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REVIEW

Urban Development in Africa and Impact on Biodiversity

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Abstract

Purpose of Review Biodiversity remains an immense source of benefit to mankind and a major contributor to his well-being. Severe loss of biodiversity necessitated the conservation of a part of the biodiversity hotspots as protected areas. Despite this initiative, a sizable part of the conserved hotspots was still lost to anthropogenic factors among which is urban development. Therefore, we assessed the current status (2014–2021) of the biodiversity hotspots in the African region by estimating landmass loss in km^2 per biodiversity hotspot, identifying the direct-and-indirect impacts of urban development on biodiversity, while also giving recommendations for further research.

Recent Findings Africa has the fifth-highest urban-population presently. Thirteen countries on the continent will become heavily urbanized within the next three decades (2016 to 2050). Perennial urban problems remain a structural constraint to Africa's urban development; hence, African biodiversity hotspots suffer both direct-and-indirect consequences of urban development. Only 13% (86,859 km^2) of the protected areas of the biodiversity hotspots remains from a total of 665,845 km^2. Furthermore, two out of the eight hotspots in Africa (Eastern Afromontane and Guinean forests of West Africa) are among the three global hotspots predicted to experience intense (about ten times) urban encroachment and possible loss of all their endemic species.

Summary We implore future research to focus on regional studies (aside from global studies) because regional studies would provide more in-depth-analysis of the hotspots, provide mapping data and reveal their current status in terms of landmass and the surviving endemic species, among others. Furthermore, the issue of climate change in the urban development biodiversity mix needs more research. Finally, there is an urgent need for sustainability and policy development studies that would advise on the appropriate management modalities for the hotspots in the face of continuous urban development.

Keywords Biodiversity · Urban growth · Development · Ecosystems · Impact · Africa

Introduction

Biodiversity represents the contraction of biological diversity source of multiple benefits without which human existence and well-being could be at risk [1, 2•], though extant literature reveals that there is no generally accepted definition for the term "biodiversity" since it does not provide itself specific meaning. Conversely, one of the regularly most cited definitions for the term is the convention on biodiversity [3] which described biological diversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." It was also tagged as "a comprehensive umbrella term for the extent of natures' variety or variation within the natural system; both in number and frequency" [4]. Furthermore, it could be described as the baseline of a complex network of life upon which humans and other interacting living phenomena depend [4].

The suggested extent of biodiversity in existence is mind boggling. Mora et al. [5] stated that about 2.1 million species of living creatures which are mainly diminutive organism like insects have been identified, though scientists believe the species count is approximately 13 million, while UNEP

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(United Nations Environmental Program) put the estimate between 9 and 52 million species. Despite this disparity in the estimated species population, one surety is that biological resources are indeed diverse; hence, the multiplicity of usefulness that has been ascribed to them is justified. Furthermore, the enormity of the beneficial services rendered by biodiversity is the volume of works available on the subject matter which attempt to conceptualize it and give cogent explanations on it. For instance, different research scholars categorized biodiversity's benefits differently. Tackacs [6] divided biodiversity valuable nature into two classes: intrinsic and anthropocentric; Rawat and Agarwal [4] established four major categories of biodiversity benefits vis-à-vis utilitarian benefits, ecosystem services, ethical and moral benefits, and aesthetic value.

According to Tackacs [6], the intrinsic value of biodiversity is the natural value of biological resources to co-exist with mankind as preplanned by the creator, while on the other hand, the anthropocentric value addresses the economic values of biodiversity resources. The work of Rawat and Agarwal [4] noted that the utilitarian benefits exemplify the influence of biodiversity to the material well-being of humans. This is made possible through the provision of a variety of materials that serve as food, medicine, and raw materials via ecosystem services and is regarded as the processes and conditions that support human activities to thrive [7, 8•]. The services include provisioning, regulating, supporting, and cultural/recreational [8•]. On the other hand, it also provides services like long-term sequestration of carbon which helps moderate climate change, as well as an instrumental in the regulation of biochemical cycles, e.g., oxygen, nitrogen, and hydrological cycles [4, 9].

In addition, ecosystem biodiversity serves as windbreak, flood barriers, and an agent of pest control and regulation as well as promoting ecosystem resilience which is important in curbing extreme events such as drought, floods, and tsunamis [4, 10•, 11•]. The biodiversity ethics and moral benefits underscore the right of every organism to exist irrespective of whether it has profound importance to man or otherwise, while the aesthetic value has to do with great pleasure that humans derive in viewing the shape, structures, and colors of the different organism in the environment [12, 13, 14•]. This could be through leisure activities, spotting activities, hearing, touching, and wildlife sighting [4, 15]. The benefits accruable to mankind from biological resources available from the many ecosystems and biomes suggestively imply that their loss would have a huge telling effect on the well-being of humans.

Urban growth and development have been cited as one of the major drivers of biodiversity loss in the time past and the future [16•, 17–20, 21•, 22, 23]. Urban development in the words of Clark [24] is the process of emergence of a world dominated by cities and by urban values. This suggests that urban development involves the metamorphosis of human communities of smaller sizes like hamlets and villages into communities that are larger and possesses attributes that are considered urban. Urban development is, therefore, profoundly dependent on the twin forces of urban growth and urbanization which are the determinant of its speed and scale of occurrence [18, 25–27].

Urban growth involves the different varieties of growth taking place within the urban environment which could span population, land area, economic activities, and land use [28–31]. These descriptions align with that of Clark [24] who considers urban growth as "a spatial and demographic process." This is because urban growth involves the consumption of space (land) for different land uses (agricultural, industrial, commercial as well as residential landuses). Urbanization on the other hand can be defined as the process through which rural areas become urbanized as a consequence of economic development and industrialization [23, 32, 33]. Annez and Buckley [34] also described it as a basic process that induces the modern transformation of multidimensional structures within rural societies accompanied by changes in income distribution. Furthermore, urbanization involves the exodus of populations from rural areas to urban areas which often result in the alteration of the physical characteristics of the urban setting [23, 33, 35]. Theoretically, urban growth is a possibility without urbanization; however, this is very rare especially as most regions of the world have experienced the two simultaneously in the last few decades [29, 36, 37]. Therefore, the processes are almost inseparable because the lure of urbanization induces urban growth.

The prospect of urban development is largely dependent on the existence of certain conditions that are summarily referred to as "urban push and pull factors." Some of the major ones include resource abundance, industrialization, commercialization, social benefits and services (like functional transportation and telecommunication systems and better healthcare services), the existence of abundant and viable economic opportunities, modernization and changes in living standards, and access to more formidable educational and recreational facilities [23, 32, 33]. Others are land pressure/natural disasters, geographical and environmental factors, demand for labor, infrastructural development (like banks, post office), psychological factors, and transformation of rural landscapes to urban areas as a result of the growth of existing villages and towns [33, 35, 38, 39].

The aforementioned factors are indicative of the transformative benefits of urban development which JICA-RI [40] described as significant growth potentials, poverty alleviation prospects, and the possibility of environmental sustainability. However, these benefits come at a significant cost to the environment, as it induces negativities like air, water, land, and noise pollution; deforestation and wetland destruction; local climate alteration; erosion and flooding; urban sprawl; slum and squatter settlement; traffic congestion; heat island; and aesthetic degradation [41–45]. These problems are common place in urban centers of developing countries like those on the African continent. For instance, in Nigeria, rapid increase in population has led to the development of several infrastructural facilities so as to provide comfort to insatiable humans wants. These have led to the destruction of ecosystems with its proximate biodiversity for urbanization and other commercial activities. Also, the prevalent environmental issues are categorized as ecological and include poaching and habitat loss, increasing desertification and soil erosion [41, 45]. These are further subdivided into pollution, deforestation, global warming, slum development, etc., all of which pose various degree of threats to biodiversity conservation [46]. This situation is not peculiar to Nigeria alone; Flintan [47] identified land speculation as a recurrent decimal in Ethiopia, Kenya, and Uganda and described it as an activity that is driven by wealthy urban residents and abetted by poor land-use planning and control whereby lands close to cities and towns are acquired for developmental purposes. Land-use conversion is also common in West Africa; a notable one is the conversion of forests to agricultural land-use to augment food demands and supply [48, 49]. Another critical pattern of degradation in the environment manifests through deforestation for transportation routes construction and expansion [49, 50, 51].

The aforementioned activities and their attendant consequences have huge implications for biodiversity which implies that urban development affects biological diversity. For instance, the land converted to varieties of land uses (like buildings of residence, industries, agricultural land, construction of roads, schools, and electricity projects) is sometimes biodiversity ecosystems. The worrisome aspect is that urban development has been predicted to be an unstoppable force [40]; this is already observable in the changing residential pattern across the globe as more people now live in urban centers. The report of the United Nations Department of Economics and Social Affairs [52•] captured these changes in dwelling patterns and essentially revealed that the urban population has increased from 751 million in 1950 to 4.41 billion in 2020, which represents a 56% increase with predictions that it would increase to 68% by 2050. The United Nations Population Division [53] gave similar urban population statistics which show that the world urban population has increased from 2.9 billion in the year 2000 to 4 billion in 2015 and is expected to grow to 5.2 billion by 2030. This implies that this demographic trend that is already a menace to biological resources could metamorphose further.

The need to curtail the rate of exploration and exploitation of the biological resources available in the human environment and its many attendant consequences led to the introduction of the biodiversity hotspot concept by Norman Myers [138]. The biodiversity hotspot concept is a conservation strategy that was suggested as a measure to arrest the rate of loss of biological resources and avoid its consequences on human well-being; this initiative was subsequently adopted by Conservation International [128, 137]. The areas designated as biodiversity "hotspots" are the most biologically rich places in the world, hosting many endemic or threatened species. The criteria to qualify as a biodiversity hotspot include the presence of a minimum of 1500 species of vascular plants that are native (endemic species) to the area, out of which 70% of the original vegetation has been lost [75]. Therefore, biodiversity hotspots are sanctuaries for lots of biological species with limited geographic span due to their exposure to habitat alteration and the possibility of further loss which could result in outright extinction [75, 77, 78•]. Despite its seeming undeniable advantages, the concept was severely criticized by some other researchers for what they considered to be loopholes. Some of the notable ones include its consideration as an economic response to biodiversity conservation due to the investment of huge financial resources over the years [123]. Furthermore, Jepson and Canney [124] described it as a partial response to conservation and should not be mistaken a comprehensive cure to the issue of conservation. There is also the exclusion criticism which highlights the fact that the impacts of invertebrates like herbivorous insects and fungi as well as nematodes are downplayed [125]. Despite all these criticisms, the hotspots concept has flourished, and currently, 36 such hotspots are scattered across the world with eight (8) in Africa.

The peculiarities of Africa as typified by the continent's demographic trends, urban development tendencies, corruption, and poverty imply that biodiversity exploitation will likely continue [48–50]. Therefore, loss of biodiversity is expected to continue in the incoming decades because the drivers of these losses (like urban growth and economic development and others mentioned earlier) are expected to grow further at a pace that may impact the environment in numerous ways like land use, consumption of energy and climate change, increased food demand, air pollution, and water security [54–59]. Therefore, this review focused on updating existing and recent knowledge on the impacts of urban development on biodiversity in Africa by pursuing the following objectives (i) identify and predict African urban growth and development, (ii) conduct a thorough literature-based assessment of the impacts of urban development on African biodiversity, and (iii) offer a synthesis of African biodiversity loss and urban development with references to biodiversity hotspots and trends in hotspot protection.

Methodology

This research study adopted a desktop review methodology. Data on keywords vis-a-vis biodiversity, urban development, urban growth, and urbanization as well as other related and useful information on subject matters gleaned from the literature that is sourced from online databases as well as available existing hardcopies journals, textbooks, etc. Explicit online databases consulted for this study include but are not limited to Google, Google Scholar, ReseachGate, and Universities' Repositories. These research search engines provided useful access to relevant peer-reviewed journals and books that housed information from global bodies such as United Nations Environmental Programme (UNEP), United Nations Department of Economics and Social Affairs (UNDESA), United Nation Population Division (UNDP), UN-habitat, and Japanese International Cooperation Agency Research Institute (JICA-RI 40). The material search was conducted using the relevant keywords of the topic vis-à-vis biodiversity, urban growth, development, ecosystems, impact, and Africa with the most relevant categorized as materials usable for the subject matter. Based on the above, a total of two hundred and twenty-six (226) materials were sourced (downloaded and accessed directly). Of the 226 materials, 161 were used for this study, while 65 were not used (rejected). This was based on the fact that most of that information is duplicated as they already exist in one or two of the 161 materials, while some lack fact to support their arguments. Of the 161 used, 99 (61.49%) are journals, 21 (13.04%) are books, 31 (19.26%) are reports, while 4 (2.48%) and 6 (3.73%) are proceedings and others (e.g., unclassified papers, monograph, internet materials). And 11.67% addressed the issues mostly related to biodiversity, 21.67% were mainly on urban growth and development, 4.99% on ecosystems, and 61.67% identified mainly the issues of impacts of urbanization on biodiversity, ecosystems, and Africa at large. All the materials were acquired, collated, reviewed, and assembled appropriately as review papers between 13 February 2022 and 12 April 2022.

Results

(a) *Urban Growth and Development in Africa*

Africa is currently the continent with the fifth highest urban population which implies that the continent still has a sizable proportion of its population in the rural areas (57%); however, the continent has the second-largest population in the world after Asia and is regarded as one of the regions with the fastest rate of urbanization in the world [56, 60, 61•]. The implication of this is that Africa's urban population would still shoot up; a pointer to that is the report of the United Nations [62] which predicted that Africa's population is expected to triple from its 395 million urban population in 2010 to 1.339 billion in 2050, a figure which would correspond to 21% of the world's projected urban population [62].

A closer look at the urbanization prediction on the African continent as presented in Table 1 reveals that thirteen (13) countries within the continent would become heavily urbanized with a considerable population in the next three decades (2016 to 2050). This is not to say, other African countries would not become urbanized; rather, it is a function of differentiation in the level of urbanization among African countries [63]. For instance, approximately 90% of Gabonese live in urban areas, while below 12% of Burundians are urban dwellers. Considered in terms of urbanization sequence, Gabon, Djibouti, Libya, Algeria, Sao Tome and Principe, the Republic of Congo, South Africa, and Tunisia are the most urbanized countries on the continent in 2016. These countries have at least 66.7% of their population residing in urban areas, a figure which supersedes the current African urban residence average of 40% [63]. This process

Table 1 Africa's urbanization prospects until 2050

Rank	2016	2020	2030	2040	2050
1	Nigeria (92)	Nigeria (111)	Nigeria (171)	Nigeria (247)	Nigeria (327)
2	Egypt (37)	Egypt (40)	DRC (54)	DRC (76)	DRC (100)
3	South Africa (36)	South Africa (40)	South Africa (47)	Ethiopia (59)	Ethiopia (84)
4	DRC (32)	DRC (37)	Egypt (46)	South Africa (53)	Tanzania (70)
5	Algeria (30)	Algeria (33)	Algeria (41)	Egypt (52)	Egypt (59)
6	Morocco (21)	Ethiopia (25)	Ethiopia (39)	Tanzania (50)	South Africa (57)
7	Ethiopia (20)	Morocco (22)	Tanzania (33)	Algeria (48)	Algeria (51)
8	Tanzania (17)	Tanzania (21)	Morocco (26)	Kenya (32)	Kenya (44)
9	Ghana (15)	Ghana (18)	Ghana (25)	Ghana (31)	Angola (42)
10	Sudan (14)	Cameroon (15)	Kenya (22)	Angola (30)	Ghana (39)

Source: United Nations [62]

is driven by three factors which include a natural increase in the population of urban dwellers, rural–urban migration, and statistical reclassification [37].

The urban population growth projection in Table 1 should ideally imply that the continent has a huge transformative potential; this is because urban centers are historically the spine of economic growth, innovation, and productivity [63]. Furthermore, extant literature has pinpointed some similarities and differences in the pattern of urban growth in developing continents like Africa and Asia to the urban development processes of the developed countries in the nineteenth century [64]. The foremost similarity lies in the accelerated rate of urbanization attained in the developed countries during the industrial revolution which manifest as a 25% (15% to 40%) escalation in urban growth between 1800 and 1910. Both Africa and Asia followed the same growth trajectory; however, these developing continents attained this fit in lesser time (60 years as against 110 years), i.e., 1950 to 2010. However, the departure from the developed countries' urban growth pattern is the disparity in income levels in the developing countries. This was highlighted by Henderson [65] that "while urbanization is positively correlated with income across countries, the world is becoming more and more urbanized at a constant income level."

Concerning Africa, the aforementioned economic stagnation and poor welfare have been attributed to the prevalence of several structural constraints which make urban development on the continent shambolic [66]. Some of the prevalent issues which characterize Africa's urban areas are the presence of informal settlements and slums, infrastructural deficiencies which means residents lack access to fundamental services, uncontrolled peri-urban constructions, high unemployment rate and employment instability, and prevalence of untaxed informal jobs (60%) which in turn causes the underestimation of Africa's GDP and susceptibility to all manner of urban violence which are worsened by the prevalence of ineffective land-use management structure and a frail local government system [63, 67, 68]. Pieterse and Parnell [66] also stated that the situation of poor welfare despite the vast urban development in Africa has been attributed to the haphazard and unregulated pattern of urban expansion (especially sprawl into rural areas), structural adjustment, the continent's colonial legacy, as well as neo-liberalism that contributes to the creation of inefficient urban planning institutions. Furthermore, the pace of transformation is exacerbated by changes in the global climate and environment, food, and energy insecurities as well as water pressure that reinforce urban poverty and increase inequalities [63].

(b) *African Biodiversity Loss and Urban Development*

Africa has a natural richness comprising approximately a quarter of global animal, plant, and marine biodiversity that provides critical ecosystem services, driving the continent's economy and serving as buffers to climate change [69]. These species flourish in a wide range of ecosystems including deserts, dry lands, savannahs, tropical forests, mountains, and mangrove forests [70•]. In order to protect these ecosystem and component species, 14% of the continent's land mass and 2.6% of the seas are designated as protected areas. Other sites have been designated as United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Sites; ecologically and biologically significant marine areas; alliance for zero extinction sites; biosphere reserves; important bird and biodiversity areas; community conserved areas; and wetlands of international importance [71].

Despite its rich potential, Africa's biodiversity is in serious decline owing to unprecedented rates of population growth, urbanization, and agricultural development. This limits nature's contributions to people's daily lives and hinders sustainable social and economic development targeted by African countries [71]. Anthropogenic disturbances have been faster in the current period than any other period in human history; thus, practically all of earth's ecosystems and existing biological resources have been distorted and in some cases depleted, while others are fast declining in population and geographical extent [4]. This situation has been attributed to the existence of diverse drivers of biodiversity loss. Drivers according to Rawat and Agarwal [4] are "natural or human-induced factors that alter the state of an ecosystem directly or indirectly." These bring about losses as reflected in the species richness and composition in the various ecosystems. For example, it is estimated that the degradation of biodiversity would bring about the loss of 50% of Africa's birds and mammals by 2100 [72]. Similarly, the World Wildlife Fund (WWF) estimated that the African elephant population will disappear by 2040 due to poaching of the elephant for its ivory tusks [70•].

The biodiversity concept as previously stated was set up to forestall the many manmade interferences like those mentioned in the foregoing. It is even more imperative that issues pertaining to the unhealthy consumption of biological resources be considered a front burner issue due to the emerging linkage with issues like climate change [4]. Numerous research works had been carried out to cover various aspects of the biodiversity hotspots [73, 75, 76•, 80, 81•, 84, 85]. A common but critical aspect of the methodologies of these works is the use of GIS and remote sensing methods in satellite image analysis and mapping of the vegetation in the hotspots, thereby aiding the estimation of the existing vegetation and also highlighting those to prioritize (or conserve). More specifically, the analysis enables the researchers to evaluate salient details like the population of endemic species, the landmass of the protected areas, and the estimated value of the remaining vegetation (RV),

Table 2 African biodiversity hotspots and relative statistics and other details

S/N	African biodiversity hotspots	Countries	Original landmass/ size (squared km)	Landmass of protected areas (squared km)	Remaining vegetation in protected area [RV] (squared km)	Hotspot endemic genera	Hotspot endemic plants population
1	Cape Floristic Region	South Africa	112,450	53,679 (47.7%)	17,660.4 (32.9%)	160	6210
2	Coastal Forests of Eastern Africa	Somalia, Mozambique, Coastal Tanzania and Kenya	308,220	63,267 (20.5%)	2404.2 (3.8%)	N/A	1750
3	Eastern Afromontane	The Albertine Rift Mountain areas of Uganda, Rwanda, Burundi, Democratic Republic of the Congo, and Tanzania, and the Eastern Arc Highlands of Kenya	1,043,190	170,099 (16.3%)	15,308.9 (9%)	N/A	2356
4	Guinean Forests of West Africa	Guinea, Sierra Leone, Liberia, Ghana, Togo, Cote d'Ivoire, Benin, Nigeria and Cameroun	626,398	84,213 (13.4%)	8926.6 (10.6%)	N/A	1800
5	Horn of Africa	Somalia, Eritrea, Djibouti and Ethiopia	1,712,970	144,116 (8.4%)	34,299.6 (23.8%)	N/A	2750
6	Madagascar and the Indian Ocean Islands	Madagascar	674,509	70,744 (10.5%)	3112.7 (4.4%)	310	11,600
7	Maputaland-Pondoland-Albany	Mozambique, South Africa	360,369	37,755 (10.5%)	2416.3 (6.4%)	N/A	1900
8	Succulent Karoo	Nambia and South Africa	138,266	41,972 (30.4%)	2728.2 (6.5%)	80	2439

Source: Küper et al. [80], Sloan et al. [123], Habel et al. [81•], and Olson [136]

among others [75, 81•]. Therefore, these analyses enable the researchers to make deductions and offer explanations on the biodiversity ecosystems, some of which are summarized in Tables 2, 3, and 4. Furthermore, Fig. 1 shows the geographic spread of the biological resources on the African continent. On the other hand, Table 2 is an excerpt from Kuper et al. [80], Sloan et al. [123], Habel et al. [81•], and Olson [136] showing the eight African biodiversity hotspots, countries affiliated with the hotspots, the original landmass of the respective hotspot, the population of the endemic (or native) species, the percentage of the original landmass that was set aside for conservation expressed in squared kilometers, and the remaining landmass (RV) also in squared kilometers. The remaining vegetation (RV) is the proportion of the protected area that has not been disturbed by natural or anthropogenic factors, i.e., the remaining natural intact vegetation which harbors what is left of biodiversity.

Table 3 shows the current dynamics of the African biodiversity hotspots. Notably, it shows the total landmass of Africa's biodiversity hotspots (approximately 4.98 million km^2) which is about 16.38% of the entire landmass of Africa (30.37 million km^2).

Table 3 Current dynamics of African biodiversity hotspots' landmass

	Landmass	Cumulative percent
Total landmass of Africa's biodiversity hotspots	4,976,372.0	
Landmass of the hotspots not conserved	4,310,527.0	86.6
Size of biodiversity hotspots conserved (protected areas)	665,845.0	13.4
Size of lost conserved hotspots (protected areas)	578,988.1	87.0
Size of remaining conserved hotspots (protected areas)	86,859.9	13.0

Source: adapted from Habel et al. [81•]

Table 4 Results of modelling hotspots remaining vegetation (NIV) against climatic pressure, agroeconomics pressure, and combined pressure like urbanization

Hotspots	Endemic species loss	
	Percentage (%)	Number
Cape Floristic Region	7–33	439–2063
Coastal Forests of Eastern Africa	100	1750
Eastern Afromontane	100	2356
Guinean Forests of West Africa	100	1800
Horn of Africa	3–15	78–402
Madagascar and the Indian Ocean Islands	100	11,600
Maputaland-Pondoland-Albany	7–32	131–617
Succulent Karoo	10–46	256–1113

Source: Habel et al. [81•]

According to Güneralp et al. [56], much of the areas currently known as biodiversity hotspots on the African continents were relatively untouched at the turn of the century. However, the situation has changed as a consequence of the vulnerability of the domicile native species and the existing vegetation to land cover changes [82, 83]. The need to conserve 13.4% (or 665,845 km^2) of the hotspots as protected areas suggests that the rate of loss of biological resources was aghast and unsustainable. Coincidentally, Table 3 also revealed what is left of the protected areas to be cumulatively 13% (or 86,859.9 km^2) which means that 87% of the natural vegetation have been gulped up by different varieties of land uses and anthropogenic factors; this is a testimonial to the intensity of activities that are impacting the land cover in these areas. This finding is similar to that of Sloan et al. [123] in their analysis of hotspots across the globe where it was deduced that only 14.9% (or 3,545,975 km^2) of natural vegetation remains. The table also revealed that the Eastern Afromontane hotspot has lost 91% (or 154,790 km^2) of its protected areas and has therefore suffered more anthropogenic interference (defined in terms of size of landmass lost) than others. Other hotspots like the Horn of Africa, Guinean forests of West Africa, Madagascar, and the Indian Ocean Islands as well as the Coastal forests of Eastern Africa have also recorded sizable landmass losses landmass 76.2% [or 109,816.4 km^2], 89.4% [or 75,286.4 km^2], 95.6% [or 67,489.8 km^2], and 97.2% [or 60,862.8.8 km^2] respectively. Losses have been recorded in the other hotspots as shown in Table 2, but the aforementioned hotspots have suffered more losses relative to others.

Urban growth and urbanization are generally expected to cause an expansion in urban lands to the tune of 1.2 to 1.8 million square kilometers between the years 2000 and 2030 [21•]. Relative to the biodiversity hotspots, urban growth and urbanization are expected to bring about similar alteration of landmass. Güneralp et al. [56] in their work stated that the size of biodiversity hotspots that would be lost to urban lands would increase from 31% (before the year 2000) to 34% (±2%) in 2030 across the world. Additionally, urban expansion towards protected areas is expected to be a global trend though the magnitude would differ from country to country; for instance, urban lands in the USA may increase by approximately 70% by 2050, while the rate of growth of urban lands within 50 km of China's protected area is expected to surpass that of North America and Western Europe by 2030 [127]. As regards Africa, the increase in urban lands in the proximity of protected areas (hotspots) is predicted to be about 20 times over [127]. Furthermore, unguarded urbanization is expected to cause a reduction in the 4.5 million square kilometers landmass of the protected areas by increasing the landmass of the occupied areas from 500 square kilometers to 140,000 square kilometers between the years 2000 and 2030 [17, 84]. Similarly, the highest urban land cover upsurge at a rate that is over ten times would occur in four biodiversity hotspots, two (Eastern Afromontane, and the Guinean forests of West Africa) of which would be within the African continent [56]. Therefore, the submission of Güneralp et al. [56] is in tandem with the data extrapolated from *Habel* et al. [81•], as these three hotspots are already expressing losses in landmasses than the other areas.

African Biodiversity Hotspots and Trends in Hotspot Protection

Over time, all global hotspots have experienced biodiversity loss, which has reduced their Natural intact vegetation (NIV) and the population of endemic plants and animal species [81•, 123]. The situation has not abated despite the efforts directed at conservation; rather, the anthropogenic drivers of biodiversity loss have been reported to be a thousand times more prevalent [150]; however, the scenario would have been worse off (about 2.9 to 4.2 times) without these initiatives [150, 154]. Therefore, biodiversity loss remains a risk that cannot be allowed to fester because the losses incurred are never solitary or peculiar to a species; instead, an extinct endemic plant can lead to the disappearance of 10 to 30 endemic animal species [138]. Therefore, it can be implied that biodiversity loss is usually extensive; hence, no species is unimportant in an ecosystem.

The global trend of events within the hotspots and other places of high biodiversity as reported by the International Union for Conservation of Nature (IUCN) Red List of Threatened Species revealed that the biodiversity species count currently stands at 147,517 species out of which 40,084 (27.2%) species are endangered [156]. From this IUCN data, it can be inferred that the population of

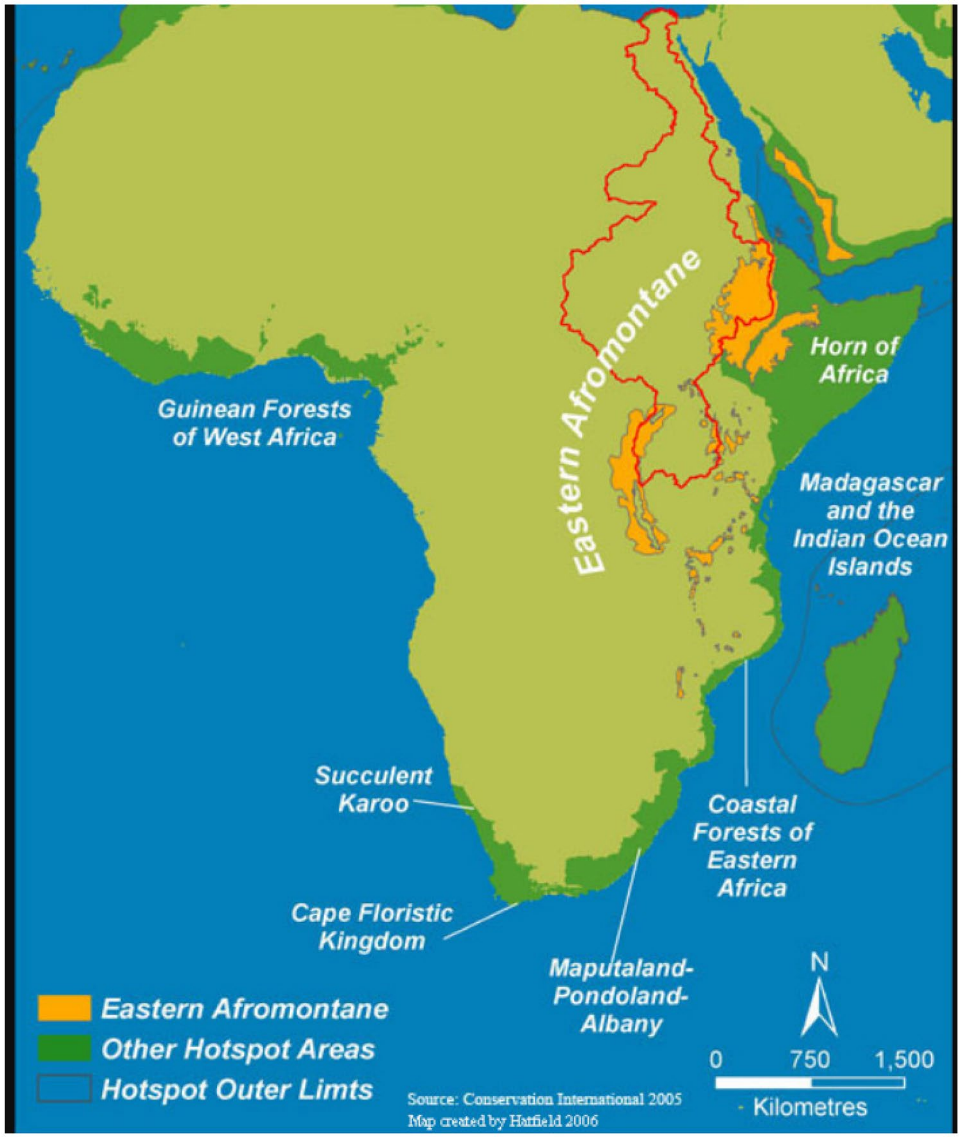

Fig. 1 Global distribution of biodiversity hotspots (source: Merritt et al. [76•]). Map of Africa showing locations of biodiversity hotspots (source: Conservation International [79])

endangered species is more than a quarter (27.2%) of the species count; this is high and requires urgent attention especially because of the crucial roles played by some of the reported endangered species in the ecosystem. For instance, coral has multiple documented importance, but it is threatened because what is left of it is just 33% of its original size and population; other endangered species are sharks (31%), and amphibians (41%) [157]. Relative to Africa, human disturbance on the ecosystem has continued to grow in leaps and bounds and has contributed to the endless encroachment into protected areas [56, 81•]. A catalyst to this encroachment is the fact that over a quarter (25%) of the terrestrial hotspots across the world are located in close proximity (within 50 km) of a city [122]. This is the case for some hotspots in Africa, for instance, the distance between the Cape Floristic hotspot and Cape Town is about 44 km, the Chimanimani Mountains National Park (which is part of Eastern Afromontane) is also 37.9 km from Nyahode, and 68.6 km from Chipinge; furthermore, Cross Rivers National Park, Oban, of the Guinean Forests of West Africa is just 45.3 km from Calabar [155, Google Map, 2022].

The result of the hotspot pressure modelling given in Table 4 emphasizes the trend that is already playing out in most of the hotspots on the African continent as a consequence of the various anthropogenic threats that are currently besieging these protected areas, thereby making conservation efforts very difficult [56, 81•]. Some of these threats are hotspots specific, while some cut across most of the hotspots; however, their effects have been undeniably destructive. As shown in the table, the pressures from human activities plus climatic pressure would induce total endemic loss in four hotspots which would translate to the loss of 17,506 species which could increase to a maximum of 21,701 endemic species if values for other hotspots are included. Four hotspots are predicted (coastal forests of Eastern Africa, Eastern Afromontane, Guinean forests of West Africa, and Madagascar and the Indian Ocean Islands) to experience total endemic loss; these hotspots are the same that were reported to have lost a significant size of their natural vegetation.

Table 5 gives another dimension to the trend analysis of urban development and biodiversity loss; this is because the table shows the projection analysis of the work of Seto et al. [85] which set out to capture the extent of urban expansion in global biodiversity hotspots by 2030 using the datasets of Myers et al. [73] and Mittermeier et al. [158] for gauging spatial overlap between hotspots locations and proximate urban areas. The results of the analysis as given in the table show the direct impacts of urbanization on biodiversity hotspots rather than its effect in combination with other anthropogenic factors. The table revealed that all the African biodiversity hotspots prior to the year 2000 were almost without any disruption; however, the passage of time is expected to change this narrative with six of the eight hotspots predicted to experience varying degrees of urban expansion by 2030. While the predicted urban influx would be mild in some of the hotspots, the forecast for both Eastern Afromontane and Guinean forests of Western Africa were higher as urban growth in the proximity of these hotspots is expected to be sizable (approximately 1900% and 920% respectively). A plausible explanation was given by Cunningham and Beazley [161] while they examined the changes in human population density in global diversity hotspots between 1995 and 2015. One of their key findings relative to Eastern Afromontane and Guinean forests of Western Africa is that the two hotspots would experience a 70.2% and 68.5% increase in population densities in the 20-year span with a forecast that a further increase of 16.1% and 15.5% would follow by 2020. This could only mean that landmass would be lost to other land uses due to an increase in the human population in the vicinity of these hotspots. Therefore, the predicted urban expansion into the hotspot localities is an indication that the perception of urbanization as a nominal driver of deforestation is erroneous [159]. A pointer to that is the fact that while the rates of anthropogenic stressors like deforestation have been declining in the recent years, urban expansion has been on the rise [85] in most of the African biodiversity hotspots with the exception of Madagascar, Maputaland-Pondoland-Albany and Succulent Karoo. It is especially instructive that the total endemic species loss expected in the Madagascar hotspots could be a consequence of other drivers other than urban development. This indicates that the effect of urban expansion while being prime in some hotspots is secondary and even negligible in others.

Discussion

Urban development, directly and indirectly, impacts biodiversity [21•, 22, 85, 88•, 89•]. Rawat and Agarwal [4] described a direct driver as one which explicitly influences the processes of an ecosystem, while the action of an indirect driver is covert as it operates by triggering one or more direct drivers. According to Rawat and Agarwal [4], the important direct drivers that have consequences on biodiversity are "alteration of habitat, climate change, invasive species, overexploitation and pollution." These consequences can all be induced by the twin processes of urban development (i.e., urban growth and urbanization).

Table 5 Urban expansion forecast in biodiversity hotspots by 2030

African biodiversity hotspots	African hotspot area Not threatened by urban expansion	Urban expansion in hotspots (Km^2) by probability quartile range (percent of hotspot)				Urban extent in hotspots (before year 2000)
		0–25	25–50	50–75	75–100	
Cape Floristic Region	80,400 (97.4%)	175 (0.2%)	25 (0.0%)	0 (0.0%)	1100 (1.3%)	875 (1.1%)
Coastal Forests of Eastern Africa	287,575 (94.6%)	9775 (3.2%)	275 (0.1%)	300 (0.1%)	5350 (1.8%)	800 (0.3%)
Eastern Afromontane	902,950 (86.2%)	99,775 (9.5%)	8400 (0.8%)	6500 (0.6%)	28,400 (2.7%)	1500 (0.1%)
Guinean Forests of West Africa	482,775 (75.1%)	101,950 (15.9%)	5800 (0.9%)	3775 (0.6%)	43,675 (6.8%)	4725 (0.7%)
Horn of Africa	1,597,450 (95.7%)	57,275 (3.4%)	2650 (0.2%)	4650 (0.3%)	5300 (0.3%)	1575 (0.1%)
Madagascar and the Indian Ocean Islands	590,525 (98.5%)	6050 (1.0%)	350 (0.1%)	75 (0.0%)	2100 (0.4%)	275 (0.0%)
Maputaland-Pondoland-Albany	260,125 (93.7%)	6300 (2.3%)	1375 (0.5%)	1475 (0.5%)	7225 (2.6%)	1075 (0.4%)
Succulent Karoo	105,050 (99.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	25 (0.0%)	50 (0.1%)

Source: Seto et al. [85]

Habitat alteration is the foremost factor impacting biodiversity globally; it involves the destruction of habitats by rendering them incapable of supporting the native species that grow naturally within them [4, 90, 91•]. Habitat alteration is an ecosystem-shattering process that reduces the carrying capacity of the living components of an ecosystem, thereby resulting in a decline in species population or outright extinction [132]. It is also characterized by the alteration of landscape composition which could cause changes in habitat conditions that may be inimical to the survival of plants and animal species [56, 92, 93]. The Millennium Ecological Assessment, MEA [129], distinguished between the causes and drivers of habitat destruction; while the causes are the specific activities that directly destroy the habitats, the drivers are the silent forces/pressures that induce the causes. The major causes of habitat alteration as given by Geist and Lambin [131] are "agriculture, infrastructural provisions, and wood extraction." These are anthropogenic activities that involve clearing the forest and felling of trees to access lands required for the provision of urban necessities like residences, factories, schools, hospitals, shopping malls, and construction of infrastructures like roads, hydroelectric projects, and other related amenities usually found in urban areas [56, 86•, 94, 95•, 96]. The quest for accessing these lands has been cited in the academic literature as a major cause of biodiversity loss. For instance, road constructions can result in habitat fragmentation which is a form of habitat alteration where the landmass within protected areas or places of immense biodiversity are reduced to smaller unconnected areas with contrasting vegetation and species; subsequently, species which were once larger in population may also become small population [133, 140, 154]. Existing literature has revealed that small species population stand the risk of losing genetic variation due to the elimination of inbuilt mechanisms that promote heterosis and foster conditions that encourage inbreeding because of reduced possibilities of outbreeding [126, 154]. This situation may cause inbreeding depression which is characterized by the emergence of species offspring that are fewer, weak, and may be incapable of reproducing which could make the affected species endangered [154]. In a like manner, hydroelectric projects on rivers may alter the habitat conditions and change it to a lacustrine habitat which may not be suitable for the native species [94, 95]. However, the salient factors that induce these habitat-altering activities are the economic, sociopolitical, cultural, demographic, and scientific factors [129]. Therefore, it can be implied that the need to meet the endless demands for food, furniture, medical supplies, stationeries, clothes, and other important human needs as well as other intricacies like bad governance, uncensored manufacturing, and increasing demands are the secondary driver of habitat alteration.

Exploitation according to Reynolds and Peres [134] "involves living off the land or seas, such that wild animals, plants, and their products are taken for purposes ranging from food to medicines, shelter, and fiber." Overexploitation occurs when the rate of harvesting of a species outstrips its natural reproductive capacity [4, 97, 98, 99]. This is a major threat to many species like trees, animals, marine fish, and invertebrates as extracts like medicinal herbs, proteinous meat, and fish may become over-harvested. Industrial fisheries, wild plants and animals harvest, resource mining, and excessive logging are examples of activities humans engaged in to meet the ever-increasing urban demands that may cause overexploitation and result in the extinction of the affected species [4, 100–103]. Overexploitation is the second commonest threat that birds, mammals, and plants across the world are exposed to, while it has also been cited as the third most prevalent driver of freshwater fish extinction [134]. Its effects are in two-fold, namely, the effects on the target species and the effects on the non-target species and the general ecosystems [134]. Overexploitation of target species involves direct targeting and selection of species at a rate that is unsustainable [134]; this is commonplace with the products of terrestrial and aquatic ecosystems like timber, exotic plants, wildlife, fish, and other products which are endlessly exploited. Overexploitation provides the foundation for habitat alteration, for instance, approximately 58,000 km^2 (5.8 million hectares) are lost yearly to logging in tropical forests; similarly, the yearly hunting estimates in Central Africa stand between 1 and 3.7 million tons [141. It is apparent that such excessive removal would have some unwanted impact on the logging and hunting sites which would be devastating. On the other hand, overexploitation involving non-target species is those exploitations that occur accidentally or coincidentally as the species affected are not directly selected or targeted [134]. The combined effect of target and non-target overexploitation is often fatal as it adversely affects the dynamism of the ecosystem and its biological processes, thereby making it vulnerable to damaging occurrences like habitat alteration, fire disturbances, and even extinction [126].

Biodiversity as a component of the ecosystem plays a critical role in the reduction of climate change which has become an issue of global concern in recent decades due to its negative impacts on the environment and human well-being [104, 142–145]. Climate change is closely linked with global warming which involves the continuous rise in the temperature of the earth as a result of the activities of greenhouse gases (GHGs); thus, these gases have been identified as "the atmospheric gases causing global warming and climatic change" [145, 146]. Notable GHGs include carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons [145]. GHGs are similar in action to a greenhouse which rather than reflecting the incident sun's energy into space traps the energy; thus, when the Earth becomes saturated due to the continuous absorption of the excessive heat, its temperature increases beyond its natural variability [144, 147].

This means that climate change is the aftermath of Earth's energy balance due to the differential in the amount of energy that got into the Earth from the sun and the amount released back into space. The energy differential represents the heat trapped by the GHG which causes the earth to warm and subsequently disrupt natural flow. The foregoing explains why the temperature of the earth has increased from –0.4 ℃ in 1850 and currently lies between 1℃ and 1.2 ℃ [149]. Details on some of the principal GHGs are given in Table 6.

The role of biodiversity in climate change is well articulated in the regulating services provided by ecosystems [129]. It serves this purpose by acting as a storage bank for carbon which it sinks into vegetation and soils while also trapping, removing, and storing carbon dioxide from the atmosphere (carbon sequestration) [135]. It is therefore apparent that the loss of biodiversity would result in a surge in the concentration of carbon and other GHGs in the atmosphere, thereby altering climatic dynamics and inducing changes [104, 105–107]. Urban areas are laboratories for many activities that induce biodiversity loss (like deforestation, construction of hydroelectric infrastructure, resource mining, and manufacturing activities) and the increase in greenhouse gases through various types of pollution [90, 108]. Another indication that urban development is strongly linked to GHG emissions across the globe is its connections to activities that are considered to be top sources of these emissions. According to Lamb et al. [148], these sources are the energy sector, industry, buildings, transportation, and agriculture; all of which contribute to biodiversity loss directly or otherwise. For instance, the quantity of energy consumed and the volume of emissions emanating from urban areas stand between 67 and 76% and 71 to 76% respectively [162]. The United Nations [62] stated that the number of megacities with over 10 million inhabitants is expected to be forty-three (43) by 2030. This suggests that more buildings would emerge and more infrastructures like roads, hospitals, energy grids, and other urban amenities would be needed which further implies that more GHGs will be released from these sources; for instance, building growth has been evaluated to be directly related to an increase in greenhouse gases and also responsible for the escalation in energy consumption [11•, 109].

The indirect consequences of urban development are fundamentally anthropogenic as human activities can cause a plethora of alterations that may impact local temperature, cause climatic change, induce biogeochemistry changes, as well as affect the hydrological systems [111, 112, 113, 114, 116]. For instance, the African urban area is known to be a hub of different types of pollution which contribute to the release of greenhouse gases that may aggravate global warming and subsequently worsen the climate change situation. Similarly, extant literature has also suggested that native biological species are susceptible to land-cover changes (like urban development) because it promotes the possibility of species extinction, engenders natural habitat decimation, and increases the likelihood of human interactions and disturbances [4, 117, 118, 119]. Furthermore, the increasing incidence of anthropogenic stressors like mining, hunting, poaching, and building of infrastructures (to support urban development) in the last few decades has led to the extinction of 75% of large mammal's population in Western and Southern Africa, while the rate of loss for the entire continent is above 50% [153, 154]. Big cats like lions and cheetahs are endangered with the lions already extinct in 16 African countries, while what is left of the cheetahs is below 9% within their traditional domain [151, 152]. Other big mammals like the rhinoceros have suffered similar fates with the last West

Table 6 Principal Green House Gases (GHGs) Inducing Climate Change

Greenhouses gases (GHG)	Sources	Lifetime in the atmosphere	Global warming potential (GWP)
Carbon dioxide (CO_2)	Electricity Production, transportation, and numerous industrial processes	Approximately 50–200 years. This is poorly defined because Carbon dioxide is not destroyed over time. It moves among different parts of the ocean–atmosphere land system	1
Methane (CH_4)	Livestock manure, food decomposition, extraction, distribution and use of natural gas	12 years	25
Nitrous oxide (N_2O)	Vehicles, power plant emissions	115 years	298
Black carbon (Soot, PM)	Diesel engines, wildfires biomass in households, cooking stoves (developing countries)	Days to weeks	3200
Fluorinated gases (PFC_S, HFC_S, NF_3,SF_6)	No natural sources. They are mostly synthetic pollutants found in coolants, aerosols, pesticides, solvents, and fire extinguishers and are useful in electricity transmission	PFC_S : 2,600 – 50,000 *years* HFC_S : 1 – 270 *years* NF_3 : 740 *years* SF_6 : 3,200 *years*	PFC_S : 7,000 – 12,000 HFC_S : 12 – 14,000 NF_3 : 17,2000 SF_6 : 22,800

Source: Public Health Institute/Centre for Climate Change and Health [144]

African black rhinoceros already dead and the northern white rhinoceros likely to follow suit [151].

Urbanization is an inevitable trend, and the consequent economic development can have major negative impacts. However, there is a need to consider biodiversity as essential parts of urban development through formal urban planning, management, and legislation processes. This is important for the attainment of many of the sustainable development goals, especially goals (3) good health and well-being, (6) clean water and sanitation, (11) sustainable cities and communities, (12) sustainable consumption and production, (13) climate action, and (15) life on land and would foster continual access to the many benefits and services of biodiversity [120].

Conclusion and Way Forward

Predictions on urban development within the African continent have shown that many more cities would emerge within the next couple of decades. Going by recent human history, this would ideally mean more biological resources would be lost. However, these losses of vital animals and plants species at the hotspots (especially the protected areas) can no longer be allowed to fester because the inextricable link between human well-being and biodiversity would be seriously threatened. The onus is therefore on the appropriate authorities and relevant institutions to act promptly to curtail the unwanted environmental challenges that our inactivity will cause. African institutions, departments, and agencies that are responsible for the management of biodiversity sanctuaries can set out to implement some of these recommendations through the formulation of policies, monitoring, and continuous public enlightenment.

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