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Urban and peri-urban agriculture and forestry: Transcending poverty alleviation to climate change mitigation and adaptation

Shuaib Lwasa [a,*], Frank Mugagga [a], Bolanle Wahab [b], David Simon [c], John Connors [d], Corrie Griffith [e]

[a] Department of Geography, GeoInformatics and Climatic Sciences, School of Forestry, Environment and Geographic Sciences, Makerere University, Uganda
[b] Department of Urban and Regional Planning, University of Ibadan, Nigeria
[c] Department of Geography, Royal Holloway, University of London, UK
[d] School of Geographical Sciences and Urban Planning, Arizona State University, USA
[e] International Project Office, IHDP Urbanization and Global Environmental Change Project, Arizona State University, USA

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ABSTRACT

A range of published and grey literature over the last three decades has underlined the importance of urban and peri-urban agriculture and forestry (UPAF) in cities of developing regions. The focus in the published literature is on livelihoods, poverty reduction and ecosystems services at multiple city scales. Cities of developing regions, particularly in Africa, are searching for ways of addressing the unavoidable impacts of climate change and UPAF has demonstrated scalable adaptation and mitigation potential. However, evidence of UPAF's role in mitigating and adaptation to climate change is scattered in various reports and has not been synthesized for its potential role in developing urban adaptation strategies. Building on the earlier poverty reduction focus of UPAF research, this paper contributes to UPAF knowledge regarding mitigating and adapting to climate change in urban and peri-urban areas in East and West Africa. The paper reports a synthesis based on a systematic review of the available literature on these regions, and selected sources on other parts of sub-Saharan Africa. The paper also examines the extent to which literature conveys any evidence for UPAF playing a role in mediating the effects of climate/environmental change. Limited empirical verification was undertaken in Kampala and Ibadan, but this does not form the basis for systematic generalization. The key emerging areas of adaptation and mitigation include enhanced food security,

* Corresponding author. Tel.: +256 772461727.
E-mail addresses: lwasa_s@arts.mak.ac.ug, shuaiblwasa@gmail.com (S. Lwasa).

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productive greening, ecosystem services and innovative policy for urban resilience and transformation.

1. Introduction

An estimated 40% of Africa's total population live in urban areas (UN-HABITAT, 2009, 2011). Although urbanization rates vary between and within countries or regions, literature shows a demographic shift toward an increasingly urban populous across the continent. The demographic change will have both social and environmental implications within urban areas and their resource providing regions (Potts, 2012a). Currently, only a modest proportion of net urbanization in Africa is related directly to climate and environment-induced migrations, but this is likely to increase in the future (Biermann and Boas, 2010). Already, some cities in the Sahel region, such as Dakar are experiencing higher net rural-urban migration due to weakened rural livelihoods exacerbated by a variable and changing climate (Cissé et al., 2005). Future urbanization trajectories pose both challenges and opportunities for addressing climate change impacts. While climate variability and environmental change impacts are well-documented in rural areas, literature is increasingly pointing to impacts in cities and their hinterland regions (UN-Habitat, 2011). There are concerns about climate change impacts reinforcing poverty, exacerbating food insecurity and increasing vulnerability of urban populations (UN-HABITAT, 2009; Simon, 2013; Satterthwaite et al., 2007).

Many city regions in Africa are experiencing or are at risk of sea level rise, storm surges, saline water intrusion, coastal erosion, floods, and droughts (Niang et al., 2002; Grimm et al., 2008; Rosenzweig et al., 2011). These impacts are likely to have implications for urban systems, urban infrastructure, public health, economic development, local environmental resources, food security, and water supplies and will affect disproportionately the vulnerable urban poor, women, elderly, and the young (Satterthwaite et al., 2007; Adejuwon, 2000; Adelekan, 2009; Roberts et al., 2011; UN-HABITAT, 2006). Since urbanization exacerbates these vulnerabilities, there is growing evidence that urban and peri-urban agriculture and forestry (UPAF) can play a role in poverty alleviation and potentially reduce vulnerability to climate change (Lwasa et al., 2009; Asomani-Boateng and Haight, 1999; International Development Research Centre (Canada), 2011; Lee-Smith, 2010; Ricci, 2012; Masashua et al., 2009). The relationship between poverty and UPAF has been well studied and emerging knowledge points to UPAF's potential to address climate risks (Dolan and Walker, 2004; Mougeot, 2000a). Several studies of UPAF point to benefits of nutrition improvement, food security, livelihoods, and the provision of ecosystem services along the urban-rural gradient, as well as contributions to mitigation of climate change at the macro-scale (Lwasa et al., 2009; Padoch et al., 2008; Swalheim and Dodman, 2008). This paper systematically analyses the evidence, focusing on eight cities in East and West Africa of Kampala, Addis Ababa, Dar es Salaam, Douala, Ibadan, Nairobi, Dakar and Accra, although drawing on relevant studies elsewhere in sub-Saharan Africa where appropriate. Limited empirical verification of the literature was undertaken in two of these cities, Kampala and Ibadan, but these are not used as the basis for broader generalization. The objective is to identify scalable strategies of UPAF for climate change mitigation and adaptation. The paper also analyses the limitations of UPAF in the context of intra-urban vulnerabilities differentiated by socio-economic structure and the power relations that are created by invariant urban policy (Action Aid, 2006; Frayne et al., 2012; Douglas et al., 2008).

2. Framing UPAF in the context of climate change

Studies on UPAF have often focused on the issues of livelihoods, poverty reduction, environmental pollution, health risks and urban policy. These studies often emphasize how cities can better provide safeguards from the negative consequences of UPAF, particularly biological-chemical risks, such as use of grey water and heavy metal contamination from fuel and oil residues that enter the food chain (Nabulo, 2002; IWMI, 2006). The scales of assessment range from household to city-regional scales and these have aided understanding of production, distribution, access and utilization of crop, animal

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and nutrient products. Increased research is directed toward the ecological importance of UPAF, focusing on the provision of ecosystem services along an urban-rural gradient in the context of expanding cities and their influence on hinterlands.

Although cities are vulnerable to the impacts of climate variability and change, Africa's cities have considerable potential to support mitigation and adaptation strategies (Simon, 2013). This potential, however, needs to be harnessed while tackling other related and on going challenges. Rapid urbanization is associated with increased demand for goods and services, particularly food, water, and waste management which will possibly lead to environmental change in peri-urban areas and rural hinterlands as the ecological footprints of urban areas increase. Food security in urban and peri-urban areas remains a challenge in Africa (and elsewhere), with disproportionate expenditure by the different urban income groups. Food security in urban areas is closely tied to food prices, which are sensitive to price fluctuations of oil and natural events induced by climate variability and change at local to global scales (Abdulsalam-Saghir and Oshijo, 2009; Atkinson, 1995). In light of this, we utilize an analytical framework that considers UPAF as an approach to alleviate food security and poverty as well as for supporting adaptation and mitigation of climate change. Mitigation is understood in this paper as the reduction of greenhouse gas (GHG) emissions to stabilize their atmospheric concentrations. This framework is extended to the linkages between urban and peri-urban food systems and the rural hinterland that play important roles in sustaining the balance of food supply, livelihoods and provision of ecosystem services along the urban-rural gradient. The framework is utilized further to analyse the potential of UPAF to address climate change impacts through the provision of micro-level ecosystem services as well as their cumulative mitigation potential at the macro-scale (Grimm et al., 2008; Lwasa et al., 2009; Grimm et al., 2008).

3. Materials and methods

We conducted an extensive systematic review of both peer reviewed and grey literatures on UPAF and urban ecological services in sub-Saharan Africa published over the last 15 years. Grey literature includes policy documents, reports from project activities, and communiqués of municipal and government agencies. This category of literature was carefully analysed by triangulation to ensure corroboration of results presented in this paper. Peer-reviewed literature was systematically selected using search criteria on Web of Science and Google Scholar as an entry point. The search criteria included urban agriculture, livelihoods, poverty, ecosystem services, urban policy, urban-rural linkages, climate mitigation and adaptation. The cut-off year of 1996 was selected to include papers prior to the Third IPCC Assessment Report through to the Fourth IPCC Assessment Report and to the present. The total sample for the systematic review was 213 papers, reports and policy documents, which were coded in a database and reviewed by the research team. We utilized an ecosystem services framework, distinguishing between supporting, provisioning and regulatory services of urban ecosystems to examine the benefits derived from the built and natural components of cities (Buechler et al., 2006; Smit et al., 1996). This approach provides a lens to explore the relationships between the intertwined urban ecological and social systems, and specific outcomes related to the adaptation and mitigation of climate change.

Fieldwork was carried out to supplement the systematic literature review. We conducted city-specific field verification visits in Kampala and Ibadan to examine practices, benefits and limits of urban and peri-urban agriculture in the cities. These sites encompassed a range of UPAF activities from small to large-scale livestock production, peri-urban forestry, crop systems, integrated crop-livestock systems, and integrated crop-livestock-aquaculture system. During these site visits, we conducted key-informant interviews with practising UPAF farmers and entrepreneurs. A total of four UPAF sites were examined in detail in Ibadan and four in Kampala. Data on production scales, nutrient recovery, mitigation potential and evidence of adaptive UPAF were collected during fieldwork. As part of fieldwork, we also interviewed policy makers in four focus group discussion workshops organized in Ibadan and Kampala.

4. Reducing poverty and enhancing food security

By 1996 an estimated 800 million people were engaged in urban agriculture worldwide – a quarter of whom were considered to be market producers, employing 150 million people on a full-time basis (Smit et al., 1996). In East and West African cities, the production and distribution of high-value products in particular has increased (Lee-Smith, 2010; Drescher, 2002; Cofie et al., 2003; Adeoti et al., 2010), driven in part by the dynamics of demand, unemployment, increasing costs for food production and distribution (Olayioye, 2012), though the explanation for this trend of increasing urban agriculture remains contested. In some cases, urban agriculture is primarily practiced by low and middle-income groups as a viable strategy to earn extra income (International Development Research Centre (Canada), 2011). Elsewhere, urban agriculture has contributed to reduction of poverty through 'thrift farming,' enabling households to save on would-be costs of food by contributing to household food supplies (May and Rogerson, 1995; Ayorinde et al., 2007; RUAF, 2010). The implications of UPAF for household income can be substantial, with farming households in some sub-Saharan African cities, including Dar es Salaam, Nairobi and Kampala, deriving between 25% and 40% of annual income from agricultural activities. In addition to supporting incomes, UPAF provides livelihood benefits for urban dwellers (Atkinson, 1995; Binns and Lynch, 1998), by contributing to the nourishment of many urban populations in Africa (Maxwell, 1995, 1999). UPAF is also the largest and most efficient tool available to transform urban wastes into food and jobs (Abdulsalam-Saghir and Oshijo, 2009).

UPAF provides varied but significant proportions of food supplies in tropical and subtropical African cities. In some cases, UPAF contributes up to 44% of calories and 32% of protein uptake to households (Torquebiau, 1992), largely owing to niche crop and livestock products. In the cities of Ibadan, Accra, Kampala, Douala and Nairobi, urban and peri-urban farming (Cofie, 2005; Odebode, 2006) contributes 30–60% of certain food supplies, such as poultry and vegetables (Mougeot, 2000a; De Bon et al., 2009), enhancing food diversity and household nutrition. Furthermore, evidence shows that average incomes of urban farmers are higher than the average among the urban poor, and to some extent also within middle income groups (Ricci, 2012; Boko et al., 2007). In all eight cities under the review, the provisioning of food for the urban poor is common, particularly subsistence production, though production by middle income and high-income groups is also evident (Ricci, 2012; Masashua et al., 2009).

While supporting food security, urban agriculture also offers co-benefits for ecological processes, i.e., nutrient cycling and wastewater management, as well as for other economic sectors, such as the recycling industry and horticulture (Grimm et al., 2008; Buechler et al., 2006; Smit et al., 1996). In addition, integrated systems such as crop-livestock, aquaculture-livestock-crop and integrated crop-forestry systems are also providing livelihood benefits to urban dwellers, contributing to reduction of poverty not only through food provisioning but also through employment (Abdulsalam-Saghir and Oshijo, 2009; Bakker et al., 2000). In the eight selected cities, for example, UPAF contributes to approximately 15% of urban household incomes from the synthesis of the literature. In many African cities, urban agriculture is also providing co-benefits for farmers and vendors through the linkage of producers to big outlets such as supermarkets and chain stores through contractual arrangements (Crush and Frayne, 2011). These linkages to markets and participation in the value chain are reported to offer additional social benefits while enhancing UPAF activities (Olayioye, 2012; Ayorinde et al., 2007; Oyejide, 2006; Adelekan, 2010). Along with agriculture for food, urban forestry has also shown benefits for urban populations. Urban forestry can improve energy supplies by producing biomass that is an important source of energy in sub-Saharan African cities (Drescher, 2002). In addition, sale of timber products and the value chain products of forestry have a potential to increase income for urban households (Cofie et al., 2003; De Zeeuw et al., 2011). Viewed from the value chain perspective, evidence adduced from the synthesis shows that urban agriculture contributes to local economic development and has a potential to absorb more individuals at the city scale if promoted and supported (Oyedipe, 2009).

By supporting the livelihoods of urban populations, urban agricultural systems constitute important elements for future adaptation to climate change for the reduction of social vulnerability. UPAF helped to alleviate the short-term food crises of 2007–2010 when world food prices soared, indicating the potential for urban areas in Africa to mitigate to some extent the impacts of exogenous factors that disrupt food systems (Cohen and Garrett, 2010). In Dakar and Dar es Salaam, it is reported that vegetable production increased during the world food crisis to supplement the rural supplies, demonstrating the potential of urban production to reduce vulnerability of urban populations to climate-driven fluctuations in agricultural production elsewhere (Simon, 2013; Mougeot, 2000b; Castillo, 2003; Dubbeling and Merzthal, 2006; Dubbeling et al., 2010). Despite trends of increasing urban agriculture, distant food sources, rising food costs related to infrastructure and distribution are increasingly shaping vulnerability of urban food systems (Frayne et al., 2012; Battersby, 2012). Scaling up urban and peri-urban agriculture and forestry in the face of climate change and increasing energy costs is a promising strategy for many African cities (Cohen and Garrett, 2010; Stage et al., 2010). A synthesis of literature, however, points to contradictions about the actual production potential of cities (Prain et al., 2010; Faling, 2012). However, what is clear from series of long-term trials in different cities, a range of possibilities exist to support production and livelihoods, including household level production (Lwasa et al., 2009; Masashua et al., 2009; RUAF, 2010).

As presented in the previous paragraphs, there has been considerable research on UPAF in Africa since the 1990s, with supporting evidence of its role in enhancing food security, sustaining livelihoods and supporting municipal authorities in managing wastes. However, studies on UPAF's positive roles have received critique with respect to its associated social, economic and environmental risks and benefits (Prain et al., 2010; Novotny and Brown, 2007). The critiques have been shaped by the professional and historical orientation in urban development as determined by planning policy frameworks. Barriers to successful UPAF practices are widespread throughout East and West African cities. They include issues of insecure access to land, inappropriate or unclear land tenure arrangements, and a persistent failure to incorporate UPAF into urban planning policies because of its perceived inappropriateness in terms of out-dated modernist planning norms (Schmidt, 2012).

4.1. Policy supporting environment for UPAF

The extent to which UPAF is successful, particularly in terms of enhancing food security and ecosystem services in the context of climate change mitigation and adaptation, depends largely on how it is perceived by city officials and its level of integration with other urban policies related to ecosystem management, water and sewage management, and landscape management policies. Much of the negative sentiment surrounding the practice of UPAF stems from concerns about health risks to humans as well as the environment (Mougeot, 2000a; Sonou, 2001). For example, UPAF frequently incorporates the use of easily accessible resources such as municipal organic waste, sewage and market refuse in crop production, which have often been found to cause microbial and heavy metal contamination of produce due to mixture of wastes (Furedy and Chowdhury, 1996; Keraita and Drechsel, 2004; Akegbejo-Samsons, 2008; Amoah et al., 2005). Livestock and poultry manures have also been reported as sources of pathogen contaminations mainly of faecal material (Sonou, 2001; Drechsel et al., 2006). Unfortunately, these risks and other concerns associated with improper management of livestock on urban farms, such as noise, odour and animals crowding nearby streets and residences, have resulted in the disregard of UPAF as a formal land use by city officials and the development of prohibitive or restrictive UPAF policies in cities of East and West Africa. Although UPAF is still widely practised due to poor implementation of these policies, the result is that public and ecological health is often negatively impacted further (RUAF, 2010; Sonou, 2001; Cole et al., 2008).

4.2. Limitations of UPAF as a food production system

Despite the evidence of poverty reduction through UPAF, it is important to recognize its limits. *Limitations* are related largely to production and distribution systems where space, risks, official recognition, and infrastructure, including water, are the key limiting factors identified in literature (Schmidt, 2012; Nsangu and Redwood, 2009). Space, in the form of land, is an important factor in production. Urban agriculture systems clearly require land for production. UPAF is, therefore, in direct competition with other potential urban land uses for real estate, urban infrastructure development and land speculation in both urban and peri-urban zones. Urban land markets are reported to have intensified in sub-Saharan African cities due to inflow of capital from the diaspora and as destinations for offshore investments (Giddings, 2009; Aubry et al., 2012; Andreasen et al., 2011). In densely urbanized areas, particularly in slum and squatter settlements, land limits coupled with lack of incorporation in city planning, have led to production on road verges, road islands, open public places, flood plains, around landfills and near railways (Mougeot, 2000b).

This is widely reported in all the study cities, with an effect of being outlawed by the municipal and city authorities, a limitation discussed in the preceding section of the paper (Schmidt, 2012; Danso

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et al., 2005; Foeken and Owuor, 2008). However, farmers are utilizing space-confined technologies to defray space limitations by cropping on any space available around structures especially with niche products. Therefore, high value vegetables, poultry and highly productive livestock tend to be the enterprises in which urban farmers are investing. The other limitation of urban agriculture is related to widely-reported biological and chemical contamination, on the basis of which cultivation is banned in many of the cities (Nabulo, 2002; IWMI, 2006). With high costs of water for agriculture, farmers tend to utilize wastewater from sewer lines, thus exposing the production to biological contamination. Where non-point source pollution is characteristic, exposure to heavy metal contamination places high risk to the food and safety of consumers (Mougeot, 2000a; IWMI, 2006; Wambui, 2007). Studies have reported contamination from cadmium (Cd) and lead (Pb) (Nabulo, 2002; Amoah and et al., 2005). There is also risk associated with soil contamination as illustrated by the case of vegetables grown in urban wetland soils being exposed to polluted floodwaters (Aubry et al., 2012; Mbabazi et al., 2010). UPAF has also been blamed for increasing the incidence of malaria because wetland conversion and irrigation increases breeding grounds for mosquitoes (Stoler et al., 2009).

A key limitation for expansion of UPAF is in relation to *infrastructure*. Infrastructure as reported in the literature is broad to cover water, transportation, storage, cooling facilities for produce and nutrient recovery infrastructure (Adebisi-Adelani et al., 2011; Mkwambisi et al., 2011). The challenge of water accessibility notwithstanding, transporting food and inputs like fertiliser within city boundaries remains a limiting factor due to costs and regulations that outlaw the activity. For example, in many of the cities, although municipal ordinances for waste management exist, these have not been designed to allow composting or any other form of nutrient recovery, although small-scale composting activities take place unchallenged in Ibadan and other African cities. In some cities composting has been implemented as part of climate change mitigation actions under the Clean Development Mechanism. This demonstrates that, if scaled up, nutrient recovery for UPAF can contribute to mitigating climate change. These ordinances are geared towards overhauling wastes to landfills (Drechsel and Kunze, 2001). Transportation limitations relate to costs, which tend to be high and have significant implications for distribution. This is particularly the case for perishables, for which cooling and storage facilities are lacking in many of the cities. Municipal regulations and ordinances vary greatly. In many of the cities, existing laws prohibit UPAF, while progressive cities like Kampala now permit UPAF but the relevant regulations are generally restrictive rather enabling (Cole et al., 2008; Schmidt, 2012). The non-recognition of UPAF as a distinct urban land-use component and its non-integration in land-use and urban and regional planning policies is a major limitation. As noted earlier, despite this limitation, UPAF is tolerated in several cities and has been more recently encouraged as part of poverty reduction and sustainable livelihood strategies (Mkwambisi et al., 2011).

Following our analysis of the limitations to UPAF, an emerging issue concerns the economic value of urban agriculture (Holmer, 2001). The hidden costs and benefits of not promoting UPAF in many cities are less known and evidenced in the literature, which is partly the reason for the range of negative responses. This study attempts to provide some results on the indirect costs associated with ecosystem services that city authorities and managers require to promote urban and peri-urban agriculture and forestry in building resilience for adaptation to and mitigation of climate change (Alberti and Marzluff, 2004; De Zeeuw et al., 2011).

5. Transcending poverty reduction to enhancement of ecosystem services

5.1. Ecosystem services and resource efficiency

There is evidence that UPAF has the potential not only to reduce poverty and to enhance livelihoods, but to also enhance urban ecosystem services. Ecosystems services have been categorised as provisioning, regulating, cultural and supporting (Alberti and Marzluff, 2004; Scholes and Biggs, 2004; Tallis et al., 2008). This paper uses the framing to assess the provisioning, regulating and supporting services derived from UPAF. This understanding is linked to resource efficiency, which according to this paper, is framed as controlling the use and extraction of resources to enable the continued functioning of ecosystems. UPAF regulates environmental processes including those related to climate,

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water filtration, nutrient reuse, biodiversity and supporting services for food production such as pollination (UN-HABITAT, 2009). Given the expected climate change impacts in African cities, ecosystem services are critical for sustaining the local resource base upon which urban residents will increasingly depend (Zoellick, 2009). UPAF needs to be evaluated not only in terms of its contribution to food provisioning and to food security, but by the associated co-benefits linked to ecosystem services and making cities resource efficient.

More specifically at the local scale, the literature contends that co-benefits of UPAF include storm protection, erosion control, flood regulation and microclimate moderation (Nsangu and Redwood, 2009; Giddings, 2009; Alberti and Marzluff, 2004; McDonnell et al., 1997). In terms of the latter, shade trees not only beautify roadways, but also provide a buffer against high and low temperature extremes by as much as 5 °C. Conversely, their removal leads to an approximate 4 °C increase in soil surface temperature and reduced relative air humidity of about 12% at 2 m above ground (e.g., soil temperature under the baobab and *Acacia tortilis* trees at a depth of 5–10 cm was found to be 6 °C lower than recorded temperatures in open areas). Additionally, shade trees can enhance soil quality by producing up to 14 Mg ha^{-1} yr^{-1} of litter fall and pruning residues, which contain up to 340 kg N ha^{-1} yr^{-1} (Steffan-Dewenter et al., 2007; Henk de Zeeuw, 2011), and offset urban heat island (UHI) effects by increasing the amount of green space within urban areas and their surrounds. The best-documented evidence is from New York City, so although outside our study region, it bears citing since similar effects are likely to occur in tropical Africa. The potential of street trees to reduce urban temperatures there during a heat island event was evaluated as part of a UHI mitigation scenario. It was found that between July and October 2005, the temperature reduced from −0.2°F to −0.6°F and from −0.2°F to −0.9°F in neighbouring Crown Heights, Brooklyn during the same time period (Corburn, 2009). Fruit crops and agroforestry also provide shade, which can reduce land surface temperature and hasten night time cooling. Agricultural lands and urban gardens increase evapotranspiration, thereby lowering temperatures through evaporative cooling (Corburn, 2009). The potential for carbon sequestration by UPAF has not been adequately analysed, but from the review, it is estimated that the cycle storage ranges from 60 to 140 g cm^{-2}/y^{-1}, depending on the rate of sequestration by different species. In particular, agroforestry is associated with minimal carbon emissions and the trees' ability to absorb carbon.

Other co-benefits of urban forestry include windstorm reduction and, to some extent, maintenance of soil hydrology (Adelekan, 2010). Hedgerows and shade trees provide buffers against strong wind gusts, reducing the overall intensity of the storms and damage to infrastructure. Landslide hazards associated with an increased frequency of rainfall events are mitigated by urban forestry and agriculture, which helps to stabilize steep slopes where urban expansion and residential development often occur (Matagi, 2002). Furthermore, the increase of impervious surfaces associated with urban development reduces soil infiltration and increases runoff during storms resulting in flooding, particularly where drainage systems are lacking (Matagi, 2002). The problems of development-induced flooding are widely reported in the cities of Ibadan, Kampala, Dakar, Douala, Nairobi and Addis Ababa (Action Aid, 2006; Douglas et al., 2008). Urban agriculture has demonstrated flood reduction capabilities in Accra, Kampala and Dar es Salaam by extending the time lag between floods and the slowing of storm waters. Reduction of surface runoff ranges between 15% and 20% of rainfall depending on city surface condition, soil composition and permeability (Dubbeling et al., 2009). In the case of coastal flooding, agroforestry has contributed to the reduction of coastal inundation during extreme events, for example, the cultivation of mangrove forests in Doula (Walters et al., 2008). In addition to reducing runoff, more porous land surfaces support recharge of water tables and increase groundwater flows. Wetland ecosystems are increasingly becoming recognized as economically sound and effective alternatives to traditional water treatment practices (Birley and Lock, 1998). Thus, ecological management of water purification may provide useful strategies in many African cities, where often only a fraction of wastewater is treated if at all, for example, in Addis Ababa and Accra (Van Rooijen et al., 2010).

Organic wastes and wastewater are the key 'resources' in cities such as Nairobi, Accra and Dar es Salaam in the context of increasing urban resource efficiency. Evidence shows that productivity can be as much as 15 times the output per unit area when organic compost and soil conditioner is utilized for high-productive livestock, high value vegetables and nutritious crops (Asomani-Boateng and Haight, 1999; de Bon et al., 2010; Tallis et al., 2008). The reuse of wastewater and of recycled and organic wastes as agricultural inputs, rather than reliance on chemical fertilizers, are common in many of the focus cities. If utilized, organic wastes can lead to improving productivity of the farming system as well as environmental health. Many benefits from urban agriculture are widely recognized in the literature such as the minimal use of fertilizer, conservation tillage, or maintaining riparian zones without affecting food production in cities (Foley, 2005; Lovell and Johnston, 2009). For planning purposes, it is important to identify not only the trade-offs but also the synergies among ecosystem services at different scales (Alberti and Marzluff, 2004). The implication of the synergies is that the full potential of urban agriculture to enhance ecosystem services is yet to be established. Therefore, city-specific assessments are needed for integrated management approaches that could help improve the provision of multiple ecosystem services through UPAF (ICLEI, 2012).

5.2. Climate change mitigation

The cities assessed in this study, like many others, are exposed to many climate change-related risks including flooding, droughts, heat waves, cold waves and sea level rise (Rosenzweig et al., 2011; Grimm et al., 2008). These risks compound the already experienced challenges related to the development deficit, increasing vulnerability among disadvantaged populations. Investigations into urban agriculture as a mediating activity for supporting climate change mitigation and adaptation in which the disadvantaged can participate, indicates a potential for reduction of urban heat island effects and GHG emissions (Novotny and Brown, 2007). Cities are well-known generators of GHG emissions and although most of the inventory data is based on proportional responsibility that downscales national level data, city-specific studies that inventory the in-boundary emissions are starting to emerge (Ewing-Thiel and Manarolla, 2011; Gentil et al., 2009).

There are several pathways evidenced from the literature for climate change mitigation through urban agriculture. The first pathway relates to the carbon footprint of food consumed in cities. The production and consumption of food grown close to cities and or within city-regions has potential to reduce energy use. A city can thereby reduce its carbon footprint by supporting UPAF efforts that require less energy typically used for transporting food over long distances, cooling, storage and packaging (Dubbeling et al., 2009).

The nutrient recycling of organics which would otherwise end up in landfills or dumping grounds to release methane is another potential mitigation measure (Friedrich and Trois, 2011). Urban nutrient cycles are characterized by importation of food and biomass, which after consumption are sent back to rural areas as waste. Urban agriculture has demonstrated capability of maintaining soil biota and recycling urban wastewater (Drescher, 2002). Wastewater management strategies have helped conserve fresh water for higher value uses and reduce emissions from wastewater treatment. Furthermore, composted solid waste can be applied to fields in urban and peri-urban areas, closing the nutrient loop. Waste recycling of poultry manure, livestock dung, market or household waste, and human waste is common practice in East and West African cities, but the associated potential for emissions reduction through proper handling and application is now recognized. The recycling of waste and sewage sludge can reduce the use of chemical fertilizers, which improves environmental quality and the functioning of ecosystem services (Holmer, 2001). An estimated 40–70% of organic waste generated in the assessed cities ends up on landfills or on neighbouring dumping grounds (Asomani-Boateng and Haight, 1999). Processing this waste as a soil conditioner can reduce potential methane that is emitted from the dumping grounds. Several of the study cities have already acknowledged this and established sustainable waste management projects (Couth and Trois, 2010; Tilman et al., 2012). Although the aim was to reduce the waste problem, the co-benefits of emissions reduction, nutrient cycling, and reduced energy use are thereby realized (Holmer, 2001).

Additionally, evidence within biodiversity research suggests that biodiversity increases ecosystem functioning (Townsend-Small and Czimczik, 2010). Biodiversity enhancement in cities has the potential to support species that can increase CO_2 sequestration (Stoffberg et al., 2010). UPAF, especially organised planting (Onyenechere, 2010) of multifunctional trees, has a potential to sequester CO_2. Given the potential for mitigation and ecosystem services enhancement, policies that would integrate urban agriculture and urban forestry will be important as cities define pathways for mitigation. These policies and strategies would have to include conservation of urban forest patches to sustain the ecosystem services they provide. A strategy for species mix is also equally important since carbon sequestration capacity varies through the growth cycle of individual species as well as seasonally. Although multiple pathways exist through which UPAF can potentially mitigate effects of climate change, there is need to identify thresholds in this potential under different scenarios and scales of urban development (Onyenechere, 2010). However, this evidence is not detailed enough for integration and utilization in planning urban specific climate mitigation plans (Cohen et al., 2008).

5.3. Adaptation to climate change

Since the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 1995, interventions to reduce the impacts at multiple scales have concentrated on mitigation to stabilize concentrations of GHGs in the atmosphere (Frayne et al., 2012). The 1995 IPCC report provided a framework for understanding adaptation to climate change as adjustments in institutions, systems and actions to deal with the changing climate and allow functioning of the systems at previous or new state. With slow progress on mitigation, focus has grown on adaptation strategies for reducing vulnerability to the anticipated negative impacts of climate change (Lwasa, 2010). The resilience of sub Saharan African cities will depend partly on how institutions, individuals, and authorities respond to reduce the impacts locally. Effective local adaptation is key and this requires short to long-term planning. Although knowledge of UPAF's adaptation potential exists, this knowledge has been scattered in reports and project documents, and are mostly site specific. Evidence on micro-scale adaptations exists on how urban agriculture is helping communities and cities to adapt (Roberts et al., 2011; Knuth, 2005).

Adapting to climate change impacts associated with extreme events such as flooding has been evaluated with a range of agro-enterprises, including productive greening strategies with fruit trees, herbal shrubs, high-value vegetables on hill slopes and in valleys to increase water infiltration and to reduce potential flood occurrence (Douglas et al., 2008). In some of the study cities, urban agriculture is utilized to support earth dams and infiltration ponds on hill slopes to slow down runoff and possible eventual flooding. In addition, the harvesting of rain water and run-off has potential to provide water for year-round production of urban crops. Evidence exists that urban vegetative cover, including agriculture, enables absorption up to 20% of precipitation, depending on the surface conditions and vegetation and landscape types (Douglas et al., 2008; Sonou, 2001). With respect to sea level rise, the rehabilitation of mangrove swamps by replanting and enabling regrowth is an adaptation measure that has been evaluated in coastal cities such as Dakar. Increased UPAF also has potential to moderate microclimates and to reduce impacts of heat waves. During the hot seasons, temperatures tend to be high, but when neighbourhood and city-level productive greening is practised, temperatures can potentially be reduced (Corburn, 2009).

There is widespread agreement that adaptation to climate change can and will be limited by social, economic, institutional and political factors (Satterthwaite et al., 2007). In addition, the damage or devastation of climate change that adaptation can prevent is also not known due to deficiencies in institutional capacities to plan for urban adaptation (Cissé et al., 2005; Potts, 2012b). From this assessment, we argue that the limition to adapt depends on identification of the risks given the uncertainties of climate change, vulnerability assessment and derived strategies for adaptation. Planned adaptation can enable communities and cities to transition to resilience. Evidence from implemented adaptation activities in, for example, Dakar, Ibadan and Kampala indicates that adaptation, which reduces vulnerability, is key to building resilience in cities. Thus, productive greening can reduce run off from rain, but would need to be planned in conjunction with drainage infrastructure provision as observed during field verifications in Ibadan and Kampala.

5.4. Scalable adaptations and urban resilience

Some sub-Saharan African cities are growing rapidly through combinations of natural increase and net in-migration which are outpacing the economic growth to absorb the labor (Potts, 2012a,b) and challenging the cities' ability to manage the environment appropriately and provide basic services for urban residents in terms of adequate housing, ensuring food security, access to clean water, employment and education (Cissé et al., 2005; Atukunda, 1998). UPAF has

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demonstrated its potential to create jobs, enhance food security and support livelihoods. In this manner, UPAF links poverty and climate change when UPAF are designed to address the impacts. Most UPAF research in Africa has focused on micro-level activities and is still widely practised at that scale. However, there is also evidence showing the scalability of UPAF to city and city-regional scales, with cumulative and multiple outcomes including building resilience (Onyenechere, 2010). Successful UPAF practices in this regard require policy responses that can create pathways for scaling up UPAF activities.

5.5. Integrating UPAF in land-use policies

Several of the study cities have begun to take steps to review bylaws and regulations that have long restricted urban agriculture. For example, colonial zoning bylaws have been revised to allow for specific production systems in specific zones in Kampala, Uganda and Kumasi, Ghana (Lee-Smith, 2010; Abutiate, 1995; Mougeot, 2005). Agriculture has been incorporated into urban expansion plans for Kinshasa, Dar es Salaam, Dakar, Bissau and Maputo. In Lagos and Ibadan, state governments have embarked on urban greening programmes involving tree and grass planting in strategic public open spaces including road islands and road setbacks as well as roundabouts. Although the aim is to promote city aesthetics, this practice of policy support has indirect benefits to building resilience for climate change (Alberti and Marzluff, 2004; De Zeeuw et al., 2011). Furthermore, there are efforts underway by many municipal governments to reduce the amount of bureaucracy involved with securing land titles to provide options for leasing public land and promote community engagement in UPAF (Bakker et al., 2000). Recognition of UPAF as a formal land-use is an important step towards its incorporation into more comprehensive and tailored city strategies to reduce their overall ecological footprint and increase resilience to climate change. All the initiatives notwithstanding, the scale of operation and implementation does not measure up to enabling adaptation and building resilience in a changing climate. Individual city experiences of UPAF are important but a concerted effort by municipalities to design urban agriculture and forestry programs that are wide spread and integrated in the urban development frameworks will enable scaling up. Policy design requires the inclusion of appropriate dissemination of good practices (Mougeot, 2005). Fast tracking of the spread of information can be undertaken through different channels of relevant non-governmental organizations (NGOs), city governments, national and regional networks and international agencies such as UN-HABITAT and CGIAR consortium members (e.g., the International Potato Centre and the International Water Management Institute (IWMI)), which have been active in the UPAF field.

6. Pathways for integrated systems

Integrating UPAF in city plans and development for resilience will require UPAF enterprises that are designed to recycle nutrients, improve water and pollution management, reduce waste streams to landfills and create value chains that can create economic opportunities or enhance food security for urban dwellers especially the poor. Evidence from experiences around the assessment cities shows an evolution of economically feasible, socially acceptable and environmentally supportive enterprises that offer entry points for integrating urban agriculture in development for climate mitigation and adaptation. We propose four integrated systems that utilize nutrients, sustainable water management and alternative sources of energy with demonstrated material flows as pathways for UPAF's contribution to building urban resilience.

6.1. Integrated crop-livestock systems

In all cities assessed, there is evidence of this type of UPAF system being practised, with the benefits of enhanced food production and security but mainly nutrient recycling. The climate mitigation potential lies in reduced carbon footprints associated with reduced dependence on long-distance food transport. Nutrient recycling and flows can potentially reduce emissions associated with dumping organic

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wastes at landfills that emit methane. The nutrient flows keep largely within the urban system by crop residues acting as feed for livestock and droppings from livestock acting as sources of crop nutrients. In this system there are other co-benefits of product development including compost, collection and distribution systems, materials and infrastructure that may be used for composting, depending on scale. This pathway provides different scales of operations that can support poor urban dwellers to join the enterprise.

6.2. Urban agroforestry systems

This type of UPAF system can occur in two forms. First, planting multi-purpose trees and shrubs for food production that would sequester CO_2. Evidence associated with this type of system and pathway suggests a high potential for mitigation of climate change if scaled up to city-regional level. Second is the form that can be practised in peri-urban zones with a little more land for production. Evidence exists around agriculture's potential in sequestering CO_2 and the adaptation potential for this type to buffer climate change impacts like floods is also high in cities where the peri-urban and adjacent rural areas are characterised by sloping, erosion-prone land.

6.3. Aquaculture-livestock-crop systems

This type of system hinges on nutrient recycling and utilization and has a potential to reduce organic wastes that would otherwise emit GHGs. This type has a high potential to contribute toward food security and enhance livelihoods while mitigating climate change by adding fish production to the urban agriculture and livestock industry of cities. The flows of nutrients among the three elements of the system are important and the knowledge needed around these flows has co-benefits of farmers becoming instructors and facilitators for new entrepreneurs.

6.4. Crop systems

This fourth pathway is associated with cities that have extensive peri-urban green zones or institutional land patches. These cities still have a high potential to contribute significantly toward food security. As explained above, diverse urban crop systems can play a significant role in addressing urban heat islands, coastal erosion and flooding.

7. Conclusion

The extensive literature review, coupled with field research in Kampala and Ibadan, has demonstrated that UPAF plays a variable but often substantial role in sub-Saharan African urban livelihood strategies. However, the considerable extent and importance of commercial-scale production by larger urban and peri-urban farmers, especially in tropical cities, is less widely appreciated. UPAF also enhances food security and contributes to the maintenance or improvement of urban ecosystem services. While challenges and risks exist, especially in relation to health, disturbance and conflict with other land uses and outdated planning regulations, well-managed UPAF crop systems, crop-livestock integrated systems, crop-forestry systems and aquaculture-livestock-crop integrated systems have considerable potential to promote urban mitigation of, and adaptation to, climate change. UPAF's role in mitigation is evident through the absorption of greenhouse gases, by reducing urban heat island effects and by reducing the carbon footprint of food systems, thereby minimizing food miles and transport-related emissions for food consumed in cities. UPAF's contributions to adaptation come in several forms. These include generating sustainable employment, reducing water demand relative to traditional decorative gardens by combined use of grey water and promoting urban food security when the adequacy of supplies from rural farms are vulnerable to a combination of climate change-related pressure, increased transport costs and rising aggregate demand.

While research on urban climate resilience has proliferated in recent years, there are still considerable uncertainties around climate change trajectories as well as responses to the risks. Although

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several studies and reports focus on the challenges and means of building climate resilience, it is not clear at the city scale how these generic strategies can translate into practical solutions. The results of this study show that building urban resilience will require three main broad sets of activities at city, regional and global scales. The first is addressing the development deficit in the cities of East and West Africa. This will support adaptation to climate change threats by building long-term resilience with supporting infrastructure. Second is the reform of institutional architecture and policy and planning instruments to support urban landscapes that are multi-functional within which UPAF and other climate-sensitive activities can be encouraged and supported. Third, urban resilience will require sharing of knowledge and other resources that can help to scale out and scale up best practices. These measures have a high potential to mainstream UPAF as one of the mediating activities and livelihoods for mitigation of and adaptation to climate change.

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References

Abdulsalam-Saghir, P.B., Oshijo, A.O., 2009. Integrated urban micro farming strategy mitigation against food crises in Odeda Local Government Area, Ogun State, Nigeria. J. Agric. Ext. 13, 35–44.

Abutiate, W., 1995. Urban and peri-urban horticultural activity in Ghana: an overview. In: Peri-Urban Interface Res. Work. Proc. UK Overseas Dev. Adm. Br. Counc, NRI, Kumasi, Ghana, pp. 45–50.

Adebisi-Adelani, O., Olajide-Taiwo, F.B., Adeoye, I.B., Olajide-Taiwo, L.O., 2011. Analysis of production constraints facing Fadama vegetable farmers in Oyo State, Nigeria. World J. Agric. Sci. 7, 189–192.

Adejuwon, J., 2000. Food security, climate variability and climate change in Sub Saharan West Africa. A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. AF 23. The International START Secretariat. Florida Avenue, NW, Washington, DC 20009 USA. 156 pp, The International START Secretariat. Florida Avenue, 2006.

Adelekan, I., 2009. Vulnerability of Poor Urban Coastal Communities to Climate Change in Lagos, Nigeria. Marseille, France, 18 pp.

Ibidun O. Adelekan, 2010. Urbanization and extreme weather: vulnerability of indigenous populations to windstorms in Ibadan, Nigeria. Tempe, Arizona, pp. 1–25.

Adeoti, A., Hope, L., Cofie, O., 2010. RUAF in Ibadan-Nigeria. Urban AgricInfo. 3, 8–11.

Action Aid, 2006. Climate change, urban flooding and the rights of the urban poor in Africa: key findings from six African countries. Action Aid, London.

Akegbejo-Samsons, Y., 2008. Impact of urban agriculture on water reuse and related activities on the rural population of the coastal settlements of Ondo State, Nigeria. Afr. J. Food Agric. Nutr. Dev. 8, 48–62.

Alberti, M., Marzluff, J.M., 2004. Ecological resilience in urban ecosystems: linking urban patterns to human and ecological functions. Urban Ecosyst. 7, 241–265.

Amoah, P. et al, 2005. Irrigated urban vegetable production in Ghana: microbiological contamination in farms and markets and associated consumer risk groups. J. Water Health.

Amoah, P., Drechsel, P., Abaidoo, R.C., 2005. Irrigated urban vegetable production in Ghana: sources of pathogen contamination and health risk elimination. Irrig. Drain. 54, S49–S61.

Andreasen, J., Andersen, J.E., Inkoom, D.K.B., 2011. Land and revenue in a "traditional town" in Ghana: the case of the Nkwanta sub-division in Mpasatia. Environ. Urban. 23, 539–561.

Asomani-Boateng, R., Haight, M., 1999. Reusing organic solid waste in urban farming in African cities: a challenge for urban planners. Third World Plan. Rev. 21, 411–428.

Atkinson, S., 1995. Approaches and actors in urban food security in developing countries, Urban Agriculture and Cities in the Developing World. Habitat Int. 19 (2), 151–163.

Atukunda, G., 1998. An analysis of the impact of IDRC funded research projects on urban agriculture in Uganda. Makerere Institute of Social Research, University of Kampala, Kampala.

Aubry, C., Ramamonjisoa, J., Dabat, M.H., Rakotoarisoa, J., Rakotondraibe, J., Rabeharisoa, L., 2012. Urban agriculture and land use in cities: an approach with the multi-functionality and sustainability concepts in the case of Antananarivo (Madagascar). Land Use Policy 29, 429–439.

Ayorinde, A., Oyedokun, P.O., Oladele, J., Akinbobola, A.A., Adeniran, F.O., Olanrewaju, F.O., et al, 2007. Review and Analysis of Policies, Regulations and Legislative Frameworks on Urban and Peri-urban Agriculture in Ibadan. Resource Centre for Urban and Agriculture and Food Security (RUAF).

Bakker, N., Dubbeling, M., Gündel, S., Sabel-Koschella, U., Zeeuw, H., 2000. Growing cities, growing food: urban agriculture on the policy agenda: a reader on urban, agriculture.

Battersby, J., 2012. Urban Food security and climate change: a system of flows. In: Clim. Change Assets Food Secur. Afr. Cities, First. Earthscan, New York, US, pp. 1–34.

Biermann, F., Boas, I., 2010. Preparing for a warmer world: towards a global governance system to protect climate refugees. Global Environ. Polit. 10, 60–88.

Binns, T., Lynch, K., 1998. Feeding Africa's growing cities into the 21st century: the potential of urban agriculture. J. Int. Dev. 10, 777–793.

Birley, M.H., Lock, K., 1998. Health and peri-urban natural resource production. Environ. Urban. 10, 89–106.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., et al, 2007. Africa. Climate change 2007: impacts, adaptation and vulnerability. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.), Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge UK.

Buechler, S., Mekala, G.D., Keraita, B., Van Veenhuizen, R. (Eds.), 2006. Wastewater Use for Urban and Peri-urban Agriculture. Cities Farming Future Urban Agriculture Green Production in Cities. RUAF Foundation/IDRC/IIRR, Ottawa, Canada, The Philippines, pp. 243–273.

Castillo, G., 2003. Livelihoods and the City: An Overview of the Emergence of Agriculture in Urban Spaces. Progress Report, Program on Development Studies.

Cissé, O., Gueye, N.F.D., Sy, M., 2005. Institutional and legal aspects of urban agriculture in French-speaking West Africa: from marginalization to legitimization. Environ. Urban. 17, 143–154.

Cofie, O., 2005. Emerging Issues in Urban Agricultural Development in West Africa. In: Moor Plantation, Ibadan, Nigeria, 17pp.

Cofie, O., van Veenhuizen, R., Dreschel, P., 2003. Contribution of urban and peri-urban agriclulture to food security in Sub Saharan Africa, in: Paper Presented at African Session of Third WWF, Kyoto.

Cohen, M.J., Garrett, J.L., 2010. The food price crisis and urban food (in) security. Environ. Urban. 22, 467–482.

Cohen et al., 2008. Climate Change in West Africa: Recommendations for Adaptation and Mitigation.

Cole, D., Lee-Smith, D., Nasinyama, G., 2008. Healthy city harvests: Generating evidence to guide policy on urban agriculture. International Potato Center.

Corburn, J., 2009. Cities, climate change and urban heat island mitigation: localizing global environmental science. Urban Stud. 46, 413–427.

Couth, R., Trois, C., 2010. Carbon emissions reduction strategies in Africa from improved waste management: A review. Waste Manag. 30, 2336–2346.

Crush, J., Frayne, B., 2011. Supermarket expansion and the informal food economy in Southern African cities: implications for urban food security. J. South. Afr. Stud. 37, 781–807.

Danso, G., Dreschel, P., Cofie, F., 2005. Developing Policy Support on Closing Rural-Urban Nutrient Recycling for Urban and Peri-urban Agriculture in West Africa: Application of multi-stakeholder processes and approaches. International Water Management.

De Bon, H., Parrot, L., Moustier, P., 2009. Sustainable urban agriculture in developing countries: a review. J. Sustain. Agric., 619–633.

de Bon, H., Parrot, L., Moustier, P., 2010. Sustainable urban agriculture in developing countries. A review. Agron. Sustain. Dev. EDP Sci. 30, 21–32.

De Zeeuw, H., Van Veenhuizen, R., Dubbeling, M., 2011. The role of urban agriculture in building resilient cities. J. Agric. Sci., 153–163.

De Zeeuw, H., Van Veenhuizen, R., Dubbeling, M., 2011. The role of urban agriculture in building resilient cities in developing countries. J. Agric. Sci. 149, 153–163.

Dolan, A., Walker, I.J., 2004. Understanding vulnerability of coastal communities to climate change related risks. J. Coast. Res. 39.

Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., Mclean, L., Campbell, J., 2008. Unjust waters: climate change, flooding and the urban poor in Africa. Environ. Urban. 20, 187–205.

Drechsel, P., Kunze, D., 2001. Waste composting for urban and peri-urban agriculture: Closing the rural-urban nutrient cycle in sub-Saharan Africa. CABI.

Drechsel, P., Graefe, S., Sonou, M., Cofie, O., 2006. Informal Irrigation in Urban West Africa: An Overview. International Water Management Institute, Colombo, Sri Lanka.

A.W. Drescher, Food for the cities: urban agriculture in developing countries, in: Intenraional Conference on Urban, Horticulture 643, 2002: pp. 227–231.

Dubbeling, M., Merzthal, G., 2006. Sustaining Urban Agriculture Requires the Involvement of Multiple Stakeholders. In: Van Veenhuizen, R. (Ed.), Urban Agric. Green Prod. Cities Farming Future. Institute of Rural Reconstruction and ETC Urban Agriculture, The Philippines, pp. 19–51.

Dubbeling, M., Caton Campbell, M., Hoekstra, F., Van Veenhuizen, R., 2009. Editorial: building resilient cities. Urban Agric. Mag., 3–11.

Dubbeling, M., de Zeeuw, H., van Veenhuizen, R. (Eds), 2010. Cities, Poverty and Food: Multi-Stakeholder Policy and Planning in Urban Agriculture. Practical Action Publishing. ISBN: 978-1-85339-709-7 <http://www.cabdirect.org:80/search.html?q=bn%3A%229781853397097%22>.

Ewing-Thiel, J., Manarolla, X., 2011. Policy Update: ICLEI USA draft framework for measuring and reporting community GHG emissions. Carbon Manag. 2, 371–375.

Faling, W., 2012. A spatial planning perspective on climate change, asset adaptation and food security: the case of two South African cities. In: Clim. Change Assets Food Secur. Afr. Cities, First. Earthscan, New York, US, pp. 163–185.

Foeken, Dick W.J., Owuor, Samuel O., 2008. Farming as a livelihood source for the urban poor of Nakuru Kenya. Geoforum 39, 1978–1990.
Foley, J.A., 2005. Global consequences of land use. Science 309, 570–574.
Frayne, B., Moser, C., Ziervogel, G., 2012. Understanding the terrain: the climate change, assets and food security nexus in Southern African cities. In: Climate Change, Assets and Food Security in Southern African Cities. Earthscan, Abingdon, UK & New York, US, pp. 1–34.
Frayne, B., Moser, C.O.N., Ziervogel, G., 2012. Climate Change, Assets and Food Security in Southern African Cities. Earthscan, Milton Park, UK, New York.
Friedrich, E., Trois, C., 2011. Quantification of greenhouse gas emissions from waste management processes for municipalities – A comparative review focusing on Africa. Waste Manag. 31, 1585–1596.
Furedy, C., Chowdhury, T., 1996. Solid waste reuse and urban agriculture; dilemmas in developing countries: the bad news and the good news. Urban Agriculture Notes. City Farmer Canada's Off. Urban Agric.
Gentil, E., Christensen, T.H., Aoustin, E., 2009. Greenhouse gas accounting and waste management. Waste Manag. Res. J. Int. Solid Wastes Public Clean. Assoc. ISWA 27, 696–706.
Giddings, S., 2009. The Land Market in Kampala, Uganda and its effects on Settlement Partterns. International Housing Coalition, Washington DC, USA, p. 33.
Grimm, N.B., Foster, D., Groffman, P., Grove, J.M., Hopkinson, C.S., Nadelhoffer, K.J., et al, 2008. The changing landscape: ecosystem responses to urbanization and pollution across climatic and societal gradients. Front. Ecol. Environ. 6, 264–272.
Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X., et al, 2008. Global change and the ecology of cities. Science 319, 756–760.
Henk de Zeeuw, 2011. Climate Change RUAF conference May 2011.pdf.
Holmer, R.B., 2001. Urban Agriculture as a Strategy for Local Economic Development. 12 pp.
ICLEI, 2012. WRI, Global Protocol for Community-based GHG emissions.
International Development Research Centre (Canada), 2011. International Potato Center, (ed.), African Urban Harvest: Agriculture in the Cities of Cameroon, Kenya, and Uganda, Fountain. Fountain Publishers, International Development Research Centre; International Potato Centre, Kampala, Ottawa, Canada, Lima, Peru.
IWMI, 2006. Recycling realities: managing health risks to make wastewater an asset. Water Policy Brief. 17.
Keraita, B., Drechsel, P., 2004. Agricultural use of untreated urban wastewater in Ghana. In: Wastewater Use Irrig. Agric. Confronting Livelihood Environ. Realities. IWMI-IDRC-CABI, Wallingford, pp. 101–112.
Knuth, L., 2005. Legal and Institutional Aspects of Urban and Peri-urban Forestry and Greening. Food and Agricultural Organization of United Nations, Rome, Italy.
Lee-Smith, D., 2010. Cities feeding people: an update on urban agriculture in equatorial Africa. Environ. Urban. 22, 483–499.
Lovell, S.T., Johnston, D.M., 2009. Designing landscapes for performance based on emerging principles in landscape ecology. Ecol. Soc. 14.
Lwasa, S., 2010. Adapting urban areas in Africa to climate change: the case of Kampala. Curr. Opin. Environ. Sustain. 2, 166–171.
Lwasa, S., Tenywa, M., Majaliwa Mwanjalolo, G.J., Prain, G., Sengendo, H., 2009. Enhancing adaptation of poor urban dwellers to the effects of climate variability and change. IOP Conference Series, Earth and Environ. Sci., p. 332002.
Masashua, H.E., Provident, J., Hawassi, G., 2009. Potentials of urban horticulture for poverty reduction in Dar es salaam: the case of Kinondoni Municipality. Eldis, Poverty Resource Guide (Online).
Matagi, S.V., 2002. Some issues of environmental concern in Kampala, the capital city of Uganda. Environ. Monit. Assess. 77, 121–138.
Maxwell, D.G., 1995. Alternative food security strategy: a household analysis of urban agriculture in Kampala. World Dev., 1669–1681.
Maxwell, D., 1999. The political economy and urban food security in sub-Saharan Africa. World Dev., 1939–1953.
May, J., Rogerson, C.M., 1995. Poverty and sustainable cities in South Africa: the role of urban cultivation. Habitat Int. 2, 165–181.
Mbabazi, J., Wasswa, J., Kwetegyeka, J., Bakyaita, G., 2010. Heavy metal contamination in vegetables cultivated on a major urban wetland inlet drainage system of lake victoria, Uganda. Int. J. Environ. Studies 67 (3), 333–348.
McDonnell, M.J., Pickett, S.T.A., Groffman, P., Bohlen, P., Pouyat, R.V., Zipperer, W.C., et al, 1997. Ecosystem processes along an urban-to-rural gradient. Urban Ecosyst. 1, 21–36.
Mkwambisi, D.D., Fraser, E.D.G., Dougill, A.J., 2011. Urban agriculture and poverty reduction: Evaluating how food production in cities contributes to food security, employment and income in Malawi. J. Int. Dev. 23, 181–203.
Mougeot, L.J.A., 2000. Urban agriculture: definition, presence, potentials and risks. In: Dubbeling, M., Geundel, S., Sabel Koschella, U., de Zeew, H. (Eds.), Grow. Cities Grow. Food Urban Agriculture. Policy Agenda Read. Urban Agriculture. DSE/ETC, Feldafing, Germany, pp. 99–117.
Mougeot, L.J.A., 2000. Urban agriculture: definition, presence, potentials and risks. In: Grow. Cities Grow. Food Urban Agric. Policy Agenda.
Mougeot, L.J.A., 2005. Agropolis: The social, political, and environmental dimensions of urban agriculture. Earthscan/James & James.
Nabulo, G., 2002. Assessment of heavy metal uptake by selected food crops and vegetables around Kampala city area, Uganda.
Niang, S., Diop, A., Faruqui, N., Redwood, M., Gaye, M., 2002. Reuse of untreated wastewater in market gardens in Dakar, Senegal. Urban Agric. Mag. 8, 35–36.
Novotny, Vladimir, Brown, P., 2007. Cities of the Future: Towards Integrated Sustainable Water and Lanscape Management. IWA Publishing, London.
Nsangu, C.A., Redwood, M., 2009. Urban agriculture and physical planning: a case study of Zaria, Nigeria. Agric. Urban Plan. Gener. Livelihoods Food Secur. pp. 217.
Odebode, S.O., 2006. Assessment of home gardening as a potential source of household income in Akinyele local government area of Oyo State. Nigerian J. Horticult. Sci. 11, 47–55.
Olayioye, J.T., 2012. Urban agriculture in Ilorin. Kwara State, University of Ibadan, Nigeria.
Onyenechere, E.C., 2010. Climate change and spatial planning concerns in Nigeria: remedial measures for more effective response. J. Hum. Ecol. 32, 137–148.

Please cite this article in press as: Lwasa, S., et al. Urban and peri-urban agriculture and forestry: Transcending poverty alleviation to climate change mitigation and adaptation. Urban Climate (2013), http://dx.doi.org/10.1016/j.uclim.2013.10.007

Oyedipe, E.O., 2009. National Food Crisis Response Programme, Food and Agricultural Organization of the United Nations (FAO). UN House, Abuja, Nigeria.
Oyejide, O., 2006. Urban agriculture as a poverty reduction strategy in Nigeria; the case of Ibadan. University of Ibadan, Oyo State.
Padoch, C., Brondizio, E., Costa, S., Pinedo-Vasquez, M., Sears, R.R., Siqueira, A., 2008. Urban forest and rural cities: multi-sited households, consumption patterns, and forest resources in Amazonia. Ecol. Soc. 13.
Potts, D., 2012a. Challenging the myths of urban dynamics in sub-Saharan Africa: the evidence from Nigeria. World Dev. 40, 1382–1393.
Potts, D., 2012a. Whatever Happened to Africa's Rapid Urbanization. Conference paper given at the World Urban Forum 6, Naples, August 2012.
Prain, G., Karanja, N., Lee-Smith, D., 2010. African Urban Harvest: Agriculture in the Cities of Cameroon, Kenya and Uganda. Springer, New York and IDRC Ottawa.
Ricci, L., 2012. Peri-urban livelihood and adaptive capacity: urban development in Dar Es Salaam. J. Sustain. Dev., 39–54.
Roberts, D., Boon, R., Diederichs, N., Douwes, E., Govender, N., McInnes, A., et al, 2011. Exploring ecosystem-based adaptation in Durban, South Africa: "learning-by-doing" at the local government coal face. Environ. Urban..
Rosenzweig, C., Solecki, W., Hammer, S.A. (Eds.), 2011. Mehrotra, Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network. Cambridge University Press, Cambridge, UK.
RUAF, 2010. Urban and peri-urban agriculture in Ibadan. Characteristics, Challenges and Prospects, A Policy Narrative.
Satterthwaite, D., Huq, S., Pelling, M., Reid, H., Lankao, P.R., 2007. Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low-and Middle-Income Nations. International Institute for Environment and Development (IIED), ISBN: 978-1-84369-669-8. Accessible at <http://www.iied.org/pubs/display.php?o=10549IIED>.
Schmidt, S., 2012. Getting the policy right: urban agriculture in Dar es Salaam, Tanzania. Int. Dev. Plan. Rev., 129–145.
Schmidt, S., 2012. Getting the policy right: urban agriculture in Dar es Salaam, Tanzania. Int. Dev. Plan. Rev. 34, 129–145.
Scholes, R., Biggs, R., 2004. Ecosystem services in southern Africa: a regional assessment. Millennium Ecosystem Assessment.
Simon, D., 2013. Climate and environmental change and the potential for greening African cities'. Local Econ. 28, 203–217.
Smit, J., Ratta, A., Nasr, J., 1996. Urban Agriculture: Food, Jobs and Sustainable Cities. UNDP.
Sonou, M., 2001. Peri-urban irrigated agriculture and health risks in Ghana. Urban Agric. Mag. 3, 33–34.
Stage, J., Stage, J., Mcgranahan, G., 2010. Is urbanization contributing to higher food prices? Environ. Urban. 22, 199–215.
Steffan-Dewenter, I., Kessler, M., Barkmann, J., Bos, M.M., Buchori, D., Erasmi, S., et al, 2007. Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. Proc. Natl. Acad. Sci. 104, 4973–4978.
Stoffberg, G.H., van Rooyen, M.W., van der Linde, M.J., Groeneveld, H.T., 2010. Carbon sequestration estimates of indigenous street trees in the City of Tshwane, South Africa. Urban For. Urban Green. 9, 9–14.
Stoler, J., Weeks, J.R., Getis, A., Hill, A.G., 2009. Distance Threshold for the Effect of Urban Agriculture on Elevated Self-reported Malaria Prevalence in Accra, Ghana. Am. J. Trop. Med. Hyg. 80, 547–554.
Swalheim, S., Dodman, D., 2008. Building Resilience: How the Urban Poor can Drive Climate Adaptation. IIED, London.
Tallis, H., Kareiva, P., Marvier, M., Chang, A., 2008. Ecosystem services special feature: an ecosystem services framework to support both practical conservation and economic development. Proc. Natl. Acad. Sci. 105, 9457–9464.
Tilman, D., Reich, P.B., Isbell, F., 2012. Biodiversity impacts ecosystem productivity as much as resources, disturbance, or herbivory. Proc. Natl. Acad. Sci. 109, 10394–10397.
Torquebiau, E., 1992. Are tropical agroforestry homegardens sustainable? Agric. Ecosyst. Environ., 189–207.
Townsend-Small, A., Czimczik, C.I., 2010. Carbon sequestration and greenhouse gas emissions in urban turf. Geophys. Res. Lett. 37, L02707.
UN-HABITAT, 2006. Planning for Climate Change: A Strategic, Values-based Approach for Urban Planners. Version 1: For Field Testing and Piloting in Training.
UN Habitat, 2009. Planning for Sustainable Cities; Global Report on Human Settlements 2009. Earthscan, London; Sterling, VA.
UN-HABITAT, 2011. Global Report on Human Settlements. The United Nations Human Settlements: Cities and Climate Change. Earthscan, London/Whashington, DC.
Van Rooijen, D.J., Biggs, T.W., Smout, I., Drechsel, P., 2010. Urban growth, wastewater production and use in irrigated agriculture: a comparative study of Accra, Addis Ababa and Hyderabad. Irrig. Drain. Syst. 24, 53–64.
Walters, B., Ronnback, P., Kovacs, J., Crona, B., Hussain, S., Badola, R., et al, 2008. Ethnobiology, socio-economics and management of mangrove forests: a review. Aquat. Bot., 220–236.
Wambui, E.N., 2007. Diversification of food production systems to enhance household food and nutrition security among peri-urban farmers in Kamae area-Nairobi.
Zoellick, R.B., 2009. Climate Smart Future. Nation NewspapersVintage Press Ltd., 18 pp.