Biodiversity and Ecosystem Services on the African continent – what is changing, and what are our options?

Corresponding author: Prof Emma Archer, Centre for Environmental Studies/Geography, Geoinformatics and Meteorology, University of Pretoria cnr Lynnwood Road and Roper Street Hatfield 0028, South Africa. E-mail: Emma.Archer@up.ac.za

Co authors:

L. E. Dziba, South African National Parks, 643 Leyds St, Muckleneuk, Pretoria, 0027, South Africa

K. J. Mulongoy, IEL, Montreal, Canada

M. A. Maoela, Council for Scientific and Industrial Research, Pretoria 0001, South Africa

M. Walters, Council for Scientific and Industrial Research, Pretoria 0001, South Africa

R. Biggs, Centre for Complex Systems in Transition (CST), University of Stellenbosch, Private Bag X1 Matieland 7602, South Africa

M-C. Cormier Salem, Institute of Research for Development, Marseille (IRD), France

F. DeClerck, EAT Foundation/Bioversity International, Parc Scientifique Agropolis II, 34397 Montpellier Cedex 5, France

M. C. Diaw, African Model Forest Network, Yaounde, Cameroon

A. E. Dunham, Department of Biosciences, Program in Ecology and Evolutionary Biology, Rice University, Houston, TX 77005, United States

P. Failler, University of Portsmouth, Richmond Building Portland Street Portsmouth P01 3DE, United Kingdom

C. Gordon, Institute for Environment and Sanitation Studies. College of Basic and Applied Sciences. University of Ghana, Legon, Accra, Ghana

K. A. Harhash, Biodiversity Central Department, Ministry of State for Environmental Affairs, Cairo, Egypt

R. Kasisi, Université de Montréal Faculté de l'aménagement, 2900 Edouard Montpetit Blvd, Montreal, Quebec H3T 1J4, Canada

F. Kizito, International Centre for Tropical Agriculture (CIAT), Kigali, Rwanda

W. D. Nyingi, Ichthyology Department, National Museums of Kenya, Nairobi, Kenya

N. Oguge, Centre For Advanced Studies in Environmental Law and Policy, University of Nairobi, Nairobi, Kenya

B. Osman-Elasha, African Development Bank, Abidjan, Côte d'Ivoire

L. C. Stringer, School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds, LS2 9JT, United Kingdom

L. Tito de Morais, Marine Environmental Sciences Laboratory, IRD, LEMAR Laboratory, Institut Universitaire Européen de la Mer, Technopôle Brest-Iroise, Rue Dumont D'urville 29280 Plouzané, France

A. Assogbadjo, Faculty of Agronomic Sciences, University of Abomey-Calavi, 05 BP 1752, Cotonou, Benin

B. N. Egoh, Earth System Science Department, University of California, Irvine, Croul Hall, Irvine, CA 92697-3100

M. W. Halmy, Department of Environmental Sciences Faculty of Sciences, Alexandria University Cairo, Egypt

K. Heubach, Palmengarten and Botanical Garden, Siesmayerstraße 61, 60323 Frankfurt am Main, Germany

A. Mensah, Institute for Environment and Sanitation Studies. College of Basic and Applied Sciences. University of Ghana, Legon, Accra, Ghana

L. Pereira, School of Arts and Social Sciences of City, University of London, Northampton Square, Clerkenwell, London EC1V 0HB, United Kingdom

N. Sitas, Centre for Complex Systems in Transition (CST), University of Stellenbosch, Private Bag X1 Matieland 7602, South Africa

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E. Archer, L. E. Dziba, K. J. Mulongoy, M. A. Maoela, M. Walters, R. Biggs, M-C. Cormier Salem, F. DeClerck, M. C. Diaw, A. E. Dunham, P. Failler, C. Gordon, K. A. Harhash, R. Kasisi, F. Kizito, W. D. Nyingi, N. Oguge, B. Osman-Elasha, L. C. Stringer, L. Tito de Morais, A. Assogbadjo, B. N. Egoh, M. W. Halmy, K. Heubach, A. Mensah, L. Pereira and N. Sitas

Abstract

Throughout the world, biodiversity and nature's contributions to people are under threat, with clear changes evident. Biodiversity and ecosystem services have particular value in Africa– yet they are negatively impacted by a range of drivers, including land use and climate change. In this communication, we show evidence of changing biodiversity and ecosystem services in Africa, as well as the current most significant drivers of change. We then consider five plausible futures for the African continent, each underlain by differing assumptions. In three out of the five futures under consideration, negative impacts on biodiversity and ecosystem services are likely to persist. Those two plausible futures prioritizing environment and sustainability, however, are shown as the most likely paths to achieving long term development objectives without compromising the continent's biodiversity and ecosystem services. Such a finding shows clearly that achievement of such objectives cannot be separated from full recognition of the value of such services.

1. Introduction

Biodiversity and ecosystem services are facing serious threats globally, impacted by a range of often interacting drivers, including land use and climate change (IPBES 2019). Africa, a continent rich in biocultural diversity, is one of the last places on Earth with a significant, intact large mammal assemblage, and with a unique diversity of indigenous and local knowledge, the majority of which, as yet, remains largely undocumented. The unrealized potential of Africa's biodiversity, ecosystem services, spirituality, culture and identities places the continent in a unique position globally- it can serve as a source for generating development pathways that are truly sustainable, where people's wellbeing and needs can be met without negatively infringing on the environment. The continent's rich biocultural heritage is, however, rapidly being exploited to meet development needs both within and outside of the continent. This has placed Africa in a vulnerable position with regards to building a resilient future for its citizens, and for those people and ecosystems that depend on Africa's resources outside the continent.

In this short communication, we draw on the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Regional Assessment Report on Biodiversity and Ecosystem Services for Africa – worked on by all authors. We show what is changing in biodiversity and ecosystem services on the African continent. We also identify future pathways and options for an African continent where long-term development objectives are recognized as inseparably connected to the conservation of the region's rich biocultural heritage.

2. . Material and approach

The Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) was established in 2012, with the intention of providing the most up to date and independent assessments of the state of biodiversity and ecosystem services (or nature's contributions to people) to support decision-making around the world. The Regional Assessment Report on Biodiversity and Ecosystem Services for Africa forms one of a suite of regional assessments, alongside those focusing on Asia-Pacific, Europe and Central Asia and the Americas, all of which were undertaken between 2015 and 2018.

The Africa Assessment was produced by 127 experts, including seven Fellows (early career scientists brought on at the start of the assessment); with support from 23 contributing authors. Authors were drawn largely from Africa. The report, as well as its Summary for Policymakers, was approved by the Member States of IPBES at the sixth session of the IPBES Plenary, in March 2018, in Medellín, Colombia.

3. What is changing?

Over the past several decades, biodiversity and ecosystem services in Africa have become increasingly threatened by anthropogenic drivers, some of the most important of which include human migration and political insecurity, climate change, habitat degradation and conversion, unstainable harvesting and illegal trade of wildlife, and invasive alien species (MA, 2005; IPBES, 2018). Changes in land use and climate appear to be the most concerning of the drivers (more detail provided below); with land use change the primary driver of change and loss to date. Given current vulnerability to climate change in Africa (IPCC 2018), future changes in biodiversity and ecosystem services are likely to be exacerbated or driven by climate change, whether acting as a direct driver or in the case of multiple stressors. Natural drivers of biodiversity decline have also been increasing over the last two decades, including (but not limited to) diseases, pests and natural disasters (IPBES, 2018), likely as a result of human-driven environmental changes affecting the region (Daszak et al., 2000). Such increasing impacts have clear implications for a range of plants, invertebrates, fish, amphibians, reptiles, birds, mammals and micro-organisms (IPBES 2018).

Table 1 shows a qualitative assessment of change in intensity of drivers of change in biodiversity in Africa per sub-region and ecosystem type, as reported by parties to the Convention on Biological Diversity (CBD). We see here, for example, that climate change and habitat conversion are increasing in intensity, and may significantly impact both terrestrial/inland waters and coastal/marine biodiversity in all subregions.

Table 1: Changes in biodiversity and the role of underlying direct and indirect drivers in Africa shown per subregion and ecosystem type

TABLE 1: CHANGES IN BIODIVERSITY AND THE ROLE OF UNDERLYING DIRECT AND INDIRECT DRIVERS IN AFRICA SHOWN PER SUBREGION AND ECOSYSTEM TYPE

		DRIVERS OF BIODIVERSITY CHANGE							
		Direct drivers						Indirect drivers	
SUBREGIONS	ECOSYSTEM TYPE	Climate change	Habitat conservation	Overharvesting	Pollution	Invasive alien species	Illegal wildlife trade	Demographic change	Protected areas
CENTRAL AFRICA	Terrestrial/Inland waters	Moderate increase	High increase	High increase	High increase	High increase	High increase	High increase	Moderate increase
	Coastal/Marine	Moderate increase	High increase	High increase	Moderate increase	Moderate increase	High increase	NI	Unchanged/Under control
EAST AFRICA AND ADJACENT ISLANDS	Terrestrial/Inland waters	High increase	Moderate increase	High increase	Moderate increase	Moderate increase	High increase	High increase	Moderate increase
	Coastal/Marine	High increase	Unchanged/Under control	Moderate increase	Moderate increase	Moderate increase	High increase	High increase	Unchanged/Under control
NORTH AFRICA	Terrestrial/Inland waters	High increase	Moderate increase	Moderate increase	Moderate increase	High increase	Unchanged/Under control	Low increase	Low increase
	Coastal/Marine	Moderate increase	Moderate increase	Moderate increase	Moderate increase	High increase	NI	Low increase	Low increase
SOUTHERN AFRICA	Terrestrial/Inland waters	Moderate increase	Moderate increase	High increase	Moderate increase	High increase	Moderate increase	Moderate increase	Moderate increase
	Coastal/Marine	Moderate increase	Moderate increase	Moderate increase	Moderate increase	High increase	Moderate increase	Moderate increase	Moderate increase
WEST AFRICA	Terrestrial/Inland waters	High increase	High increase	High increase	Moderate increase	Moderate increase	High increase	Moderate increase	Low increase
	Coastal/Marine	High increase	Moderate increase	Moderate increase	Moderate increase	Low increase	High increase	Moderate increase	Low increase

DIRECTION OF ARROW: Trend of the respective impact of the driver

High increase · Moderate increase · Low increase · Decrease · **NI** No information available · Unchanged/Under control

It is well established that Africa is prone to the adverse impacts of climate change (see, for example, Myhre et al., 2013; Wright et al., 2015; Connolly-Boutin & Smit, 2016; Li et al., 2019). Temperatures throughout the continent are projected to rise more rapidly than the global rate

(IPBES, 2018; IPCC, 2018). In addition, there is a high probability that high intensity extreme rainfall events will increase in frequency (Akumaga & Tarhule, 2018). The most severe projections suggest that distribution, migration and population sizes of African plant species critical for food security (e.g., common bean) are likely to be affected by climate change (see Hummel et al., 2018). By 2100, it is estimated that climate change could result in significant loss of certain bird and mammal species (due to range retraction), and cause a decline in productivity of Africa's lakes by more than 20% (IPBES 2018).

In addition, climate change impacts on pests and pathogens are likely to significantly affect human health and the livestock sector throughout the continent (e.g., Bett et al., 2019; IPBES 2018). Negative climate change impacts on marine and coastal environments (e.g. salinization of water and soil, coastal erosion) pose a substantial risk for fisheries and the regulating and cultural ecosystem services these systems provide. For instance, extreme ocean warming caused massive coral bleaching events in 1998 and 2016, which resulted in reef mortality of more than 50% in certain regions (Obura, 2016), particularly the Western Indian Ocean (Gudka et al., 2018). Climate change and marine heatwaves (Smale et al., 2019), coupled with marine protected areas for which spatial data is available covering only 2.6% of Africa's marine jurisdiction (Belle et al., 2015), increases the impacts of current and future harvesting pressures on marine resources.

Land cover change throughout the continent is already driving a loss of key natural assets and reducing the continent's capacity to support biodiversity. Land cover change includes intensive agriculture, unregulated conversions of intact forest, mining, and use for urban and infrastructure development (IPBES 2018). Effectively, we are seeing the impact of competing demand for land through urban/infrastructure development, extractive industries and agricultural expansion and intensification – an example here would be development and investment choices that strongly emphasize expansion and intensification of primary and extractive industries. An estimate of 20 % of Africa's land surface is degraded due to direct drivers of change such as vegetation loss and adverse impacts on soils, including pollution, erosion, decreased fertility and salinization (Nyingi et al., 2018). In a significant finding, agricultural expansion appears as a dominant driver of biodiversity loss with unregulated conversion to agricultural land leading to loss and erosion of soils, habitats and water catchments, thus hampering Africa's long-term sustainable development (IPBES 2018). The interactions between land-use and climate change compound the impacts on biodiversity and ecosystem functioning, with ecosystems in environments that are climatically challenging displaying lowered resistance to land-use change (Peters et al., 2019).

Tackling the negative impact of these drivers of change is a critical aspect for sustainable development on the continent. Most African countries have committed to achieving particular targets by particular deadlines – including (but not limited to) the Aichi Biodiversity targets and the Sustainable Development Goals; as well as, for the continent specifically, AU Agenda 2063. Some countries are progressing well towards their targets and are on track within the mandated timeframe; others are not (Figure 1). For instance, awareness of biodiversity (Aichi Target 1) has grown, exceeding the target in some countries (Stringer et al 2018). For Aichi Target 10 which calls for reduction of pressures on ecosystems vulnerable to climate change however, evidence of progress is lacking. Information to monitor progress is absent for several countries, while in six nations, the direction of travel is away from the target.

Figure 1: Countries' progress towards selected Aichi targets

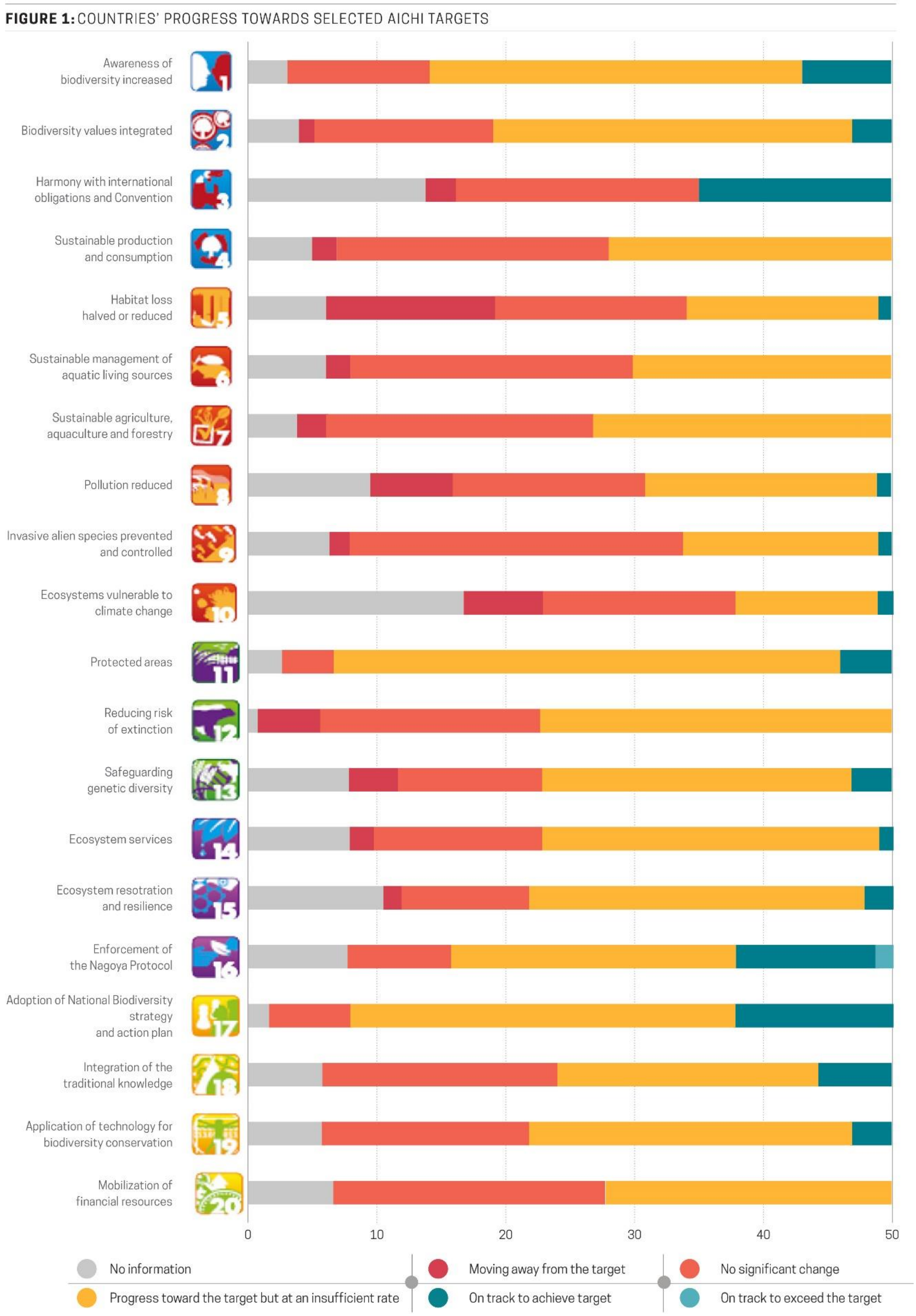


Figure 1 also shows some progress in the case of Aichi Target 11 – namely, protected areas (although this finding should be placed in the context that much progress in the case of targets is still only effected on paper – we discuss more in terms of conservation success stories below). Thirty-nine countries are progressing towards the target, albeit at an insufficient rate (Stringer et al., 2018).

Opportunities exist to learn from examples of better practice, including how we might be able to scale up approaches and initiatives worthy of replication. One key example here, shown in Box 1, is the West African Marine Protected Area Network that supports the growth and maintenance of Marine Protected Areas (MPAs) in West African countries (Failler et al. 2019).

Box 1: The West African Marine Protected Area Network

> West African MPAs have been set-up initially for the protection of the fish biomass and/or certain emblematic species (turtles, manatees, birds, etc.). With the implementation of the National Determined Contribution in the context of the Paris Agreement on Climate Change, they further play the role of supplying key services for mitigation (blue carbon sequestration mainly) and for adaptation (coastal protection for instance). Overall, their habitats provide about 25% more regulating services than similar ones without special protection (Failler and Binet, 2012). A recent study, for example, showed that the Banc d'Arguin National Park, the largest African coastal MPA, would contribute to 20% of Mauritania's mitigation objective valued at 9 billion euros (with an annual running cost of only 1 million euros). Thus, the government, while recognising the key role of MPA, is taking steps toward the integration of coastal ecosystem services into its NDC (Tregarot et al., 2019). In other words, those measures put in place for the preservation of the biodiversity are now benefiting the society far beyond their initial mandate, with a very high return on public investment.

Indeed, as shown in Box 1 and elsewhere, protected areas serve as a key example of measures that are already contributing to the recovery of some threatened species. A further example here is the African Wild Dog (*Lycaon pictus*) in southern Africa (Davies-Mostert et al., 2009). Prudent land uses that maintain extensive, well-connected wildlife habitats, and reduce conflict with farmers through careful herding of livestock, have also been shown to facilitate recovery of the African wild dog in East Africa (Woodroffe, 2011), while Dube (2020) working in the Waterberg Biosphere Reserve in South Africa, highlights innovative measures for private landowners to monitor and track wild dogs, helping to reduce human-carnivore conflict. The example of the African Wild Dog is particularly interesting, since it includes land ownership and management that falls outside of, for example, formally designated national and provincial parks.

Other measures include control of alien invasive species and restoration of ecosystems (Nyingi et al., 2018), for example as articulated in the Volta Basin Authority's Strategic Action Plan. As at 2015, 13.4% of the continent's terrestrial and 2.6 % of the marine realm had been declared as protected areas (Belle et al., 2015); with other sites identified as wetlands of international importance, significant bird and biodiversity areas, community conserved areas, UNESCO World Heritage Sites, and Biosphere reserves, amongst others.

4. Future pathways and options

Understanding the directions of changes to biodiversity and ecosystem services, and their contributions to human wellbeing can provide useful insights into how future changes could impact progress towards key targets, such as those outlined in the African Union Agenda 2063, the Sustainable Development Goals, and the post-2020 Aichi Biodiversity targets. The Africa Regional Assessment considered five plausible futures (Table 2) based on an archetype approach (Sitas and Harmáčková et al. in press) – all underpinned by various assumptions as to what each future could look like.

Table 2: The Global Scenarios Group (GSG) archetypes (at the global level) with their key characteristics and assumptions. Source: based on van Vuuren *et al.* (2012) (taken with permission from Biggs et al. 2018)

TABLE 2: THE GLOBAL SCENARIOS GROUP (GSG) ARCHETYPES (AT THE GLOBAL LEVEL) WITH THEIR KEY CHARACTERISTICS AND ASSUMPTIONS

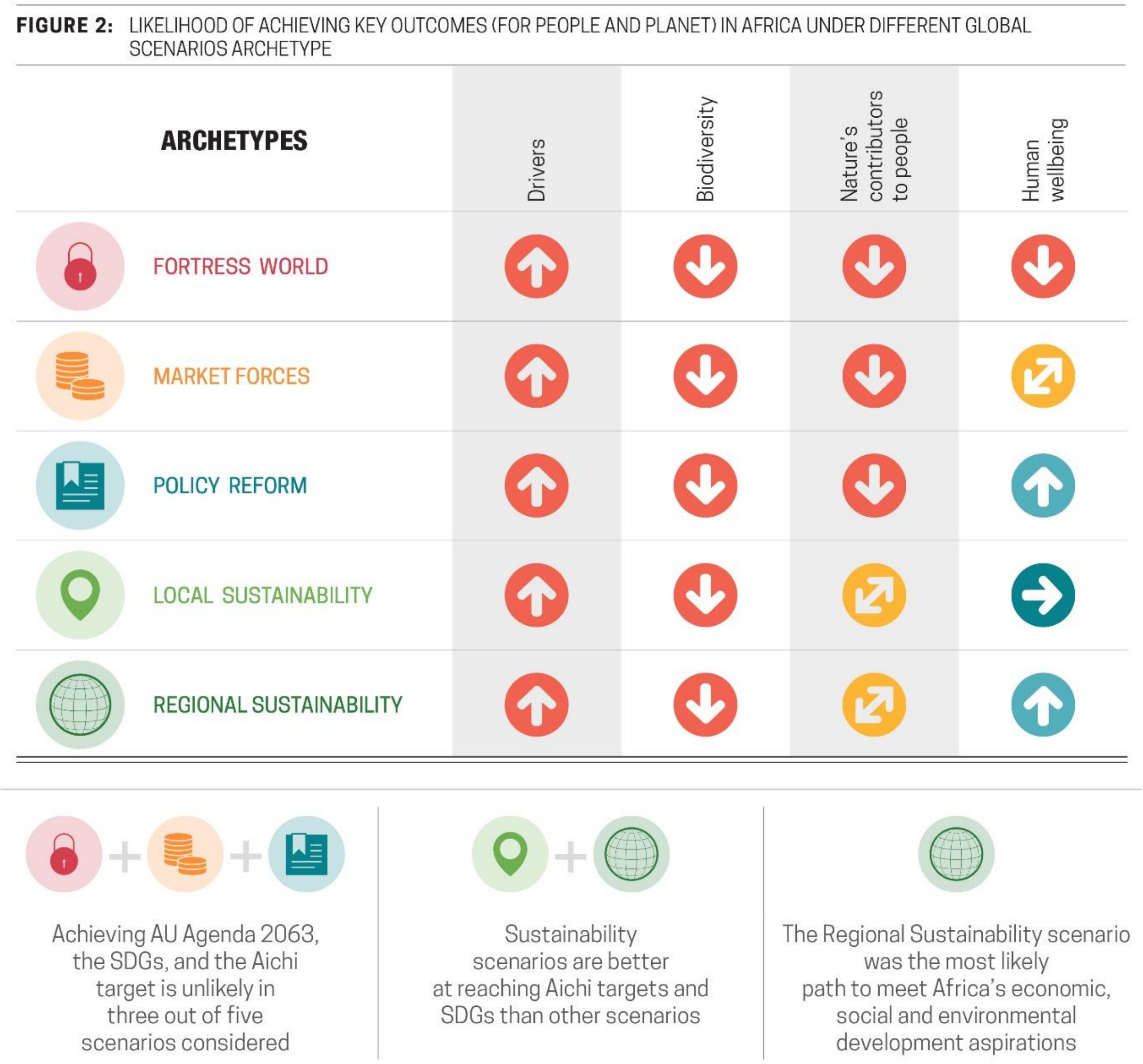
GSG ARCHETYPE CATEGORY	FORTRESS WORLD	MARKET FORCES	POLICY REFORM	LOCAL SUSTAINABILITY	REGIONAL SUSTAINABILITY
MAIN OBJECTIVES	Security	Economic growth	Various goals	Local sustainability	Regional and global sustainability
GLOBAL POPULATION GROWTH	High	Low	Low	Medium	Low
GLOBAL TECHNOLOGY DEVELOPMENT	Slow	Rapid	Rapid	Ranging from slow to rapid	Ranging from mid to rapid
GLOBAL ECONOMIC DEVELOPMENT	Slow	Very rapid	Rapid	Ranging from mid to rapid medium	Rangin from slow to rapid
TRADE	Trade barriers	Globalization	Globalization	Trade barriers	Globalization
POLICIES AND INSTITUTIONS	Strong national governments	Policies create open markets	Policies reduce market failures	Local steering: local actors	Strong global governance
ENVIRONMENTAL MANAGEMENT	Reactive	Reactive	Both reactive and proactive	Proactive	Proactive

The analysis showed that drivers of adverse changes in biodiversity and ecosystem services will increase under all the scenarios (Biggs et al. 2018). In turn, such changes are likely to further negatively impact on the ability of nature to contribute to human wellbeing and sustainable development under most cases, except in regional and local sustainability and supportive policy reform. It was unlikely that the African Union Agenda 2063, the SDGs and the Aichi Biodiversity would be achieved in three out of the five different futures (see Figure 2). Overall, only the regional and local sustainability futures offered pathways that offer Africa the greatest chances to meet its development goals in an economic, social and environmentally friendly way (Biggs et al 2018).

All future scenarios present trade-offs but multiple synergies and policy alignments can support the feasibility of more desirable, equitable and sustainable development options. Our assessment demonstrated that the ‘Fortress World’ scenario was least likely to support Africa in the achievement of multiple goals and targets. Overall, this future was found to result in failure to achieve important development goals. Market forces (MF) and policy reform (PR) scenarios, representing ‘Business-as-usual’ approaches, offer some potential for achieving multiple policy goals. Nevertheless, these futures do not adequately support biodiversity conservation, nor the diverse benefits of nature to human well-being. Conditions under a more ‘managed transformation’ type of future, through policies and practices aligned with regional sustainability and, to a lesser extent, local sustainability, increased the likelihood of reaching a range of sustainable goals.

Taking all the goals, targets and aspirations together, no single scenario option allows Africa to achieve them all, despite that some pathways appear more desirable for decision makers. If Africa is to achieve a desirable future (including that envisaged by commitment to targets), it is critical that development of policy and practice be not only based on inclusive and responsible economic tools, but also support the conservation and sustainable use of natural resources and their benefits to people (Figure 2).

Figure 2: Likelihood of achieving key outcomes in Africa under different global scenarios archetypes



5. Conclusions: where to from here?

As shown, there are options for Africa to balance development goals with protection of biodiversity and ecosystem services – in fact, such protection forms the basis for achieving development goals and improved human well-being. This may only be achieved, however, through a commitment to transformative change. Progress towards achievement of the Aichi Biodiversity Targets, SDGs, African Union's Agenda 2063, and the 2ºC commitment under the 2015 Paris Agreement on climate change, whilst helping support aspirations for a prosperous Africa, requires a fundamental shift away from the status quo.

Such transformative change towards sustainability, in line with aforementioned targets, will also depend on governance options that are able to harness synergies and deliver multiple benefits (IPBES 2018). By promoting policy coherence with adequate resources and capacity, and encouraging adaptive governance approaches that bring together different perspectives, a more equitable approach to accessing natural resources can ensue, helping to more effectively distribute costs and benefits. In addition, a more enabling environment that embraces Africa's diversity will help to ensure justice and fairness in access to the continent's diverse natural resources. A key finding here is that success stories regarding, for example, species stabilization or recovery, can not only rely on conservation within formal protected areas. This is, of course, a long addressed argument – but it is strongly emphasized in our review of those measures that might be scaled up. Measures that focus, for example, on private landowners or land managers outside of formally designated protected areas are clearly absolutely key (and must be evidence based). Africa has an ambitious development agenda that is critically tied to maintaining and sustainably harnessing its diverse natural systems, biodiversity and ecosystem services – as we have shown, they cannot be decoupled. In order to achieve this transformative agenda, it is necessary for all stakeholders to make use of effective policies that minimise trade-offs and maximise synergies under uncertainty so as to achieve a desirable and prosperous future for Africa.

We cannot conclude this paper without addressing COVID19, and the situation within which African conservation finds itself (this paper was first submitted in October 2019, and our context has, of course, changed dramatically). Certain models of conservation in Africa rely, to varying extents, on international tourism – and the recovery of this sector will be key to it's long term ability to achieve, for example, those biodiversity targets where regions and countries currently face difficulties (see, for example, Lindsey et al 2020 and their consideration of how to achieve conservation on the continent during COVID19, and in the post COVID19 period). In turn, conservation of biodiversity and ecosystem services is, of course, key to preventing and controlling zoonotic disease. As stated above, the continent has an ambitious development agenda – one that, along with the world at large, now faces possibly it's greatest economic challenge to date. To quote Lenzen et al in their recent paper in PLOSOne – 'How humanity reacts to this crisis will define the post pandemic world' (Lenzen et al 2020: 1). We can truly say that the post pandemic conservation world will help define our future, as a continent and as a planet.

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References

Akumaga, U., & Tarhule, A. (2018). Projected Changes in Intra-Season Rainfall Characteristics in the Niger River Basin, West Africa. Atmosphere, 9, 497. https://doi.org/10.3390/atmos9120497

Belle, E., Wicander, S., Bingham, H., & Shi, Y. (2015). Governance of Protected Areas in Africa, A Global Review. UNEP-WCMC, Cambridge, UK. Available from http://papaco.org/wpcontent/uploads/2015/04/PAPACO-study-17_GOVERNANCE-STUDY-0-FINAL_REPORT-CONTEXT.pdf.

Bett, B., Lindahl, J., & Delia, G. (2019). Climate Change and Infectious Livestock Diseases: The Case of Rift Valley Fever and Tick-Borne Diseases. In The Climate-Smart Agriculture Papers: Investigating the Business of a Productive, Resilient and Low Emission Future. Edited by T.S. Rosenstock, A. Nowak, & E. Girvetz. Springer International Publishing, Cham. pp. 29–37. doi:10.1007/978-3-319-92798-5_3.

Biggs, R., Kizito, F., Adjonou, K., Ahmed, M. T., Blanchard, R., Coetzer, K., Handa, C. O., Dickens, C., Hamann, M., O'Farrell, P., Kellner, K., Reyers, B., Matose, F., Omar, K., Sonkoue, J-F., Terer, T, Vanhove, M., Sitas, N., Abrahams, B., Lazarova, T., & Pereira, L. Chapter 5: Current and future interactions between nature and society. In IPBES (2018): The IPBES regional assessment report on biodiversity and ecosystem services for Africa. Archer, E. Dziba, L., Mulongoy, K. J., Maoela, M. A., & Walters, M. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany, pp. 297–352.

Connolly-Boutin, L., & Smit, B. (2016). Climate change, food security, and livelihoods in sub-Saharan Africa. Regional Environmental Change, 16(2), 385–399. https://doi.org/10.1007/s10113-015-0761-x

Daszak, P., Cunningham, A. A., & Hyatt, A. D. (2000). Emerging infectious diseases of wildlife– threats to biodiversity and human health. Science, *287*(5452), 443–449. https://doi.org/10.1126/science.287.5452.443

Davies-Mostert, H.T., Mills, M.G.L. & Macdonald, D.W. (2009). A critical assessment of South Africa's managed metapopulation recovery strategy for African wild dogs. In Reintroduction of top-order predators. [Conservation Science and Practice No 5.]: 10–42. Hayward, M.W. & Somers, M.J. (Eds.).

Dube, L. (2020). Drivers of farmer-wild dog (lycaon pictus) conflict in the Waterberg Biosphere Reserve. MSc thesis, University of Pretoria. Pretoria, South Africa.

Failler P., Binet T. (2012), Évaluation de la valeur socio-économique des écosystèmes marins et côtiers des Aires marines protégées de l'Afrique de l'Ouest, Rapport synthèse, RAMPAO/PRCM/EVA, 8 p.

Failler, P., G. Touron-Gardic, M.-S. & Traoré (2019). Is Aichi Target 11 Progress correctly measured for developing Countries? Trends in Ecology and Evolution, available online 05 Aug. 2019, https://doi.org/10.1016/j.tree.2019.07.007.

Hummel, M., Hallahan, B.F., Brychkova, G., Ramirez-Villegas, J., Guwela, V., Chataika, B., Curley, E., McKeown, P.C., Morrison, L., Talsma, E.F., Beebe, S., Jarvis, A., Chirwa, R., & Spillane, C. (2018). Reduction in nutritional quality and growing area suitability of common bean under climate change induced drought stress in Africa. Sci Rep 8(1): 1–11. doi:10.1038/s41598-018-33952-4.

IPBES (2018). The IPBES regional assessment report on biodiversity and ecosystem services for Africa. Archer, E. Dziba, L., Mulongoy, K. J., Maoela, M. A., & Walters, M. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 492 pages. http://doi.org/10.5281/zenodo.3236178

IPBES (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E. S. Brondizio E.S., H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, & C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany.

IPCC (2018). Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)].

Lenzen M., Li M., Malik A., Pomponi F., Sun Y-Y. & Wiedmann T., et al. (2020) Global socio-economic losses and environmental gains from the Coronavirus pandemic. PLoS ONE 15(7): e0235654. https://doi.org/10.1371/journal.pone.0235654

Li, L., Cao, R., Wei, K., Wang, W., & Chen, L. (2019). Adapting climate change challenge: A new vulnerability assessment framework from the global perspective. Journal of Cleaner Production 217: 216–224. doi:10.1016/j.jclepro.2019.01.162.

Lindsey, P., Allan, J., Brehony, P., Dickman, A., Robson, A., Begg, C., Bhammar, H., Blanken, L., Breuer, T., Fitzgerald, K. & Flyman, M. (2020). Conserving Africa's wildlife and wildlands through the COVID-19 crisis and beyond. Nature Ecology & Evolution: 1-11.

MA (Millennium Ecosystem Assessment) (2005). Ecosystems and human well-being: Synthesis. Washington, DC, USA: Island Press. Retrieved from https://www.millenniumassessment. org/documents/document.356.aspx.pdf

Gudka, M., Obura, D., Mwaura, J., Porter, S, Yahya, S. & Mabwa, R. (2018). Impact of the 3rd Global Coral Bleaching Event on the Western Indian Ocean in 2016. Global Coral Reef Monitoring Network (GCRMN)/Indian Ocean Commission. pp. 65

Myhre, G., Shindell, D., Bréon, F-M., Collins, W., Fuglestvedt, J., Huang, J., Koch, D., Lamarque, J-F., Lee, D., Mendoza, B., Nakajima, T., Robock, A., Stephens, G., Takemura, T., & Zhang, H. (2013). Anthropogenic and natural radiative forcing. In T. F. Stocker, D. Qin, G-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, & P. M. Midgley (Eds.), Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press. Retrieved from https://www.ipcc.ch/pdf/assessmentreport/ar5/wg1/WG1AR5_Frontmatter_FINAL.pdf

Nyingi, W., Oguge, N., Dziba, L., Chandipo, R., Didier, T. A., Gandiwa, E., Kasiki, S., Kisanga, D., Kgosikoma, O., Osano, O., Tassin, J., Sanogo, S., von Maltitz, G., Ghazi, H., Archibald, S., Gambiza, J., Ivey, P., Logo, P. B., Maoela, M. A., Ndarana, T., Ogada, M., Olago, D., Rahlao, S., & van Wilgen, B. Chapter 4: Direct and indirect drivers of change in biodiversity and nature's contributions to people. In IPBES (2018): The IPBES regional assessment report on biodiversity and ecosystem services for Africa. Archer, E., Dziba, L., Mulongoy, K. J., Maoela, M. A., & Walters, M. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany, pp. 207–296.

Obura, D. O. (2016). Coral bleaching response guide 2016 (Western Indian Ocean). Retrieved from http://cordioea.net/ bleaching_resilience/wio-bleaching-2016

Peters, M. K., Hemp, A., Appelhans, T., Becker, J. N., Behler, C., Classen, A., ... & Gebert, F. (2019). Climate–land-use interactions shape tropical mountain biodiversity and ecosystem functions. Nature, 568(7750), 88.

Smale, D. A., Wernberg, T., Oliver, E. C., Thomsen, M., Harvey, B. P., Straub, S. C., ... & Feng, M. (2019). Marine heatwaves threaten global biodiversity and the provision of ecosystem services. Nature Climate Change, 9(4), 306.

Stringer, L. C., Osman-Elasha, B., DeClerck, F., Ayuke, F. O., Gebremikael, M. B., Barau, A. S., Denboba, M. A., Diallo, M., Molua, E. L., Ngenda, G., Pereira, L., Rahlao, S. J., Kalemba, M. M., Ojino, J. A., Belhabib, D., Sitas, N, Strauß, L., & Ward, C. Chapter 6: Options for governance and decision-making across scales and sectors. In IPBES (2018): The IPBES regional assessment report on biodiversity and ecosystem services for Africa. Archer, E. Dziba, L., Mulongoy, K. J., Maoela, M. A., & Walters, M. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany, pp. 353–414.

Tambling, C. J., & Toit, J. T. D. (2005). Modelling Wildebeest Population Dynamics: implications of predation and harvesting in a closed system. Journal of Applied Ecology, 42 (2005), pp. 431-441.

Trégarot E., Catry T., Pottier A., Cornet C., Maréchal J.-P., Fayad V., Sidi Cheick M.A., David G., Dia A.D., Fall A.D., Sarr O., El Valy Y., Wagne O.H., Meisse B., Kane E.A., Ball A.C., Haidallah M.S., Braham C.B., Dia M., Abdel Hamid M.L., Rey-Valette H., Salles J.-M., Ly D., Gascuel D., Cissé C.B. & Failler P. (2018). Évaluation des services écosystémiques du Banc d'Arguin, Mauritanie. Rapport final pour le Parc National du Banc d'Arguin, 402 p.

UNEP (2016). Blue Carbon Financing of Mangrove Conservation in the Abidjan Convention Region: A Feasibility Study. United Nations Environment Programme, Abidjan Convention Secretariat and GRID-Arendal, Nairobi, Abidjan and Arendal.

Van Vuuren, D.P., Kok, M.T., Girod, B., Lucas, P.L. & de Vries, B. (2012). Scenarios in global environmental assessments: key characteristics and lessons for future use. Global Environmental Change, 22(4), pp.884-895.

Woodroffe, R. (2011). Demography of a recovering African wild dog (*Lycaon pictus*) population. Journal of Mammalogy, 92(2): 305–315

Wright, H., Huq, S., & Reeves, J. (2015). Impact of climate change on least developed countries: Are the SDGs possible? Retrieved from http://pubs.iied.org/17298IIED/