BACKGROUND PAPER

Applying the mitigation hierarchy in a complex world

Multisectoral development in Africa and implications for biodiversity and ecosystem services

Report prepared by Fauna & Flora International

Fauna & Flora International (FFI) protects threatened species and ecosystems worldwide, choosing solutions that are sustainable, based on sound science and take account of human needs. Founded in 1903, FFI is the world's longest established international conservation body and a registered charity. For more information see: www.fauna-flora.org

Cover photograph: Bondgrunge/Shutterstock.com (main image), Jeremy Holden/FFI (top and bottom right), Rich Carey/Shutterstock.com (middle right)

Cover design: Dan Barrett, Brandman

Lead authors: Nicky Jenner, Pippa Howard, Michelle Villeneuve, Erin Parham, Anna Lyons, Twyla Holland, Emma Scott and Laura Fox.

Citation: Fauna & Flora International (FFI). 2021. *Applying the mitigation hierarchy in a complex world. Background paper: Multisectoral development in Africa and implications for biodiversity and ecosystem services FFI: Cambridge U.K.* Available from: www.fauna-flora.org

Acknowledgements
Thanks are extended to the Arcus Foundation for their support and funding that has enabled the development of this report.

arcus FOUNDATION

FAUNA & FLORA INTERNATIONAL

SUMMARY

This background paper provides a brief overview of the status and projected trends for the following economic sectors in sub-Saharan: agriculture, forestry, mining, oil & gas, renewables and linear infrastructure. It highlights some of the linkages between sectors as well as broader regional challenges. A broad overview of some of the major impacts of multi-sectoral development are discussed, with a particular focus on the different ways that species and ecosystems respond to impacts and cumulative effects. This background paper sets the context and serves as the first of two background resources supporting the 'Collaborating Across the Landscape to Mitigate impacts of development - the CALM Framework' (FFI, 2021a).

Across sub-Saharan Africa projections for growth in energy, infrastructure, extractives and agriculture are staggering. Planned infrastructure developments and their associated highways, rail links, power networks and pipelines, cut across vast swathes of the continent. Many are designed to catalyse economic growth by improving access to resources, enhancing the flow of goods and people, supporting trade and economic integration and reducing production constraints. The scale of unregulated development and activities such as small-scale agriculture is also growing, driven by rapid human population growth. Rates of growth in West Africa are the highest in the world.

No single sector, project or activity acts in isolation. There is always a footprint. Development projects take place in complex socioecological landscapes, alongside other sectoral projects and activities, and in the context of complex and inter-related challenges, including those relating to poverty, disease, rising inequality, conflict, climate change and ecosystem degradation. Together the many past, present and future decisions and actions that influence the landscape accumulate and interact.

Species and ecosystems respond to the effects of development in different ways, often depending on the type of activities taking place and the temporal and spatial scale thereof. In other words, not all impacts are equal and not all species or habitats will respond to threats and pressures in the same way. Understanding the ecological requirements of individual species and populations, the degree of flexibility in their responses to cope with impacts, and the environmental conditions that may enable or constrain those responses, is an essential, yet often overlooked, consideration.

Decisions and actions at all scales have an effect. Transformative projects that induce growth in other sectors can lead to significant large-scale and long-term consequences (e.g. for land conversion, carbon emissions and unsustainable wildlife exploitable), whilst the incremental expansion of small-scale agriculture is driving extensive deforestation at the landscape scale in some contexts. As each decision, project and activity cuts away a little more forest, adds pollutants to the rivers and soils, and extracts more natural resources than they put back, the cumulative effects on species, ecosystems and the people that depend on them are often significant. Where impacts go unmitigated, multi-sector development will increasingly contribute to an irreversible legacy of degradation, pollution, extinctions, conflict and unsustainable trade-offs. The dramatic population declines reported for some of the great apes in Africa, is both an indicator and a stark warning of the intense pressures facing biodiversity and deterioration in ecosystem health.

Reconciling economic development objectives with biodiversity conservation, climate mitigation, human health and water security presents an enormous challenge; one that will require a transformative shift in how land and resources are used and managed.

CONTENTS

AFRICA'S BIODIVERSE LANDSCAPES UNDER PRESSURE

Africa's extraordinarily rich and diverse biodiversity, ecosystem services, and wealth of indigenous and local knowledge, comprise a strategic asset for sustainable development in the region – providing food, water and energy, supporting human health, underpinning livelihoods, driving the economy, and serving as buffers to climate change (IPBES, 2018).

More than 62% of the population depend directly on these services in rural areas, while the urban and peri-urban population supplement their incomes, as well as their energy, medicine and other essentials, from ecosystem-based resources (IPBES, 2018). Yet the true value of biodiversity's contributions to human well-being is underappreciated in decision-making processes from local to landscape, and national to regional scales.

Biodiversity on the continent declined by 65% between 1970 and 2016 (WWF, 2020)**.** In 2014, 6,419 animals and 3,148 plants in Africa were recorded as threatened with extinction on the IUCN Red List, with African birds increasingly at risk of extinction and freshwater ecosystems especially threatened (UNEP-WCMC, 2016). The dramatic population declines reported for some taxa in Africa are both an indicator and a stark warning of the intense pressures facing biodiversity.

Today, all great ape species face a very high or extremely high risk of extinction in the wild and are categorised on the IUCN Red List as Endangered or Critically Endangered. Grauer's gorilla has declined from an estimated 16,900 individuals to less than 4,000 in the last 20 years (Plumptre et al., 2016). Numbers of western chimpanzees dropped by 80% in 24 years, with the species already lost from three of the 11 countries where it ranged historically (Kühl et al., 2017). In 2016, the IUCN up-listed the western chimpanzee from Endangered to Critically Endangered, reflecting the dire status of the subspecies unless further declines are averted.

Biodiversity loss is being driven by a combination of human induced factors with land use change the major driver of biodiversity loss in Africa (WWF, 2020). Between 2010 and 2020, Africa had the highest annual rate of net forest loss in the world at 3.9 million hectares (ha) and there has been an increase in the rate of net forest loss since 1990, particularly in Eastern and Southern Africa, where it grew from 1.35 million ha per year in the 1990s to 1.91 million ha per year in 2010–2020 (FAO, 2020).

Land use change is also the primary transmission pathway for emerging infectious diseases (UNCCD, 2020) and today, the effects of habitat loss, degradation and fragmentation, in combination with the unsustainable exploitation of wildlife and spread of certain non-native invasive species, **pose the most imminent and rapidly intensifying threat** to the persistence and health of species and ecosystems across the continent. Impacts that are exacerbated by the negative effects of climate change (UNEP-WCMC, 2016)**.** Climate change alone could cause the loss of over 50%of some African bird and mammal species by 2100 and trigger a decline in the productivity of Africa's lakes (the plant and animal life produced by a lake) by some 20 – 30% (IPBES, 2018).

The loss of biodiversity and the degradation and fragmentation of landscapes in the short- and long-term, affects livelihoods, water supply, food security and lessens resilience to extreme events, particularly for rural communities dependent on the services natural ecosystems and healthy, resilient landscapes provide. Land use change is also the primary transmission pathway for emerging infectious diseases (UNCCD, 2020).

It is within this context of rapid and ongoing biodiversity loss and deterioration of landscape integrity and health that we consider the effects of multi-sectoral development in the sections that follow.

MULTI-SECTOR DEVELOPMENT IN AFRICA

Across sub-Saharan Africa the projections for growth in mining, infrastructure, oil & gas, large hydropower, and agriculture are significant, with planned infrastructure developments cutting across vast swathes of the continent. The section below considers the status of sectoral development (agriculture, forestry, mining, oil & gas, renewables and linear infrastructure) across the region, the future outlook, and provides a multi-sectoral perspective considering the linkages between sectors.

Agriculture

Across sub-Saharan Africa, an estimated 43.7% of the total land area was under agriculture in 2016, varying considerably by country: from 8.2% in the Central African Republic to over 50% in countries including Guinea (59%); Cote d'Ivoire (64.8%) and Rwanda (73.4%), (World Bank databank). Agricultural expansion in the region continues apace.

Agriculture is important for the majority of African economies, contributing more than $100 billion or at least 15% of the region's Gross Domestic Product (GDP) in 2016 (OECD/FAO, 2016). For some countries, its contribution (including agriculture, forestry, and fishing) to the national economy is considerably higher, accounting for more than 50% of GDP in Guinea-Bissau and Sierra Leone in 2019 (World Bank databank). About two-thirds of the African population is employed within the agricultural sector, the majority working in small-scale productions systems that contribute at least 90% of food production (Oxford Business Group, 2019).

Smallholder farming accounts for 90% of agricultural activity in Africa (Oxford Business Group, 2019) and the majority of the food in the region is produced by smallholders (Fraval et al., 2019). Alongside a rise in medium-size farms, increased smallholder productivity is expected to be the biggest growth driver for the sector (Goedde et al., 2019). With a rapidly growing young population, smallholder farming is expected to remain the single largest source of employment in the coming decade (OECD & FAO, 2016) and smallholders will be a crucial entry point for agricultural interventions to improve food and nutrition security on the continent (Fraval et al., 2019).

Agroforestry systems that provide permanent tree cover continue to be promoted across the region as a crucial strategy for addressing land degradation and loss of soil fertility and support landscape restoration and climate commitments (such as those made under the Bonn Challenge). The ecosystem service benefits (e.g. improving soil fertility, controlling erosion, improving water availability etc.) and potential to improve resilience among rural communities are recognised. Uptake of agroforestry has to date been less than projected with widespread uptake requiring an enabling legal and policy environment that guarantees rights to and ownership of trees and landscape and provides the necessary combination of incentives, investment and market access (FAO, 2017a).

Looking ahead, Africa's food production is forecast to grow by 60% by 2050 (Oxford Business Group, 2019). Estimates of the extent of land that could be used to increase agricultural production vary considerably, from 200 million hectares to 840 million hectares (Goedde et al., 2019; Oxford Business Group, 2019). Focusing on areas with lower population density, McKinsey analysis indicates an additional 20-30 million hectares of cropland could be available in the shorter term (Goedde et al., 2019), concentrated in countries including Ethiopia, Nigeria and Tanzania, as well as Angola, the Democratic Republic of Congo, Madagascar, South Sudan and Zambia. Collectively, this could result in a 10%potential increase in Africa's cultivated land (Goedde et al., 2019).

Longer-term regional analyses using modelled projections under a range of scenarios suggest that in West Africa cropland area expansion could be over 50% by 2050 (Palazzo et al., 2017). This is supported in other studies which suggest that population growth coupled with rising demand for particular commodities, such as palm oil, will result in a considerable amount of future land conversion (Strona et al., 2018).

Yet much of this land is currently inaccessible and/or unavailable for cultivation. Poor road networks, a lack of infrastructure within countries and across regions constitute major barriers for accessing and cultivating land that has been identified as unused and suitable for growing crops (Oxford Business Group, 2019). Other areas are located in conflict zones, forests and/or in conservation areas. Desertification and soil degradation further constrain current potential for cultivation (Jacquemot, 2020). Undocumented land is also a major issue, making it vulnerable to land grabs.

Analysis indicates that for sub-Saharan Africa to realise its agricultural potential, significant investment will be required including: eight times **more fertiliser**, six times **more improved seed**, at least $8 billion of investment in **basic storage** (not including cold-chain investments for horticulture or animal products), and as much as $65 billion in **irrigation** (Goedde et al., 2019). Improvement in basic infrastructure (roads, ports, and electricity) will also play an important role.

Forestry

Total forest area in Africa is estimated at 675 million ha, or about 23% of land area, with wooded landscapes (trees outside forests) accounting for another 13%, or 350 million ha: five countries - the Democratic Republic of Congo, Sudan, Angola, Zambia, and Mozambique - account for half of this forested area (PROFOR, 2012). Africa is home to 25% of the world's remaining rainforests (PROFOR, 2017).

Most of the world's wood comes from production or multiple-use forests (FAO, 2016), with much of the world's timber sourced from natural growth forests (FIM, 2017). Increasingly, plantation forests play a role in tropical log and sawnwood production (e.g. for teak in Benin, Cameroon, Republic of Congo, Côte d'Ivoire, Ghana, Liberia, Nigeria), and are important in the production of plywood (International Tropical Timber Organization, 2017).

Tropical industrial roundwood[1] production in Africa is comparatively less than other regions, however International Tropical Timber Organization (ITTO) members in Africa still produced 22.9 million m^3 of logs in 2018 (ITTO, 2018). Production of tropical sawnwood is also growing in Africa, whilst exports of tropical plywood remain insignificant[2]. In Africa, wood removals increased between 1990 and 2018 with a total of 779 million m^3 of wood removals reported for 2018: **90% of wood removals are a result of fuelwood removals** and 10% from the removal of industrial roundwood (ITTO and non-ITTO members). Average annual growth in wood removals was in line with population growth. Western and Central Africa account for over half (55%) of wood removals in the continent in 2018 (FAO, 2020).

Demand for African forestry products is increasingly from Asia. China's consumption of imported tropical logs has risen significantly in recent years to 14.3 million m^3 in 2015; 59% of total ITTO imports of tropical logs globally. Outside Papua New Guinea and the Solomon Islands, significant suppliers are mostly in the African region, with Equatorial Guinea, Nigeria, Cameroon and the Republic of Congo together supplying 23% of China's imports. Significant volumes were also imported in 2015 from the African countries of Liberia and Gambia (International Tropical Timber Organization, 2017). Export log bans in several countries including Gabon, are also putting pressure on alternative supplies, namely from African region. Both China and India are additionally driving demand for larger sizes of sawn timber. **Asian operators are successfully marketing a wide range of products** compared to European markets, there is also less market pressure for sustainable products than in Europe. Investment in African processing facilities is impaired by poor infrastructure, high costs from the poor business environment, low labour productivity, poor governance and corruption, hence timber is not processed but exported (ITTO, 2017).

World demand for timber is expected to quadruple by 2050 (World Bank, 2016). GDP and population growth are two main drivers of industrial roundwood consumption. Supply from natural growth forests where most timber is sourced will be increasingly constrained through restrictions on illegal logging, availability and cost of natural resources, and competition for conservation and agriculture (FIM, 2017). Increasing demand for forest products, as well as ecological services and climate mitigation will likely be met from expanding planted forests, particularly in Africa. Globally the rate of planted-forest expansion since 1990 was close to a 2.4% per annum target to replace wood supplied from natural forests in the medium term (Sloan & Sayer, 2015; FAO, 2016).

The **formal forest sector (forestry and logging) in Africa employed more than 2 million people** in 2015 (FAO, 2020). Yet this figure reflects only a part of the real contribution of the sector to employment and the economy, as much of the forest sector is in the informal economy and therefore not well tracked in national statistics. In Africa, for example, and rural small, micro, and medium enterprises (SMMEs) often provide substantial direct employment (PROFOR, 2012) and if informal wood production were incorporated into GDP estimates would double timber's contribution to GDP (World

[1] Industrial roundwood includes sawlogs or veneer logs, pulpwood, other industrial roundwood (e.g. poles, posts) and, in the case of trade, also chips and particles and wood residues FAO definitions

[2] Exports from Ghana, the largest exporter of tropical plywood in the region, have declined with the bulk of those exports to the EU market. Rising production costs and volatile exchange rates are affecting the export from Ghana. Tropical veneer used in flooring, furniture and for plywood is traded from African countries of Gabon, Côte d'Ivoire, Ghana, Cameroon and the Republic of Congo to France and Italy.

Bank, 2016). The FAO further estimate that the **number of people working in the informal forestry sector is at least 1.63 times the number in the formal sector** (FAO, 2018a).

For many rural communities with access to forests, forest income is second only to income derived from agriculture. Yet for too long, forests in Africa have been considered narrowly as a source of export revenues from industrial timber or as global public goods. In reality, forests and woodlands serve as a diverse source of jobs and livelihoods and more than 70% of the population in Sub-Saharan Africa depends on forests and woodlands for livelihoods; one fifth of rural families' daily needs come from forests (PROFOR, 2017). Forests further provide essential ecosystem services, increasing resilience through protecting watersheds and stream-flows, controlling erosion, enhancing soil fertility, regulating the climate and protecting biodiversity. Woodlands and forests also supply approximately 60% of all energy (PROFOR, 2017).

Despite significant international financial support to the forestry sector in the Sub-Saharan African countries, impacts on sustainable management and poverty alleviation are still below expectations.

Mining

For many African countries the **mining sector is an important contributor to the national economy**: the Democratic Republic of Congo, Guinea, Mali, Sierra Leone, Liberia and Ghana are ranked among the top 10 countries in the ICMM's Mining Contribution Index which provides an indication of the relative importance of mining to the economic life of a country (ICMM, 2018). The Democratic Republic of Congo, Zambia, Ghana and Zimbabwe were also among the top 10 priority countries for forest mining attention, given high forest cover, high economic dependence on mining, a high density of mines in forest areas, and forest degradation and loss being an important contributor to national greenhouse gas emissions (World Bank, 2019a).

Globally, the number of new large-scale mines in forest areas commissioned yearly has increased from 4-10 during the 1980s to 20 or more in the last decade, with most of the **growth in large-scale mining in forest areas occurring in tropical regions including notable recent increases in forest mining in sub-Saharan Africa** (World Bank, 2019a). The top three minerals mined by large-scale operators in forests globally are gold, iron ore, and copper, while the industries for bauxite, titanium, and nickel have the highest reliance on forest mines.

Mineral exploration permissions, large-scale **mining concessions and artisanal mining zones extend over large areas of West and Central Africa**. The majority of minerals produced in West Africa are currently exported for further processing and in 2017 West African countries exported minerals worth US$16.1billion, 26.3% more than the previous year, mainly as a result of the large increase in Guinea's exports. Concessions often overlap other land uses, community forests, forest reserves, protected areas and proposed protected areas, conflict with existing property and use rights, and extend across the ranges of threatened and rare species.

Given the sector's economic significance, **mining in sub-Saharan Africa is set to expand in economically, socially, and environmentally sensitive forest areas**, with recent exploration hotspots such as West and Central Africa offering significant greenfield exploration potential (World Bank, 2019a). Many countries in this hotspot have identified by most countries in West Africa as a potential catalyst for economic development, and there is a determined effort to attract foreign direct investment.

Despite strong government focus on large-scale mining, the **artisanal and small-scale mining (ASM) sector is still by far the largest mining sector in most developing countries** in terms of employment most of which is informal (World Bank, 2016). ASM is expected to continue to respond to demand both for low-value minerals used in domestic markets (such as construction) and high-value minerals, as well as fluctuations in commodity prices. Rising demand for minerals such as cobalt and 3TG, for example, are expected to drive increased ASM activity in the Congo Basin (World Bank, 2019b, 2019c).

In some areas, ASM is primarily driven by poverty and limited livelihood options, yet it can also be driven by the perceived opportunity to increase income quickly. Thus, **ASM will also continue to expand** because of the growing number of youth unemployment across the continent as well as the ease of entry into the sector (P. Diallo pers. com). In so-called 'rush' situations, evidence shows significant numbers of people moving into an area in response to commodity price spikes or discovery of deposits. For example, in eastern Democratic Republic of Congo, an estimated 12,000 coltan miners moved into Kahuzi-Biega National Park in 2002 after an international price spike, clearing vegetation to access shallow deposits; whereas in Madagascar, some 45,000 miners moved into the Corridor Ankeniheny Zahamena area following the discovery of secondary ruby and sapphire deposits in 2016 (World Bank, 2019c)

Oil & Gas

The **oil & gas sector has historically been a primary driver of economic growth for some African countries**, despite volatility in market prices and barriers to attracting investment linked to challenging operating environments, lack of transparency, regulatory uncertainty and political instability, as well as poor infrastructure networks. In 2018, following the recovery of international energy prices, the continent was reported to be attracting investor interest again (Botes et al., 2018) and **oil & gas continues to be a focal point of development in a number of countries.**

"From a continent described as 'hopeless' in 2000 to one bursting with potential 20 years later, Africa is back on the oil map"

(AOW, 2019)

Key oil & gas producing countries in sub-Saharan Africa include Angola, Congo Brazzaville, Ghana, Gabon, Nigeria, Equatorial Guinea, Uganda, Tanzania, Mozambique (Botes et al., 2018). The relative importance of the oil & gas sector for national economies and current trajectories vary across the region. Gabon holds the fourth largest oil resources in the region and is the fourth largest oil producer, but production has been declining since 2010. In contrast, Ghana has seen the highest growth in oil production over the same period, the majority offshore (Botes et al., 2018).

Looking ahead, **the potential of the oil & gas sector remains** (Botes et al., 2018; IEA, 2019). With significant offshore finds, and more countries turning into producers of both natural gas and petroleum products, coupled with regulatory changes and fast-growing energy demand from expanding local consumer markets, growth in this sector will continue. A reported 20 deals worth $30bn were signed relating to development of African fields and attendant infrastructure in 2017 alone, with further bidding rounds forecast beyond 2020 with a further 55 blocks to be auctioned via mix of public tender, limited public tenders or direction requisition (AOW, 2019). With projections for rapid population growth in the continent, comes higher demand for liquid fuels and energy in general. Estimates suggest that African energy demands are to grow 60% from now until 2030 (AOW, 2019).

Renewable energy

Africa faces an enormous energy challenge. Its growing population and economic progress have sent energy demand soaring requiring a rapid increase in supply, to which all forms of energy must contribute moving forward. Africa is richly endowed with fossil-based and renewable energy sources yet continued reliance on oil and gas along with traditional biomass combustion for energy will bring considerable social, economic and environmental constraints (IRENA, 2015).

Large areas of Africa remain without access to modern energy services and it is the only region in the world to have both an increase in population and a decrease in electricity access (REN21, 2014, 2020). Africa's renewable energy power potential is substantially larger than the current and projected power consumption of the continent (IRENA, 2013), and renewables are uniquely positioned to provide needed energy services in a sustainable manner, more rapidly and generally at lower cost than their alternatives. Their potential for the African continent is therefore significant (REN21, 2018) with the IRENA Renewables Scenario, projecting that the share of renewables in Africa could increase from 17% in 2009 to 50% in 2030, and nearly 75% by 2050 with total installed renewable capacity growing to around 800 Gigawatts (GW) by 2050, dominated by solar photovoltaic and wind followed by hydropower, concentrating solar power, biomass, and geothermal (IRENA, 2013).

In 2011, 46 African countries with the participation of 25 African energy ministers adopted the **Abu Dhabi Communiqué on Renewable Energy for Accelerating Africa's Development**, which called for the increased utilisation of Africa's renewable energy resources to accelerate development (IRENA, 2013). Yet there has been **continued decline in investment in renewables in the region**: sub-Saharan Africa attracted USD 2 billion in renewable energy investment in 2016 - 60% less than the previous year and equivalent to around 1% of global renewable energy investment (REN21, 2018). Investment is mostly concentrated in small number of countries in the region.

Improvement in policy can be a prerequisite for mobilising finance to improve energy access, promote renewable energy generation, and more efficient use of existing energy sources. Yet **most countries in the region remain at the early stages of building a sound policy environment and around half have undeveloped policy frameworks for sustainable energy**. However, progress is being made with Cote d'Ivoire and Rwanda featuring among the five countries to have made the largest improvements in their policy environment in recent years (ESMAP, 2018).

Hydropower continues to be the main renewable resource in Africa with over 37 GW of installed capacity and 138 terawatt hours (TWh) electricity generation, accounting for 15% of the total electricity share in the region (International Hydropower Association, 2020). Despite continued growth in installed capacity, annual growth in terms of generation has been lower in part due to climate change effects and the age of hydropower installations (International Hydropower Association, 2020). Across the continent, **Angola, Uganda,**

Ethiopia, Cameroon and Malawi added the most capacity in 2019 (International Hydropower Association, 2020). New dams in the continent continue to be built without examination of how climate change will affect them, even though many existing dams are already plagued by drought-caused power shortages.

The African Union's 2063 Agenda, the Common African Position on the post-2015 Development Agenda, the African Development Bank priority to '**Light up and power Africa'**, and the African Union Commission commitment to implementing the Paris Climate Agreement, provide the framework for economic transformation while accelerating renewable energy development (International Hydropower Association, 2020). **All 54 states have signed the 2015 Paris Agreement** and submitted ambitious Intended National Determined Contributions (INDCs). The development of renewable energy is often central to these commitments.

As demand for water regulation, irrigation, and energy access increases, more investments in dams and hydropower facilities are also being made (World Bank, 2016). Average annual hydropower capacity growth in the continent over the 2020-2025 period is expected to double (International Hydropower Association, 2020). Contributing to this is **over 50 hydropower projects that are currently under construction**, representing more than 15 GW of installed capacity expected to be commissioned by 2025.

This includes the construction of a 420 Megawatt (MW) Nachtigal project in Cameroon - the biggest independent hydropower project in Sub-Saharan Africa – which started in 2019 and is expected to provide one-third of the country's energy needs. Other examples include the construction of Stiegle's Gorge (2,100 MW) in Tanzania that was launched in mid-2019 and Karuma (600 MW), the biggest hydropower project in Uganda, which is expected to be commissioned in November 2020 (International Hydropower Association, 2020). The **contribution of hydropower to the total electricity share in the region is predicted to increase to more than 23% by 2040** (International Hydropower Association, 2020) following moves towards universal access and low-carbon energy transition.

Interest in other renewables (wind, solar, geothermal and bioenergy) is rising, given the lower cost structures of more reliable, affordable and greener solutions, coupled with rising energy demand fuelled by a rapidly growing population, urbanisation and economic development which is set to put the region's energy system under considerable strain. Africa has the richest solar resources on the planet yet has installed only 5 gigawatts of solar photovoltaics (PV), accounting for less than 1% of global capacity. With the right policies, solar could become one of the continent's top energy sources (IEA, 2019). The **energy landscape is thus expected to undergo rapid change**, subject to securing the necessary investment needed to harness the region's renewable energy potential.

Linear infrastructure

Linear infrastructure such as roads, highways, railways, power lines and gas pipelines are rapidly expanding in the tropics (Laurance et al., 2009). Linear transport infrastructure, including roads and rail, constitute one of the most significant infrastructure investments in Africa; improving the mobility of goods and people, facilitating trade and commerce and enabling other types of infrastructure development (World Bank, 2016).

At least **25 million km of additional roads are anticipated worldwide by 2050** (enough to circle the Earth more than 600 times), 90% of them in developing nations including many regions with exceptional biodiversity and vital ecosystem services (Laurance & Arrea, 2017; Laurance, 2018). In West and Central Africa, major road developments include, for example, the Douala-Bengau Road that was completed in 2003 and connects Cameroon and Central African Republic through a 1,400 kilometres highway that cuts across the north-western Congo Basin (Laurance et al., 2009). Additional road development is planned for this region, driven by national developmental priorities and foreign investments, promoting logging and extractive industries (Kleinschroth et al., 2019).

Projections for large scale expansion and improvement of linear transport infrastructure are backed by considerable financial investment. At the 2014 G20 summit, USD 69-70 trillion was committed to infrastructure by 2030 (Arcus Foundation, 2018). In an African context, the agreement to establish the African Continental Free Trade Area was ratified by 22 African countries in May 2019 and is likely to prove pivotal for infrastructure development. Future freight transport demand in Africa is tied to growth in international trade, which is expected to grow sevenfold to 3.6 billion metric tons over the next 30 years, as countries increase the value added of their exports through processing, consumers with rising incomes import more expensive goods, and manufacturing and mining businesses import more expensive processing equipment (Globe Newswire, 2019).

With this emphasis on regional integration, African governments continue to think beyond development within border lines. This has placed the **focus on the development of regional economic corridors, interlinking highways, railways and ports** in the region, providing connectivity between international, national and rural networks and facilitating the movement of people and commodities (Globe Newswire, 2019). Across Africa, much of the major **transport infrastructure is being built in over 30 planned 'development corridors', traversing 38 countries and spanning over 53,000 km in length** and comprising networks of roads, railways, pipelines and ports (Laurance et al., 2015; Collinson et al., 2019).

Recent analysis of 448 large-scale transport projects (road, rail and bridges) in Africa at varying stages of development indicates a **total investment value of USD 430.3 billion**. On completion, these projects are expected to total over 110,000 km in length (54,110 km for roads, 55,345 km for railway and 599 km for bridges) of which 75,297 km will be newly constructed, 29,197km will be upgraded and 5,561 km will have an element of both construction and upgrade, crisscrossing the African continent (Globe Newswire, 2019). Proponents include national governments, donors and private lenders. Whilst over half of the tracked project pipeline is reported to be publicly driven by African governments allocating funds, a third is funded through public-private sector arrangements, with **Chinese infrastructure commitments having grown at an average annual rate of 10%** from 2013 to 2017 (Lakmeeharan et al., 2020).

According to the Infrastructure Consortium for Africa, between 2013 and 2017 the average annual funding for infrastructure development in Africa had grown substantially to USD 77 billion (Lakmeeharan et al., 2020). Of the recent activity, almost half was in West and East Africa and nearly three-quarters of the total investment was in the transport and energy sectors. At least five African countries have had their railway systems funded by China: Kenya, Ethiopia, Angola, Djibouti and Nigeria.

China is thus having a dramatic impact on infrastructure in developing nations and is **investing more than USD 100 billion annually in Africa** (Arcus Foundation, 2018). China's

Belt and Road Initiative involves a massive development of trade routes between and within Asia, Africa and Europe: roads and railways will cross many areas of high environmental value in parts of tropical Africa (Ascensão et al., 2018). China's support includes some of the continent's most ambitious infrastructure developments in recent years. For example China's EXIM Bank financed more than 90% of the USD 3.6 billion Mombasa-Nairobi Standard Gauge Railway in Kenya that opened in 2017 (Lakmeeharan et al., 2020). More recently, in 2017, a USD20 billion project financing agreement was signed between the countries of Guinea and China as part of the Belt and Road Initiative (Moussa, 2018).

With **electricity demand expected to triple by 2040, efforts are being made to improve and increase transmission and distribution assets in Africa**. The construction of a transmission line connecting Kenya to Ethiopia, the longest in East and Central Africa, is near completion with a capacity of 2,000 MW. Other projects under development include the Nigerian-Benin-Togo-Ghana-Cote d'Ivoire Median Transmission Backbone and the West African Power Transmission Corridor, linking Ghana to Senegal, with branches, among others (International Hydropower Association, 2020).

Yet, many more projects are needed (Lakmeeharan et al., 2020) with infrastructure investment in Africa staying low at around 3.5 percent of GDP per year since 2000; compared a spend of 7.7 percent of GDP on infrastructure in China. The McKinsey Global Institute estimated in 2016 that this would need to rise to 4.5 percent if the continent is to close its infrastructure gaps.

Multi-sectoral perspectives

Infrastructure developments induce growth in other sectors

The projections for sector specific growth across the continent are staggering, affecting vast areas, diverse ecosystems and communities, and likely to impact areas of significant value for people and biodiversity. Yet no single sector, project or activity operates in isolation.

Sector-specific development is often linked with subsequent or parallel development in other sectors. For example, mining operations are often associated with the development, expansion or improvement of linear infrastructure (roads, railways), sea ports, hydropower dams, towns, and so on. Oil and gas operations have ancillary infrastructure such as pump stations, power plants and refineries that may have significant footprints. Infrastructure development in general, and transport infrastructure in particular, has long-term effects on both settlement patterns and agricultural strategy (individual and national), incentivising movement of people and industry into a previously rural or much less populated area.

For farmers, roads are an unparalleled advantage, as they allow greater, cheaper and faster access to more markets, increasing competitive advantage in a number of ways. The development of linear infrastructure may also directly or indirectly influence changes in agricultural production systems themselves—not just where crops are grown, but what crops are grown and how they are grown. A population of mine workers will have increased purchasing power as compared to the previous local demographics, and may demand different agricultural products, for example.

Industrial logging, oil and gas development, agribusiness and mining can all provide an economic impetus for the expansion of linear infrastructure developments (road, rail, power lines), with industrial logging operations identified as the greatest driver of road expansion in forest frontiers (Laurance et al., 2009). In Central Africa, the total length of road networks inside logging concessions has doubled since 2003 (Kleinschroth et al., 2019), with over 50,000 km of logging and other roads built in the Congo Basin alone since 2000 (Arcus Foundation, 2018).

Boom and bust cycles in tropical forestry have also been associated with secondary growth in other industries, such as agriculture. During a boom logging and exports will continue increasing until timber resources are depleted, and harvest is no longer economically advantageous. Depleted forests, if no longer seen to be commercially valuable, may be converted to more profitable land uses, including plantation agriculture and cropland (Burivalova et al., 2020).

Secondary, induced growth in infrastructure, settlements and economic activities may be **unplanned (though arguably reasonably foreseen) or be a pivotal part of planned economic development**. For example, in Guinea a condition attached to the exploitation of the large Simandou iron ore deposit is the construction of a 650 km railway and port; infrastructure that will form the backbone of the southern development corridor designed to promote economic growth in a range of sectors including agriculture across the entire southern extent of the country.

Other examples of **growth-inducing infrastructure include electrical transmission lines**, pipelines, export facilities and roads that facilitate access to land and resources, support or lower the costs of resource extraction (e.g. through provision of electric power through powerlines, creation of trade routes), or increase market access through value added processing (e.g. establishing an Liquified natural gas facility or mineral processing plant) (Banerjee et al., 2017; Johnson et al., 2020; World Bank, 2019b). Pipelines may facilitate increased levels of production or make isolated oil and gas reserves more economically viable by connecting reserves with refining facilities or markets. Similarly, within the agricultural sector, the introduction of electrical infrastructure improves market access by allowing for improved drying and/or processing. Electrical infrastructure also increases options and access for sectors involving cold chain requirements, such as livestock. **Growth-inducing developments have the potential to initiate rapid, extensive and potentially irreversible development** trajectories (Johnson et al., 2020).

Given the projections for growth in planned linear infrastructure and extractive industries with their associated road and rail developments in parts of the region, one of the major production constraints for agricultural development, access to markets, may be partially alleviated in some regions, resulting in **substantial and rapid increases in the amount of additional cropland cultivated across the continent**. Central Guinea, for example, is considered to be ideal for both agricultural development and mining development. The implementation of a mining and infrastructure development plan that includes long-term strategy consideration for agricultural and rural development could see positive impact if thoughtful land conversion and permitting choices are made. Conversely, a lack of foresight and long-term planning could lead to difficult outcomes due to the intertwined nature of the sectors, and the scale at which development occurs.

Economic development corridors

At a macro scale, **economic development is focussed to a large degree on development corridors designed** to improve access to resources, enhance the flow of goods and people, support trade and economic integration and/or boost a particular sector of the economy by reducing production constraints (e.g. for agriculture). The **backbone of these corridors are highways, rail links, pipelines, power networks and deep seaports** (Williams, 2017). Such growth-inducing infrastructure developments link manufacturing hubs, areas with high supply and demand, and markets with the aim of cutting costs, improving efficiencies and speeding up implementation and realization of benefits.

There are **over 30 major development corridors currently underway or planned** in sub-Saharan Africa and many more within countries. Examples include the Southern Agriculture Growth Corridor of Tanzania (SAGCOT) and the Cross River Calabar-Ikom-Kastina Ala Superhighway in Nigeria. Significant investment has been committed and/or promised for the development and improvement of transport infrastructure networks across the continent (see 'Linear infrastructure', above), the expansion of infrastructure-dependent sectors, such as agriculture, is expected to be considerable (see Williams, 2017).

These corridors can provide ideal conditions for the improvement of agricultural and other livelihoods, but they can just as easily impact the sector negatively, such as through the displacement of people and loss of farmland in concession demarcation and any associated land grabs. Roads attract people in linear settlements that spread from the infrastructure into previously inaccessible landscapes, often harbouring sensitive and vulnerable biodiversity and ecosystem services (Laurance et al., 2009; Laurance & Arrea, 2017). Very often, supporting, formal infrastructure is absent, thereby exacerbating the magnitude and effect of these land use activities.

Shared dependencies and potential for conflict

Potential for competition and conflict within and among sectors over **access to and availability of ecosystem services** in adequate quality and quantity to meet all needs is high and many countries face **existing and potential future land use conflicts**, e.g. between mining, forestry, agriculture, conservation, and indigenous and other community land uses. Mining permits, even exploration permits for multiple different minerals, oil & gas exploration and forestry concessions often overlap. Many foresters have found artisanal mining camps and information subsistent farming inside their operational areas. Permits for mining, hydropower, forestry and agriculture are often reported to overlap with community lands, conservation areas (existing and proposed), and other sensitive or high value areas. This is largely because of inconsistent levels of transparency and coordination across the natural resource sectors, and lack of clear land use planning at the territorial level (World Bank, 2016) and dysfunctional inter-ministerial communication exacerbated by poor strategic planning.

SECTORAL GROWTH AMIDST COMPLEX REGIONAL CHALLENGES

Multi-sectoral development in sub-Saharan Africa is taking place in a context of rapid human population growth and myriad complex and inter-related challenges including poverty, malnutrition, disease, rising inequality, an expanding middle class, urbanisation and rural diversification, conflict, climate change and ecosystem degradation. Whilst there is tremendous heterogeneity across the region there are also notable overarching trends that will shape the development of different sectors and the extent and magnitude of their individual and cumulative impacts.

- From 2020 to 2050, most of the world's population growth is predicted to take place in Africa with the population across the continent **predicted to grow by 1.3 billion people by 2050** (Collinson et al., 2019) – almost double the current population. The **West African region has the highest population growth rate in the world** and is expected to reach 909 million people by 2050 (Hurley et al., 2019).
- Due to rapid population growth, sub-Saharan Africa has a young population, which will result in an estimated **17 million people entering the labour force annually** (OECD & FAO, 2016). Providing employment opportunities to a growing and increasingly urbanised young population, whilst boosting farm yields will be key to increase incomes of millions of farmers and ensure food security (Oxford Business Group, 2019).
- Whilst incomes and personal wealth vary greatly across the region, **extreme poverty remains high.** Almost 60% of Africa's population lives in rural areas although an increasing share is moving to the expanding urban areas. Poverty rates in rural areas are three times higher than in urban areas (United Nations, 2019).
- **Over half of the 736 million people that lived on less than USD1.90 a day in 2015 were in sub-Saharan Africa** in 2015. This figure is higher than the number of poor people in the rest of the world combined and is rising (United Nations, 2019).
- Although good progress is being made to alleviate poverty in some countries, in 2018, **more than one third (38%) of employed workers in sub-Saharan Africa still live below the poverty line on less than USD1.90 a day**. Among young people the working poverty rate is double that of adult workers (United Nations, 2019).
- Sub-Saharan Africa also remains one of the **most unequal regions in the world**. Half of the twenty most unequal countries in the world (measured by the Gini co-efficient) are in sub-Saharan Africa (UNDP, 2017).
- In sub-Saharan Africa only **13% of children are covered by social protection** and only 13% of adults have at least one form of social protection (United Nations, 2019).
- Almost **one in four people in sub-Saharan Africa (SSA) were estimated to be undernourished in 2017**, representing about one-third of the 821 million people suffering from chronic hunger globally (FAO et al., 2018). In terms of food access, a recent study found that as many as **39% of households in sub-Saharan Africa were severely food insecure** whilst up to 49% of households were likely to be deficient in micronutrients in the lean period (Fraval et al., 2019), with wide-ranging implications for health and disease risk.

- Close to **600 million people in the region are still without access to electricity**, representing more than two-thirds of the global total. In sub-Saharan Africa 55% of people lack access to electricity; **in thirteen countries, more than three-quarters of the population do not have access to electricity**. However, in parts of East Africa there has been a rapid rise in access to electricity, particularly via home solar systems (IEA, 2019). The challenges now is how to provide access those currently deprived while reaching the millions born every year in areas without access to electricity. Progress is being made: the number of people gaining access to electricity in the period 2014-2018 was over 20 million a year; more than double that of the period 2000-2013, outpacing population growth for the first time.
- In urban areas, on average, almost three-quarters of households have access to electricity, compared to just a quarter in rural areas. In remote rural areas finding affordable off-grid solutions and business models is key (IEA, 2019).
- **Local energy needs are largely met by informal wood production** whilst the fuelwood value chain creates employment opportunities for millions of households through small-scale wood collection, charcoal production, transportation, and last-mile retail (World Bank, 2015).
- Progress to improve access to clean energy remains slow, with around 900 million people without access today and **in 32 countries more than 75% of the population is without access to clean cooking facilitates**. West Africa has made the fastest progress since 2010, with almost 3 million people gaining access each year (IEA, 2019).
- **Harvesting of non-timber forest products for fuel, food, building materials and medicine generates significant income and constitutes an important livelihood strategy** for many. For example, in Cameroon, bushmeat and valuable wild fruits account for more than 59%of the income of local communities (Angelsen et al., 2014). Together wood and non-timber forest products provide around 20%of income for rural households in developing countries with moderate to good access to forest resources (Angelsen et al., 2014).
- In Africa, forest-related income reportedly lifts 11%of rural households out of extreme poverty (Poverty and Environment Network (PEN) survey results reported in: World Bank, 2016) and **forests provides an important safety net** in times of economic distress (Angelsen & Dokken, 2015).

Temperatures in all African countries are rising faster than the global rate, and in some areas, at double the global rate of warming (IPBES, 2018). The **effects of climate change,** manifesting in the form of changes to weather patterns and temperature and extreme climate events (such as more frequent and/or severe droughts, excessive rains and floods) are already **profoundly impacting people, land and nature** across the continent: implications for human health, livelihoods, productivity and food security, access to shelter, security and ecosystem degradation are evident across the continent. According to the Climate Change Vulnerability Index 2017, the majority of West, Central and East Africa are considered high to extreme risk with the Central African Republic, Democratic Republic of Congo, Liberia and South Sudan are among the top five countries in terms of climate risk.

Due to a combination of naturally high levels of climate variability, high reliance on rain-fed agriculture and limited economic and institutional capacity to cope with and adapt to climate variability and change, sub-Saharan **Africa's agriculture sector is particularly**

vulnerable to current and future climate change effects - affecting the arability of land, crop productivity and livestock rearing, adding pressure on natural resources and shifting the distribution of what can be produced where (Sultan & Gaetani, 2016; FAO, 2018b; Oxford Business Group, 2019).

For example, **more frequent and severe droughts are driving land degradation**; changes in rainfall distribution, pattern and intensity have severe consequences for smallholder farmers; and ffuture disease trends and climate change will impact the distribution of disease vectors and water availability with substantial effects on the livestock sector (IPBES, 2018). Recurrent food crises and water scarcity triggered or exacerbated by climate variability and extreme events are already affecting agricultural productivity and rural household food security (Sultan & Gaetani, 2016). Forests can play an important role in offsetting losses in agricultural income, such as those caused by weather shocks or changes in commodity prices (Noack et al., 2015).

These complex and evolving trends and challenges shape sectoral development and influence the type, severity and duration of direct, indirect and cumulative impacts linked to single and multi-sectoral development. This presents operators and governments with challenges and opportunities for impact mitigation and management.

IMPACTS OF MULTI-SECTORAL DEVELOPMENT ON SPECIES AND ECOSYSTEMS

The impacts of extractives, forestry, agriculture, energy and infrastructure sectors on human societies and natural ecosystems are extensive and diverse – driving deforestation, biodiversity loss, habitat loss and fragmentation, and contributing to water security issues, land degradation, and global climate change (World Bank Group, 2007; Laurance et al., 2009, 2015; Hosonuma et al., 2012; Arcus Foundation, 2014, 2015, 2018; Mancini & Sala, 2018; World Bank, 2019a, 2019c; Collinson et al., 2019; FAO, 2019; WWF, 2020). The purpose of this section is to highlight some of the common impacts across sectors, influencing factors, and the potential for cumulative impacts on species and ecosystems and the people that depend on them.

Diverse impacts from sectoral development

Operations across all sectors have the potential to adversely affect biodiversity and ecosystem services. There is always a footprint. Table 1 summarises some of the major direct and indirect impacts associated with each sector. This is followed by examples of some of the operational aspects that influence environmental impacts. Development impacts are complex and inter-linked and may be expressed at various spatial (site, landscape, regional and global) and temporal scales (immediate, medium and long term) through direct activities and processes[3] and indirect or induced effects[4]. Indirect impacts are also known as secondary or even third level impacts. Impacts may be individual or compounded as cumulative effects[5] over space and time in combination with other threats and pressures in the landscape. The type, duration and magnitude of impacts varies due to a range of factors including operational parameters, the characteristics of the ecological system as a whole and its component parts, the governance and socioeconomic context, and the influence of other threats and stressors.

3 Direct or primary impacts occur through direct interaction of an activity with an environmental, social, or economic component (BBOP, 2012).

4 Indirect or secondary impacts: Impacts triggered in response to the presence of a project rather than being directly caused by the projects own operations. Induced impacts are defined as those impacts that are not directly caused by a project itself but occur as an unplanned consequence of it. Induced impacts are often a result of socioeconomic changes resulting from the presence of a project and responsibility for managing them is likely to be shared with others, including government. They may include positive and negative impacts (BBOP, 2012).

5 Cumulative impacts: The total impact arising from the project (under the control of the developer), other activities (that may be under the control of others, including other developers, local communities, government) and other background pressures and trends which may be unregulated. The project's impact is therefore one part of the total cumulative impact on the environment. The analysis of a project's incremental impacts combined with the effects of other projects can often give a more accurate understanding of the likely results of the project's presence than just considering its impacts in isolation (BBOP, 2012)

Table 1: Main impact classes with outcomes for species, habitat, water, air, soils and climate and their relevance to forestry, agricultural, infrastructure and extractives and renewables sectors. Direct impacts are indicated with (·) and indirect or induced effects with (+). The table is intended to be illustrative only. It does not provide an exhaustive list of impacts associated with featured sectors and that may arise in particular landscape contexts.

Impact class *The impact that affects biodiversity, ecosystem services or society component*	**Industrial plantation**	**Industrial logging concession**	**Intensive agriculture**	**Smallholder agriculture**	**Agro-forestry**	**Infrastructure**	**Mining**	**Oil & gas**	**Wind**	**Hydropower**	**Solar energy**	**Geo-thermal energy**	**Bio energy**
Air pollution	· +	· +	· +	· +	· +	· +	· +	· +	+	+	+	· +	+
Alteration of drainage network	· +	· +	· +	· +	· +	· +	· +	· +	·	·	·	·	·
Barrier to movement	·		·	·		·	·	·	·	·	·		
Bushmeat/trade	·	·	·	·	·	·	·	·					
Change to soil properties	·	·	·	·	·								
Agrochemical pollution	·		·	·	·								
Chemical pollution / contamination	·	·	·	·	·	·	·	·	·	·	·	·	·
Disease exposure	· +	· +	· +	· +	· +	· +	· +	· +	+	+	+	+	+
Drowning	·						·	·		·			
Dust pollution	+	+	+	+	+	· +	· +	+					
Electrocution						·	·	·	·		·	·	
Fire damage	· +	· +	· +	· +	· +	+	· +	· +	+	+	+	+	+
Greenhouse gas emissions (operations)							·	·				·	·
Habitat clearance	· +	· +	· +	· +	· +	· +	· +	· +	· +	· +	·	·	·
Habitat degradation	· +	· +	· +	· +	· +	· +	· +	· +	·	· +	·	·	·
Habitat fragmentation	· +	· +	· +	· +	· +	· +	· +	· +	·	· +	· +	· +	· +
Human-wildlife conflict	· +	· +	· +	· +	· +	· +	· +	+					
Increased nutrient load	·	·	·	·		·	·	·		·			
Increased sedimentation	· +	· +	· +	· +	· +	· +	· +	· +	·	·	·	·	·
Increased soil erosion	·	·	·	· +	+	·	·	·		·			
Increased water use			·										
Intra-specific conflict (territorial disputes)	· +	· +	· +	· +	· +	· +	· +	· +	·	·	·	·	·
Introduction and spread of alien and invasive species	· +	· +	· +	· +	· +	· +	· +	· +	·	·	·	·	·
Light	+	+	· +	· +	+	· +	· +	· +					
Noise	· +	· +	· +	· +	· +	· +	· +	· +	·	·			·
Pollution of food and water resources			·		·		·	·					
Reduced absorption of particles	· +	· +	· +	· +	· +	· +	· +	· +	·	·	·	·	·
Reduced carbon sequestration	· +	· +	· +	· +	· +	· +	· +	· +	·	·	·	·	·
Reduced resources	· +	· +	· +	· +	· +	· +	· +	· +	·	· +	·	·	·
Reduction in soil quality	· +	· +	· +	· +	· +	· +	· +	· +	·	·	·	·	·
Road collision	·	·	·			·	·	·	·	·			
Starvation								·					
Turbine collision									·				
Water pollution	·		·		·		·	·				·	

Operational aspects influence environmental impacts

The extent to which a sector threatens biodiversity and ecosystem services depends on various factors related to operational considerations, including:

Suitable land characteristics and their distribution over space.

- In agriculture, soil, climate and topography interact in determining the agro-ecological suitability of a site for a given crop. For example, coffee is highly sensitive to temperature and rainfall making its cultivation vulnerable to geographic shifts in its response to climate change. This could lead to the establishment of coffee plantations in new areas and potential conflicts with other land uses and ecosystems including natural forest, with consequent implications for biodiversity and ecosystem services (Magrach & Ghazoul, 2015).
- In mining, the spatial distribution and depth of the target resource influences the affected natural ecosystems (e.g. mining of subsurface alluvial gold deposits affects riparian and downstream ecosystems, whereas iron ore deposits in West and Central Africa typically form mountains that support rare montane forest ecosystems) and the extent of the footprint (e.g. the distribution of bauxite in West Africa results in the excavation of numerous shallow pits resulting in a patchwork of mining areas and widespread loss of habitat rather than a single large open pit).

Scale of operations (small-scale to large-scale, industrial), with larger operations likely to have greater potential impacts (but see BOX 4, below) yet may also have greater capacity to mitigate their impacts.

Production methods required for different commodities. For example:

- Selective logging causes much smaller losses in biodiversity compared to intensively managed plantations for timber or tree crops such as oil palm or rubber (Burivalova et al., 2020).
- Production of different agricultural commodities are associated with varying environmental impacts. For example, oil palm plantations have been shown to support low numbers and diversity of birds compared with shade grown cacao, pasture and natural forest (Donald, 2004). Different farming systems and cropping practises for a specific crop can also strongly influence its impacts on biodiversity. For example, monoculture production compared with more diversified systems (IPES-Food, 2016); shade grown compared with full sun systems for producing cacao, with use of shade trees supporting the survival of some degree of structural and biotic diversity, aiding pollination and the biological control of pests and diseases (Donald, 2004).
- Open pit or underground mining, manual or mechanised extraction: the severity and extent of ASM-led deforestation increases with scale and the degree of mechanization, with semi-mechanised operations being particularly destructive, especially when poorly regulated (World Bank, 2019b).

Stage of operation

- In extractive industries greatest impacts typically associated with construction and production phases (Arcus Foundation, 2014).

- In plantation systems, the greatest impacts are associated with initial clearance, with altered communities of flora and fauna following clearance and as plantations age (Foster et al., 2011). There is some evidence indicating that mixed age stands can be associated with higher species richness for some taxa (Savilaakso et al., 2014).
- In some industries and contexts, the cessation of activity after resources have been depleted or are no longer commercially viable (e.g. in tropical timber production) may leave inactive concessions under sustained or greater pressure from other threats including smallholder and industrial agriculture (Burivalova et al., 2020).

Direct impacts lead to the loss, degradation and fragmentation of natural habitat

Conversion of natural habitat to allow for the development of sectoral activities is both a direct and indirect or induced impact associated with all sectors, though the extent of clearance varies considerably between and within sectors. Conversion contributes to habitat loss and fragmentation, degradation of water catchments, soil erosion and reduced resources (food, water, shelter) leading to the loss of biodiversity and livelihoods (IPBES, 2018). In Africa, growth in commercial and subsistence agriculture is the most significant driver of deforestation (Hosonuma et al., 2012), with growth in agricultural output (particularly in land constrained areas) having accrued predominantly from area expansion and intensification of cropping systems (e.g. reduced fallow periods), rather than through large-scale improvements in productivity (Oxford Business Group, 2019).

Mining and infrastructure were identified as the third and fourth most significant drivers of deforestation in the continent (Hosonuma et al., 2012), despite the fact that these industries have traditionally been perceived to have more discrete and contained footprints (but see Sonter et al., 2018; Maddox et al., 2019). Yet studies increasingly reveal that mining can be a major direct contributor to deforestation in some landscapes as a result of having a large footprint, tailings dam failures, and implications of waste disposal (Arcus Foundation, 2014; World Bank, 2019b, 2019a, 2019c). **Timber extraction and logging is a major driver of forest degradation** (Hosonuma et al., 2012), with habitat alteration and loss of biodiversity associated with plantation establishment and harvesting activities.

Infrastructure fragments landscapes, often impeding ecological patterns and processes fundamental to the maintenance of ecological function and integrity and the production and maintenance of ecosystem services. Existing and proposed linear infrastructure result in the destruction, degradation and fragmentation of habitat, bisecting remaining intact forest (e.g. the proposed Cross River Calabar-Ikom-Kastina Ala Superhighway in Nigeria), disrupting wildlife movement and fragmenting populations (e.g. a proposed road bisecting the Serengeti National Park to link gold fields near Lake Victoria in Tanzania would disrupt the migrations of terrestrial wildlife) and increasing edge effects and degradation (Collinson et al., 2019).

Analysis indicates that collectively **33 planned or existing development corridors** (totaling over 53,000 km in length, if completed) **would bisect over 400 existing protected areas and could degrade a further 1,800** (Laurance et al., 2015). Other direct impacts of road and rail corridors resulting from their construction and use include pollution, altered microclimate and hydrology, invasive species, and collisions (Laurance et al., 2009, 2017; Arcus Foundation, 2018; Collinson et al., 2019). Bridges may also act to change the hydrodynamics of rivers with consequent changes in niche habitats, species preferences, interrupting trophic relationships and ecological balance within the river but potentially also leading to increased corrosivity and erosion potential, flood attenuation and water provision.

In the case of **large dams, the area of inundation can submerge forests**, adversely affecting the species they support, their ecological functions, and some of the ecosystem services they provide (World Bank, 2016). There is also evidence of increases in the frequency and duration of seasonal flooding following development of hydropower projects, abandonment of agricultural land, increased livestock disease, degradation of water quality for drinking and bathing, and problems for human health, losses of aquatic wildlife and freshwater fisheries (Baird & Barney, 2017).

Other direct impacts common across a number of sectors include **impacts on water quantity and quality** which may, for example, be linked to abstraction or irrigation systems, pollution through chemical contamination (e.g. from fuels, lubricants, agrochemicals, waste products etc), as well as soil erosion and sedimentation, and alteration of drainage networks. For example, timber harvesting and road construction leading to seasonal hydrologic changes with impacts on downstream biota, communities and fisheries with the highest risk of impacts from soil erosion and sedimentation following immediate final harvesting and from cleared slopes during heavy rain. This can directly affect **human health** (e.g., having toxic or carcinogenic effects) or indirectly, for example, through reduced water supply or contamination (and consequential prevention of fishery and loss of means of livelihood), (Mancini & Sala, 2018). Water use competition, increased water scarcity and depletion are recurrent issues relevant to most sectors, with implications for wildlife populations and local communities (Mancini & Sala, 2018).

Impacts on soil productivity and stability are also common across many sectors (e.g. physical, chemical and biological impacts including compaction, contamination, erosion and changes to micro fauna and flora). Whilst the **noise, light and vibrations** associated with operational infrastructure and activities (e.g. machinery, increased presence of people) can have serious adverse outcomes for some species (e.g. disrupting behaviour, triggering displacement) and for people in nearby settlements.

The combined effects of sector development adversely impact human wellbeing, for example through the loss of biodiversity and ecosystem services (including food and water security, microclimate regulation, flood defences etc.) whilst the **emission of greenhouse gases** and loss of carbon sequestration services through habitat clearance and degradation contributes to global climate change.

Indirect effects often dwarf direct impacts

The direct impacts of project development, particularly in the case of industrial extractives and infrastructure projects (mining, oil & gas, logging, roads and railways, powerlines, pipelines etc.) are often dwarfed by far **more wide-ranging and significant secondary impacts** that may have landscape or region-wide implications for biodiversity and ecosystem services. The impacts that result from boosting of economic activities, installation of electrical transmission lines, improvement of transport infrastructure and accessibility of the area (including forests and other sensitive ecosystems) and socioeconomic change (e.g. people moving into and away from a mining area) can have a much larger effects.

These developments can **open up intact areas, induce or intensify industrial development, accelerate carbon emissions and exacerbate pre-existing threats to biodiversity** (such as unsustainable resource extraction, poaching and wildlife trafficking, invasive species and habitat loss) and/or contribute to the emergence of new threats (Sonter et al., 2018; Collinson et al., 2019; Johnson et al., 2020; World Bank, 2019a). In turn, driving biodiversity and ecosystem degradation and loss. For example, fuelwood collection and charcoal production, uncontrolled fire and livestock grazing have been identified as major drivers of forest degradation (Hosonuma et al., 2012); practises that can be exacerbated with the presence of large-scale industry. Human-wildlife conflict and the resultant threats related to poaching and wildlife trafficking have also been linked to resource development and infrastructure.

Extractive project and associated infrastructure development invariably requires large numbers of workers during construction phase, often requiring peaks in demand for housing, energy, logistics, water and social services. Whilst these may be ephemeral, waning post construction into operational phases, or seasonal (e.g. increases of plantation workers during harvesting periods), there is often a large residual population attracted into the vicinity that becomes either formally or informally settled. This in turn stimulates both formal and informal land use change and economic activities that draw on ecosystem services and spatial land use demands.

Socioeconomic and cultural factors can further influence the combined implications of induced effects. For example, there is some evidence that gorilla and chimpanzee densities may be higher in areas where local communities have taboos against eating their meat (Strindberg et al., 2018; Heinicke et al., 2019). Where induced in-migration draws people from other areas this can undermine local cultural values and weaken the effect of cultural protection for some species.

Many large-scale mines in forest landscapes are surrounded by large-scale forest losses with spikes in deforestation linked to the period when the mines were being developed and likely associated with indirect or secondary impacts (World Bank, 2019b, 2019a). Around 10% of the world's forests lie within 50 km of existing large-scale mines, rising to nearly a third if mines in development or currently non-operational are considered (World Bank, 2019a). Evidence indicates that mines can exert influence on species and ecosystems over vast distances – at least 50 km from the mine – through, for example, sediment transport along rivers, emission and dispersion of chemicals and dust in air and water, as well as through direct and induced habitat degradation and loss (Sonter et al., 2018; World Bank, 2019b). A large number of large-scale mining operations also occur within 50 km of protected areas and Key Biodiversity Areas thus posing potentially serious threats to biodiversity (World Bank, 2019a).

Roads and paved highways, often developed as part of large extractives (mining, oil & gas, logging) projects, **act as major drivers of deforestation**, drawing people and investment to areas previously inaccessible (Laurance et al., 2009). They reduce barriers to investment and make operations economically viable, facilitate development of secondary road networks, and open areas up to colonisation and exploitation (from loggers, hunters and miners). The consequence is that resultant deforestation, ecosystem degradation and biodiversity impacts spreads:

- In the Amazon, the unofficial, secondary road network associated with the Trans-Amazonian Highway is a major cause of deforestation, with 95% of all forest clearing occurring within 5.5 km of a road (Barber et al., 2014).

- In the Congo Basin, resource and road development is closely followed by the loss and degradation of biodiversity and ecosystem services, including carbon storage, with old active roads contributing to a higher rate of annual deforestation within 1km of the road compared to new or abandoned roads (Kleinschroth et al., 2019).
- Logging roads in the Democratic Republic of Congo, even those subject to anti-poaching controls, are exploited by elephant poachers, negatively affecting elephant distribution (Stokes et al., 2010)
- Strindberg et al., (2018) report that (in the absence of wildlife guards) the density of western lowland gorillas (*Gorilla gorilla gorilla*), and central chimpanzees (*Pan troglodytes troglodytes*) declined closer to roads.

Research suggests that **no amount of mitigation will prevent deforestation from occurring after a road is built** (Fearnside, 2015).

The potential for devastating effects of planned development corridors on biodiversity has been demonstrated with potential for irreversible environmental changes (Laurance et al., 2015). Modelling by the IUCN and African Wildlife Foundation, further highlights the **effects of planned development corridors for inducing agricultural expansion** and implications of this for select species and habitat. Results suggested that cropland pressure could increase by 56% in key habitat areas (formed by combining protected areas and Key Biodiversity Areas), with some key habitat areas overlapped by multiple corridors particularly in East and southern Africa (Williams, 2017). To account for the fact that many iconic and globally threatened species depend on lands outside of key habitat areas, further analysis (considering species ranges for bonobo, elephant, lion and lowland gorilla subspecies), found that with a 100 km buffer, corridors overlapped 43% of the species ranges (Williams, 2017).

Where impacts to high biodiversity value are significant and agricultural benefits are low the costs of some infrastructure projects and development corridors may far outweigh the benefits. A growing body of evidence points to **high social and economic, as well as environmental, costs of poorly planned infrastructure development** (Alamgir et al., 2017; Vilela et al., 2020). For example, analyses of the expected social, economic and environmental impacts of 75 road projects totaling 12,000 km in the Amazon region found that almost half (45%) will generate economic losses and that cancelling economically unjustified projects could avoid 1.1 million hectares of deforestation and USD 7.6 billion in lost funds (Vilela et al., 2020).

Industrial-scale resource extraction and infrastructure development is driving protected areas downgrading, downsizing and degazettement (PADDD), alongside pressures arising from local land uses and land claims (Qin et al., 2019). The application of legal changes to protected areas that temper regulations (downgrading), reduce protected area size (downsizing), or remove protections completely (degazettement) is increasingly widespread yet remains underreported. Examples include:

- Successive downgrading of Virunga National Park (2010, 2015 and 2018) and the Salonga National Park (2018) in the Democratic Republic of Congo for oil and gas
- Downsizing of Mount Nimba National Park and World Heritage Area in Guinea in1993 to accommodate mining for iron ore
- Successive downsizing and downgrading of Selous Game Reserve in Tanzania in 2012 and 2018 for mining and infrastructure

- Downgrading and downsizing of Serengeti National Park, Tanzania, in 2010 and 2012 for infrastructure

Other secondary effects include, for example, the **displacement of people and activities by large-scale industries**. In cases where smaller-scale industries, such as smallholder agriculture and artisanal and small-scale mining, are displaced by larger operations this can drive activities and their associated impacts into areas that are: less favourable for production (e.g. the periphery of a larger mine; areas with steeper slopes or poor soils); where land and resources may be more limited (e.g. areas that are more densely populated and face land shortages); and that support more sensitive ecosystems and protected areas.

As a result, the **magnitude of social and environmental impacts may be more severe due to increased social conflict,** challenges to traditional governance of land and resources, loss of livelihoods, erosion of health and well-being, safety and personal security risks, and due to high biodiversity, carbon and other ecosystem service values. Impacts are often compounded by socioeconomic conditions. For example, smallholder farming affects the condition of ecosystems and whilst impacts are not always negative, poverty and the need to meet immediate needs can drive smallholders to adopt environmentally damaging agricultural practices, contributing to habitat loss and degradation, soil erosion, agrochemical pollution etc.

Multisectoral development, particularly when developed under rapid timescales, has direct and indirect implications for local communities, including human health and security, livelihoods and poverty, cultural identify and values, social cohesion, and critical infrastructure (e.g. transport, energy and waste systems, health and education services). For example, whilst development often gives stimulus to local economy and may increase population income and business opportunity for some, income inequality and corruption can trigger social tensions (Mancini & Sala, 2018).

Where **competition for land and resources arise** (e.g. through development of a mine or forestry concession) this can endanger the rights and wellbeing of local communities, reduce access to land of adequate quality and the essential ecosystem goods and services which people depend, and contribute to impoverishment (e.g. through land expropriation, displacement and resettlement). Where in-migration occurs due to resource and infrastructure development, this can change local demographic structure and dynamics (e.g. creating gender imbalance due to the prevalence of male workers), undermine customary systems governing the access and use of land and natural resources, and disrupt or dilute traditional cultural values (e.g. taboos on hunting of certain species). This has implications for social cohesion, human rights, and the governance of land and resources, and can exacerbate pressure on wildlife, natural ecosystems and the functions and services they provide for people.

Land use change has also been identified as the primary transmission pathway for emerging infectious diseases (UNCCD, 2020). For example, forest fragmentation and increased human forest presence have been linked to the zoonosis of Ebola Virus Disease (EVD) from bats to humans (Rulli et al., 2017). The introduction of alien and invasive species and heightened risks of disease exposure will further put both species and human communities at risk (e.g. through people transferring disease to threatened species such as chimpanzees, and wildlife transferring disease to people such as in the case of EVD, SARS and Covid-19).

Ecological responses to different impacts vary

Species and ecosystems respond to the effects of development in different ways, often depending on the type of activities taking place and the temporal and spatial scale thereof. In other words, not all impacts are equal and not all species or habitats will respond to threats and pressures in the same way. Nevertheless, habitat destruction and species mortality are inarguably immutable. See BOX 1 on multi-sectoral development in ape range states and the implications for ape conservation.

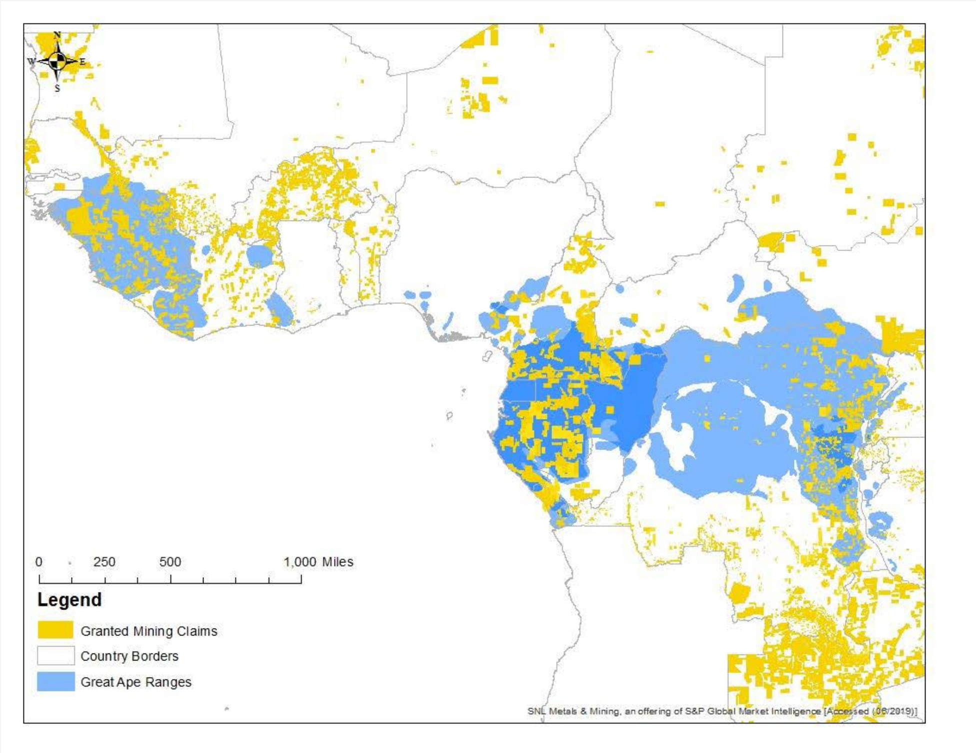
BOX 1: MULTI-SECTORAL DEVELOPMENT IN APE RANGE STATES AND IMPLICATIONS FOR APE CONSERVATION

Great ape habitats increasingly interface with extractive, productive and infrastructure sectors (see Figure 1 below). Habitat loss and poaching are the greatest threats to the conservation of great apes, with wild populations also at risk from the spread of human diseases (Arcus Foundation, 2014). A boom in mining activities, especially for bauxite, gold and iron-ore, and the development of roads and railways, logging, hydroelectric dams and agricultural expansion are contributing to declines in great ape populations across the continent (Arcus Foundation, 2014, 2015, 2018), exacerbating pre-existing threats to apes by destroying and fragmenting vast areas of their habitat. Such projects also often reduce ape numbers, by facilitating hunting through increased access to remote areas.

Additionally, such projects frequently result in large influxes of people, which can further increase hunting pressure and habitat destruction, expose apes to human diseases and force them out of their habitual ranges. When apes are forced into ranges of adjacent communities of apes, or into marginal habitat, or closer to humans, this can result in competition, stress, increased conflict with humans and each other, and can have long-term consequences for the health and reproduction of the population. When territorial species like chimpanzees are forced into the range of another community, mortalities are likely to occur.

Although apes are impacted by many of the same threats as other taxa, they are especially vulnerable due to their socioecology (Arcus Foundation, 2014 and references therein): they are sensitive to human intrusion and disturbance, they nest and forage in trees, they take a long time to reach sexual maturity and have low birth rates, resulting in very slow population growth rates. Any disturbances that increase mortality rates even slightly can quickly result in rapid population decline.

All African great ape species has mining occurring within their range with particular areas of intense mining occurring in Guinea, Gabon and Liberia (Howard, 2019). In Guinea, mining is extensive and increasing, with the majority of bauxite and iron ore mining concessions intersecting with areas supporting populations of the IUCN Red Listed Critically Endangered western chimpanzee: the entirety of the western chimpanzee population in northwest Guinea occur within mining concessions and, if not effectively managed and protected within and across concessions, individuals are being displaced and have nowhere to go. Whilst many oil & gas projects are situated offshore, there are numerous oil and gas projects located in landscapes with vulnerable great ape populations, particularly around Lake Albert in Uganda and Tanzania, as well as in Gabon (Howard, 2019).



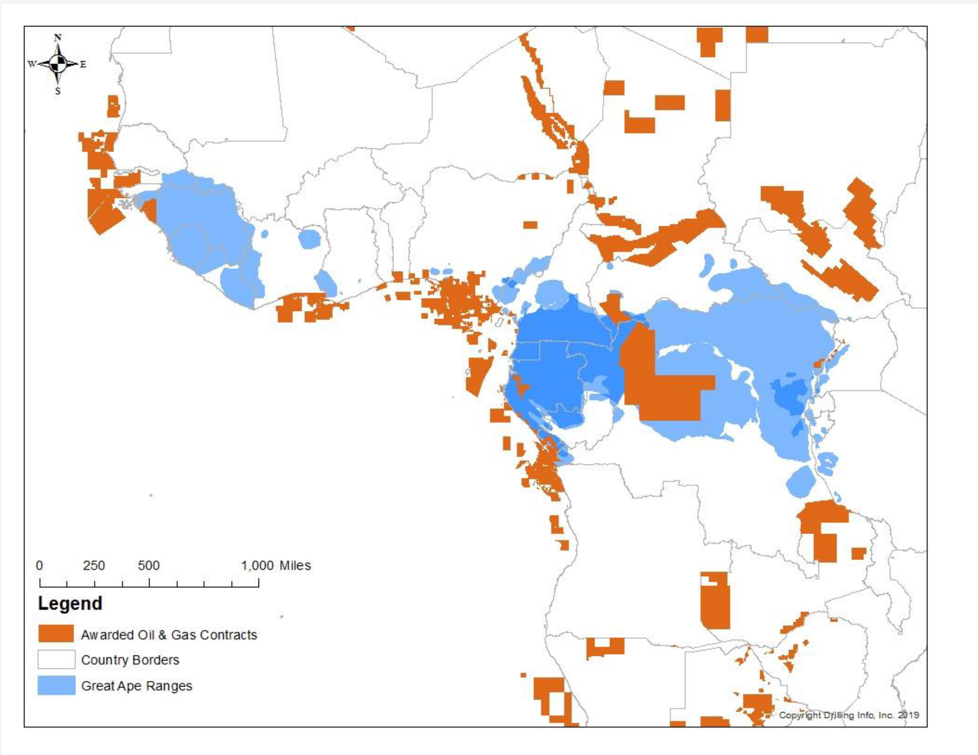


Figure 1: Ape range states and multi-sector developments. Top: granted mining claims and mining concessions; bottom: awarded oil and gas contracts. All are shown in relation to ape ranges according to the APES portal survey on ape populations (Howard, 2019).

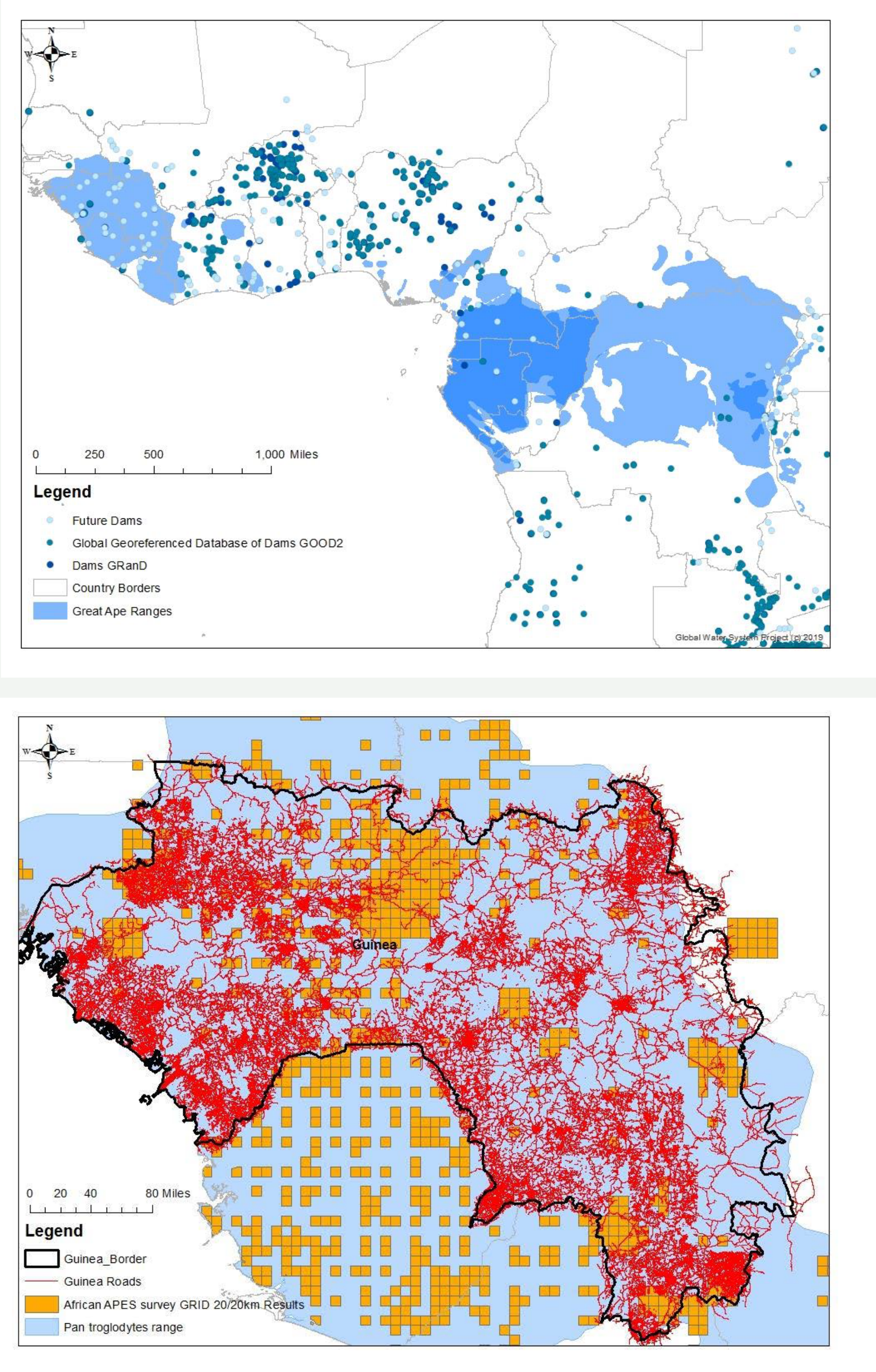


Figure 1 continued: Ape range states and multi-sector developments. Top: hydroelectric power dams; bottom: road network of Guinea. All are shown in relation to ape ranges according to the APES portal survey on ape populations (Howard, 2019).

Agricultural expansion and associated loss and degradation of forest habitat is also occurring at pace across great ape ranges. A recent study by Strona et al. (2018) revealed that if projections for global demand of oil palm for alimentary use materialise (i.e. doubling over the period 2005–2050), cumulative habitat loss could be extensive, affecting over 400 million hectares of habitat and more than 40 primate species in a worst-case scenario; a situation that could be considerably worse if estimated future demand for palm oil for biofuel is taken into account.

In multi-use landscapes, the **effects on species and habitats becomes complex and difficult to predict, often compounded due to “busy-ness” in the landscape** and the inability of species to find refuge or for habitat to buffer and absorb and recover from impacts. In multi-use landscapes, the distribution of species and habitats is likely to be forcibly altered. The ways in which species and ecosystems respond to different sectors, types of impact and their cumulative effects will vary according to ecological and behavioural characteristics, life histories and the patterns and processes of the ecosystem. Understanding this variation and complex interactions and collective context specific influencing factors is key to their effective management and conservation (Morgan et al., 2018; Pardo et al., 2018).

Tropical forests are particularly vulnerable to the impacts of industrial development and linear infrastructure, including effects of forest clearance and fragmentation, because of their complex structure, uniquely humid, dark and stable microclimate, and an abundance of ecologically specialised species (Laurance et al., 2009), including some forest specialists that avoid even narrow (less than 30 meters wide) clearings and forest edges, as well as other species that are susceptible to collisions with traffic, hunting or predation near roads, and species invasions. **Noise and vibrations associated with industrial activity can modify species behaviour and cause displacement** from a much larger area than that directly affected by forest clearance and degradation (World Bank, 2019b).

Montane systems are another example of ecosystems that can be highly vulnerable to impacts, often supporting high levels of endemism and diversity and with mountain species typically holding small, disjunct distributions, having limited capacity to disperse and large distances between suitable habitats (if they exist at all); factors that increase their vulnerability to the effects of disturbance (de Castro Pena et al., 2017). The rare montane forest ecosystems of Guinea and Liberia are increasingly under pressure from mining interests, drawn to the unique geomorphology of these high elevation areas and associated iron ore reserves. Given high levels of endemism, limited capability and/or options for dispersal, and the compounding effects of mining alongside other unregulated pressures and stressors, the risk of local population losses and potential for species extinctions is likely to be high (see report (FFI, 2021b).

Understanding the ecological requirements of individual species and populations, the degree of flexibility in their responses to cope with impacts, and the environmental conditions that may enable or constrain those responses, is an essential, yet often overlooked, consideration. Species’ responses to impacts vary according to their socioecology and biological dispositions, the condition, extent and accessibility of suitable habitat, as well as the type, scale and duration of disturbance. For example, **although great apes face many of the same threats as other taxa, they are especially vulnerable due to their socioecology**: they are sensitive to human intrusion and disturbance, they are forest-dependent - nesting and foraging in trees, and they reproduce slowly with long periods of maturation and low birth rates, resulting in very slow population growth rates (Arcus Foundation, 2014). Even a slight increase in mortality rates can quickly result in negative growth rates and population declines, from which it will take decades or centuries to recover (IUCN Species Survival Commission (SSC) Primate Specialist Group ARRC Task Force, 2020). Some species and some environments are more sensitive than others (BOX 2).

Generalist species and those with greater ecological flexibility may be more tolerant of disturbance compared to those with highly specialised ecological requirements, limited mobility, and/or social systems that constrain their ability to spatially shift their range (Putz et al., 2001; Peters et al., 2006; Morgan et al., 2018). Studies of sympatric species reveal the strong influence of ecological and behavioural attributes in how different species respond to the impacts of industry activity (e.g. Stokes et al., 2010; Caruso et al., 2016; Morgan et al., 2018; Pardo et al., 2018; and see BOX 2). In landscapes under pressure from multiple land uses, unmitigated human-induced changes are expected to modify the structure of communities, favouring the more adaptable species (Caruso et al., 2016).

However, **there will always be exceptions**. In Colombia, for example, whilst the relative abundance of most mammal species declined in response to oil palm cultivation, some species appeared unaffected or respond positively in oil palm occurrence. In addition to some mesopredators (e.g. fox and jaguarondi) that may have benefitted from oil palm effects on the presence of prey species (e.g. rodents), the giant anteater – a species with highly specialised dietary requirements – was found to persist and even respond positively in oil palm areas owing to the high prevalence of ants found in plantations (Pardo et al., 2018). This stresses the importance of understanding the needs of different species and populations, but also the diverse and context specific ways that changes in land use can affect complex ecological systems.

These studies highlight the importance of multi-species landscape-scale studies for assessing the likely impacts of multi-sectoral development.

BOX 2: THE INFLUENCE ON ECOLOGICAL PREFERENCES AND SOCIAL SYSTEMS ON SPECIES-SPECIFIC RESPONSES TO HUMAN-INDUCED DISTURBANCE IN GREAT APES

Sympatric western gorilla and central chimpanzee differ in ecological preferences, resource use, social systems and, in turn, their responses to the effects of industrial activity. Gorillas are seasonal frugivores consuming mostly herbaceous ground vegetation and fruit whilst chimpanzees are specialists with over half their diet comprising fruit. Their social systems also vary and this has a strong influence on the ability of individuals and groups to shift their ranging patterns. For example, chimpanzees are territorial and will aggressively defend their home range from incursions by neighbouring groups often resulting in death, thereby limiting their options for spatial shifts in range, whereas gorillas are not territorial and have limited social restrictions on their movement, allowing them the flexibility to spatially shift their ranges in response to disturbance from human activities (Morgan et al., 2018).

Given these specific-specific socioecological profiles, chimpanzees are likely to be more adversely affected by human-induced disturbance. For example, chimpanzee densities have been found to increase with distance from roads and villages, whereas gorilla densities showed little response to either, indicative of species-specific responses to human disturbance and habitat modification (Stokes et al., 2010). Strindberg et al. (2018) further indicate that chimpanzees tended to occur in areas with low or moderate human influence, their density dropped rapidly after a certain level of human influence was reached.

Research by Morgan et al. (2018) shows that whilst chimpanzees may be better able to respond to impacts at a small, local scale (i.e. within the group's home range), gorillas are more able to shift their ranging patterns over a larger area with gorilla densities varying in response to entire logging fronts. The cumulative effect of logging over time also had greatest impact on chimpanzees whereas gorillas were found to recolonise areas after forestry activity ceased. The spatial avoidance of impacts is only possible because gorillas can tolerate spatial overlap among groups and were there are adequate resources to support such fluctuations in numbers. Changes in forest composition and structure as a result of recurrent logging cycles may play a key role in the persistence of different ape species.

See Gabon case study (FFI, 2021c)

Cumulative effects of multi-sectoral development

No single sector, project or activity acts in isolation. The reality is that there is complexity both in the planned and unplanned development outcomes that prevail in any landscape. Whilst in some cases individual decisions and actions may have minor, manageable effects by themselves, when considered together the many past, present and future decisions and actions occurring across the landscape accumulate and interact. As each project cuts away a little more forest, adds pollutants to the rivers and soils, and extracts more natural resources than it puts back, the **cumulative effects** on species, ecosystems and the people that depend on them can be significant, particularly in the context of other pressures and stresses, leading to "**death by a thousand cuts**".

Cumulative effects are the successive, incremental and/or combined impacts of actions, projects or activities and result from the **aggregation and interaction of impacts** caused by past, present and/or future activities. They can be positive and/or negative and vary in intensity as well as spatial and temporal extent. Impacts can aggregate linearly or nonlinearly and the impacts of multiple individual stressors or threats can be **additive** (the sum of individual effects), **synergistic** (producing a combined effect greater than the sum of individual effects) or **antagonistic** (combined effect that is less than would be expected if the known effects of the individual impacts were added together).

Impacts can aggregate in many different ways (Whitehead et al., 2017), for example:

- through the **accumulated impacts of multiple stressors** (e.g. cumulative effects of habitat clearance, degradation and fragmentation, and light, noise and vibrations, and soil erosion, water abstraction and pollution);
- **spatial accumulation of impact footprints** from multiple independent and/or consecutive developments leading to habitat clearance and progressive degradation, changing habitat extent, structure and connectivity, population dynamics, community composition, and ecosystem function;
- **the accumulation of impacts over time** at site or landscape scale (e.g. increase in pollutant concentrations in water and soil).

Examples of cumulative impacts (IFC, 2013; World Bank, 2019a) include:

- Reduction of water flow in a watershed due to multiple withdrawals over time;
- Fragmentation of habitat and loss of connectivity;

- Interference with migratory routes and/or wildlife movement;
- Increases in sediment loads on a watershed or increased erosion: Unpaved roads appear to be on the same order of importance as agricultural lands in contributing sediment to the stream network, despite occupying a fraction of the total surface area in the basin (Ziegler et al., 2004);
- Increased pressure on the carrying capacity or the survival of indicator species in an ecosystem;
- Cumulative secondary or induced social impacts of multiple projects, such as in-migration and associated impacts on wildlife populations through increases in hunting, road traffic collisions and extraction of timber and non-timber forest products.

Cumulative effects may arise from multiple large and/or small-scale operations in a single sector and these can be extensive and severe, contributing to widespread habitat loss and degradation, changes to hydrological systems, reduced landscape connectivity, loss of agricultural land, regional species losses, water crises, loss of traditional practices and values, and food insecurity (BOX 3 and BOX 4). For example, the cumulative effects of consecutive logging cycles over time have been shown to have particularly detrimental effects for species with specialised ecological requirements and constraints on their ability to spatially shift their range or otherwise adapt to cope with repeated disturbance (Morgan et al., 2018). Whilst multiple small hydropower projects, can drive alteration of hydrological conditions and dynamics, loss of fish habitats, alteration in fishing activities and riverine communities downstream.

Evidence further suggests that where **large-scale mining and artisanal or small-scale mining co-occur there can be heightened competition and conflict** over mineral resources and the cumulative, negative impacts on forests are often exacerbated. For example, in Tarkwa, Ghana, growing competition over gold-bearing land led to conflict between artisanal miners and large-scale mine operators over concessions and increased illegal artisanal mining on large-scale mine sites, protected areas, and agricultural land (Calys-Tagoe et al. 2015; Hilson and Potter 2005), exacerbating forest impacts both directly, indirectly and cumulatively (World Bank, 2019b).

In light of project growth trends, **cross-sectoral, cumulative impacts for natural habitat, species and rural human communities in many African landscapes are set to intensify dramatically** and may result in significant adverse effects that could not be expected in the case of a single sector or operation alone. Yet these complex interactions, processes and their consequences for biodiversity and ecosystem services have received comparatively little attention (Sonter et al., 2018). Where cumulative impacts of development projects have been considered, assessment often focuses primarily on a single sector.

Cumulative effects transcend the boundaries between terrestrial and aquatic ecosystems as well as national borders and jurisdictions through their effects on ecosystem structure and function, population dynamics, and through impacts on human communities and the ways in which traditional governance, cultural practises and livelihood strategies and resource management practices change over time. For example, the interactive effects between agribusiness development and hydropower development are reported to produce multiple, cascading displacement effects in local communities, as property rights are reorganised, livelihood thresholds are crossed, and as resource degradation takes effect (Baird & Barney, 2017). Transboundary dynamics can influence the cumulative effects of various industries. The mineral province of the Nimba Range in West Africa, for example, can be considered a single entity geologically, ecologically, and even, to some degree, sociologically, but political borders mean impacts in one area may be difficult to ascertain and control by actors in another jurisdiction (World Bank, 2019b, 2019a).

Growth-inducing infrastructure, such as roads and railways, electrical transmission lines and export facilities, create incremental changes in where and how natural resources are exploited. These projects open intact areas, induce or intensify industrial development, and accelerate carbon emissions (Johnson et al., 2020). The secondary and cumulative effects of these initial developments and their associated 'spin-off' developments in transport infrastructure, agriculture, forestry, mining, oil and gas and/or other industries and activities (e.g. human settlements) can affect extensive areas and may **trigger a set of cascading, irreversible development effects** that contribute to the loss of biodiversity, degrade ecological integrity and diminish associated ecosystem services (Johnson et al., 2020).

Cumulative impacts can reach 'tipping points' (also called thresholds or system boundaries), beyond which even modest changes in complex systems may cause disproportionately large shifts in ecosystem properties (e.g. at the individual, population, species and ecosystem levels), radically changing ecosystem structure and function and the dynamics of associated environmental, social, cultural and economic systems (Franks et al., 2010; Whitehead et al., 2017). For example, gradual increases in nutrient loading in aquatic systems may have limited impacts on ecosystems until a threshold is reached beyond which harmful algal blooms and oxygen-depleted zones occur and threaten water quality, human health, and wildlife (Selkoe et al., 2015). Another example of ecological tipping points include the sudden shifts in species dominance or population collapse. Whilst some rapid ecological shifts can be anticipated, many are not and such unanticipated ecological changes can be socially, culturally, and economically costly (Selkoe et al., 2015). The cascading environmental transformations resulting from cumulative effects can further undermine developers' attempts at social and environmental impact mitigation and livelihood compensation (Baird & Barney, 2017).

Multi-sectoral development is occurring alongside unregulated development of infrastructure and human settlements, overharvesting of natural resources, introduction of invasive alien species, and air, water and soil pollution (see section 'Sectoral growth amidst complex and evolving challenges'). The result is unregulated conversion and degradation of forest, rangelands and other natural areas, such as wetlands, e.g. for food production, woodfuel, and other non-timber forest products, and is exacerbated by the erosion of indigenous knowledge, as communities change their cultural use of space and resources (IPBES, 2018). It is also happening at a rapid pace. Around a third of woodfuel harvesting in tropical regions is unsustainable (FAO, 2017b) and analyses indicate that in Africa fuelwood collection and charcoal production is the major driver of forest degradation, followed by timber extraction and logging, uncontrolled fire and livestock grazing (Hosonuma et al., 2012). Climate change exacerbates all the other direct drivers of biodiversity loss (IPBES, 2018).

In a context of rapid population growth, poverty, water and food insecurity, and climate change the compounding effects of multi-sectoral development will transform inter-dependent ecological, sociocultural and economic systems in planned and unplanned ways. For example, the impacts of large hydropower dams and agribusiness concessions have been shown to be overlapping and responsible for complex and frequently unanticipated socioecological changes (Baird & Barney, 2017). Studies have also shown that mining-led impacts can be particularly significant in the context of other diverse drivers of habitat degradation and deforestation (World Bank, 2019a): affecting vast areas, myriad ecosystems and the many species and human communities that depend on them.

By fragmenting habitat, degrading ecosystems, contaminating soils, water and air, and disturbing populations of threatened or sensitive species, the cumulative effects of development in combination with other threats and pressures can undermine ecosystem structure, function and resilience. Without adequate planning, safeguards and coordination, the impacts of rapid, multi-sector development can therefore leave a legacy of degradation, pollution, extinctions, social conflict, and trade-offs - undermining landscape resilience and exacerbating the effects of climate change and other external threats.

BOX 3: CUMULATIVE EFFECTS OF MULTI-OPERATOR BAUXITE MINING IN GUINEA

The Boké prefecture of north-western Guinea contains some of the world's largest reserves of high-grade bauxite and has a long history of mining with the first mine established in 1973. More recently, however, the region has been experiencing a rapid increase in large-scale mining activity with new concessions being allocated, green field projects underway and the expansion of existing operations. Within a 10-year period, the area has gone from less than five active operations to 14 operations. Some concessions in this landscape are being leased for long time frames (over 60 years in one example) and the size of concessions are considerably larger than for other minerals (up to 114,000 hectares), though the operational mining area within may be considerably smaller.

Operations involve a series of relatively shallow open pits and typically include a range of associated infrastructure including new and/or improved roads, railway lines, warehouses and stockyards, housing and administrative facilities, processing plants, development or expansion of ports, water and waste water treatment facilities. Operations are run by companies from all over the world, each with different starting points, financing arrangements and standards of environmental and social practice. The rapid pace of project development in some cases is also extremely concerning with projects moving from feasibility to full production phase within 12 months. Rapid expansion of the mining sector and has been accompanied by the development and improvement of supporting infrastructure including roads, railways and ports.
In the past, the landscape supported a matrix of woodland, wooded grassland (also referred to as savannah), gallery forest (situated along the rivers and watercourses), grassland, and bowal habitat. Today, wooded grassland and woodland is increasingly under pressure from mining and agriculture and gallery forests are becoming rare, fragmented and degraded. Despite ongoing degradation, the landscape continues to support important populations of globally threatened, rare and restricted range species (e.g. western chimpanzee, West African red colobus, African white-backed vulture, kunda half-toed gecko, Rueppell's griffon vulture, Pintoi's puddle frog, various freshwater fish species), maintain essential ecosystem functions and services (e.g. gallery forest habitat protects headwaters and water resources and forest ecosystems

provide a source of natural resources for community use), and hold important cultural value (e.g. sacred forests, genie residences linked to trees, forest, rocks, streams).
The cumulative effects of prospecting and mining by multiple operators across large, adjacent concessions are expected to be severe. The impact of mining on forests is already evident through patterns of forest loss with recent analysis revealing spikes in forest loss that coincide with increases in mining interest and activity (World Bank, 2019a). Anticipated and realised cumulative effects include:

- **widespread clearance of natural habitat**, particularly woodland, wooded grassland and mangroves, with implications for dependent species and associated ecosystem functions. Impacts are expected to be severe and regional (rather than local)
- **loss of grassland and bowal habitat** which constitute important pasturage and have vital water catchment functions, leading to a shift in agricultural pressure to areas with higher biological value and impacts for water access and supply
- **degradation and fragmentation** of natural habitats from the development of multiple adjacent concessions and transport networks, exacerbating edge effects, adversely impacting habitat specialists, reducing connectivity between forest fragments and increasing the vulnerability of small isolated populations to shocks and stressors
- **degradation and loss of cultural heritage** and traditional practices
- **air pollution** including dust surges, affecting human and wildlife health and crop yields
- **light**, **noise and vibration disturbance** leading to the displacement of sensitive species such as chimpanzees and red colobus from a much larger area than that directly affected by forest clearance, degradation and activities.
- facilitated **access to bushmeat,** including chimpanzees; many roads and interconnected access may attract hunters and facilitating the movement of bushmeat and other non-timber forest products from the area
- **regional losses of species**
- **seasonal or permanent reduction in water supply** (river flows and groundwater), poor waste management and build up of aluminium contributing to **water pollution** with implications for aquatic ecosystems and ecosystem services (potable water supply, fishing, riparian agriculture etc). Water supply and quality concerns have already been raised by communities.

Induced in-migration leading to rapid population growth, particularly around mine camps and in urban and suburban areas, with associated impacts for resident communities, biodiversity and ecosystem services are a major concern across Boke. At the same time, resident rural communities are being displaced and dispossessed of farmland to make way for mines and associated infrastructure and are seeking alternative arable lands or moving to more urbanised areas to seek jobs. Increased land occupancy by mines and a growing population is further impacting the conditions governing access to land and natural resources, undermining the legitimacy of traditional governance systems, changing cultural norms (e.g. relating to the hunting of chimpanzees), and reducing the availability of arable land and pasturage, in turn increasing social conflict and competition over land and resources (e.g. between herders and sedentary farmers), reducing food production capacity leading to greater food insecurity and affecting quality of life.

Beyond bauxite, infrastructure is intended for use in the import of capital goods (e.g. fertilizers and pesticides) and development of a regional hub for the West Africa region. The trend towards elevated levels of forest loss and degradation, wildlife population declines, human health issues and societal unrest is set to continue and intensify as new players enter this multi-operator mineral region and operations and their associated impacts increasingly draw down on the land, natural resources and ecosystem services that the landscape provides.

Sources: EEM Sustainable Management, n.d., 2015; SGS Environment, 2014; ERM, 2015a, 2015b; World Bank, 2019a.

BOX 4: CUMULATIVE EFFECTS OF SMALLHOLDER COCOA PRODUCTION IN WEST AFRICA

Côte d'Ivoire is the world's biggest cocoa producer, with about 40% of global output. Full-sun cocoa (as opposed to shade-grown cocoa) is currently the dominant cocoa cultivation system in the country, contributing to higher short-term yields and its global status. However, the country also has one of the highest deforestation rates in Africa. The government estimates that more than 80% of the country's forests have disappeared since the 1970s, mostly as a result of cocoa bean production over a prolonged period (Oxford Business Group, 2019), and with implications for biodiversity, soil fertility and soil quality, and the ecological processes and services that these forest ecosystems provide for people (Tondoh et al., 2015). Around 40% of the country's cocoa production is believed to come from protected forest areas that have been burned down by farmers in order to plant trees. With cocoa providing a direct or indirect living to one-quarter of the population and accounting for around 30% of the nation's export earnings, tackling forest degradation is a challenging task (Oxford Business Group, 2019).

Similarly in Ghana cocoa dominates the agricultural sector, contributing about 30% of export earnings, employing an estimated 800,000 people directly and supporting many more indirectly (Appiah Takyi & Amponsah, 2020). Cocoa production is constrained to the favourable climatic conditions of Ghana's forest agroecological zone presenting significant challenges for forest conservation. A recent study revealed that between 2010 and 2015 a total of 117,240 hectares of forest were cleared for the expansion of cocoa farms. Another major source of deforestation linked to cocoa production is through the construction of feeder roads with recent research revealing that a total of 3,000 km of new feeder roads have been constructed since 1999 to link cocoa farms to marketing outlets. Pollution from the use of pesticides and insecticides has further contributed to the environmental impacts of the industry (Appiah Takyi et al., 2019). Cocoa production across the region is also vulnerable to climate change which is projected to lead to future shifts cocoa production within the region with risks of local production expansion contributing to new deforestation (Schroth et al., 2016).

IMPLICATIONS FOR LONG-TERM SUSTAINABLE ECONOMIC GROWTH

The prominence of environmental concerns in global risk analyses have been steadily rising over recent years. Each year the World Economic Forum (WEF) publishes its Global Risk Report to identify and analyse the greatest risks and issues facing the world. For the first time, 2020 sees environmental concerns dominating the top long-term risks in terms of likelihood. Extreme weather events were rated as the most likely risk to occur over the next 10 years, consistent with the results of the previous year. This was closely followed by failure of climate change mitigation and adaptation, a trend attributed to the growing environmental policy failure "having fallen in the rankings after Paris."

The accelerating pace of biodiversity loss and ecosystem collapse are also identified as important concerns featuring in the top five risks in terms of likelihood and impact. Natural and human-made environmental disasters are among the top five likelihood risks. Three of the top-five risks in terms of impact are also environmental and include climate action failure, biodiversity loss and extreme weather with water crises, categorised as a societal risk, also featuring and with fundamental relationship to environmental issues (WEF, 2020).

Millions of people are dependent on agricultural, forestry and extractives industries across the continent, underscoring the need for governments to develop the sectors in a way that promotes sustainability. With the ever increasing extent and magnitude of cross-sectoral and cumulative impacts resulting from past, present and anticipated future multi-sectoral development in combination with other threats and stressors in landscapes across Africa, there is an urgent need to place biodiversity, ecological integrity and landscape resilience at the centre of development planning. Sustainable land-use planning could ensure that critical ecosystems such as freshwater streams, wetlands, natural forests, or endemic ecosystems that are key reservoirs of biodiversity, are sufficiently protected (IPBES, 2018).

"Landscapes across Africa need to transform quickly to inclusive, 'green' economies, if they are to meet the pressing challenges of employment generation, climate, food and water security and biodiversity conservation. ***The natural resource base must be used and managed carefully in alignment with economic activity to achieve a sustainable or even regenerative economy, while also sustaining nature. Thus individual businesses in the landscape that use or impact natural resources need to become landscape-friendly****, and available financial resources need to be redirected to businesses and other public, private and civic projects that support agreed landscape goals"*

African Landscapes Dialogue (2020).

REFERENCES

African Landscapes Dialogue (2020) The African Landscapes Action Plan Phase 3. EcoAgriculture Partners, for the Landscapes for People, Food and Nature initiative: Fairfax, Virginia.

Alamgir, M., Campbell, M.J., Sloan, S., Goosem, M., Clements, G.R., Mahmoud, M.I. & Laurance, W.F. (2017) Economic, Socio-Political and Environmental Risks of Road Development in the Tropics. *Current Biology*, 27, 1130–1140.

Angelsen, A. & Dokken, T. (2015) Environmental Reliance and Climate Vulnerability: A Cross-Section Analysis of Structural and Stochastic Poverty. Policy Research Working Paper 7474. World Bank: Washington, DC.

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N.J., Bauch, S., et al. (2014) Environmental Income and Rural Livelihoods: A Global-Comparative Analysis. *World Development*, 64, 12–28.

AOW (2019) The Africa oil & gas investment outlook: a big continent with bigger prospects. *Africa Oil Week: africa-oilweek.com*. https://africa-oilweek.com/Articles/africa-oil-gas-investment-outlook.

Appiah Takyi, S. & Amponsah, O. (2020) Ghana's cocoa production relies on the environment, which needs better protection. *The Conversation*. https://theconversation.com/ghanas-cocoa-production-relies-on-the-environment-which-needs-better-protection-134557 [accessed 4 August 2020].

Appiah Takyi, S., Amponsah, O., Inkoom, D.K.B. & Abagna Azunre, G. (2019) Sustaining Ghana's cocoa sector through environmentally smart agricultural practices: an assessment of the environmental impacts of cocoa production in Ghana. *Africa Review*, 11, 172–189.

Arcus Foundation (2014) State of the Apes: Extractive Industries and Ape Conservation. Cambridge University Press: Cambridge, UK.

Arcus Foundation (2015) State of the Apes: Industrial Agriculture and Ape Conservation. Cambridge University Press: Cambridge, UK.

Arcus Foundation (2018) State of the Apes: Infrastructure Development and Ape Conservation. Cambridge University Press: Cambridge, UK.

Ascensão, F., Fahrig, L., Clevenger, A.P., Corlett, R.T., Jaeger, J.A.G., Laurance, W.F. & Pereira, H.M. (2018) Environmental challenges for the Belt and Road Initiative. *Nature Sustainability*, 1, 206–209.

Baird, I.G. & Barney, K. (2017) The political ecology of cross-sectoral cumulative impacts: modern landscapes, large hydropower dams and industrial tree plantations in Laos and Cambodia. *Journal of Peasant Studies*, 44, 884–910.

Banerjee, S.G., Malik, K., Tipping, A., Besnard, J. & Nash, J. (2017) Double dividend: power and agriculture nexus in sub-Saharan Africa. World Bank Group: Washington DC.

Barber, C.P., Chochrane, M.A., Souza, C.M. & Laurence, W.F. (2014) Roads, deforestation, and the mitigating effect of protected areas in the Amazon. *Biological Conservation*, 177, 203–209.

BBOP (2012) Business and Biodiversity Offsets Programme Glossary. Business and Biodiversity Offset Programme (BBOP): Washington, DC. http://bbop.forest-trends.org/guidelines/Updated_Glossary

Botes, A., Lane, A. & Cornelissen, B. (2018) Africa Oil & Gas State of Play November 2018. Deloitte Touche Tohmatsu Limited.

BURIVALOVA, Z., GAME, E.T., WAHYUDI, B., RUSLANDI, RIFQI, M., MACDONALD, E., ET AL. (2020) Does biodiversity benefit when the logging stops? An analysis of conservation risks and opportunities in active versus inactive logging concessions in Borneo. *Biological Conservation*, 241, 108369.

CARUSO, N., LUCHERINI, M., FORTIN, D. & CASANAVE, E.B. (2016) Species-specific responses of carnivores to human-induced landscape changes in central Argentina. *PLoS ONE*, 11, 1–16.

DE CASTRO PENA, J.C., GOULART, F., WILSON FERNANDES, G., HOFFMANN, D., LEITE, F.S.F., BRITTO DOS SANTOS, N., ET AL. (2017) Impacts of mining activities on the potential geographic distribution of eastern Brazil mountaintop endemic species. *Perspectives in Ecology and Conservation*, 15, 172–178.

COLLINSON, W., DAVIES-MOSTERT, H., ROXBURGH, L. & VAN DER REE, R. (2019) Status of Road Ecology Research in Africa: Do We Understand the Impacts of Roads, and How to Successfully Mitigate Them? *Frontiers in Ecology and Evolution*, 7: 479.

DONALD, P.F. (2004) Biodiversity impacts of some agricultural commodity production systems. *Conservation Biology*, 18, 17–37.

EEM SUSTAINABLE MANAGEMENT (undated) Environmental and Social Impact Assessment of the CBG mine expansion project. Report prepared for Compagnie des Bauxites de Guinée (CBG).

EEM SUSTAINABLE MANAGEMENT (2015) Supplementary Information Package (SIP) to the ESIA of the CBG expansion project. Third release. Volume I - Appendcies 9.1 to 9.6. Report prepared for Compagnie des Bauxites de Guinée (CBG).

ERM (2015a) Social and Environmental Impact Assessment (SEIA) Addendum for GAC's Bauxite Export Projet, Guinea. Stakeholder Engagement Plan. Guinea Alumina Corporation S.A. (GAC).

ERM (2015b) Social and Environmental Impact Assessment (SEIA) Addendum for GAC's Bauxite Export Project, Guinea. Non-technical summary. Guinea Alumina Corporation S.A. (GAC).

ESMAP (2018) Regulatory Indicators for Sustainable Energy. ESMAP Report. World Bank: Washington DC.

FAO (2016) *Global Forest Resources Assessment 2015. How are the world's forests changing?* Second edition. Food and Agriculture Organisation of the United Nations: Rome, Italy.

FAO (2017a) Agroforestry for landscape restoration. Food and Agriculture Organisation of the United Nations: Rome, Italy.

FAO (2017b) Sustainable woodfuel for food security. A smart choice: green, renewable and affordable. Working Paper. Food and Agriculture Organisation of the United Nations: Rome, Italy.

FAO (2018a) The State of the World's Forests 2018 - Forest pathways to sustainable development. Food and Agriculture Organisation of the United Nations: Rome, Italy.

FAO (2018b) The future of food and farming. Alternative pathways to 2050. Food and Agriculture Organisation of the United Nations: Rome, Italy.

FAO (2019) The state of the world's biodiversity for food and agriculture. FAO Commission on Genetic Resources for Food and Agriculture Assessments. Food and Agriculture Organisation of the United Nations: Rome, Italy.

FAO (2020) Global Forest Resources Assessment 2020. Main Report. Food and Agriculture Organisation of the United Nations: Rome, Italy.

FAO, IFAD, UNICEF, WFP & WHO (2018) The State of Food Security and Nutrition in the World 2018. Building Climate Resilience for Food Security and Nutrition. Technical report. Food and Agriculture Organisation of the United Nations: Rome, Italy.

FEARNSIDE, P.M. (2015) Highway construction as a force in destruction of the Amazon forest. In

Handbook of Road Ecology (eds R. van der Ree, D. Smith & C. Grilo), pp. 414–424. John Wiley & Sons: Oxford, UK.

FFI (2021a) Coordinated and collaborative application of the mitigation hierarchy in complex multi-use landscapes in ape range states in Africa. A conceptual framework integrating socioecological considerations. Fauna & Flora International (FFI): Cambridge UK.

FFI (2021b) Coordinated and collaborative application of the mitigation hierarchy in complex multi-use landscapes in Africa: Upper Guinean Forest Transboundary Landscape. Opportunities and challenges for maintaining a connected forest landscape in the face of develop. Fauna & Flora International (FFI): Cambridge UK.

FFI (2021c) Coordinated and collaborative application of the mitigation hierarchy in complex multi-use landscapes in Africa: Gabon. Industry leadership and multi-stakeholder collaboration to mitigate impacts to high biodiversity values. Fauna & Flora International (FFI): Cambridge, UK.

FIM (2017) Update on Global Timber Demand. FIM Services Limited: Burford, UK.

FOSTER, W.A., SNADDON, J.L., TURNER, E.C., FAYLE, T.M., COCKERILL, T.D., FARNON ELLWOOD, M.D., ET AL. (2011) Establishing the evidence base for maintaining biodiversity and ecosystem function in the oil palm landscapes of South East Asia. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366, 3277–3291.

FRANKS, D., BRERETON, D., MORAN, C., SARKER, T. & COHEN, T. (2010) Cumulative impacts: A Good Practice Guide for the Australian Coal Mining Industry. Centre for Social Responsibility in Mining & Centre for Water in the Minerals Industry, Sustainable Minerals Institute, The University of Queensland. Australian Coal Association Research Program: Brisbane, Australia.

FRAVAL, S., HAMMOND, J., BOGARD, J.R., NG'ENDO, M., VAN ETTEN, J., HERRERO, M., ET AL. (2019) Food Access Deficiencies in Sub-saharan Africa: Prevalence and Implications for Agricultural Interventions. *Frontiers in Sustainable Food Systems*, 3: 104.

GLOBE NEWSWIRE (2019) African Transport Network Projects, 2019 - $430.3Bn Investment Value, with Focus on Road, Railway and Bridges. Https://www.globenewswire.com/news-release/2019/07/09/1879924/0/en/African-Transport-Network-Projects-2019-430-3Bn-Investment-Value-with-Focus-on-Road-Railway-and-Bridges.html [accessed 30 July 2020].

GOEDDE, L., OOKO-OMBAKA, A. & PAIS, G. (2019) Winning in Africa's agricultural market. *McKinsey&Company*. https://www.mckinsey.com/industries/agriculture/our-insights/winning-in-africas-agricultural-market [accessed 23 July 2020].

HEINICKE, S., MUNDRY, R., BOESCH, C., AMARASEKARAN, B., BARRIE, A., BRNCIC, T., ET AL. (2019) Characteristics of Positive Deviants in Western Chimpanzee Populations. *Frontiers in Ecology and Evolution*, 7, 1–14.

HOSONUMA, N., HEROLD, M., DE SY, V., DE FRIES, R.S., BROCKHAUS, M., VERCHOT, L., ET AL. (2012) An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters*, 7: 044009.

HOWARD, M. (2019) Safeguarding Africa's Great Apes. Applying the International Finance Corporation's Performance Standard 6 Guidance Note Paragraph 73 on Great Apes - An Assessment of Capacity and the Compliance of Extractive, Energy and Associated Infrastructure Projects. Submitted for MSc in Environmental Economics and Environmental Management. Department of Environment and Geography, University of York, UK.

HURLEY, K., KOMINEK, B., ROOKE, J. & DIALLO, S. (2019) USAID Global Environmental Management Support (GEMS). USAID/West Africa Tropical Forestry & Biodiversity Assessment.

ICMM (2018) Role of mining in national economies. Mining Contribution Index 2018. 4th Edition. International Council on Mining & Metals (ICMM): London, UK.

IEA (2019) Africa Energy Outlook 2019 – Analysis Scenarios. World Energy Outlook Special Report. International Energy Agency. Available: www.iea.org/africa2019

IFC (2013) Good Practice Handbook. Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets. International Finance Corporation: Washington, DC.

International Hydropower Association (2020) 2020 Hydropower Status Report. Sector trends and insights. Available: https://www.hydropower.org/sites/default/files/publications-docs/2020_hydropower_status_report.pdf

IPBES (2018) The IPBES regional assessment report on biodiversity and ecosystem services for Africa. Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services: Bonn, Germany.

IPES-Food (2016) From uniformity to diversity. A paradigm shift from industrial agriculture to diversified agroecological systems. International Panel of Experts on Sustainable Food systems.

IRENA (2013) Africa's Renewable Future. The Path to Sustainable Growth. International Renewable Energy Agency (IRENA): Abub Dhabi, United Arab Emirates.

IRENA (2015) Africa 2030: Roadmap for a Renewable Energy Future. International Renewable Energy Agency (IRENA): Abu Dhabi, United Arab Emirates.

ITTO (2017) Biennial review and assessment of the world timber situation 2015-2016. International Tropical Timber Organization (ITTO): Yokohama, Japan.

ITTO (2018) Biennial review and assessment of the world timber situation 2017-2018. International Tropical Timber Organization (ITTO): Yokohama, Japan.

IUCN Species Survival Commission (SSC) Primate Specialist Group ARRC Task Force (2020) Task Force on Avoidance, Reduction, Restoration and Compensation of negative impacts from Energy, Extractive and Associated Infrastructure Projects on Apes (ARRC) Webpage. https://www.arrctaskforce.org/ [accessed 1 December 2020].

Jacquemot, P. (2020) Agricultural land available in sub-Saharan Africa. *WillAgri.com*. https://www.willagri.com/2020/01/02/agricultural-available-sub-saharan-africac/?lang=en [accessed 20 July 2020].

Johnson, C.J., Venter, O., Ray, J.C. & Watson, J.E.M. (2020) Growth-inducing infrastructure represents transformative yet ignored keystone environmental decisions. *Conservation Letters*, 13: e12696.

Kleinschroth, F., Laporte, N., Laurance, W.F., Goetz, S.J. & Ghazoul, J. (2019) Road expansion and persistence in forests of the Congo Basin. *Nature Sustainability*, 2, 628–634.

Kühl, H.S., Sop, T., Williamson, E.A., Mundry, R., Brugière, D., Campbell, G., et al. (2017) The Critically Endangered western chimpanzee declines by 80%. *American Journal of Primatology*, 79: e22681.

Lakmeeharan, K., Manji, Q., Nyairo, R. & Poeltner, H. (2020) Solving Africa's infrastructure paradox. *McKinsey&Company Our Insights*. https://www.mckinsey.com/business-functions/operations/our-insights/solving-africas-infrastructure-paradox#.

Laurance, W.F. (2018) Conservation and the Global Infrastructure Tsunami: Disclose, Debate, Delay! *Trends in Ecology & Evolution,* 33, 568-571.

Laurance, W.F. & Arrea, I.B. (2017) Roads to riches or ruin? *Science*, 358, 442–444.

Laurance, W.F., Campbell, M.J., Alamgir, M. & Mahmoud, M.I. (2017) Road expansion and the fate of Africa's tropical forests. *Frontiers in Ecology and Evolution*, 5, 1–7.

LAURANCE, W.F., GOOSEM, M. & LAURANCE, S.G.W. (2009) Impacts of roads and linear clearing on tropical forests. *Trends in Ecology and Evolution*, 24, 659–679.

LAURANCE, W.F., SLOAN, S., WENG, L. & SAYER, J.A. (2015) Estimating the Environmental Costs of Africa's Massive 'development Corridors'. *Current Biology*, 25, 3202–3208.

MAGRACH, A. & GHAZOUL, J. (2015) Climate and pest-driven geographic shifts in global coffee production: Implications for forest cover, biodiversity and carbon storage. *PLoS ONE*, 10: e0133071.

MANCINI, L. & SALA, S. (2018) Social impact assessment in the mining sector: Review and comparison of indicators frameworks. *Resources Policy*, 57, 98–111.

MORGAN, D., MUNDRY, R., SANZ, C., AYINA, C.E., STRINDBERG, S., LONSDORF, E. & KÜHL, H.S. (2018) African apes coexisting with logging: Comparing chimpanzee (Pan troglodytes troglodytes) and gorilla (Gorilla gorilla gorilla) resource needs and responses to forestry activities. *Biological Conservation*, 218, 277–286.

MOUSSA, K. (2018) Belt and Road opens new path for Guinea. *ChinaDaily.com*. Http://www.chinadaily.com.cn/a/201808/21/WS5b7b6117a310add14f386d13.html.

NOACK, F., WUNDER, S., ANGELSEN, A. & BÖRNER, J. (2015) Environmental Income, Rural Poverty, and Adaptation to Climate Variability: A Cross-Sectional Analysis. Policy Research Working Paper 7478. World Bank: Washington DC.

OECD & FAO (2016) Agriculture in Sub-Saharan Africa: prospects and challenges for the next decade. In *OCED-FAO Agricultural Outlook 2016-2025*. OECD Publishing: Paris.

OXFORD BUSINESS GROUP (2019) The Report. Agriculture in Africa 2019. Oxford Business Group.

PALAZZO, A., VERVOORT, J.M., MASON-D'CROZ, D., RUTTING, L., HAVLÍK, P., ISLAM, S., ET AL. (2017) Linking regional stakeholder scenarios and shared socioeconomic pathways: Quantified West African food and climate futures in a global context. *Global Environmental Change*, 45, 227–242.

PARDO, L.E., ROQUE, F. DE O., CAMPBELL, M.J., YOUNES, N., EDWARDS, W. & LAURANCE, W.F. (2018) Identifying critical limits in oil palm cover for the conservation of terrestrial mammals in Colombia. *Biological Conservation*, 227, 65–73.

PETERS, S., MALCOLM, J. & ZIMMERMAN, B. (2006) Effects of Selective Logging on Bat Communities in the Southeastern Amazon. *Conservation Biology*, 20, 1410–1421.

PLUMPTRE, A.J., NIXON, S., KUJIRAKWINJA, D.K., VIEILLEDENT, G., CRITCHLOW, R., WILLIAMSON, E.A., ET AL. (2016) Catastrophic decline of world's largest primate: 80% loss of grauer's gorilla (Gorilla beringei graueri) population justifies critically endangered status. *PLoS ONE*, 11, 1–13.

PROFOR (2012) Forests, trees and woodlands in Africa. An Action Plan for World Bank engagement. World Bank: Washington DC.

PROFOR (2017) Forests in sub-Saharan Africa: challenges and opportunities. *www.profor.info*.

PUTZ, F., BLATE, G., REDFORD, K., FIMBEL, R. & ROBINSON, J. (2001) Tropical forest management and conservation of biodiversity: an overview. *Conservation Biology*, 15, 7–20.

QIN, S., GOLDEN KRONER, R.E., COOK, C., TESFAW, A.T., BRAYBROOK, R., RODRIGUEZ, C.M., ET AL. (2019) Protected area downgrading, downsizing, and degazettement as a threat to iconic protected areas. *Conservation Biology*, 33, 1275–1285.

REN21 (2014) ECOWAS Renewable Energy and Energy Efficiency Status Report 2014. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), REN21 and UNIDO.

REN21 (2018) SADC Renewable Energy and Energy Efficiency Status Report. REN21 Secretariat: Paris, France.

REN21 (2020) Renewables 2020 Global Status Report. REN21 Secretariat: Paris, France.

RULLI, M.C., SANTINI, M., HAYMAN, D.T.S. & ODORICO, P.D. (2017) The nexus between forest fragmentation in Africa and Ebola virus disease outbreaks. *Scientific Reports*, 7: 41613.

SAVILAAKSO, S., GARCIA, C., GARCIA-ULLOA, J., GHAZOUL, J., GROOM, M., GUARIGUATA, M.R., ET AL. (2014) Systematic review of effects on biodiversity from oil palm production. *Environmental Evidence*, 3:4.

SCHROTH, G., LÄDERACH, P., ISAAC, A., MARTINEZ-VALLE, I., BUNN, B. & JASSOGNE, L. (2016) Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities and limits to adaptation. *Science of the Total Environment*, 556, 231–241.

SELKOE, K.A., BLENCKNER, T., CALDWELL, M.R., CROWDER, L.B., ERICKSON, A.L., ESSINGTON, T.E., ET AL. (2015) Principles for managing marine ecosystems prone to tipping points. *Ecosystem Health and Sustainability*, 1, 1–18.

SGS ENVIRONMENT (2014) COBAD Environmental and Social Impact Assessment for the Dian-Dian Project. Compagnie des Bauxite and Alumina Dian-Dian (COBAD).

SLOAN, S. & SAYER, J.A. (2015) Forest Resources Assessment of 2015 shows positive global trends but forest loss and degradation persist in poor tropical countries. *Forest Ecology and Management*, 352, 134–145.

SONTER, L.J., ALI, S.H. & WATSON, J.E.M. (2018) Mining and biodiversity: Key issues and research needs in conservation science. *Proceedings of the Royal Society B: Biological Sciences*, 285: 20181926.

STOKES, E.J., STRINDBERG, S., BAKABANA, P.C., ELKAN, P.W., IYENGUET, F.C., MADZOKÉ, B., ET AL. (2010) Monitoring great Ape and elephant abundance at large spatial scales: Measuring effectiveness of a conservation landscape. *PLoS ONE*, 5: e10294

STRINDBERG, S., MAISELS, F., WILLIAMSON, E.A., BLAKE, S., STOKES, E.J., ABA'A, R., ET AL. (2018) Guns, germs, and trees determine density and distribution of gorillas and chimpanzees in Western Equatorial Africa. *Science Advances*, 4: 2964.

STRONA, G., STRINGER, S.D., VIEILLEDENT, G., SZANTOI, Z., GARCIA-ULLOA, J. & WICH, S.A. (2018) Small room for compromise between oil palm cultivation and primate conservation in Africa. *Proceedings of the National Academy of Sciences of the United States of America*, 115, 8811–8816.

SULTAN, B. & GAETANI, M. (2016) Agriculture in West Africa in the twenty-first century: climate change and impacts scenarios, and potential for adaptation. *Frontiers in Plant Science*, 7, 1–20.

TONDOH, J.E., KOUAMÉ, F.N. GUESSA., MARTINEZ GUÉI, A., SEY, B., WOWO KONÉ, A. & GNESSOUGOU, N. (2015) Ecological changes induced by full-sun cocoa farming in Côte d'Ivoire. *Global Ecology and Conservation*, 3, 575–595.

UNCCD (2020) Supporting the Global Response to the COVID-19 Pandemic: Land-based Solutions for Healthy People and a Healthy Planet. United Nations Convention to Combat Desertification.

UNDP (2017) Income inequality trends in sub-Saharan Africa: divergence, determinants and consequences. United Nations Development Programme: New York.

UNEP-WCMC (2016) The State of Biodiversity in Africa: a mid-term review of progress towards the Aichi Biodiversity Targets. UNEP-WCMC: Cambridge, UK.

UNITED NATIONS (2019) The Sustainable Development Goals Report 2019. United Nations.

VILELA, T., HARB, A.M., BRUNER, A., DA SILVA ARRUDA, V.L., RIBEIRO, V., ALENCAR, A.A.C., ET AL. (2020) A better Amazon road network for people and the environment. *Proceedings of the National Academy of Sciences of the United States of America*, 117, 7095–7102.

WEF (2020) The Global Risks Report 2020. World Economic Forum: Cologny/Geneva, Switzerland.

WHITEHEAD, A.L., KUJALA, H. & WINTLE, B.A. (2017) Dealing with Cumulative Biodiversity Impacts in Strategic Environmental Assessment: A New Frontier for Conservation Planning. *Conservation Letters*, 10, 195–204.

WILLIAMS, D. (2017) On sizing up Africa's major development corridors. *The IUCN Water Knowledge Platform*. http://www.waterandnature.org/stories/david-williams-sizing-africa's-major-development-corridors [accessed 31 July 2020].

WORLD BANK GROUP (2007) Environmental, Health, and Safety Guidelines for Forest Harvesting Operations. World Bank Group: Washington, DC.

WORLD BANK (2015) NEPAD Launches Initiative for the Resilience and Restoration of African Landscapes. *World Bank website*. https://www.worldbank.org/en/news/press-release/2015/12/06/nepad-launches-initiative-for-the-resilience-and-restoration-of-african-landscapes [accessed 1 September 2020].

WORLD BANK (2016) World Bank Group Forest Action Plan FY16-20. World Bank: Washington, DC.

WORLD BANK (2019a) Forest-Smart Mining : Identifying Factors Associated with the Impacts of Large-Scale Mining on Forests. World Bank: Washington, DC.

WORLD BANK (2019b) Making Mining Forest-Smart. Executive Summary Report. World Bank: Washington, DC.

WORLD BANK (2019c) Forest-Smart Mining: Artisanal and small-scale mining in forest landscapes (ASM). World Bank: Washington, DC.

WWF (2020) Living Planet Report 2020 - Bending the curve of biodiversity loss. WWF: Gland, Switzerland.

ZIEGLER, A.D., GIAMBELLUCA, T.W., SUTHERLAND, R.A., NULLET, M.A., YARNASARN, S., PINTHONG, J., ET AL. (2004) Toward understanding the cumulative impacts of roads in upland agricultural watersheds of northern Thailand. *Agriculture, Ecosystems and Environment*, 104, 145–158

Applying the mitigation hierarchy in a complex world

FAUNA & FLORA INTERNATIONAL

The David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, United Kingdom.
Telephone +44 (0) 1223 571 000
Email info@fauna-flora.org · www.fauna-flora.org