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Current Opinion in Environmental Sustainability

A meta-analysis of urban and peri-urban agriculture and forestry in mediating climate change

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This paper systematically reviews literature on urban and peri-urban agriculture and forestry (UPAF) in mediating climate change. The study includes both peer-reviewed and grey literature (274 literature sources), and synthesizes evidence and agreement on both UPAF's potential and limitations for mitigating and adapting to climate change. Eight East and West African cities were included in the review: Accra, Addis Ababa, Dakar, Dar es Salaam, Douala, Kampala, Ibadan and Nairobi. The review focuses on urban livelihoods, ecosystem services and urban policy responses as pathways to mediating climate change. Literature on UPAF indicates emerging consensus on the potential of UPAF in adaptation, but less agreement with respect to mitigation of climate change. African cities are implementing several measures including UPAF to address issues of development, reduce inequality and move towards low emissions development strategies. This calls for integrated urban development that supports green growth to harness economic opportunities with social and environmental benefits. The review reveals that through UPAF, the potential for mitigation and adaptation of climate change can address some development deficit issues and transform institutions at the city-regional level by leveraging good UPAF practices.

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Current Opinion in Environmental Sustainability 2015, **13**:68–73

This review comes from a themed issue on **Sustainability challenges**

Edited by **David Simon** and **Hayley Leck**

Received 21 September 2014; Accepted 12 February 2015

http://dx.doi.org/10.1016/j.cosust.2015.02.003

Introduction

As city leaders search for more sustainable urbanization pathways that respond to global environmental change, understanding specific urban system processes from a socio-ecological perspective is imperative [1••]. One such potential strategic pathway and urban system component is urban and peri-urban agriculture (UPA), defined in this paper as agricultural (including livestock) production, and processing and distribution activities, which compete with other urban activities for scarce resources (such as land, water, energy and labor), within and around cities, with the main motivation of both personal consumption or income generation [2,3,4•]. UPA includes small-scale and large-scale activities in horticulture, livestock keeping, fodder and milk production, and aquaculture — where several activities may be carried out within one or several enterprises [5••]. Urban forestry, on the other hand, is defined in this paper as practice that includes managing trees and forest resources in and around urban ecosystems for multiple purposes with socio-economic, aesthetic and ecosystem benefits. Different integrated enterprises of urban and peri-urban agriculture and forestry are practised within city regions that extend from core urban areas to peri-urban zones. Urban and peri-urban agriculture and forestry (UPAF) has recently begun to attract interest beyond its more traditional survivalist and livelihoods focus, towards its potential for adaptation to and mitigation of climate change due to its integrated nature [6]. Although this is a new focus of the literature, the vast body of work on UPAF contains useful data and insights relevant to current efforts in understanding how UPAF can enhance ecosystem services for climate change adaptation and mitigation [7]. Accordingly, this paper presents the results of a systematic review of literature focused on micro-scale to meso-scale studies of socio-ecological transitions in urban systems in tropical Africa. The objective of the study was to synthesize both grey and peer-reviewed literature to identify evidence of UPAF with respect to firstly, enhancement of ecosystem services, and finally, scalable and replicable urban climate change adaptation and mitigation strategies.

Method for the review and analytical framework

Meta-analyses are an increasingly common tool in the social sciences and global environmental change research in the search for generalizable principles through the systematic assessment of carefully selected literature [8•,9]. The methodological approach of this study involved

extensive review of both peer reviewed and grey literature published since 1996. The assessment focused on eight East and West African cities in a range of coastal, inland and mountainous ecosystems, namely, Accra; Addis Ababa; Dakar; Dar es Salaam; Douala; Ibadan; Kampala and Nairobi. A total of 274 papers, reports and policy documents were collected and integrated into a database. Online sources from Web of Knowledge and Google Scholar were utilized, with grey literature collected from websites and municipal authorities. The search criteria for online resources included *Urban Agriculture* AND *Adaptation* AND *Mitigation* AND *Peri-urban Agriculture* AND *Urban Forestry* AND *Policy* AND *Ecosystem Services*. Considered studies spanned various disciplines, in order to assess the linkages between the social and ecological dimensions of UPAF, climate change adaptation and mitigation.

The review analysis is informed by adaptation planning frameworks that have emerged in the process of incorporating adaptation into national agendas by the United Nations Framework Convention on Climate Change (UNFCCC) member states [10]. Similarly, recent discussions and negotiations have led to the emergence of voluntary climate change mitigation to reduce greenhouse gases (GHGs), for example, through Nationally Appropriate Mitigation Actions (NAMAs) formulated by developing countries [11]. Mitigation of climate change involves generating baselines for emissions, establishing emissions targets and taking action that directly or indirectly reduces emissions. Thus, UPAF's potential has been assessed against measurable, reportable and verifiable actions that reduce both direct and embodied emissions. The review is further informed by the Eisenack and Stecker [12••] adaptation framework, and the urban ecological services analysis framework in Piracha and Marcotullio [13]. The former conceptualizes adaptation as a 'response' to climate change impacts and defines the actors, actions, processes and critical elements for implementation. The urban ecological services analysis framework focuses on supporting, provisioning and regulatory services from urban ecosystems, which includes nutrient recycling, provisioning of food and enhancement of climate regulating services in urban areas [14,15]. Informed by these integrated frameworks, this study analyses the potential of UPAF in climate change mitigation and adaptation.

Urbanization and climate change impacts in cities of East and West Africa

Africa is undergoing an unprecedented urban transition both in pace and scale [16••]. This transition is characterized by peri-urban developments, emergence of urban corridors creating complex socio-economic and spatial linkages between rural, peri-urban and urban areas by transforming ecosystems [6,17]. The rapid and unplanned development is associated with increased inequality and vulnerability of urban populations to climate change impacts [18–20]. Both experienced and projected climate change patterns, such as extreme weather events, are likely to impact human activities and wellbeing in cities. Cities across Africa are likely to face challenges of increased droughts, floods, fires, heat waves and reduced ecosystem services [10,21]. At the local level, impacts are unevenly distributed, with the most impoverished urban dwellers suffering the greatest effects [22,23]. A city's geophysical and built environment, access to services and institutional arrangements shape the exposure to risks [17,23], while the adaptive capacity is shaped by socio-economic conditions necessary or lacking to recover from shocks. Despite the challenges and limitations, there is a great opportunity to leverage UPAF as a transformational strategy for inclusive and sustainable cities in Africa.

Results

The assessed literature consisted of peer-reviewed sources (52%) and grey literature (48%) (n = 274). The vast majority of literature focused on livelihoods (72.3%), followed by vulnerability assessments (10.4%), adaptation to climate change (6.8%) and UPAF policy (9.2%). Consideration of UPAF as a mitigation strategy is yet to receive attention, with only 1.2% of the literature directly addressing the topic. The geographic coverage was a key element of the analysis, with most studies focusing on West Africa (55.3%), 1.5% on East Africa and 22.4% on global scale studies that report on specific cities within the regions of focus. There is very limited literature from Central Africa, perhaps due to the issue of language, as potentially relevant French written papers were not included. Further assessment of geographies by scale indicates that city scale studies were represented (64%), also city-regions (22%), and micro studies at community level (14%). Although the topic of climate mitigation and adaptation is relatively rare in the UPAF literature, this review unpacks and expands on some of the relevant findings from this literature in the following sections.

UPAF as a livelihood enhancing strategy

Urban and peri-urban agriculture's role in livelihood enhancement is well-documented throughout the literature and there is evidence about the positive influence on poverty reduction and food security [6,24–26]. The economic, social and environmental benefits of UPAF to individuals, households, communities, cities and city-regions underpin its practice. The most documented motivation of UPAF practice is the contribution to household food security and nutrition [26,27•,28]. Evidence shows that UPAF directly supports food production, diets and contributes to incomes [29]. Evidence also shows that UPAF is an important source of employment for the urban poor in cities, where there is a mismatch between the labor force and employment opportunities in industrial and service sectors [30]. It is estimated that 40% of urban dwellers in Africa are involved in agricultural

and related sectors [31]. For example, in Kampala, an estimated 33% (2006) of urban dwellers were involved in UPAF [6]. In Ibadan, an estimated 5000 urban residents were engaged in urban farming, with 15.5% practicing fish farming, 11.1% involved in livestock (poultry, goat/sheep, cattle, piggery, aquaculture and dog rearing), 73% in crop farming including floriculture, vegetable (such as *Amaranthus*, *Cochorus*, *Celosia*, okra, peppers), fruit (such as, plantain/banana, citrus, pineapple) and arable crops (maize, cassava), and 1% in non-traditional farming (snails, mushroom, bee keeping, herbs, spices and sericulture) [32]. Between 23% and 25% of food sold in Ibadan city markets is produced in the city [33]. Also, 54.3% of food supplied to the city of Ibadan comes from peri-urban neighborhoods, while the rural areas in the Ibadan region supply only 14.5% of the total food [34]. Urban agriculture in Dar es Salaam is an important component of the urban food system, providing a source of nutrition and livelihood. Between 1967 and 1991, the percentage of households practicing urban agriculture rose from 18% to 67% [35]. In 1999, an estimated 60% of eggs and 90% of leafy green vegetables consumed within the city were produced locally in urban and peri-urban areas, while 70% of the milk consumed was produced in the city and 74% of urban dwellers kept livestock. In Dar es Salaam farmers earned a monthly net income of $24–$60 USD while in Ibadan farmers earned an estimated $80–$200 USD per month by 2010 [35,36].

A number of early studies on urban agriculture cautioned against its promotion without a better understanding of potential implications and effects on sustainability [37–39]. As attention turns towards the promotion of UPAF in developing countries, more studies have focused on the associated risks, especially relating to health (see below). More recently, studies have addressed the ongoing transformation along the urban–rural gradient in improving food systems, ecosystem services and material flows [30]. In general, livelihood enhancement and poverty alleviation are thought to reduce the sensitivity of urban populations to climate change by increasing their ability to prepare for, adapt to and cope with environmental stresses [40]. This is largely through production, processing and distribution of UPAF products but also enhancing ecosystem-based adaptation practices.

Adaptation and mitigation of climate change

Adaptation: Climate change adaptation in urban areas of developing regions has emerged more strongly than mitigation in the literature. Despite notable exceptions [40,41], UPAF practices are generally not explicitly expressed as climate change related, but rather implicitly through urban environmental management and sustainability lenses [42,43]. The synthesis shows that adaptation opportunities for UPAF include urban greening, reduction of the urban heat island (UHI) effect and enhancing biodiversity and ecosystem services [44]. However, these are, again, generally couched as environmental concerns, not potential measures for climate change adaptation [12••,7]. Explicit identifications of adaptation measures are often in the context of household and community responses to impacts such as windstorms, heavy rainfall and flooding. Examples of the adaptations include tree planting, crop farming, infiltration technologies and water storage [23,45]. Various studies ranging from micro–meso to city-regional scales show support of micro-climate mediation [40], and closing nutrient loops through water and organic waste recycling [43,47,48]. For example, in Kampala, Dar es Salaam and Ibadan, adaptation to flooding has encouraged tree planting on hill slopes, greening drainage channels and increasing crop canopy to reduce potential runoff from rainfall at plot level to catchment-wide scales as part of ecosystem services enhancement [6]. The purpose is to increase infiltration and retention of storm water for reduced flooding risk [2,35].

Mitigation: Evidence of UPAF's climate change mitigation potential is not as strongly represented in the literature, despite studies that show the potential for carbon sequestration through tree planting and other urban-based carbon sinks. The proximity of production areas to reduce GHG emissions associated with food systems is discussed in terms of economic costs associated with energy for food production and transportation [40,42]. But UPAF's mitigation potential through nutrient recycling and avoiding landfill methane emissions is now recognized [13,49].

The growth and expansion of cities is known to alter natural ecosystems, creating complex socio-ecological systems. The increase in impervious surfaces and the reductions of vegetation cover has an influence on the UHI effect, with built up areas characterized by higher temperatures and less variation in night-time and daytime temperatures [1••]. Cities are often considered as bounded spatial entities, but in reality, can have extensive flows of fiber, timber, food, water and labor resources from the hinterlands and other cities. This makes enhancing urban ecosystems an important strategy for mitigation in addition to the adaptation potential. However, from the reviewed literature, limited work exists that specifically addresses urban green spaces and ecosystem services for mitigation [50••]. The potential for ecosystem services in the assessed cities is substantive, but studies indicate that piloting and validation of UPAF still largely exists at the micro level [46,51]. It is necessary to bring UPAF to a level that would have city-wide impacts in the context of climate change mitigation.

One noteworthy feature of the reviewed literature is that, apart from very recent sources, adaptation and mitigation have almost invariably been considered separately, both

epistemologically and in terms of the concerns of those undertaking the research [20,40,50••]. However, current thinking is moving beyond this conventional dichotomy, seeking to identify and prioritise interventions that address both simultaneously [52,60••]. Promotion of UPAF exemplifies this well, since it can provide both under appropriate circumstances. Its potential adaptation benefits include livelihood opportunities, contributing to urban food security (potentially both at the household and wider commercial scales), health benefits to producers and ecosystems services such as erosion control. In terms of mitigation, UPAF can contribute to carbon sequestration, organic waste and nutrient recycling, and the reduction of the UHI effect if practiced on waste or other open land, or if it replaces impervious surfaces in which ecosystems services from cities would be enhanced. However, if other vegetation is cleared for cultivation as a result, the net gain or loss will be context-dependent.

Despite the potential, certain factors may limit UPAF's actual contributions to climate change adaptation and mitigation. These include perception of human and environmental risks, restrictive policy and a lack of awareness [40]. The real or perceived concerns related to contamination by wastewater recycling, utilization of manure and other environmental and health concerns related to livestock are limiting the uptake, institutional legitimacy and overall success of UPAF [53,29,54].

Policy for adaptation and mitigation

Policy support is often closely related to successful education and capacity building in institutions at the municipal level [40,48]. City authorities in some cities are yet to appreciate the potential contribution of UPAF to climate change mitigation and adaptation. Owing to varying combinations of outdated modernist attitudes that perceive agriculture as properly a rural rather than urban activity and concern about possible environmental risks, city officials often display conflicting attitudes to UPAF. These account for the persistence of restrictive policies, laws and regulations [43]. Initiatives by organizations including the Resource Center on Urban Agriculture and Food Security (RUAF) and Urban Harvest have supported both research and policy development of UPAF in several cities within African countries [48]. However, more effort is needed for wider acceptance and integration into municipal plans [55,56]. Recent developments in low-income and middle-income countries to reduce emissions voluntarily through NAMAs provide an entry point to frame UPAF practice as avoiding and reducing GHG emissions. For example, organic nutrient recycling in cities has potential for avoided landfill methane emissions. Policy on UPAF requires the recognition of these actions as an integral part of the urban socio-economic and ecological system for building urban resilience to climate change [40,57].

Conclusions

UPAF is growing as a strategy to adapt to climate change [40,58,59]. Although only a small portion of the literature specifically addresses the role of UPAF for climate change adaptation and mitigation, work on the social and ecological impacts of UPAF reveals the potential. Evidence indicates that UPAF supports livelihoods, enhances food security and various provisioning, regulating and supporting ecosystem services of flood attenuation, biodiversity and carbon sequestration. In addition, UPAF can support the reduction of the UHI effect and flood mitigation with co-benefits for adaptation in terms of livelihood and urban food security enhancement, physical health as well as urban greening and run-off reduction [58]. Though challenges and risks associated with UPAF exist, well-managed UPAF activities can reduce these risks with benefits providing pathways for both adaptation to and mitigation of climate change impacts. While this potential is apparent from the literature assessed and analytical approaches deployed, most of these sources draw from household and city case studies. The geographies of UPAF reported from this meta-analysis indicate the importance attached to scale at which UPAF strategies can be implemented. Studies confined to household and municipal levels, present challenges in terms of scalability and transferability. These general strategies would have to be elaborated and translated into practical solutions that suit each city's needs to mitigate and adapt to climate change.

From this synthesis of literature, the potential contribution of UPAF as part of broader strategies for adapting to, and mitigating the effects of, climate change is clear but scaling up will require three main sets of activities at city-regional scales. First is addressing the development deficit in the cities of East and West Africa to support adaptation to risks, but in parallel building long-term resilience by sustaining and expanding integrated assemblages of green infrastructure. Second is the reform of institutions and policy to support multifunctional urban landscapes including ecosystem services within which UPAF and other climate-sensitive activities can be encouraged and supported. Third is the sharing of knowledge and other resources that can help scale out and scale up best UPAF practices appropriate to local conditions and circumstances. These three broad sets of activities have a high potential and likelihood to mainstream UPAF as one of the mediating processes for adaptation and mitigation of climate change.

Acknowledgements

This was prepared following research with support of several individuals. We would like to acknowledge Global Systems Analysis, Research and Training (START) for the financial support to conduct the study. We also acknowledge all who were involved in the study through information provision: David Mukungu and Moses Nambassi of Makerere University Uganda and Adesoji Akinwumi Adeyemi of University of Ibadan. Community members including Moses Nadiope, Chief Ogunnaike, Mr Elias-Ide, Mr & Mrs Aribisala, Mr Balogun and Mr Salami; Government

representatives including Dayo Ayorinde of the Sustainable Ibadan Project, Dr Adeoluwa of University of Ibadan, FO Adeniran of Oyo State Ministry of Agriculture, AA Adepoju (Director of Agriculture, Ibadan South West Local Government), and Ogundipe Adetokunbo (Director of Agriculture, Akinyele Local Government). This paper forms part of the special issue on *Bearing the Brunt of Environmental Change: Understanding adaptation and transformation challenges in urban Africa* edited by David Simon and Hayley Leck, which arises from the *Urban Studies* Seminar of the same name held at Royal Holloway, University of London, in April 2013.

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A chapter in the AR5 that is focused on cities and urban areas. Its most important contribution to this paper's argument is the integration of adaptation and mitigation strategies where possible. It does not explicitly talk about UPAF but generally raises passive systems of emissions reduction in which specific strategies like UPAF integrated into planning can play a key role.