International Workshop: Urbanisation and its Impact on Peri-urban Water and Food Security in Africa: Developing Research Collaboration and Capacity Building

Date: 4—5 December 2017, Makerere University, Kampala, Uganda

Discussion Paper

Urbanisation, Peri-urban Water and Food Production: Perspectives on Emerging Challenges in the African Context

Contributors: *Richard Bawden, Ashantha Goonetilleke, Dharma Hagare, Basant Maheshwari, Ronald Muchelo, Inakwu Odeh, Roger Packham, Elly Sabiiti, Maria Varua, and Willem Vervoort*

Abstract

Rapidly increasing population and urban migration across Africa and other developing regions of the world are creating new and complex challenges. The current water and land-use changes in urban and peri-urban regions have serious consequences for water and food security, lifestyle, environment, health and the overall well-being of urban and peri-urban communities. It is now increasingly being realised that we cannot altogether stop urbanisation due to the various reasons but need to restructure and rebalance the way we plan land use and manage urban growth. Achieving and maintaining sustainability, liveability and productivity of urban and peri-urban regions must address several key goals which include local water and food security, provision of adequate infrastructure, adaptation to new environments created by climate change, reduction energy consumption and greenhouse gas emissions, provision of adequate water supply and safe use and disposal of urban wastewater and maintaining biodiversity. It is therefore important for policy makers, urban and peri-urban planners and municipal council managers to understand the current issues and challenges in order to develop suitable strategies and practices to cope with current and future pressures of urbanisation and peri-urban land-use changes.

In this paper, we discuss how urbanisation is impacting on water availability and peri-urban food production and the importance of understanding hydrology, stormwater management, urban wetlands, climate change and socio-economic issues and incorporating systemic thinking and different worldview in creating liveable urban and peri-urban regions. The need for balanced urban development cannot be overemphasised, but it is not easy to achieve, particularly in developing countries of Africa. The next important step is to understand the issues and challenges more closely and have an effective dialogue at different levels to develop innovative strategies that will help in balancing urban development with water and food security and liveability outcomes.

Introduction

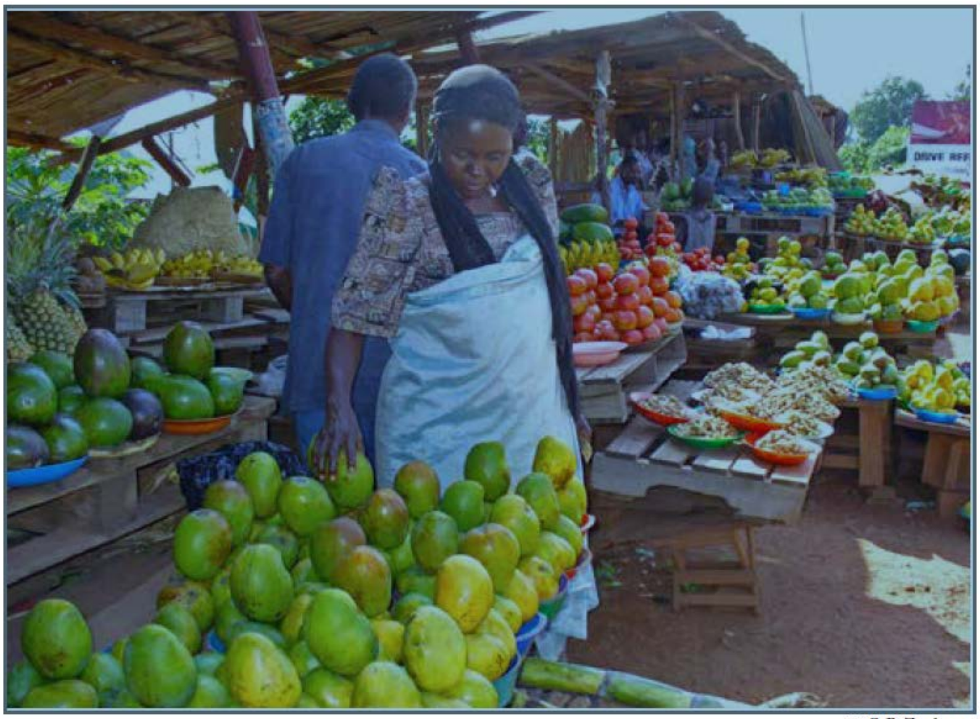
Peri-urban areas are everywhere. They are in both developed and developing countries and in small towns and mega cities. These are the zones of transition from rural to urban land uses which are located between the outer limits of urban and regional centres and the rural environment. The boundaries of peri-urban areas are not static. They are porous and in transition as new suburbs are developed outwards from towns and cities into rural lands. Regardless of how urbanisation occurs the boundaries between urban and peri-urban areas change. There will always be peri-urban zones. The global area of urban irrigated agriculture is estimated to be 24 Mha, about 11 % of the total area under irrigated agriculture in the world (Thebo et al., 2014). As such, urban agriculture is in direct competition with high priority water users such as for drinking and other domestic water uses in urban areas. Furthermore, the water availability for urban agricultural irrigation can get quite limited in times of drought.

The current world population is about seven billion, split almost evenly between rural and urban. Projections are that by 2050 the global population will increase to about ten billion. It is likely that the bulk of the increase will occur in urban population, perhaps due to migration from rural areas. The massive migration is and will be posing huge challenges with regard to water security, energy security, food security, transportation, housing, education, health services, protection from natural disasters, social tranquillity, economic opportunities and health of ecosystems. These challenges will be daunting for any government – local, state and national. Already, migration of people from rural areas to urban areas is occurring at an accelerating pace, particularly in developing countries, such as Brazil, China, Egypt, India and Mexico. For the lack of space, urban development is moving into the countryside, eliminating much of the best farmland surrounding cities, and periurban areas are rapidly sprouting. In many countries, some of the highly valued natural resource assets, such as biodiversity, native vegetation, peri-urban agriculture, wetlands and waterways, occur in peri-urban landscapes. In view of the impacts of climate change, energy costs, rising world population and changing patterns of food consumption, the value of these assets will increase even further.

Agricultural land at the periphery of towns and cities has been an important source of local fresh vegetables, fruits and other farm produce (Figure 1). One study indicate that peri-urban zones produce 15 - 20 % of the world's food supply (Corbould, 2013). There are, however, growing concerns about conversion of productive agricultural land into suburbs and industrial and other urban uses, as this reduces the availability of agricultural land and water for food production worldwide. This situation is creating challenges for food security to meet increases in population in urban areas. For cities to be liveable and sustainable into the future, there is a need to maintain the natural resource base of soil and water, food production and ecosystem services in the peri-urban areas surrounding towns and cities.

Development of peri-urban areas involves the conversion of rural lands to residential use, closer subdivision, fragmentation and a changing mix of urban and rural activities and functions. Changes within these peri-urban areas can have significant impacts on ecohydrological functions, environmental amenity, natural habitat and supply and quality of water. Peri-urban areas also result in increased water and energy consumption. These changes affect peri-urban water and land management, as well as food production.

The main aims of this paper are to (i) understand how urbanisation can impact on water availability and food production in peri-urban areas, (ii) identify key peri-urban issues and challenges in African context and (iii) explore possible actions and strategies for sustaining peri-urban food production.



© G.P. Zachary

Figure 1. Maintaining food production in urban and peri-urban areas is critical for the sustainable development goal.

Urbanisation is unstoppable

Urban expansion is increasing with projections that more than 70 % of the global population will live in cities by 2050 (United Nations, 2011). The growth of urban areas will be through vertical expansion of towns and mega cities, and via horizontal expansion of surrounding peri-urban zones (Figure 2). There is often a lack of understanding and appreciation of the changes that take place in peri-urban areas, which can affect both the urban areas and surrounding rural environments. The urbanisation process involves complex interactions between environmental, social, economic and political issues, resulting in what are known as 'wicked problems' (Rittel and Webber, 1973; Harris, 2012)

(a)

©U. Betin

(b)

Figure 2. Examples of urban encroachment into peri-urban lands.

There may be differences in some local conditions and scales, but the problems of expanding cities have similarities worldwide – both in developed and developing countries. It is projected that in the period up to 2050, urban growth will occur primarily in developing countries in Asia and Africa (McGee, 2009) and that these regions could account for up to 60% of the increase in urbanisation. The urban growth will be dominated by both the growth of central cities and an ongoing horizontal urban expansion into peri-urban areas. It is the horizontal expansion that presents most of the environmental, social, economic and political challenges in achieving sustainable, liveable and productive urban regions with significant local food production.

Urbanisation and water availability for agriculture

Urbanisation affects the availability of land and water resources. Land developers can afford to outbid land beyond what farmers can afford, and they can induce temptations to them to sell their land for urban development. Once a new suburb has been developed around existing farms in peri-urban areas, complaints from new non-farm neighbours tend to increase about 'problems' including manure smells, chemical sprays, noise, dust and slow-moving farm machinery on commuter roads. This can give rise to conflict between farmers and urban dwellers (Sinclair et al, 2003). The change in land use resulting from urbanisation also increases stormwater run-off from housing developments resulting in an increased risk of erosion and increased competition for water supplies. As farmers become more of a minority in expanding peri-urban areas and availability of water decreases, farming can become too difficult to continue.

Water is critical both for environmental flows, and production agriculture. Water is fundamental for ensuring regional food security, especially fresh fruit and vegetables, economic growth and wellbeing of people. There is on-going debate about maintaining peri-urban agriculture. However, it is often not sufficient to justify the economic value of the agricultural product and its flow-on effects, as this is unlikely to be adequate politically on its own against community expectations and political imperative for 'affordable housing' for the growing urban population. Furthermore, there are some implicit value-positions that need to be identified and articulated to justify the use of land and water for agriculture in peri-urban areas. One important point in this regard could be whether the community wants to maintain the rural character and agriculture around cities, or if they will just convert another piece of land close to urban areas not yet developed. Also, whether urban food security is valued by the urban community, or if it is simply assumed that food will always be produced somewhere else irrespective of what urbanisation might do to water availability and agricultural lands in peri-urban areas.

Peri-urbanisation impacts on food production in Africa

The 2017 Revision of the World Population Prospects (UN DESA, 2017) puts Africa's human population at about 1.3 billion people (17% of the world's population). Of this population, over 500 million live in urban areas. Today, Africa and Asia are the least urbanized regions of the world, with 40 and 48% of their respective populations living in urban areas, as compared to 82, 80 and 73% for Northern America, Latin America and the Caribbean, and Europe (respectively). However, although all regions of the world are expected to urbanize further over the coming decades, Africa and Asia are urbanizing more rapidly, and are projected to become 56 and 64% urban, respectively, by 2050 (UN DESA, 2015). For instance, in 2010, only 48 African cities, were counting more than 1 million inhabitants (Africa's million+ cities) (Vermeiren et al., 2012). Less than 10 years from 2010, the number has increased to over 57 cities with more than 1 million inhabitants (UN DESA 2016). Cities are the centrepiece of economic, political and social transformation; hence they are an attraction for settlement for many people from countryside areas.

This rapid urbanization in Africa is occurring almost exclusively at the expense of agricultural land in peri-urban zones, which has placed food production in these areas at risk. For instance, Kampala (the capital city of Uganda) has evolved from a "city of seven hills" (8 km2) at independence (1962) from Great Britain, to a city of more than 25 hills (approximately 197 km2) today (Nyakaana et al., 2007). This points to a significant expansion of the city into peri-urban agricultural areas, which would otherwise be agricultural land (Sabiiti and Katongole, 2016). Today, limited land accessibility ranks among the most critical challenges in the peri-urban zones of Kampala. Peri-urban farmers are competing for available land with urban development pressures, such as buildings, brick-making (motivated by the booming house construction industry), creation of spacious recreation and leisure facilities etc., which have a greater return on financial investment than food production (Sabiiti and Katongole, 2016). Due to the rapid urbanization, land and rental accommodation in the inner-city zones have become insufficient and expensive. Hence, there is movement of populations from the inner-city zones to peri-urban zones in search of cheaper land and rental accommodation. In response to the increased demand for rental accommodation in peri-urban zones, many peri-urban farmers are moving their small land areas away from agricultural activities (food production) in favour of constructing rental houses for better income generation (Katongole et al., 2012).

Additionally, the migration of populations from the inner-city zones has escalated the cost of land in peri-urban areas of Kampala has, which has made food production-related investments to become economically not viable in those areas. The cost of 1 acre of land within a 20 km radius from Kampala city ranges between 30,000 and 40,000 US$, which is far beyond the means of most peri-urban food producers. This has fuelled many farmers in peri-urban areas of Kampala to sell their land, and opt out of food production. To make matters worse, there are no policy and institutional arrangements directed towards supporting and protecting agricultural lands in the peri-urban areas of the expanding metropolitan Kampala.

Agricultural land use changes – The Greater Kampala Metropolitan area

The Greater Kampala Metropolitan area (GKMA), the 13th fastest growing urban centre globally (http://www.citymayors.com/), was selected as a case study to explore the effect of urban growth on UPA land. We are therefore using GKMA as case study representative of the rapidly growing major urban centres in SSA that are experiencing loss of prime agricultural land. According to KCCA, GKMA has a population of over 3 million and a population density of 9,429.6/km2 but the population is projected to grow to 5 million by 2025 and to 10 million by 2040 (KCCA, 2012).

Multi-temporal (decadal) land use/cover classification of Landsat images between 1989 and 2015 were analysed. In addition, we assessed the trends of household landholding using UPA farmer survey and data from the Uganda National household surveys (UNHS) (del Mar López et al., 2001)

The training samples were obtained from the existing aerial photos and field surveys between August and October 2014 and between August and December 2015. The training and validation samples focused to areas that did not experience a change between the dates of remote sensing data and the field surveys. The use of known unchanged land use location was suggested by (Mertens and Lambin, 2000). Testing of assessment accuracy involved the use of an independent data set from that used for training to avoid overestimation of classification accuracy (as recommended by (Congalton, 1991). Table 1 shows the accuracy assessment of the LULC images.

Table 1: Overall and kappa accuracy of final LUCC maps.

Sensor	Date	Overall classification accuracy	Kappa index of agreement
Landsat TM	27/02/1989	87.8 %	0.81
Landsat ETM$^+$	27/11/2001	77.1 %	0.76
Landsat OLI/TIRS	27/02/2015	89.9 %	0.86

The results are presented in table 2 and Figure 3. Although there was significant increase in UPA land areas between 1989 and 2001, generally UPA land area had declined between 1989 and 2015. This decline had occurred mainly in good quality agricultural lands, usually more amenable to urban development. Results from our other studies indicate that urban expansion and intensification in GKMA had taken up much UPA lands that are characterised by good soil quality and close to water sources.

Table 2. Land use and cover changes over past 25 years in and around Kampala (in km^2)

Land use	1989	2001	2010	2015
Agricultural land	430.6	491.4(+14%)	393.8(-9%)	336.1(-22%)
Urban	218.0	254.3(+17 %)	377.7(+73 %)	459.6 (+111%)
Wetlands	188.7	179.1	202.8	193.0
Savannah/others	763.5	677.2	629.6	610.2

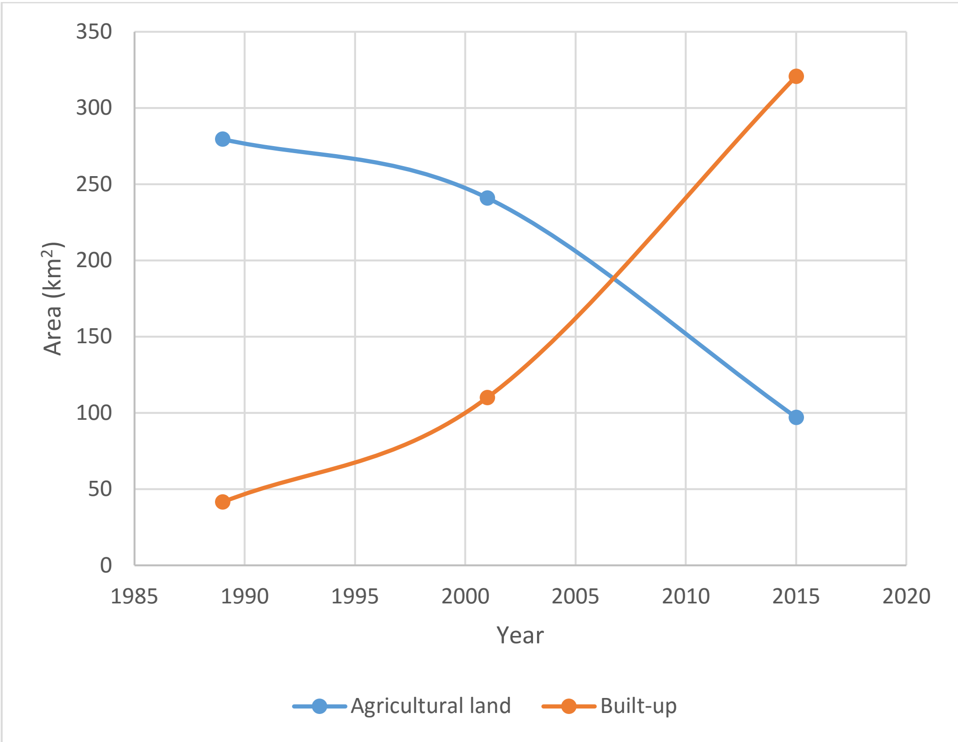


Figure 3. UPA land decline due to urban growth in Kampala

In addition, the average farm size has greatly reduced. This is illustrated in Figure 4 which shows that the average size of UPA land has decreased from 1.9 acres in 2002 to 0.55 acres in 2015. Generally, it is recognized that there is a downward link between population density and size of household landholding (Niroula and Thapa, 2005; Muyanga and Jayne, 2014). This is also partly attributable to the increasing practice of land fragmentation leading to many UPA farmers owning more than one separate parcels of land. The reduction of UPA farm size over time could be attributable to the general reduction of agricultural land in the GKMA which has increased pressure on the remaining UPA illustrated above. Figure 2 shows that average household agricultural landholding in Kampala has decreased 3.5 times.

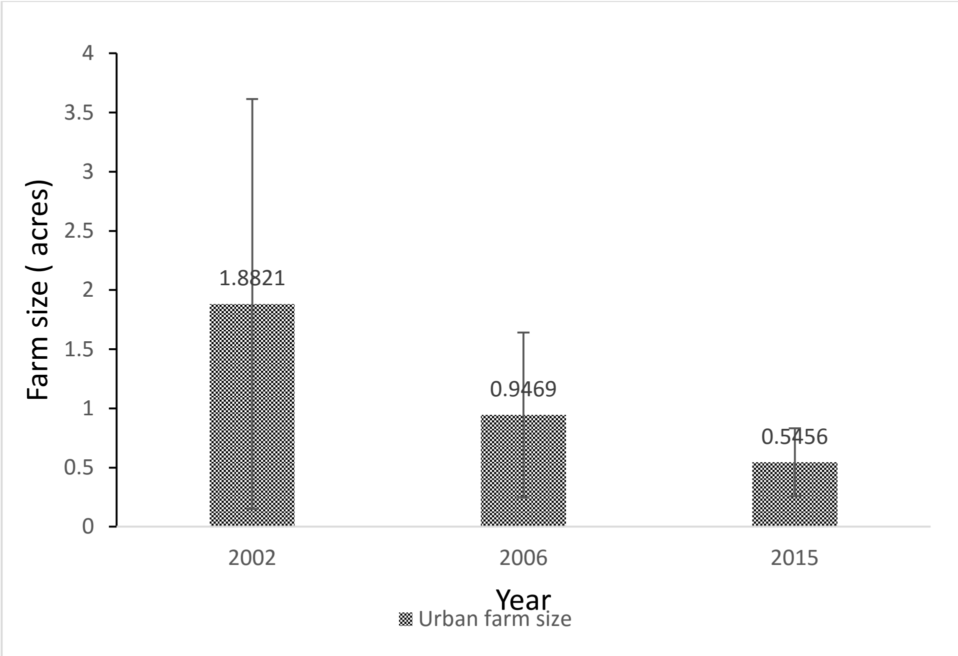


Figure 4. UPA land decline due to urban growth in Kampala.

Based on the broad FAO soil quality classification, 74% of the soils under urban uses in GKMA belong to medium to high productive soils for agriculture, a figure higher than the national average for Uganda which was reported to be 22% by Parsons, (1970). This implies that the soils which have been encroached by urban area is 3.4 times as productive as the national average. This is similar to the average agricultural land lost to urban expansion in Africa, reported to be 3 times as productive as average agricultural land on the continent (d'Amour et al., 2016).

Need for systemic approaches for peri-urban futures

Peri-urban futures present many complex issues that do not easily get resolved through traditional discipline-based or even multi-disciplinary methodologies. Rather they belong to the types of issues that have been referred to as wicked problems (Rittel et al, 1973; Wikipedia 2017), but are better looked at as systemic issues. Systemic issues are characterised by uncertainty, change and complexity, and are the intractable issues facing many areas of society today; such as 'what is a liveable city?', 'how to improve transport in modern cities?', 'what is the best way to educate our population?'. None of these have easy answers, as they depend on who is asking the question, what is the purpose in asking the question, what is the context, and other such factors.

This also illustrates a quiet revolution in perspective transformation that has been taking place, as such complex issues no longer respond to the methods and approaches of the mechanistic world view that has dominated thinking since the Renaissance. Instead, complex issues such as peri-urban futures require a different, systemic approach, one that recognises that the whole is not knowable from just the sum of its parts (mechanistic thinking) but that the whole is more than the sum of its parts (systemic thinking). As the elements of a system interact, surprise happens, or what are called emergent properties in systems language. A common example is the wetness of water that is not predicable from a knowledge of hydrogen and oxygen; it is the interaction that results in wetness. It is this unpredictable surprise emerging from interactions that politicians and economists in particular fall foul of when making changes or predicting outcomes of changes.

Complex issues are best addressed with systems approaches if they are contestable, dynamic and contextual in nature. The first thing a systems approach then needs to establish is the boundary of the issue by deciding what the purpose of the system is, enabling the system to be defined. The boundary then can be established as separating the system over which some control can be imparted (but never complete control) from its environment which affects the system and interacts with the system, but over which the system has no direct control. All these - the system, boundary and environment - are conceptually decided by those wishing to improve the issue of concern, as well as those who might be involved in enabling such improvements. Another feature of a system is that it is itself made up of systems (sub-systems) and is a part of wider systems (supra-systems) in a hierarchical fashion – the 'Russian dolls' toy makes a good metaphor for this idea.

There are many methodologies available for improving issues using systems approaches (Midgley, 2000; Jackson, 2000), but above all I believe they should all be seen as ways of developing learning systems for issues, with participation of relevant stakeholders in the learning process. The aim would always be to get an improvement not defined by one group, but one that is defined by all the stakeholders to the greatest extent possible. Participation is a key issue in the systemic improvement of issues. Any improvement needs to be technically feasible, economically responsible, ethical, culturally sensitive and bio-physically possible. It is my sense that peri-urban futures would benefit from such a trans-disciplinary, systemic approach, one that has benefited many other complex issues.

Urbanisation and peri-urban hydrology

Urbanisation has profound impact on the local hydrology. The transition from peri-urban landscapes to fully urbanised areas results in a decline of open space and an increase in impervious areas. As result this creates an increased runoff peak and faster peak runoff (Bhaduri Budhendra et al., 2001) as impervious areas reduce infiltration and change the evaporation signal(Alberti, 2010; Haase, 2009). Urbanisation therefore leads to a concentration of flows and changes in the flood behaviour (Remondi et al., 2016). This effect is more pronounced when transitioning from a rural environment to an urban environment (the typical peri-urban scenario) then when changes take place within an urban environment

(Miller et al., 2014). Overall this is the result of a loss of water storage or buffering within the landscape between the peri-urban and urban environments.

In addition, urbanisation alters the recharge behaviour, potentially leading to reduced flows to groundwater aquifers (Han et al., 2017), but this is dependent on the local infrastructure. Peri-urban development with its more open structure has more opportunity for infiltration. Unless this characteristic is maintained or enhanced within a more urbanised environment, impacts on groundwater can be significant (Passarello et al., 2014). More extremely and more long term, changes to the hydrological cycle such as lack of infiltration combined with increased groundwater extraction can cause subsidence, such in Mexico City or Jakarta (Chaussard et al., 2013, 2014).

The challenge is to transition the peri-urban space in to urban areas that have similar hydrological behaviour in terms of storage and recharge of water. This requires of course a good understanding of the processes, but more importantly a solid model to develop policy alternatives that can capture the different spatial arrangements. Regrettably, modelling the urban environment is challenging due to the complexity of the urban environment, and this results in higher uncertainty (Salvadore et al., 2015). More simplified approaches, using ecohydrological principles might therefore be more promising (Arden et al., 2014). Developing a simplified model that can help understand the optimal spatial arrangement of natural and impervious areas within an urbanised environment therefore remains an open research challenge.

Increased population, while increasing waste water streams, can also lead to opportunities for surrounding peri-urban areas (Figure 5). Reuse of waste water in urban and peri-urban agriculture has immense potential, but also carries significant risk due to pathogens and the general management of salts and nutrients (Elgallal, 2016; Woltersdorf et al., 2015). The lack of global data on actual waste water management indicates that this problem is bigger than just peri-urban transitions (Sato et al., 2013) . However, new approaches to managing infection risks using solar technology might improve the future use of waste water (Ferro et al., 2015). Again, development of a modelling system that integrates water, salt, pathogen and nutrient flows would be crucial to evaluate different alternatives. Some promising approaches have been reported from small scale evaluations (Woltersdorf et al., 2016), but an integrated hydrological approach that once again incorporates the spatial arrangement of different landuses is still a research challenge.

Figure 5. Challenges of using wastewater safely to produce food and reduce contamination to surface and groundwater resources peri-urban areas.

Stormwater use and management challenges

Stormwater can be considered as a nuisance as it causes flooding, damages infrastructure, transports a diversity of pollutants, degrades land and water resources and poses potential human and ecosystem health risks (Goonetilleke et al., 2014). To meet community expectations, municipal authorities devote a significant component of their budget to capture and remove stormwater as expeditiously as possible. However, there is very limited understanding within the community and among water authorities that stormwater is the last available uncommitted water resource for our urban communities as the demand escalates due to growing urbanisation, industrialisation and higher living standards.

An Australian study found that the volume of stormwater runoff generated is greater than the volume of potable water used most cities in the Country (PMSEIC, 2007). Consequently, it is rather unfortunate that more effort has not been made to convert this perceived 'nuisance' and grossly under-utilised resource into a valued product. It will then help to preserve existing freshwater resources for agriculture and ecosystem services. The dire necessity of an alternate resource to meet the needs of an urban community arises from the following critical facts:

- A significant number of the world's largest cities are currently under water stress and this trend will only worsen with time (McDonald et al., 2014).

- Currently, about 60-70% of water use is for agriculture.
- According to the United Nations (UN, 2015), by 2050, it will be necessary to produce 60% more food globally, and 100% more in developing countries (UN, 2015).

The above noted realities should be viewed in the context of the predicted adverse impacts of climate change on water resources (IPCC, 2007; 2008). Based on weather records and climate projections, IPCC (2008) has confirmed that increased temperatures and changes to rainfall patterns such as annual rainfall, timing of the wet seasons and frequency of droughts and rainfall extremes will adversely affect water availability and quality and the reliability of supply for various consumptive uses. The more frequent drought conditions will lead to reduced soil moisture and annual stream flow in some catchments. In current water deficient areas, the severity of water scarcity will be further worsened due to greater withdrawal of water from existing sources during dry periods. Essentially, water resources will become increasingly stressed.

Accordingly, the widespread adoption of stormwater reuse can become a key adaptation measure to counteract the impacts of climate change on water resources available for urban use. For example, large scale studies undertaken in Australia on household rainwater tanks have reported that typical water savings can amount to over one third of the daily water requirements per person in most metropolitan areas in the Country provided these are designed to supply the internal household water demand rather than just for outdoor use (Beal et al 2015). Therefore, stormwater reuse will strengthen water and food security for urban communities. Wastewater is also a major urban water resource, but it requires more sophisticated treatment for portable reuse

However, storage of stormwater poses a significant management challenge in the case of centralised harvesting of stormwater as large volumes of treated stormwater needs to be stored so that demand can be met due to the episodic nature of rainfall. Consequently, the underground storage of stormwater after suitable treatment, termed as 'managed aquifer recharge' (MAR) provides an attractive alternative. However, MAR requires favourable hydro-geological conditions to enable the subsurface storage of large volumes of water. In the absence of favourable conditions, the only option is the construction of either above ground or underground storage tanks, which can be costly.

Considering the potential pollutant sources, human health risk management can be another significant management challenge in stormwater reuse. Untreated rainwater reuse is least risky when used for non-potable purposes as there is credible microbiological and chemical health risks associated with ingestion. However, public health monitoring and epidemiological studies have suggested otherwise. Therefore, it is essential that appropriate risk management processes are in place for rainwater reuse, either constraining end uses or applying water treatment. This also highlights the need for further ongoing research into the risks associated with rainwater reuse.

However, to assess the true viability of stormwater harvesting, more scientifically robust and comprehensive techniques for cost benefit analysis is needed. This is because conventional economic analysis methodology is generally unable to take qualitative benefits into consideration such as flow-on social and environmental benefits which will accrue as a result of stormwater reuse. This in fact is a common and major constraint in the assessment of sustainable development initiatives and not necessarily only in the case of stormwater reuse. A further requirement is the availability of scientifically rigorous guidelines for stormwater reuse to protect public health and to guide good practice. These are currently available in some countries, but are not common around the world. WHO guidelines are available for the safe use of wastewater (WHO, 2006), but not for stormwater harvesting and reuse.

Despite the many challenges detailed above, the key benefit of stormwater reuse is that it provides the opportunity to create a tangible sustainable development agenda. In the context of climate change, stormwater reuse has the inherent robustness as an adaptation measure to counteract the anticipated adverse impacts on urban water supply and the robustness to build climate resilience among communities. Even otherwise, stormwater reuse can significantly contribute to mitigating the ever escalating demand for urban water supply due to the increasing population, rising living standards and greater industrialisation. It will contribute to drought proofing of urban communities.

Socio-economic challenges

Rapid and universal urbanization has become one of the most characteristic phenomena of modern times and has led to important economic and social consequences. Urban growth is a powerful factor for development including the rapid expansion of commercial activities, increased provision of better–quality services and efficient use of resources. However, there are also a number of adverse effects of urbanisation especially when it happens in an accelerated pace. Buhaug and Urdal (2010) contend that urban population growth has three complementary drivers: reproduction rate, migration and reclassification of rural land. Although there is no doubt that natural increase due to high birth to death ratio is still an important factor that contributes to urban population growth, rural to urban migration is identified by the UN (2012) as the most important contributor to urban growth in many developing countries. The following are identified by the studies reviewed to be the causes of accelerated urbanization process:

- Economic causes, such as increased employment in manufacturing or services, concentration of investment and employment opportunities, high the rural exodus and the need for better services (hospitals, schools, etc.);
- Social and cultural causes, such as the attraction of modern life in the towns;

- Temporary or contingent causes: people displaced by conflict, disasters, drought, etc.

However, rapid urban population growth also causes instability. Above a certain threshold, urban growth eventually leads to social exclusion and creates increasingly more resistant pockets of poverty. Widespread shanty towns around major cities in the developing world represent the challenges of accommodating a growing population. In the long term, these pockets of poverty become virtually impossible to deal with, and are the cause of insecurity and high social costs which may even outweigh the urban achievements. How can towns and cities reasonably absorb so many population flows and provide employment for them? It would appear reasonable to try to curb migration from the countryside, which only accentuates the gravity of urban problems. But this can only be done if innovative agricultural development policies are introduced. Urban poverty is fuelled by rural poverty; just as urban progress is fuelled by progress in the countryside.

In addition, high population growth puts significant demands on society's ability to provide basic services like adequate housing, electricity, water supply, sanitation, enforcement of law and order, health care, education and jobs. Goldstone (2002) argued that when over-urbanisation is combined with underdevelopment- a characteristic of many developing countries in Asia and Africa – resulting to a situation where the job market and economy cannot cope with the population growth bringing about a rise in violence and instability. Further, the mixing of ethnicities and shifting demographic composition of the urban centres are cited as fundamental destabilising factor in urban environments. Additionally, climate – induced urban population growth as well as temporary rural-urban distress migration may add to these challenges.

Buhaug and Urdal (2013) pointed out that rural-urban migration could act as a safety valve when communities are faced with certain form of resource scarcity, relieving the country side of the impending population pressure. However, large scale migration to cities might only translate the problem of overpopulation into the urban setting, potentially causing security challenge (Kahl 2006, Cincotta et. al 2003). Gizewski and Homer-Dixon (1995) identified three (3) risk factors. First, rural-urban migrants are likely to experience economic marginalisation and relative deprivation, increasing their awareness of their own situation and hence the potential for political radicalisation. Next, migrants may have difficulty adjusting socially and psychologically to life in the city, and traditional sources to social authority and control are weakened. Lastly, the urban environment facilitates high levels of social communication, including the opportunities for collective political action.

Moreover, fast increasing population rate may lead to a decline in overall supply of certain resources, for instance overgrazing, deforestation, unrestricted fishing, and conversion of agricultural lands for housing. Resource scarcity may escalate inter group competition and if under unfavourable economic conditions may evolved into a violent conflict (Benjaminsen et al 2012; Devitt and Tol, 2012). Also, as more agricultural lands are converted to housing or industry use, the challenge of supplying nutritionally adequate and safe food to the city dwellers is substantial. Basic resources (water and soil) needed for agricultural production are in competition with other priority urban needs (drinking and industrial water use, infrastructure construction) and there is a risk that the quantity and quality of urban natural resources may not be maintained resulting to risks to urban dwellers. The risks from agricultural production systems in urban and peri-urban areas to health and environment can be a result of inappropriate or excessive use of agricultural inputs (pesticides, raw organic matter containing undesirable residues such as heavy metals) which may leach or runoff into drinking water sources. Further, zoonotic diseases and veterinary public health issues can arise from intensive livestock production methods without proper space and equipment. None of these resource problems are specific to urban and peri-urban production as they are a result from inappropriate management of the rural areas.

Climate change challenges

Climate Change is another area that currently presents many challenges for local governments in urban and peri-urban areas. The future climate is likely to include more hot days, less rainfall and runoff, and increased frequency and intensity of extreme events, such as drought, flash flooding and wildfire (Figure 6). It is, therefore, important to identify, analyse and evaluate climate change risks and develop an adaptation plan that would assist planning for likely impacts of climate change. Climate change impacts are exacerbating the number and extent of disasters. Rapid population growth, uncontrolled urban development, and non-implementation of various policies are creating a peculiar situation for many African countries. Scarcity of water resources is already at an alarming situation and climate change impacts will exacerbate it. It is found that in many developing countries local officials have low level of education and are poorly trained. Local officials are ill-equipped for preparing any climate change adaptation plan to reduce future flooding.

Climate change can affect food production, with particular reference to urban agriculture and the associated impacts on food security. The value of urban agriculture to the health and nutrition of developing and developed countries needs to be assessed. There are international, including urban, aspects, such as agricultural disruption, economic disruption and logistical disruption to food availability, food access and food quality as a result of natural disasters remains an under-investigated topic. Climate change is affecting (and will affect) global food production and hence global food security. Urban agriculture plays a significant role in maintaining and improving the health of city dwellers, particularly those disadvantaged. Climate change is likely to impact more severely urban environments with associated negative effects on food security. Existing research programmes are not addressing these aspects of climate change and deserve attention.

Floodwaters force their way into Kampala suburbs following heavy downpours in April 2014 © KMF News

Figure 6. Due to increased impervious surfaces, the risk of flooding in urban and peri-urban areas is substantially amplified.

The role of wetlands and urban lakes

Urban lakes, wetlands and water fountains can serve the purpose of improving the wellbeing of an urban society by providing areas for various recreational activities for its citizens and visitors. If designed in an aesthetically pleasing manner, these systems can promote participation of the visitors for a variety of recreational activities. Typical recreational activities could include: walking, running, exercising, picnicking, and bird watching (Beal 2007). Furthermore, if equipment for exercise and other activities are provided, it would encourage and promote more intensive physical activities (Apostolaki and Jefferies 2009). It will also promote communication and interactions between visitors (Thompson 2002). Several studies have also identified the psychological benefits of humans interacting with nature (Berman, Jonides & Kaplan 2008; Keniger et al. 2013). Water-based recreational systems can be also home to many species of fauna and flora, and hence promote other activities such as photography (Waltham et al. 2014). Community members will regard the system as an asset, if designed and maintained satisfactorily (Mitsch and Gosselink 2000).

A few studies have been completed using surveys to understand the opinions individuals in a community on their local urban lake (Crase and Gillespie 2008; D'Souza and Nagendra, 2011; Debo, 1977; Walker et al. 2013). Walker et al. (2012) established a link between community wellbeing and a series of urban lakes in Queensland, Australia. Debo (1997), Dillman (2014) identified the positive impacts on the price of properties that are located near urban lakes. D'Souza and Nagendra (2011) surveyed visitors to the Agra Lake, located in Bengaluru, India and found that lakes added significant value to the community by providing a place for recreation and other leisure activities. Recently, Hagare et al. (2015b) analysed the prices of properties that are located near the Wattle Grove Lake, Wattle Grove, NSW. The authors found that the values of properties adjacent to the lake are 15% to 40% higher than those located between 100 to 300 m away from the lake. Hagare et al. (2015a) showed that including a wetland as part of the urban lake can improve the water quality of the lake and can further increase the community benefits from the lake.

Sustainability of peri-urban areas and worldviews

As with many human areas of endeavour, sustainability has become an important focus of concern with respect to the development and dynamics of peri-urban areas across the globe. Yet, both as a concept and as its practical expression, it remains essentially contestable. Unlike relatively straightforward features such as production and productivity, or even stability, 'sustainability' means different things to different people. While there would be some underlying agreement that it has something to do with persistence, there are a host of uncertainties about what this actually means in practice. Somewhat ironically however, this confusion represents a strength rather than a weakness. Whenever the matter is raised in sensible discourse, it encourages sets of questions that are of profound significance to relationships among us and between us and both the biophysical and sociocultural environments in which we are embedded.

Three different types of questions need to be addressed in this context. In the first place there are the obvious issues of precisely what it is that needs to be sustained and for how long. Is it actual entities like farms or lakes, forests or barrier reefs, cities, villages or peri-urban areas, or the somewhat more obscure but constantly cited natural 'ecosystems'? Is it more useful to focus the arguments on processes such as access to and the flow of material resources like water or the human resource of labour or of money or information - or of the process of development itself? And is the reliable yield of some desirable product or another the most useful measure of sustainability? What about challenges like the sustainability of an entire community, or perhaps the even more complex notion of livelihoods or well-being that is inclusive of both people and the natural environment? And how are the inherent structural and organisational dynamics embraced of circumstances of ever-changing human-nature interactions such as those that characterise peri-urban areas? It is questions of this kind that led to the emergence of the argument that sustainability should embrace the integration of economic, environmental and social concerns: the profit, planet, and people triple bottom line that seems to have grasped the attention of many development professionals, corporate executives, and even policymakers.

The underlying assumption with all of these issues in debate is that it is possible to achieve a multi-dimensional sustainable state, especially in the face of almost continual turbulence both within the domain of interest and between it and its environment. But what would such a sustained 'entity' or set of processes eventually look like? Is it even sensible to think about the sustainable peri-urban social ecologies, or processes within them such as water management, health and education provision, and food production?

As these first order issues are under discussion, it quickly becomes apparent that there are some higher order questions that need to be addressed. In the first place there is the very significant matter of how all of these lower order questions are to be actually addressed. Who needs to be involved in the discourse and how can a consensual vision of a sustainable future be generated? How, where and when are the discussions to be conducted? And when all is said and done, who makes the decisions about actions to be taken and who bears the responsibility for the outcomes for all who, and all of that which might be affected? When questions of this order raised, they foster the need to distinguish between, on the one hand, what it is that could be 'engineered' in such a way that it can be sustainable into the future, and what should be allowed, encouraged or enabled to persist. From this perspective, the discourse must assume an ethical turn to accompany the much more usual empirical focus.

And this now introduces the need for a number of third order considerations that involve questions about personal and collective sets of beliefs and assumptions that represent the foundations of all shared discussions and discourse. Every one of us holds to particular beliefs about such matters as the nature of reality, the nature of knowledge and of the processes of knowing, and of the nature of human nature with particular respect to values that include ethics and aesthetics. Together these constitute what is best regarded as our worldview perspectives. They are the philosophical and psychological constructs which essentially 'frames' the way that each of us makes sense of the world about us and accordingly profoundly influences the way we act and behave. In essence, how we see the world determines what we do in (and to) it. Whilst our worldviews are characteristically idiosyncratic - unique to each of us as individuals - the particular cultures to which we are exposed and in which we are fundamentally embedded, play a significant formative role.

Most regrettably, most of us are quite unaware that we even hold to specific foundational beliefs and assumptions let alone be conscious of their particularities. We remain unconscious of these matters even under circumstances when our own worldview perspectives are challenged in any significant manner. It is a surprising fact therefore, that even in our ignorance, we are remarkably resistant to question these personal foundations let alone be sufficiently self-critical of them to consider re-evaluating or transforming them. If anything, we tend to trivialise our foundational perspectives by referring to them as opinions or points of view or mind-sets.

Interpersonal conflicts are fundamentally expressions of differences in worldview perspectives with our reluctance to acknowledge and address such a matter contributing very significantly to the lack of resolution of so many of the complex issues that surround us.

It is for this reason that we should celebrate the contestability of sustainability as, through robust discussion about matters like those raised above, we can come to realise the nature and significance of worldview perspectives. Once realised, we can then start to address not just our differences but our quest for improving relationships among us and between us and our environments. We can, more confidently, generate collective visions for the better, and manage our resources and relationships far more effectively and efficiently and ethically.

Paradoxically it must be observed that it is the very sustainability of such culturally prevailing worldview beliefs of reductionism, positivism, mechanism, neoliberalism and progressivism, that represents the severe impediment to these latter aspirations.

Key challenges of peri-urban water management

The rate and complexity of urban expansion often results in ad-hoc and fragmented land and water policies and planning approaches with unsustainable development that is not able to incorporate peri-urban agriculture. The use of urban wastewater is one of the ways to improve water availability and sustain urban agriculture whilst enhancing safe disposal of wastewater to protect environmental and public health. However, particularly in developing countries, irrigation with wastewater is largely informal. And due to toxic chemicals and pathogens in this water, food safety is becoming a critical food security issue (Drechsel and Keraita, 2015; Makoni et al. 2016).

Urban areas globally are becoming increasingly water stressed and they are constantly searching for new sources of water. The demands for water are diverse, with domestic, industrial, food production and recreational needs to be met against a backdrop of increasing population and climate change. Stormwater is a local untapped water resource that can be directed to these diverse needs, particularly for agricultural irrigation. Stormwater is currently considered a liability because it has to be collected and transported outside the city and can cause damage and inconvenience due to flooding during extreme rain events. However, with some innovative land and water-use policy and planning, and using mixed and mosaic land uses, it may still be possible to harvest stormwater to improve agricultural water security and hence enable fresh food production in peri-urban areas.

Unless appropriate policies are put in place to address the challenges resulting from urbanisation and the subsequent impacts of increased stormwater and wastewater generation, the availability of water for peri-urban agricultural use in the future will suffer from escalating costs and will make agricultural production unviable. Because urbanisation is complex (a ‘wicked problem’) it would help to employ transdisciplinary approaches that integrate science, government (policy and legislation), industry (including land and water managers) and community (Bristow and Stubbs, 2010). This will improve development of new knowledge, tools and processes required to understand and manage the ecological, social, economic, political and cultural dimensions of sustainable peri-urban and urban agricultural production.

Need for balancing urban development for liveability

There is at present insufficient focus on developing water and land policy to address the challenges the peri-urban and growing urban areas face. This is because peri-urban areas are not yet recognised as an integral part of the functional activities that drive the growth of urban areas and that they provide much fresh agricultural produce for city dwellers. Current policies tend to focus on making the central city more globally connected and internationally competitive. These often absorb a large proportion of national budgets for urban development, but not much for harmonised, peri-urban development (Maheshwari and Simmons, 2014). There is a need to create a more balanced approach in terms of planning, infrastructure development and management so that challenges facing peri-urban water and agriculture can be met in the future (Figure 7). There is also a need for more innovative research that can be fed into the formulation of peri-urban water and land policies that will make urban and peri-urban regions more liveable and sustainable through improved water, food and energy security. This will require that future policies for peri-urban regions be given priority at both national and global levels to ensure that peri-urban areas transition to more 'globally equitable and liveable urban places'.

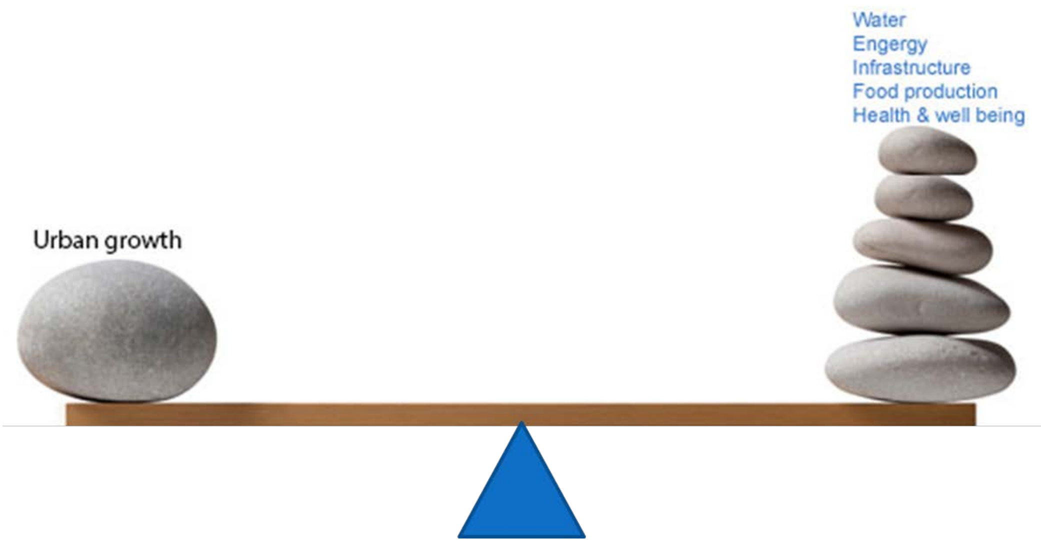


Figure 7. The balanced urban development requires transdisciplinary approach for delicately balancing and managing urban growth and considering complex issues and stakeholder interests.

Conclusions

Urbanisation and its impacts on water cycle, urban and peri-urban agriculture and liveability create complex and 'wicked' problems, and as such these problems must be approached in a new integrated and transdisciplinary manner to achieve sustainable and liveable urban and peri-urban regions. Productivity of these regions is affected by how we manage water. If we properly understand the roles of stormwater, wetlands, rivers and other water sources in these regions for food production and other uses, they will have direct influence on regional resilience, sustainability and liveability. In general, we need to develop a greater understanding of how water cycle is influenced by land use changes and the role it plays in local production and processing of food and benefits it creates in terms of food security and liveable cities as well as local jobs and opportunities for livelihood improvement of urban and peri-urban communities.

References

Alberti, M., 2010. Maintaining ecological integrity and sustaining ecosystem function in urban areas. Current Opinion Environmental Sustainability 2, 178–184. doi:10.1016/j.cosust.2010.07.002.

Angel, S., Parent, J., Civco, D.L., Blei, A., Potere, D., 2011. The dimensions of global urban expansion: Estimates and projections for all countries, 2000–2050. Progress in Planning 75, 53-107.

Arden, S., Ma, X. (Cissy), Brown, M., 2014. An ecohydrologic model for a shallow groundwater urban environment. Water Sci. Technol. 70, 1789–1797. doi:10.2166/wst.2014.299

Benjaminsen, T.A. Alinon, K. Buhuag, H. Buseth, J.T. 2012. Does climate change drive land-use conflicts in the Sahel? Journal of Peace Research. 49, pp. 97-111.

Bhaduri Budhendra, Minner Marie, Tatalovich Susan, Harbor Jon, 2001. Long-Term Hydrologic Impact of Urbanization: A Tale of Two Models. J. Water Resour. Plan. Management: 127, 13–19. doi:10.1061/(ASCE)0733-9496(2001)127:1(13)

Bristow, K.L. and Stubbs, T. 2010. Reinventing Irrigation Catchments: The System Harmonisation Story, CRC for Irrigation Futures (ISBN 978 0 9808109 5 0) 146 pp.

Buhaug, H. Urdal, H. 2013. An urbanization bomb? Population growth and social disorder in cities. Global Environmental Change. 23, pp. 1-10.

Chaussard, E., Amelung, F., Abidin, H., Hong, S.-H., 2013. Sinking cities in Indonesia: ALOS PALSAR detects rapid subsidence due to groundwater and gas extraction. Remote Sens. Environ. 128, 150–161. doi:10.1016/j.rse.2012.10.015

Chaussard, E., Wdowinski, S., Cabral-Cano, E., Amelung, F., 2014. Land subsidence in central Mexico detected by ALOS. In SAR time-series. Remote Sens. Environ. 140, 94–106. doi:10.1016/j.rse.2013.08.038

Cincotta, R. Engelman, R. Anastasion, D. 2003. The Security Demographic: Population and Civil Conflict After the War. Population Action International. Washington D.C. accessed 16 October 2017https://www.wilsoncenter.org/event/the-security-demographic-population-and-civil-conflict-after-the-cold-war

Congalton, R.G., 1991. A review of assessing the accuracy of classifications of remotely sensed data. Remote sensing of environment 37, 35-46.

Corbould, C., 2013. Feeding the Cities: Is Urban Agriculture the Future of Food Security? http://futuredirections.org.au/wp-content/uploads/2013/11/Urban_Agriculture-_Feeding_the_Cities_1Nov.pdf (Accessed September 11, 2016)

d'Amour, C.B., Reitsma, F., Baiocchi, G., Barthel, S., Güneralp, B., Erb, K.-H., Haberl, H., Creutzig, F., Seto, K.C., 2016. Future urban land expansion and implications for global croplands. Proceedings of the National Academy of Sciences, 201606036.

del Mar López, T., Aide, T.M., Thomlinson, J.R., 2001. Urban expansion and the loss of prime agricultural lands in Puerto Rico. AMBIO: A Journal of the Human Environment 30, 49-54.

Devitt, C. Tol, R.S.J. 2012. Civil war, climate change, and development: a scenario study for Sub-Saharan Africa. Journal of Peace Research. 49. Pp. 51-64.

Drechsel, Pay; Keraita, B. 2015. Agriculture in the rural-urban continuum: a CGIAR research perspective. Agriculture for Development, 26:14-19.

Elgallal, M., 2016. Assessment of potential risks associated with chemicals in wastewater used for irrigation in arid and semiarid zones: A review. Agric. Water Management, 177, 419–431. doi:10.1016/j.agwat.2016.08.027

FAO-WRB, 2014. World reference base for soil resources 2014 international soil classification system for naming soils and creating legends for soil maps. FAO, Rome [http://www.fao.org].

Ferro, G., Fiorentino, A., Alferez, M.C., Polo-López, M.I., Rizzo, L., Fernández-Ibáñez, P., 2015. Urban wastewater disinfection for agricultural reuse: effect of solar driven AOPs in the inactivation of a multidrug resistant E. coli strain. Appl. Catal. B Environ., Photocatalysis: Science and Applications 178, 65–73. doi:10.1016/j.apcatb.2014.10.043

Giwenski, P. Homer-Dixon, T. 1995. Urban Growth and Violence: Will the Future Resemble the Past? Occasional Paper, Project on Environment, Population and Security. American Association for the Advancement of Science and the University of Toronto, Washington, D.C. accessed 15 October 2017, http://www.ibrarian.net/.../paper/Urban_Growth_and_Violence__Will_the_Future_RResemb.

Goldstone, J.A. 2002.Population and security: how demographic change can lead to violent conflict. Journal of International Affairs. 89.pp.31-43.

Haase, D., 2009. Effects of urbanisation on the water balance – A long-term trajectory. Environ. Impact Assess. Rev. 29, 211–219. doi:10.1016/j.eiar.2009.01.002

Han, D., Currell, M.J., Cao, G., Hall, B., 2017. Alterations to groundwater recharge due to anthropogenic landscape change. J. Hydrol. 554, 545–557. doi:10.1016/j.jhydrol.2017.09.018

Harris, P. 2012. Too many 'wicked problems': how science, policy and politics can work together. The Conversation, http://theconversation.com/too-many-wicked-problems-how-science-policy-and-politics-can-work-together-8990 .

Jackson, M.C. (2000) Systems Approaches to Management Kluwer Academic/Plenum Publishers, New York USA.

Kahl, C.H.2006. States, Scarcity, and Civil Strife in the Developing World. Princeton University Press, Princeton, NJ.

Katongole, C.B., Nambi-Kasozi, J., Lumu, R., Bareeba, F., Presto, M., Ivarsson, E. and Lindberg, J.E. 2012. Strategies for coping with feed scarcity among urban and peri-urban livestock farmers in Kampala, Uganda. Journal of Agriculture and Rural Development in the Tropics and Subtropics. 113(2): 165-174.

KCCA, 2012. Updating Kampala Structure Plan and Upgrading the Kampala GIS Unit. preliminary report. 583.

Maheshwari, B. and Simmons, B., 2014. Planning for water and land: Sustainability of expanding cities. Australian Water Association 41 (7):39-40.

Makoni, F.S., Thekisoe, O.M. and Mbati, P.A., 2016. Urban Wastewater for Sustainable Urban Agriculture and Water Management in Developing Countries. In *Sustainable Water Management in Urban Environments*. Springer Publishers, the Netherlands. Vol 47:265-293.

McGee T (2009): The Spatiality of Urbanization: The Policy Challenges of Mega- Urban and Desakota Regions of Southeast Asia. UNU-IAS Working Paper No. 161, www.as.unu.edu/resource_centre/161%20Terry%20McGee.pdf

Mertens, B., Lambin, E.F., 2000. Land-cover-change trajectories in southern Cameroon. Annals of the association of American Geographers 90, 467-494.

Midgley, G. (2000) Systemic Intervention: Philosophy, Methodology and Practice Kluwer Academic/Plenum Publishers, New York USA

Miller, J.D., Kim, H., Kjeldsen, T.R., Packman, J., Grebby, S., Dearden, R., 2014. Assessing the impact of urbanization on storm runoff in a peri-urban catchment using historical change in impervious cover. J. Hydrol. 515, 59–70. doi:10.1016/j.jhydrol.2014.04.011

Muyanga, M., Jayne, T., 2014. Effects of rising rural population density on smallholder agriculture in Kenya. Food Policy 48, 98-113.

Niroula, G.S., Thapa, G.B., 2005. Impacts and causes of land fragmentation, and lessons learned from land consolidation in South Asia. Land use policy 22, 358-372.

Nyakaana, J.B., Sengendo, H. and Lwasa, S. 2007. Population, urban development and the environment in Uganda: the case of Kampala city and its environs. Faculty of Arts, Makerere University, Kampala, Uganda.

http://www.cicred.org/Eng/Seminars/Details/Seminars/PDE2007/Papers/NYAKAANA_paper Nairobi2007-2.pdf

Passarello, M.C., Pierce, S.A., Sharp, J.M., 2014. Uncertainty and urban water recharge for managing groundwater availability using decision support. Water Sci. Technol. 70, 1888–1896. doi:10.2166/wst.2014.437

Remondi, F., Burlando, P., Vollmer, D., 2016. Exploring the hydrological impact of increasing urbanisation on a tropical river catchment of the metropolitan Jakarta, Indonesia. Sustain. Cities Soc. 20, 210–221. doi:10.1016/j.scs.2015.10.001

Rittel, H.W. and Webber, M.M., 1973. Dilemmas in a general theory of planning. Policy sciences, 4(2):155-169.

Rittel, Horst W. J.; Webber, Melvin M. (1973). "Dilemmas in a General Theory of Planning" (PDF). Policy Sciences. 4: 155–169

Sabiiti, E.N. and Katongole, C.B. 2016. Role of peri-urban areas in the food system of Kampala, Uganda. In: Basant Maheshwari, Vijay P. Singh and Bhadranie Thoradeniya (Eds.), Balanced Urban Development: Options and Strategies for Liveable Cities. Water Science and Technology Library 72: 387 - 392, Springer International Publishing. DOI: 10.1007/978-3-319-28112-4_23

Salvadore, E., Bronders, J., Batelaan, O., 2015. Hydrological modelling of urbanized catchments: A review and future directions. J. Hydrol. 529, 62–81. doi:10.1016/j.jhydrol.2015.06.028

Sato, T., Qadir, M., Yamamoto, S., Endo, T., Zahoor, A., 2013. Global, regional, and country level need for data on wastewater generation, treatment, and use. Agric. Water Management: 130, 1–13. doi:10.1016/j.agwat.2013.08.007

Sinclair, I., Bunker, R. and Holloway, D., 2003, From the outside looking in – Planning and land management in Sydney's fringe. State of Australian Cities National Conference 2003, Urban Frontiers Program, University of Western Sydney. www.ruralplanning.com.au/library/papers/soac03.pdf

Thebo, A.L., Drechsel, P., Lambin, E.F., 2014. Global assessment of urban and peri-urban agriculture: Irrigated and rainfed croplands. Environmental Research Letters, 9(11, 9p.

UN DESA. 2015. United Nations, Department of Economic and Social Affairs, Population Division. World Urbanization Prospects: The 2014 Revision, (ST/ESA/SER.A/366).

UN DESA. 2016. United Nations, Department of Economic and Social Affairs, Population Division. The World's Cities in 2016 – Data Booklet (ST/ESA/ SER.A/392).

UN DESA. 2017. United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP/248.

UN.2012. World Urbanization Prospects: The 2011 Revision. Highlights. United Nations Population Division, New York. Accessed 17 October 2017 http://www.un.org/en/development/desa/population/publications/pdf/urbanization/WUP2011_Report.pdf

United Nations (2011): Population Distribution, Urbanization, Internal Migration and Development: An International Perspective. Department of Economic and Social Affairs, Population Division, Publication no. ESA/P/WP/223, 363 pp.

Vermeiren, K., Van Rompaey, A., Loopmans, M., Serwajja, E. and Mukwaya, P. 2012. Urban growth of Kampala, Uganda: pattern analysis and scenario development. Landscape and Urban Planning. 106(2): 199-206.

Wikipedia (2017) https://en.wikipedia.org/wiki/Wicked_problem accessed October 2017

Woltersdorf, L., Liehr, S., Scheidegger, R., Döll, P., 2015. Small-scale water reuse for urban agriculture in Namibia: Modeling water flows and productivity. Urban Water J. 12, 414–429. doi:10.1080/1573062X.2014.900691

Woltersdorf, L., Scheidegger, R., Liehr, S., Döll, P., 2016. Municipal water reuse for urban agriculture in Namibia: Modeling nutrient and salt flows as impacted by sanitation user behaviour. J. Environ. Manage. 169, 272–284. doi:10.1016/j.jenvman.2015.12.025.

*****