

GREEN INFRASTRUCTURE IN RELATION TO INFORMAL URBAN SETTLEMENTS

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Abstract. Green infrastructure plays a critical role in environmentally sustainable urbanization in developing countries. Based on a review of academic outputs, this paper explores green infrastructure in the context of informal urban settlements. It identifies three ways informal settlements are connected to green spaces and natural ecosystems functioning as urban green infrastructure and then shows examples of benefits derived (ecosystem services) by the urban poor from these connections. Undesirable aspects and negative outcomes, regarded as ecosystem disservices, from the connection to natural ecosystems are also pointed out. The potentials of enhancing ecosystem services in terms of improving quality of life and the environment in informal settlements came to the fore. This work contributes to the growing body of knowledge on urban green infrastructure from the perspective of informal settlements in developing countries.

Keywords: slums, low-income housing, green spaces, ecosystem services, disservices, developing countries.

Introduction

Urban sustainability is impossible without considering green infrastructure. Charles Little in the book *Greenways for America* first introduced the term “green infrastructure”, using it to describe networked assemblage of natural landforms and green open spaces that create alternatives to municipal or regional infrastructure (Little 1990). Since then, green infrastructure has been (and still) seen as natural, semi-natural and artificial networks of multifunctional natural ecosystems at different spatial scales (Tzoulas *et al.* 2007). A network of green spaces (for example, parks) and blue spaces (for example, wetlands), “productive natural landscapes” such as allotment/domestic gardens (Bohn, Viljoen 2011: 150) or a small-scale ecological solution for stormwater management can all be considered as components of green infrastructure.

The notion that environmentally sustainable urbanization cannot be achieved without considering green infrastructure does not seem entrenched in developing countries. As argued in the last two decades, environmental sustainability (with reference to green infrastructure) in low-income informal parts of cities, has not been much of a concern/priority to the state and

some non-state actors in many developing countries (Dalglish *et al.* 1997; Magi 1999; Irurah, Boshoff 2003; Groebel 2007; French, Lalande 2013; Shackleton *et al.* 2014).

This incognizance or poor concern is problematic for the following reasons. Firstly, low-income and informal forms of shelter constitute a notable (and at times growing) proportion of the urban territory and population.¹ In some developing countries, between 30 and 60 percent of the urban population live in illegal or informal settlements (Mitlin, Satherthwaite 2013). Secondly, these informal areas are usually peopled by the socio-economically disadvantaged, to which environmental disadvantage must be added. They are “victims” of inequalities and vulnerable to the negative impacts of global climate and environmental change (Agbor 2013; Nenweli 2015).

This situation implies there are knowledge gaps regarding bio-physical assets and processes in the

¹ This paper uses “informal settlements” in broad reference to under-serviced, unregistered, at times illegal, low-income urban environments with flimsy and overcrowded dwellings occupied by the urban poor. These areas might be named differently across the various countries touched on in the paper.

context of informal settlements. It appears that knowledge about the way poor urban dwellers in informal settlements relate with green spaces and natural ecosystems – the benefits derived and detriments experienced – is scanty. Certain examples are available, but they are in bits, scattered in disparate literature not generally articulated in terms of informal housing or urbanism. These gaps preclude appropriate contribution of the necessary understanding to sustainable urbanization (Quilan, McCarthy 1995; Fitchett 2014) and leads to missed opportunities for resilience in the informal context (Schaffler, Swilling 2013; Sachikonye *et al.* 2016).

This gap informed the research question – how do informal settlement residents relate with green infrastructure, and what benefits/problems emanate from this relationship? In considering the direct or indirect benefits from natural features and ecosystems functioning as green infrastructure (framed as ecosystem services, Fisher *et al.* 2009), this paper utilizes the Millennium Ecosystem Assessment's (MA) classification of ecosystem services into provisioning, regulating, socio-cultural and supporting services (MA 2005). MA's classification is commonly used and easier to understand, based on the linkage between human welfare and ecological processes (Fisher, Turner 2008). *Provisioning* services are goods/material outputs from natural ecosystems e.g. food, water while *Regulatory* services refer to processes that control the environment, for example, micro-climate moderation, air quality control, flood regulation. *Socio-cultural* services are non-material – socio-cultural, spiritual, educational gains from green space and ecosystems. *Supporting* services underpin the production of other services, with photosynthesis, soil formation, production of atmospheric oxygen as examples. Functions of natural ecosystems that are negative for human beings (regarded as ecosystem services, Lyttimaki, Sipila 2009) were also considered.

Research methods

This paper is based on a literature review that followed a five-step process (after Green 2005) which include: i) framing a research question; ii) identifying relevant studies; iii) assessing the quality of studies; iv) extracting evidences; v) analyzing and presenting findings. In identifying relevant studies, a comprehensive search for academic outputs (journal articles, conference proceedings, book chapters) was conducted in Scopus/Web of Science. Google scholar database was also searched to access outputs such as thesis/dissertation, reports and books which are unavailable in Scopus. Since informal settlements are a third world phenomena and as Onyancha and Ocholla (2009) explain publications by researchers in developing countries that

cannot afford the Scopus's subscription fees will be readily available through Google Scholar.

Search algorithms used in the databases combined words such as green infrastructure, green spaces, ecosystem services, ecosystem disservices, informal settlements, slums, ecological, upgrading, sustainability, developing countries. Searching Scopus returned a total of 3000+ items whose titles were immediately scanned to identify potentially relevant ones. For instance, searching for “green/greening in slums/settlements” led to 1207 items, of which 41 were saved as potentially relevant. Combining “ecological upgrading” with slum/settlement led to 183 items, of which 19 were potentially relevant. “Urban agriculture” in slum/settlement led to 576 items (22 were potential relevant) while “green infrastructure/space” led to 20 items, with 7 designated as potentially relevant. Search using “sustainability and environment” with slum/settlement yielded 1039 items, of which 20 were potentially relevant. Searching Google Scholar also yielded 10000+ items, of which about 40 thesis/dissertations/books/reports were selected as potentially relevant.

All the items regarded as potentially relevant were later screened. The criteria – whether the content or part of it conceptualizes or provides example(s) on green spaces and natural ecosystems in relation to low-income informal urban settlements and people living there. The screening reduced the total number. References of the screened publications were checked to identify relevant publications not captured in the searched databases. A total of 68 items were eventually reviewed. These, though at times not conceptually articulated in direct relation to informal housing, reveals how poor urban households draw benefits from natural and semi-natural ecosystems and landforms, vegetation, gardens, waterscapes, agricultural areas and so on. Of the 68 items, 45 are journal articles, 3 conference proceedings, 9 book chapters, 10 thesis/research reports and 1 book. Twenty-six emanated from/reported research done in South Africa, 8 from India, 4 from Kenya, 2 each from Bangladesh, Brazil, Nigeria, Indonesia, Uganda and Morocco. One each came from Argentina, Burkina Faso, Cameroon, Ethiopia, Ghana, Mexico, Nepal and Rwanda. Ten were either conceptual or generalist and do not fall into any country-specific category.

Connections between informal settlements and green infrastructure

Generally, there is a connection between informal settlements and green spaces and natural ecosystems functioning as urban green infrastructure. As evident in literature, this connection occurs in three

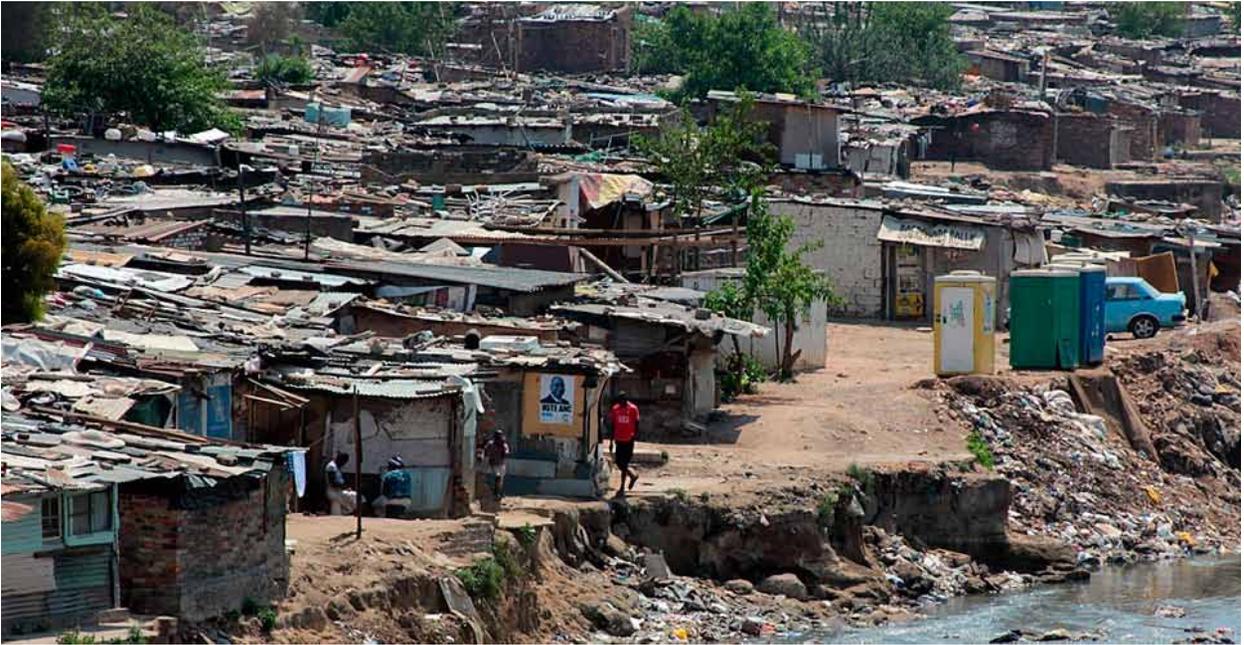


Fig. 1. Alexandra in Johannesburg includes an informal settlement located by the Jukskei River
Source: Heather Mason, 2011 (used with permission).



Fig. 2. Kibera settlement is located on a low-lying part of the Nairobi river bank
Source: Author's Photograph, September 2012.



Fig. 3. Langrung informal settlement in Stellenbosch (South Africa) is located on a steep hillside
Source: Author's Photograph, October 2013.

main ways. Location in ecologically-significant, environmentally-sensitive and biodiversity-rich places within cities is one. Agricultural cultivation within low-income urban areas is another, while an ecological approach to infrastructure is the third form of connection.

Across developing countries, informal settlements are generally established through processes that take advantage of unutilized land (Alsayyad 1993; Van Gelder 2010). Such land, often of ecological significance and biodiversity wealth, is unsuitable for residential development because of its location near streams, on low-lying river banks, within wetlands, on steep hillsides or servitudes, buffer strips and other kinds of interstitial space. Through an analysis of urbanisation in developing countries, Seto *et al.* (2012) and Guneralp

et al. (2013) found that urban growth through informal housing development is taking place around and expanding into some of the world's biodiversity-rich areas.

Practical examples of the locational pattern abound. Alexandra settlement in Johannesburg is located the Jukskei River bank (see Fig. 1) while Kibera settlement in Nairobi is located on the Nairobi river bank (see Fig. 2). Langrung informal settlement in Stellenbosch is located on a steep hillside (see Fig. 3). Regarding riparian zones, Vollmer and Gret-Regamey (2013: 1544), observe that due to the presence of informal settlements in low-income Asian countries "population density appears to increase by roughly 10% within 1 km of waterways". In Mexico City, between 295 and 300 informal settlements – about 36% of the city's informal settlements, are located on ecologically

significant conservation land (Wigle 2014). Part of this informally occupied land make up a unique socio-ecological heritage designated as a World Heritage Site by the United Nations and declared as a Natural Protected Area (NPA) by the Mexican government (*ibid.*).

It is noteworthy that interventions in and for informal settlements at times tend to perpetuate the locational characteristic pointed to above. This might be an outcome of formal urban planning where certain trade-offs have taken place or otherwise (Hetz, Bruns 2014).

Apart from their location, the second form of connection between informal settlements and green infrastructure takes place through agricultural practices. To a greater or lesser extent, residents of informal settlements undertake various forms of agricultural cultivation, whether through planting in containers or beds in yards, home gardens in stands/plots and communal gardens in open spaces (see Figs 4 and 5) (Redwood 2009; Webb 2011; Hamilton *et al.* 2014). Irrespective of size and form, these cultivated spaces make up part of green infrastructure.

The third form of connection occurs when infrastructural needs are met through natural or semi-natural systems, at times referred to as ecological infrastructure. This might be at dwelling scale or through catalytic insertions at strategic points. A roof or domestic garden is an example of an ecological infrastructure at the household level. The garden attenuates rainwater, thus controlling runoff's quality and quantity and subsequently reducing the capacity of surface or underground drainage system needed in the settlement. Vertical gardens (for instance in Mtshini Wam settlement, Cape Town – Fig. 4) provides infrastructural functions through micro-climatic controls at the dwelling scale (Henning *et al.* 2012: 5).

At a wider scale, patches of green open spaces or a wetland can catalyse neighbourhood-wide im-

provements. Shaping a wetland as multifunctional – for runoff retention, water treatment and vegetable production reduces capacity of the sewage treatment facility needed at the township/municipal level. This wetland-based socio-ecological approach to infrastructure was explored as part of the Tactical Landscape Operations for Informal Settlement Upgrading project in Cantinho do Ceu, Sao Paulo (Werthmann 2011). A positive relationship between ecological development and socio-economic improvement emerged from catalytic projects such as public use of small leftover land, developing wetlands for storm runoff treatment (*ibid.*).

The connection between informal settlements and urban green infrastructure reveals prospects for climate change adaptation and mitigation in cities (Gill *et al.* 2007). As shown in the CLUVA project (Lindley *et al.* 2015) and by Kithiia and Lyth (2011), in the light of resource decline accompanying global climate change, it presents multi-functional, soft engineering alternatives to grey infrastructure in low-income urban areas.

Benefits from green infrastructure in informal settlements

Provisioning Ecosystem Services

As a resource fundamental to life, water is a notable product from natural ecosystems. Since municipally-supplied potable water is generally inadequate or absent in informal settlements, the residents often depend on freshwater sources such as streams, wetlands, hand-dug shallow wells or other forms of ground/surface water. For instance, in a Jarkarta settlement where under 30% of households have access to municipal water provision, over 80% of households obtain groundwater for washing through wells (Vollmer, Gret-Regamey 2013). Kimani-Murange and Ngindu (2007) reported that 89% of households depend on groundwater from wells in the Langas settlement in Nairobi while Ochieng *et al.* (2011) found that 85% of households depend on wells in three settlements in Ibadan. A similar situation was reported in Assam, India (Phukan 2014). These ground/surface sources are generally of poor quality (Cairncross 1990), but residents use them for cooking, laundry, sanitary purposes and irrigation because they are readily available.

Food, including edible medicinal plants, is another useful product. Academic papers and project outcomes, internationally, affirm the positive role of agricultural cultivation in food supply and food security in low-income informal urban settlements (Davoren 2009; Rau *et al.* 2011; Dubbeling 2011; Gallaher *et al.* 2013;



Fig. 4. Vertical gardens by shack walls in re-blocked Mtshini Wam settlement

Source: Stephen Lamb/Design Indaba, 2013 (used with permission).



Fig. 5. Home garden in Slovo Park (left) and Elias Motsoaledi (right) informal settlements in Johannesburg
 Source: Photograph by Marie Huchzermeyer (left), June 2013 and Author (right), December 2012.

UAC 2013; Kornienko 2013), although the informal nature and lack of political recognition in sub-Saharan Africa is an intractable problem (Drechsel, Dongus 2010). Over half of the households in five of Pretoria's informal settlements farmed in home gardens and communal gardens located in public open spaces (van Averbeke 2007). Group farming in open spaces supplied households with about 25% of annual staple food but home gardeners harvested a meagre 1.7 kilograms of fresh food monthly, which represents 6.7% of the recommended monthly vegetable intake (*ibid.*). This means that smaller amounts of food are produced from home gardens, compared to group/communal gardens. In the same vein, informal settlement residents produced fruit and vegetable in Delhi's wetlands (Singh *et al.* 2013) while those in the Pallikaranai settlement – located along the Adyar river in Chennai live on harvested fish (Coelho, Raman 2013).

Timber is another product common in informal settlements. Since the settlements are not formally connected to the electricity grid, timber collected from nearby trees provides fuel for cooking, indoor heating and materials for construction and household furniture. Street trees were sources of timber in low-income Touroua, Cameroon (Epule *et al.* 2014). Nissing and Von Blottnitz (2007) estimate that 142,000 tonnes of timber, sourced from nearby vegetated areas or industrial waste is used for household thermal purposes annually in Cape Town's informal settlements. In their study of three South African towns, Kaoma and Shackleton (2014) found that at least 43% of households in informal settlements collected firewood from their own home gardens/plots. These authors did not indicate long-term horizons for replenishment so that timber supply is sustainable.

Regulatory ecosystem services

People living in informal settlements also benefit from green infrastructure through services that regulate the environment. Three forms of regulatory services are identified. The first relates to micro-climate moderation. An experimental green wall in a Lagos settlement led to around 0.5 °C decrease in ambient temperature (Oluwafeyikemi, Jullie 2015). In Bangalore, Gopal (2011) observes that most dwellings in informal settlements have plants grown in different kinds of containers. The plants and trees contribute to decrease in local air temperature (by 3 to 5 °C in summer) and air quality improvement through reduction of pollutants in the neighbourhood (Gopal 2011; Sudhira, Nagendra 2013; Gopal, Nagendra 2014). As a result of their shade, trees in the settlements create cool space for domestic activities (e.g. cooking), livelihood activities (e.g. operation of a mechanic workshop, phone booth) and recreational activities (Gopal 2011; Nagendra *et al.* 2013).

A further illustration of micro-climatic control comes from the mapping of residential urban morphological types (UMT) in Addis Ababa (Cavan *et al.* 2014). In what may be particular to Addis Ababa, the study observes that “informal settlements and traditional housing areas have higher proportions and better composition of green structures than other residential areas, and are thus associated with the lowest modelled land surface temperatures” (*ibid.*: 54). The residents benefit from temperature moderation of green spaces in the settlements. Further confirming green spaces' temperature moderation functions, “the use of roof canopies or vegetation to reduce heat exposure were identified as regular practices” in Dakar (Bangladesh) informal settlements (Jabeen *et al.* 2010: 429).

As another way of regulating the natural environment, certain natural/semi-natural landforms renders drainage-related functions to informal settlements. As mentioned earlier, a roof garden regulates runoff’s quantity and quality. Wetlands and riparian spaces aid flood control and greywater treatment (Adegun 2013; Vollmer *et al.* 2015; Douglas 2016). Button *et al.* (2010) experimented with a Sustainable Urban Drainage System (SUDS) that consisted artificial swales and infiltration trenches linked to a wetland in Monwabisi Park informal settlement, Cape Town. Vegetation covering the swales redirects runoff away from unwanted areas. The soakaways incorporate a layer of bio-filtering plants which also redirect excess water to the wetland.

Wind moderation/erosion control is the third form of regulatory ecosystem service. Literature search did not show any contribution made by green infrastructure in this regard. This is being mentioned because some studies show that windstorms are one of the worst climatic events experienced by people living in low-income urban areas (Adelekan 2012; Nenweli 2015).

Socio-cultural ecosystem services

Benefits related to socio-cultural services are obtained through green spaces that provide aesthetically pleasing environment and opportunities for recreational activities, social interaction, inspirational enrichment or cultural expression in and around informal settlements. For instance, water-bodies or natural areas connected to settlements serve as object of worship and location for religious/cultural ceremonies by residents (Nagendra *et al.* 2013). Regarding natural ecosystems around the Mandela Park settlement (Cape Town), the residents remarked: “the mountains are beautiful and the trees”, “when they do their ritual, the moun-

tain becomes the ideal spot” (respondents quoted in Ballantyne, Oelofse 1999: 209). In the same vein, the Macassar informal settlement community’s historical connection and cultural ties with the Macassar dune in Western Cape (South Africa) are expressed through recreational practices such as horse riding and fishing by the dune (Graham, Ernstson 2012).

Natural areas also offer opportunities for cognitive development. In La Lagunita settlement, Rosario (Argentina), Dubbeling *et al.* (2009) observed that green spaces serve as an educationally productive space for children’s cognitive development through a demonstration garden and an educational path. As a result of interactions through communal gardening in informal settlements, the gardens contribute to social capital, an outcome that often surpass food benefits from such gardens (Kornienko 2013).

Supporting ecosystem services

Based on the literature accessed, it is unclear how informal settlements specifically benefit from supporting ecosystem services. However, O’Farrell *et al.*’s (2012) work stands out as it shows how informally built-up areas (among other land use types) contribute to (but not necessarily benefit from) supporting services. Through an expert opinion’s rapid assessment of ecosystem services in Cape Town, O’Farell *et al.* (2012) shows that natural vegetation remnants in informal areas contribute less to soil retention, critical infiltration and groundwater recharge, yield and quality when compared with formal areas (See Table 1).

Table 2 shows key ecosystem services related to informal urban settlements. It summarises the services (provisioning, regulatory, socio-cultural and supporting) identified so far and includes some references not cited in the narrative.

Table 1. Comparison between certain types of ecosystem services in Cape Town. 0 represents no service while 10 represents maximum potential service

	Formal built-up residential area	Informal built-up residential area
Flood mitigation	5	3
Soil Retention	9	5
Critical Infiltration	8	5
Coastal Zone Protection	3	2
Groundwater Recharge	6	4
Groundwater Yield	5	4
Groundwater Quality	7	5

Source: Extracted from O’Farell *et al.* (2012).

Table 2. Summary of key ecosystem services in informal urban areas

Service Type	Example	Description	Source(s)
Provisioning	Food	Food and vegetable production in wetlands, communal/private open spaces used as gardens; Fish production and harvesting in blue spaces	Van Averberke (2007); Honning (2009); Rau <i>et al.</i> (2011); Hennings <i>et al.</i> (2012); Singh <i>et al.</i> (2013); Coelho and Raman (2013)
	Water	Groundwater from shallow wells and Surface water from streams/ivers – for domestic use and irrigation	Kimani-Murange and Ngida (2007); Ochieng <i>et al.</i> (2011); Vollmer and Gret-Regamey (2013); Phukan (2014)
	Others	Timber from trees – for household fuel and construction; Therapeutic flowers, medicinal items, broom making and incense stick from plants and trees	Ballantyne and Oelofse (1999); Gopal (2011); Nagendra <i>et al.</i> (2013); Kaoma and Shackleton (2014); Epule <i>et al.</i> (2014)
Regulatory	Water Management	Runoff control management and flood mitigation; Greywater treatment	Adegun (2013); Button <i>et al.</i> (2010); O'Farrell <i>et al.</i> (2012); Douglas (2016)
	Moderating Micro-climate	Trees with canopy provide shade (decreasing ambient air temperature by 3–5 °C in summer in Bangalore urban area/slums)	Jabeen <i>et al.</i> (2010); Gopal (2011); Sudhira and Negrada (2013); Oluwafiyekemi and Julie (2015)
	Air Quality Regulation	Cleaning the air through removal of pollutants such as SO ₂ and suspended particulate matter.	Sudhira and Nagendra (2013)
Socio-cultural	Aesthetic	Pleasant views of nearby natural environment	Ballantyne and Oelofse (1999)
	Recreation	Mountain climbing, tree climbing, horse riding, fishing, green open spaces used for other games/sports	Ballantyne and Oelofse (1999); Graham and Ernstston (2012)
	Religious/Cultural fulfilment	Mountainous/lowland areas and other natural areas used for religious activities or cultural rites; Wetlands and other water-bodies as object of worship	Ballantyne and Oelofse (1999); Gopal (2011); Nagendra <i>et al.</i> (2013)
	Educational	Green Spaces used for demonstrative teaching and Cognitive development, especially for children	Dubbeling <i>et al.</i> (2009)
Supporting	Soil formation/retention; Critical Infiltration; Groundwater Recharge		O'Farrell <i>et al.</i> (2012)

Demand for and supply of ecosystem services types in informal urban areas

From the aforementioned, it is clear that benefits from green infrastructure (especially provisioning ecosystem services) play a critical role in the lives and livelihood of poor people in informal settlements. According to Sukhdev (2009: 277), these ecosystem services are a kind of wealth – so called “Gross Domestic Product (GDP) of the poor”, because of their primary reliance on natural resources. This highlights the need to consider demand (reliance and dependency) and supply (availability of) ecosystem services in informal settlements.

A number of studies compare demand for provisioning services (material products) with other categories of services. It appears that residents in low-income

urban communities place more demand on provisioning services compared with other categories. Of the 720 respondents surveyed by Waters (2013) in three Kampala settlements, 11% drew benefits related to provisioning services, while only 5.2% and 3.7% of the benefits are related to regulatory and cultural services respectively. Although available ecosystem services only make meagre contributions to adaptive capacity in the areas, the study shows that “poorer individuals tend to use provisioning services more while only relatively higher-income individuals value cultural services” (*ibid.*: 109).

Similarly, Shackleton *et al.*'s (2014) survey compared informal settlements with townships in three South Africa cities. Although both informal settlement and township neighbourhoods are largely low-income

areas, townships are legally recognised, enjoy better infrastructural services and are wealthier in comparison to informal settlements. The study's comparison on use of tree products shows that informal settlement residents made more use of trees for supply of fruits, timber, fuel and herbal medicine. Township residents were consistently the least likely to collect tree products from within and outside their homes. In total, 80.7% of respondents in informal settlements collected tree products from their homestead or elsewhere while only 41.3% did so in the townships (Shackleton *et al.* 2014). The study did not explore socio-economic factors that might have influenced the lower rate of tree product collection in the formal townships.

In Potchefstroom (South Africa), Lubbe *et al.* (2010) analysed plant diversity patterns across six urban residential typologies – from peri-urban informal settlements to up-market neighbourhoods. The study found that “a relatively strong negative relationship exists for fruit trees and socio-economic status ($R^2 = 0.65$), suggesting that poorer households grow more fruit trees” in order to avoid dependence on market products, gain additional income and improve livelihoods (*ibid.*: 2907). In the same vein, Seburanga *et al.*'s (2014) observed that non-fruit bearing aesthetic trees were more in high-income areas while fruit-bearing plants were ubiquitously present in the poor non-formal settlements in Kigali.

Seeing that there is higher demand (reliance) on provisioning services in the low-income urban context, is there sufficient and sustainable supply? Here, supply of ecosystem services is understood as the capacity of a particular area (e.g. an informal settlement) to provide or secure those ecosystem goods and services which people rely on, and to do that within a given period (Burkhard *et al.* 2012). While it is still unclear how the supply of ecosystem services to informal urban areas can be quantified, city-wide supply must be inclusive for the sake of justice. Supply of ecosystem services must respond to inequalities that McConnachie and Shackleton (2010) identifies often characterize the distribution of green spaces in developing countries.

Disadvantages from green infrastructure experienced in informal settlements

Considering negative outcomes and undesirable aspects in the connection between people in informal settlements and natural ecosystems helps to holistically understand the impacts of ecosystems on human well-being. These outcomes, referred to as ecosystem disservices, can emanate from normal functioning of undisturbed ecosystems or result from anthropogenic degradation of ecosystems (Lyytimaki, Sipila 2009).

They are real harm while others are issues based on perceptions (Dunn 2010). I illustrate these with examples from literature.

Problems related to natural ecosystems generally manifest through health threats and other physiological problems. As Douglas (2012) explains, certain aspects of the natural environment have been associated with negative impacts on physical and mental well-being in informal settlements in some situations. Through a survey of informal settlements in Dakar, Gruebner *et al.* (2012) found that, combined with poor waste disposal and inadequate sanitation, patches of vegetation increased the risk for infectious diseases, especially diarrhea. People living in settlements located close to wetlands often experience invasion of mosquitoes and other insects, because they are bred in these water-logged spaces. Evidences of this come from Kumasi (Campion 2012), Ouagadougou (Baragatti *et al.* 2009) and Kampala (Isunju *et al.* 2016). In Ouagadougou, malaria risk correlates with ecological strata (proximity to hydrographic network) and living in irregularly planned settlements (*ibid.*).

Furthermore, while urban agriculture supports food production and social capital, it can involve health hazards. Irrigation with greywater from polluted drainage channels/streams in informal settlements can contaminate crops. Gallaher *et al.* (2013) pointed to this as a challenge associated with sack gardening in Kibera settlement in Nairobi.

Disservices from natural ecosystems related to perceptions are exemplified through phobia. Some people dread densely vegetated spaces because they can conceal miscreants and criminal activities (Donaldson-Selby *et al.* 2007). Fear of being attacked or dwellings being infested by dangerous animals such as snakes, scorpions is another case (Stretha 2010). Problems based on perception can result to those involving real harm. As an illustration, fear of being mugged or raped in an unlit vegetated space can lead to anxiety and depression (psychological problems) as well as hypertension (physiological problems).

These disservices could also occur in formal areas of a city. They, however, stand out in informal settlements because poor spatial configuration, inadequate services and infrastructure, precarious tenure among others make the emanating problems difficult to mitigate. For instance, absence of electricity and street lighting in a settlement makes security measures against night-time criminal activities difficult in densely vegetated areas.

Discussion

A notable thread emerges from the findings. Benefits (ecosystem services) from green infrastructure have the potential for improvements in the quality of life,

livelihood and the environment. Aspects of socio-cultural services can support environmental justice and equity (Ferris *et al.* 2001). “Ecosystem-based adaptation” can create opportunities for local economic development (Roberts *et al.* 2012: 167). Although seldom harnessed presently, much can be done incrementally to enhance provisioning, regulatory, socio-cultural and supporting ecosystem services in this context. This could be achieved through by encouraging domestic and communal gardening, tree-planting or facilitating co-management of natural ecosystems adjoining settlements.

Harnessing the range of benefits however demands attention that addresses and mitigates the undesirable aspects from green infrastructure. It also demands appropriate local buy-in. For instance, while SUDS presents a promising drainage approach (Jiusto, Kenney 2016), “community involvement in both planning and implementing” is necessary in the low-income, informal setting (Button *et al.* 2010: 16). As a Rio case shows, the same principle applies to other kinds of greening activities in settlements (Rekow 2016).

High demand on provisioning services, earlier shown, corroborates Cilliers’ *et al.* (2013) view that people from poorer communities directly need useful plants (provisioning ecosystem services) more than people in affluent communities. It can also be linked to the fact that poor people depend directly on the natural resource environment for their livelihood (Nadkarni 2000). Furthermore, higher demand highlights the notion of “reliance” and “dependency” in urban settlements in developing countries, contrary to the notion of “enjoyment”. Literature from developed countries frames primary benefits from green infrastructure as “enjoyment” (See for example, Andersson 2006; Roy *et al.* 2012; Buchel, Frantsezkaki 2015). Socio-economic conditions in informal urban areas make ecosystem services, especially provisioning, something relied on (fundamental) rather than enjoyed (dispensable). In this situation, reliance relates to survivalism rather than well-being.

Conclusions

This paper has shown how the urban poor in informal settlements relate with, derive benefits and are negatively affected by connection to different components of green infrastructure. Through the literature reviewed, it is clear that green infrastructure contributes to quality of life, livelihoods and environment – and these contributions can be enhanced. This paper contributes to the growing body of knowledge on green infrastructure from the perspective of informal urban settlements in developing countries.

Future research needs to consider trade-offs that are made in the relationship with natural ecosystems. That is, how a benefit(s) is valued in relation to other benefit(s) or detrimental aspects by those in informal settlements. Also, unpacking the way physical transformations accompanying informal settlement intervention affects the relationship between residents and green infrastructure would be useful. It is necessary to know how ecosystem services and ecosystem disservices are experienced by the residents before or after in situ upgrading or relocation to new housing. This knowledge can contribute to environmentally sustainable intervention in informal settlements across developing countries.

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