The Imperatives in Mainstreaming Climate Change Mitigation and Adaptation in Urban Management Practices: African Perspectives

Abstract

This paper is anchored on argument that cities contribute to global warming and climate change through the interaction of the urban morphological factors notably; the development density, distribution of land uses, building configuration, nature of the construction materials used in the city and the amount of vegetation within the city, the utility of public transportation, vehicular traffic volume, industrialisation and energy consumption in the city, all of which influence the occurrence of urban heat island effects and greenhouse gas emissions to compromise the air quality and surface temperatures. Therefore, urbanisation is a significant factor contributing to global warming and climate change, leading to heightened drought and flood prevalence, heat waves, sea level rise, increased pest invasions, disease incidences, food insecurity and occurrences of extreme weather events. This is likely to lead to population displacement with the hosts being urban centres already experiencing infrastructure inadequacies. Experience from Africa corroborate that mitigation and adaptation to climate change is a challenge at the urban level due to socioeconomic conditions accentuated by insufficient regional and national assistance rendered to urban authorities. The paper therefore annunciates the African urban climate change mitigation and adaptation scenarios and further discuss the challenges the nations and cities in Africa face in mainstreaming climate change in the national urbanization agenda. To anchor the arguments and to propose strategies for mainstreaming climate change in the urban sustainability agenda, concise review of literature and policy documents on climate change as informed by the urban management practices in Africa is undertaken.

Keywords: Urbanisation, Development, Climate Change, Mitigation, Adaptation, Resilience City

1. Introduction

The sustainable development goal in its 11th goal seeks to make cities inclusive, safe, resilient, and sustainable (United Nations, 2015). Additionally, the New Urban Agenda 2016, presents impetus among the African nations to ensure sustainable urbanisation. According to UN-Habitat (2018), over 50% of the world's population will be living in urban areas by the year 2030. With an average annual urbanisation rate of 3.5%, urbanisation is projected at 68% by the year 2050. While cities should be centres of economic growth, opportunity and innovation, Africa which is expected to attain urban population of up to 1.3 billion by the year 2050 has continued to experience deteriorating urban infrastructure and services (World Bank, 2016).

In the year 2021, average urbanization rate in Africa stood at 47% of which Gabon had the highest urbanization rate approximated at 90%. This was followed by Libya at 85% and Djibouti at 79%. While the least urbanized counties in Africa with urbanization rates below 20% are Malawi, Rwanda, Niger and Burundi, countries with highest urbanization rates of 5.2% per annum are Burundi, Niger, Uganda, Tanzania and Burkina Faso (World Bank, 2021). The largest cities in Africa are Cairo in Egypt with a population of 22.3 million, followed by Lagos in Nigeria and Kinshasa in the Democratic Republic of Congo with a population of 16.3 million each. At city level, Bujumbura in Burundi has the highest

urbanization rate approximated at 9.4% per annum. Other fast-growing cities in Africa are Zinder in Niger, Kampala in Uganda and Kabinda in the Democratic Republic of Congo (World Bank, 2021).

With a 28% of the total population living in urban areas and annual urbanisation rate of 3.5% per annum, about half of the Kenyan population will be living in cities by 2050 (Wold Bank, 2021). The anticipated growth will take place in the existing urban centres, consequently exacerbating levels of urban poverty, unemployment, proliferation of informal settlements, environmental risks and increased exposure to disasters with adverse impacts on the urban poor and the vulnerable. Notwithstanding the above, Kenyan cities and urban areas like elsewhere in Africa are yet to mainstream climate change in urban development plans, policies and regulations as prioritized in Kenya's long-term development plan (Wold Bank, 2021).

2. The Nexus of Urbanization and Climate Change

Cities are development hubs as corroborated by agglomeration of land uses within them. The agglomeration leads to both urban sprawl and internal densification to accommodate the increasing population and competition among land uses for strategic sites. The urban sprawl and re-densification compromise the urban sustainability which is a measure of urban condition as presented by air, water and thermal quality and the potential effects which such conditions may have on human health, urban ecosystem and biodiversity. The effect of urbanisation on global warming and climate change has raised challenges to urbanization theory with efforts being made on postulating models explaining the correlation between the two. Despite various postulations on the relationship existing between urban morphological variables, urban air quality and thermal values, majority of the models offering an explanation on the same are descriptive rather than quantitative. However, it is quantitative models as facilitated by the geospatial techniques which have a niche in validating the correlation towards aiding in the formulation of environmental policies for the mitigation of global warming and climate change.

Climate change is the long-term shifts in temperatures and weather patterns induced by anthropogenic activities and natural factors. However, since the 1800s, anthropogenic activities occasioned by agricultural development, deforestation, and combustion of fossil fuel to support industrialization and transportation have been the main driver of climate change. The combustion of fossil fuel generates Greenhouse Gas (GHGs) notably; carbon dioxide, sulphur dioxide, nitrogen dioxide and the Suspended Particulate Matter (SPM). Other GHGs, which act as blanket wrapped around the earth, trapping the heat emitted by the earth from escaping to the atmosphere and subsequently causing global warming are water-vapour, methane, and ozone gases. Further postulation is put forward by Oke (1997) that for every increment of 100,000 urban population, there is a corresponding 1°C temperature increase in the city. Climatologists have proved that while the average temperature of the earth's surface is now about 1.1°C warmer than it was in the late 1800s (before the industrial revolution), the years from 2011to 2020 were the warmest on record, with each successive decade being warmer than the preceding decade since 1850.

In densely populated cities of the tropics, urban infrastructure, morphology, topography, and climate interact to produce uncomfortable thermal and hazardous effects. This is because cities influence GHGs emissions and sinks both directly and indirectly (Sánchez-Rodríguez *et al.*, 2005). For instance, carbon dioxide which is a major component of the GHGs is a by-

product of urban anthropogenic activities such as industrial and transportation activities. Clearance of land for urban expansion and infrastructure development are drivers of regional land cover changes which reduces the global carbon sinks.

Empirical evidence shows that cities which constitutes 2% of the earth surface are responsible for 75% of global energy consumption and 80% of GHG emissions (Satterthwaite, 2008). This is occasioned by the distribution of development densities, land uses and building configuration which define a city's form. The city's form in turn, influence transportation mode used in the city, energy consumption and GHG emissions. Proximity of homes and concentration of services coupled with provision of efficient public transportation accentuated by compact (high density) urban development encourages walking, cycling and use of mass transportation, consequently leading to decline in fossil fuel consumption per capita (Gottdiener & Budd, 2005). However, this is complicated by the fact that urban centres are industrial hubs and GHG emissions coming from industries outstrip those from the transportation sector. A study of GHG emission in Toronto city concludes that low density suburban developments consume between 2.0 to 2.5 times more energy annually than densely developed neighbourhoods. This is because high development density encourages low car ownership and requires less energy for heating, cooling and to power the buildings (VandeWeghe & Kennedy, 2007).

Inasmuch as density is the best tool for shaping urban morphology, agreements on whether to adopt low or high development density is emotive. Views on the impacts of urban development densities have tended to be polarising as noted by the works of Howard (1898) and Jacobs (1996). While Howard (1898) argues that it is universally agreed by men of all parties that it is deeply deploring that people are still streaming in already overcrowded cities, Jacobs (1996) whose work, The *Death and Life of Great American Cities* is taken as a mantra for new urbanism movement (those opposed to the suburban sprawl and restrictive residential enclaves) is passionate in the defence of high development densities. As noted by Burton (2000), inasmuch as high urban development densities lead to reduced living spaces, it has the ability to improve public transportation, reduce social segregation and enhance access to utilities and amenities. Based on the lessons learnt from the European and North American cities, it is imperative to find a middle ground between the low density and high-density development models. While high density development is viewed as anti-suburbanisation and an indicative of claustrophobic squalor, poverty, and deprivation, low-density urbanism is equated with selfish gated communities and the environmentally disastrous car-orientated suburbs (Dodman, 2009).

While low development densities are viewed as the main causes of urban sprawl, which is associated with social isolation, demise of farmlands and extinction of wildlife, global warming and climate change, the definition and the effects of urban sprawl on environmental quality are widely debated. For example, some scholars argue that urban sprawl is inevitable for it is an outcome of free-market mechanism (Gottdiener & Budd, 2005). Frenkel and Ashkenazi (2008) states five parameters for detecting urban sprawl as growth rates, development density, spatial geometry, accessibility, and aesthetics. In low and middle-income countries, peri-urbanization is increasingly taking place and the boundaries between urban and rural areas are continually being re-negotiated. The interfaces between the two are often afflicted by slums, inadequate urban services, and degradation of farmlands. This is because planning regulations are inadequately enforced in the peri-urban neighbourhoods for such neighbourhoods are outside the legal and administrative boundaries of the cities.

High urban development density is beneficial to the conservation of open spaces and natural resources, enhancement of social relationships and enabling urban authorities to deliver more housing stock, services, and employment stations within walking distances. However, high development densities exacerbate overcrowding and noise. Equally, changes associated with urban developments have profound effects on urban surface temperatures and air quality which consequently have effect of inducing global warming and climate change. New surface materials associated with urban buildings, roads and other urban infrastructure alters the natural surfaces (vegetation) which consequently alters energy balance, water exchanges and airflow. New surfaces have high thermal properties due to their ability to store more solar energy and converting the same to sensible heat.

Further, urban topographical features such as surface roughness, building configuration and anthropogenic activities contribute to higher urban surface temperatures by generating and attenuating outgoing long wave radiations. The skyscrapers provide multiple surfaces for reflection and absorption of terrestrial energy. This hinders the loss of sensible heat and distribution of the same, resulting into increased urban surface temperatures. Equally, building configuration further attenuates wind velocity and cause turbulences which restrict air pollutants to building canyons, leading to the accumulation of the pollutants in the city. According to Klaus *et al* (1999), stale and polluted air accumulates in the highly built-up areas due to convergence of air into the areas during the day for they are warm and acts as urban heat islands. The areas thus experiences warm rising air during the day but this may be replaced at night by cool fresh air from adjacent cold neighbourhoods. It is therefore evident that the urban air quality and surface temperatures is determined by both anthropogenic and physical processes through alteration of natural ecology of cities and long-term energy exchanges taking place within the boundary layer which consequently influence local, regional and global climatic and terrestrial systems. The above results in distinct urban climates of which cities are warmer than the surrounding rural areas but with internal urban spatiotemporal variations (Oke, 1997). On average, urban temperatures may be 1^0C to 3°C warmer than rural environs, but in calm and cloudless nights, air temperatures can be more than 10°C warmer than the rural environs (Vougt, 2002). The dynamics equally lead to the alteration of the precipitation regime in the urban metropolis as well as the frequencies of urban floods and changes in urban biodiversity (Zhao & Wang, 2002; Dixon & Mote, 2003). Therefore, global warming and climate change is a combined manifestation of the effects of GHG emissions and urban heat islands (Arnfield, 2003).

Inasmuch as high urban development density encourages compact form which reduces GHG emissions, high development densities cause urban heat-island effects as well as increased outdoor and indoor air pollution (Coutts *et al.*, 2007). As noted by Neumann (2005), compact urban form is not singly sufficient for the improvement of urban sustainability. Therefore, other strategies such as enactment of policies related to public transportation, building regulations and reduction of household energy consumptions must be entrenched in the urban development agenda if sustainability has to be realised (Campbell-Lendrum & Corvalán, 2007). For urban sustainability to be achieved, Jabareen (2006) identifies seven pillars that must be considered as urban form, public transportation, development density, mixed land uses, diversity, passive solar design and greening. Indeed, doubling a neighbourhood's density combined with green buildings and smart-growth technologies decreases automobile usage by 30%, thus decline in gasoline consumption and GHG emissions (Walker &King, 2008).

The urban spatial structure equally influences the GHG emissions. This is demonstrated by energy usage differentials in four urban spatial structures notably mono-centric, poly-centric, composite (multiple-nuclei) and urban village models. In the mono-centric cities, most economic activities and amenities are concentrated in the Central Business District (CBD). In this scenario, the authorities focus on promoting public transportation as the most convenient mode of transportation, for most commuters travel from the suburbs to the CBD while in the poly-centric cities, few jobs and amenities are located in the centre and most trips are from suburb to suburb. In this regard, a large number of possible travel routes exists, but with few passengers per route. Therefore, public transportation becomes expensive to operate, making private means of transportation the convenient option for users.

The composite model manifests a dominant centre with a large number of jobs located in the suburb's minor centres. Therefore, most trips from the suburbs to the CBD are made using public transportation, while trips from suburb to suburb are made using private means of transportation. The urban village model is utopian construct of the urban master plans in which urban areas contain many business centres and commuters travel only to a centre closest to their residence, thus creating opportunities to walk and cycle to work. The model presents ideal scenario requiring less motorised modes of transportation due to the reduced distances travelled to work. This lowers the energy usage and the GHG emissions. The more the urban spatial structure encourages public transportation, cycling or walking, the more it lowers the emission of GHGs, air pollutants and climate change.

The primacy of vegetation in the nexus of urbanisation and climate change is profound for vegetation mitigates the heating and polluting effects generated by the urban developments through a combination of photosynthesis, evapotranspiration, and shading effects. Vegetation through photosynthesis sequences carbon dioxide gas in the atmosphere, thereby mitigating the GHG effects (Weng *et al.,* 2004). Vegetation facilitates urban cooling through evapotranspiration which converters solar radiation into latent heat of vaporisation. The latent heat of vaporisation then escapes with the sensible heat to the atmosphere (Chudnovsky *et al.,* 2004). Therefore, vegetation density differentials within urban neighbourhoods explain the surface temperature variations among the same. Vegetation also has effect on wind velocity and precipitation regime of urban areas which in turn affects the urban air quality (Moll, 1997). Further to mitigating climatic parameters, vegetation also impacts on urban storm water management. For example, in Baltimore, it was determined that neighbourhoods with 40% tree cover reduce surface runoff by 60% more than neighbourhoods without trees. Indeed, the alteration of land cover indirectly modify the urban climate. Kalnay and Cai (2003) estimates that in the United States of America, land-cover changes have resulted in 0.27°C mean annual surface warming. This is supported by Narisma and Pitman (2003) having observed the impacts of land cover change on temperatures in Australia. Other studies such as Sailor and Fan (2002) and Unger *et al.* (2001) concludes that for large urban areas, depletion of vegetation cover increases surface temperatures by between 1.67°C to 2.22°C during summer and by 5.6°C during winter.

3. The Effects of Climate Change to Sustainable Development in Africa

Africa which is experiencing rapid population growth rate of 2.8% per annum in the background of increasing poverty and shrinking natural resources has experienced ravages of climate change aggravated by the COVID-19 pandemic, yet the continent accounts for about 2% to 3% of global GHG emissions (FAO, 2022). It is evident that Africa's climate has warmed more than the global average since pre-industrial times (1850-1900) and it is

projected that extensive parts of the continent will exceed 2°C of warming above pre-industrial levels by the last two decades of the 21st century (IPCC, 2019). Continued global warming and climate change is likely to heighten the prevalence of disasters hitting the vulnerable hardest. Indeed, the ravages of climate change will be borne by the urban centres where the displaced population will congregate as climate refugee, heightening urbanization of poverty. Some of the effects of climate change include increased temperatures and drought frequencies, retreating mountain glaciers, sea level rise, occurrence of extreme weather exemplified by heat-waves, wildfire, and dust storms especially in predominantly desert countries of Tunisia, Algeria, Morocco and Libya. Other effects include high rainfalls leading to severe floods and elevated water levels of lakes and rivers and invasion of desert locusts. Drought also causes dwindling water stress and food insecurity.

At global warming mean temperature of 2°C, significant climatological changes will occur in all Sub-Saharan regions. According to the IPCC (2019), Western Sahel region will experience increased length of dry spells. Similarly, Central Africa will witness decreased length of rainy seasons but with a slight increase in the amount of rainfall. West Africa which is a climate change hotspot is likely to experience decline in crop production leading to food insecurity. At 2°C of warming, Southern Africa is projected to face a decrease in precipitation of about 20% and increases in the number of consecutive dry days in Namibia, Botswana, northern Zimbabwe, and southern Zambia. This will cause reductions of between 5% to 10% in the volume of the Limpopo and Zambezi Rivers (FAO, 2022).

Climate change is likely to increase the intensity of natural hazards such as storms, cyclones, tsunamis, flooding, and erosion in the coastal cities (Satterthwaite *et al.*, 2007). According to IPCC (2007), a rise in global average temperatures by 2°C will exacerbate coastal flooding while temperature rises of more than 3°C may result in loss of about 30% of global coastal wetlands and agricultural land as occasioned by water logging and salt stress. Other likely effects of temperature rise are inadequate freshwater supplies, destruction of property, loss of human lives and increased prevalence of environmental, malnutrition and cardio-respiratory diseases. Further to temperature rise associated with global warming and climate change inducing frequent and intense heat waves, it also results in additional cost of environmental control within buildings as well as increased concentration of air pollutants in the urban canyons (Kovats & Akhtar, 2008).

Drought, floods, increased pests, and diseases associated with global warming and climate change have resulted in food insecurity and loss of livelihoods at the regional, national, and individual household levels. By the middle of the 21st century, major cereal crops grown in Africa will be adversely impacted albeit with regional variability and differences among crops. Under the worst-case climate change scenario, a reduction in mean yield of maize is projected at 13% in West and Central Africa, 11% in North Africa and 8% in East and Southern Africa. Millet and sorghum will experience comparative minimal yield loss of 5% and 8%, respectively by the year 2050 due to their greater resilience to heat-stress conditions, while rice and wheat are expected to be the most affected crops with a yield loss of 12% and 21%, respectively. The impact of this is already manifesting in the number of undernourished people who have since increased by 45.6% since the year 2012 in Sub-Saharan countries (FAO, 2022). Drought, desertification, and scarcity of resources has further heightened conflicts between crop farmers and pastoralists. In concert with prevalence of armed conflict and military operations in Africa, millions of people have been displaced and require humanitarian assistance.

Whereas sea-level rise reached 5 mm per annum in several oceanic areas surrounding Africa, it exceeded 5 mm per year in the south-western Indian Ocean from eastwards Madagascar and beyond Mauritius. This is more than the average global sea-level rise of 3 mm to 4 mm per year. This has exacerbated coastal flooding, erosion and salinity, which is expected to worsen in the future with implications on coastal towns, notwithstanding the impact the phenomenon have on agriculture sector, ecosystem, and biodiversity. This has been complicated by other extreme events such as cyclones of which Tropical Cyclone Idai is cited as among the most destructive tropical cyclones ever recorded in the southern hemisphere and which resulted in hundreds of casualties and thousands of displacements (IPCC, 2019).

Increase in temperature and changes in rainfall patterns will significantly affect population health across Africa, for warmer temperatures and higher rainfall provides conducive habitat for pathogens, insects and the transmission of vector-borne diseases such as dengue fever, malaria and yellow fever. In addition, new diseases are emerging in regions where they were previously not present. In 2017, an estimated 93% of global malaria deaths occurred in Africa. Similarly, warming in the East African highlands is allowing malaria-carrying mosquitoes to survive at higher altitudes. Africa being an exposure and vulnerability hot spot for climate variability and change impacts, the continent is destined to significantly experience declining Gross Domestic Product (GDP) occasioned by the global temperature increase (International Monetary Fund, 2023). For scenarios ranging between 1°C and 4°C increase in global temperatures relative to pre-industrial levels, the continent's overall GDP is expected to decrease between 2.25% and 12.12% with West, Central and East Africa exhibiting higher adverse impacts than Southern and North Africa (African Climate Policy Centre, 2021).

The compounded impacts of temperature increase, heat waves, floods, tropical cyclones, droughts, and sea level rise resulting in loss of property and lives as well as population displacement is undermining Africa's ability to achieve the targets of the sustainable development goals and the African Union's Agenda 2063, which outlines Africa's path for attaining inclusive and sustainable economic growth and development. Water stress in Africa occasioned by frequent droughts, receding lake, and river volumes, disappearing glaciers and devastating floods, rising water demand combined with limited and unpredictable supplies threatens to aggravate water-based conflict, displacements, which undermine human health and safety, food security and other socio-economic development parameters, making urban communities, economies and ecosystems increasingly vulnerable.

4. International and National Agenda for the Mitigation and Adaptation to Global Warming and Climate Change

In its 13^{th} goal on climate action, the sustainable development goal agenda endeavours to combat climate change and its impacts by limiting global warming to between 1.5^0C to 2^0C. Recognizing that the years from 2015 to 2021 were the warmest accompanied by devastating climatic impacts, 196 countries came together in the year 2015 and signed the Paris Agreement which was adopted on 12^{th} December 2015 into the United Nations Framework Convention on Climate Change (COP21), a development which is significant for the reduction of GHG emissions and building of climate resilience cities. All the African nations, except Angola, Eritrea and South Sudan are signatory to the agreement.

The twenty second session of the United Nations Framework Convention on Climate Change (COP 22) took place in Marrakesh, Morocco on 7^{th} to 18^{th} November 2016. This marked the

beginning of the preparations for the entry into force of the Paris Agreement and implementation of actions for addressing climate change. Further, the United Nations Framework Convention on Climate Change (COP23) which took place in Bonn, Germany, from 6th to 18th November 2017 and which brought together leaders of national governments, cities, states, businesses, investors, NGOs, and civil society further accentuated the resolves of COP22.

The United Nations Framework Convention on Climate Change (COP24) which took place on 2nd to 14th December 2018 in Katowice, Poland was instrumental in finalizing the rules and work plan for the implementation of the Paris Agreement. The convention also called for increased financial support from developed countries in assisting climate action efforts of developing countries. Since the year 2015, the Nationally Determined Contributions (NDCs) have become the main instrument for guiding policy responses to climate change. Towards this end, 52 African countries have submitted their first NDCs. The United Nations Framework Convention on Climate Change (COP25) which took place from 2nd to 16th December 2019 in Madrid, Spain came at a time when emerging data exhibited worsening impact of climate change. This was authenticated by COP26 which took place from 13th October to 13th November 2021 in Glasgow, the United Kingdom. The COP26 brought together 120 world leaders and over 40,000 participants from diverse sectors.

The United Nations has continued to encourage all stakeholders to take action towards reducing the impacts of climate change. This is corroborated by COP27 which was held in Egypt's coastal city of Sharm el-Sheikh from 6th to 18th November, 2022. In attendance were the Heads of States, Ministers, and Negotiators, along with Climate Activists, Mayors, Civil Society Representatives and Chief Executive Officers of various companies. The convention built on the outcomes of COP26 on delivery of issues critical to tackling the climate emergency notably; the need to urgently reduce GHG emissions, building climate resilience, climate change adaption and delivering on the commitments to finance climate action in developing countries. In concert with United Nations conventions, the Africa's Agenda 2063, which was concluded in 2013 has also recognized climate change as a major challenge to the continent's socioeconomic development and has called for invigorating efforts towards the mitigation of the same. This is demonstrated by ratification of the Paris Agreement by over 90% of the African nations with commitments to transition to green energy and agriculture within a relatively short time frame as prioritized in over 70% of the African NDCs.

Other initiatives for mainstreaming climate change mitigation and adaptation into urban development agenda is the urban resilience initiatives, which have been adopted by many global cities participating in the 100 Resilient Cities (100RC) Network, pioneered by the Rockefeller Foundation to build cities' capacity in becoming resilience to the environmental, physical, social and economic challenges, of which climate change is part of. Apart from climate change, the 100 Resilient Cities Network supports cities in building resilience capacity to mitigate and adapt to shocks such as floods, fires, riots, and stresses such as urban poverty, unemployment and aging population among others.

The realization that real action for climate change mitigation and adaptation should involve collaborations between national and county governments, business community, the civil society, and communities in reducing GHG emissions, initiatives at building climate resilience in Kenya include but not limited to the following: -

i. Article 42 of the Constitution of Kenya 2010 guarantees the citizens clean and healthy environment. This empowers persons to seek legal redress in the courts of law when their right to a healthy and clean environment is violated or infringed upon. The courts are empowered to issue orders that prevent, stop or discontinue acts that are injurious to the environment and provide compensation to an offended party.

ii. Climate Change Act of 2023 – the Act is paramount for the development, management and implementation of mechanisms to enhance climate change resilience and low carbon emissions in Kenya. It is a precursor for the Kenya National Action Plan on climate change which aims at strengthening the country's pathways to sustainable and climate resilient development.

iii. Environmental Management and Coordination Act (EMCA) of 1999 – A comprehensive environmental law providing legal framework for environmental management in Kenya. It covers various environmental issues including air pollution and empowers regulatory authorities to enforce compliance and take necessary actions to protect the environment.

iv. Urban Areas and Cities Act - An Act of Parliament giving effect to Article 184 of the Constitution. The Act provide for the classification, governance and management of urban areas and cities. One of the fundamental issues of governance considered in the Act is environmental management

v. Physical Planning and Land Use Act of 2019 regulates development of land for sustainability of which environmental consideration is part of.

vi. National Climate Change Response Strategy

vii. National Policy for Disaster Management

viii. Development of Kenya County Climate Risk Profile Series

ix. Development of Urban Resilience Strategies for five cities in Kenya, namely Nairobi, Mombasa, Kisumu, Nakuru and Eldoret since the year 2021

x. Nairobi Climate Action Plan 2020-2050

xi. Mombasa County Climate Change Action Plan

xii. Mombasa-Climate-Change-Policy, 2021

xiii. Kisumu Sustainable Mobility Plan 2021

xiv. The Kisumu County Disaster and Emergency Management Act, 2015

xv. Kisumu climate change policy

xvi. Kisumu County Climate Change Action Plan

xvii. Kisumu County Climate Change Act

5. Mainstreaming Climate Change Mitigation and Adaptation in Urban Management Policies

As acknowledged by global frameworks and agreements such as the sustainable development goals, the United Nations Framework Convention on Climate Change and the Paris Agreement, mitigating and adaptation to climate change needs implementation of multiple strategies and techniques. Such strategies include promotion of green infrastructure, innovative urban design and conservation, tightening up legislations on protection of urban ecosystems such as the green belts, gardens and trees, urban river restoration and implementation of sustainable drainage and transportation networks. Other measures include cutting GHG emissions by reducing the utility of fossil fuels such as coal, oil and gas and switching to renewable energy such as solar energy. Indeed, the policy approach should promote investment in sustainable solutions such as ending subsidies on fossil fuel and ensuring that polluters pay for their pollutions. Other measures include popularization of the use of public transportation, reduction of household energy consumptions, investment in green transition which accelerate the decarbonization of all aspects of the economy, creation of green economy, jobs and inclusive growth as well as strengthening transboundary collaboration and corporation for climate resilience in realization that no country can succeed alone in climate change mitigation and adaptation.

Additional measures for building resilience to climate change include strengthening early warning systems, data exchange and knowledge sharing. Climate change mitigation and adaptation further requires a new environmental contract encompassing civil society, public and private sector participations as well as reorientation of legal, institutional and development infrastructure towards delivering urban environmental quality. This should build on the strengths of planning and other environmental management strategies which give more scope and encouragement to local action, behavioural change and innovation. Therefore, building climate resilience cities should be anchored on proactive policies focussed on socioeconomic development strategies and institutional capacity building for planning, both at the community, city, county and national government levels.

Inadequate consideration of climate change in national, county and city plans lead to potential increase in vulnerability, risks and a reduction in coping capacities of urban communities and socioecological systems, yet development policies, urban plans and climate programs are examples of immediate adaptation interventions. Therefore, there is need to change the way current development and climate policies are positioned and prepared across cities in Africa as well as changing the capacity of urban plans and planning practices to respond to climate risk. Climate change awareness, analysis and action need to be improved together with enactment of dynamic, comprehensive risk assessment and flexible climate adaptation strategies.

Enhancement of vegetation cover within the city through adoption of sustainable urban growth policies is imperative in the climate change mitigation and adaptation. Recent studies show that nature-based solutions can contribute up to 37% reduction on GHG emissions required to keep global warming below 2^0C (IPCC, 2019). This is occasioned by the vegetation's ability to sequestrate carbon dioxide and subsequently reducing the GHG effects

to mitigate global warming and climate change. Further, vegetation moderates surface temperatures, making vegetation density the most significant urban morphological variable influencing urban thermal values. However, this may be negated by urban sprawl characterising many cities of the south. Therefore, measures such as the design and implementation of appropriate, innovative and dynamic development policies geared towards increasing the vegetation cover should be prioritised. Such policies should entail implementation of programmes such as development of urban forests, arboretum, open parks, playgrounds and/or village squares and picnic sites in the residential, commercial and industrial neighbourhoods as well as tightening up legislations protecting urban ecosystems such as the green belts, gardens and urban river restoration among others. The above can be achieved through implementation of development policies which minimises land fragmentations and urban sprawl such as up-scaling of sky lines through increments of plot coverages, ratios and minimum plot sizes for various developments.

Hindrances to the enhancement of the vegetation cover in the cities are *ad-hoc* enactments of the development control policies and regulations, inadequate implementation of the development plans and land speculations which accentuate proliferation of illegal developments, leading to undesirable land use and land cover conversions. To rectify this, the cities should regularly update the existing development plans and enforce strict adherence to the development control standards. This should also include shortening the time in plan approval process to minimise illegal developments. The evolved development plans should spell out the number of trees to be planted per acreage of a developed plot. In accordance with the provisions of Environmental Impact Assessment Regulations of 2003, all the proposed developments within the cities which are likely to generate significant GHGs should be subjected to environmental impact assessment and enforced by National Environment Management Authority in conjunction with the city authorities.

Privatisation and restitution concepts which have found niche in the management of public affairs have altered the urban housing market. The concepts empower the private sector to be the main providers of the urban housing, yet the sector is more interested in providing housing for the middle and high-income groups. This has made housing unaffordable to the urban poor who move to the urban periphery and/or open lands to establish informal settlements, consequently leading to rapid land use and land cover changes as well as environmental degradation. Therefore, the government should roll-out sustainable urban low-income housing development programmes if the environmental degradation and encroachments into the fragile ecosystems which are carbon sinks has to be managed.

Industries and motor vehicles emit GHGs and suspended particulate matter, contributing to global warming and climate change. Therefore, cities should formulate policies and enact legislations and standards for the reduction of air pollution. The policies should include popularisation of public and none-motorised modes of transportation as well as limiting the number of vehicles coming into the city. Other transportation policy measures should include the development of arterials which supports rapid vehicular flow for it has been established that vehicles emit more GHGs and suspended particulate matter when their speeds are low. However, for the above to be undertaken, there is need for frequent air quality monitoring which can be achieved through the establishment of adequate network of stationary air quality monitoring stations as well as undertaking mobile air quality monitoring along road transects and in the industrial plants.

Climate information is the foundation of climate change resilience building. However, limited uptake and use of climate information services in development planning in Africa is partially due to the paucity of reliable and timely climate information. Despite climate action gaining momentum, only 40% of the African population have access to early warning systems to protect them against extreme weather and climate change impacts (IPCC, 2019). This necessitates prioritization of universal access to early warnings and revision of the national climate plans. Additionally, there is need for increased investment in hydrometeorological data collection and improvement of climate services provision in Africa. Currently, 28 countries provide climate services from basic to essential level. While only 9 countries provide the services at full level, only 4 countries are providing end-to-end drought forecasting services at advanced capacity (IPCC, 2019).

In undertaking regular reviews of development plans and standards as earlier proposed, cognisance should be taken of land use suitability. This is impetrative in protecting the fragile ecologies such as the forest and riparian reserves against encroachment by anthropogenic activities. The land use suitability analysis is also imperative in protecting human life and property against disasters such as floods. However, the above can efficiently be undertaken if the city authorities institute the utility of geospatial, information and communication technologies notably; Remote Sensing and Geographical Information Systems as planning tools in line with sustainable development goals stipulations. This is also imperative in climate proofing urban planning strategies and promotion of evidence-based decision-making (Oyugi, 2018).

As occasioned by increased frequencies of sewer blockages and bursts, there are indications that developments in the African cities are surpassing the capacity of the existing infrastructure. Therefore, for the cities to continue supporting the current population through re-densification of the existing land uses to curtail urban sprawl, expansion and regular maintenance of the urban infrastructure such as water, sewer and roads should be prioritised. In order to finance such climate change mitigation projects, city authorities should actively seek out and utilize financial resources from international, national, own funding mechanisms, actively involve the private sector through public-private sector partnerships as well as establish capacity building programs and trainings to improve climate change awareness and analysis among urban planning practitioners, policy makers and the general public.

Despite the constitutional stipulations on the involvement of the citizens in the development plan formulation and implementation, it is glaring that the current climate change mitigation and adaptation paradigms operational in the Kenyan cities are not people driven and various development agents feel left out in the process. Therefore, in the evolution and review of the climate action plans for the cities, the people and various development agents should be brought on board. This makes it easy for people and the development agents to understand the issues entailed in the plans and to take charge in implementing the same. Therefore, city authorities should reactivate policy on partnership building with citizens and other development agents as well as registering the neighbourhood associations and empowering the same to undertake self-driven development control and climate change compliance monitoring. It is equally imperative to explore broad based (in issues and stakeholders) and participatory institutional framework on which various strategies that are meant to enhance the cities' climate resilience can be implemented. Further to the above, the capacity of cities should also be strengthened to ensure effective implementation of climate change mitigation and adaptation policies and plans.

A promising approach to the reduction of climate risks and hazards posed by extreme weather events in Kenya is the reduction of poverty through promotion of socioeconomic growth in the agricultural sector which employs approximately 60% of the population (World Bank, 2016). This should entail the utility of value-addition techniques using green energy sources in the agricultural production. For example, solar-powered, efficient micro-irrigation is increasing farm-level incomes by between 5 to 10 times, improving yields by up to 300% and reducing water usage by up to 90% while at the same time offsetting carbon emissions by generating up to 250 kW of clean energy (International Monetary Fund, 2023).

Conclusion

While strategizing mitigation and adaptation to climate change, cognizance should be taken of the correlation existing between urbanization, global warming and climate change. Therefore, with growing urbanization, global warming and climate change are likely to reach significant levels with varied consequences. However, urbanization is inevitable and cities shall continue being anchors to socioeconomic development as corroborated by the concentration of industries and being transportation hubs to their hinterlands. This will exacerbate the GHG emissions if sustainable strategies are not enacted to mitigate the same. Mitigation of climate change is possible with concerted partnership building efforts among various stakeholders at international, national and city levels. This is because GHGs responsible for climate change are transboundary and multisource phenomenon. Indeed, efforts should be geared towards data and knowledge sharing on the best practices. The primacy of public awareness and participation on the policies enacted to mitigate and adapt climate change is imperative in achieving the objective. As much as high urban development density encourages compact urban form which reduces GHG emissions, it is not a panacea to the mitigation and adaptation to climate change. As such, other strategies popularising public transportation and reduction of household energy consumptions must be entrenched in the urban development agenda.

References

African Climate Policy Centre, (2021). State of the Climate in Africa 2021, World Meteorological Organization (WMO), Geneva, Switzerland

Arnfield, A. J (2003). Two Decades of Urban Climate Research: A Review of Turbulence, Exchanges of Energy, Water, and the Urban Heat Island. *International Journal of Climatology* 23:1-26.

Burton, E (2000). The Compact City: Just or Just Compact? A Preliminary Analysis. *Urban Studies,* 37(11): 1969-2001

Campbell-Lendrum D & Corvalán, C (2007). Climate Change and Developing Country Cities: Implications for Environmental Health and Equity. *Journal of Urban Health.* 84(1):109-117.

Chudnovsky, A., Ben-Dor E, & Saaroni, H (2004). Diurnal Thermal Behavior of Selected Urban Objects using Remote Sensing Measurements, *Energy and Buildings*, 36:1063-1074

Coutts, A. M, Beringer J & Tapper N.J (2007). Impact of increasing urban density on local climate: spatial and temporal variations in the surface energy balance in Melbourne, Australia. *J. Appl. Meteor. Climatol*, 46: 477-493

Dixon, P.G & Mote, T. L (2003). Patterns and Causes of Atlanta's Urban Heat Island–Initiated Precipitation. *Journal of Applied Climatology*, 4(3):34-78

Dodman, D (2009). 'Blaming Cities for Climate Change? An Analysis of Urban Greenhouse Gas Emissions Inventories' *Environment and Urbanization,* 21(1):185-201

FAO (2022). Potential population-supporting capacities of lands in the developing world. Technical Report FPA/INT/513

Frenkel, A & Ashkenazi, M (2008). Measuring Urban Sprawl: How Can We Deal With It? *Environment and Planning B: Planning and Design*, **35:**56-79.

Gottdiener, M & Budd, L (2005). Key Concepts in Urban Studies. London, Sage

Howard, E (1898). Originally published in 1898 as To-Morrow: A Peaceful Path to Real Reform and reissued in 1902 under its present title, Garden Cities of Tomorrow. London, Routledge

International Monetary Fund (2023). Working Paper European Department Eye of the Storm: The Impact of Climate Shocks on Inflation and Growth Prepared by Serhan Cevik and João Tovar Jalles1 Authorized for distribution by Bernardin Akitoby April 2023, wpiea2023087-print-pdf.pdf

IPCC (2007). Climate Change 2007 Synthesis Report: Summary for Policymakers. Cambridge, Cambridge University Press.

IPCC (2019). Global warming: severe consequences for Africa, New report projects greater temperature increases, Global warming: severe consequences for Africa | Africa Renewal (un.org)

Jabareen, Y (2006). Sustainable Urban Forms: their typologies, models and concepts, Journal *of Planning Education and Research,* **26**:38-52.

Jacobs, J (1996). The Death and Life of Great American Cities. In LeGates R and Stout F (eds) The City Reader. London, Routledge.

Kalnay, E & Cai, M (2003). Impact of urbanization and land-use change on climate. *Nature* 423: 528-531.

Klaus D, Jauregui E, Poth A, Stein G & Voss, M (1999). Regular Circulation Structures in the Tropical Basin of Mexico City as a Consequence of the Heat Island Effect. *Erdkunde* 53: 231-243

Kovats, S & Akhtar, R (2008). Climate, Climate Change and Human Health in Asian cities. *Environment and Urbanization*, 20(1):165-175

Moll, G (1997). In search of an ecological urban landscape. In Moll, G and Ebenreck, S (Eds.). Shading Our Cities. Washington, DC, Island Press

Narisma, G.T & Pitman, A.J (2003). The impacts of 200 years of land cover change on the Australian near-surface climate. *J. Hydrometeorol.,* 4: 424-436.

Neumann, M (2005). The Compact City Fallacy, *Journal of Planning Education and Research* 25:11-26.

Oke, T.R (1997). Urban Climates and Global Environmental Change: Applied Climatology, Principles and Practices, New York, Routledge

Oyugi MO (2018) Modelling the Effects of Urban Morphology on Environmental Quality of Nairobi City, Kenya. PhD Thesis, School of Environmental Studies, University of Eldoret, Kenya

Sailor, D.J & Fan, H (2002). Modeling the Diurnal Variability of Effective Albedo for Cities, *Atmospheric Environment*, 36(4): 713-725.

Sánchez-Rodríguez, R., Seto K., Simon D., Solecki W., Kraas F & Laumann G (2005). Urbanization and Global Environmental Change, *IHDPGEC* Report 15, Bonn

Satterthwaite D., Huq S., Reid H., Pelling M & Romero L.P (2007). Adapting to Climate Change in Urban Areas: The possibilities and constraints in low- and middle-income nations. Human Settlements. Discussion Paper, IIED, London.

Satterthwaite, D (2008). Cities' contribution to global warming: Notes on the allocation of greenhouse gas emissions, *Environment and Urbanization*, 20(2), London, Earthscan.

UN - Habitat (2018) Global Report on Urban Resilience: Data Speak Louder Than Words 2.0. https://urbanresiliencehub.org/the-library/

Unger, J, Sumeghy Z & Zoboki, J (2001). Temperature cross-section features in an urban area, *Atmospheric Research*, 58: 117-127

United Nations (2015) Transforming our world: The 2030 agenda for sustainable development resolution adopted by the General Assembly on September 25, 2015, A/RES/70/1, New York: United Nations General Assembly. Available at https://unstats.un.org/sdgs/

VandeWeghe, J & Kennedy, C (2007). A Spatial Analysis of Residential Greenhouse Gas Emissions in the Toronoto Census Metropolitan Area, *Journal of Industrial Ecology*, 11(2): 133-144.

Vougt, J (2002). Urban Heat Island. *Encyclopedia of Global Environmental Change*, Vol. 3, Chischester; John Wiley and Sons.

Walker, G & King, D (2008). The Hot Topic: How to Tackle Global Warming and Still Keep the Lights On. London, Bloomsbury Publishers.

Weng Q, Lu D & Schubring J (2004). Estimation of land surface temperature – vegetation abundance relationship for urban heat island studies. *Remote Sensing of Environment*, 89:467-483

World Bank (2016) Kenya Urbanization Review. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/23753 License: CC BY 3.0 IGO

World Bank, 2021. Urbanization in Africa 2021, by country, World Bank, Washington, DC, Africa: urbanization rate by country 2021 | Statista

Zhao, J & Wang, N (2002). Remote Sensing analysis of urbanization effect on climate in Lanzhou. *Arid Land Geography*, 25(1): 90-95.