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Boosting African cities' resilience to climate change: The role of green spaces

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BOOSTING AFRICAN CITIES' RESILIENCE TO CLIMATE CHANGE: THE ROLE OF GREEN SPACES

This paper has been prepared by

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OECD BETTER POLICIES FOR BETTER LIVES

WEST AFRICAN PAPERS

The *West African Papers* series explores African socio-economic, political and security dynamics from a regional and multidisciplinary perspective. It seeks to stimulate discussion and gather information to better anticipate the changes that will shape future policies. The series is designed for a wide audience of specialists, development practitioners, decision makers and the informed public. Papers are available in English and/or French, and summaries are available in both languages. Initiated by the Sahel and West Africa Club (SWAC) to highlight and promote West African issues, the work presented is prepared by its Secretariat, Members and partners, other OECD departments, related international organisations, associated experts and researchers.

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Abstract

The next few decades will bring an era of rapid urbanisation and unprecedented climate stress to African cities. Green spaces can boost the resilience of cities to heatwaves, floods, landslides, and even coastal erosion, in addition to enhancing sustainability by improving air quality, protecting biodiversity, and absorbing carbon. All of which can enhance well-being. Yet, data on the availability of green spaces in African urban agglomerations is scarce. This analysis fills the gap by combining new and novel data sources to estimate the availability of green spaces in 5 625 urban agglomerations with 10 000 inhabitants and above. The rest of the report then uses this novel dataset to first evaluate the dynamics between urbanisation and green spaces, and second, explore the potential of green spaces to boost the resilience and sustainability of cities in the future. The results show that as urban agglomerations become larger and more compact, green spaces disappear, exacerbating their vulnerability to climate change and deteriorating liveability. However, building taller buildings (i.e., growing vertically), offers a way for cities to grow whilst minimising loss of green space. Results show that more green space can boost sustainability by significantly lowering air pollution in African cities, which could be vital for public health in the future since outdoor air pollution is rising. The potential for green spaces to enhance resilience to climate events, like heatwaves, depends on the location of green spaces throughout the city and the percentage of the population that lives close to a green space (i.e., within 300 metres). Green spaces may play a limited role in coping with heatwaves in a city like Khartoum where only 3% of the population lives close to a green space, but could be a nature-based solution to heatwaves in a city like Abuja, where 55% of the population can benefit from its cooling effects. Moving forward, local actors have clear evidence of the power of green spaces to build a sustainable and resilient future. Still, the report reveals that local actors need support from regional and national actors to realise the potential of green spaces.

Key words: Green spaces, cities, resilience, sustainability, nature-based solutions, ecosystem services, Africa

JEL classification: Q53, Q54, Q56, Q57, R14, R15, R52

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The Sahel and West Africa Club

The Sahel and West Africa Club (SWAC) is an independent international platform. Its Secretariat is hosted at the Organisation for Economic Co-operation and Development (OECD).

Its mission is to promote regional policies that will improve the economic and social well-being of the people in the Sahel and West Africa. Its objectives are to produce and collect data, draft analyses and facilitate strategic dialogue in order to nurture and promote public policies in line with rapid developments in the region. It also promotes regional co-operation as a tool for sustainable development and stability. Its current areas of work are food dynamics, cities and territories, and security. SWAC Members and partners include: Austria, Belgium, Canada, CILSS (Permanent Interstate Committee for Drought Control in the Sahel), the ECOWAS (Economic Community of West African States) Commission, the European Commission, France, Luxembourg, the Netherlands, Switzerland, the UEMOA (West African Economic and Monetary Union) Commission and the United States. SWAC has a memorandum of understanding with the University of Florida Sahel Research Group.

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Executive summary

Africa is rapidly urbanising. An additional 950 million people will live in cities by 2050 compared to 2015. This unprecedented urbanisation is arising in a time of extreme and volatile climate stress. Africa will disproportionately suffer from the impacts of climate change in the coming decades. African cities, in particular, will face overlapping risks from extreme heat, flash floods and drought. Even though climate change is a global challenge, its response rests on the actions of local actors.

Green spaces, i.e. the fraction of the urban footprint covered by trees, shrubs and grasslands, are a lever of action at the disposal of cities to increase resilience to climate change and provide a host of other ecosystem services to enhance sustainability, such as pollution and carbon absorption. The importance of green spaces for resilience and sustainability is emerging across political agendas as seen by its inclusion in the African Union (AU) Green Action Recovery Plan 2021-27 as well as in Target 7 under SDG 11 for Sustainable Cities and Communities, which aims for universal access to public green spaces by 2030.

Yet, data on the availability of green spaces in African urban agglomerations is largely absent. When data exists, it is primarily skewed towards large cities, above one million inhabitants, overlooking small and intermediary cities (10 000 to 50 000 inhabitants and 50 000 to 1 million inhabitants, respectively). Because of limited data, it is hard, if not impossible, to evaluate the dynamics between urbanisation and green spaces. It is equally difficult to fully assess green spaces' potential as a nature-based solution to climate change or their contribution to sustainability.

This report fills the gap by combing two recently released datasets: (1) the European Space Agency's World Cover Map, which classifies land cover across the continent, and (2) Africapolis, which is the most up-to-date tracking of urban agglomerations across the continent of 10 000 inhabitants or more. With this, it is feasible to calculate the availability of green space for 5 625 urban agglomerations in Africa. Similar metrics are used by cities worldwide to track green spaces in cities. Future updates will be possible with new releases of the data becoming available.

The report explores the dynamics between urbanisation and green spaces, and finds that similar to the rest of the world; increasingly compact cities tend to have less availability of green space. This is a worrying trend since these cities will be more prone to urban heat island effects, which can cause heat-related illness and mortality for young children and elderly. However, cities that grow vertically by building taller tend to have greater availability of green space. A deep dive into three case studies reveals that preserving green spaces in urbanising cities requires more than provisions in city planning documents. Resources, clarity of authority, and enforcement are also needed.

The analysis illustrates the potential for green spaces to improve air quality by reducing air pollution (in particular, fine particulates), which may be essential to public health since outdoor air pollution is expected to increase exponentially. None of the 5 625 cities in this analysis meet the clean air standard set by the World Health Organisation (WHO). Yet, the model shows that greater availability of green spaces leads to significantly less air pollution in cities. Results show that green spaces are effective at reducing air pollution, especially when embedded in a broader policy package.

To increase resilience to heat waves, living close to a green space is vital. Temperatures are reduced typically within the 300 metres surrounding a green space. The analysis reveals that the availability of green spaces is not the same as proximity — i.e., the proportion of the population living close to green spaces. This report combined the spatial data on green spaces with data on population density in 15 cities (5 in West Africa). For example, Abuja and Accra have the same availability of green space in cities (approximately 20% of the urban footprint), but with drastically different proportions of the population who can benefit from its cooling effects during a heat wave — 16% in Accra and 55% in Abuja. Local-level actors who plan to use green spaces as a nature-based solution to heat waves should try to ensure varying-sized patches throughout the city.

This report can help local-level actors by providing new data on their cities and illustrating the importance of steering urbanisation such that these spaces do not disappear. If these spaces are present, there is great potential to boost cities' sustainability and resilience. Even though the choices of local-level actors greatly influences how cities evolve, they need to be supported by national and regional governments. Many countries are highly centralised, which constricts local-level actors' ability and financial capacity to restore, maintain, and enforce existing regulations that pertain to green spaces. Many national governments do not recognise the importance of the local level when it comes to mitigation and adaptation. Moving forward, national governments must support local actors to fully realise the potential of green space.

Introduction

Cities are central to a sustainable future. How urban areas are built and grow will have long-term implications on the environment and the lives of billions of people worldwide. Cities in Africa are urbanising at a very quick pace, and doing so under incredibly unique circumstances. Collectively, an additional 950 million people will live in African cities by 2050 compared to 2015 — but at far quicker rates of urbanisation and with far fewer economic resources than their counterparts had globally (OECD/SWAC, 2020[1]; Page et al., 2020[2]). A handful of cities could reach city sizes that are unheard of in today's world nearly 80 million people are projected to live in the city of Lagos (Nigeria) by 2100, up from approximately 16 million today, more than double the current size of Tokyo, today's largest city globally (Angel et al., 2016[3]). Ensuring the liveability of cities during this transition, e.g., access to clean air, safe streets, public services, job opportunities, and reasonable commutes, will be no easy feat.

In the midst of this already remarkable urbanisation is climate change, meaning cities must undergo this transition at a time of extreme and volatile climate stress. African cities are and will continue to suffer disproportionately from climate change. Africa is projected to warm 1.5°C faster than the global average under a future 2°C scenario (IPCC, 2018[4]; Osima et al., 2018[5]). As a result, cities in West Africa are likely to be the most severely affected by dangerous heat, reaching 145 to 196 days per year by the 2090s under different climate scenarios (Rohat et al., 2019[6]). Extreme heat is associated with a myriad of health risks like heat stroke, heat cramps, and heat-related mortality. Moreover, cities face overlapping risks in the future. West African cities will not only confront increasing heat-related mortality and heat-related loss of labour productivity, but also reduced food production from crops, diminished fisheries production, water scarcity, and increased flooding risk, to name a few (IPCC, 2018[4]; IPCC, 2022[7]).

Climate stress places strain on basic services in cities, indirectly harming citizens' well-being, as shown by Cape Town's water crisis in 2018. After three years of poor rainfall, the city almost ran out of water. Its response ranged from rather unobtrusive recommendations such as showering for no longer than two minutes to the most extreme, of restricting residents to a maximum of 50 litres per day and imposing fines for violations (Edmond, 2019[8]). Cape Town managed to avert the worst of the water scarcity crisis, yet, the risk of future shortages remains. These events will only become more likely for many cities in Africa with increasing urbanisation, fragile infrastructure, and growing climate stress.

How can cities urbanise resiliently and sustainably, and ultimately, — be liveable? Green spaces are one lever of action at the disposal of cities, which is often overlooked and underappreciated in the competition for land when urbanising (Mensah, 2014[9]). "Green spaces" is an all-encompassing term for greenery in cities: trees, scrublands, mangroves, grasses, urban agriculture, and everything in between, which may be public or private.

Green spaces deliver indispensable ecosystem services (e.g., the benefits provided by nature to humans) that boost cities' resilience to climate change (e.g., as a nature-based solution) as well as strengthen its sustainability. Green spaces can attenuate the impacts of extreme weather events such as heat waves, heavy rainfalls, storm surges and floods, as well as slow-onset risks like drought, land erosion and landslides. Other ecosystem services from green spaces can enhance the sustainability of cities, by reducing air and noise pollution, sequestering and storing carbon, contributing to water quality and even contributing to the conservation of biodiversity (OECD, 2021[10]). These services, in turn, contribute to public health, including lowering rates of asthma mortality in young children through the absorption of pollution, and reducing heat stress amongst the elderly. In addition, their presence is associated with the protection of biodiversity, improved social cohesion, better mental health from lower levels of stress and depression, and better self-rated physical health (Jimenez et al., 2022[11]; Rigolon et al., 2018[12]; Wood et al., 2017[13]; Hong et al., 2021[14]; Patino et al., 2021[15]).

In day-to-day life, though, not all of these ecosystem services are cited as reasons why green spaces improve quality of life. In urban agglomerations, for example, in the Sahel, the Sudanian savanna, and the northern part of the Guinean savanna, trees are often valued for shade, as meeting places, and for the production of food or medicine within home gardens (Adegun, 2021[16]). Similar benefits were cited from green spaces in a survey of individuals living in informal settlements in Africa (Adegun, 2021[16]).

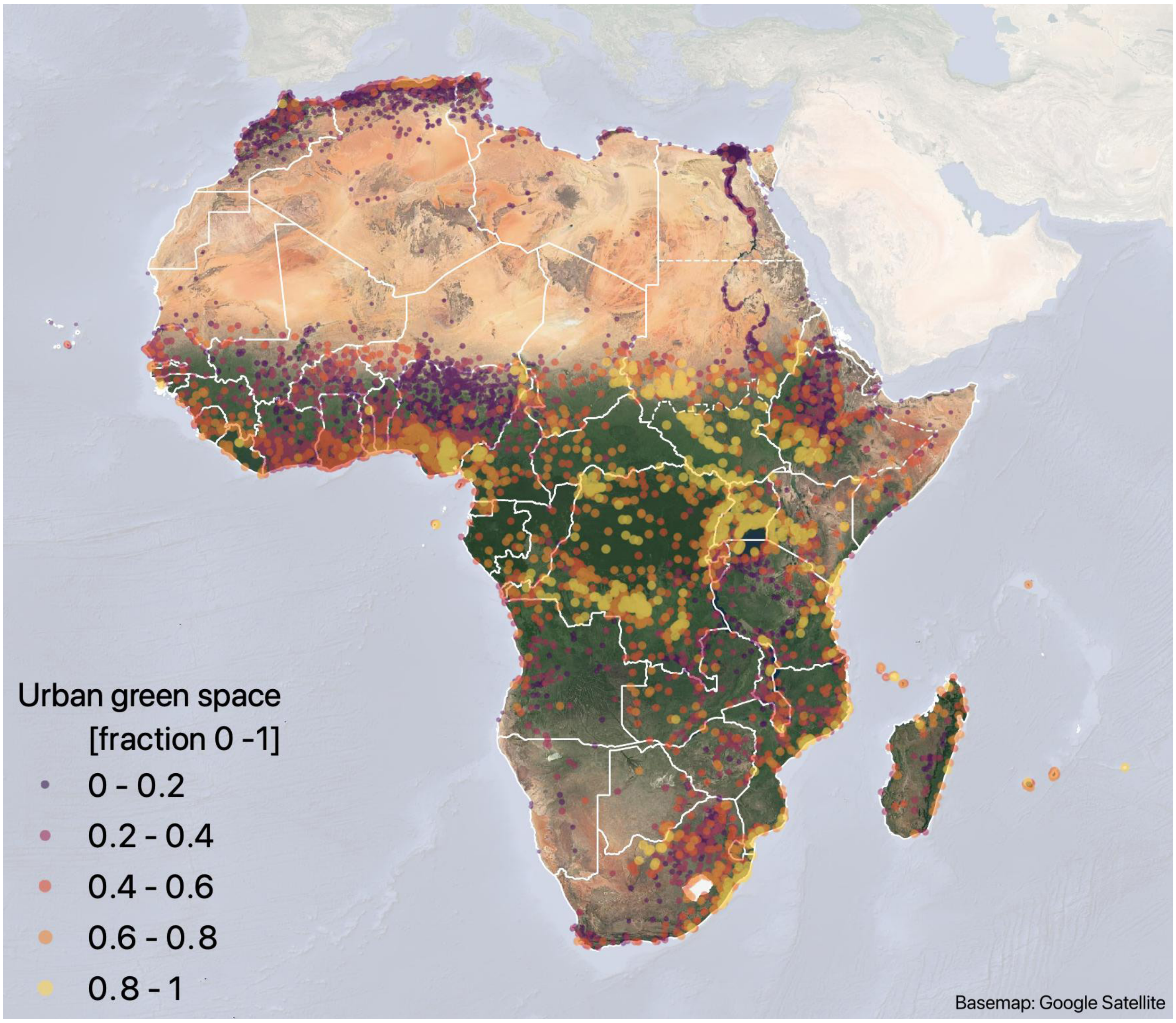
A growing number of political agendas in Africa and globally recognise the importance of green spaces for the resilience of cities. The AU Green Recovery Action Plan 2021-27 states, "Public green space urban planning… minimise[s] air pollution in African cities [and] has a positive effect on biodiversity, climate, wellness, and air quality…Additionally, parks with trees, shrubs, water basins, and recreational areas as well as more extended forest lands can mitigate the consequences of climate change." Likewise, one of the key takeaways from the 2022 Africities Summit summarised by Eugene Wamalwa, Acting Cabinet Secretary of Kenya's Ministry of Devolution is that "[w]e must … intensify the conservation of urban green spaces to build community resilience." All of which reflect the international agenda under SDG 11 for Sustainable Cities and Communities, Target 7 to "provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities".

In addition to local initiatives, several large African cities are attempting to restore green spaces as nature-based solutions to climate change. Cocody, a borough of Abidjan, in Côte d'Ivoire is replanting several kilometres of mangrove along the lagoon bay to restore biodiversity, manage floods as well as enrich fish stocks. In addition, Cocody is participating in Côte d'Ivoire's "One Million Tree Campaign" to replace at least 30% of the lost forest cover by 2030 (CDP, 2021[17]). Lagos (Nigeria) is also undertaking a tree planting initiative to reduce heat stress, whilst Freetown (Sierra Leone) is pursuing tree restoration to prevent landslides (which simultaneously provides local employment). Other similar initiatives can be found outside of West Africa — in Ekurhuleni, Pietermaritzburg, Kampala, and Kinshasa (CDP, 2021[17]). For example, in Durban, South Africa, the eThekwini Municipality developed the Green Roof Pilot Project, which puts greenery on the top of public buildings (eThekwini Municipality, 2020[18]). This lowers the temperature inside and outside the buildings, reduces the need for air-conditioning, decreases the speed at which water flows off the roof — thus reducing flood risk — and generally increases the visual appeal of buildings.

Despite their relevance in boosting the resilience of cities, the availability of green space is unknown for thousands of urban agglomerations in Africa, especially small (10 000 to 50 000 inhabitants) and intermediary ones (50 000 to 1 000 000 inhabitants). Reliable data on green spaces is paramount for actors at all levels of government. Robust data assists governments to design appropriate responses and prioritise actions that will have the greatest impact, while still contributing to other long-term socio-economic development goals.

The novel contribution of this report is to fill this gap for cities across the continent by measuring green space availability for 5 625 urban agglomerations. This is achieved by using newly available land cover data from the European Space Agency combined with spatial data on urban agglomerations identified by Africapolis, see Box 1 for details (OECD/SWAC, 2022[19]; Zanaga et al., 2021[20]). Map 1 shows the calculated availability of green space — i.e., the fraction of the urban footprint covered by green space in 5 625 cities. Great heterogeneity in the availability of green spaces exists, within regions, climates, and even within countries. These differences will be explored in detail in the next section. This data will be publically available on OECD/SWAC platforms and updated over time.

Map 1.
Availability of green spaces in 5 625 urban agglomerations across Africa



Source: Authors' calculations based upon urban boundaries from Africapolis (OECD/SWAC, 2022[19]). Urban green space extracted from ESA WorldCover 2020 (Zanaga et al., 2021[20])

The first section of this report analyses the effects of urbanisation on green spaces, as well as other factors, such as climatic zones and topography. The key finding from the model is that **as cities become more compact, green space disappears**, but vertical growth — i.e., building taller buildings — can attenuate this phenomenon. Other factors, indeed, play a role — namely, the elevation of a city and the humidity of the climatic zone. The section then explores three case studies to deep-dive into the loss of green spaces in three cities due to urbanisation. Many green spaces are progressively sold and transformed into shops, apartments or other building types. The case studies found that green spaces appear and disappear due to many reasons, including poor governance. Even if the provision of green space is included in city planning, the lack of budget for monitoring and enforcement and the lack of clarity of over responsibilities, amongst other factors, often leads to their loss.

The second section of this report investigates the potential for green spaces to improve air quality in African cities. Outdoor air pollution is on the rise in Africa, and estimates indicate that levels of pollution (i.e. $PM_{2.5}$) exceeded “clean air” levels in 2019, according to the WHO. Therefore, the ability of green spaces to absorb pollution could significantly improve a city’s sustainability and by consequence, public health. The analysis shows significantly lower levels of air pollution in cities with greater availability of green space. If green space covers at least 25% of the urban footprint, PM 2.5 levels reach moderately safe levels, according to the model’s predictions. This could be a potential target, and viable tool for cities to ensure better air quality in the future.

The final section evaluates the potential of green space for other ecosystem services, such as to serve as a nature-based solution to heat waves in 15 cities (5 of which are in West Africa) — by analysing the proximity of the population to green spaces using data from the Global Human Settlement Layer project (Schiavina, Freire and MacManus, 2019[21]). The results vary significantly with respect to heat waves; only 3% of the population lives close to a green space in Khartoum, but green space could be a nature-based solution to heat waves in a city like Abuja, where 55% of the population can benefit from its cooling effects. Living in close proximity to green space also matters for physical and mental health. For other ecosystem services, such as biodiversity, it is important to have larger connected patches of green space. A key takeaway is that to reap all of these benefits, it is not only important to have green space available, in percentage terms, but have varying sized patches scattered throughout a city so that people and nature can access and benefit from it.

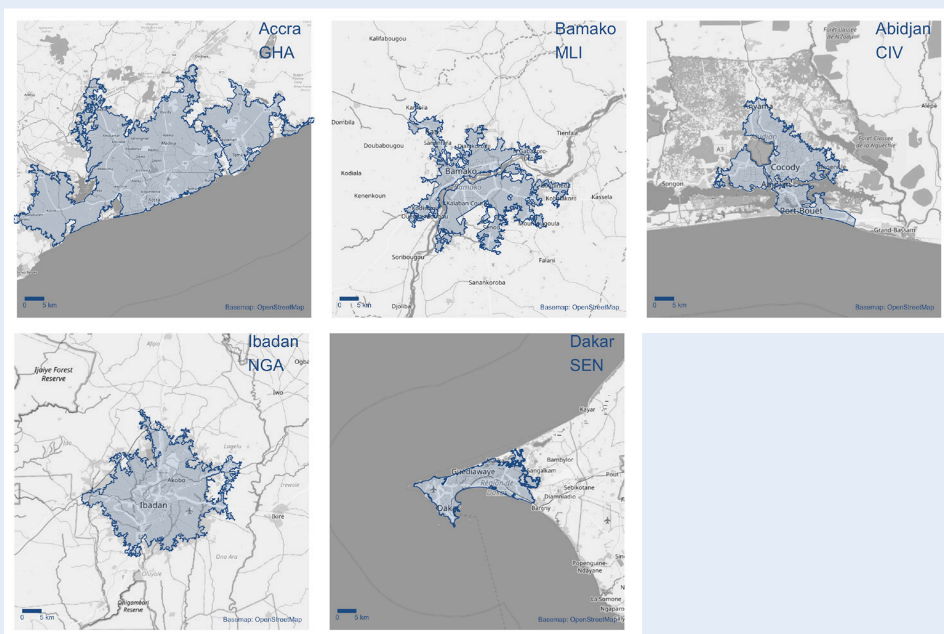
Box 1.

Measuring the availability of green space in cities

The availability of green space in cities is measured as the fraction of a city's urban area covered by trees, shrubs and grassland. The analysis combines two open and recently produced spatial data sources on (1) the urban boundaries of cities and (2) the presence of vegetation cover. Africapolis provides the spatial boundaries of urban agglomerations in Africa (OECD/SWAC, 2022[19]). It applies the same definition across the continent for delineating an urban agglomeration based on spatial and demographic criteria: an urban agglomeration is defined as a continuously built-up area that has at least 10 000 people with less than 200 metres between buildings. Map 2 shows examples of the urban agglomeration boundaries in different major African cities.

Map 2.

Examples of urban agglomeration boundaries



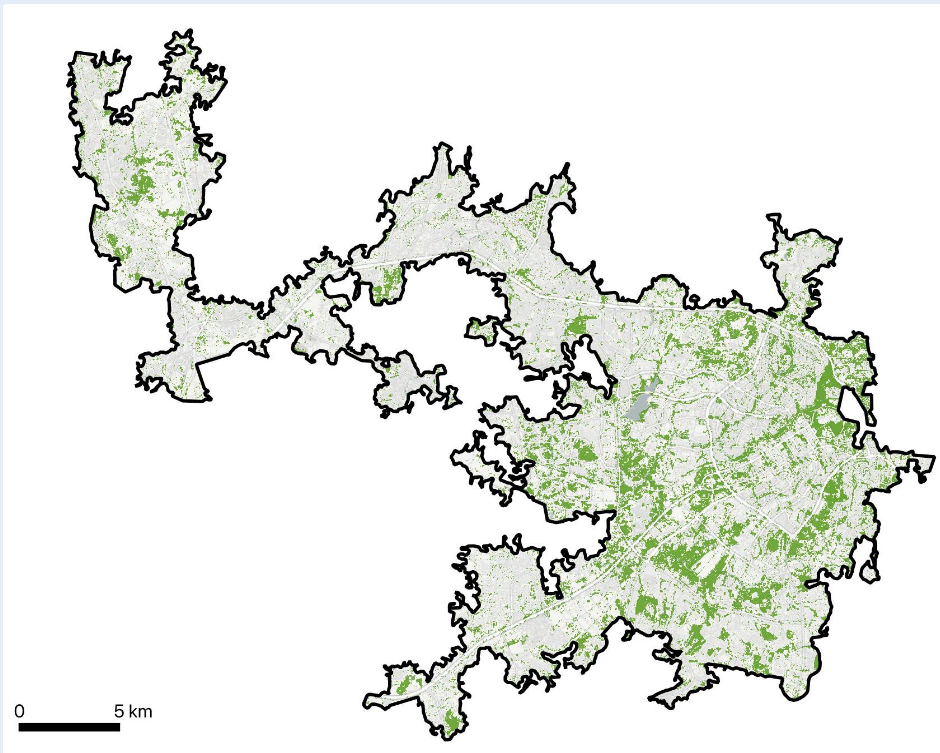
Note: From left to right: Accra (Ghana), Bamako (Mali), Abidjan (Côte d'Ivoire), Ibadan (Nigeria) and Dakar (Senegal).
Source: Africapolis (OECD/SWAC, 2022[19]). The base map is from OpenStreetMap, 2021.

The amount of urban green space is computed using the European Space Agency's (ESA) 2020 WorldCover dataset which was released in 2021 (Zanaga et al., 2021[20]). The ESA WorldCover provides a global land cover map at 10 metres of spatial resolution and uses radar as well as optical satellite imagery from the Copernicus Sentinel missions. The dataset classifies 11 different types of land cover, including tree cover, shrubland, and grassland.

The **availability of green space** in cities is defined as the sum of the area of the three types of land cover (km^2) — e.g., trees, shrubland, and grassland

— divided by the total area of the urban agglomeration (km²) as defined by Africapolis. Map 3 shows the example of Abuja (Nigeria) with the urban agglomeration boundary and the urban green areas from ESA WorldCover. The measure is likely a "maximum" estimate of the availability of green spaces in cities, since a 10 metre x 10 metre cell is classified as trees, shrubland, or grasslands cover if at least 10% of the cell is covered.

Map 3.
Green spaces in Abuja (Nigeria)



Source: Urban boundary from Africapolis (OECD/SWAC, 2022[19]). Urban green space extracted from ESA WorldCover 2020 (Zanaga et al., 2021[20]).

The dynamics of urbanisation and the availability of green spaces

Urbanisation shapes the availability of green spaces in cities, worldwide. Other factors which influence green spaces are topography (e.g., whether a city is mountainous or close to a border), climate (e.g., heat extremes and average temperature, wildfire regimes, wind patterns, precipitation), the vulnerability of vegetation to climate change and institutional frameworks (e.g., clarity of responsibility, planning frameworks, and financing to monitor and evaluate). This section focuses on urbanisation which will become one of the most significant phenomena sweeping the continent in the forthcoming decades, and which, unlike topography and climate, can be shaped by local actors. The section starts with a brief overview of these dynamics, explains the effects of urbanisation on green spaces in the 5 625 observed cities, explores other factors that affect green spaces and then dives into three case studies on the loss of green spaces in growing cities.

WHY DOES URBANISATION MATTER?

As the population of a city increases, so does the demand for housing, food, employment and services. Urbanisation is often uncontrolled and unco-ordinated, and this contributes to the existence of a variety of urban forms across Africa (OECD/SWAC, 2020[1]). A city's urban form refers to its physical characteristics: the shape, size, density and configuration of buildings. Some agglomerations are compact and others sprawling, others shaped more circular whilst others more elongated, some polycentric and others monocentric.

A compact city aims for a more circular shape with high-density development, often with mixed-used land, while sprawling cities are characterised by irregular shapes, lower density development and are frequently associated with single-use land (Angel et al., 2018[22]; Ahlfeldt et al., 2018[23]; Gaigné, Riou and Thisse, 2012[24]). Compact cities often have a contiguous built environment with fewer unused spaces between buildings than fragmented ones. A fragmented agglomeration, for example, could have unused plots of land in the city centre left over from land speculation (Korah, Matthews and Tomerini, 2019[25]; Gómez-Baggethun and Barton, 2013[26]; Angel, Parent and Civco, 2010[27]).

Cities around the world often aim to curb sprawl and grow in compact contiguous forms. This type of growth is more likely to curb emissions and energy consumption (e.g., from transport and buildings) and avoid losses of biodiversity, as well as the type of growth that avoids loss of agricultural and non-agricultural land on the periphery. At the same time, this type of growth can have adverse effects like higher pollution concentrations, higher risk of land subsidence in coastal regions, and even less green space.

The focus of this analysis is to assess the tension between lowering sprawl and green space availability (Stuhlmacher et al., 2022[28]; Haaland and van den Bosch, 2015[29]; Byomkesh, Nakagoshi and Dewan, 2012[30]). Evidence shows that urban growth through infill and redevelopment strategies — which leads to greater compactness — causes a decrease in green spaces to the detriment of resilience and the well-being of city dwellers (Giezen, Balikci and Arundel, 2018[31]; Jim and Chan, 2016[32]; Gavrilidis et al., 2019[33]). The relationship may be nonlinear. For example, a study of 21 cities in China showed that more people in cities led to less green space. However, once a city's density reached 2 200 people per square kilometre, the proportion of green space increased as greater attention was given to environmental protection. Yet, once the population reached 3 820 people per square kilometre, the relationship was negative again, meaning more people caused a decrease in green space, despite existing environmental protections (Li et al., 2013[34]).

So far, analyses of whether and to what extent greater compactness and disappearing green spaces affect African cities are rare. Despite the particularly rapid urban population growth in Africa, studies on the impacts of urbanisation on green spaces typically skew towards the Asia, European sub-region, Latin America and North America. The few studies on Africa examine only a handful of cities or concentrate on green spaces within a particular city (Mensah, 2014[35]; Adjei Mensah et al., 2016[36]; Mensah, Gough and Simon, 2018[37]; Rigolon et al., 2018[12]).

The sparse research on African agglomerations makes it difficult to draw conclusions on the impacts of urbanisation on green space. Moreover, the cities that are studied tend to be large (above 1 million people), rather than small (between 10 000 to 50 000 people) and intermediary cities (between 50 000 to 1 million). Small and intermediary cities will also experience rapid urbanisation in the decades to come and likely have the highest chance for planning for green space and avoiding its loss. Yet, the bias towards large cities —, which is mainly due to lack of data for small and intermediary cities — means it is unclear how the dynamics between urbanisation and green spaces are playing out.

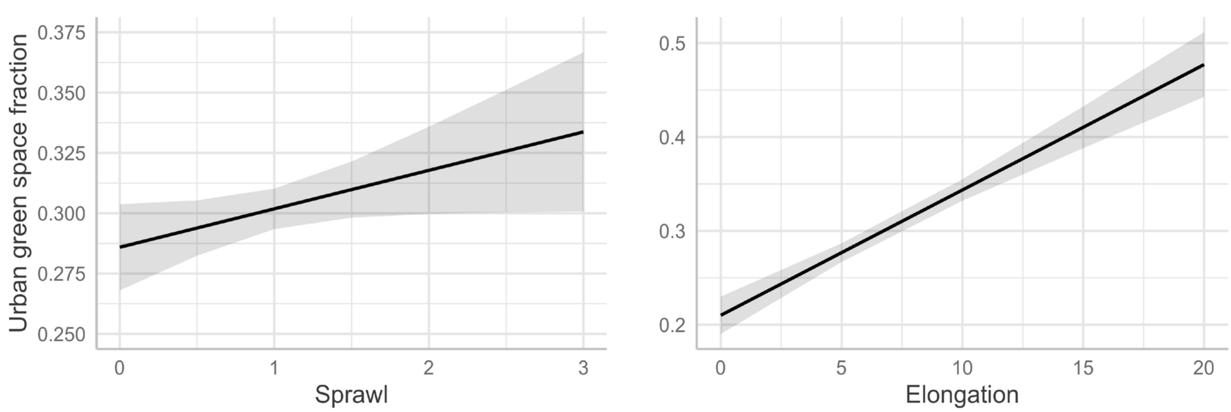
LESS GREEN SPACE IN COMPACT CITIES

The analysis uses two measures of compactness, its level of sprawl and elongation, to evaluate its effect on the availability of green space. Box 2 explains the two measures in detail. Sprawl captures the distances between buildings, therefore, the smaller the average distance between buildings, the more compact a city is. Elongation, on the other hand, captures a city's shape. The more circular a city, the more compact it is. This analysis shows that **greater compactness leads to less green space in urban agglomerations**, as seen globally when cities urbanise in Asia, Europe Latin America and North America. This holds for both sprawl and elongation (Box 2).

Figure 1 uses the model mentioned above to predict the availability of green space across the two measures of compactness, holding all else constant (see Appendix A for full model). Decreasing distances between buildings, a sign of greater infill, puts pressure on green spaces within the boundaries of a city. The right-hand side of Figure 1 shows that a more circular shape — very compact urban form — is associated with less availability of green space. The model also shows that more people living in a city leads to less green space (see Annex A for results).

Figure 1.

Effects of sprawl and elongation on the availability of green space



Note: Urban green space variability with urban form metrics, controlling for physical geography and size covariates.
Source: Based on authors' model results (see Annex A).

These results partly explain the limited green space in North Africa as seen in Map 1. For example, the availability of green space is extremely limited in Egypt. Egyptian cities have a circular shape (average value of 6, for reference, this is between Kaduna, Nigeria and Aba, Nigeria in Map 6 below in Box 2) and display high urbanisation levels as 93.4% of the population lives in cities, but only approximately 4% of the urban footprint is on average covered by green space.

Box 2.
Measuring sprawl in African cities

Measuring the urban form of African cities is challenging due to limited data availability. Often metrics use (1) the boundaries of urban agglomerations, without regard to the inner structure, (2) population density data, which may or may not be geospatially located in a reliable way, especially for small and intermediary cities, and (3) street networks, primarily Open Street Map, which may be incomplete. Building footprint data is a recently available alternative to measuring sprawl, which can better capture the realities on the ground. In 2021, Google AI Africa released the Open Buildings Dataset which, for the first time, maps every single building on the entire African continent (with certain regions excluded mainly for security concerns) (Sirko et al., 2021[38]). Map 4 illustrates the varying quality of available datasets through Makoko, the informal water settlement, off the coast of Lagos. The buildings footprint image from the Open Buildings Dataset (left) is able to capture nearly every building in Makoko (Sirko et al., 2021[38]), whilst Open Street Map (middle figure) is only able to capture the main water ways and population density data (right figure), estimates that there is no one living in substantial portions of the informal settlement (the purple region) (Schiavina, Freire and MacManus, 2019[21]).

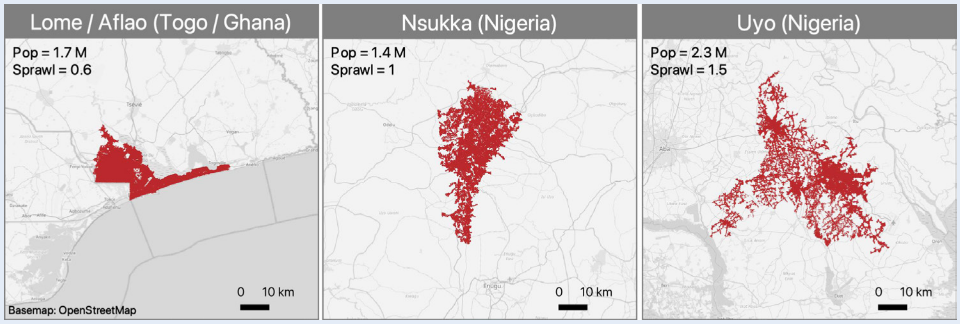
Map 4.
Comparing the accuracy of different datasets in Makoko (Nigeria)

Source: Open Buildings Dataset (Sirko et al., 2021[38]), OpenStreetMap (OpenStreetMap, 2022[39]), and Human Population Density Dataset (Schiavina, Freire and MacManus, 2019[21]).

This analysis conducted in this report assigned the buildings from the Open Buildings Dataset to each urban agglomeration in Africapolis. This analysis used several variables (see Annex A), but the focus of this chapter is on two measures, in particular: (1) sprawl and (2) elongation. Our measure of sprawl is the average distance between buildings in a city, and controls for city size. Higher values of this metric signal greater sprawl, so more "empty" space, whilst lower values mean a more compact shape (Prieto Curiel, Patino and Anderson, 2022[40]). Map 5 measures sprawl in three West African cities of similar size, the red dots represent all the buildings. Smaller values like Lomé/Aflao (0.6) are more compact with higher values increasingly more sprawling like Nsukka (1) and Uyo (1.5).

Map 5.

Examples of sprawl in three cities

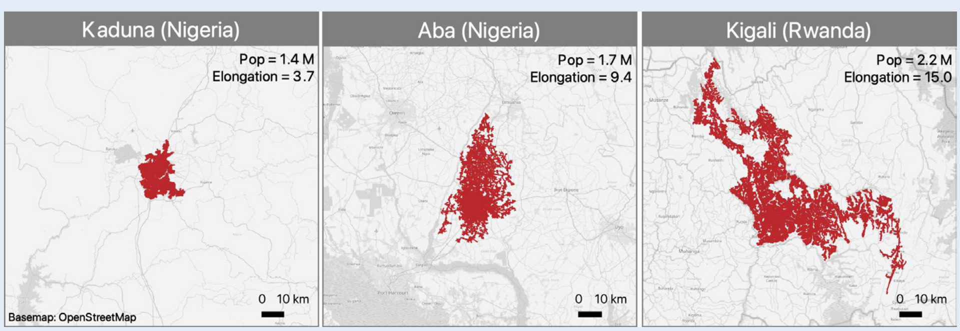


Source: (Prieto Curiel, Patino and Anderson, 2022[40]), Measuring the morphology of African cities, https://arxiv.org/pdf/2207.03003.pdf.

Elongation measures how much a city shape departs from being a circle — the most compact shape (Angel et al., 2018[22]; Prieto Curiel, Patino and Anderson, 2022[40]). A value of 1 is a circle whilst greater values become increasingly elliptical all the way to a line. The city shape of Kaduna (NGA) is very close to a circle (3.7) as seen in Map 6, the elongation of Aba (Nigeria) starts to increase to 9.4, followed by Kigali (Rwanda), which is almost a line (15).

Map 6.

Examples of elongation in three cities



Source: (Prieto Curiel, Patino and Anderson, 2022[40]), Measuring the morphology of African cities, https://arxiv.org/pdf/2207.03003.pdf.

The alarming loss of green space in cities is to the detriment of the well-being of their inhabitants. Without any additional interventions, the urban heat island effect could be prevalent in the future. Urban heat islands are due to transformations in land cover, i.e., replacing green spaces or agricultural lands with impervious surfaces such as concrete, asphalt and rooftops. The National Space Research and Development Agency of Nigeria (NASRDA) found that land surface temperatures within 300 metres of public parks in Abuja are almost 2-3°C cooler than other areas of the city, helping nearby residents cope with heat waves. It concluded that the potential loss of green spaces would be detrimental to public health (Chibuike et al., 2018[41]). This phenomenon is known as the urban green space cooling effect, which can extend beyond the 300 metres surrounding a green space depending on its size and composition (Aram et al., 2019[42]; Bowler et al., 2010[43]). The disappearance of green spaces can also lead to increased flash floods. Rivers habitually overflow at the peak of rainy season inundating nearby settlements. In Kumasi (Ghana), the replacement of green spaces by concrete, pavement and other impermeable surfaces was one cause of greater flood incidence between 2004 and 2017 and led to drastic increases in the number of people who experienced floods (100 times more) (Abass et al., 2020[44]). These kinds of problems could potentially worsen over the next few decades if local actors do not take action to curb the loss of green space.

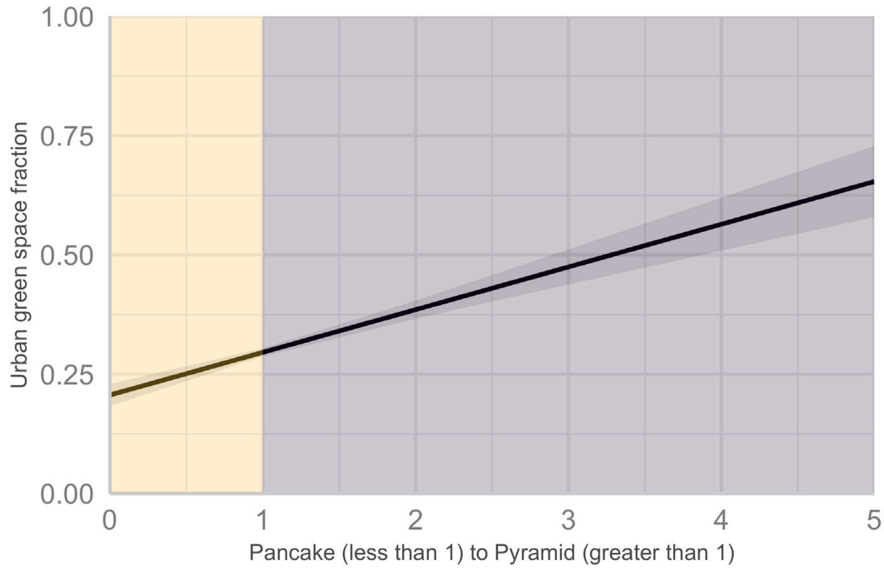
REDUCE LOSS OF GREEN SPACE IN CITIES WITH VERTICAL GROWTH

A possible way for policymakers to reduce potential pressure of compactness and the availability of green space is to control the way cities are growing. Cities can grow (i.e., add more people) in three ways: (1) adding more floor space by growing outward (sprawl — i.e., horizontal growth), (2) inward (infill/redevelopment), or (3) building taller buildings, i.e., vertical growth (Lall et al., 2021[45]). The analysis shows that cities with taller buildings in the centre (referred to as “pyramid” cities by the World Bank) have significantly greater availability of green space than cities that spread horizontally (referred to as a “pancake” cities), where most buildings are relatively low (Lall et al., 2021[45]).

The analysis assessed the extent of vertical growth by comparing the average building area in a 750-metre radius at the most built up point of a city, to the average building area of rest of the city (outside the centre). A value of less than 1 indicates that the buildings in the maximum density point are, on average, smaller than those outside, a value of 1 means the buildings are the same, whilst a value larger than 1 means that the buildings in the city centre are greater. For example, a value of 2 means the buildings in the city centre are twice the size of those outside of the centre.

Figure 2 predicts the effect of the pyramidal character of a city on the availability of green space using the results of the model — and the relationship is significant and increasing. To put this in perspective, if a city is a pancake (less than 1), the buildings in the city centre are smaller or about the same size as rest of the city, the availability of green space is between 20 to 30%. However, if the city is pyramidal, for example, if buildings in the centre are 5 times bigger, then the availability of green space is nearly 60% in the entire city. For the reasons mentioned above, if cities can grow vertically instead of only infill or horizontally, then less land needs to be converted to add buildings to the urban footprint and accommodate a growing urban population.

Figure 2.
"Pancake" versus "pyramidal" effect on urban green space availability in African cities



Note: Effect of city configuration (pyramid vs. pancake continuum) on urban green space availability in African cities, after controlling for physical geography, urban form metrics, and population size.
Source: Based on authors' model results (see Annex A).

CONTEXTUAL FACTORS AFFECTING THE AVAILABILITY OF GREEN SPACE

Even if efforts by policymakers to encourage vertical growth could improve the availability of green space, their leeway for decision-making is influenced by the context in which a city is embedded. The model highlights contextual factors play a significant role to determine green space availability. Greater precipitation, more mountainous regions (measured by differences in elevation in the city) and proximity to the coast leads to significantly more green space in cities. In contrast, the higher the maximum annual temperature in a city, the less green space is available. Annex A presents the full results of the model.

Extreme weather events likely also influence availability of green space as well as the vulnerability of vegetation to such extreme events. The historical legacy of droughts, for example, likely contribute to lower levels of green space in cities near the Sahel. The most recent 2012 droughts severely affected Senegal, Mauritania, Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan, and Eritrea. Efforts to replenish the loss of green space exist, like the Great Green Wall Initiative for the Sahara and Sahel, which aims to restore 100 million hectares of degraded land, stretching across the width of the continent. For example, the droughts in Burkina Faso in the 1970s and 1980s led to a dramatic decrease in tree coverage and loss of green spaces in cities, however, since then, drought-resistant and exotic species of trees have been introduced as a replacement, recovering much of what was lost in terms of green cover area (Hänke et al., 2016[30]). Eucalyptus, an exotic species, is among the most widely used hardwood trees in replanting efforts. However, this, in turn, has resulted in a loss of biodiversity in the region.

CASE STUDIES: THE REALITY OF PRESERVING GREEN SPACES IN GROWING CITIES

The examples of Kumasi (Ghana), Sekondi-Takoradi (Ghana), and Mafikeng (South Africa) offer insights into the loss of green spaces from urbanisation and why the development of green spaces occurs. In all three cities, planning documents included the preservation of green spaces, but the realities of expanding the cities led to these plans being ignored, altered, or impossible to implement.

Kumasi, Ghana: Lack of enforcement of plans to preserve green spaces

Kumasi, the second largest city in Ghana (2.8 million people) is gradually losing green spaces. Mensah (2014[35]) investigated why by conducting a series of interviews with Kumasi city authorities and officials involved in the management of green spaces (e.g., Department of Parks and Gardens, Wildlife Division, Forest Service Division, Town and Country Planning Department, Environmental Protection Agency, Department of Urban Roads and the Development Control Unit) in addition to a series of focus groups in five neighbourhoods. The analysis identified a number of factors leading to the loss of green spaces in the process of urbanisation: lack of enforcement of development controls, low prioritisation by city authorities, ambiguity of landownership, poor co-ordination amongst the governing bodies of green spaces, lack of pre-emptive interventions by city authorities leading to total green space destruction, and exploitation by residents.

There was a clear lack of enforcement of Kumasi's master plans and layouts which intend to guide a city's growth and preserve green spaces. Mensah (2014[35]) found that often green spaces that should have been preserved, did not actually exist on the ground. Instead, the land was developed for either commercial or residential purposes (the process of "infill"). A recurring finding in the interviews is that lack of resources and poor logistics prevented officials from properly enforcing planning documents. In addition, interviewees stated that political interference, nepotism and favouritism made enforcement nearly impossible. If the developer of a project had strong political or social ties to government officials or city authorities, the project continued, even if previously halted by Kumasi city authorities. Therefore, having a city plan available without a supporting framework in place, does not result in the preservation of green spaces.

In parallel, there was often a lack of prioritisation of green spaces by public authorities. For example, a representative from the Department of Parks and Gardens stressed that the top priorities of Kumasi have been poverty issues, education, health and commercial activities. This comment, however, overlooks the ecosystem services that green spaces provide, such as those related to public health and an increase of property values, even for commercial spaces.

Another interesting finding was the destruction of green spaces, in some instances, by the public for personal gain. Other work found that the public, generally, does not feel ownership over such spaces. A notable example was the destruction of a substantial part of Fante Newtown Park for commercial activities. However, the public was often not consulted nor informed on green space projects (parks and gardens) by the city authorities in Kumasi, nor was the community empowered to self-facilitate initiatives on green spaces and only passively involved in final decisions (Adjei Mensah et al., 2016[36]).

The public has reacted when the loss of green spaces goes too far in other Ghanaian cities such as Accra where residents began to build their own parks, reclaiming green space that was lost in the fierce competition to develop land. For example, the Teshie Nungua Estate residents' association built a small children's park — via crowdfunding to purchase grass; residents pitched in to construct; a local imam provided water for the construction, whilst a resident provided tools for welding and storage space for materials (Asiedu, 2019[47]). Other examples of residents fighting against the losses of green space can be found in Cocody, Lagos and Cape Town (Petzer and Udo-Udoma, 2016[48]).

Sekondi-Takoradi Metropolis, Ghana: Rezoning green spaces

Sekondi-Takoradi is an industrial hub for oil companies, which has led to an influx of migrants and physical urban expansion. This transition is overwhelming the metropolitan planning and management systems leading to rezoning of existing green spaces for infill development (Mensah, Gough and Simon, 2018[37]). Unlike in Kumasi, this development of green spaces often has institutional support from local authorities (Mensah, Gough and Simon, 2018[37]). Green spaces could be especially relevant in this location as they could help to absorb air pollution from the oil refineries.

Rezoning is a spatial planning tool, which changes the existing land use for another (e.g., residential, commercial), in order to meet the changing needs of a population. In Sekondi-Takoradi, green spaces approved for rezoning are often unsuitable for the new purpose (e.g., building in flood zones) and may even violate Ghanaian planning standards reflecting the tension that can arise between national objectives and local realities. For example, the 1996 National Building Regulations of Ghana (LI 1630) restricts the erection of houses or building structures on waterways and areas liable to flooding, as well as protects land for public health and safety. Yet, the development of these areas appears to occur without impunity, limiting the benefits which could be obtained from such spaces (Adjei Mensah et al., 2016[36]).

Mafikeng, South Africa: Rezoning and lack of resources

Munyati and Drummond (2020[49]) investigated the loss of green spaces in Mafikeng, South Africa, a small city located near the border with Botswana. Over the last couple of decades, the city has been faced with limited means for outwards expansion as it is surrounded by commercial and privately owned farmland as well as land under tribal ownership. Therefore, the city has accommodated growing numbers of people by developing green spaces. The city also rezoned some green spaces to provide amenities and infrastructure such as schools, housing and commuter transportation to previously marginalised groups following Apartheid.

In addition to limits on space, similar to Kumasi, authorities face limited resources. A decreasing municipal budget reduces the city's financial capacity to sustain green spaces – e.g., mowing, irrigation, preventing waste dumping. Notwithstanding, municipal authorities understood the value of green spaces – e.g., cooling effects of shade, social gathering, biodiversity, cultural, amongst others. 86% of the interviewees in the study indicated that there were benefits from keeping green spaces, but only 19% could name more than one benefit (Munyati and Drummond, 2020[49]).

Better air in greener cities

Converting green spaces to other land uses — with or without the approval of local authorities — can be necessary, as seen in Mafikeng where the development of some green spaces helped to uplift marginalised groups following Apartheid. In other instances, the trade-off, and the loss of ecosystem services, such as the absorption of air pollution, may not be fully weighed and the potential for co-benefits may be overlooked.

A consequence of greater urbanisation is increasing outdoor air pollution, which is a major threat to health, human capital, and economic development (Fisher et al., 2021[50]). In Africa, household air pollution is the predominant form of air pollution, but has declined over the last few decades, whereas outdoor air pollution has increased. Outdoor air pollution contributes to premature deaths including pneumonia, heart disease, stroke, diabetes, chronic lung disease and lung cancer. Outdoor air pollution accounted for an estimated 400 000 deaths in 2019 in Africa, less than one percent of Africa's population, up from 339 690 in 1990. "While this [current] increase is still modest, it threatens to increase exponentially as African cities grow in the next two to three decades and the continent develops economically," (Fisher et al., 2021[50]). Outdoor air pollution is not only a "health" issue but also an economic one. For example, the economic output lost to air-pollution-related disease was 3 billion (in 2019 USD) in Ethiopia (1.16% of gross domestic product, GDP), USD 1.6 billion in Ghana (0.95% of GDP), and USD 349 million (1.19% of GDP) in Rwanda (Fisher et al., 2021[50]). Therefore, controlling outdoor air pollution will become a pressing issue in decades to come, from not only a health perspective, but also an economic one.

So far, studies on whether greater availability of green space reduces outdoor air pollution in African cities are rare — because of data availability. It is difficult to find monitoring stations; therefore, this analysis uses newly available data and on the ground estimates that draws on a combination of satellite data to measure of fine particulates ($PM_{2.5}$) concentrations, a particularly dangerous pollutant. This analysis uses data from the Atmospheric Composition Analysis Group at Washington University (van Donkelaar et al., 2021), combined with Africapolis, to calculate the annual levels of outdoor air pollution in the 5 625 cities studied, for the year 2019 before the COVID-19 pandemic. The next subsection models the effect of green space on air pollution for the 5625 cities where data is available, and finds that **cities with greater availability of green space have less air pollution**.

Therefore, local stakeholders have a lever of action at their disposal for limiting air pollution: preserving and developing green spaces in cities.

CURRENT SITUATION

According to the WHO, clean air contains up to 12 micrograms per cubic metre (ug/m^3) of $PM_{2.5}$ (Fisher et al., 2021[50]). **All of the analysed cities exceed this level of outdoor air pollution**. In contrast, the WHO considers moderate outdoor air pollution when the level of $PM_{2.5}$ is between 12 and 35.4 ug/m^3. At this level of pollution, activity and outdoor time does not need to be restricted, but sensitive groups like children and the elderly may experience health issues. The data shows that 40% of the cities in the analysis have an annual mean above 35.4 ug/m^3 meaning that the air is "unhealthy" to "extremely hazardous". This result is driven by observed cities Nigeria, Egypt, Sudan and Senegal, as shown in Table 1.

Table 1.
Cities with unhealthy and moderate levels of air pollution in the dataset

	Unhealthy	Moderate
Angola	0	89
Burundi	8	18
Benin	40	57
Burkina Faso	21	55
Botswana	0	15
Central African Republic	5	23
Côte d'Ivoire	0	195
Cameroon	1	1
Democratic Republic of the Congo	78	175
Republic of the Congo	14	11
Comoros	0	10
Cabo Verde	0	3
Djibouti	4	2
Algeria	10	446
Egypt	769	92
Eritrea	6	17
Ethiopia	8	399
Gabon	1	11
Ghana	4	196
Guinea	1	35
Gambia	8	3
Guinea-Bissau	0	6
Equatorial Guinea	3	4
Kenya	0	101
Liberia	0	19
Lesotho	0	8
Morocco	0	2
Madagascar	0	60
Mozambique	0	105

	Unhealthy	Moderate
Mauritania	15	0
Mauritius	0	19
Malawi	0	63
Namibia	0	15
Niger	61	0
Nigeria	850	186
Rwanda	0	30
Sudan	106	43
Senegal	67	3
Sierra Leone	0	20
Somalia	6	32
Sao Tome and Principe	0	3
Eswatini	0	2
Seychelles	0	1
Togo	15	35
Tunisia	0	79
Tanzania	0	218
Uganda	0	94
South Africa	60	352
Zambia	0	69
Zimbabwe	0	42

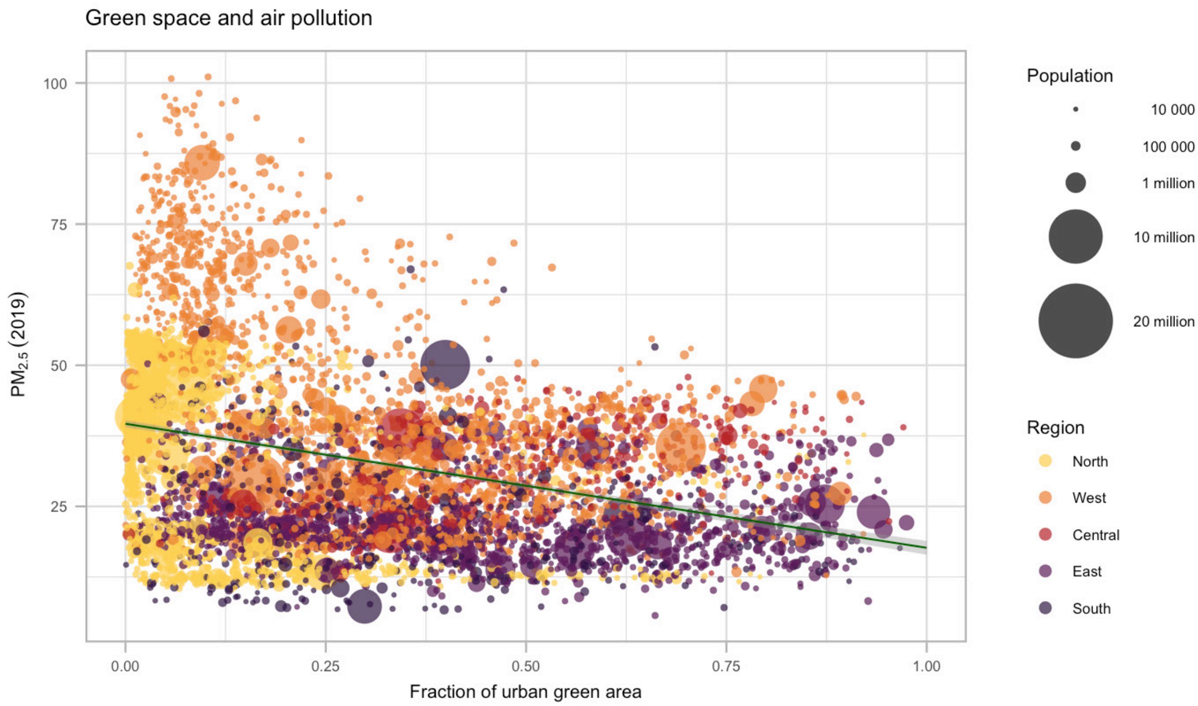
Source: Authors' calculations based upon air pollution data (van Donkelaar et al., 2021) and urban boundaries from Africapolis (OECD/SWAC, 2022[19]).

CITIES WITH MORE GREEN SPACE ARE LESS POLLUTED

The model shows that **greater availability of green space is associated with less air pollution** in the cities studied (Annex B), after taking into account physical geography and urban form. Therefore, green spaces could be one tool of many to limit outdoor air pollution today and in future decades.

Figure 3 shows the fraction of green area in each city compared to the level of air pollution. The size of the bubbles represents the population and the colour represents the region. The green line represents the overall trend. However, this relationship varies by region. Central and East Africa do not show the same relationship between green space and air pollution.

Figure 3.
Air pollution ($PM_{2.5}$) and fraction of urban green area for African cities



Source: Fraction of urban green area as described above, air pollution data (van Donkelaar et al., 2021), for the each of the Africapolis urban agglomerations (OECD/SWAC, 2022[19]).

There are several possible reasons for regional differences that would need to be explored further to understand whether green space could be a viable lever of action for cities to limit pollution in the decades to come. First, regional differences may reflect differences in the species of vegetation — which may have more or less absorption capacity for pollution. For example, while trees are generally effective at reducing air pollution, some trees are markedly more effective at filtering pollutants from the air than others and, therefore, more effective in improving the air quality in a street or a city. Second, the cities where green space is associated with significantly less air pollution tend to have a more comprehensive policy package to tackle air pollution, e.g., import reductions on used cars, which often have higher pollution. Africa imports 40% of the world's used light-duty vehicles (UN Environment, 2020[51]). These used vehicles often have high emissions, compromised roadworthiness and crashworthiness in direct relation to their age, degree of wear and tear and technical design. Several countries in the regions of North, Southern and West Africa have either outright banned the import of used cars or have age limits on the used cars that can be imported (UN Environment, 2020[51]). For example, in Côte d'Ivoire imported vehicles must be less than five years old, whilst in Senegal and Nigeria less than eight. Countries in Central and East Africa tend to have no age limits (UN Environment, 2020[51]). Therefore, the effectiveness of green space to tackle air pollution could depend on the broader policy package in place.

Box 3.
Does urban form influence air pollution?

The analysis of urban forms in African cities shows that besides urban green space availability, the attributes of urban form significantly relate to air pollution (annual average PM 2.5 concentrations). Previous research has shown that the spatial structure of a city and its land use configuration play an important role in economic performance (Duque et al., 2021[52]), public health (Patino, 2020[53]) , environmental sustainability (OECD, 2018[54]), and quality of life (OECD, 2019[55]). The way the urban land uses are spatially arranged and the structure of the street network that connects housing and working places have a direct impact in travel distances and their related energy needs. According to Angel et al. (2018[22]), both population density and a city's shape compactness help determine the average travel distances in cities and affect energy consumption and greenhouse gas emissions, as well as the length of transport infrastructure lines and commuting times. African cities are no exception in this regard.

The most elongated cities are often those urban agglomerations that have grown along main roads, and are usually structured as a single main road with small secondary roads that connect to it following a fishbone structure. This structure forces most of the city traffic to go along one main corridor and leads to high levels of congestion and high fuel consumption because most of the trips have to use same road, which in turn translates into higher air pollution (see Annex B for results).

On the other hand, more sprawling cities cast lower values of air pollution concentrations (see Annex B). Sprawl usually encroaches rural green land, and the presence of greater vegetation helps to reduce air pollution levels. This also could be related to the fact that the analysis takes into account the average PM 2.5 concentration across the entire urban agglomeration, which can include the high-density city centre with high air pollution as well as the suburban areas that surround it that usually have cleaner air.

A very interesting finding is that greater densities at the city centre (pyramid-shaped cities), as well as greater street connectivity are related to lower air pollution, while the presence of more street intersections contributes to higher air pollution levels (see Annex B for full results). More connectedness leads to mobility that is more efficient and reduces transport fuel consumption, while more street intersections means that vehicles have to stop and start again more often, increasing fuel consumption and related emissions.

Proximity to green space: Coping with heat waves

Until now, the analysis has concentrated on the availability of green space without considering that some of the co-benefits of green space are closely tied to their location. In many cities, green spaces are not in the right place to provide all the ecosystem services needed for resilience and sustainability. For example, trees must be next to or on hilly areas to prevent landslides. For people to benefit from the cooling effects of green space, proximity matters — i.e., living close to green space. This ecosystem service, in particular, will be vital for the resilience of cities in West, Southern and North Africa, since projections estimate a substantial increase in the number of extreme heat days (IPCC, 2018[4]). This section analyses the proportion of the population likely to benefit from the cooling effects of trees in cities to better understand their resilience potential.

Living close to a green space can also provide mental and physical health benefits, if it is accessible. In many cities, public and green infrastructure is more abundant and accessible in high-income areas than in low-income areas (Ferguson et al., 2018[56]; Zepp, Groß and Inostroza, 2020[57]), and this holds for middle and low-income countries (Chen, Yue and La Rosa, 2020[58]; Huang et al., 2021[59]; Patino, 2020[53]). In Cairo, for example, it is hard to find free public green space and most well-kept parks are fenced and ticketed. El-Azhar Park is immaculately clean, but the entrance fee of EGP 10 (USD 1.40) is completely inaccessible for a large segment of the population living on less than USD 2 a day. Inaccessible green space limits the number of people who can reap the mental health benefits, but does not interfere with its cooling benefits. Sustainable Development Goal 11 recognises the importance of accessibility to urban green space for all population groups, regardless of income, gender, age, or ethnicity. While the WHO advocates for universal access to green space, and more specifically, that every urban dweller should be live within 300 metres (linear distance) of a green space, or less than a 5-minute walk.

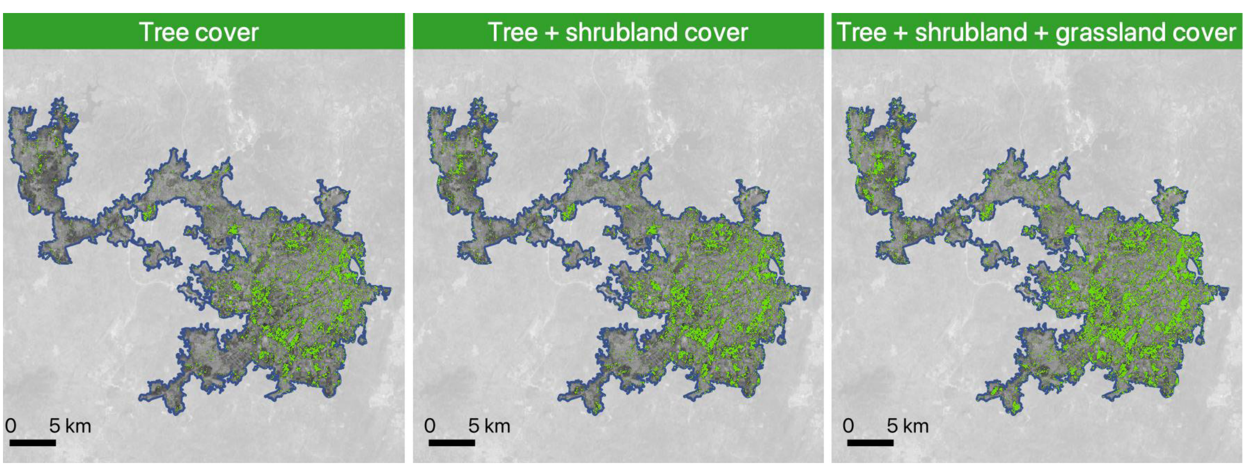
This section presents an analysis of the proportion of the population living within 300 metres of a tree patch of at least 1 hectare in 15 different African cities to assess the role that green space can play in helping cities cope with heat. The cities include Algiers (Algeria), Abuja (Nigeria), Accra (Ghana), Alexandria (Egypt), Bangui (Central African Republic), Benin (Nigeria), Cotonou (Benin), Dakar (Senegal), Khartoum (Sudan), Luanda (Angola), Lusaka (Zambia), Mombasa (Kenya), Cidade de Maputo (Mozambique), and Cape Town (South Africa). The second part of this analysis looks at how close people live next to at least 15 hectares or more of green space. The analysis reveals that planning strategies, therefore, often have to consider the role of location for optimal provision of ecosystem services (Jarvis et al., 2020[60]).

MEASURING THE PROXIMITY TO URBAN GREEN SPACE

This part of the analysis uses the ESA World Cover 2020 to extract and measure the patches of green cover within urban agglomeration boundaries — i.e., trees, shrubland, and grassland. Each type of green space can play a different role in ecosystem services, for example, trees may be more relevant for addressing heatwaves, whilst grasslands may play a greater role in preventing floods. All classes may be equally relevant for biodiversity. Proximity to urban green space is measured as the percentage of the urban population that is within a defined distance of an urban green space patch of a minimum size. The analysis uses spatially distributed population data from the Global Human Settlement Layer project for the year 2015 (Schiavina, Freire and MacManus, 2019[21]). The analysis estimated the percentage of urban population from green space of all classes of difference sizes (at least one ha to 25 ha) and different distances from 300 to 1500m (Annex C for full results).

Map 7.

Green space classes from ESA World Cover 2020, Abuja (Nigeria)



Source: Africapolis urban agglomerations (OECD/SWAC, 2018), ESA WorldCover 2020 dataset (Zanaga et al., 2021[20]).

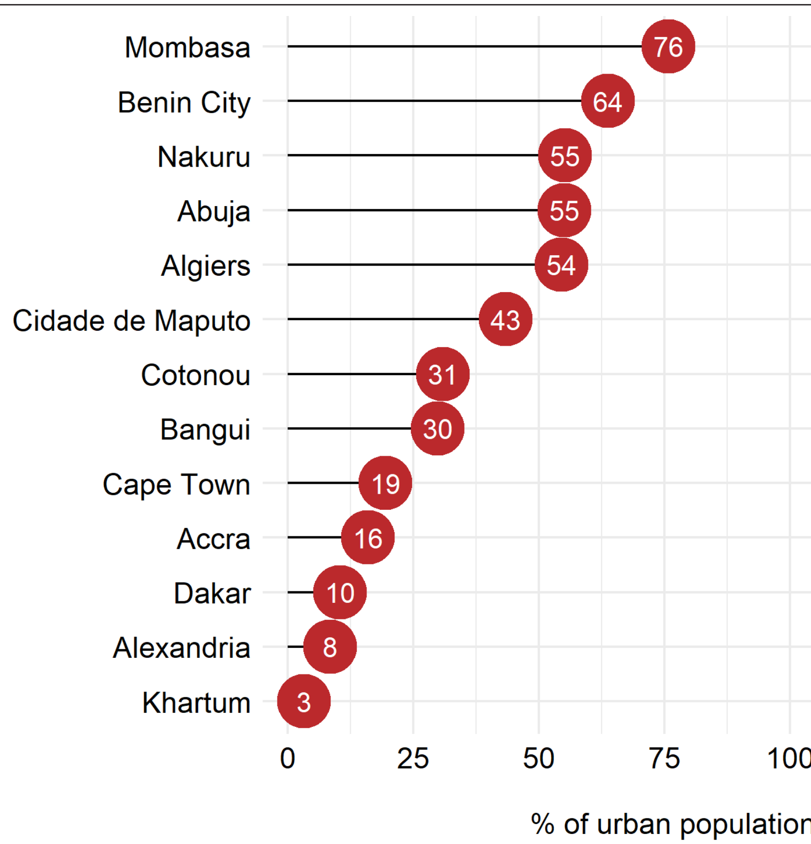
SUBSTANTIAL HETEROGENEITY IN THE POTENTIAL FOR GREEN SPACE AS A NATURE-BASED SOLUTION TO HEAT

The share of the urban population living close to a small patch of trees varies widely, from 3.2% in Khartoum (Sudan) to 75.7% in Mombasa (Kenya). Figure 4 shows the share of the urban population (percentage) that is located within a 5-minute walk (300 metre linear distance) from a patch of trees (at least 1 hectare).

Only 5 of the 15 cities analysed have more than 50% of people located in close proximity to green areas with trees of a least 1 hectare, and in 6 cities, the percentage of people living close to these green areas is below 25%. Khartoum (Sudan) and Alexandria (Egypt) show the lowest percentages of urban population located close to a small patch of trees, 3.2 and 8.4%, respectively. This low proximity means residents could suffer more from heat waves and heat-related illnesses and mortality, since even very small patches of trees can decrease temperature significantly. Therefore, for cities like Dakar (Senegal) and Accra (Ghana), green space has limited potential to be a nature-based solution to heat waves. Restoration of green space or alternative measures will need to be put in place to ensure that people do not suffer from extreme heat.

Figure 4.

Percentage of urban population located 300 metres from a small urban green space with trees (at least 1 hectare)



Note: Only urban green space with tree cover and at least one hectare were considered.
Source: Author's calculations based on Africapolis urban agglomerations (OECD/SWAC, 2018), ESA WorldCover 2020 dataset (Zanaga et al., 2021[20]) and Human Population Density dataset (Schiavina, Freire and MacManus, 2019[21]).

AVAILABILITY DOES NOT MEAN PROXIMITY: ABUJA (NIGERIA) VS. ACCRA (GHANA)

It is crucial to recognise that the availability of green space does not translate into proximity, as shown in the example of Abuja and Accra. Both cities have the same availability of green space. Approximately 20% of the built environment is covered in trees, shrubs and grasslands, yet with drastically different outcomes with respect to accessibility. Only 16% of the population of Accra is located within 300 metres (less than a 5-minute walk) from a small patch of trees — and can therefore benefit from its cooling effects — whilst 55.1% of the population of Abuja can access a green space within 5 minutes. This difference holds even when shrubs and grasslands are included in the calculation. Only 40% of the population in Accra can reach a small patch of trees, grasslands or shrubs within 5 minutes versus 74.6% in Abuja (Annex C).

This difference in accessibility is partially due to the history of urbanisation in each city — and the resulting urban form. Abuja was a planned city constructed from the 1980s to replace Lagos as the country's capital in 1991. The entire conceptualisation of Abuja, according to the master plan, was entrenched in the idea of equal access, equal citizenship, environmental conservation and the garden city movement (Rego, 2021[61]). Even though green space is accessible, only the very wealthy can actually live in Abuja. A plot of land in Abuja costs between 10 million to 20 million naira (approximately USD 78 000-157 000), compared with approximately 500 000 naira (approximately USD 3 900) in adjacent villages. The average annual wage in Abuja is USD 8 200. Although the city is able to cope with heat waves, only the very rich stand to benefit.

The first planning document for Accra is from 1958. In 1966, President Kwame Nkrumah was overthrown, marking the beginning of a long period of political instability, which led to a period of uncontrolled urban expansion. In 1991, an integrated planning document for the Greater Metropolitan Area of Accra was established but it was only in 2017 that the metropole implemented a new three-tier planning system to replace the colonial system of 70 years ago. The city, therefore, underwent 30 years without a single planning document and even longer with outdated planning laws, all of which contributed to the inaccessibility of green space in the city (Amedzro, 2020[62]).

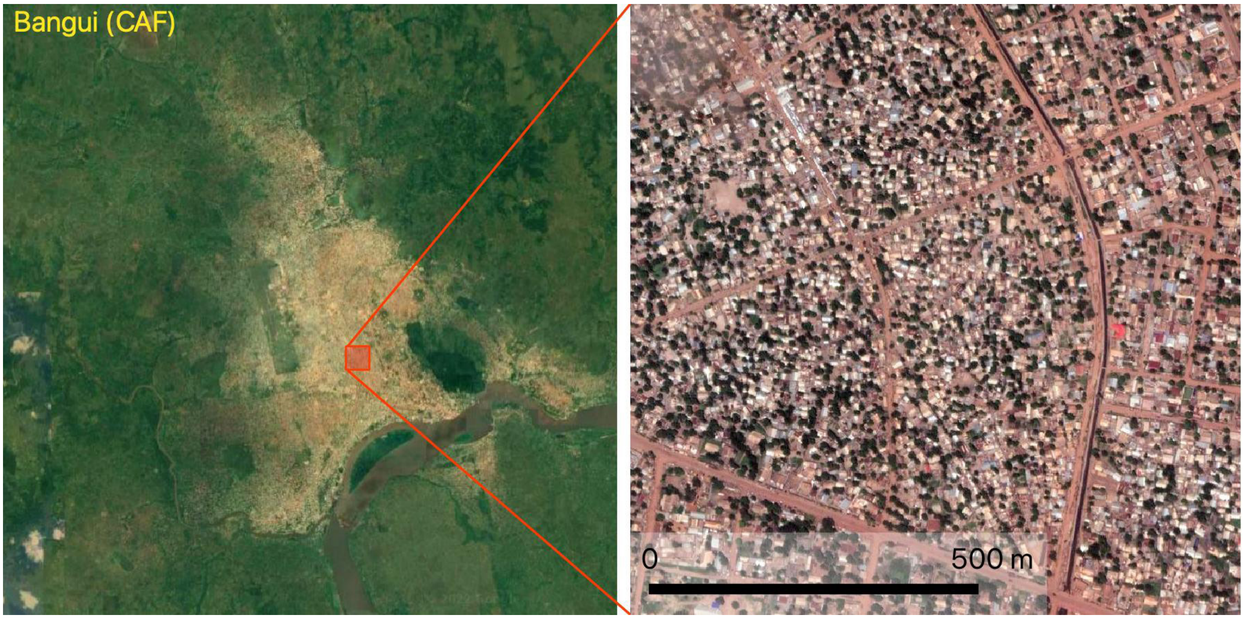
The bulk of cities in Africa follow similar histories to Accra. The key takeaway is that planning — when backed with resources and intention — leads to better outcomes for accessibility to green space. However, the ability of a city to plan and the budget allocated depends on the level of decentralisation, which exists in a country. Some African cities are still highly centralised with respect to planning and financial resources. It remains to be seen what the future of Abuja holds. The city is one-quarter the size of Accra, (1 million vs. 4 million people) but increasing numbers of people are moving there in search of jobs and safety. The city administration is struggling to keep up and provide housing, basic public services and an efficient transportation system, against a backdrop of constrained resources. So far, the government has filled in gaps with public-private partnerships, but it is unclear whether this strategy can keep pace with needs and avoid greater loss of green space.

VERY SMALL PATCHES IN BANGUI (CENTRAL AFRICAN REPUBLIC)

The case of Bangui shows relatively low accessibility to green space given its geographic setting (see Figure 4). Nevertheless, a close inspection of a satellite view of the city shows that there are many trees and other forms of urban greenery across the urban layout, which is good for reducing air pollution and can reduce vulnerability to heat waves (although to a lesser extent than larger patches). For example, in Lisbon (Portugal) a 0.24-hectare patch (less than 1 hectare) of park decreased land surface temperature up to a surrounding area of 200 metres. Therefore, anyone living very close to the green space may benefit from its cooling effects (Oliveira, Andrade and Vaz, 2011[63]).

At the same time, Bangui has few patches of green space larger than one hectare as seen in Map 8, which cannot provide other ecosystem services like biodiversity conservation. Larger green space and greater connectedness between these spaces is important for maintaining biodiversity because they allow animal populations to move across larger areas and help cross-pollinate plants along their way. Much remains unknown about how large individual patch sizes need to be for species, ecosystems and genetic diversity. However, evidence suggests that patch size and quality are important factors driving both plant and animal populations in cities (Lepczyk et al., 2017[64]). Some studies on birds have suggested that 10 to 35 hectares of continuous green space are required to support most urbanised species with forest bird species requiring larger areas (Lepczyk et al., 2017[64]).

Map 8.
Close-up of a sector of Bangui (Central African Republic)



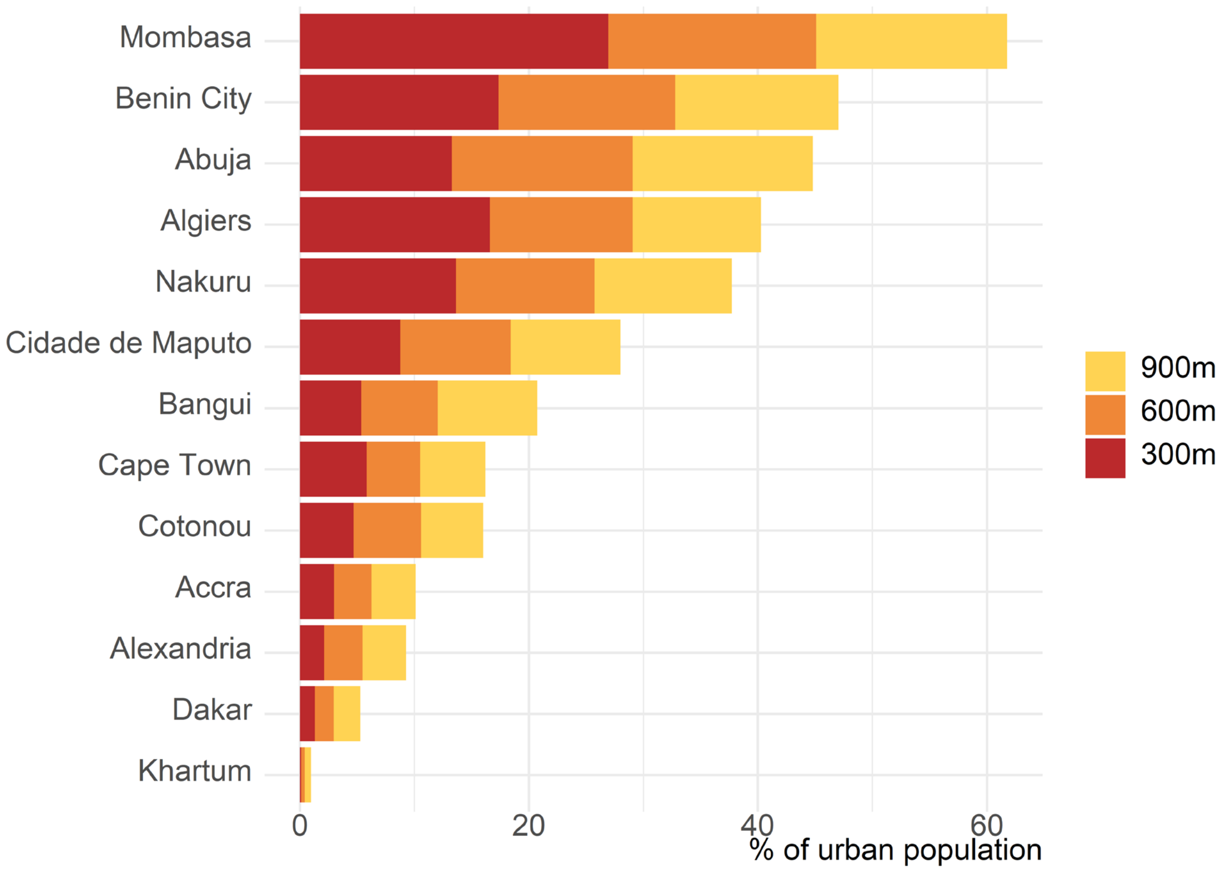
Note: Satellite view of a sector of the city at a detailed spatial scale showing trees intertwined in the urban fabric.
Source: Urban agglomeration boundary from Africapolis (OECD/SWAC, 2018). Satellite views from Google Satellite web map service (© Google).

LARGE PATCHES OF GREEN SPACE ARE FAR AWAY

In the cities analysed, proximity of the population living next to large urban green spaces ranging from 0.12% in Khartoum (Sudan), to 27% in Mombasa (Kenya). In 8 out of the 15 analysed cities, less than 6% of their urban populations are located within a 5-minute walk (distance of 300 metres) from an urban green space of at least 15 hectares (Figure 5, red bars). With the exception of Mombasa, the other six cities have between 17.4% (Benin City, Nigeria) and 8.8% (Maputo, Mozambique) of their urban population located within a 5-minute walk of urban green spaces with at least 15 hectares of trees. When measuring the urban population located within a 10-minute walk from a large green space (600 metres), the percentages rise significantly, but stay below 50% in all the analysed cities (Figure 5, orange bars). When estimating the share of the urban population located within 15 minutes (900 metres) of these large green spaces (Figure 5, yellow bars), only four of the 15 cities have more than 40% of their respective populations within this reach, and only Mombasa (Kenya) has more than half its urban population (61.8%) located within 15 minutes of a large green space.

Recent research has found that greater biodiversity close to home (which requires large connected patches) has positive effects on people's mental health and well-being, meaning that the ecological quality and the species-richness of urban green space are both important benefits to human health and well-being (Fairchild, Weedon and Griffin, 2022[65]).

Figure 5.
Accessibility to large green space with trees (minimum 15 hectares)



Note: Minimum patch size is 15 hectares. 300 metres is a “5-minute walk”, 600 metres is a “10-minute walk”, and 900 metres is a “15-minute walk”.
Source: Author’s calculations based on Africapolis urban agglomerations (OECD/SWAC, 2018), ESA WorldCover 2020 dataset (Zanaga et al., 2021[20]) and Human Population Density dataset (Schiavina, Freire and MacManus, 2019[21]).

Looking forward: Options for greener African cities

African cities will grow significantly in the coming decades in the context of severe climate stress. Local authorities and national policy makers, together with their partners and regional and international organisations, must take action to drive this growth in a resilient and sustainable way to ensure the well-being of city dwellers. Green space can be a nature-based solution to the potential impacts of climate change, from heat waves to floods, reinforcing a city's resilience whilst contributing to its sustainability by limiting pollution and carbon absorption, and improving well-being and the quality of life. The preservation of green space may be a particularly relevant tool in boosting a city's resilience because other avenues are less available, for example, access to climate finance can be very difficult.

Given the limited access to other adaptation options and the relevance of green space, this report fills a significant gap by producing data for local actors on the availability of green space in over 5 625 cities with 10 000 or more inhabitants. This data will be made publically available on the SWAC/OECD Mapping Territorial Transformations in Africa (MAPTA) platform (https://mapping-africa-transformations.org/).

The report reveals that green space significantly declines as cities in Africa become more compact (i.e., infilling, construction between buildings), which is observed worldwide. More people need places to live, work, shop, and conduct the other aspects of daily life. Nevertheless, the analysis also shows a greater availability of green space in cities that adopt vertical growth in already built-up areas (i.e., building taller and denser buildings). One policy option would be to preserve green space in city planning — many national governments do not even have an urbanisation plan, let alone one, which protects green space. However, several case studies reveal that even the preservation of green space is included in planning documents, this may not be sufficient to protect them. First, the institutional landscape across African countries is very complex, with overlapping jurisdictions. There is a need to improve horizontal co-ordination of different institutions across sectors, as well as vertical co-ordination between different levels of government. Second, improving access to data is required to better understand local initiatives and challenges in order to design more contextualised policies. Lastly, resources are needed for the maintenance and enforcement of green space preservation. In Mafikeng (South Africa), for example, the budget for the maintenance of green space has gradually decreased, leading to a slow degradation of these spaces, as well as the ecosystem services they provide. Many African countries are highly centralised — in terms of the planning authority but also regarding revenues and transfers. Therefore, there are limited financial resources at the disposal of local governments. There needs to be greater recognition by national governments of the role that cities can play.

Preserving and increasing urban green space is a considerable challenge in light of other more visible matters like poverty, transport and informal housing. However, improving and increasing urban green space is, at the same time, a great opportunity. As shown above, green space can significantly reduce air pollution, especially when embedded in a broader policy package, such as import bans on certain heavily polluting vehicles. Lessons from boosting green space in Latin America show that targeting the busiest areas for green space restoration could have the most significant impact. High pedestrian traffic areas with pollution issues have more significant potential for environmental returns and will positively impact urban populations. Box 4 offers other insights on how cities in Latin America have boosted the availability and proximity of green spaces in their cities.

However, to realise the full benefits of green space, it is essential to ensure that green space are not only available, but that there are patches of varying sizes throughout the city. Certain benefits like attenuating the impacts of heat waves require people to live in proximity. Other ecosystem services benefits — like improved mental and physical well-being — also need access to green space. Notably, the availability of green space does not necessarily translate to proximity, as in Accra and Abuja. Therefore, cities — and national governments through their urbanisation strategies — should plan for scattered green space across the urban layout to maximise access and proximity of residents to green space and their benefits.

Despite the relevance of cities to future sustainability and resiliency, most national governments do not recognise their role in either mitigation or adaptation. For example, only a handful of National Determined Contributions (NDCs), eleven countries mention the role of cities in mitigation. The few countries that have produced National Adaptation Strategies also rarely mention cities. This is an oversight. Climate change is an international challenge, but its solution rests on the shoulders of local actors. Cities need to be supported moving forward to ensure the quality of life of city dwellers in the face of rapid urbanisation and climate change.

Box 4.

Peer learning: Lessons from boosting green space in Latin America

South-South networking and collaboration may help African policymakers and local authorities to learn best practices from other cities in different regions across the world that also deal with limited budgets and face similar issues. In the last decade, some Latin American cities have been making efforts to increase urban green space and other forms of urban greenery, like Medellin (Colombia), Salvador (Brazil), Buenos Aires (Argentina) , Lima (Peru), and Santiago (Chile)

(Vásquez et al., 2016[66]), all of them with promising results so far. Some of the lessons that these cities have learned and that African cities could benefit from are:

Governance

- Policy priorities need not be in conflict. Cities could integrate urban and environmental development for the benefit of all by valuing properly the many benefits that urban green space can bring to urban populations — e.g., payments for ecosystem services (PES).
- Emphasise access and proximity. In line with the 15-minute city principle, which is a residential urban concept in which most daily necessities can be accomplished on foot or by bicycle from residents' homes. Plan for scattered green space across the urban layout to maximise access and proximity of residents to green space and their benefits.

Targets

- Establish clear targets for urban green space. Having clear targets (e.g., 20% of the urban footprint covered in green space, 50% of population lives within 300 metres of a minimum 1 hectare patch of green space) helps to allocate resources and to track the progress to reach them (e.g., incorporate these targets into national, regional or city-level adaptation plans).

Citizen Involvement

- Raise awareness to increase involvement. Environmental education programmes on the importance of conserving and regenerating urban green areas are a good way to increase people's involvement in caring and preserving green space.
- Take a holistic approach to leave no one behind. If possible, new urban interventions should aim to tackle other urban issues at the same time. The Barrio 31 intervention in Buenos Aires, for example, aims to provide not only new green areas, but to combine them with health care and education facilities for the neighbourhood's population.
- Build trust with residents and enable their participation in the delivery and maintenance of green space. Local residents' involvement in the planning process and management of greening projects will help enforce regulations aiming to protect the green space from degradation — e.g., as seen in Luanda, Angola with the involvement of children in planning for green space.
- Use participatory urbanism to recover and upgrade green space. Collaboration with civil society and private-sector partners will help to prioritise areas for intervention or restoration.

References

Abass, K. et al. (2020), "Urban sprawl and green space depletion: Implications for flood incidence in Kumasi, Ghana", *International Journal of Disaster Risk Reduction*, Vol. 51, https://doi.org/10.1016/J.IJDRR.2020.101915. [44]

Adegun, O. (2021), "Green Infrastructure Can Improve the Lives of Slum Dwellers in African Cities", *Frontiers in Sustainable Cities*, https://www.frontiersin.org/articles/10.3389/frsc.2021.621051/full (accessed on 28 April 2022). [16]

Adjei Mensah, C. et al. (2016), "Community Participation in Urban Planning: The Case of Managing Green Spaces in Kumasi, Ghana", *Urban Forum 2016 28:2*, Vol. 28/2, pp. 125-141, https://doi.org/10.1007/S12132-016-9295-7. [36]

Ahlfeldt, G. et al. (2018), "Demystifying compact urban growth : Evidence from 300 studies from across the world", *OECD Regional Development Working Papers*, No. 2018/03, OECD, Paris, https://www.oecd-ilibrary.org/development/demystifying-compact-urban-growth_bbea8b78-en (accessed on 31 March 2022). [23]

Amedzro, K. (2020), *History and current politics of master planning in Accra*, UCL Urban Lab, https://www.ucl.ac.uk/urban-lab/research/research-projects/making-africa-urban/publications-resources/publications/history-and (accessed on 22 May 2022). [62]

Angel, S. et al. (2018), "The shape compactness of urban footprints", *Progress in Planning*, Vol. 139, https://doi.org/10.1016/J.PROGRESS.2018.12.001. [22]

Angel, S. et al. (2016), *Atlas of Urban Expansion*, Lincoln Land Institute, https://www.lincolninst.edu/sites/default/files/pubfiles/atlas-of-urban-expansion-2016-volume-1-full.pdf (accessed on 10 November 2021). [3]

Angel, S., J. Parent and D. Civco (2010), "The Fragmentation of Urban Footprints: Global Evidence of Sprawl, 1990-2000". [27]

Aram, F. et al. (2019), "Urban green space cooling effect in cities", *Heliyon*, Vol. 5/4, https://doi.org/10.1016/j.heliyon.2019.e01339. [42]

Asiedu, K. (2019), "'Accra is becoming a concrete jungle' so locals are building their own parks", *DW*, https://www.dw.com/en/accra-is-becoming-a-concrete-jungle-so-locals-are-building-their-own-parks/a-49730607 (accessed on 22 May 2022). [47]

Boeing, G. et al. (2022), "Using open data and open-source software to develop spatial indicators of urban design and transport features for achieving healthy and sustainable cities", *The Lancet Global Health*, Vol. 10/June, pp. 907-918, https://doi.org/10.1016/S2214-109X(22)00072-9. [76]

Bowler, D. et al. (2010), "Urban greening to cool towns and cities: A systematic review of the empirical evidence", *Landscape and Urban Planning*, Vol. 97/3, pp. 147-155, https://doi.org/10.1016/j.landurbplan.2010.05.006. [43]

Byomkesh, T. et al. (n.d.), "Urbanization and green space dynamics in Greater Dhaka, Bangladesh", https://doi.org/10.1007/s11355-010-0147-7. [78]

Byomkesh, T., N. Nakagoshi and A. Dewan (2012), "Urbanization and green space dynamics in Greater Dhaka, Bangladesh", *Landscape and Ecological Engineering*, Vol. 8/1, pp. 45-58, https://doi.org/10.1007/S11355-010-0147-7/FIGURES/6. [30]

CDP (2021), *Carbon Disclosure Project: 2021 Full Cities Dataset*, Carbon Disclosure Project. [17]

Chen, Y., W. Yue and D. La Rosa (2020), "Which communities have better accessibility to green space? An investigation into environmental inequality using big data", *Landscape and Urban Planning*, Vol. 204, https://doi.org/10.1016/J.LANDURBPLAN.2020.103919. [58]

Chibuike, E. et al. (2018), "Assessment of green parks cooling effect on Abuja urban microclimate using geospatial techniques", *Remote Sensing Applications: Society and Environment*, Vol. 11, pp. 11-21, https://doi.org/10.1016/J.RSASE.2018.04.006. [41]

Diener, A. and P. Mudu (2021), "How can vegetation protect us from air pollution? A critical review on green spaces' mitigation abilities for air-borne particles from a public health perspective - with implications for urban planning", *Science of The Total Environment*, Vol. 796, https://doi.org/10.1016/J.SCITOTENV.2021.148605. [79]

Duque, J. et al. (2021), "Urban form and productivity: What shapes are Latin-American cities?", *Environment and Planning B: Urban Analytics and City Science*, Vol. 49/1, https://doi.org/10.1177/2399808321999309. [52]

Edmond, C. (2019), *Cape Town almost ran out of water. Here's how it averted the crisis, World Economic Forum*, https://www.weforum.org/agenda/2019/08/cape-town-was-90-days-away-from-running-out-of-water-heres-how-it-averted-the-crisis/ (accessed on 22 May 2022). [8]

eThekwini Municipality (2020), *Green Roof Pilot Project*, The Adaptation Network, https://www.adaptationnetwork.org.za/projects/research/research-project-11/ (accessed on 22 May 2022). [18]

Fairchild, T., J. Weedon and J. Griffin (2022), "Species diversity enhances perceptions of urban coastlines at multiple scales", *People and Nature*, Vol. 00, pp. 1-18, https://doi.org/10.1002/PAN3.10330. [65]

Ferguson, M. et al. (2018), "Contrasting distributions of urban green infrastructure across social and ethno-racial groups", *Landscape and Urban Planning*, Vol. 175, pp. 136-148, https://doi.org/10.1016/J.LANDURBPLAN.2018.03.020. [56]

Fisher, S. et al. (2021), "Air pollution and development in Africa: impacts on health, the economy, and human capital", *The Lancet Planetary Health*, Vol. 5/10, https://doi.org/10.1016/S2542-5196(21)00201-1. [50]

Gaigné, C., S. Riou and J. Thisse (2012), "Are compact cities environmentally friendly?", *Journal of Urban Economics*, Vol. 72/2-3, pp. 123-136, https://doi.org/10.1016/J.JUE.2012.04.001. [24]

Gavrilidis, A. et al. (2019), "Methodological framework for urban sprawl control through sustainable planning of urban green infrastructure", *Ecological Indicators*, Vol. 96, pp. 67-78, https://doi.org/10.1016/j.ecolind.2017.10.054. [33]

Giezen, M., S. Balikci and R. Arundel (2018), "Geo-Information Using Remote Sensing to Analyse Net Land-Use Change from Conflicting Sustainability Policies: The Case of Amsterdam", https://doi.org/10.3390/ijgi7090381. [31]

Gómez-Baggethun, E. and D. Barton (2013), "Classifying and valuing ecosystem services for urban planning", *Ecological Economics*, Vol. 86, pp. 235-245, https://doi.org/10.1016/j.ecolecon.2012.08.019. [26]

Gordon, P. and H. Richardson (2007), "Are Compact Cities a Desirable Planning Goal?", *Journal of the American Planning Association*, Vol. 63/1, pp. 95-106, https://doi.org/10.1080/01944369708975727. [73]

Haaland, C. and C. van den Bosch (2015), "Challenges and strategies for urban green-space planning in cities undergoing densification: A review", *Urban Forestry & Urban Greening*, Vol. 14/4, pp. 760-771, https://doi.org/10.1016/J.UFUG.2015.07.009. [29]

Hänke, H. et al. (2016), "Drought tolerant species dominate as rainfall and tree cover returns in the West African Sahel", *Land Use Policy*, Vol. 59, pp. 111-120, https://doi.org/10.1016/J.LANDUSEPOL.2016.08.023. [75]

Hong, A. et al. (2021), "Neighbourhood green space and health disparities in the global South: Evidence from Cali, Colombia", *Health and Place*, Vol. 72/September, p. 102690, https://doi.org/10.1016/j.healthplace.2021.102690. [14]

Huang, C. et al. (2021), "Mapping the maximum extents of urban green spaces in 1039 cities using dense satellite images", *Environmental Research Letters*, Vol. 16/6, p. 064072, https://doi.org/10.1088/1748-9326/AC03DC. [59]

IPCC (2022), "Chapter 6: Cities, Settlements and Key Infrastructure", in *Sixth Assessment Report, Climate Change 2022: Mitigation of Climate Change, the Working Group III contribution*, Intergovernmental Panel on Climate Change, https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_FinalDraft_Chapter06.pdf (accessed on 1 June 2022). [7]

IPCC (2018), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, Intergovernmental Panel on Climate Change, https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf. [4]

IPCC (2012), Managing the risks of extreme events and disasters to advance climate change adaptation, Intergovernmental Panel on Climate Change, Intergovernmental Panel on Climate Change , https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/. [86]

Irwin, E. and N. Bockstael (2007), "The evolution of urban sprawl: Evidence of spatial heterogeneity and increasing land fragmentation", *Proceedings of the National Academy of Sciences*, Vol. 104/52, pp. 20672-20677, https://doi.org/10.1073/PNAS.0705527105. [74]

Jarvis, I. et al. (2020), "Greenspace access does not correspond to nature exposure: Measures of urban natural space with implications for health research", *Landscape and Urban Planning*, Vol. 194, p. 103686, https://doi.org/10.1016/J.LANDURBPLAN.2019.103686. [60]

Jim, C. and M. Chan (2016), "Urban greenspace delivery in Hong Kong: Spatial-institutional limitations and solutions", *Urban Forestry and Urban Greening*, Vol. 18, pp. 65-85, https://doi.org/10.1016/J.UFUG.2016.03.015. [32]

Jimenez, M. et al. (2022), “Residential Green Space and Cognitive Function in a Large Cohort of Middle-Aged Women.”, *JAMA network open*, Vol. 5/4, https://doi.org/10.1001/jamanetworkopen.2022.9306. [11]

Korah, P., T. Matthews and D. Tomerini (2019), “Characterising spatial and temporal patterns of urban evolution in Sub-Saharan Africa: The case of Accra, Ghana”, *Land Use Policy*, Vol. 87, https://doi.org/10.1016/J.LANDUSEPOL.2019.104049. [25]

Lall, S. et al. (2021), *Pancakes to Pyramids: City form to promote sustainable growth*, World Bank Group, https://documents1.worldbank.org/curated/en/554671622446381555/pdf/City-Form-to-Promote-Sustainable-Growth.pdf (accessed on 15 March 2022). [45]

Lepczyk, C. et al. (2017), “Biodiversity in the City: Fundamental Questions for Understanding the Ecology of Urban Green Spaces for Biodiversity Conservation”, *BioScience*, Vol. 67/9, pp. 799-807, https://doi.org/10.1093/BIOSCI/BIX079. [64]

Li, C. et al. (2013), “The Long-Term Relationship between Population Growth and Vegetation Cover: An Empirical Analysis Based on the Panel Data of 21 Cities in Guangdong Province, China”, *International Journal of Environmental Research and Public Health 2013*, Vol. 10, Pages 660-677, Vol. 10/2, pp. 660-677, https://doi.org/10.3390/IJERPH10020660. [34]

Mensah, C. (2014), “Destruction of Urban Green Spaces: A Problem Beyond Urbanization in Kumasi City (Ghana)”, *American Journal of Environmental Protection*, Vol. 3/1, pp. 1-9, https://doi.org/10.11648/j.ajep.20140301.11. [35]

Mensah, C. (2014), *Urban green spaces in Africa: Nature and challenges*, https://ir.ucc.edu.gh/xmlui/handle/123456789/6416 (accessed on 1 March 2022). [9]

Mensah, C., K. Gough and D. Simon (2018), “Urban green spaces in growing oil cities: The case of Sekondi-Takoradi Metropolis, Ghana”, *International Development Planning Review*, Vol. 40/4, pp. 371-395, https://doi.org/10.3828/IDPR.2018.16. [37]

Morancho, A. (2003), “A hedonic valuation of urban green areas”, *Landscape and Urban Planning*, Vol. 66/1, pp. 35-41, https://doi.org/10.1016/S0169-2046(03)00093-8. [72]

Munyati, C. and J. Drummond (2020), “Loss of urban green spaces in Mafikeng, South Africa”, *World Development Perspectives*, Vol. 19, https://doi.org/10.1016/j.wdp.2020.100226. [49]

OECD (2021), *Scaling up Nature-based Solutions to Tackle Water-related Climate Risks: Insights from Mexico and the United Kingdom*, OECD Publishing, Paris, https://doi.org/10.1787/736638c8-en. [10]

OECD (2019), *Accelerating Climate Action: Refocusing Policies through a Well-being Lens*, OECD Publishing, Paris, https://doi.org/10.1787/2f4c8c9a-en. [55]

OECD (2019), “Population and Morphology of Border Cities”, *West African Papers*, No. 21, OECD Publishing, Paris, https://doi.org/10.1787/80dfd9d8-en. [85]

OECD (2018), *Rethinking Urban Sprawl: Moving Towards Sustainable Cities*, OECD Publishing, Paris, https://doi.org/10.1787/9789264189881-en. [54]

OECD (2017), *Investing in Climate, Investing in Growth*, OECD Publishing, https://doi.org/10.1787/9789264273528-en (accessed on 21 November 2017). [68]

OECD/SWAC (2018), *Africapolis (database)*, OECD and Sahel and West Africa Club, OECD Publishing, Paris, https://africapolis.org. [19]

OECD/SWAC (2020), *Africa’s Urbanisation Dynamics 2020: Africapolis, Mapping a New Urban Geography*, West African Studies, OECD Publishing, Paris, https://doi.org/10.1787/b6bccb81-en. [1]

Oliveira, S., H. Andrade and T. Vaz (2011), “The cooling effect of green spaces as a contribution to the mitigation of urban heat: A case study in Lisbon”, *Building and Environment*, Vol. 46/11, https://doi.org/10.1016/j.buildenv.2011.04.034. [63]

OpenStreetMap (2022), *OpenStreetMap*, https://www.openstreetmap.org/#map=7/4.259/2.274 (accessed on 19 July 2022). [39]

Osima, S. et al. (2018), “Projected climate over the Greater Horn of Africa under 1.5 °C and 2 °C global warming”, *Environmental Research Letters*, Vol. 13/6, https://doi.org/10.1088/1748-9326/AABA1B. [5]

Page, J. et al. (2020), “Urban economic growth in Africa A framework for analyzing constraints to agglomeration”, *Working Paper*, No. 24, Brookings Institute, https://www.brookings.edu/wp-content/uploads/2020/09/20.09.28_urban_economic_growth_in_africa_FINAL.pdf (accessed on 28 April 2022). [2]

Patino, J. (2020), “Analyzing Long-Term Availability of Urban Green Space by Socioeconomic Status in Medellin, Colombia, Using Open Data and Tools”, *2020 IEEE Latin American GRSS and ISPRS Remote Sensing Conference, LAGIRS 2020 - Proceedings*, pp. 87-92, https://doi.org/10.1109/LAGIRS48042.2020.9165672. [53]

Patino, J. et al. (2021), “Built environment and mortality risk from cardiovascular disease and diabetes in Medellín, Colombia: An ecological study”, *Landscape and Urban Planning*, Vol. 213/April, pp. 104-126, https://doi.org/10.1016/j.landurbplan.2021.104126. [15]

Pedrosa, L. et al. (2021), "Planning for Informal Urban Green Spaces in African Cities: Children's Perception and Use in Peri-Urban Areas of Luanda, Angola", *Urban Science 2021*, Vol. 5, Page 50, Vol. 5/3, p. 50, https://doi.org/10.3390/URBANSCI5030050. [83]

Petzer, B. and O. Udo-Udoma (2016), "Perhaps public space is the best catalyst to enlighten citizen's imaginations about their city's potential", *Our Future Cities*, http://ourfuturecities.co/2016/02/fighting-for-public-space-in-cape-town-and-lagos/ (accessed on 22 May 2022). [48]

Prieto Curiel, R., J. Patino and B. Anderson (2022), "Measuring the morphology of African cities", No. 2207.03003v1, arXiv, https://arxiv.org/pdf/2207.03003.pdf (accessed on 19 July 2022). [40]

Rego, R. (2021), "New capital cities in the Global South Post-modernist context, modernist layout in Nigeria and Brazil", *Cities*, Vol. 42/PA, https://doi.org/10.1016/J.CITIES.2014.05.008. [61]

Rigolon, A. et al. (2018), "Access to Urban Green Space in Cities of the Global South: A Systematic Literature Review", *Urban Science 2018*, Vol. 2, Page 67, Vol. 2/3, p. 67, https://doi.org/10.3390/URBANSCI2030067. [12]

Rohat, G. et al. (2019), "Projections of Human Exposure to Dangerous Heat in African Cities Under Multiple Socioeconomic and Climate Scenarios", *Earth's Future*, Vol. 7/5, pp. 528-546, https://doi.org/10.1029/2018EF001020. [6]

Schiavina, M., S. Freire and K. MacManus (2019), *GHS population grid multitemporal (1975, 1990, 2000, 2015) R2019A*., https://ghsl.jrc.ec.europa.eu/ghs_pop2019.php (accessed on 18 July 2022). [21]

Seto, K. and B. Pandey (2019), "Urban Land Use: Central to Building a Sustainable Future", *One Earth*, Vol. 1/2, pp. 168-170, https://doi.org/10.1016/J.ONEEAR.2019.10.002. [69]

Sirko, W. et al. (2021), "Continental-Scale Building Detection from High Resolution Satellite Imagery", *arXiv*, https://doi.org/10.48550/arxiv.2107.12283. [38]

Stuhlmacher, M. et al. (2022), "Are global cities homogenizing? An assessment of urban form and heat island implications", *Cities,* March 2021, https://doi.org/10.1016/j.cities.2022.103705. [28]

Tzoulas, K. et al. (2007), "Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review", *Landscape and Urban Planning*, Vol. 81/3, pp. 167-178, https://doi.org/10.1016/J.LANDURBPLAN.2007.02.001. [70]

UN Environment (2020), Gl*obal Trade in Used Vehicles Report*, UN Environment, https://www.unep.org/resources/report/global-trade-used-vehicles-report (accessed on 19 July 2022). [51]

Vásquez, A. et al. (2016), "Green Infrastructure Systems Facing Fragmented Cities in Latin America - Case of Santiago, Chile", *Procedia Engineering*, Vol. 161, pp. 1410-1416, https://doi.org/10.1016/J.PROENG.2016.08.602. [66]

Venter, Z. et al. (2020), "Green Apartheid: Urban green infrastructure remains unequally distributed across income and race geographies in South Africa", *Landscape and Urban Planning*, Vol. 203, p. 103889, https://doi.org/10.1016/J.LANDURBPLAN.2020.103889. [80]

White, R. (2017), *Greening Africa's Cities: Enhancing the realtionship between urbanization, envrionmental assets and ecosystem services*., World Bank. [84]

WHO Regional Office for Europe (2016), *Urban Green Spaces and Health*, https://doi.org/10.1111/j.1744-7429.2008.00398.x. [71]

Wolch, J., J. Byrne and J. Newell (2014), "Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'", *Landscape and Urban Planning*, Vol. 125, pp. 234-244, https://doi.org/10.1016/J.LANDURBPLAN.2014.01.017. [82]

Wood, L. et al. (2017), "Public green spaces and positive mental health – investigating the relationship between access, quantity and types of parks and mental wellbeing", *Health & Place*, Vol. 48, pp. 63-71, https://doi.org/10.1016/J.HEALTHPLACE.2017.09.002. [13]

WorldClim (2020), *WorldClim Historical Climate Data*, https://www.worldclim.org/data/worldclim21.html (accessed on 20 May 2022). [67]

WWF (2021), *Waterways to resilience nature-based solutions for adaptation in Africa*, WWF-World Wide Fund for Nature, https://wwfint.awsassets.panda.org/downloads/waterways_to_resilience_naturebased_solutions_wwfabinbev.pdf (accessed on 20 May 2022). [77]

Zanaga, D. et al. (2021), E*SA WorldCover 10 m 2020 v100*, https://doi.org/10.5281/ZENODO.5571936. [20]

Zepp, H., L. Groß and L. Inostroza (2020), "And the winner is? Comparing urban green space provision and accessibility in eight European metropolitan areas using a spatially explicit approach", *Urban Forestry & Urban Greening*, Vol. 49, https://doi.org/10.1016/J.UFUG.2020.126603. [57]

Annex A. Effects of urban forms on the availability of green space

This annex shows the results of the linear econometric model of the availability of urban green space explained by urban form metrics, while controlling for physical geography and population size for the year 2015 (log-transformed). The physical geography controls include the average elevation within the city, the elevation difference between its maximum height and its minimum height, the annual maximum temperature (1970-2000 average), the average (1970-2000) annual precipitation, and the distance to the nearest coast. The climatic variables were downloaded from the bioclimatic variables of WorldClim, Historical Climate Data, version 2.1 for 1970-2000 (WorldClim, 2020[67]).These climatic variables are organized in grid format at 30″ of spatial resolution (~ 1 km^2). The spatial mean was calculated within the urban agglomeration polygons to obtain a single value for each city. Table A1 shows the models' coefficients.

The urban form variables included in the model are:

- **Elongation**: City elongation, measure of how elongated the urban footprint is (see Box 2).
- **Sprawl**: City sprawl, measure based on the average distance between buildings compared to the maximum distance between buildings within the city (see Box 2).
- **Polycentrism**: Polycentrism index, the higher the value, the higher the polycentrism (Prieto Curiel, Patino and Anderson, 2022[40]).
- **Buildings per node**: Total number of buildings divided by the total number of street network nodes within the city. It is a proxy for built-up intensity in the city.
- **Centre density**: Building density at the city centre. The city centre is the maximum building density point within the urban agglomeration.
- **Is pyramid**: Ratio between the average area of buildings within 500 metres of the city centre and the average area of buildings in the city.

Table A.1.
Econometric model of urban green space as a function of urban form variables

	Dependent variable: **UGS fraction**
Controls:	
Average elevation	-0.0001*** (0.00001)
Difference in elevation	0.0004*** (0.00002)
Annual maximum temperature	-0.008*** (0.001)
Annual precipitation	0.0002*** (0.00000)
Distance to coast	0.0001*** (0.00001)
Log(Population 2015)	-0.00001 (0.004)
Urban form variables:	
Elongation	0.013*** (0.001)
Sprawl	0.016** (0.008)
Polycentrism	-0.001*** (0.0005)
Buildings per node	-0.00004*** (0.00001)
Centre density	-0.000*** (0.000)
Is pyramid	0.089*** (0.010)
Constant	0.258*** (0.044)
R^2	0.546
Adjusted R^2	0.545
Residual std. error	0.165 (df = 5517)
F Statistic	552.626*** (df = 12; 5517)

Note: N = 5 530. Standard errors shown in parenthesis. Statistical significance:
* p < 0.1; ** p < 0.05; *** p < 0.01.

Annex B. Effects of availability of green space on air pollution

This annex shows the results of the linear econometric model of the air pollution measure ($PM_{2.5}$ mean annual concentration within the city boundary for the year 2019) explained by urban form metrics and the fraction of urban green space, while controlling for physical geography, geographic regions, and population size for the year 2015 (log-transformed). The physical geography controls in this model include the average elevation within the city, the average slope (in degrees), the annual maximum temperature (1970-2000 average), the average (1970-2000) annual precipitation, and the distance to the nearest coast. The climatic variables were downloaded from the bioclimatic variables of WorldClim, Historical Climate Data, version 2.1 for 1970-2000 (WorldClim, 2020[67]). These climatic variables are organised in grid format at 30″ of spatial resolution (~ 1 km^2). The spatial mean was calculated within the urban agglomeration polygons to obtain a single value for each city. Table B1 shows the models' coefficients. Explanations for sprawl, elongation, polycentrism, buildings per node and Is pyramid can be found in Annex A. Additional variables include:

- **Total footprint centre 1 km**: Total footprint of buildings at 1 km from city centre.
- **Average node degree**: Average numbers of streets that connect to the same intersection.
- **Intersection density**: Number of street intersections divided by the area of the city.

Table B.1.
Econometric model of air pollution as a function of green space and urban form variables

	Dependent variable: **$PM_{2.5}$ (2019)**
Controls:	
Average elevation	-0.001 (0.0005)
Average slope	-0.556*** (0.106)
Annual maximum temperature	0.523*** (0.070)
Annual precipitation	-0.004*** (0.0005)
Distance to coast	0.020*** (0.001)
Log(Population 2015)	3.669*** (0.284)
Region North	-0.179 (0.930)
Region West	14.098*** (0.765)
Region East	-4.746*** (0.746)
Region South	-0.681 (0.927)
Urban form variables:	
UGS fraction	-14.677*** (0.973)
Elongation	0.094 (0.094)
Sprawl	-1.319** (0.560)
Polycentrism	0.015 (0.030)
Buildings per node	-0.002*** (0.001)
Total footprint centre 1 km	-0.00002*** (0.00000)
Average node degree	-4.559*** (0.325)
Intersection density	0.035*** (0.003)
Is pyramid	-2.444*** (0.686)
Constant	8.566*** (3.898)
R^2	0.526
Adjusted R^2	0.524
Residual std. error	11.253 (df = 5510)
F Statistic	552.626*** (df = 19; 5510)

Notes: N = 5 530. Standard errors shown in parenthesis. Statistical significance:
* p < 0.1; ** p < 0.05; *** p < 0.01.

Annex C. Proximity to green space

This annex shows the accessibility to urban green space estimations for 15 selected cities. The estimations for the urban population that has access to urban green spaces were calculated for different green patch sizes (1, 5, 10, 15, and 25 hectares), for different types of green cover (trees; trees and shrubs; and trees, shrubs and grasslands), and for different walking times (5, 10, 15, 20 and 25 minutes). The following figures show the results for the 15 cities analysed in this work.

Figure C.1.
Abuja (Nigeria)

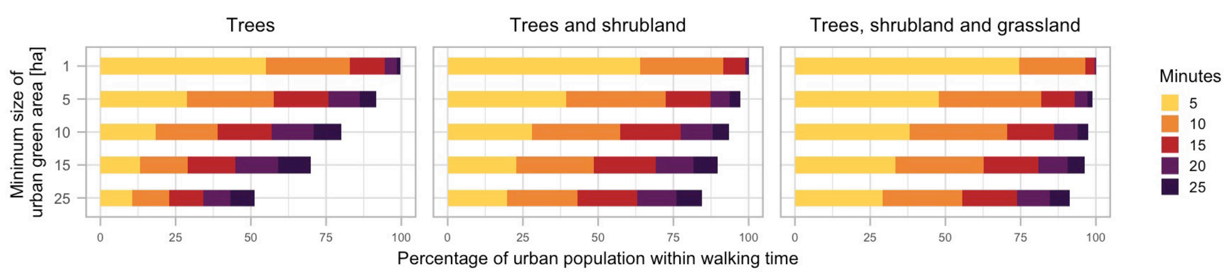


Figure C.2.
Accra (Ghana)

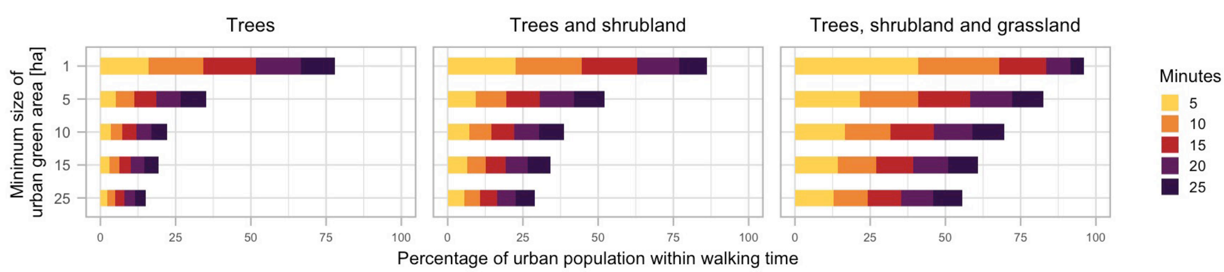


Figure C.3.
Alexandria (Egypt)

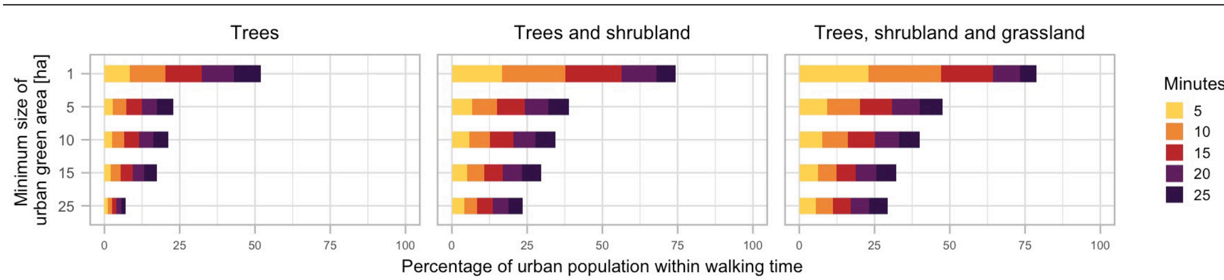


Figure C.4.
Algiers (Algeria)

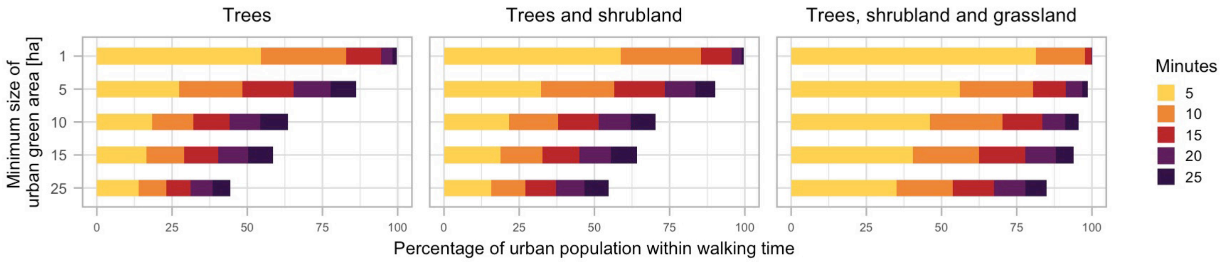


Figure C.5.
Bangui (Central African Republic)

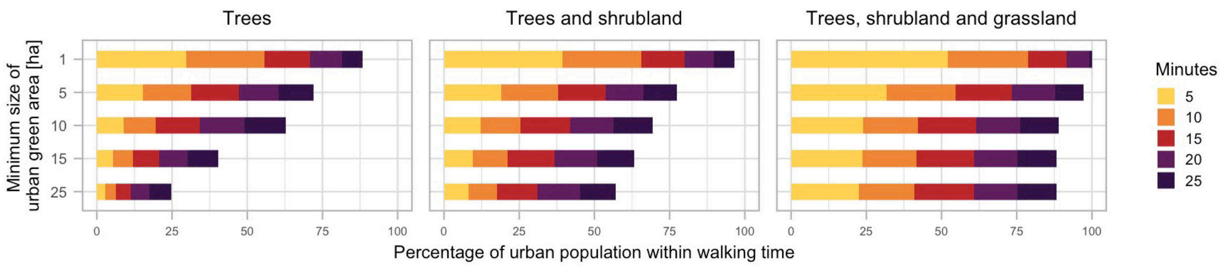


Figure C.6.
Benin City (Nigeria)

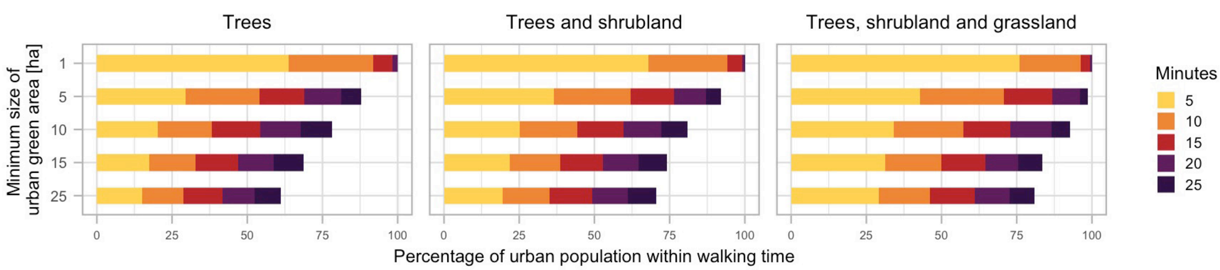


Figure C.7.
Cape Town (South Africa)

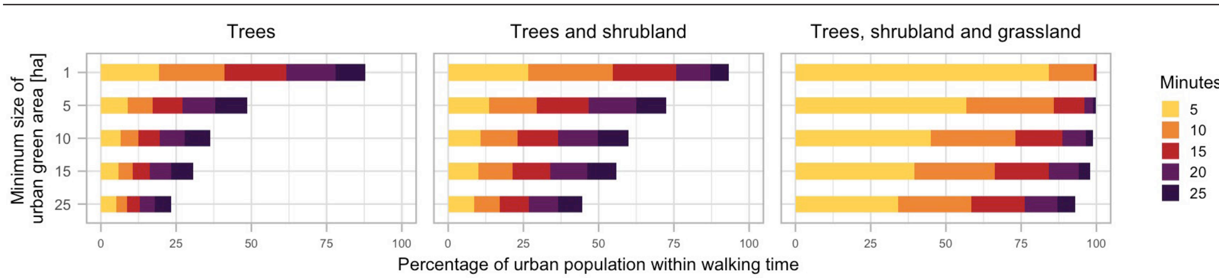


Figure C.8.
Cidade de Maputo (Mozambique)

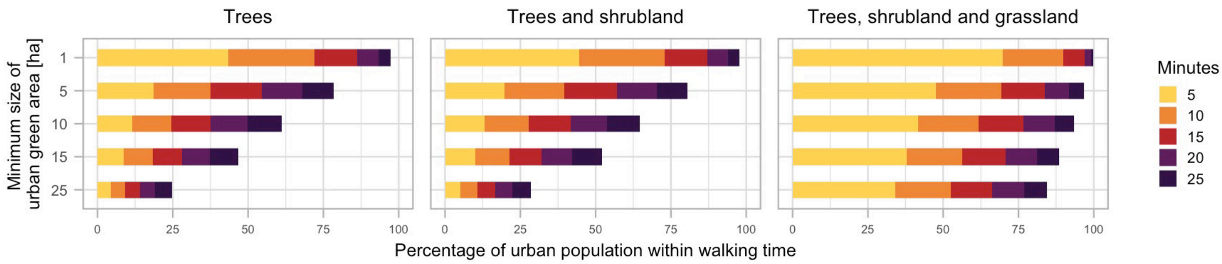


Figure C.9.
Cotonou (Benin)

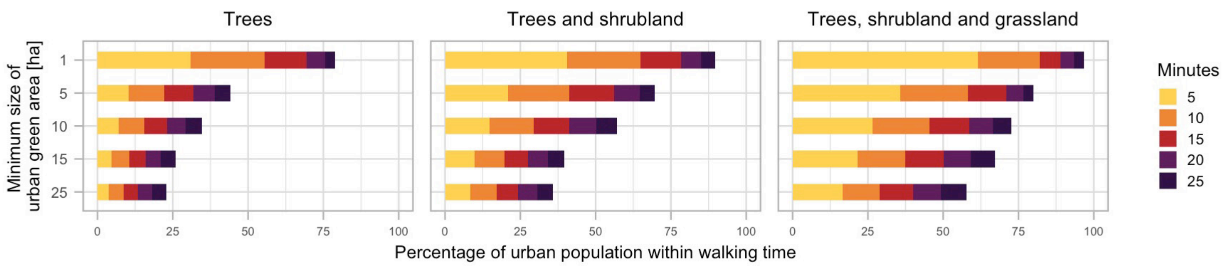


Figure C.10.
Khartum (Sudan)

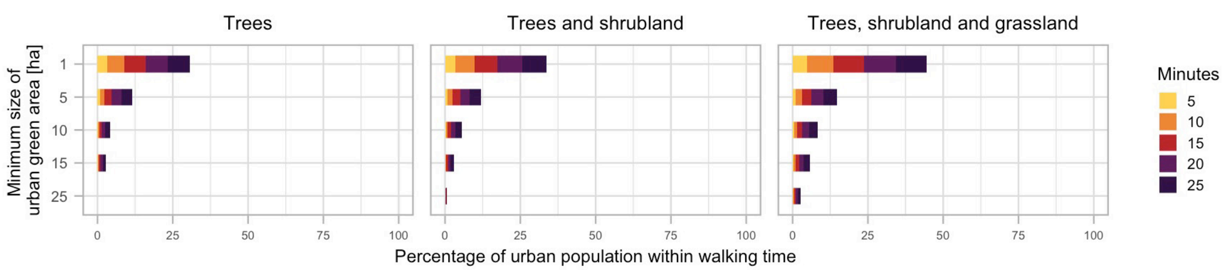


Figure C.11.
Luanda (Angola)

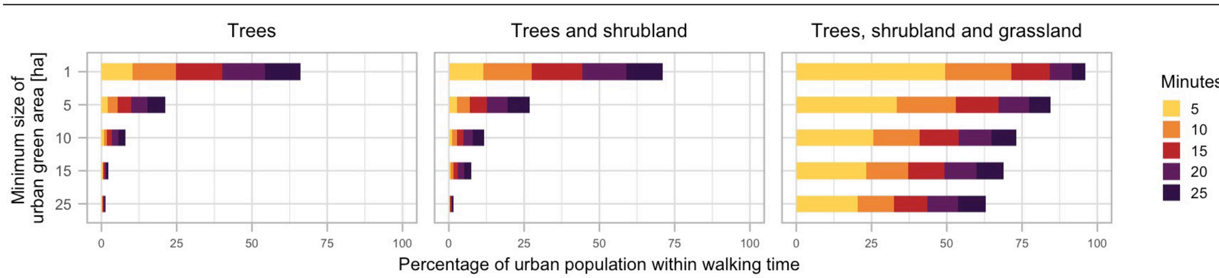


Figure C.12.
Lusaka (Zambia)

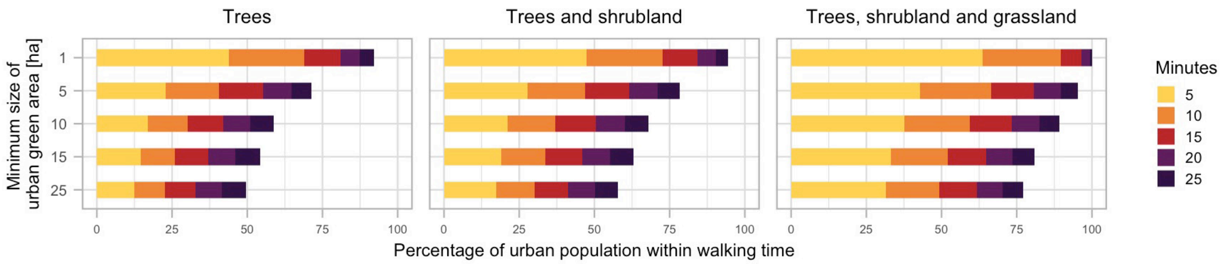


Figure C.13.
Mombasa (Kenya)

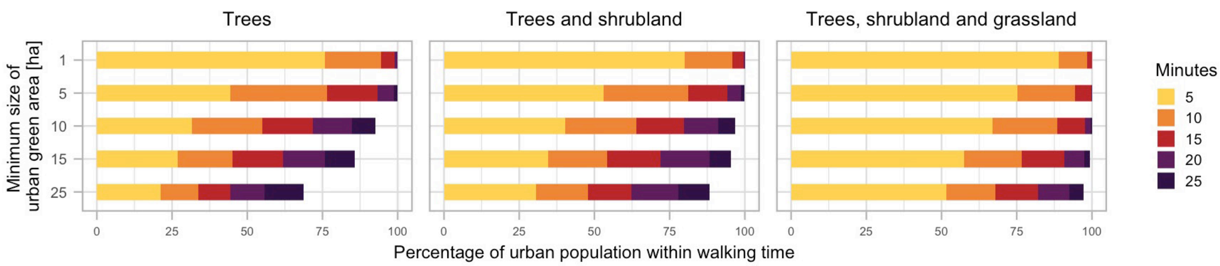
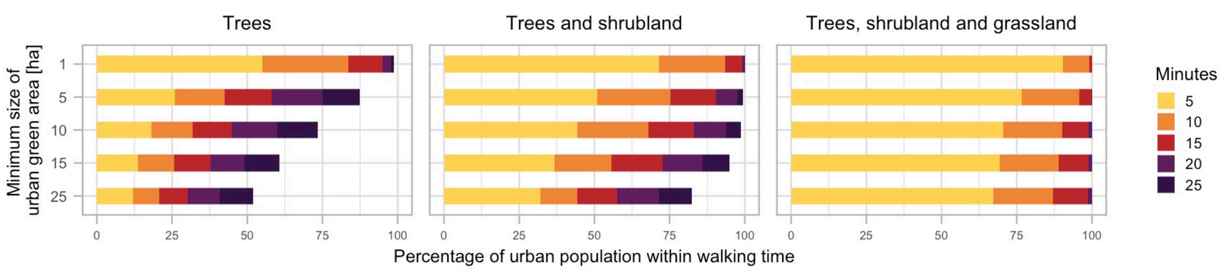


Figure C.14.
Nakuru (Kenya)



West African Papers

Boosting African cities' resilience to climate change: The role of green spaces

The next few decades will bring an era of rapid urbanisation and unprecedented climate stress to African cities. Green spaces can boost the resilience of cities to heatwaves, floods, landslides, and even coastal erosion, in addition to enhancing sustainability by improving air quality, protecting biodiversity, and absorbing carbon. All of which can enhance well-being. Yet, data on the availability of green spaces in African urban agglomerations is scarce. This analysis fills the gap by combining new and novel data sources to estimate the availability of green spaces in 5 625 urban agglomerations with 10 000 inhabitants and above. The rest of the report then uses this novel dataset to first evaluate the dynamics between urbanisation and green spaces, and second, explore the potential of green spaces to boost the resilience and sustainability of cities in the future. The results show that as urban agglomerations become larger and more compact, green spaces disappear, exacerbating their vulnerability to climate change and deteriorating liveability. However, building taller buildings (i.e., growing vertically), offers a way for cities to grow whilst minimising loss of green space. Results show that more green space can boost sustainability by significantly lowering air pollution in African cities, which could be vital for public health in the future since outdoor air pollution is rising. The potential for green spaces to enhance resilience to climate events, like heatwaves, depends on the location of green spaces throughout the city and the percentage of the population that lives close to a green space (i.e., within 300 metres). Green spaces may play a limited role in coping with heatwaves in a city like Khartoum where only 3% of the population lives close to a green space, but could be a nature-based solution to heatwaves in a city like Abuja, where 55% of the population can benefit from its cooling effects. Moving forward, local actors have clear evidence of the power of green spaces to build a sustainable and resilient future. Still, the report reveals that local actors need support from regional and national actors to realise the potential of green spaces.

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