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Urban soil management of marginalized lands: recognizant of history

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Urban agriculture (UA) forms a crucial part of the urban food chain in many cities in sub-Sahara Africa (SSA). As urbanization continues, it becomes increasingly important to acknowledge the role of UA within the socioeconomic fabric of the city, and build inclusive business models to empower its practitioners. A crucial constraint for this is that various stakeholders in UA often take conflicting stances on the phenomenon. Some see it as an illegal, unsustainable practice leading to pollution and soil degradation. Others claim that it sustainably increases food security and offers employment opportunities, particularly for the urban poor. This leads to a conflict in perception and value sets between the various stakeholders involved in UA, which inhibits the further development of UA into a sustainable, more inclusive business. Recently we also see an emerging view that UA can help address the issue of climate change by sustainable management of soil carbon stocks in addition to providing food and other services. An element that is mostly ignored in the discussion surrounding UA is land-use history and its effect on composition and nutrient status of UA soils, and with it the potential for sustaining UA and mitigating climate change. We propose that the sustainability of UA can only be understood within the context of land-use practices during and before UA. Only by understanding and acknowledging this context can UA be part of inclusive business practices in the urban environment. Here we review scientific literature on UA sites in SSA to unravel the extent of the knowledge gap in this area, and derive a guiding framework to integrate land-use history effects in the discussion on UA within the context of developing inclusive business models for its practitioners.

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Introduction

Urban Agriculture (UA) is a significant and growing phenomenon in sub-Sahara Africa (SSA) that plays a decisive role in food and nutrition security for urban households [1,2•,3•,4]. UA forms a critical source of household food that is intimately connected to factors such as high urbanization rates, low incomes of urban households, and the opportunity to serve an emerging niche market of fresh local produce in African cities [3•,4,5•].

The development of UA is a complex process in SSA, involving a plethora of actors with different socio-economic profiles, and producing a vast variety of products [1,6,7]. The majority of food entrepreneurs practicing UA are low-income, female slum and peri-urban dwellers with limited assets for production, processing, and marketing of food [8,9]. It is imperative to build inclusive business models for these actors, as they often face multiple constraints including limited access to markets, contested land ownership, and a lack of knowledge and/or assets needed to optimize their business [8–10]. A particularly important aspect herein is that UA practitioners and institutions, such as governments responsible for land planning and management, often have conflicting perceptions of the value and optimal use of the patches of land on which UA is practiced, [5•,11–13]. Optimal agricultural use of the patches is crucial to the livelihoods of UA practitioners, as well as for those who depend on UA as an important link in the urban food chain. In contrast, land planners often perceive UA patches as marginal lands better put to other use, for example, to support new built infrastructure [5•,11–13]. The conflict between different optimal land uses as linked to different value sets and perceptions is described by Hobbs *et al.* [14,15] in a more general perspective. They define hybrid and novel ecosystems as two types of systems of combined abiotic, biotic and social components that have undergone increasing degrees of human alteration causing them to deviate from their historical composition [14,15]. Hybrid ecosystems, and to an extremer extent novel ecosystems, have undergone such alteration that returning them to the historical state would face virtually unsurmountable social, environmental and/or ecological thresholds [15]. The conflict arises from the perception of hybrid and novel ecosystems as degraded versions of the historic ecosystem from which they derive, versus their perception as unique ecosystems with potentially valuable properties in their own right [15]. Each perception leads to a dramatically different management strategy. Therefore, to build inclusive business models for UA practitioners and ensure sustainability of their practices, it is essential to acknowledge that ecosystems have a history of human impact that not only defines their present state, but also the different values assigned to them by different stakeholders. This is further supported by McClintock [16] who identifies UA as arising from interrelated ecological, social and individual dimensions of metabolic rift, while at the same time attempting to overcome those rifts. Also here, land use-history plays a key role. For instance, age-old nutrient cycling practices not only define where UA stands now, but also how it can play a role in reducing the urban ecological footprint and providing inclusive business opportunities [16]. However, while the importance is recognized, in UA research there seems to be surprisingly little attention for the influence of previous land-use on the viability and future of current practices.

Therefore, here we review how and to what extent prior land-use is and/or should be taken into account as factor when studying the potential and efficacy of building inclusive business models for the urban poor practitioners of UA in SSA. We do so in the context of increasing policy awareness of the need to optimize soil ecosystem services to contribute to globally reducing hunger and mitigating climate change, as for instance formulated in the United Nations Sustainable Development Goals (SDGs) [39••]. Specifically, we review contemporary scientific literature to derive the current state of knowledge on: i) the potential of UA to contribute to reducing hunger, and mitigating climate change through optimal sustainable productivity; ii) the processes governing the initial selection of sites to be subsequently used for UA; iii) the influence of past and present UA land management on its productivity and carbon storage potential; and iv) the extent and way in which the previous land use shapes the opportunities and constraints for developing inclusive business models for UA in SSA.

Urban agriculture and land use history in the context of the novel ecosystem approach

If we view UA sites as novel ecosystems *sensu* Hobbs *et al.* [14,15], this implies that we should take into account the fact that different stakeholders will assign different values to them. These will include socio-economic as well as ecological values. However, in reality socio-economic and ecological values of UA are often studied in separation. Studies of the functioning of UA traditionally focus either from a socio-economic and political science perspective on its role in the urban food chain related to the factors that shape the choices and possibilities of the farmers [1,3•,7,17,18]; or focus from a natural sciences perspective on productivity as related to the current agricultural land management and its impact on soil biogeochemistry [13,19,20]. In addition, the influence of previous land-use management on UA and the values assigned to it is mostly not taken into account at all or dismissed under the (implicit) assumption that UA in SSA is mainly initiated on marginalized, nutrient poor, and soil organic carbon (SOC) depleted soils [19,21,22].

To truly assess the options for building inclusive business models for UA, interdisciplinary studies are needed that combine the socio-economic and political science domains with that of soil science, explicitly taking into account previous land use and the historic composition of the natural and socio-economic ecosystem, as also advocated by Hobbs *et al.* [15]. However, while recognizing that novel ecosystems can have value in their own right, Hobbs *et al.* [15] still imply that the transition from historic through hybrid to novel ecosystem is generally one of degradation [15]. The reverse option that returning to a historic state may be perceived socially, economically and/or ecologically as degradation by local communities, including the UA practitioners, is not fully incorporated. Neither does the approach by Hobbs *et al.* [15] fully take into account that when an UA plot is further transformed into another novel ecosystem with a more traditional urban function, this can widen the gap between the values assigned to it by different stakeholders. Such traditional urban functions, as for instance the construction of a shopping mall or apartment buildings, may be perceived as being of higher value than UA for urban planners, but are often less inclusive than UA as their services are mostly unavailable for the urban poor, whose access to resources is restricted. As such, the novel ecosystem approach does not fully acknowledge the real-life constraints in resources, knowledge, and so on. faced by the urban poor in their role as UA land managers faced with the task of optimizing the management of their land.

Soil fertility as key parameter in assessing the ecological, economic and social values of UA

When assessing the ecological, economic and social value of agricultural land, including UA, soil fertility is a key parameter. It is soil fertility that determines the potential crop production of an UA plot, and it is ecologically sustainable fertility that ensures long-term productivity of the site. As a result, UA sites that have a sustainable high fertility have a large economic and social value for its practitioners.

Two fundamental determinants of soil fertility are the inherent mineralogical and biogeochemical composition of the soil [23,24••]. Both are subsequently altered by the agricultural management practices such as the manuring regime, plowing strategy, and crop type grown [23,25]. However, the inherent soil composition strongly affects the necessity, intensity, and direction of subsequent agricultural management practices [24••]. As a result, the initial soil composition combined with subsequent land management before the onset of UA can be expected to be driving factors for its viability. For instance, an inherently poorly fertile, marginalized soil that is transformed into a UA plot can be expected to require a vastly different agricultural management approach than a soil that was already highly fertile, inherently and/or through previous agricultural management [24••]. Indeed, our own recent work in Kisumu, Kenya indicates that the effects of current land management practice may be overridden by the biogeochemical composition of the soil that was the result of previous land-use before the application of UA [10]. At the same time, the investments needed to supply the amendments required to make a marginal soil fertile can be expected to be much larger than when an inherently fertile piece of land is transformed to a UA plot.

Nevertheless, agricultural productivity as linked to soil fertility is only one of multiple ecosystem services potentially rendered by any form of agriculture, including UA. As we advocated in a recent white paper [26], the role of soil science in addressing important other challenges such as mitigating climate change is still grossly underestimated by policymakers and the general public. However, this has changed recently with the development of the 4 per mil initiative aimed at counteracting anthropogenic CO_2 emissions by sustainably increasing SOC contents worldwide by 4 per mil per year [27]. Climate Smart Agriculture aimed at reducing SOC losses due to conversion of other land uses to agriculture, and even transforming agricultural land into a net carbon sink, is advocated as an important means to reach the 4 per mil goal [27].

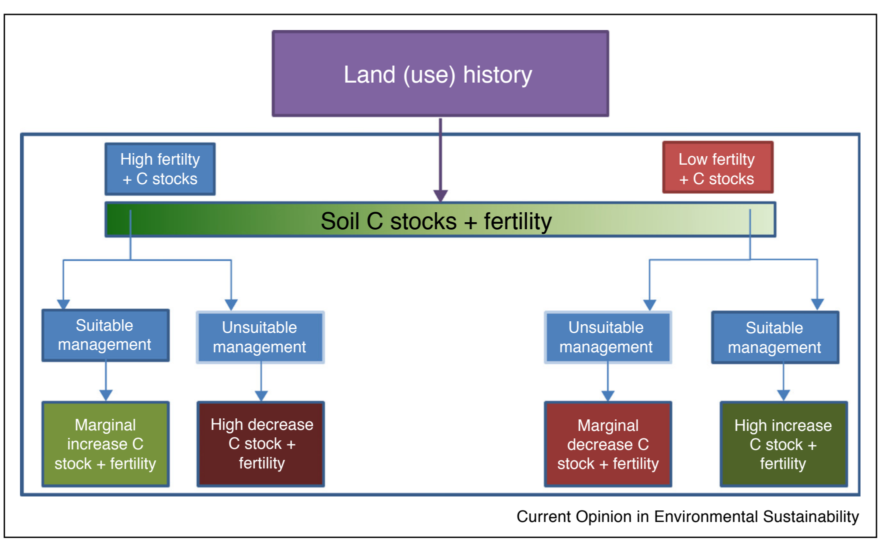
As visualized in Figure 1, the combination of both initial biogeochemical composition and previous land-use will influence the strategy for optimal current Climate Smart Agricultural management to reduce hunger and mitigate climate change. Moreover, the increased policy awareness for soil carbon storage as additional valuable ecosystem service rendered by the soil, when recognized for UA may play a role in closing the potential perception gap of the value of UA plots between practitioners and land planners. While at the same time mitigating climate change in its own right is beneficial for UA practitioners. As such, it is an important aspect to consider in the context of developing inclusive business models for UA practitioners.

Processes governing the initial selection of sites to be subsequently used for UA

Based on what was discussed in the previous paragraph, previous land-use may play an important role in the decision to initiate UA at a particular location. One would expect that given the choice the most fertile piece of land is selected to initiate UA. However, several studies have shown that the development of UA in SSA is a much more complex process, strongly influenced inter alia by the variety of actors involved, their access to resources, and the formal or informal land negotiations and transactions between such actors [2•,5•,6]. In addition, the development of UA also strongly depends on specific government policy guiding UA, or as is frequently the case, the lack of such policy [5•,11–13].

All of the mentioned factors influence the selection of certain areas to be used as UA plots. It often involves grabbing of former agricultural land at the fringes of cities [5•,6]. In addition, it encompasses the use of open spaces in the city ranging from public land along

Figure 1



Land-use history significantly influences the initial status of the soil in terms of carbon stocks and nutrient content (i.e. fertility), this in turn influences which agricultural management practice is needed to maintain or improve the soil. Soils with high initial C stocks and fertility have the highest potential for loss, whereas poor soils, with low initial C stocks and fertility have the greatest potential for increase under the right management.

roads to privately or institutionally owned land, and may include endurance of existing agriculture that is incorporated in the expanding city [2•,5•,6,13,28]. The latter is corroborated by studies of urban evolution based on satellite data as well as urban expansion models in SSA [28–30]. Especially valuable UA sites are those close to water supply, leading to a preference for sites along streams or in lowlands with a shallow water table [2•,31]. These in particular are sites that one can expect to have been under agricultural use already before urban encroachment. The reason is that water availability is an import asset for agriculture in general, and proximity to a stream in particular when it periodically floods, potentially resulting in replenishment of the soil with fertile young sediments. An example of this is the Boulmiougou UA site in Ouagadougou, Burkina Faso, which is located next to a water reservoir [20,32]. The site is considered to be a model for UA, however it has been an agricultural site for many decades that only in the last 20–30 years has been truly classified as UA when urban sprawl encroached on the site [20,32]. At the same time, as a result of the mentioned diversity in factors governing the development of UA, in addition to former agricultural sites like Boulmiougou, marginal lands that have no prior history of agriculture are also still frequently used for the initiation of UA [29,33].

Therefore, we conclude that the previously mentioned, often voiced assumption that UA in SSA is mainly initiated on nutrient poor and SOC depleted soils, and the coupled conclusion that it is therefore an urban land use of low value [19,21,22] is too simplistic. It does not do justice to the complexity of the processes leading to the initiation and subsequent endurance of UA at a certain location. As a result, the influence of previous land-use on UA cannot be dismissed a-priori, and must be considered in urban land planning and in developing inclusive business models for UA practitioners. The latter relates to the opportunities and constraints governing the selection of a piece of land to initiate UA, as well as the subsequent strategy and assets needed to make or keep it fertile.

The influence of past and present urban agricultural land-use on productivity and carbon storage potential

In the context of SSA, specific case studies in Tanzania, Kenya and Nigeria all point towards an important role for Climate Smart Agriculture to help mitigate climate change [27]. An important observation here is that for instance in Kenya the highest potential for increasing SOC stocks through agricultural management has been reported in the areas that have the highest degree of urbanization [27]. Others also indicate that urban soils can and should play an important role in sequestering carbon [34]. An extensive study of the development of soil biogeochemistry in soils in Ghana that were transformed to UA plots since 1986 shows an increase in SOC stocks as well as pH due to the soil amendments used [35]. A study of UA plots in Ouagadougou in 2012 also found a significant influence of fertilization practices on the soil carbon content [20]. This view is supported by a study in the UK that showed that under adequate management UA can maintain fertile soils with high SOC stocks, surpassing even conventional agriculture [36]. However, at the same time the authors of the first study indicate that the influence of urbanization on fertility and tropical SOC stocks is still largely unknown and remains controversial [35]. In addition, some studies indicate that while UA may sequester carbon, other urban land-use may sequester even more carbon [34].

Zooming in on the effect of management practices upon the initiation of UA at a particular site, multiple studies of UA in various SSA cities indicate a high diversity in soil fertility, yields and SOC stocks that they mainly correlate to present land-management [2•,7,31] Two case studies from Tamale and Ouagadougou in Burkina Faso show conflicting trends of soil fertility and SOC stocks in urban versus peri-urban farms that are strongly linked to the type and amount of amendments used [19,31]. In some instances the land-management resulted in significant carbon losses even though amendments aimed to increase SOC stocks [19,31]. The availability of amendments as well as irrigation water are seen as the major constraints for the yield, the long term fertility, and the productivity of a given UA site [2•,7,12,20,31]. The need for continuous cropping on the same plots makes many urban farmers soil conservation specialists, but at the same time increases the risk of depletion of the soil [2•]. Moreover, the level of knowledge and experience present varies greatly given the great heterogeneity of UA actors [10,37]. This implies that custom strategies are needed for the development of inclusive business models for UA, which acknowledge the observed diversity in both actors and soil biogeochemical conditions.

However, while the great heterogeneity of UA actors and their socio-economic circumstances and constraints are broadly recognized, in none of the studies cited in the previous paragraph prior land-use was taken into account. Since UA is initiated on a variety of lands, including fertile soils previously used for rural agriculture, also from the perspective of present day UA management, the effects of previous land-use cannot be dismissed a-prior. Consequently, there is a need for more research to systematically examine the influence previous land-use has on soil fertility and SOC stocks in UA in SSA and how this translates to optimal case-specific present day fertilization strategies that are accessible and available to UA practitioners. These could then form the foundation on which to build optimal, site and actor(s) specific inclusive business models for UA.

To take previous land-use into account, firstly systematic information about previous land-use of present day UA plots is needed. A possible direction to acquire such information is the use of past and present satellite images to track urban development and thus document where the UA sites originate from [29,30,33,38]. For instance, Coulter *et al.* [29] used a combination of landsat imagery to classify land-use change, including increased urbanization, in Ghana; whereas Tarawally *et al.* [30] used landsat imagery to study the expansion of Freetown and Bo Town in Sierra Leone. In combination with interviews this could give a detailed picture of what the origins of UA sites are. Subsequently, more information is needed about the effects of previous land-use on the potential fertility and SOC stocks that can be achieved, the management practices needed to achieve them, and how this compares to UA that is initiated on marginal lands.

Discussion

From the literature reviewed in this exploratory review, it is clear that the question whether or not UA in SSA is recognized as valuable link in the urban food chain continues to depend on the values and perceptions of the stakeholders involved. This puts the vulnerable groups that practice and/or depend on it for their livelihoods and food supply in an uncertain position. At the same time, UA may play a key role in closing the urban metabolic rift and empower its practitioners.

Previous land-use has a potentially decisive influence on subsequent site-specific management practices required to achieve or maintain optimal soil fertility and SOC storage potential. This may form an important constraint for the often resource-limited UA practitioners. They will, for instance, be able to maintain sustainable productivity much easier on an inherently fertile patch of land that has always been used for agriculture, than on a truly marginal piece of land that would require extensive investments to make fertile. However, the influence of previous land-use is not limited to the variety in costs of custom fertilization schemes. It also includes aspects such as differences in land ownership in case of incorporation of existing agricultural land by an expanding city, as compared to initiation of UA on marginal lands within the city.

Opportunities to close the perceptive gap between UA practitioners and actors such as policy makers and urban planners arise from increasing awareness by the latter that UA patches may be inherently fertile, and thus valuable, lands. Their perceptive value may be further enhanced by the increasing recognition that UA can potentially play a role in mitigating climate change through SOC accumulation. Combined this may lead to the acknowledgement of UA patches as valuable novel ecosystems that warrant protection rather than restoration to a historic state, or further development into yet another novel ecosystem.

Conclusions

Based on the present exploratory review, we can conclude that to further shape inclusive business models for UA practitioners, previous land-use of the UA plots is an important, yet mostly overlooked aspect that should be taken into account. However, to include land use history several remaining knowledge gaps must be addressed. These include answering questions such as: Is there a potential for higher ultimate fertility and SOC stocks to be achieved depending on prior land-use? To what extent does previous land-use influence the long term land management practices needed, and how does this translate to long term costs and opportunities for UA practitioners? What are the social and cultural drivers for past and current land-use? A more fundamental, systemic review of the entire socio-economic, political sciences, and natural sciences knowledge base combined with dedicated experimental (field) research is needed to address these questions and gain a more holistic understanding of UA in SSA and its potential to contribute to inclusive business.

Declaration of interests

Nothing declared.

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