmers in peri-urban Ibadan switching from maize to cassava because of heat and water stress (Adelekan et al., 2014; Gebremichael et al., 2014; Gyasi et al., 2014; Mlozi et al., 2014). Conversely, Chennai farmers are facing difficulties in switching from rice to finger millet, as a drought mitigation strategy, because of labor shortages, lack of appropriate processing facilities and other institutional barriers to agricultural diversification (Nambi et al., 2014). Grothmann and Patt (2005) report a similar situation in Zimbabwe where high institutional barriers obstructed farmers who were trying to shift from maize to millet during low rainfall periods.

The strong interactions between climatic and non-climatic stresses, and the high likelihood that these stresses will intensify in the future, call into question UPA's suitability as an effective adaptation response in rapidly growing urban environments, as has been suggested by others (e.g. Dubbeling and de Zeeuw, 2011; FAO, 2012; Gerster-Bentaya, 2013; Lwasa et al., 2014). Though UPA could play a role in bolstering adaptive capacity and urban resilience, in its current form UPA's potential as an adaptation response is seriously constrained and will become increasingly so in the absence of significant policy interventions and investments to enhance its sustainability. Lwasa et al. (2014) identify a number of nascent initiatives toward integrating UPA and urban forestry into urban land use planning that could provide a way forward for UPA. However, it will be critical to identify and address knowledge

and governance barriers to their full implementation. Moreover, significant uncertainties exist concerning interactions between land cover change and climate change in urban environments that will need to be captured in land-use planning. Section 5 explores responses that could advance such efforts.

4.3. Pollution and wastewater

In most of the nine cities assessed in this study, farmers rely on urban wastewater and on heavily polluted surface waters to irrigate vegetables. Increased industrialization and unregulated dumping of industrial and household wastes into urban surface waters was noted as an important threat to the safety of UPA products in Addis Ababa, Dar es Salaam, Ibadan, Dhaka, Kathmandu, and Tamale, particularly where industry is moving rapidly into the largely unregulated peri-urban territory (Adelekan et al., 2014; Dixit et al., 2014; Gebremichael et al., 2014; Gyasi et al., 2014; Mlozi et al., 2014; Rahman et al., 2014). Risks identified from the assessments include industrial pollution of surface waters in peri-urban Ibadan that is increasing health risks associated with food production; contaminated runoff behind micro-dams increasing pollutant levels in irrigation water used for urban agriculture in Tamale; and a pilot investment in wastewater treatment for irrigated vegetable production in Dakar that has not led to a meaningful reduction in farmer reliance on untreated wastewater for irrigation.

These findings are consistent with those from other developing-country cities, where use of contaminated waters for irrigation of urban crops is a widespread practice by urban farmers. The practice entails benefits derived from providing nutrient-rich irrigation water at no or little monetary cost (e.g. Allen, 2003; Eaton and Hilhorst, 2003; Parkinson and Tayler, 2003; Qadir et al., 2010; Raschid-Sally, 2013), as well as hazards, related to biological and chemical contamination for both producers and consumers of UPA products (Birley and Lock, 1998; Qadir et al., 2010; Hanjra et al., 2012; Hofmann, 2013). The conveyance and use of wastewater is another critical concern for accountability and property rights governance (Raschid-Sally and Jayakody, 2013). To achieve more sustainable wastewater use, Hanjra et al. (2012) stress the need to create adaptive co-management processes that emphasize inclusiveness, dialogue, and conflict resolution, as well as improved inter-sectoral policy coordination.

The challenge of managing urban water resources risks will increase with the intensification of both urban development pressures and climate change. While the general contours of the health hazards associated with untreated wastewater use in UPA are fairly well understood, understanding is still weak about how such hazards could change under a warmer and more variable climate. Farmers are expected to increase their reliance on irrigation to cope with greater evaporative losses from crops under warmer conditions; thus, there is a strong need for new information about potential shifts in risk thresholds. Increased reliance on irrigation, in the absence of measures to pre-treat wastewater and/or reduce unregulated industrial discharge into rivers, could result in heavier loading rates of heavy metals and other pollutants in soil (Rattan et al., 2005; Li et al., 2009; Hanjra et al., 2012) leading to greater potential exposure of producers and consumers to contaminated food.

5. Resilience of UPA, and responses that promote an urban resilience transition

5.1. Analysis of resilience

Drawn from the theory of ecological resilience –the ability of systems to resist, endure and recover from disturbances and perturbations–the application of urban resilience requires approaches that are able to harness the innovation potential of cities and that recognize inter-dependencies between ecosystem health, livelihoods and multi-functional landscapes (Leichenko, 2011; Bahadur et al., 2013; Forster and Escudero, 2014). The forces shaping UPA's resilience are largely circumscribed by the accessibility and quality of the land and water resource base that underpins UPA's productivity, as well as by a number of economic and sociopolitical factors that interact with the resource base. These factors include the degree of policy recognition of, or antagonism toward, UPA; the timeliness and adequacy of inputs and information that can be productively used by farmers; and, the availability

of other livelihood options that allow flexibility in responding to risks and opportunities associated with farming in urban and peri-urban environments.

The factors that shape the multi-stressor context of UPA, as described in the preceding sections, provide a basis for identifying key attributes of UPA's resilience in rapidly growing developing-country cities and for identifying critical entry points for bolstering its resilience. In Table 5, we evaluate the state of resilience of UPA across the nine cities assessed, adapting a framework developed by Tyler and Moench (2012) as a basis for considering components of systems, agents, and institutions that shape UPA. The Tyler and Moench framework views resilience in terms of the interplay among the three components: *systems* that contain human and environmental elements; *agents* that carry out actions responding to and recovering from shocks and stresses; and *institutions* that shape the ability and capacity of agents to act effectively.

For the purposes of this analysis, the *systems* are agricultural activities intermixed with residential and industrial settlements in urban and peri-urban settings, the *agents* are primarily though not exclusively farmers and the *institutions* primarily encompass those related to city-level governments and the policy frameworks in which they act. These do not represent the full sweep of systems, agents and actors that influence UPA but they are the principal ones examined in this nine-city assessment.

The information contained in Table 5 demonstrates diminishing resilience of UPA in the face of significant urban development pressures, with the potential of climate change to act as a stress multiplier. In the 'systems' category, development pressures are impinging on the flexibility and robustness of UPA, and the ability for safe failure is undermined by climate risks interacting with other non-climatic changes, such as rapid land-use conversion in urban areas. Flexibility and robustness in turn link directly to impoverished rights and entitlements and decision making for UPA, as described in the 'institutions' category. Attributes of UPA in these nine cities that have potential to support greater resilience include redundancy and diversity in the 'systems' category, and responsiveness and reorganization in the 'agents' category, though these are relatively minor contributions to resilience when set against the factors that undermine resilience of UPA.

The findings of this analysis are specific to UPA in the nine assessed cities and thus cannot be extended to other cities without careful consideration of city-specific dynamics that influence the vitality of UPA systems. However, the consistency with which urban pressures, governance failures and policy shortcoming were manifested across the nine cities suggests that this analysis could have broad applicability to other urban areas in the developing world. Sections 5.2–5.4 describe potential responses that could enhance resilience though improved risk management, more comprehensive knowledge generation, and stronger policy measures that would seek to optimize ecosystem services provided by UPA. Such efforts have the potential to also advance resilience transition in the cities themselves.

5.2. Enhance risk management and effective policy outcomes

City-specific recommendations from the nine knowledge assessments addressed a range of risk management priorities relating to UPA. These include improved access to productive inputs and credit, stronger links to markets and other opportunities for value-added agriculture, enhanced support from extension services, and better access to information, especially regarding weather forecasts and flood early-warning systems (Adelekan et al., 2014; Gebremichael et al., 2014; Gyasi et al., 2014; Sabiiti et al., 2014; Sy et al., 2014). Such investments largely conform with near-term needs identified to enhance climate risk management for current, and near-term future, climate change and development challenges in rural areas (Niang et al., 2014). Achieving progress toward enhanced risk management requires a flexible and varied response. Across the nine cities, there were a number of recommendations to give greater agency to farmers through creating opportunities to form farmer associations, convening multi-stakeholder task forces to explore ways of addressing threats to UPA sustainability, and integrating UPA into existing policy frameworks for both food security and poverty reduction.

Our analysis suggests that more robust and responsive policy outcomes for UPA could be achieved by embedding UPA within urban resilience-building and adaptation-planning efforts, which emphasize just and accountable governance and effective coordination. For example, there are a number of potential links between efforts to bring UPA into a more supportive policy environment and efforts

Table 5
Characteristics of UPA resilience in the nine cities examined in the UPA assessment, framework adapted from Tyler and Moench (2012).

Criteria	State of play in the nine cities
1. Systems category	
Flexibility	UPA is spatially and temporally opportunistic and innovative but that flexibility is increasingly constrained by urban growth pressures An example of where flexibility remains strong is in some urban livestock systems (e.g. Kampala) that are transitioning to zero grazing and able to productively use urban organic wastes as a feed substitute for traditional fodder that is becoming increasingly scarce, and in the use of elevated platforms for floriculture production that reduces exposure to flooding
Robustness	UPA is becoming less robust as competition for land and water interact with more intensive flooding, higher temperatures that limit cropping cycles, heightened pest and disease pressures, and greater difficulties in accessing adequate irrigation water Robustness will be further diminished by future climate change; however the extent this could be offset by adaptation is unclear. Robustness of UPA is likely to be further undermined by sea-level rise in coastal cities
Redundancy, modularity and diversity	Redundancy and diversity remain sources of strength for UPA in most of the 9 cities, as evident by short value chains and high source diversity that contribute milk, eggs, poultry, vegetables, etc. to informal markets Modularity is diminishing to the extent that agriculture on high value lands in peri-urban areas, such as those with good soils and not flood prone, is being displaced to lower quality lands
Safe failure	At the production systems level, safe failure for UPA may be diminished where slow-onset disaster risks are punctuated by extreme events, as in the case of saline intrusion into aquifers added to increased risk of storm surges that affect freshwater sources for agriculture, or where haphazard urban planning interacts with extreme rainfall events to increase the frequency of failure in production systems, thus increasing the recovery burden At the individual or household level, potential for safe failure is variable. For low-income producers the loss of vegetable crops to flooding diminishes safe failure whereas for middle and high income farmers safe failure is presumably greater to the extent that this income class has greater capital resources for diversification and recovery
2. Agents category	
Responsiveness and reorganization	UPA systems, given the right conditions, can be responsive to market signals that create new opportunities. Responsiveness is evident through new market opportunities that have emerged, particularly for high-income producers (e.g. in aquaculture and livestock)
Resourcefulness	Resourcefulness is circumscribed by external forces that shape robustness and flexibility (described above), and where farmers lack access to credit, timely inputs and formal information streams, as in the case of weather forecasts and early warning systems
Capacity to learn	A capacity to learn that spans formal and informal spheres, and institutional and jurisdiction levels, is constrained by lack of farmer voice within the urban policy and planning process, poor interagency and inter-ministerial communication, an outdated and fragmented knowledge base regarding UPA's contribution to urban food systems and food security, as well as by poor understanding of how the amplitude of risks and impacts on UPA may increase with climate change Recent efforts to formalize UPA within policy frameworks could enhance learning capacities, particularly where such policies contain strong outreach and enforcement mechanisms
3. Institutions category	
Rights and entitlements	Erosion of rights and entitlements for UPA farmer is evident through policy gaps and governance failures, lack of formal land tenure, escalating land prices and the emergence of informal land markets Diminishing access to quality land and water, poor access to formal credit and markets, and information streams contribute to low entitlements
Decision making	UPA is gradually gaining visibility in urban policy and planning frameworks though in many cities it is still largely ignored or actively discouraged in the policy-making realm The lack of coherent and enforceable urban planning frameworks, and political corruption in peri-urban land allocation decisions, contribute to the invisibility of UPA in urban land use decisions
Information	The flow of information between farmers and urban policy and sectoral planning is

Table 5 (*continued*)

Criteria	State of play in the nine cities
	generally quite weak though in some of the assessed cities it is improving Lack of access to flood early warning systems and to actionable weather forecasts was noted as an important information bottleneck. The hindrances noted in the Capacity to Learn entry above also play into poor information flow

to promote community-based adaptation (CBA). The CBA approach operates at the local level in communities that are particularly vulnerable to the impacts of climate change. It focuses on empowering and strengthening the capacity of local people by implementing community-based development activities, in a highly participatory manner, building on existing cultural norms and addressing local development concerns that underlie vulnerability (Ayers and Forsyth, 2009; Dodman and Mitlin, 2013); such characteristics complement the need for greater support of UPA in the policy process. Recognition of the need for greater inclusion of NGO and civil society coalitions in strategic planning processes for adaptive urban governance (Brinkmann et al., 2012) and for robust stakeholder platforms to empower local communities and inform policy development (Dodman and Mitlin, 2013; Prain and Lee-Smith, 2010) provide opportune entry points for UPA. However, it is important to bear in mind that the "right" policies are only one part of an enabling environment. Other critical enabling factors include capacity building mechanisms and financial support for relevant institutions, and a clear understanding of local-level impediments and trade-offs associated with new policies and of the solutions to such impediments (Halloran and Magid, 2013; Kithiia, 2010; Roberts et al., 2012).

5.3. Optimize UPA's ecosystem services

Better understanding and optimizing the multi-functionality of UPA, and quantifiably estimating ecosystem services associated with its use, are key to strengthening the sector in the face of urban encroachment and the rapidly increasing demand for non-agricultural uses of urban land and water resources (Lwasa et al., 2014; Moglia, 2014). Notable examples of ecosystem service provision from UPA that emerged through the knowledge assessments include the productive reuse of urban organic wastes for food production, and the use of wetland fringe areas and other flood-buffering lands for agriculture. The concept of urban ecosystem services has taken on greater importance as cities grapple with building resilience to a wide range of shocks and stresses in increasingly hazard-prone urban landscapes (Cilliers et al., 2014; Gómez-Baggethun and Barton, 2013; Lwasa et al., 2014; Roberts et al., 2012). Urban and peri-urban agriculture can be an important component of urban ecosystem services, beyond food provisioning, offering opportunities to regulate water flow and moderate runoff, mitigate urban temperature extremes, and recycle wastes (Gómez-Baggethun and Barton, 2013). Such 'multi-functionality' has developed as an approach to optimize the range of positive externalities generated from agriculture that ultimately contributes to society beyond the market-based valuation of agriculture (Renting et al., 2009).

On the reverse side of these positive externalities, ecosystem disservices are recognized as an important part of the urban resilience equation, given the interlocking nature of food, water, health, energy and commerce systems within urban areas (Cilliers et al., 2014; Gómez-Baggethun and Barton, 2013). In the context of UPA, our analysis suggests that these disservices include biological and chemical contamination of food and the environment, as well as nuisances associated with livestock keeping in confined areas and zoonotic diseases. While the ecosystem services associated with UPA outweigh its disservices, the latter category deserves attention because of the potentially significant health risks associated with unregulated use of dangerous pesticides, reliance on untreated wastewater and heavily polluted surface waters for irrigation, air pollution particulates and heavy metals deposits in soils and crops, and potential for emergence of zoonotic disease outbreaks in confined areas (Agrawal et al., 2003; Binns et al., 2003; Birley and Lock, 1998; Carvalho, 2006; Galt, 2008; Lynch et al., 2001; Prajapati and Tripathi, 2008). As noted in Section 5.3 below, there is a need to better

understand how health and environmental risks associated with UPA may change under warmer and more variable climate regimes.

As with other urban ecosystem services, the capacity to optimize the multi-functionality of UPA requires greater understanding of trade-offs associated with its various functions in the context of other non-agricultural demands for urban land. The concept of 'territorial sustainability' (Aubry et al., 2012) may provide a useful way of unpacking the complex issue of multi-functionality. Aubry et al. argue that where UPA can be shown to contribute a critical function, such as flood protection that cannot easily be replaced by alternative land uses, then a high territorial sustainability value for UPA can serve as a counterforce against urban expansion pressures. To be appropriate to the reality of rapidly expanding urban areas, territorial sustainability should also consider the strong linkages between urbanization, agriculture, and deforestation in situations where displacement of urban and peri-urban agriculture by urban development pushes farming further out into forests, wetlands and other environmentally sensitive areas (Brinkmann et al., 2012; Forkuor and Cofie, 2011; Vermeiren et al., 2012; Seto et al., 2010). Moreover where known limits to such expansion exist, for example in semi-arid urban areas where absolute water scarcity prevents UPA from expanding outwards, anticipatory measures and monitoring strategies will become increasingly important to preserve farmland (Brinkmann et al., 2012).

Inclusion of UPA's territorial sustainability in urban planning requires a robust foundation of knowledge on land-use change and hydrologic functions aligned with strong governance systems and political will. In this context, stronger capacities are needed for instituting spatial planning that considers locally relevant climate and land-use scenarios, and that evaluate the potential for increased frequency of damaging floods and other impacts from extreme events under different land-use scenarios. It is important to understand where UPA can be most strategically placed to enhance flood protection and where potential food production trade-offs exist. Significant research efforts are needed to inform decision making in this arena (Aubry et al., 2012).

As noted in Section 5.2, efforts to strengthen capacities for urban adaptation offer an opportunity to encompass flood suppression, urban waste stream reduction and other ecosystem services of UPA, provided that governance shortcomings and institutional weaknesses are sufficiently understood and addressed. Addressing these challenges requires multilevel institutional coordination, stronger horizontal interplay across sectors and policies, better cooperation across formal and informal spheres that engage key actors, advocates, and champions, and mechanisms for enforcement of legal codes (Bahadur and Tanner, 2014, 2013; Mimura et al., 2014). Experiences gained through resilience-building initiatives, such as the Asian Cities Climate Change Resilience Network, indicate potential modalities for achieving vertically integrated problem solving (Sharma et al., 2014). The lack of these elements in the nine cities involved in the UPA assessment contributed strongly to on-going loss of high quality agricultural lands to urban development pressures that in turn diminishes the potential of UPA to support resilient, adaptable cities. The situation in these nine cities reflects planning challenges in both developing and industrialized regions, though they are often more acutely experienced in rapidly growing developing-country cities.

5.4. Address critical knowledge gaps

Garnering greater support for actions that enhance UPA's sustainability requires a robust evidence base to inform and support policy and action. Information about UPA is fragmented and largely out of date, as was apparent across the nine cities examined in this assessment. The lack of reliable data on the contribution UPA to urban food systems, food security, and livelihoods in cities reflects the informal nature of the enterprise and its various non-income dimensions that do not conform to official information-gathering efforts that prioritize economic indicators within the formal economy. Bringing greater prominence to UPA and positioning it squarely within the urban adaptation realm requires new research to better quantify and analyze long-standing uncertainties around UPA related to food and livelihood security, its urban economic dimensions, and its ecosystems provisioning. Moreover, embedding UPA within broader challenges facing urban food systems and food security—where and how is food produced, transported, processed, stored, marketed and consumed—would

be a more robust approach than would one that focuses solely on urban food production (Battersby, 2013).

Knowledge generation on emerging global change challenges for UPA is also required. Understanding climate change impacts on UPA, such as those manifested through abiotic and biotic stress of crops and livestock, lags far behind understanding of such impacts on staple crops and extensive livestock systems in rural agricultural systems. In considering UPA, the urban context brings a unique set of challenges with respect to food production. Climate surprises may reveal new thresholds for crop and livestock components of UPA and, for that matter, the infrastructure systems that deliver food, water and energy to cities. The IPCC's recent Special Report on Climate Extremes (IPCC, 2012) estimated a substantial reduction in the return period for a 1-in-20 year heat wave event by mid-century across much of Africa and Asia, raising significant challenges for managing urban services and producing food in urban environments.

There are also important knowledge deficits with respect to how expected increases in temperature and humidity and changes in rainfall patterns could influence existing or emerging pest and disease pressures on urban crops and livestock. Understanding of interactions between climate change and agricultural pests and diseases is increasing (Anderson et al., 2004; Garrett et al., 2006; Thomson et al., 2010; Müller et al., 2011), though not for the kinds of widespread but small-scale vegetable and livestock production systems found in urban areas of developing countries. In such systems, research lags behind farmer observations and knowledge of local conditions and trends. Our analysis established that pest and disease management for crops and livestock were a significant concern in many of the assessed cities (e.g. Dar es Salaam, Dakar, Kampala, Addis Ababa, and Ibadan). Farmers succumb to advice and advertisements for highly toxic pesticides—many of them banned in northern regions—with little or no extension service-advice on the dangers involved with the use of these compounds, the suggested timing or rates for applications to have optimal effect, or measures to protect the user or surrounding areas from the toxic effects (Binns et al., 2003; Carvalho, 2006; Galt, 2008). While integrated pest management and organic vegetable production are being promoted on a project-by-project basis there is no sustained support for this effort.

Knowledge gaps also exist with respect to how a warming climate could affect waterborne pathogens and parasites. This particular concern is relevant to the widespread use of wastewater in UPA. Studies by Mas-Coma et al. (2008, 2009) and Karvonen et al. (2010) detected increased activity of common human parasites under elevated water temperatures, suggesting a potential for increased risk in a warming climate, though there have been no studies done to specifically understand the health hazards dimensions across the variety of UPA systems that rely on untreated or inadequately treated wastewater.

6. Conclusions

This is the first study that the authors are aware of in which UPA is examined through the dual lens of urban and climate pressures. The paper was able to draw from a large array of developing region cities to describe important governance dimensions of UPA that have relevance for urban adaptation and resilience.

Overall, UPA across these nine cities remains reasonably vibrant despite the fact that the sector faces significant interlocking stresses stemming from marginalization of land and water resources and climate risks that could diminish its resilience and undermine its long-term sustainability. Many of these stresses are slow onset in nature (i.e. changes in land and water access, increasing pollution loads, etc.) and the impacts of these stresses on UPA are largely invisible within the formal urban planning and policy milieu.

Urban pressures are currently a much larger driver of vulnerability in UPA systems than is climate change. However, climate stresses are likely to intensify as urban areas, and the UPA systems embedded within them, become increasingly vulnerable to impacts stemming from storm surges and sea level rise, heat stress, heavy rainfall, flooding, drought, and water scarcity associated with climate change. Farmers across the assessed cities consistently noted the degree to which the increasing urban footprint is reducing thresholds for damaging floods that impact their production systems. Such

circumstances call into question UPA's potential to play a significant role in advancing urban adaptation and resilience-building efforts, absent significant policy interventions and investments to strengthen the sector, and indicate the need for proactive measures to help UPA itself adapt to increased risks from climate change and other pressures.

Urban policies are slowly beginning to recognize urban food production as a legitimate and desirable activity yet substantial hurdles remain in moving these nascent policy efforts toward formalized actions that produce substantive benefits for UPA. Weak governance—manifested as vague and overlapping institutional mandates, lack of clear delineation of functions and responsibilities between national, state and local governments, lack of incentives for cross-sectoral coordination among relevant government ministries, and corruption in the allocation of land—presents significant impediments to progress on the policy front. Sharply rising land prices, the emergence of informal land markets, and erosion of traditional tenural arrangements compound these governance failures.

Responding effectively to the broad swath of sustainability challenges facing UPA, as well as the uncertainties associated with climate and other global change drivers, requires a comprehensive approach to risk management that encompasses resiliency. Strategies to enhance the resilience of UPA will not succeed based solely on the merit of its food producing function given the substantial demand for non-agricultural uses of land and water in rapidly expanding cities. The greatest opportunities for bolstering UPA instead lie in understanding and optimizing the multi-functionality of UPA in increasingly hazard prone urban landscapes. The ability to optimize multi-functionality requires greater understanding of the various tradeoffs associated with the environmental services to urban areas provided by UPA, notably flood dampening, set against other non-agricultural demands for land in urban areas. Such knowledge will become increasingly critical as urban areas contend with increasing flooding and other risks stemming from haphazard urban development interacting with climate change.

Acknowledgements

The authors wish to acknowledge, and sincerely thank, the assessment teams in Addis Ababa, Chennai, Dakar, Dar es Salaam, Dhaka, Ibadan, Kampala, Kathmandu, and Tamale whose efforts through the UPA assessments provide the basis for this paper. The authors also acknowledge, and are grateful for, the financial support for the assessments provided by the European Commission, the United Nations Environment Programme, the United States Agency for International Development, and the United States Global Change Research Program.

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