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EDITORIAL

Rural–urban transformation: a key challenge of the 21st century

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The global challenge of rural–urban transformation

During the last two decades the benefits, risks, negative externalities, and future social-ecological challenges of urban and (peri-) urban agriculture (UPA) have received increasing attention (Lydecker and Drechsel 2010; Safi and Buerkert 2011; Drechsel and Keraita 2014; Thebo et al. 2014). A main cause for this attention is the growing awareness of rapid rural–urban transformation processes that are changing matter flows, resource allocation, and ecosystem functioning as a consequence of strong shifts in the distribution of people along the rural–urban gradient (Cumming et al. 2014; Angel et al. 2005). It has been estimated that by 2050 the share of the global urban population may reach 68% compared with 55% today (United Nations 2017). Given continuing population growth, this phenomenon, in absolute numbers, entails the migration of hundreds of millions of people into urban areas. While the *status quo* of urbanization varies by continent with > 80% of the population already being urban in the Americas followed by 75% in Europe, 42% in Africa, and 50% in Asia, the rate of urbanization is much faster on the latter two continents (United Nations 2017). Rural-urban transformation is accompanied by rapid losses of prime agricultural land in urban areas which until 2050 are estimated to reach 2% of the agricultural area globally, with 60% of it occurring in Asia (Bren d'Amour et al. 2016). In this context provisioning, supporting, and regulating cultural ecosystem services, which characterise ecological and social systems in rural and urban contexts, are increasingly challenged (Pickett et al. 2014). This special issue highlights a range of recent or future problems related to UPA and possible approaches for their mitigation.

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Externalities of UPA

The advantages of UPA production systems comprise the supply of fresh vegetables, fruits and dairy products to consumers (Diogo et al. 2010a, b; Fig. 1), and they may also foster the conservation of plant biodiversity and pollinator functions (Bernholt et al. 2009). Also reported are provision of jobs and income opportunities for (poor) producers and street vendors across value chains, recycling of water and

Fig. 1 In many low-income countries of the Global South, urban and peri-urban agriculture (UPA) strongly depends on the effective recycling of waste water and other urban resources such as idle land, abundance of capital, cheap labour, and reliable consumer markets. UPA thereby also addresses multiple demands of urban consumers for ecosystem services. Problems of recycling of nutrients become evident in large leaching and volatilisation losses, high faecal bacterial loads and pesticide residues of agricultural produce. Curbing these negative externalities of UPA requires sensible regulations taking into account the needs of producers and consumers in a highly dynamic social-ecological environment driven by new quality criteria along value chains and global competition for goods and services

organic waste, and coverage of free space with urban green (Graefe et al. 2019). Nevertheless, a major problem of UPA are lacking legal frameworks for this mode of production including tenure rights for the producers (Cabannes 2012). Most producers are illegally occupying land and can easily be pushed away when land developers need their plots. The same is true for livestock systems in cities as animals are often regarded as a nuisance given related odor and manure production. An exception to this is India where cattle in cities have a very important cultural role and are thus tolerated even if legislators may have recently tried to confine them to colonies (Prasad et al. 2019). Also crop production along Indian railway tracks is strongly regulated and tenants have a land title linked to their obligation of keeping the tracks clear of building encroachment (Vazhacharickal et al. 2013).

Research and development efforts in UPA indicate that in contrast to widespread concern of consumers and administrators, heavy metal contamination of UPA produce from dust deposition or wastewater irrigation seem to be much less of a human toxicity problem than the contamination with faecal pathogens (Abdu et al. 2011; Akoachere et al. 2018; Dao et al. 2018), except for very specific cases in the tanning and dying industry of countries with lacking or poorly enforced legislation, such as Nigeria (Mashi and Alhassan 2007) or Pakistan (Rehman et al. 2008). Pathogen contamination of fresh (peri-)urban produce, however, is often not recognized as a serious problem by the local population as diarrhea and related early child death are common phenomena which have many causes. Uptake of heavy metals in UPA is generally low due to the comparatively high pH and organic carbon levels of UPA soils to which often large amounts of organic waste are applied, including sewage sludges, manure, and composts of varying origin and quality. While it is well known that plastics ingested by ruminants in grazing fields or on municipal dumpsites accumulate in their rumen and may cause animal death (Mushonga et al. 2015), it remains open to further research whether microplastic particles produced in this context are a health concern for animals or humans as they enter the food chain.

While UPA undoubtedly provides important pathways to recycle organic waste in urban areas, links between urban livestock keepers and vegetable producers are often weak or even lacking. This may be because of attractive alternative uses for manure, such as shown for the brick industry in Khartoum (Sudan; Abdalla et al. 2012; Babiker Abdalla et al. 2012), fuel material in Faisalabad (Pakistan; Erbach 2014) or because manure management and transport seem too cumbersome compared to the easy availability of mineral fertilizers.

Open nutrient cycles in UPA systems may become a concern as balance studies demonstrated that excessive surplus of nutrients can lead to large volatilization and leaching losses during manure storage or after field application (Predotova et al. 2010a, b; Diogo et al. 2010a, b). On the other side, detailed studies indicate that regular manure and compost applications are necessary to maintain organic carbon balances in year-round cropped and intensively irrigated UPA plots (Lompo et al. 2019).

Food self-sufficiency and telecoupling

Given their high population densities and related consumer demands, cities are major sinks for resources among which food, fiber, energy, labour, and water are the most important. In recent years numerous studies have been conducted to quantify the dependence of cities from their hinterland whereby for food so called "foodsheds" were defined. They describe the area from which food items come and—in combination with the *virtual water* contained in imported food—allow to link local consumption patterns with regional and even global supply (telecoupling; Liu et al. 2013; Drechsel et al. 2007; Karg et al. 2016). Depending on the time-resolution of the data collected, these dependencies may have crop-specific, seasonal patterns and may thus gain substantial political relevance. They allow predicting the effects of price increases for imports as well as responses to taxation and transport blockage. At the regional and global level, such studies may contribute to making food aid, water use and resource planning more effective (Akoto-Danso et al. 2019a).

The road ahead

With a global population reaching 9.7 billion by 2050 (UN DESA 2017), continuing rural–urban transformation and increasing demands for instant availability of healthy, fresh and affordable food, agriculturalists once more are asked to enhance production and efficiency on shrinking land resources. Increasingly well-defined standards for modes of food production (e.g. organic food), labour rights, food quality and safety, carbon and water footprints, and use efficiency of nutrients and space will need to be implemented.

The ten papers compiled in this volume report about recent collaborative research in Africa and Asia conducted along these lines. They provide a comprehensive review of the available scholarly literature on the topic as well as data from well-defined case studies and insights into social-ecological production systems along urban value chains. The introductory review (Graefe et al. 2019) on recently published studies dealing with UPA in general and particularly in tropical countries highlights the widespread concerns about food safety—in particular of vegetables—produced in cities. It also points to the largely untapped potential of close crop-livestock integration in and around cities which could enhance nutrient use efficiency. In line with the general trend, the majority of contributions investigate urban and peri-urban vegetable cultivation. Four contributions from Burkina Faso and/or Ghana focus on nutrient balances in urban vegetable production, thereby also testing the effects of biochar as a soil amendment. At UPA-typical fertilizer application levels exceeding official recommendations four- to seven-fold, apparent nutrient use efficiency of potassium (K) and nitrogen (N) ranged from 54 to 85% and from 44 to 66%, respectively (Lompo et al. 2019). The application of 20 t ha^{-1} of biochar improved marketable average yields of different UPA crops by 6%, but yield increases were significant only on fertilized plots (Manka'abusi et al. 2019). On unfertilized plots, vegetable yields increased with wastewater irrigation, by a factor of 10–20 during the dry season and by a factor of 4 during the wet season. Fertigation with wastewater thus contributed to nutrient recovery within the city while yield-increasing biochar effects disappeared with irrigation (Akoto-Danso et al. 2019b). When irrigation exceeded crop demands, N leaching losses in the order of 200 kg N ha^{-1} were measured. The high nutrient load of wastewater contributed to these losses, which could not be curbed by biochar application to the soil (Werner et al. 2019). The contribution investigating vegetable contamination with heavy metals in railway gardens of Mumbai, India, reports that the related health threat of consumers is moderate to considerable (Vazhacharickal et al. 2019). Three contributions of this issue focus on nutrient use efficiency in urban and peri-urban livestock holdings. An estimated 190,000 farm animals (tropical livestock units of 250 kg body weight) are currently kept in Ouagadougou, Burkina Faso. In nearly 70% of the studied cases, their homestead feeding was characterized by excess N supply. Through their (partly unused) manure an annual amount of up 1100 tons N is estimated to accumulate in the peri-urban space (Schlecht et al. 2019). Likewise, N use efficiency was found to be suboptimal in peri-urban crop-livestock systems of two Ethiopian cities. Suggested improvement measures across the studies include targeted exchange of crop residues and manure between crop and livestock activities within and between farms and precision feeding (Tadesse et al. 2019). At the national level, exemplified for India, nutrient fluxes in UPA livestock systems are related to feed production, transformation of nutrients from feed into animal products, and waste management. Enhancing nutrient recycling efficiency therefore requires strengthened crop-livestock links and increased awareness of stakeholders (Prasad et al. 2019). However, no city is self-sufficient in food production: Tamale in Ghana and Ouagadougou in Burkina Faso, for example, import 10% and 40% of the N contained in human food from outside the country. In Tamale, 50% of the food nutrient inflows leave the city again for other destinations, pointing to the cities' function as food trading hubs (Karg et al. 2019). Whether or not raising urban demands for meat in Asia and Africa (OECD/FAO 2016) can be met by local producers and thereby also generate new opportunities for rural livestock keepers to regularly sell their products and thus enhance the resilience of agro-pastoral dryland systems, will partly depend on local infrastructure and flexible food processing and distribution systems. The same is also true for staples and vegetables, of which UPA only covers part of the cities' demand (Karg et al. 2016). In any case (urban) consumers' demands for multiple ecosystem services will likely increase faster than their willingness to pay for what they long had for free. Across rural to urban production systems and value chains, this will require enhanced resource use efficiency, factor productivity and a strengthening of the systems' resilience against shocks to cope with the often location-specific effects of climate change and market developments.

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