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Climate Change

Abstract On its current development trajectory the world is headed for serious climate change trouble. More carbon emissions will affect all of humanity and with its low adaptation capacity, arid climates and rainfall-dependent agriculture, Africa is particularly at risk. Cillliers offers an in-depth assessment of the implications of climate change for Africans. In addition to reviewing the scientific consensus on the threats climate change is likely to pose in the coming decades, he sheds light on how Africa's future trends in energy, population and lifestyle will affect carbon emissions. The chapter concludes by comparing Africa's carbon emissions in four scenarios with the Current Path forecast, namely Made in Africa and Free Trade (highest carbon emissions) and Leapfrogging and Demographic Dividend (lowest carbon emissions).

Keywords Climate change · Anthropocene · Emissions · Adaptation · Mitigation · Desertification · Energy · Oil · Coal · Renewables

Learning Objectives

- Understand how and why Africa is especially vulnerable to the impacts of climate change
- Explain and critically evaluate the difference between climate change mitigation and adaptation
- Understand key climate change projections and their potential implications for Africa.

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The 1997 blockbuster series *The Matrix* describes a world within a world where the earth has effectively been rendered uninhabitable and is run by artificial intelligent systems. The villain, Agent Smith, captures the leader of the human resistance movement, Morpheus, and in the subsequent interrogation talks about the impact that humanity has on the environment:

> Every mammal on this planet instinctively develops a natural equilibrium with the surrounding environment. But you humans do not. You move to an area and you multiply and multiply until every natural resource is consumed and the only way you can survive is to spread to another area. There is another organism on this planet that follows the same pattern. Do you know what it is? A virus. … Human beings are a disease, a cancer of this planet. You are a plague.[1]

The Matrix trilogy were for entertainment and do not purport to present reality, but many scientists believe that the world is in the midst of its sixth mass extinction event, known as either the Holocene or Anthropocene.

Human activity may not be causing the extinction but humanity has clearly accelerated the onset. That message is set out starkly in a statement released in November 2017 titled *World Scientists' Warning to Humanity: A Second Notice* by several thousand scientists from 184 countries who warned: '… we have unleashed a mass extinction event, the sixth in roughly 540 million years, wherein many current life forms could be annihilated or at least committed to extinction by the end of this century'.[2]

The statement went on to include twelve 'examples of diverse and effective steps humanity can take to transition to sustainability', none of which have been implemented.

Six months later, in May 2019, the United Nations released the summary findings of sweeping a 1 500-page assessment compiled by hundreds of international experts that provides the most exhaustive look yet at the decline in biodiversity on earth. Among various depressing findings was that the average abundance of native plant and animal life has fallen by 20% or more over the last century and that many species are being pushed closer to extinction.[3]

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[1] *The Matrix.* 1999. [Film] Directed by Lana and Lilly Wachowski. US: Warner Bros.

[2] Ripple, W. J., Wolf, C., Galetti, M., Newsome, M. T., Alamgir, M., Mahmoud, E. C., Mahmoud, M. I., and Laurance, W. F. 2017. World Scientists' Warning to Humanity: A Second Notice. *Bioscience,* 67(12), pp. 1026–1028, p. 1.

[3] Díaz, S., Settele, J., and Brondízio, E., 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.* Bonn: Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services.

This chapter presents the challenge of climate change and Africa's role within the global context. Rather than explore an alternative scenario, it reviews the impact of four scenarios from previous chapters that have the greatest impact on carbon emissions, namely demographics, manufacturing, leapfrogging and trade, and compares these with the Current Path forecast. The combined impact of all eleven scenarios, the Closing the Gap scenario, is presented in the concluding chapter.

Before proceeding, it is important to underline that IFs is not a climate model. It uses data from the Intergovernmental Panel on Climate Change (IPCC), the Carbon Dioxide Information Analysis Centre and other sources to initialise its forecasts and bases these on relationships from the academic literature reflected in various algorithms for the associated forecasts.

Africa as a Climate Change Taker

Africa is a climate change taker, even if it was not a climate change maker. Despite having very little to do with creating the problem, Africa is disproportionately vulnerable to the impacts of climate change—the most severe challenge facing human life on earth today.

Although natural climatic variability is undoubtedly at play (El Niño was clearly a factor in Cape Town when it almost ran out of water in 2018, for example), the scientific consensus is that human activity, primarily the release of CO_2 and other greenhouse gases, has caused all global warming since 1970.[4]

The 2018 water crisis in Cape Town is a textbook example of the dangerous confluence of long-term anthropogenic climate change, natural variation in weather and poor planning. Cape Town has long been a water-stressed area, but has been able to cope. That is, until temperatures got a little warmer, El Niño got a little worse and the national government failed to upgrade and maintain the necessary water infrastructure and invest in alternative water purifying and treatment systems.

A three-year drought started in the Cape metropole in 2015 and peaked in mid-2017 to mid-2018 when dam water levels hovered between 15 and 30% of total dam capacity. By late 2017 authorities were talking about 'Day Zero', when municipal water supplies would largely be switched off and residents would have to queue for a daily ration of water, much of which would

[4]IPCC, 2014. *Climate Change Synthesis Report Summary for Policymakers.* Geneva: s.n.

have to be trucked in. Eventually the City of Cape Town was able to implement significant water restrictions and, after good rains in June 2018, water restrictions were eased.[5]

The line between barely getting by and a national emergency can be very thin indeed.

Cape Town managed to forestall a water crisis by the skin of its teeth, but going forward this 'new normal' will leave the city and surrounding area increasingly vulnerable, particularly because it serves as a destination for many poor South Africans who move there from the Eastern Cape and because it is a global tourist destination. The result is extremely rapid urbanisation and intense pressure on infrastructure.[6]

The amount of CO_2 and other greenhouse gases that human activities have already released into the atmosphere has locked the world into a temperature increase of at least 1.2°C above pre-industrial levels.[7] The United Nations Environment Programme (UNEP) warns that on the current trajectory it is realistic to prepare for a 3°C increase. However, should greenhouse gas emissions continue unmitigated, warming of 3.4°C above pre-industrial levels will occur by the end of the century.[8] In this world 'the limits for human adaptation are likely to be exceeded in many parts of the world, while the limits for adaptation for natural systems would largely be exceeded throughout the world'.[9] As a result large portions of the Sahel and West Africa are likely to be unsuited for human habitation.

This is a world that has moved beyond a tipping point and large parts of Africa could consist of desert.

The IPCC expects that the 'current cropping areas of crops such as maize, millet and sorghum across Africa could become unviable'.[10] In a report on a 4°C warmer world the World Bank noted some of the better known foreseen consequences, such as 'the inundation of coastal cities; increasing risks for food production potentially leading to higher malnutrition rates; many dry regions becoming dryer, and wet regions wetter; unprecedented heat waves in many regions, especially in the tropics; substantially exacerbated

[5]City of Cape Town, 2018. *Water Outlook Report.* Cape Town: Department of Water and Sanitation.

[6]Department of Water and Sanitation, 2019. *National Integrated Water Information System.* [Online] Available at: http://niwis.dws.gov.za/niwis2/SurfaceWaterStorage.

[7]Pre-industrial is defined as the average for the period 1850–1900.

[8]United Nations Environment Programme, https://www.unenvironment.org/explore-topics/climate-change.

[9]Warren, R., 2011. The Role of Interactions in a World Implementing Adaptation and Mitigation Solutions to Climate Change. *The Royal Society,* 369(1934).

[10]IPCC, 2014. *The IPCC's Fifth Assessment Report: What's in It for Africa?* s.l.: Climate & Development Knowledge Network.

water scarcity in many regions; increased frequency of high-intensity tropical cyclones; and irreversible loss of biodiversity, including coral reef systems'.[11]

Meanwhile, a 2018 special report from the IPCC found that an increase to 1.5°C is essentially inevitable and may be reached as early as 2030.[12] According to the report, limiting warming to this 1.5°C marker as reflected in the Paris Agreement, would require the entire world to cut greenhouse gas emissions by nearly half of 2010 levels by 2030 *and* make an aggressive push to reach net-zero emissions by 2050.

Instead, the Current Path forecast is that annual global emissions will *increase* by 600 million tonnes by 2037. World annual emissions would only plateau between 2035 and 2040 before starting to decline, as is reflected in Fig. 15.1. Even though developed countries are weaning themselves off fossil fuels and moving towards renewable energy—albeit with varying degrees of urgency—the pace of global emissions is increasing, with the digital world requiring increased amounts of electricity to power its electric cars, artificial intelligence and higher levels of automation.

Drawing on data provided by the Carbon Dioxide Information Analysis Centre, the Current Path forecast is that global CO_2 in the atmosphere will increase from the current levels of just above 415 parts per million to 460 parts per million by 2040 and to 520 parts per million by 2100, translating to a 2.1°C warming over 1990 levels by 2100.

Carbon can be released in many ways, but the three most important contributors to greenhouse gasses are carbon dioxide (CO_2), carbon monoxide (C0) and methane (CH_4) with the latter having the biggest negative impact. Since each gas has a different molecular mass, i.e. they have different weights (carbon dioxide/CO_2 weighs about four times more than CH_4/methane), the unit of measure that is used when calculating carbon emissions is known as the carbon contribution, i.e. just the mass of the carbon component of each of the various greenhouse gasses.[13]

Globally, carbon emissions are projected to increase from a current 9.6 billion tonnes per annum, peak at 10.22 billion tonnes in 2037 and decline to 5.8 billion tonnes per annum by 2100, as reflected in Fig. 15.1, which

[11]As summarized by The GreenFacts initiative, n.d. *Impacts of a 4°C Global Warming*. [Online] Available at: https://www.greenfacts.org/en/impacts-global-warming/l-2/index.htm.

[12]Intergovernmental Panel on Climate Change, October 2018, 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 climate change, sustainable development and efforts to eradicate poverty: IPCC, 2018. *Global Warming of* 1.5°C. Geneva: Intergovernmental Panel on Climate Change.

[13]What this means is that the mass of CO_2 is 44.01 grams per 22.4 L at 25^0 Â°C and at sea level. CO weighs 28.01 grams per 22.4 L and CH_4 weighs 16.04 grams per 22.4 L. However, the carbon contribution for each is 12.01 grams per 22.4 litres.

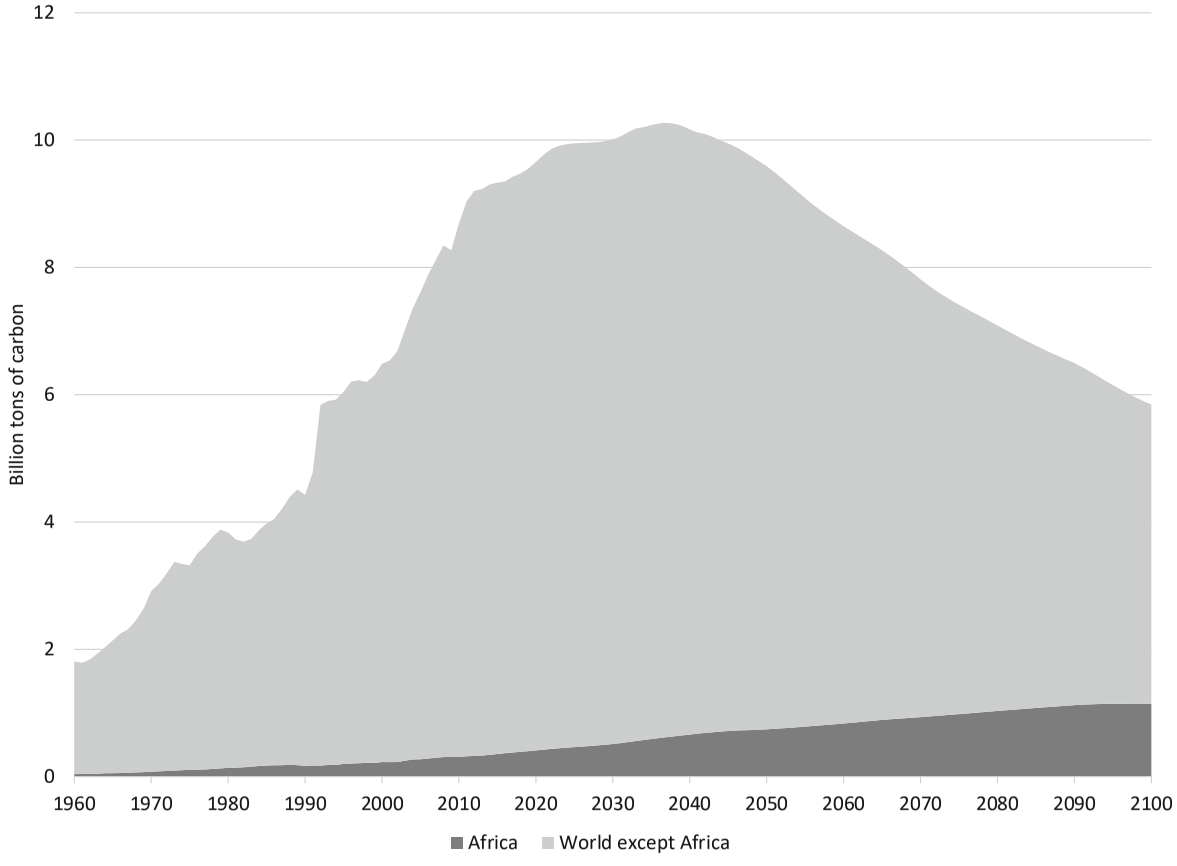

Fig. 15.1 History and Current Path forecast of carbon emissions from Africa and the world: 1960 to 2100 (*Source* IFs version 7.45 initialising from Intergovernmental Panel on Climate Change and Carbon Dioxide Information Analysis Centre)

also highlights the Current Path emissions from Africa. To be sure, this is a cataclysmic forecast.

Most emissions are essentially locked into an expensive energy infrastructure. In Asia the average coal plant is just 11 years old and has decades left of its operational life. Coal plants in the USA and Europe, meanwhile, are roughly 40 years old, on average.[14] Countries like China and India would have to be willing to prematurely decommission a very large number of recently built coal plants for the world to make progress towards global sustainability. In the absence of an extraordinary technological breakthrough, there is no other pathway for reducing emissions. All regions, including Africa, will have to contribute to the necessary shift towards renewable energy to the best of their ability, although the largest contributions inevitably have to come from the biggest polluters.

Climate change might be taking place at a slow pace, but it has lots of momentum. Even if we were to magically cease adding more greenhouse gases to the atmosphere today, the climate would still warm for a few hundred years before slowly returning to pre-industrial levels of atmospheric carbon concentrations.[15]

On our current trajectory extended droughts, heat waves, and other extreme weather events will become the norm; the sea will continue to rise and acidify, killing off vast swathes of marine species; and biodiversity is increasingly threatened. Already research done by the University of Melbourne has found that extreme winds in the Antarctic Ocean have increased by 1.5 metres per second over the past 30 years and that extreme waves have increased by 30 centimetres.[16]

In the short term, these impacts pose grave threats to 'health, livelihoods, food security, water supply, human security, and economic growth'.[17] And the IPCC has acknowledged that their previous risk assessments likely understated the risks of a 1.5°C–2°C temperature increase. In addition, extreme weather events and increased threats to biodiversity all become more acute and pervasive with warmer temperatures.

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[14]International Energy Agency, 2018. *World Energy Outlook.* [Online] Available at: https://www.iea.org/weo2018/.

[15]https://www.atmos.washington.edu/academics/classes/2011Q1/101/Climate_Change_2011_part2.pdf.

[16]Young, I. R., and Ribal, A., 2019. Multiplatform Evaluation of Global Trends in Wind Speed and Wave Height. *Science,* 364(6440), pp. 548–552.

[17]Intergovernmental Panel on Climate Change, October 2018, 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 climate change, sustainable development and efforts to eradicate poverty: IPCC, 2018. *Summary for Policymakers: Global Warming of 1.5.* Geneva: Intergovernmental Panel on Climate Change.

Even limiting warming to 2°C would require dramatic action. Meeting that target would involve a 25% reduction in global greenhouse emissions by 2030 and a net-zero world by 2070. That seems highly unlikely when one looks at the Current Path global forecast of emissions to 2100 in Fig. 15.1.

The Global Energy Transition

Like fossil fuels shaped the geopolitical map over the last two centuries, so 'the energy transformation will alter the global distribution of power, relations between states, the risk of conflict, and the social, economic and environmental drivers of geopolitical instability'.[18] Whereas fossil fuels are concentrated in specific geographic locations and vulnerable to disruption, renewable energy resources are distributed in one form or another in most countries. This means that renewables are better suited to decentralised forms of energy production and consumption.

Countries like the USA are already close to being self-sufficient in terms of energy, largely due to the shale oil and gas revolution. Energy self-sufficiency is accelerating the international withdrawal and isolation of the USA, while China's determined investment in connecting Asia through the Belt and Road Initiative, its leadership in research and development and investments in renewables is likely to improve its geopolitical standing.[19]

Once the energy storage problem is resolved, countries and populations across Africa will benefit greatly from the dispersed nature of renewables, particularly through reduced fossil fuel imports. Actually most African countries have a unique opportunity to leapfrog the fossil-fuel centred development model to renewables. Some, such as Libya, the Republic of Congo, Angola, Equatorial Guinea, South Sudan and Gabon will suffer since they are extraordinarily dependent on the foreign exchange earnings from their fossil fuel exports. Others with large fossil fuel import bills, such as Tanzania, Côte d'Ivoire, Guinea and Senegal, will benefit.

High energy bills transfer large amounts of wealth abroad and make countries vulnerable to price swings. Renewables have none of these risks. Some countries, such as Ethiopia and Lesotho, could obtain all or most of their electricity from hydropower. Others, like Kenya, can achieve similar results

[18]Global Commission on the Geopolitics of Energy Transformation, 2019. *A New World: The Geopolitics of the Energy Transformation.* Abu Dhabi: s.n., p. 12.

[19]This analysis is based on Global Commission on the Geopolitics of Energy Transformation, 2019. *A New World: The Geopolitics of the Energy Transformation.* Abu Dhabi: s.n.

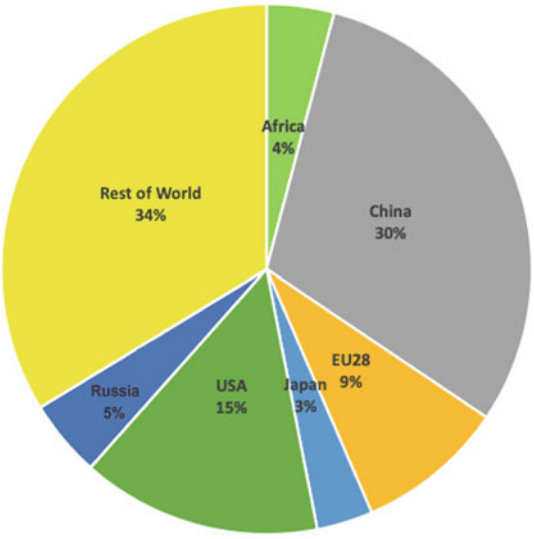

Fig. 15.2 Carbon Emissions by countries or region as a percent of the total (2018) (*Source* United States Environmental Agency, Global Greenhouse Gas Emissions Data)

using a mix of renewables, such as hydro, geothermal, wind, biomass and solar power.[20]

Most carbon dioxide (CO_2) is emitted from the energy sector, followed by transport, agriculture land and forestry, residential and commercial and industry. Most methane (CH_4) comes from agriculture and energy production and most nitrous oxide (N_2O) emissions are from agriculture.[21]

Data on emissions is often, and quite misleadingly, presented on the basis of emissions per country. That is presented for key countries in Fig. 15.2, with all of Africa responsible for about four percent of global emissions in 2018. A much more appropriate comparison would be to calculate emissions per person. On average Africans produce around 1.2 tonnes of CO_2 per annum compared to more than 16 tonnes by Americans, almost 12 tonnes by Russians, more than nine tonnes by Japanese and around seven tonnes by Chinese. The global average is about 4.8 tonnes. In other words, the average

[20] Ibid. Yet Kenya is ironically building a coal-fired plant near the Lamu Port South Sudan Ethiopia Transport corridor project that may even be dependent on coal imports. Leithead, A. 2019. Row over Chinese Coal Plant Near Kenya World Heritage Site of Lamu. [Online] Available at: https://www.bbc.com/news/uk-48503020.

[21] Ritchie, H., and Roser, M., 2017. *CO_2 and Greenhouse Gas Emissions*. Our World in Data. [Online]. Available at: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions Also see United States Environmental Protection Agency, n.d. *Global Greenhouse Gas Emissions Data.* [Online] Available at: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data (Fig. 15.2).

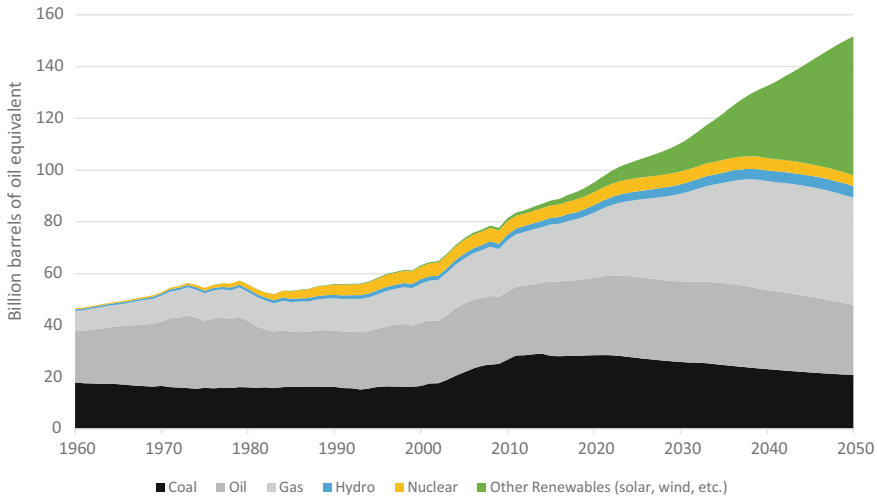

Fig. 15.3 Current Path forecast of world energy production by type: 1980 to 2050 (*Source* IFs version 7.45 initialising from International Energy Agency World Energy Outlook)

African produces less than eight percent of the emissions of the average American. Few numbers better illustrate the stark differences in responsibility for global emissions—and these numbers do not account for the stock of carbon emitted by the populations of these different countries over time.[22]

The Current Path forecast for world energy production is presented in Fig. 15.3 in billion barrels of oil equivalent from coal, oil, gas, nuclear, hydro and other renewables.[23] In this forecast the production of coal oil and gas dominates out to 2060, although renewables start growing strongly beyond 2030. The forecast is that the contribution made by renewables will be larger than that from coal in 2038, bigger than that from oil in 2040 and will surpass natural gas in 2046. Clearly this Current Path forecast is nowhere near the target of keeping global warming to 1.5 or even 2 degrees Celsius by the end of the century.

[22]Calculated from data available from the csv file on the chart CO_2 emissions per capita: Ritchie, H., and Roser, M., 2017. *CO_2 and Greenhouse Gas Emissions.* Our World in Data. [Online]. Available at: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

[23]The forecasts from the International Energy Agency (IEA) in its World Energy Outlook 2018 is that almost two-thirds of global capacity additions to 2040 will come from renewables, thanks to falling costs and supportive government policies. In the most recent forecast from the IEA, natural gas overtakes coal in 2030 to become the second largest fuel in the global energy mix. By 2040, the most likely IEA scenario is that the share of renewables in generation would have increased from its current 25% to more than 40%, but that coal is likely to remain the largest source of energy globally and gas the second largest.

Globally the energy transition path in high-income countries is typically from coal to oil and then to natural gas, which emits 50–60% less greenhouse gases than coal, and, finally, to renewables.

Carbon Emissions and Energy in Africa

Next to the uninhabited Antarctic, Africa and Australia are probably the continents that are most vulnerable to the impact of climate change. Yet Africa contributes very little to global carbon emissions, as can be seen from Fig. 15.1. In 2018 Russia's net emissions were higher than that of the entire African continent.

The Current Path forecast is that, by 2040, Africa will be responsible for 6.6% of carbon emissions. Its relative contribution would modestly increase thereafter as emissions in the rest of the world decreases. Emissions from Africa will increase for several subsequent decades in the Current Path forecast given increased populations and industrialisation.

On the Current Path, most African countries will, by 2040, be releasing more than one million tonnes of carbon each year. Figure 15.4 presents the African countries that will release more than 10 million tonnes of carbon per year in 2018 and 2040. As expected, Nigeria is projected to experience the largest increase in carbon emissions levels by 2040. In South Africa, total emissions will decline as older coal-fired electricity plants are retired and the country experiences modest economic growth. Egypt and Algeria, Nigeria and South Africa consistently release the most carbon in Africa.

The Current Path forecast for Africa for energy production is presented in Fig. 15.5. Gas production will be greater than oil in 2026. Coming from a very low base, renewables overtake coal in 2034 and gas in 2050. From this graph it should be evident that Africa is well-positioned for a much earlier transition to renewables than other regions. It also has some of the most valuable solar, hydro and wind real estate on the planet. Wind and solar are both becoming increasingly price-competitive and electricity storage and efficiency are also improving.

Although gas features prominently in Fig. 15.5, it is important to note that this is a graph of *production* by type, often for export, not in-country use by type. African countries with big proven natural gas reserves are Nigeria, Algeria, Mozambique, Egypt, Tanzania and Libya. However, even in these countries there is very little installed gas infrastructure that would allow for domestic use. Instead, since demand for gas is expanding particularly rapidly

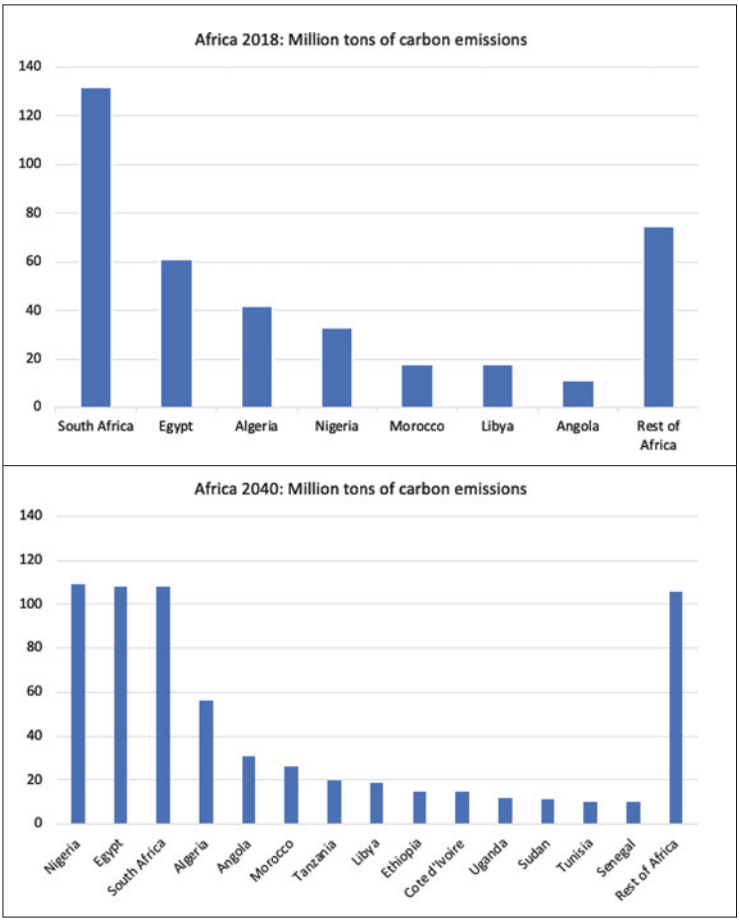

Fig. 15.4 Current Path carbon emissions: African countries that release more than 10 million tonnes in 2018 and 2040 vs Rest of Africa (*Source* IFs version 7.45 initialising from Carbon Dioxide Information Analysis Centre)

in Asia it is very likely that the vast majority of Africa's natural gas production (like its oil) will end up as exports to feed demand in China, India and elsewhere.

Oil is currently the largest source of energy produced in Africa and is likely to remain central to oil-producing Nigeria, Angola, Algeria, Libya, Egypt, the Republic of Congo, Equatorial Guinea, Gabon, Chad, Ghana and Cameroon. Most of that oil is exported rather than refined and then the refined product is imported again although various plans are afoot to build refineries. Libya and Nigeria have globally significant proven oil reserves, while Nigeria and Algeria hold Africa's largest proven gas reserves. In general,

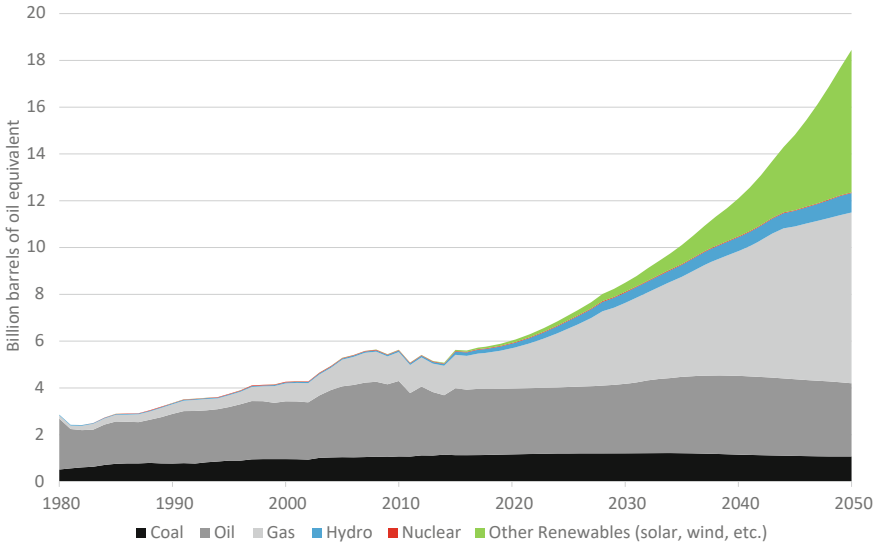

Fig. 15.5 Current Path forecast of Africa's energy production by type: 1980 to 2050 (*Source* IFs version 7.45 initializing from International Energy Agency World Energy Outlook)

though, Africa remains quite unexplored and the potential for additional oil and gas finds is therefore quite good.

The Impact of Climate Change

Chapter 6 showed that agricultural yields in Africa are low by comparative regional standards, but that production can be improved considerably by increasing the amount of land under irrigation, using more fertilisers and genetically modified seeds, and by improving farming practices. However, climate change poses a major threat and will constrain such improvements, particularly in North and West Africa as higher temperatures and shifting rainfall takes its toll.

In 2006, three major flood events (normally a once in every 10–20-year phenomenon) occurred within the space of two months in East Africa, displacing almost 200,000 people in Ethiopia, Somalia and Kenya and destroying thousands of hectares of cropland.[24]

[24]Swarup, A., 2007. *Eastern Africa: Worst Floods in Decades.* [Online] Available at: https://www.ifrc.org/en/nouvelles/nouvelles/common/eastern-africa-worst-floods-in-decades/.

Maize and wheat production have already been affected in many countries, including fisheries in the Great Lakes Region and fruit trees in the Sahel.[25] Droughts and floods are likely to become more frequent and more difficult to predict and could exacerbate food security issues and migratory push factors.

In 2017, weeks of heavy rain led to catastrophic mudslides in Sierra Leone, killing more than 600 people outside Freetown.[26] In 2018 extreme flooding in Niger killed more than 80 people, displaced 50,000 more and wiped out 400 hectares of farmland and 26 000 head of livestock. Meanwhile, these countries have some of the fastest growing populations in the world.[27]

Africa has already experienced some of the most severe effects of climate change to date. Owing to the regions' existing hot and dry climate, high rates of poverty and profound dependence on rain-fed agriculture, the IPCC has identified the Sahel and West Africa as climate change 'hot spots' that are projected to experience unprecedented effects of climate change before anywhere else in the world. In typically antiseptic language the IPCC notes that during the 1970s and 1980s, the Sahel region 'experienced the most substantial and sustained decline in rainfall recorded anywhere in the world within the period of instrumental measurements'.[28]

It was initially thought that this drought was caused mainly by human modification of the surrounding landscape, i.e. desertification. However, it has subsequently become clear that rising sea temperatures was the primary driver, reflecting the extent to which climate change is a truly global problem.[29]

West Africa has recently also been exposed to massive flooding, illustrating the complexity of the challenges. For example, in Nigeria nearly 200 people lost their lives and more than 150 000 were displaced in the 2018 floods which also led to a spike in cholera cases.[30]

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[25]IPCC, 2014. *The IPCC's fifth assessment Report: What's in it for Africa?* s.l.: Climate & Development Knowledge Network.

[26]UNOCHA, 2017. *West and Central Africa: 2017 Flood Impact.* [Online] Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/OCHA-ROWCA%20West%20and%20Central%20Africa%202017%20Flood%20Impact_18%20Oct%202017.pdf.

[27]Countries are listed in order of fastest growing populations. All in all, 18 of 25 the fastest growing populations are in Africa, interestingly the rest are all in the Middle East.

[28]The Sahel is a poorly defined area but is generally considered to consist of the area underlying the Sahara desert—stretching from Mauritania in the west to Ethiopia or Eritrea or Djibouti or Somalia in the east. IPCC, 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. New York: Cambridge University Press, p. 518.

[29]Giannini, A., Saravanan, R., and Chang, P., 2003. Oceanic Forcing of Sahel Rainfall on Interannual to Interdecadal Time Scales. *Science*, 302(5647), pp. 1027–1030.

[30]UN OCHA, 2018. *West and Central Africa: Weekly Regional Humanitarian Snapshot.* [Online] Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/External%20weekly%2025%20sep%201%20oct.pdf.

While vulnerable populations are the most susceptible to the direct effects of climate change like flooding and drought, there are also other impacts such as the incidence and distribution of infectious diseases like malaria. Increased temperatures will enable malaria to develop in regions where it was previously absent, such as in the African highlands of Ethiopia, Uganda and Kenya.[31] Heavy rainfall in parts of Central Africa, particularly in areas with limited access to improved sanitation and proper waste management, is again likely to drive an increase in the transmission of water and vector-borne diseases.[32]

The increased desiccation of arid climates like the Sahel and parts of Southern Africa will also affect groundwater recharge rates. Combined with cyclical weather phenomena like droughts or El Niño, it will further exacerbate water security issues. In more affluent communities, this could mean higher prices or even restrictions on the use of basic services, but in poor communities this could lead to an inability to access these fundamental rights, with dire consequences. These trends threaten to negate the progress Africa has made on reducing the burden of communicable diseases and the associated maladies of undernutrition and chronic hunger.

In March 2019 Cyclone Idai smashed into Mozambique, unleashing hurricane-force winds and rain that flooded swathes of this poor country before battering eastern Zimbabwe. More than 700 people died in the two countries, leaving some 1.85 million people in need of assistance in a catastrophe that United Nations Secretary-General Antonio Guterres said rang 'yet another alarm bell about the dangers of climate change'.[33] As if to emphasise the point, Cyclone Kenneth arrived a few days later, first smashing its way across the Comoros islands before making landfall in northern Mozambique. Kenneth was reportedly the strongest cyclone to ever hit Africa.

Climate change makes things worse in areas that are already struggling with high levels of poverty and poor governance. In the first half of 2018 in Nigeria, farmer–herder conflict resulted in more than six times as many fatalities than has been attributed to terrorist group Boko Haram.[34] With climate changes, grazing lands have shifted, which has forced herders to move southward. This has led to competition and violence between farmers and

[31] IPCC, 2014. *The IPCC's fifth assessment Report: What's in It for Africa?* s.l.: Climate & Development Knowledge Network, p. 14.

[32] Field, C. B., and Barros, V. R., 2014. *Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A Global and Sectoral Aspects*. New York: Cambridge University Press.

[33] Rumney, E., and Eisenhammer, S., 2019. *Destructive Cyclone Idai Rings 'Alarm Bell' on Climate Change: U.N. Chief*. [Online] Available at: https://af.reuters.com/article/topNews/idAFKCN1R80JJ-OZATP.

[34] Crisis Group, 2018. Stopping Nigeria's Spiralling Farmer-Herder Violence. *Report 262*, 26 July.

herders. In Mali, the situation has escalated to the point where, '[m]ass repression based on faulty generalisations, and ethnic tensions between farmers and pastoralists are at the core of the ongoing insecurity'.[35]

Western Africa is home to diverse climates that range from rainforests to hyper-arid deserts and is, in a sense, a microcosm of the continent. Its arid regions are likely to get significantly warmer and drier, with droughts becoming more severe and frequent. This will harm agricultural production and could in turn drive large internal and international displacement.

Rising temperatures are likely to have the greatest negative effect on agricultural production with many crops already at their tolerance limits. This problem will be exacerbated by the increasing variability of rainfall that is most pronounced in Eastern and Southern Africa. These regions experience year-to-year variations exceeding 30% around the mean, a rate much greater than the temperate climates in Europe and North America. High seasonal variability compounds these effects, causing droughts and floods.[36] High inter- and intra-annual rainfall variability explains the unpredictable, and relatively low, seasonal and annual flows in many African rivers.

The IPCC expects that agricultural production could decline by more than 20% across Sub-Saharan Africa by 2050, with South Africa and Zimbabwe experiencing reductions of around 30% or more.[37]

These negative effects are likely to be most severe in semi-arid regions, much of which is in North and West Africa. In the Current Path forecast the countries that would be most affected by 2050 would be Mauritania (at 7.5% loss in agricultural yields compared to 2015), Mali, Eritrea, Sudan, South Sudan, Senegal, Burkina Faso and Djibouti (at six percent loss). Countries that will suffer a yield loss of between five and six percent are Egypt, Niger, Gambia, Namibia, Chad, Botswana, Algeria, Benin, Guinea and Morocco.

Although Africa's climates will generally become more arid, Central and Eastern Africa will experience heavier rainfall, especially after mid-century. These changes will likely increase the incidence and spread of water- and vector-borne diseases.[38]

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[35] Diallo, O. A., 2017. Ethnic Clashes, Jihad, and Insecurity in Central Mali. *Journal of Social Justice,* 29(3), pp. 299–306.

[36] Foster, V., and Briceno-Garmendia, C., 2010. Africa's Infrastructure: A Time for Transformation. *Africa Development Forum Series World Bank*.

[37] IPCC, 2014. *The IPCC's Fifth Assessment Report: What's in It for Africa?* s.l.: Climate & Development Knowledge Network.

[38] Field, C. B., and Barros, V. R., 2014. *Climate Change 2014 Impacts, Adaptation and Vulnerability: Part a Global and Sectoral Aspects.* New York: Cambridge University Press, p. 762.

Comparing Carbon Emissions in Different Scenarios

In this section, I compare the results of the Current Path with the four scenarios in this book that have the greatest positive and negative impact on carbon emissions. These are Africa achieving a Demographic Dividend (Chapter 4), Made in Africa on industrialisation (Chapter 8), and the implementation of the African Continental Free Trade Agreement (Chapter 11).

Africa has roughly the same population size in 2040 (at about 2.1 billion people) in all scenarios, except for the Demographic Dividend scenario that results in 100 million fewer people than in the other scenarios.

Just as development elsewhere in the world has increased carbon emissions, Africa, with its burgeoning population and huge demands for improved livelihoods, will also increase its carbon contribution, even if relatively marginally compared with the development path of other regions. Consequently, even the Current Path forecast of solid but unspectacular economic growth would see Africa's annual carbon emissions increase from the current level of roughly 410 million tonnes per year to 660 by 2040 and 750 million tonnes by 2050. The Current Path forecast is indicated with a dashed line in Fig. 15.6.

Generally one would expect that carbon emissions would follow rates of economic growth, i.e. that the scenario where the size of the African economy increases the most would also have the largest emissions, but this is not evident in Fig. 15.6. Each of the five scenarios depicted in Fig. 15.6 presents an aggressive but reasonable positive development pathway on which economic growth rates are above those of the Current Path. However, in two scenarios, the Demographic Dividend and Leapfrogging, CO_2 emissions are actually *below* the Current Path forecast.

In the case of the Demographic Dividend, a smaller population translates into less carbon emissions. In the Leapfrogging scenario growth rates increase but because of the impact of digitisation that is less resource-intensive, and the more rapid transition to renewable energy, carbon emissions is below the Current Path forecast.

The implementation of the African Continental Free Trade Area (Chapter 11), Made in Africa (Chapter 8) and the Agricultural Revolution (Chapter 3) release more carbon emissions over the time horizon 2020–2050 than in the Current Path. Previously I noted that globally the agricultural sector is responsible for almost a quarter of global emissions so it comes as no surprise that a larger agricultural sector increases emissions above the Current Path. Manufacturing is by nature more energy-intensive than other sectors

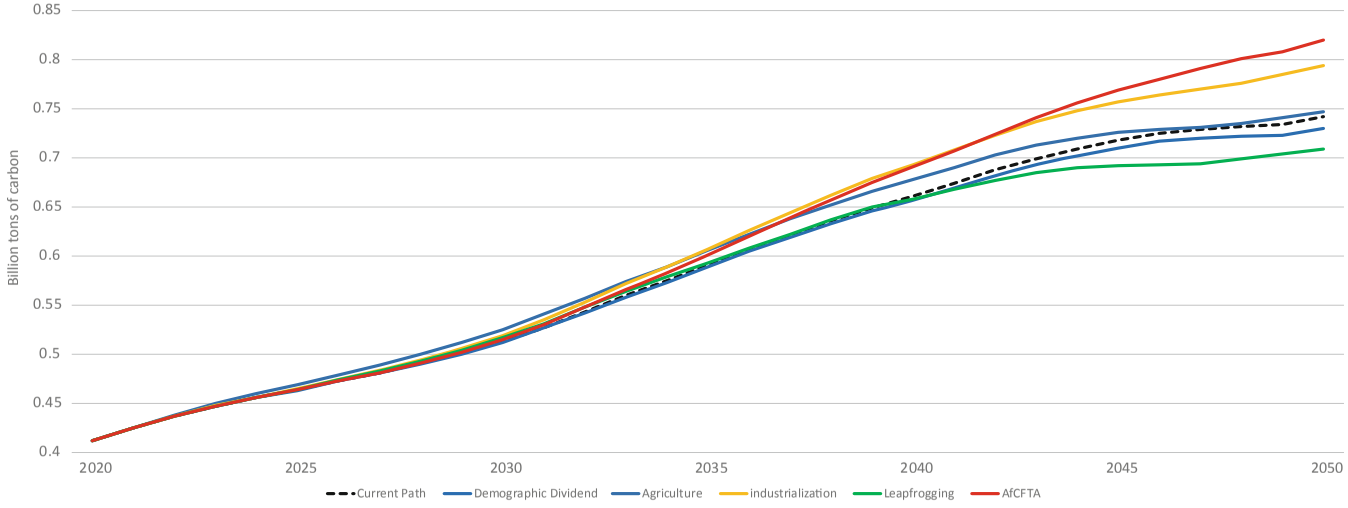

Fig. 15.6 Africa's carbon emissions under different scenarios: 2020–2050 (*Source* IFs version 7.45 initialising from Intergovernmental Panel on Climate Change and Carbon Dioxide Information Analysis Centre)

and hence, in the Made in Africa scenario, carbon emissions increase above the Current Path.

A different and perhaps more useful measure is to see which scenario provides the highest GDP per capita for the lowest carbon emissions. Social Grants (Chapter 7) shows the least improvement in GDP per capita (since it results in slow economic growth) while Leapfrogging (Chapter 10) again gives the best results. In the case of the Social Grants scenario the lower levels of emissions likely follows the transfer of resources to poorer families that are responsible for less emissions.

Responding to Climate Change

The previous comparisons demonstrate how the nature of economic growth and the associated policy decisions impacted Africa's carbon emissions. In responding to this environmental challenge one can either adapt your way of life to the inevitable impacts of climate change, resort to mitigative actions, or both. Mitigative efforts focus on reducing emissions and stabilising the levels of greenhouse gases in the atmosphere. In this way, mitigation is a long-term climate change response as its benefits will only emerge during the second half of the century.

The Paris Agreement represents a global effort to mitigate the future impacts of climate change by trying to reduce greenhouse gas emissions now. And under the Kigali Amendment to the Montreal Protocol (the 1987 agreement to protect the stratospheric ozone layer) that came into force in January 2019, all countries will gradually phase down production and consumption of hydrofluorocarbons (HFCs) and replace it with more environmentally friendly alternatives. Indeed, the global regime to protect the ozone layer remains one of the most successful coordinated international environmental efforts to date.

A second possible reaction is to adapt to life in a changing climate, therefore to the change that is already locked into the climate system. For example, in June 2018 Tanzania completed 2.4 kilometres of sea walls at a cost of US$8.34 million in an effort to protect Dar es Salaam and surrounding areas from rising sea levels. According to USAID, the country could suffer about US$200 million per year in lost land and infrastructure damage due to sea-level rise.[39]

[39] Cusick, D., 2018. *New Walls Aim to Hold Back Rising Seas off Tanzania.* [Online] Available at: https://www.scientificamerican.com/article/new-walls-aim-to-hold-back-rising-seas-off-tanzania/?redirect=1.

On the other side of the continent Lagos is one of the largest and fastest growing cities in the world, but much of the city is less than one meter above sea level.[40] Lagos is, and has always been, a city-oriented towards the sea. In fact, it is expanding into the Atlantic through expensive developments on newly reclaimed land on the one hand and overpopulation in slum settlements on the other. With many of its slum communities literally built in the sea, vulnerable communities in Lagos are already highly exposed to rising sea levels and more severe storm activity caused by climate change.

Seventy percent of Lagos' population live in slums and, with a population density 10 times that of New York City, a powerful storm would affect millions. Furthermore, average sea-level rise is projected to reach approximately 30 cm by 2050 and between 30 cm and 1.8 m by 2100 (then rising an additional 30 cm or more after each decade).[41]

Against this backdrop the 'Great Wall of Lagos' promises to offer protection from climate change, but only for those Nigerians who can afford to live in Eko Atlantic—a massive Dubai-style city under construction. The 8.5 km seawall will protect the shoreline of Victoria Island[42] and early phases of Lekki (a city on a peninsula to the east of Lagos) from coastal erosion.[43] What will happen to the people of Makoko and other slum areas is, of course, an entirely different matter.

And then there is the Great Green Wall. For more than a decade affected countries in the Sahel and others have advanced and promoted the Great Green Wall of the Sahara and the Sahel Initiative (*Grande Muraille Verte pour le Sahara et le Sahel*) that aims to halt the southward spread of the Sahara desert and to constrain the impact of climate change. The original concept, that dates from colonial times, is for a front-line of trees 50 km deep (now reduced to 15 km) to be planted to help contain the desert.

The project has subsequently evolved into an integrated rural development effort to respond to the detrimental social, economic and environmental impacts of land degradation and desertification straddling eleven countries and 8000 km from Senegal in the west to Djibouti in the east.[44] In 2017 it was adopted as a flagship project by the UN Conference on Sustainable

[40]The UN Population Division uses data from the state of Lagos that is then standardized.

[41]Romm, J. J., 2015. *Climate Change: What Everyone Needs to Know.* Oxford: Oxford University Press.

[42]Victoria Island is the financial heart of Lagos and historically one of the city's more affluent areas.

[43]Eko Atlantic's website boasts the 'best prime real estate in West Africa' and features a video starring the 42nd President of the United States Bill Clinton. Eko Atlantic, n.d. *Prime Real Estate in West Africa.* [Online] Available at: https://www.ekoatlantic.com/.

[44]The width of the wall has been scaled back to 15 km and it is estimated to cost US$8 billion. See BBC News, 2017. *YouTube. Why Is Africa Building a Great Green Wall?.* [Online] Available at: https://www.youtube.com/watch?v=4xls7K_xFBQ; BBC Newsnight, 2017. *The Great Green Wall of*

Development and 20 countries have pledged support to it but according to the United Nations, the initiative has only reached 15% of its targets over a decade.

Apart from a minimum effort in Burkina Faso and Senegal, little progress has been made. Recently (on 30 July 2019) Ethiopia claimed to have planted more than 353 million trees in just twelve hours as part of a wider reforestation campaign that is being spearheaded by Prime Minister Abiy Ahmed as part of 'Green Legacy'—an example of what could be possible.[45] The slow progress with the rest of the Great Green Wall notwithstanding, this is the kind of effort that will be required in all countries that form part of the Wall as well as moving away from the idea of a narrow band of trees along the southern edge of the Sahara.

Africa's forests could actually be a game changer in terms of tackling climate change. Approximately 2.6 billion tonnes of carbon dioxide, one-third of the CO_2 released from burning fossil fuels, is absorbed by forests each year. 'Halting the loss and degradation of forest ecosystems and promoting their restoration', according to the International Union for Conservation of Nature 'have the potential to contribute over one-third of the total climate change required by 2030 to meet the objectives of the Paris Agreement'.[46] According to the Global Forest Watch, tree-cover loss peaked in 2016 but the overall trend is still negative. The Democratic Republic of the Congo is now the country with the second largest losses by area and Madagascar lost two percent of its entire primary forest in 2018. Ghana and Côte d'Ivoire showed the highest rise in percentage terms in losses of primary forest.[47]

Most of this increase, particularly in Ghana, is likely to be due to small-scale gold mining. There has also been an expansion of cocoa farming that has led to forest loss.

Africa does have some ability to mitigate climate change—massive tree planting is just one example—but needs to direct significant effort at adaptation. The African Union has acknowledged as much in the Agenda 2063 planning document, which states that 'Africa shall address the global challenge of climate change by prioritizing adaptation in all our actions…

Africa: Will It Help Fight Climate Change? [Online] Available at: https://www.youtube.com/watch?v=HVOYN70scS8.

[45]Karasz, P., 2019. Ethiopia Says It Planted Over 350 Million Trees in a Day, a Record. *New York Times*. 30 July 2019 [Online] Available at: https://www.nytimes.com/2019/07/30/world/africa/ethiopia-tree-planting-deforestation.html.

[46]Rizvi, A. R., Baig, S., and Kumar, C., 2016. *Forests and Climate Change*, Gland: IUCN.

[47]World Resources Institute, n.d. *Global Forest Watch*. [Online] Available at: https://www.globalforestwatch.org/.

for the survival of the most vulnerable populations… and for sustainable development and shared prosperity'.[48]

Development as a Coping and Planning Mechanism

Developed countries which often have carbon-intensive economies, have, by definition, more capacity to adapt to climate change and are also more responsible for mitigating it.

A good proxy with which to measure the mitigation capacity of a country is average income levels or GDP per capita—a well-known yardstick for measuring and comparing technological sophistication and well-being across countries. Generally the higher a country's GDP per capita the more developed its infrastructure, the larger its carbon emissions and the greater its ability to adapt to and mitigate climate change. Countries with developed water-borne sewerage systems and that provide safe drinking water to the majority of its citizens through appropriate piped systems have more capacity to absorb the impact of climate change including responding to severe weather events. Only 3.5% of Africa's agricultural land that is equipped for irrigation, some seven million hectares concentrated in a handful of countries. Expanding land under irrigation means that countries are less susceptible to the impact of climate change.[49]

Conversely, countries with large poor communities, who often lack basic infrastructure and agricultural technology, have much more limited adaptation capacity.

The provision of improved water is particularly critical in the context of climate change. In Central Africa, for example, only around 60% of the population is estimated to have access to an improved water source (piped supplies, boreholes, protected wells and springs and collected rainwater)—the lowest regional access rate on the continent. Across all of Africa, an estimated 290 million people are living without access to improved water owing to poor physical water infrastructure.

On the Current Path, the number of people without access to improved water is projected to grow for the next five to 10 years in all African regions

[48] African Union Commission, 2015. *Agenda 2063: The Africa We Want*, Addis Ababa: African Union.

[49] Foster, V., and Cecilia Briceño-Garmendia, C. (eds.), 2010. Africa's Infrastructure: A Time for Transformation, Africa Development Forum Series, Agence Française de Développement and the World Bank. n.d. [Online] Available at: https://openknowledge.worldbank.org/handle/10986/2692, pp. 1–14, 272 and 287.

except Northern Africa, although the region will face increasing water scarcity and likely deteriorating water quality.[50] More rapid development will therefore mitigate some of these effects. The scenarios with the largest impact on improving access to safe water are the Improved Health scenario (Chapter 3) and Leapfrogging (Chapter 10).

Conclusion: Finding an Environmentally Sustainable Pathway

On its current development trajectory, the world is headed for serious climate change trouble. More carbon emissions will affect all of humanity and with its low adaptation capacity, arid climates and rainfall-dependent agriculture, Africa is particularly at risk.

In recognising the role of humanity in accelerating climate change, leaders have to make difficult choices that would impact upon their election prospects. There are some leaders, such as former US President Donald Trump, who are unwilling to make these choices, instead arguing that humans have not contributed to climate change and that what we are seeing is a natural change in the global system. Their denialism is based on short-term, self-serving political considerations. Politics is supposed to be about leadership, not only about attaining and retaining power. Many of today's young children will be alive by 2100. Theirs may be a world of technological wonders but could also be one of environmental disasters.

Africa is a small player in this unfolding drama. However, it can play an important role in combating deforestation and forest degradation. The impact of climate change upon the continent will be huge and its leaders should therefore seize every opportunity to prepare and to make their voice heard. With a large, vulnerable population it has more to lose than almost any other world region. Climate change is also a potential long-term accelerator of violent resource competition. Shifts in precipitation patterns are likely to have negative impacts on regions that are already water stressed. Together with a growing population this is becoming a lethal combination. Decreases in agricultural yields may impact both human development and governmental legitimacy.

Increases in carbon in the atmosphere are driving more intense weather patterns that lead to more and greater threats from famines, droughts

[50]Niang, I., and Ruppel, O. C., 2014. Africa. In: IPCC, ed. *Impacts, Adaptation, and Vulnerability: The Assessment of Impacts, Adaptation, and Vulnerability in the Working Group II Contribution to the IPCC's Fifth Assessment Report (WGII AR5).* Cambridge: Cambridge University Press.

and plagues. These disruptive climate and weather conditions will change migration patterns with possibly significant impacts.

Africa needs faster demographic change, higher productivity but at lower levels of emissions, better education, a functioning health system, investment in basic infrastructure such as the provision of potable water, needs to extend agricultural land under irrigation and good governance to drive development and to provide improved living conditions and security.

However, these development gains will need to be weighed against the long-term goal of mitigating and adapting to climate change. Good governance and long-term planning in Africa is now more important than ever. Mitigation and adaptation to climate change should be an intrinsic part of the African development agenda, such as the purposeful choice to transition to renewable energies and away from fossil fuels.

Africa's leadership is fully aware of the challenges that the continent faces in respect of climate change but action is limited. A purposeful response is required if Africa is to embark upon a sustainable development pathway. This includes the insistence that its development projects and those of its partners, China in particular, are based on the requirements of an environmentally sustainable development pathway.

Hence, when looking in the final chapter at the combined impact of the scenarios that have been modelled in each of the chapters, it is important to weigh the costs associated with an environmentally unsustainable development pathway.

Further Reading

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