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Exploring urban green packages as part of Nature-based Solutions for climate change adaptation measures in rapidly growing cities of the Global South

Eliakira Kisetu Nassary [a], Bahati Hakimu Msomba [b], Wilson Elias Masele [c], Patrick Madulu Ndaki [c], Caren Anatory Kahangwa [d]

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Abstract

Given a lot of elusive information on the use and implementation of Nature-based Solutions (NbS) in the Global South, this review provides a synthesis of the evidence on the: - (1) distribution of urban green technologies in form of arboriculture and urban agriculture as a part of NbS packages for the sustainability of cities against population growth and impact of climate change; and (2) options of integrating and mainstreaming various NbS packages into city development policies, planning processes, and decision-making agendas. The sustainability of urban green as part of NbS packages and the usefulness for improvement of livelihoods is determined by the spatial (geographical location) and temporal (time of action) scales, and socio-ecological and institutional factors. Various NbS packages have shown the ability for use as climate change adaptation measures throughout the world. These functions include protection from soil erosion, protection from inland flooding, buffering natural resources against drier and more variable climates, protection from coastal hazards and sea-level rise, moderation of urban heatwaves and effects of heat island, and managing storm-water and flooding in urban areas. Furthermore, the benefits of urban agriculture and arboriculture include use as sources of food and generation of income; improve recreation and social interactions, and the sustainability of biodiversity. They also mitigate the impact of environmental pollution and climate change through reduction of gas emissions and act as carbon sinks. While the starting capital and lack of policy on urban agriculture and arboriculture in many countries, the importance of the industry is inevitably a useful agenda especially in the Global South due to vulnerability to the impact of climate change. This review also suggests the inclusion of all institutions, governments, and

relevant stakeholders to emphasize gender sensitization at all levels of planning and decision-making in food production and adaptation measures to climate change.

Graphical abstract

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Introduction

The dwellers in cities worldwide were estimated to be 1.1 billion people by 2021 but the number is expected to double (2.2 billion) (Gulati and Scholtz, 2020), with the total world's population expected to reach 9.1 billion by 2050 (Nassary et al., 2020). Cities in the Global South are experiencing rapid expansion with the population growth was estimated to be 75% by 2020 throughout all countries in Africa, Asia, Latin America, and Oceania (FAO, 2012; Friend and Moench, 2015; Anaafo and Akolgo, 2018). The significant demographic and economic growth in cities coupled with urbanization is high in the Global South compared with the rest of the world but in the absence of proper planning as well as inadequacy of the key services (FAO, 2012; Gulati and Scholtz, 2020; Mabon and Shih, 2021).

It signals a big challenge to the growing cities to align with the Sustainable Development Goals (SDGs) 2030 Agenda of urban sustainability (SDG 11), which states that “make cities and human settlements inclusive, safe, resilient and sustainable” (FAO, 2018). UN-Habitat (2017) report highlights that in the SDG Global Monitoring Framework about one-third of the 231 indicators can be realized at the local level as are directly specific to urban policies and impact human settlements. Furthermore, the Habitat III conference of Ecuador held in 2016 endorsed a global strategy of the New Urban Agenda (NUA) that cities must develop strategies based on three-fold principles: (1) no one is to be left behind; (2) cities should ensure sustainability and inclusiveness of urban economies; and (3) the sustainability of environments should be critically considered (FAO, 2018). Along with these principles during NUA all countries adhered to SDG 11 of green spaces in cities as important ecosystems in improving living standards of people as well as enhancing cohesion within communities. Other SDGs agendas considered under the agreement were the SDG 3 of contributing to human health and wellbeing; SDG 8 of promoting economic exchange, cultural expression, and dialogue among a wide diversity of people and cultures; SDGs 10 & 11 of providing urban dwellers with

multifunctional areas designed for social interaction and inclusion; and SDGs 10 & 16 of designing and managing to ensure human development and build peaceful, inclusive and participatory societies as well as promoting living together, connectivity and social inclusion.

Cities in the Global South are expanding with a high impact on critical services and destruction of natural landscapes through increased deforestation, habitat fragmentation, and loss, and soil erosion (Zhang et al., 2020). More challenges in the sustainability of cities are offered by the impact of climate change and extreme weather events (Msomba et al., 2021), and the increasing vulnerability of these cities to the impacts of climate change (Gulati and Scholtz, 2020). The fast-growing population and impact of climate change exacerbate the ability of cities to accommodate the growth of population and provide necessary services for wellbeing. For instance, 58% of the population in urban areas of Sub-Saharan Africa (SSA) lives in informal settlements (Zhang et al., 2020). The rapid population growth in the Global South is triggered by the impact of climate change on rural areas, especially in agriculture hence causing an increase in the rural-urban migration of the young generation as an adaptation strategy to diversify income sources through remittances (Dai et al., 2021). Furthermore, land scarcity due to population growth increases challenges related to the communities' displacement hence social settings, and increases in prices of land and house renting/purchasing costs (de Souza and Torres, 2021). The climate-migration association varies by location characteristics, access to social networks, and demographic factors such as gender and will affect the tropical low-income countries as well as a larger share of populations whose livelihoods depend predominantly on rain-fed agriculture (Amoah-Antwi et al., 2020; Dai et al., 2021).

Population growth also increases pressure on the environment as it causes an increase in demand for more food production and more land is expanded for habitats while water and energy become the limiting factors (Nassary et al., 2020). The knowledge and capacity gaps on the environmental responses to these changes are globally reported (Gill and Malamud, 2014; Simpson et al., 2016; Aksha et al., 2019). Environmental exhaustion by the population pressure translates into susceptibility to natural hazards (the physical phenomena) including tsunamis, landslides, severe storms, earthquakes, floods, volcanic eruptions, and tornadoes (Gill and Malamud, 2014; Shen and Hwang, 2019). An increase in environmental risks, as well as the increasing extremes and uncertainties linked to the impact of climate change and the changing demographics and socio-economic conditions, can parallel increase human-environment interactions (Aksha et al., 2019). The impact and risks associated with climate change on biodiversity and ecosystems in cities escalate underdevelopment as a major global threat (Thompson et al., 2009; Crawford and Terton, 2016; Sintayehu, 2018; Roy et al., 2018; Martin et al., 2019; Mngumi, 2021). The quality of life of the population in cities depends largely on the quality of city environments, including ecological and hard infrastructure (housing, transportation systems, sanitation, and water) (Rasmussen, 2013; Roy et al., 2018; Zhang et al., 2020).

A healthy environment is always mandatory in cities which have to depend on the presence and/or establishment of active green spaces as well as proper planning of functional and aesthetic qualities (Cetin, 2015). According to Cetin (2015), policies have to specify adequacy of green spaces through relevant legislation and credit facilitation from financial institutions. It is also reported that spatiotemporal variability of green spaces in the cities could be related to the human provision of recreational needs (Cetin, 2015). A study conducted by Hu et al. (2021) provides important of land policy in establishment of green spaces and the need for land title or tenure system. The policy of land use and tenure are reported to

motivate land conservation by various users including those in cities for green spaces. According to Hu et al. (2021), the policies where land consolidation and reallocation of land reallocation are combined can be effective in enhancing development of green spaces tailed with soil health and agricultural green in the open spaces of the cities. Hu et al. (2022) indicated that ecological red line policy is important to be implemented by the governments to protect important ecosystems including green spaces in cities. Hu et al. (2022) found that the communities were willing to pay for water resources reserve areas and nature reserve areas as well as for cultural landscape areas in Nanjing city of China. Hu et al. (2022) perceived that willingness to pay for the natural resources increases participation of the community to the importance of these resources thereby improving awareness in the protection of ecologically valued resources. Using ArcGIS, Cetin (2015) concluded that green spaces should be developed in an integrated system with the growing cities giving options for the sustainability of natural potentials. The land use agenda and designing in cities are reported to be the operational drivers of higher learning institutions like the universities but tailed with economic and socio-cultural focus (Cetin et al., 2021a, Cetin et al., 2021b). In Turkey, for instance, Cetin et al., 2021a, Cetin et al., 2021b found that 6 of the 13 universities restored the natural environment towards urbanization with 4.5% describing negative changes in the boundaries at the centre of the city.

Cities in the Global South are also growing rapidly due to their connecting nodes with small towns and villages, which are expanding towards urbanization (Yin et al., 2021). In China, for instance, Yin et al. (2021) found that over 80% of the towns improved their efficiency by production scale expansion and economic density. According to Yin et al. (2021), the economic development of small towns in close proximity to cities can also shape their important role in integrating rural-urban and city development.

Sustainable development is regarded as one of the important approaches in reducing the environmental impacts of cities resulting from high population growth. Cetin et al., 2021a, Cetin et al., 2021b using GIS software calculated the ecological footprint with the aiming of quantifying the relationship between population growth and the environment at the campus of Eskisehir Technical University of Turkey. According to Cetin et al., 2021a, Cetin et al., 2021b, the pasture, agricultural land and natural plant patterns covers present by 1990 were converted into areas for buildings thereby diminishing green spaces. Cetin et al., 2021a, Cetin et al., 2021b emphasized that the increase in population also increased construction of buildings while increasing occupation of recreational areas, energy consumption, construction of roads for transport, and high rate of waste production. Cetin et al. (2018) evaluated the sustainability of natural and cultural resources in Turkey's ancient city of Kastamonu-Pompeiopolis with high population and found that untapped recreational areas of the city are underexploited and reached suggesting that the city is sustainably developed with wealth of ecotourism activities.

Environmental factors and human characteristics can be evaluated using computer based indices (Gungor et al., 2021). According to Gungor et al. (2021), Physiological equivalent temperature index (PET) and classification summer calculation model (CSCM) are useful in bioclimatic comfort calculations were relative humidity, wind speed, and surface-and-air temperature are considered. However, GIS analysis is used to evaluate the changes in thermal perceptions over a long period (Gungor et al., 2021). A study conducted by Gungor et al. (2021) revealed that there was an increase in PET in the areas close to the water bodies in cities. Furthermore, a study conducted by Adiguzel et al. (2021) revealed that the tourism climate indices (TCI) are the important environmental indicators when considering appropriate seasons for the local and international tourists in a densely populated city. According to Adiguzel et al. (2021), the TCI are determined

through weather elements such as relative humidity, wind information (speed and direction), temperature, and total rainfall with the findings generated being important in the sustainable development of recreational calendars for the tourists in growing cities. Construction of buildings in cities also results in an increase of surface temperatures thereby resulting in the formation of heat islands (Sert et al., 2021). According to Sert et al. (2021), the selection of materials for construction of buildings is important in the sustainable development of healthy and liveable rapidly growing cities. Sert et al. (2021) insisted that there is a need of policy intervention from governments to enforce on green spaces (with grass, shrubs, herbs, and trees), landscaping, and water bodies to reduce surface heat islands and increase thermal comfort.
Apart from the reality that cities in the Global South are highly expanding in terms of population growth with high exhaustion of natural resources including land, forest, water, and energy, there is little attention towards strategies for restoration and prospects for the sustainability in future (Hansen et al., 2017; Amoah-Antwi et al., 2020). In light of ensuring the sustainability of the ecosystems and support of population wellbeing in the rapidly growing cities, the context of urban green (UG) that sets urban green infrastructure (UGI) and ecological infrastructure (EI) has been one of the global agenda (Hansen et al., 2017; Sun et al., 2020). Use of UGI and/or EI as the elements of land-use planning has been defined as open spaces of land reserved for water resources, parks, vegetation cover (plant life), and other kinds of the natural environment (Taylor and Hochuli, 2017; Feltynowski and Kronenberg, 2020). The environmental benefits of green spaces are derived through their effects on offsetting greenhouse gas emissions (GHG), attenuating stormwater, and negating warming (Lee et al., 2015). It is challenging that while focusing on green spaces as one of the solutions towards the sustainability of cities, it is also important to note that there is high variability in plant species (of grass, shrubs, forests) due to past climatic stability (e.g., Kreft and Jetz, 2007). Furthermore, besides being poorly explored, the importance of green spaces, inferring to agriculture and arboriculture, along with EI as part of Nature-based Solutions (NbS) for climate change mitigation measures in cities, the topic and results have received long debate and consensus but the implementation is still elusive.

Nature-based Solutions (NbS) cover a package of practices that are typically natural but enhance nature in addressing the challenges facing the community of the people as well as lower and higher animals and plants (Seddon et al., 2016). The NbS includes ecosystems adaptation and mitigation to climate change, reduction of disasters before translated to risks, water (blue/green) bodies in cities, and use of natural approaches in solving climate problems (Kooijman et al., 2021). The benefits derived from NbS in solving environmental problems are widely documented as part of research and innovation (e.g., European Commission, 2015; Cohen-Shacham et al., 2016; Kabisch et al., 2017; Albert et al., 2021; Seddon et al., 2016, Seddon et al., 2020a, Seddon et al., 2020b, Seddon et al., 2021), but adoption of the technology is not globally in practice (Frantzeskaki et al., 2017; Faivre et al., 2017; Dumitru et al., 2020; Kooijman et al., 2021). Since 2014, improvement in biodiversity and ecological services through funding projects on research in the Global North (e.g., Europe) dealing with NbS have created more jobs and increased income to different societies involved (Kooijman et al., 2021; Seddon et al., 2021). However, the importance of UGI in the same region was considered critically in 2009 focusing on natural and semi-natural options of city restoration and adaptation to climate change (Werguin et al., 2005; Sturiale and Scuderi, 2019). According to the European Commission (2019), the continuous deployment of NbS is acknowledged to contribute to a net-zero society by 2050 in the Global North, especially Europe, and ensure sustainable adaptation and mitigation measures to climate change in the region. The lack of proper involvement of all stakeholders, absence of guidelines, uncertainties of the value to be delivered, lack/shortage of financing sources and/or expertise, and availability of land and time are the important challenges facing the effective implementation of NbS at all

levels (Sarabi et al., 2019; Kooijman et al., 2021). Even though the NbS has been implemented in Global North since 2014, the private sector has been left behind by the public sector without co-involvement in implementation hence causing a lot of these barriers towards the success of the objectives set for NbS (Kooijman et al., 2021). To date, the only available NbS investors in Europe are public-private companies, public/community groups, and networking in community gardens, forestry, and tourism but not pure private companies (Kooijman et al., 2021).

Since then, several studies have concentrated on NbS and the feedbacks associated with them in delivering both climate change mitigation and adaptation measures while also supporting other ecosystem services (Hansen et al., 2017; Price, 2021; Seddon et al., 2016, 2020 a,b, 2021). The NbS takes many forms (Price, 2021), but Seddon et al. (2020a, 2021) stretched that the same must deliver benefits for biodiversity and people and ensure that they support a range of the pillars in the Sustainable Development Goals (SDGs). However, there is a high discrepancy in realizing the significance of NbS throughout the world as Escobedo et al. (2019) acknowledge limited research on the use of NbS packages as adaptation measures to climate change in cities of regions outside the Global North (e.g., Europe and North America). Therefore, given a lot of elusive information on the use and implementation of NbS in the Global South, this review is designed to provide a synthesis of the evidence on the: (1) Distribution of urban green (UG) technologies in form of arboriculture and urban agriculture as a part of Nature-based Solutions (NbS) packages for the sustainability of cities against population growth and impact of climate change in the Global South; and (2) Explore options of integrating and mainstreaming various NbS packages into city development policies, planning processes, and decision-making agendas.
Worldwide, there are existing examples of NbS for climate change adaptation including protection from soil erosion in Ethiopia (Brown et al., 2011), China (Huang et al., 2012; Jia et al., 2017), protection from inland flooding in Europe (Vermaat et al., 2015), Canada (Buttle, 2011), USA (Kelly et al., 2016). Other examples are buffering natural resources against drier and more variable climates in Panama (Paul et al., 2017), Europe (Torralba et al., 2016), global protection from coastal hazards, and sea-level rise (Scyphers et al., 2011; Narayan et al., 2016; Menendez et al., 2020; Seddon et al., 2020a). There is also global moderation of urban heatwaves and effects of heat island (Bowler et al., 2010; Seddon et al., 2020b), and managing stormwater and flooding in urban areas (Liquete et al., 2016).

The relationship between biodiversity and NbS has been confused as some definitions do not explicitly provide reference to biodiversity (European Commission, 2015), but Seddon et al. (2016, 2021) insisted that NbS must deliver benefits for biodiversity and to the people. Further, Seddon et al. (2021) view this need to be in line with the International Union for Conservation of Nature (IUCN) definition and the Global Standard for NbS stipulated in Cohen-Shacham et al. (2019) and IUCN (2020). Under this observation, Seddon et al. (2021) state that there are clear differences between NbS from practices that exploit nature but can damage biodiversity including certain agricultural activities, BioEnergy Carbon Capture and Storage (BECCS), commercial forestry, and recreational activities that harm sensitive habitats or species. Whereas studies conducted by Price (2021) and Seddon et al. (2016, 2020a,b, 2021) show the existing potential of NbS in protecting communities and infrastructure from the impacts of climate change while providing a range of other benefits for society worldwide, such studies are rarely reported in the Global South. Despite the benefits that ecosystems can provide to societies in adapting to the impacts of climate change, Seddon et al. (2020a) insisted that national-based policy targets that benefit people and nature remain to be explored.

Section snippets

Methods deployed in literature search

The present review is based on the deployment of the PRISMA method described by Moher et al. (2009) to conduct a systematic review of the literature on access to urban green infrastructure in the rapidly growing cities of the Global South (Fig. 1). According to Rigolon et al. (2018), the PRISMA method deployed in systematic reviews provides checklists of important items to be covered depending on the subject being addressed.…

Urban green infrastructure in the Global South

The distribution of studies describing UGI in the Global South shows high geographic variation (Table 1). Results indicated that by 2021, more than 50 publications were in place addressing about the UGI in the cities of the Global South (Larbi et al., 2021; Kiddle et al., 2021). These include 46 articles described by Rigolon et al. (2018) plus nine (9) articles acknowledged from other researchers (Lado, 1993; Mkwela, 2013; Rao et al., 2013; Trundle and McEvoy, 2016; Drakakis-Smith, 2017; Skar…

Existing policies of green infrastructure in the Global South

Green infrastructure development in cities is an important strategy of the North and South Globes. However, whereas the policy of UGI in the Global North is clearly defined such that ecosystems and their services are maintained and at least 15% of the degraded portions are restored, but this is not the case in the Global South. It has been difficult for the large part of the Global South, especially Africa, to grasp science and policy concurrently due to high discrepancy in urbanization…

Lessons from the review and conclusions

The sustainability of urban green in form of urban agriculture and/or arboriculture as part of NbS packages and the usefulness for improvement of livelihoods is determined by geographical location, socio-ecological, and institutional factors. The benefits of urban agriculture and arboriculture include the provision of food and generating income, improving recreation and social interactions, improving the sustainability of biodiversity, and mitigating the impact of environmental pollution and…

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.…

Glossary

The glossary with the definitions of the key terms used in the present review is provided as Annex 1.…

Declaration of competing interest

The authors declare that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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