Climate risk report for the Central Africa region: Technical Reference Document

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Contents

A: Methods and Data

Climate in context methodological approach

The key stages in the methodology and division of responsibilities across the project team are presented in a schematic in Figure A1 and described in more detail below.

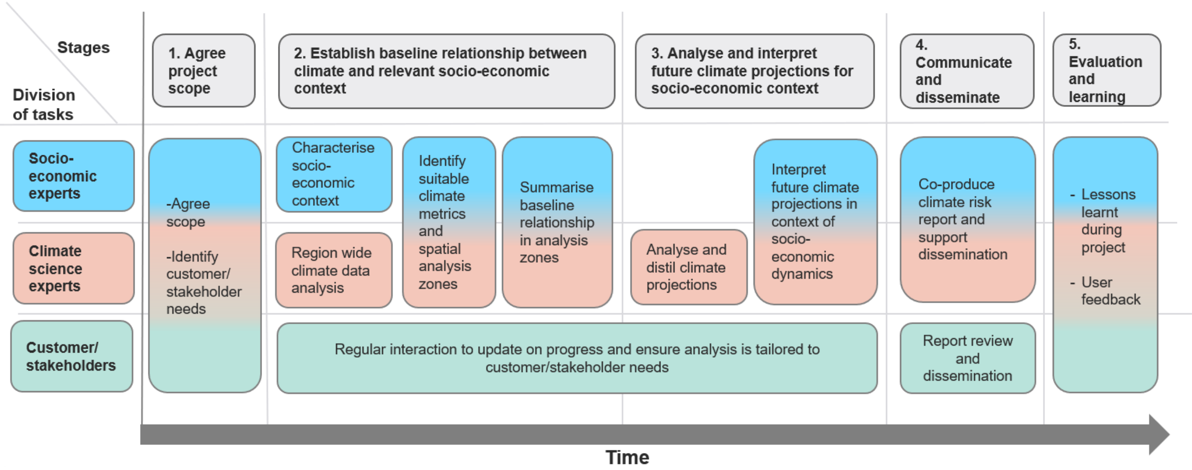

Figure A1 – Schematic diagram of the key stages of the methodology and division of tasks between the socio-economic experts (ODI), climate science experts (Met Office) and customer (FCDO) roles of the project team. This diagram is included in the Climate in Context methodology (Richardson et al. 2022)

Stage 1 involves agreement on the scope of the work and the format of the outputs through iterative discussions across the project team. Consultations with the customer (FCDO) are conducted to identify the socio-economic themes relevant to their decision context.

Stage 2 involves establishing the baseline relationship between climate and the key socio-economic themes identified in Stage 1. This includes:

- Preliminary analysis is conducted to characterise the regional socio-economic context and regional climate through a combination of literature review and processing climate reanalysis data by the relevant experts.
- Identification of suitable climate metrics and spatial analysis zones via an iterative process between the experts, drawing on the outcomes of the preliminary analysis.
- Characterisation of the baseline climate, the key climate-related vulnerabilities and exposure to climate-related hazards in each of the spatial analysis zones.

Stage 3 involves analysis of future climate projections and interpretation in the context of the key vulnerabilities and baseline assessments developed in Stage 2. This includes:

- Selection of appropriate climate model simulations for the region and quantitative analysis of projected changes in relevant climate variables in each of the spatial analysis zones.

- Distillation of the future climate projections into narrative summaries for the relevant climate metrics in each spatial analysis zone.
- Translation of the future climate summaries into climate risk impacts with a focus on the key socio-economic themes.

Stage 4 involves the co-production of a report summarising the analysis and outcomes, tailored to the needs of the customer.

Finally, **Stage 5** involves evaluation and learning of the process to support future applications of the methodology.

Climate data and analysis methods

This report makes use of bespoke climate data analysis in the selected spatial analysis zones (see Section 3.2) and relevant scientific literature. The bespoke data analysis involved processing gridded reanalysis[1] data to characterise the current climate over the 1981-2010 baseline period, and climate model projections to assess the projected trends in average temperature and precipitation for the 2050s (using the 2041-2070 future period compared to the baseline period).

To characterise the baseline climate, we processed temperature from ERA5[2] (Hersbach et al., 2020) and precipitation data from WFDE5 (Cucchi et al., 2020) over the 1981-2010 baseline period. Using this dataset and time-period keeps this report consistent with FCDO climatology briefing notes provided to FCDO offices for many of the countries in the Central Africa region.

For the future climate projections, we used global and regional climate model simulations to assess the projected change in temperature and precipitation for the 2050s under different scenarios of future greenhouse gas emissions. The results presented in this report show

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[1] A gridded dataset that blends climate observations and model data to present the current climate for use as a baseline in future climate assessments.

[2] All observational and reanalysis datasets have associated uncertainties and limitations. For example, reanalysis datasets may underestimate observed extremes, and cannot fully represent localised features such as intense precipitation caused by complex topography, partly due to their limited resolution in space and time. Additionally, ERA5 precipitation fields are derived from 'forecast' output and are therefore more affected by imperfections within the underlying model. The benefit, however, of using reanalyses is that they provide a systematic approach to producing gridded, dynamically consistent datasets for climate monitoring, particularly over data-scarce regions. However, the use of these data to characterise climatological means for the purpose of this analysis is largely uninfluenced by these biases, and the benefits of using a dataset that is globally consistent and consistent with other climate information products outweighs this.

projected changes for the 2050s under the RCP8.5[3,4] scenario (van Vurren et al., 2011). This future time period and scenario combination represents an increase in global average temperature of around 2.5˚C compared to pre-industrial levels. This is higher than the target of limiting warming to well below 2˚C set by the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement. The baseline period of 1981-2010 considered in this report represents an observed increase of around 1°C in global average temperature compared to pre-industrial levels.

The climate projections in this report comprise an 80-member ensemble; 30 World Climate Research Project (WCRP) Coupled Model Intercomparison Project Phase 5 (CMIP5; Taylor et al., 2012) global climate model simulations (see Table A1), 20 WCRP CMIP Phase 6 (CMIP6; Erying et al., 2016) global climate model simulations, and 20 regional climate model simulations from the WCRP CoOrdinated Regional climate modelling Downscaling EXperiment (CORDEX; Giorgi & Gutowski, 2015) project (see Table A2).

CMIP5 models were used to inform the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5; IPCC, 2013), with horizontal model resolution ranging from 100-300 km. CMIP6 models informed the latest Assessment Report (AR6; IPCC, 2021). Like CMIP5, the horizontal resolution of the CMIP6 models varies by model. The range is large; many models are higher resolution compared to those in CMIP5, whereas some are unchanged. The regional climate models are downscaled CMIP5 simulations over the CORDEX Africa domain (AFR-44) at a resolution of 50km.

The models selected are those that were available to access at the time of analysis. Model simulations were assessed for their suitability in simulating the climate of the region by comparing the baseline periods from the model simulations with the reanalysis. The results from this assessment were taken into consideration when interpreting the future projections from the model simulations. More detail on evaluation of these model simulations and known biases is available in IPCC (2013).

The climate data analysis focuses on quantifying projected changes in annual, seasonal and monthly means in the spatial analysis zones. Information on the projected changes in other relevant climate variables and indicators – such as Sea Surface Temperatures (SSTs), Sea Level Rise (SLR) and relevant climate extremes – is drawn from appropriate scientific literature and from the IPCC Interactive Atlas (2021).

Table A1 – GCM simulations from CMIP5 used in the climate data analysis, from https://pcmdi.llnl.gov/mips/cmip5/availability.html.

[3] The RCP8.5 Representative Concentration Pathway represents a future pathway of on-going and substantial increases in future global emissions of greenhouse gases. Other pathways represent stabilisation or reduction of future emissions, however there is little difference in the projected climate change between these pathways in the 2050s time period. Analysis of the RCP4.5 scenario was also conducted and results were broadly consistent with those presented here for RCP8.5.

[4] The SSP5-8.5 scenario was used for the CMIP6 generation of climate models.

Modelling Centre	Model	Institution
BCC	BCC-CSM1-1 BCC-CSM1-1	Beijing Climate Center, China Meteorological Administration
CSIRO-BOM	ACCESS1-0 ACCESS1-3-m	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)
CCCma	CanESM2	Canadian Centre for Climate Modelling and Analysis
CMCC	CMCC-CM CMCC-CMS	Centro Euro-Mediterraneo per I Cambiamenti Climatici
CNRM-CERFACS	CNRM-CM5	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique
CSIRO-QCCCE	CSIRO-Mk3-6-0	Commonwealth Scientific and Industrial Research Organisation in collaboration with the Queensland Climate Change Centre of Excellence
EC-EARTH	EC-EARTH	EC-EARTH consortium
GCESS	BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University
INM	INMCM4	Institute for Numerical Mathematics
IPSL	IPSL-CM5A-LR IPSL-CM5A-MR IPSL-CM5B-LR	Institut Pierre-Simon Laplace
MIROC	MIROC5 MIROC-ESM MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
MOHC	HadGEM2-CC HadGEM2-ES	Met Office Hadley Centre
MPI-M	MPI-ESM-LR MPI-ESM-MR	Max Planck Institute for Meteorology
MRI	MRI-CGCM3	Meteorological Research Institute
NCAR	CCSM4	National Center for Atmospheric Research
NCC	NorESM1-M	Norwegian Climate Centre
NIMR/KMA	HadGEM2-AO	National Institute of Meteorological Research/Korea Meteorological Administration
NOAA-GFDL	GFDL-CM3 GFDL-ESM2G GFDL-ESM2M	NASA Goddard Institute for Space Studies
NSF-DOE-NCAR	CESM1-CAM5	National Science Foundation, Department of Energy, National Center for Atmospheric Research

Table A2 – GCM simulations from CMIP6 used in the climate data analysis, from https://pcmdi.llnl.gov/mips/cmip5/availability.html.

Modelling Centre	Model	Institution
BCC	BCC-CSM2-MR	Beijing Climate Center, China Meteorological Administration

CCCma	CanESM5	Canadian Centre for Climate Modelling and Analysis
CNRM-CERFACS	CNRM-CM6-1	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique
	CNRM-CM6-1-HR	
	CNRM-ESM2-1	
CSIRO	ACCESS-ESM1-5	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia)
EC-EARTH consortium	EC-Earth3	EC-EARTH consortium
	EC-Earth3-Veg	
INM	INM-CM4-8	Institute for Numerical Mathematics
	INM-CM5-0	
	INM-CM6A-LR	
MIROC	MIROC6	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
MOHC	HadGEM3-GC31-LL	Met Office Hadley Centre
MOHC	UKESM1-0-LL	
MPI-M	MPI-ESM1-2-LR	Max Planck Institute for Meteorology
MRI	MRI-ESM2-0	Meteorological Research Institute
NCC	NorESM2-MM	Norwegian Climate Centre
NOAA-GFDL	GFDL-ESM4	NASA Goddard Institute for Space Studies
	GFDL-CM4	
NUIST	NESM3	Nanjing University of Information Science and Technology

Table A3 – RCM simulations from CORDEX AFR-44 used in the climate data analysis. These are downscaled simulations of a subset of the CMIP5 models in Table A1 at ~50km resolution.

Modelling centre	**Institution**	**RCM**	**Driving GCM**
CLMcom	Climate Limited-area Modelling Community (CLM-Community)	CCLM4-8-17	CNRM-CM5
			MPI-ESM-LR
			EC-EARTH
			HadGEM2-ES
DMI	Danish Meteorological Institute	HIRHAM5	EC-EARTH
GERICS	Helmholtz-Zentrum Geesthacht, Climate Service Center Germany	REMO2009	IPSL-CM5A-LR
			MIROC5
			HadGEM2-ES
MPI-CSC	Helmholtz-Zentrum Geesthacht, Climate Service Center, Max Planck Institute for Meteorology	REMO2009	EC-EARTH
			MPI-ESM-LR
SMHI	Swedish Meteorological and Hydrological Institute	RCA4	CNRM-CM5
			CSIRO-Mk3-6-0
			CanESM2
			HadGEM2-ES
			EC-EARTH
			MPI-ESM-LR

			IPSL-CM5A-MR
			NorESM1-M
			MIROC5
			GFDL-ESM2M

B: Vulnerability and climate resilience in Central Africa

The Central Africa region is rich in natural resources and home to the world's second largest tropical rainforest, with rare biodiversity and crucial regulating and carbon capture/sink functions. However, the region is characterised by high levels of wealth inequality, poor infrastructure, and political instability and conflict.[5] GDP values per capita in the region vary widely between countries, ranging from US$493 in CAR to $7,143 in Equatorial Guinea in 2020 (World Bank, 2022 – see Annex G). Two of the poorest countries in the world, CAR and DRC, account for almost 60% of the region's population. Robust economic growth and progress on poverty reduction have slowed or reversed in recent years (World Bank, 2020). Over 70% of the population in those two countries live below the World Bank's international poverty line (less than USD 1.90/day)[6] and over 70% of the population are defined as food insecure. In 2019, more than half of the populations of Cameroon, CAR, R. Congo, DRC, and Angola faced moderate or severe levels of food insecurity (FAOSTAT, 2022 – see Annex G).

Poverty and food insecurity are not confined to countries defined as 'low income'. In middle-income Cameroon, Equatorial Guinea, Gabon, R. Congo and Angola, wealth inequalities and poverty remain high, with the benefits of national resources (e.g., oil) not widely shared and the provision of basic services (e.g., water, sanitation, electricity, health care, education) remains skewed to urban elites (World Bank, 2021). Understanding the nature and distribution of poverty remains crucial to any understanding of climate risk. Recent analyses demonstrate how climate shocks keep people in poverty and push people back into poverty (Hallegatte et al., 2016, 2017; Trisos et al, 2022). Poorer people are typically more exposed and more vulnerable to the hazards that destroy assets and income streams; to waterborne diseases and pests that become more prevalent during heat waves, floods or droughts; to crop failure and livestock mortality caused by drought; and to the spikes in food prices that often follow local production failures or, at present, shocks to international trade (Hallegatte et al, 2017; Raga and Pettinotti, 2022).

The Central Africa region is bordered to the west by a long coast on the Atlantic Ocean characterised by low sandy beaches, high population densities and mangrove forests that are vital for biodiversity, carbon storage and coastal protection. However, coastal environments are vulnerable to SLR and erosion. The northern and southern extents of the region are arid, but the central area is dominated by the Congo River basin (in

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[5] Four of the seven focus countries are included in the World Bank's latest list of fragile and conflict-effected 'situations': Cameroon, CAR, DRC (because of medium-intensity conflict), and R. Congo (for high institutional and social fragility) (https://www.worldbank.org/en/topic/fragilityconflictviolence/brief/harmonized-list-of-fragile-situations)

[6] Updated in September 2022 to USD2.15/person/day, but calculations in this report use the USD1.90 benchmark.

Cameroon, Central African Republic, DRC, Republic of Congo, Equatorial Guinea and Gabon) which is mainly forested and humid. This region is a global biodiversity hot spot, with the highest species diversity on the continent, and rainforests that sequester more carbon than any other tropical forest in the world in both above-ground biomass and major peat deposits (Abernethy et al., 2016; Eba'a Atyi et al., 2022).

Central Africa is also the most water-abundant region of Africa, with DRC alone accounting for 23% of Africa's internal renewable water resources (Karam et al, 2022). All seven focus countries fall within the low or no 'water stress' categories used for monitoring Sustainable Development Goal (SDG) 6.4.2 (UNICEF/WHO, 2021), and have the potential to meet all present and future water (and hydropower) needs with robust infrastructure, finance and management. However, these regional building blocks are absent or fragile, leaving millions exposed to unsafe water and sanitation, floods and energy poverty (Hallegatte et al, 2016; Trisos et al, 2022).

All countries in the Central Africa region export mostly primary commodities rather than manufactured goods. Agricultural production (including forestry and fishing) accounts for a relatively low proportion of national GDP – an average of 14% in 2020 across the seven Central African countries - ranging from just 3% in Equatorial Guinea to 32% in CAR (World Bank, 2022 – see Annex G). The significance of agriculture to national GDP in Central Africa has declined in recent decades, in part due to the expansion of petroleum and mineral exports (Dixon et al., 2020a). However, rates of agricultural employment as a proportion of total (paid or profit-making) employment in the region highlight the importance of agriculture to peoples' livelihoods and socioeconomic wellbeing, ranging from roughly 30% in R. Congo and Gabon, to 60-70% in DRC and CAR in 2019 (World Bank 2022 – see Annex E).

Central Africa is characterised by a diverse range of agricultural systems, including agropastoral, cereal-root crop, tree crop and forest-based, root and tuber crop, highland perennial, and maize mixed systems, alongside inland and coastal fisheries (Dixon et al, 2020a). Marine and inland fisheries represent an essential livelihood and source of protein for the region's population. In coastal Central African countries (excluding CAR, but including Sao Tome and Principe), roughly 60-70% of the overall population is located within coastal zones. More than half of the urban population in the region lives in coastal cities, and coastal communities are growing faster than those inland (UNESCO/IOC, 2020).

The majority of the region's poor still live in rural areas and depend, directly or indirectly, on rainfed agriculture (Trisos et al, 2022). The most vulnerable to climate change, particularly to rising temperature and rainfall variability, are those engaged in low intensity, low input rainfed farming, disconnected from markets, and with few opportunities to adapt cropping patterns or diversify in rural or urban economies (Devereux, 2009; Ellis 2013; Trisos et al, 2022). For rural smallholders, the climate determines the harvest, and the harvest determines the ability to meet most staple food needs. Pastoral and agro-pastoral livelihoods, significant across much of the more arid lowlands of northern Cameroon, Central African Republic and DRC, are similarly climate-sensitive, as rains (and heat) affect forage and water availability, as well as livestock health (Trisos et al, 2022). The productivity of the region's abundant inland fisheries is also affected by (amongst other things) increasing temperatures and floods.

Rapid urbanisation is changing the exposure and vulnerability landscape. The urban population across the seven countries increased from roughly 20 million in 1990 to an estimated 87 million in 2020 and is projected to rise to over 243 million by 2050 (see Annex H). By 2050, roughly 76% of the region's population is expected to be urban, up from 63% today. The number of settlements of more than 10,000 people rose from 272 in 1990 to 881 in 2015, the vast majority of these in DRC (OECD/SWAC, 2020; UN Habitat, 2021). Infrastructure provision (safe water and sanitation, housing, etc.) lags behind urban expansion, however, exposing people to climate risks. Residents of 'informal' settlements, especially, are exposed to multiple threats, including power and communication outages, heat stress, damage to housing and the destruction of water, sanitation and drainage systems, and land and housing markets often leave new migrants with little choice but to settle in riskier places (Hallegatte, 2017; Dodman et al, 2022). Those include low-lying areas of the rapidly growing coastal cities of Pointe-Noir (R. Congo), Libreville (Gabon), Luanda and Lobito (Angola), Malabo (Equatorial Guinea) and Douala (Cameroon), threatened by a combination of rising sea levels, coastal erosion/retreat, more frequent and intense storms, and floods.

Key risk factors in the report

Climate and socio-economic risk analysis is conducted at the regional scale in this report. Geographical regions which share similar climate, such as rainy season characteristics and seasonal temperature ranges, are identified and used as a basis to bring together the climate and socio-economic information, providing context to the climate projections. The climate analysis conducted includes a combination of bespoke climate data analysis in the zones and review of relevant scientific literature, including the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report (AR6) and the IPCC Interactive Atlas (2021). The interpretation of climate projections and risk analysis is informed by the following six key issues[7]:

[7] This list is not exhaustive or definitive. Other (similar) framings can be used, including the 'risk informed development' approach outlined in Appendix B.

- Economic growth and infrastructure, including disparities in income/wealth distribution.
- Capacity and human capital, including ways in which climate risks are shaped by gender and differences in power, rights and opportunities.
- Population and demography, including rapid urbanisation and the growth of informal settlements where climate risks are amplified.
- Livelihood systems and key crops, with a focus on more exposed (rainfed) agricultural and pastoral systems.
- Disaster risks, given projected increases in the frequency and magnitude of extreme events such as floods and droughts.
- Conflict and migration in a region where political instability and violence undermines efforts to build resilience.

The factors above help guide the analysis but are not exhaustive or definitive. Other (similar) framings can be used, including the 'risk informed development' approach outlined in Focus Box 1.

Focus box 1: Risk-informed development

There is increasing recognition that development is exposed to multiple, intersecting threats. Thus, the full implications for development programming will not be captured by traditional single threat analysis. In order to be risk-informed, programme decision making must undertake multi-threat analysis that considers how different threats merge with existing and changing socioeconomic contexts to create complex risk. In practice, this means that climate-resilient development must not only consider threats to programme outcomes from climate and environmental degradation, but also political, economic and financial instability, cyber and technology, transboundary crime and terrorism, geopolitical volatility, conflict and global health pandemics. [Opitz-Stapleton et al., 2019].

The study also notes risk-informed development requires us not only to think about risks to development but also risks from development. Development outcomes are uneven, creating opportunities for some and risks for others. Risk-informed development must account for trade-offs inherent in development choices, including climate adaptation and mitigation. Such decisions are inherently political, involving the redistribution of resources and navigating unequal power structures (Eriksen et al., 2015).

Climate risk rankings and comparisons

Figure B1 provides a snapshot of climate risk across the region using the widely used ND-GAIN[8] country rankings for 2019 – the most recent year for which data are available. The ND-GAIN country index uses a range of metrics to assess both a country's vulnerability to climate change and other global challenges and its readiness to build resilience. Vulnerability is measured by assessing a country's exposure, sensitivity, and capacity to adapt to the negative effects of climate change, looking at six sectors: food, water, health, ecosystem services, human habitat, and infrastructure. Readiness is measured by assessing a country's ability to leverage investments and convert them into adaptation actions, looking at three components: economic readiness, governance readiness, and social readiness.

All of the Central African countries considered in this report occupy the top left quadrant of the ND-GAIN matrix with the exception of Gabon (GAB - bottom left quadrant, yellow highlight). Countries in the top left quadrant combine high vulnerability with low levels of readiness, indicating an urgent need for adaptation action.

Within the 'high risk' quadrant the two main two main outliers are Central African Republic (CAF) and the Democratic Republic of Congo (COD), with the former ranked lower than any other country globally in terms of readiness. Both countries have been plagued by violence, conflict and political instability for many years, include large numbers of internally displaced people, and have extreme poverty rates (<USD 1.90/day) of over 70%, albeit with significant in-country differences.

[8] Notre Dame Global Adaptation Initiative: https://gain.nd.edu/ ND-GAIN country scores and rankings are used by, amongst others, the World Bank in their climate risk country profiles – see https://climateknowledgeportal.worldbank.org/. Scores are available for a total of 182 countries based on data for 2019.

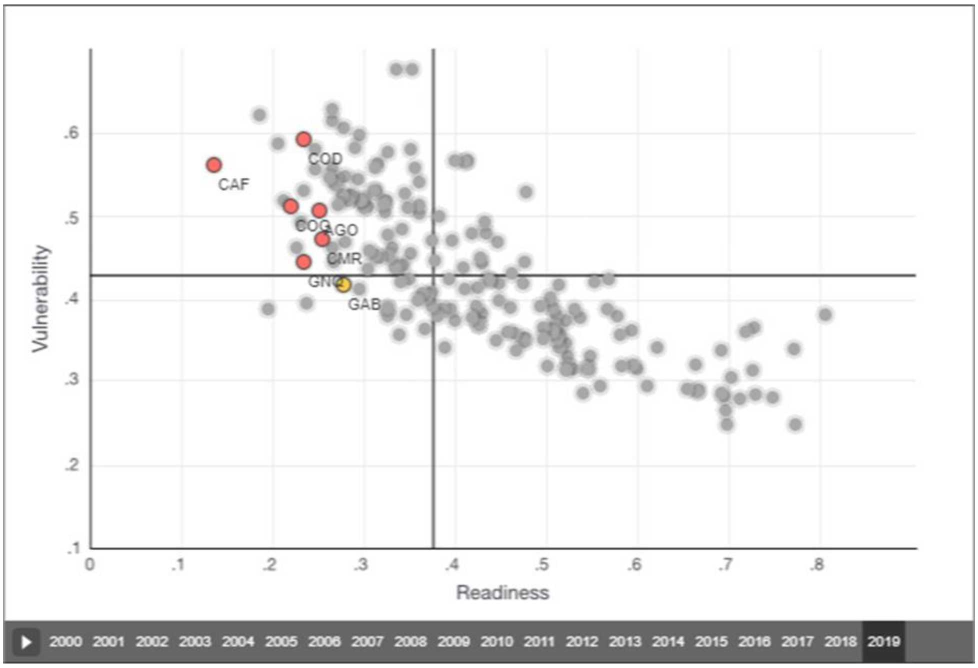

Figure B1: ND-GAIN country scores for the Central Africa region. From bottom left to top left: Gabon (GAB); Equatorial Guinea (GNQ); Cameroon (CMR); Angola (AGO); Republic of Congo (COG); Central African Republic (CAF); and the Democratic Republic of Congo (COD).

C: Climate analysis in the zones

Selection of spatial analysis zones

To assess the magnitude and direction of projected climate trends at a sub-regional scale it is useful to spatially aggregate gridded climate data over climatologically similar regions. As the Central Africa region represents a large, meteorologically diverse area, it is also important to reflect this. Averaging the climate data by country borders is often not useful, as these do not reflect the climate and some countries may experience a range of climate types. Therefore, the region is divided into four sub-regional spatial analysis zones that reflect the different climate types.

The zones were selected using a combination of the Köppen-Geiger climate classifications (Figure C1), the baseline climatology and future trends (Section 2), information about elevation, population density and livelihoods (Figure 2), and the Natural Earth[9] country borders (v4.1.0). The four zones used for the spatial analysis are shown in Figure C2. Additionally, reference was made to the IPCC AR6 WG I reference regions (Figure D3).

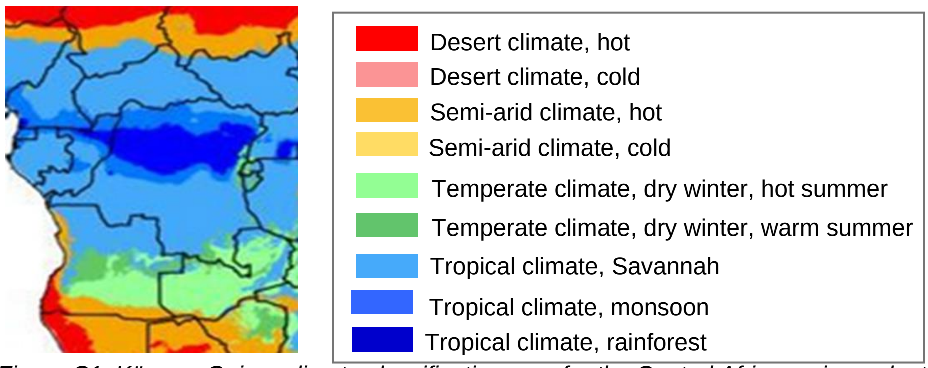

Figure C1: Köppen-Geiger climate classification map for the Central Africa region, adapted from Beck et al. (2018)

Figure C2: The four spatial analysis zones across the Central Africa region

[9] https://www.naturalearthdata.com/

Figure C3: IPCC AR6 reference regions, as defined by WGI. Source: IPCC AR6 Regional factsheet – Africa[10].

Zone 1 has a tropical Savannah climate, including the north of Cameroon and the Central African Republic (CAR). Zone 2 has a tropical climate, including the south of Cameroon, Equatorial Guinea, Gabon, northern Republic of Congo (R. Congo) and the north of the Democratic Republic of the Congo (DRC). Zone 3 has a tropical Savannah climate including southern R. Congo, central DRC and northern Angola. Zone 4 represents the more temperate climates of southern Angola and south DRC, characterised by dry winters and warm/hot summers.

IPCC AR6 WG I CAF 'Central Africa' region incorporates the Savannah climate of southern Chad and western South Sudan which are not included in our definition of Central Africa for this risk report. The CAF region also does not include the southern part of Angola and DRC (but are included in the West Southern Africa, WSAF, region), which comprise zone 4 and is a drier, cooler zone. The WG I region findings are interpreted here accordingly.

10 https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Africa.pdf

Results from the zonal analysis

Maps of the baseline climatology with the zones overlaid are shown in Figure C4. Other outputs from the bespoke zonal data analysis are presented in the following zone-specific sections. This includes time series plots for the baseline climate and scatter plots of the future climate model projections for the 2050s under RCP8.5 (see Appendix A for detail on the data and methods).

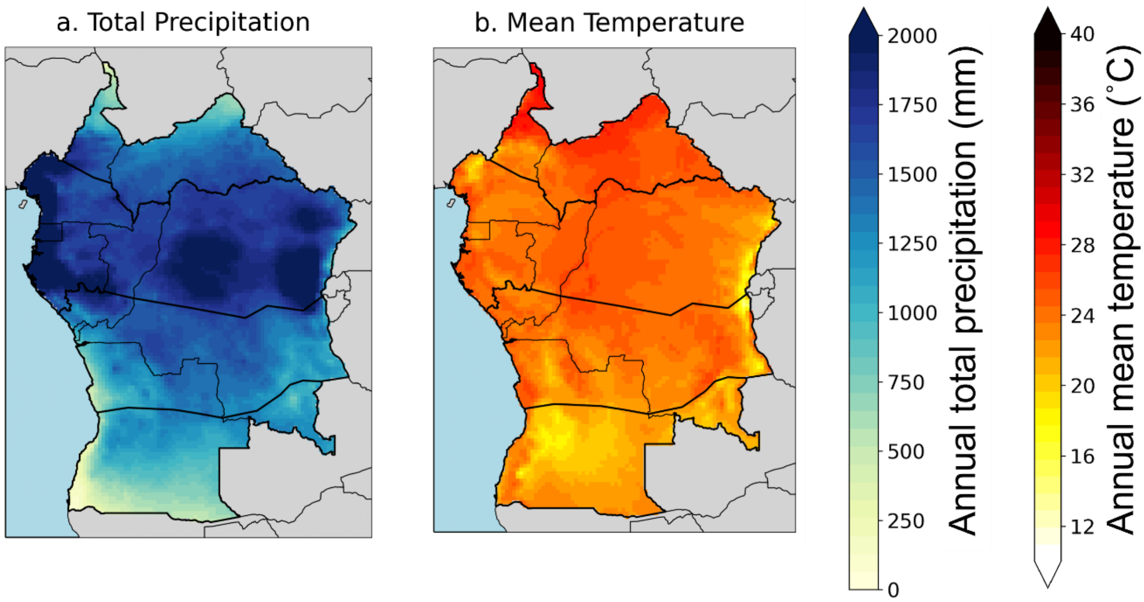

Figure C4: Baseline climate for the Central Africa region for the period 1981-2010 with the spatial analysis zones overlaid. Maps show climatological average values of annual mean total precipitation (mm/year; left panel) and annual mean temperature (°C; right panel). Temperature and precipitation data come from the ERA5 and CHIRPS reanalysis datasets respectively.

The climate in context assessment at the zone scale includes this bespoke zonal data analysis, supplemented by regional findings from IPCC (2021) and the IPCC Interactive Atlas (as presented in the main report), and the socio-economic and geographic context to identify relevant impacts in each of the zones. Summaries of this assessment are provided in Tables C1-C4 in the following sections.

Zone 1: Northern tropical savannah

Zone 1 includes Northern Cameroon and Central African Republic (Figure D5) which experience a topical savannah climate, semi-arid in the north and more rainfall in the south.

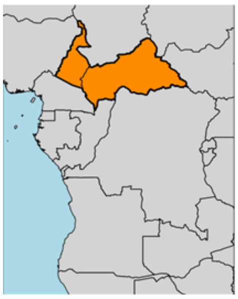

Figure C5: Zone 1

Plots of the baseline climate are shown in Figures C4 and C6. Scatter plots of the future projections are shown in Figure C7. The climate in context assessment for Zone 1 is summarised in Table C1.

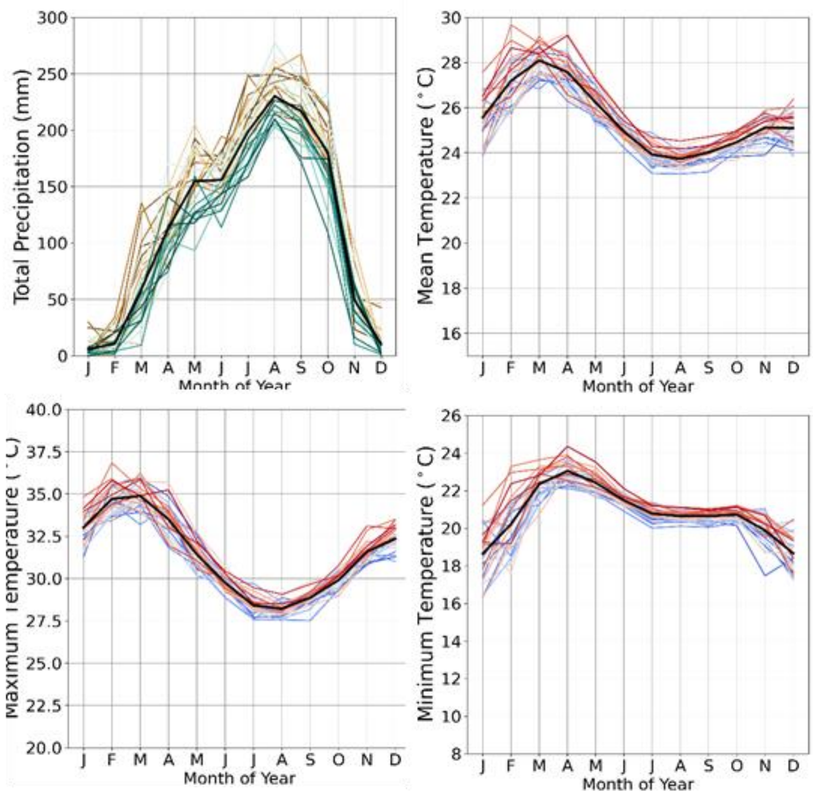

Figure C6: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 1. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean temperature) – this highlights the presence, or lack of, a trend over the baseline period. The bold black line indicates the average of the 30-year period.

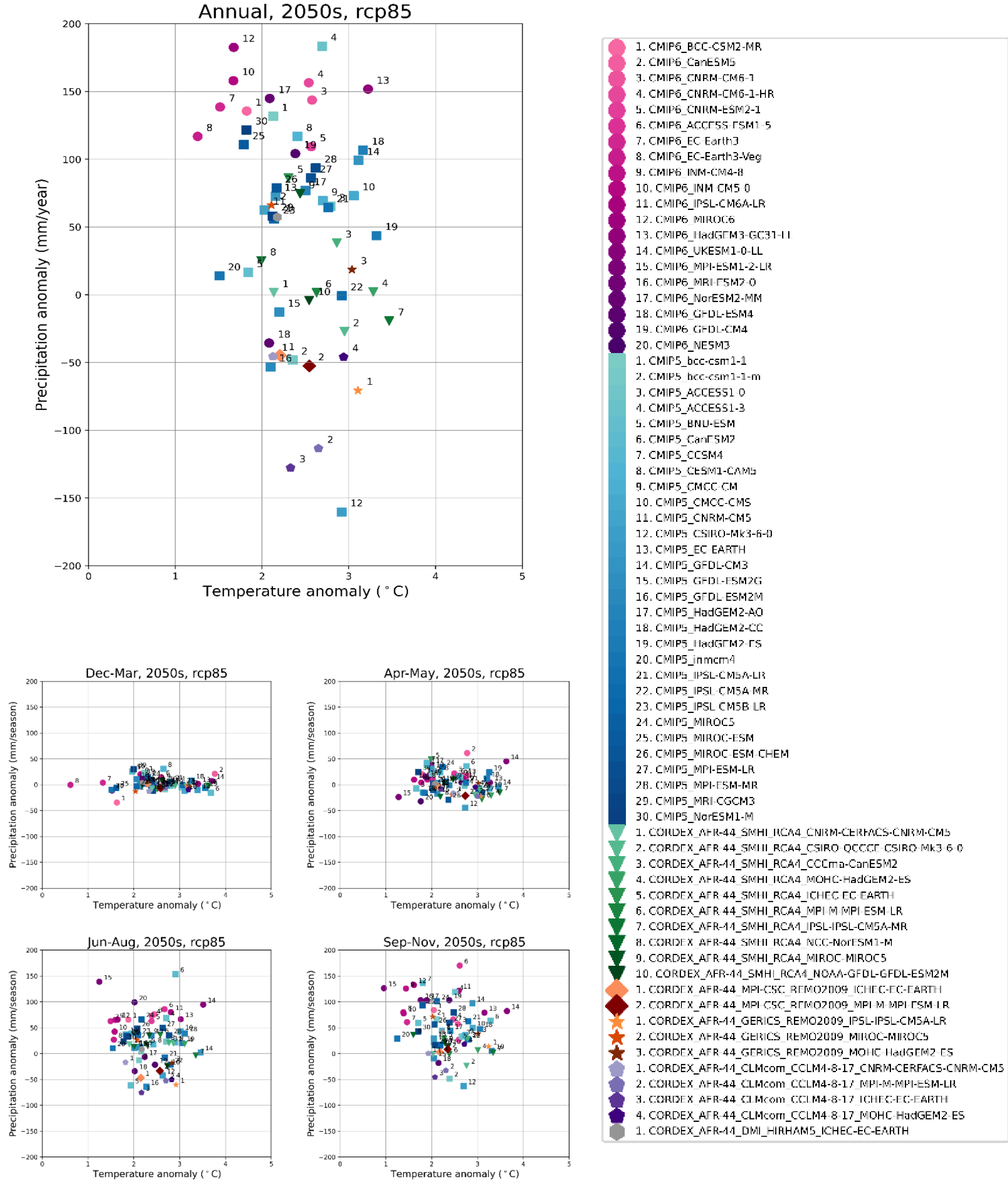

Figure D7: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 1. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

<table>
<tr><th colspan="3">Table C1: Climate in context analysis for Zone 1</th></tr>
<tr><td rowspan="2">Baseline (1981-2010)</td><td>Current climate</td><td>Temperatures range from 21-30°C, daily maximums can exceed 35˚C in hottest months (January-April), daily minimums below 20˚C in coolest months (December–February).
Very dry, receives 15-200 mm of rain per month in the wettest months (May–October), less than 25 mm/month in the dry season (December–February).
Since pre-industrial times zone 1 has warmed by 0.6-1°C.</td></tr>
<tr><td>Context</td><td>Benue River Basin, Sangha River Basin, Oubangi River Basin, and Lake Chad Basin, Mandara Mountains (Cameroon) and Karre Mountains (CAR), Waza National Park (Cameroon), Manovo-Gounda St Floris National Park (CAR).
Agropastoralism is the main livelihood system in north, integrating livestock and cereal crops plus cereal-root crop mixed systems. Root and tuber crop systems dominate in the south.
Inland fisheries (e.g., on Lake Chad in Cameroon and rivers in CAR) also play an important socioeconomic role.
Guineo-Sudanian Savannah.
Manovo-Gounda St Floris National Park in CAR - largest park in the Central African Savannah is a UNESCO World Heritage Site in Danger.
Historical risk of locust infestation.</td></tr>
<tr><td rowspan="3">Future projections (2050s)</td><td colspan="2">Zone 1 is projected to be hotter on average, and potentially wetter during September-November.</td></tr>
<tr><td>Climate trends</td><td>High confidence for an increase of 1-4°C in annual mean temperature in the 2050s, under a very high GHG concentration scenario (0.8˚C or 0.5˚C for low or medium emissions scenario).
High confidence in an increase in extreme heat and decrease in cold spells.
Low confidence in wetter conditions overall, with medium confidence in more rainfall from September–November, by 0-35% under a low, medium or high emissions scenario.</td></tr>
<tr><td>Relevant Impacts</td><td>Increasing water stress and irrigation demand due to warmer conditions.
Significant risks to water and grazing options.
Potential to utilise wide range of agroecological zones to cultivate numerous major crops to support regional staple food demands.
Less suitable climate for malaria but more suitable for dengue, chikungunya, and other arboviruses.
Impacts of future climate-related risks on Lake Chad are discussed in detail in the climate risk report for the Sahel region: Holmes et al., 2022.
Substantial increase in heat stress and other heat-related risks.</td></tr>
</table>

Zone 2: Equatorial forest zone

Zone 2 includes Southern Cameroon, Equatorial Guinea, Gabon, Northern R. Congo and Northern DRC (Figure C8) which experience a humid tropical climate.

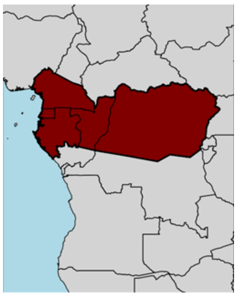

Figure C8: Zone 2

Plots of the baseline climate are shown in Figures C4 and C9. Scatter plots of the future projections are shown in Figure C10. The climate in context assessment for Zone 2 is summarised in Table C2.

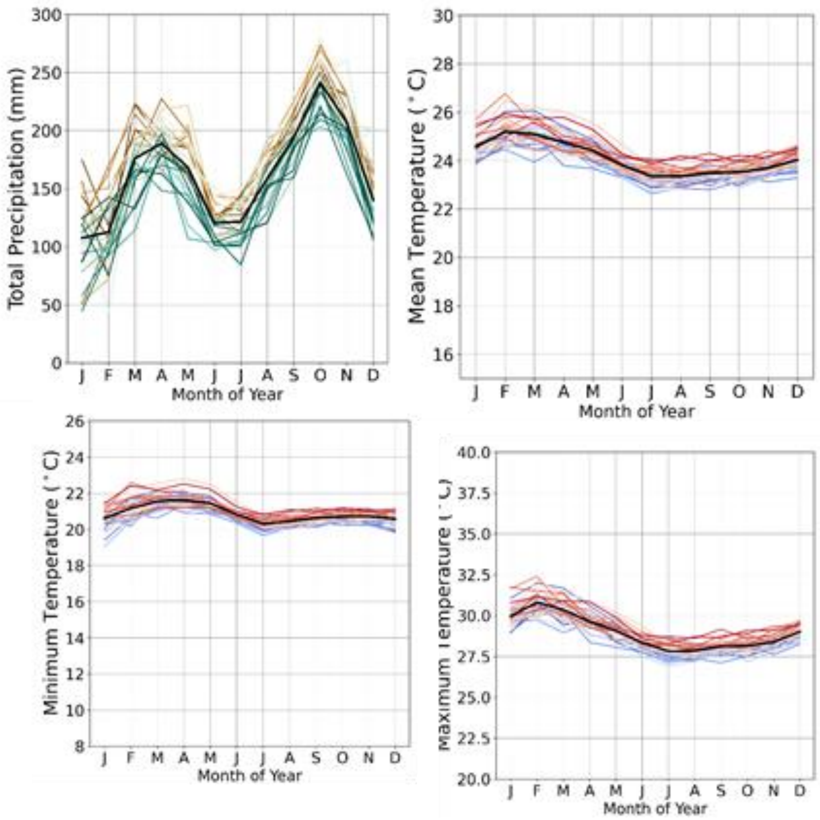

Figure C9: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 2. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean temperature) – this highlights the presence, or lack of, a trend over the baseline period. The bold black line indicates the average of the 30-year period.

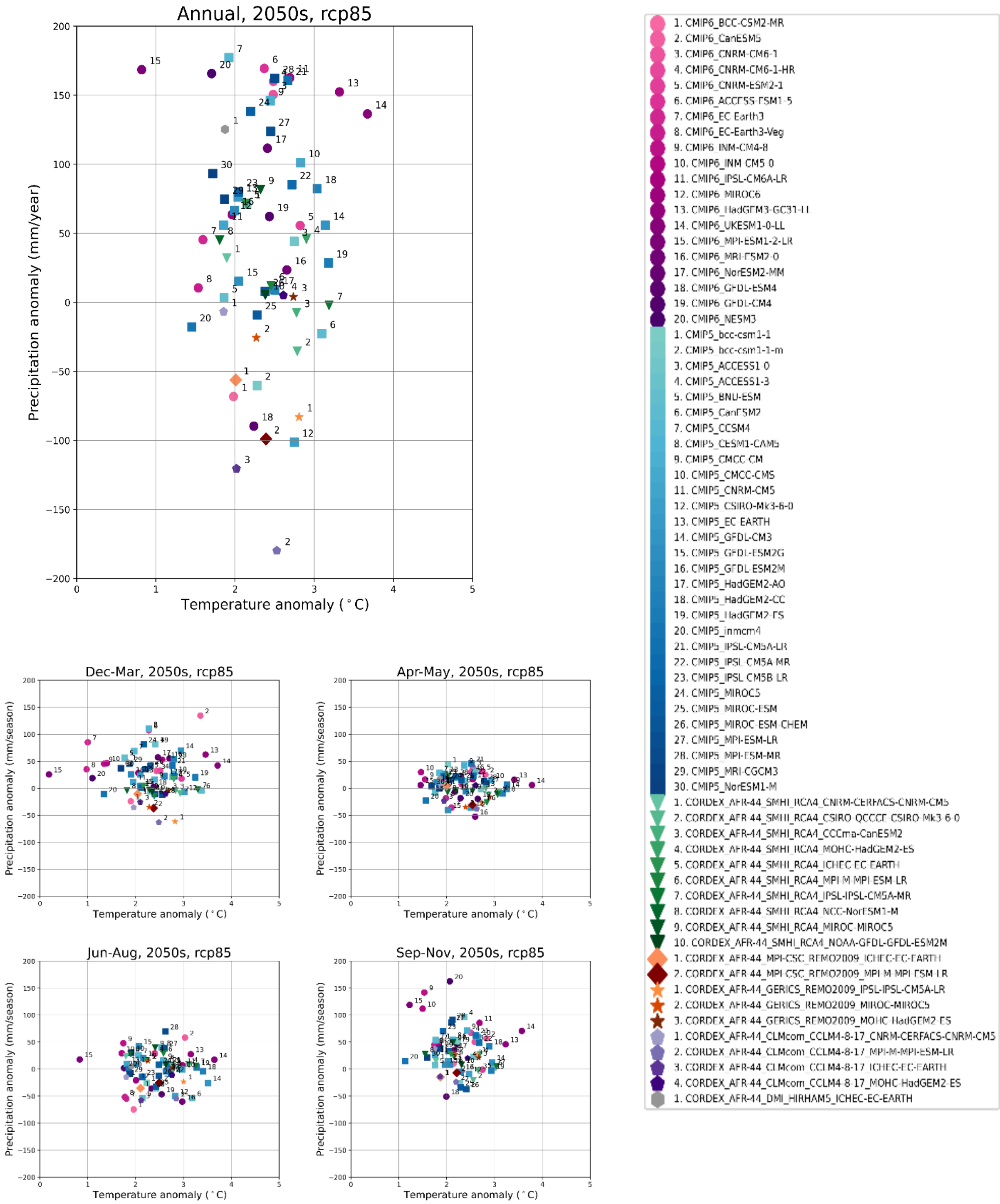

Figure C10: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 2. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Table C2: Climate in context analysis for Zone 2		
Baseline (1981-2010)	Current climate	• Daily mean temperatures 21-26˚C, daily maxima sometimes exceed 30˚C in hottest months (January-April) and minima rarely go below 20˚C. Temperatures show little seasonal variability. • Two peaks in rainfall (March/April and October), receives 200-275 mm/month in wettest months (September-November) and totals are high year round (>100 mm/month). Most rainfall over forested areas of DRC and coastline. • Since pre-industrial times zone 2 has warmed by 0.6-1°C. • Sea levels have risen ~0.3 m since.
	Context	• Congo rainforest; Congo River Basin; Lakes Kivu, Edward, and Albert, part of the African Great Lakes system (DRC); mangrove forests; islands that form part of Equatorial Guinea; the Rwenzori and Virunga Mountains (DRC); and Mount Cameroon. • Tree crop and forest-based food crop systems are the main agricultural system, alongside highland perennial tree crop systems in the south-eastern part of the zone. • Inland (lake and river) fisheries and marine fisheries play an important socioeconomic role.
Future projections (2050s)		**Zone 2 is projected to be hotter and wetter on average, particularly in the wettest months.**
	Climate trends	• High confidence for an increase 1.5-4°C in annual mean temperature in the 2050s, under a very high emissions scenario (0.8˚C or 0.5˚C lower under a low or medium emissions scenario). High confidence in an increase in extreme heat and decrease in cold spells. • Low confidence in wetter conditions on average in a very high emissions scenario, seasonally focussed during September–November and December–March. In south-eastern DRC high confidence for wetter conditions December-March. For low and medium emission scenarios there is less confidence for changes in both annual and seasonal precipitation totals. • Sea levels will continue to rise, and ocean temperatures will continue to increase with associated erosion and shoreline retreat.
	Relevant Impacts	• Areas suitable for Robusta cultivation may expand in some central parts. • Tree crops in the west offer high potential for food security up to 2030. • Significant risks to water and grazing options (Cameroon). • Substantial increase in heat stress and other heat-related risks (S. Cameroon, Equatorial Guinea, Gabon, R. Congo, northern DRC). • Emergence of new seasonal malaria regions in R. Congo. • Increase and expansion of dengue fever incidence in Cameroon, Equatorial Guinea, Gabon, and northern DRC. • Shoreline retreat is projected to be significant along the coasts of Gabon. • Declining marine fish productions in the region and increased tensions in management of fisheries between countries in the region. • Risk to fish processing in coastal fisheries - need for improved refrigeration and cold storage. • The coast of Zone 2 is low lying with many beaches important for tourism at risk of erosion and shoreline retreat, particularly in Gabon where an erosion hotspot has been identified. In Cameroon the Limbe coastal area is already flood-prone, and this will worsen. Mainland and the islands of Equatorial Guinea are vulnerable to beach erosion affecting turtle nesting habitat.

Zone 3: Southern tropical savannah

Zone 3 includes southern Republic of Congo, central DRC and northern Angola (Figure C11) which experience a tropical savannah climate.

Figure C11: Zone 3

Plots of the baseline climate are shown in Figures C4 and C12. Scatter plots of the future projections are shown in Figure C13. The climate in context assessment for Zone 3 is summarised in Table C3.

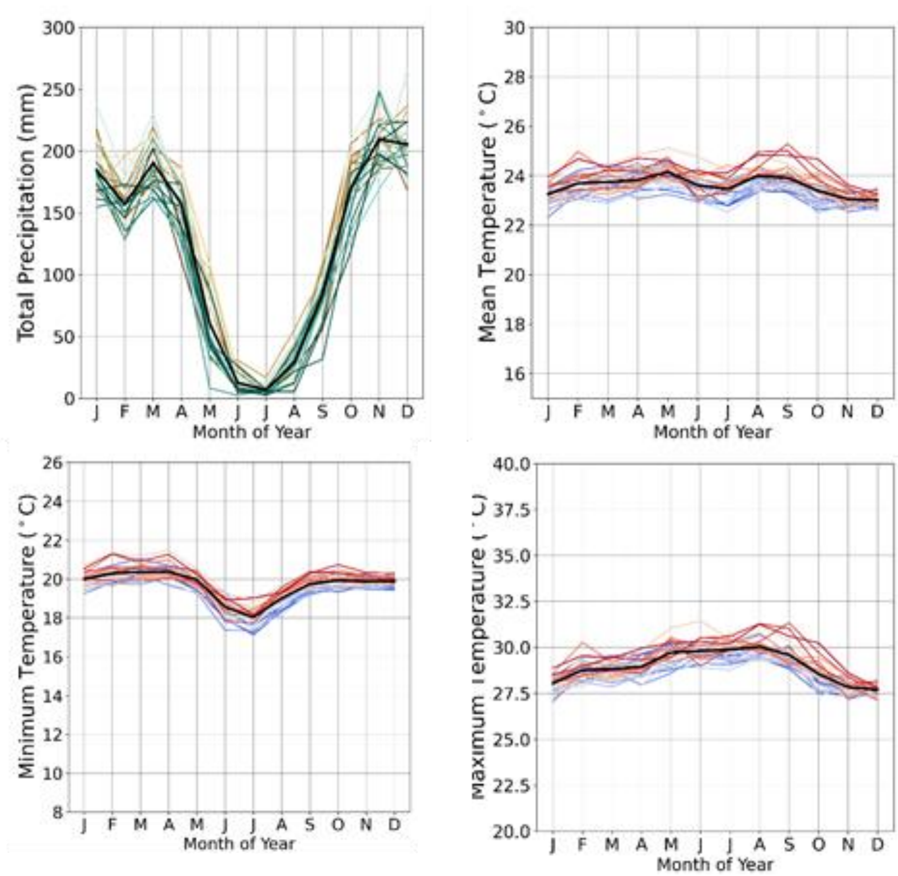

Figure C12: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 3. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean temperature) – this highlights the presence, or lack of, a trend over the baseline period. The bold black line indicates the average of the 30-year period.

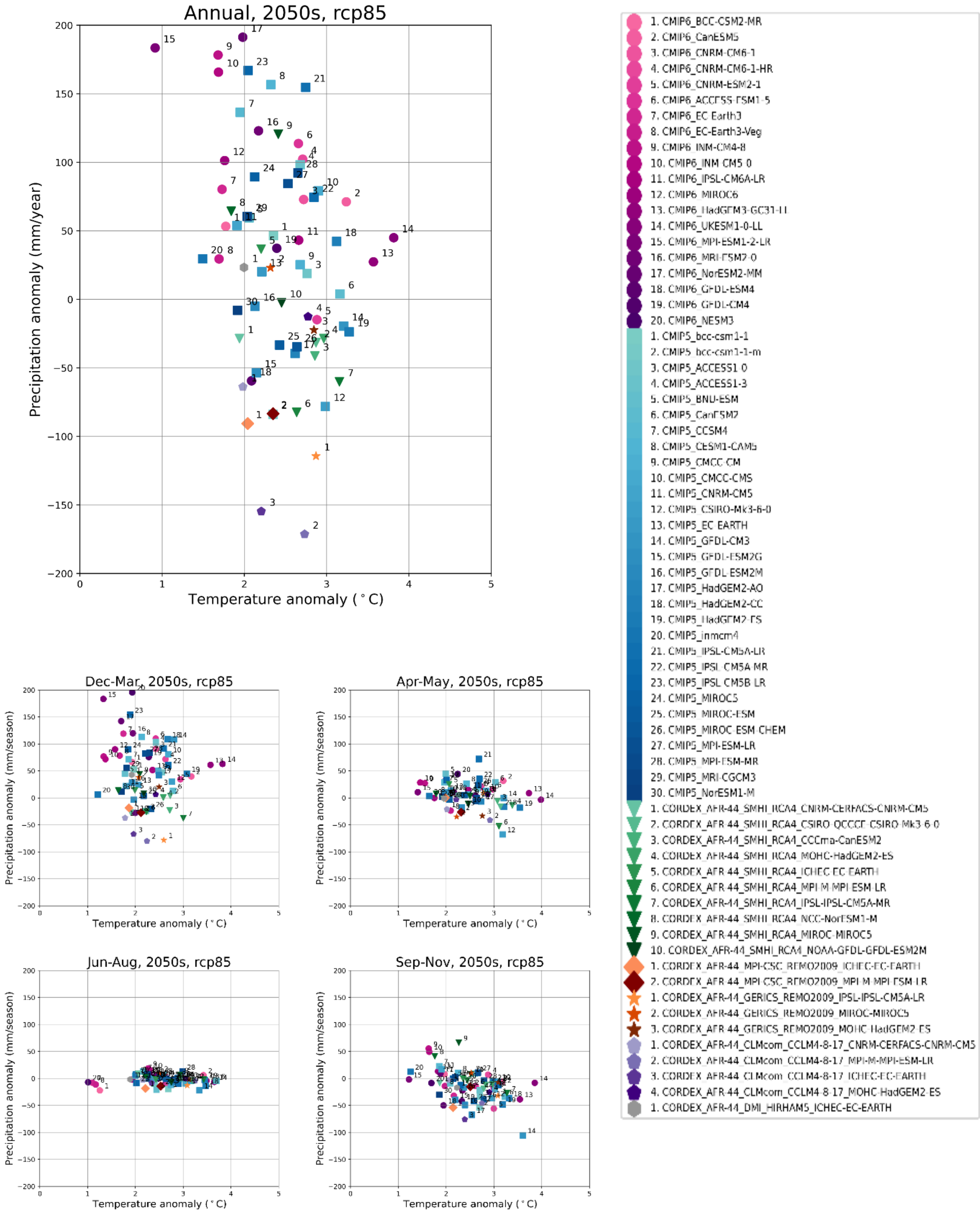

Figure C13: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 3. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Table C3: Climate in context analysis for Zone 3

Baseline (1981-2010)	Current climate	• Daily mean temperatures 21˚C-25˚C, daily maximums sometimes over 30˚C 9n hottest months (June-September), daily minimums rarely below 18˚C in cooler months (June–August). Temperatures show very little seasonal variability. • Distinct dry season May–August, most rain falling inland, coastline receiving lower annual totals. Wettest months (October-December) occasionally receive more than 200 mm/month, December–April receives 150-200 mm/month. • Since pre-industrial times zone 3 has warmed by 0.6-0.9°C with no clear wetting or drying signal.
Baseline (1981-2010)	Context	• Lake Tanganyika (DRC), Congo Forest and the Congo River Basin. • Main agriculture is root and tuber crop systems, alongside highland perennial systems in the north-eastern part of the zone. • Inland (lake and river) fisheries and marine fisheries.
Future Projections (2050s)		**Zone 3 is projected to be hotter on average, potentially wetter in the wet season, and potentially drier September-November.**
Future Projections (2050s)	Climate Trends	• High confidence for a warming of 1.5-4°C in annual mean temperature in the 2050s, under a very high emissions scenario (0.8˚C or 0.5˚C lower under a low or medium emissions scenario). Medium-high confidence in warming greater than 2°C in June-August, and 2-3°C September-November. High confidence in an increase in extreme heat and decrease in cold spells. • Model projections range from moderately drier (by -20%) to moderately wetter (by +25%). Seasonally, under a very high emissions scenario, there is some consensus for wetter conditions (up to 25%) in rainy season (December-March). Low confidence in drier conditions (up to 205) (September-November). For low and medium emission scenarios there is less confidence for changes in both annual and seasonal precipitation totals. • Sea level rise, inundation and SSTs will increase, Zone 3 is an accretion hotspot.
Future Projections (2050s)	Relevant Impacts	• Root and tuber crops and highland perennials in north-east have high potential for food security up to 2030. • Substantial increase in heat stress and other heat-related risks (R. Congo and northern Angola). • Shoreline retreat is projected to be significant along the coasts of southern R. Congo. • Declining marine fish production and increased tensions in management of fisheries between countries. • Risk to fish processing in coastal fisheries - need for improved refrigeration and cold storage.

Zone 4: Temperate climate

Zone 4 includes Southern Angola and Southern DRC (Figure C14) which experience a temperate climate, cooler and drier than the other zones.

Figure D14: Zone 4

Plots of the baseline climate are shown in Figures C4 and C14. Scatter plots of the future projections are shown in Figure D15. The climate in context assessment for Zone 4 is summarised in Table C4.

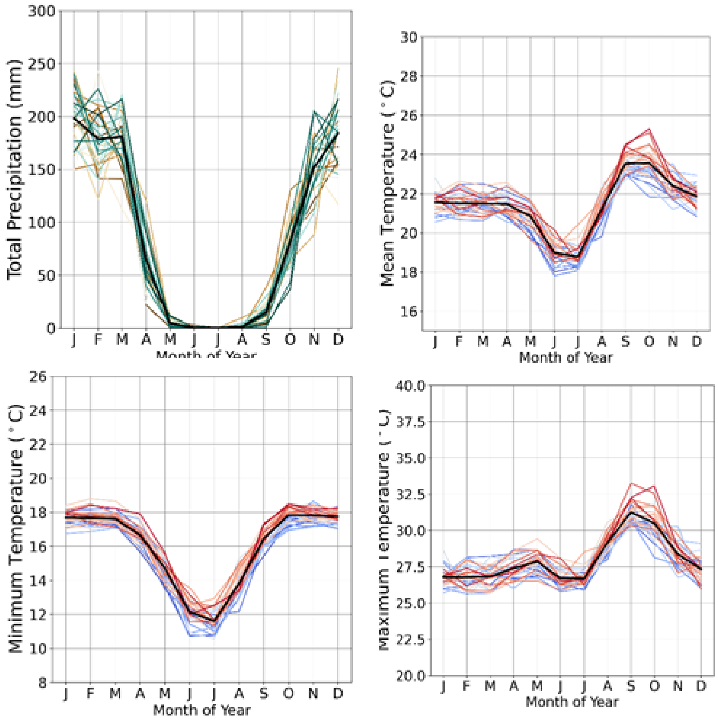

Figure C14: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 4. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean temperature) – this highlights the presence, or lack of, a trend over the baseline period. The bold black line indicates the average of the 30-year period.

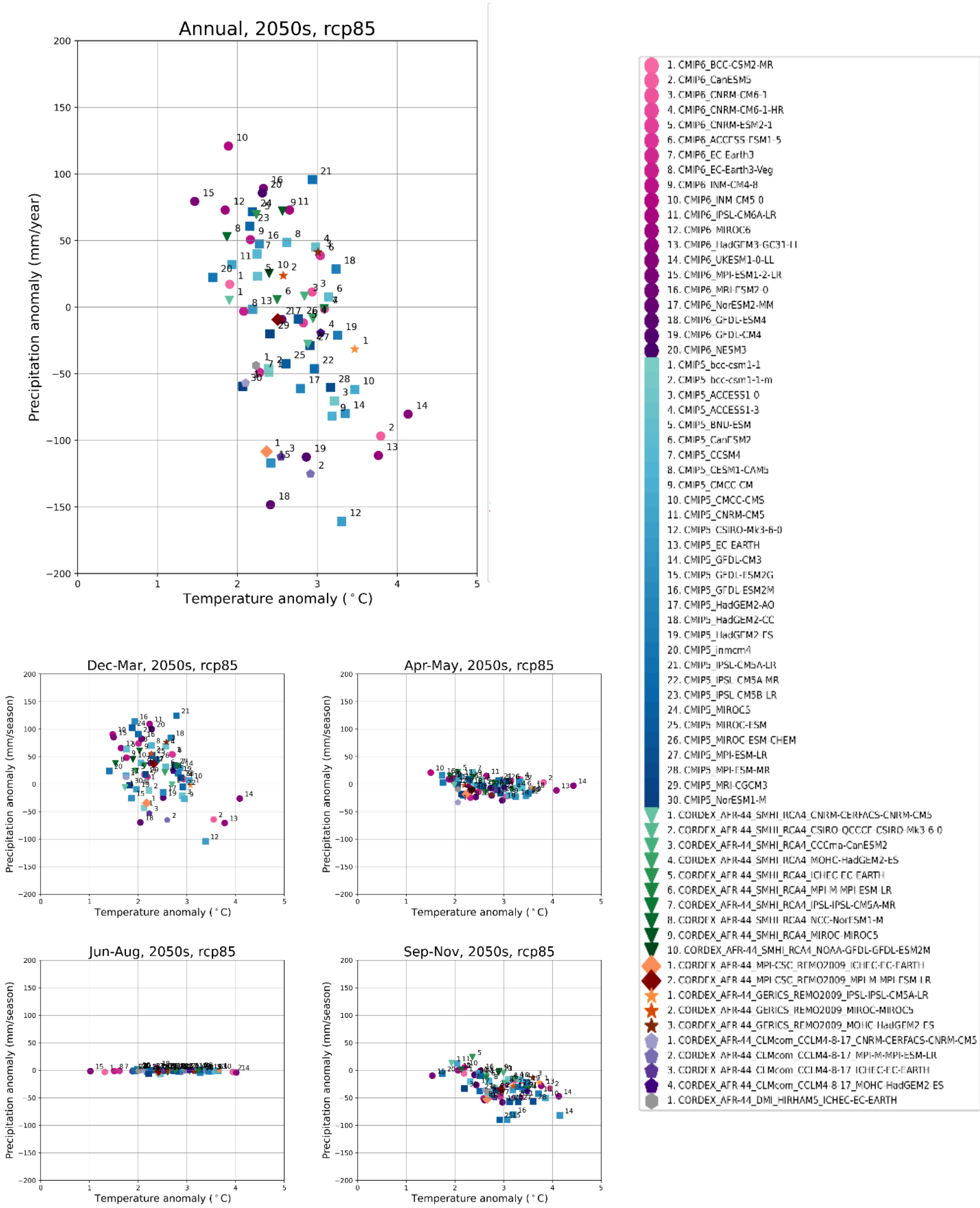

Figure C15: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 4. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

<table>
<tr><th colspan="3">Table C4: Climate in context analysis for Zone 4</th></tr>
<tr><td rowspan="2">Baseline (1981-2010)</td><td>Current climate</td><td>• Cooler and drier than other zones. March–September: cool, dry season known as Cacimbo.
• Daily mean temperatures 18-26˚C, daily maximums over 30˚C in hottest months (September-November), daily minimums below 12˚C in cooler months (June–August).
• Most rain falls inland, coast receiving low annual totals (<100 mm/year), wettest months (December-March) receive 150-250 mm of rain per month.
• Since pre-industrial times this zone has warmed by 0.6-0.9°C with no clear wetting or drying signal.</td></tr>
<tr><td>Context</td><td>• Cubango/Okavango River and Mount Moco.
• Maize mixed systems are main agricultural system, alongside agropastoralism in the southernmost part of the zone.
• Marine fisheries play an important socioeconomic role.</td></tr>
<tr><td rowspan="3">Future projections (2050s)</td><td colspan="2">Zone 4 is projected to be hotter and potentially drier on average, except in December-March when it could be potentially wetter.</td></tr>
<tr><td>Climate trends</td><td>• High confidence for a warming of 1.5-4.5°C under a very high emissions scenario (0.8˚C or 0.5˚C lower under low or medium scenario), this is higher than in other zones. Seasonally more warming (2.5-4°C) is projected September-November. High confidence in an increase in extreme heat and decrease in cold spells.
• Model projected changes in annual mean precipitation show large variability but with a stronger confidence in a drying signal in this zone compared to others in the Central Africa region. Very little change in rainfall June-August under a very high emissions scenario. Low confidence in a low or moderate increase (up to +20%) during December-March (north of the zone, particularly along the coastline), medium confidence in low or moderate decrease (up to -25%) September-November (south/south-east of the zone). The low and medium emissions scenario show similar projections, but with lower magnitude and confidence.
• SLR and higher SSTs, significant erosion of the coast. The Angola and Benguela currents diverge off the coast of Angola creating a strong upwelling system that supports rich marine life, under threat as warming and marine heatwave affect the circulation of the oceans.</td></tr>
<tr><td>Relevant Impacts</td><td>• Significant risks to water and grazing options.
• Declining marine fish productions in the region and increased inter-country tensions around management of fisheries.
• Risk to fish processing in coastal fisheries - need for improved refrigeration and cold storage.</td></tr>
</table>

D: Central African Bioregions and zones

Table D1: Central African bioregions, their species counts and endemism rates, from Droissart et al. (2018), using data from the RAINBIO mega-database (the largest and most accurate database of tropical African vascular plant distributions, Dauby et al., 2016; Sosef et al., 2017).

Bioregion	Location	Number of plant species recorded	Endemic plant species recorded	Endem-ism rate
Guineo-Sudanian	Northern half of Cameroon; parts of northern and eastern CAR and northern DRC.	4631	424	9.2%
Guineo-Congolian	n/a	10,060		41.5%
- Upper Guinea (West Africa)		4324	554	12.8%
- Lower Guinea	Cameroon Volcanic Line, southern Cameroon, Equatorial Guinea, Gabon, parts of SW and NW Rep. of Congo.	6928	1677	24.2%
- Congolia	Congo Basin of DRC, part of eastern Rep. of Congo, southern CAR.	3875	246	6.3%
Albertine Rift Montane	Rwenzori Mountains (DRC – Uganda border), Virunga Mountains (DRC).	3211	260	8.1%
Central Zambezian	Upper Katanga, south-eastern DRC.	4583	1041	22.7%

The zoning of Central Africa's diverse ecology

The Congo Basin rainforest forms the largest part of the Guineo-Congolian forest area, but technically it does not include the Lower Guinea rainforests of Cameroon, Gabon, Equatorial Guinea, and part of south-west and north-west R. Congo (Abernethy et al, 2016). The Lower Guinea forests form a distinct floristic area that is actually more species diverse than the Congolian forests, and with higher endemism (Droissart et al., 2018). The tropical rainforests of central Africa consist of both wet and moist/drier areas of Guinean-Congolian forest, coastal forests, and upland forests on mountains and plateaus. Much of the lowland rainforest is moist evergreen forest. The wet forests include the enormous swamps of central DRC, which contain the world's largest peatlands and are extremely important carbon deposits.

The mountain ecosystems of the Albertine Rift bordering the eastern DRC form another bioregion and include biodiversity hotspots in the Rwenzori Mountains and the Virunga National Park (one of the remaining refuges of endangered eastern mountain gorillas). The Central Zambezian bioregion that extends from Zambia to Katanga (south-east DRC) is a diverse Savannah, particularly rich in herbaceous plants (Sosef et al., 2017). According to data from Stévart, T. et al. (2019) the flora in southern DRC is possibly the most endangered in Central Africa, due to the presence of many narrow range species and due to land use pressures from mining and other activities. The other Savannah area is classified as Guineo-Sudanian and covers the northern half of Cameroon, parts of northern and eastern CAR, and part of northern DRC. This also has a high diversity of Savannah vegetation and megafauna in protected areas including elephants, giraffes, buffalos, antelopes, and many other species.

The highest mountains in Central Africa are in Cameroon in the west and along the eastern borderlands of DRC in the east. In both these areas the mountains rise to more than 4000 metres above sea level and contain high biodiversity. The Rwenzori Mountains and the Virunga Mountains are part of the Albertine Rift Montane floristic area and have high biodiversity (Table D1). There are also lower mountain ranges and hills in Central Africa, including coastal mountains of just over 1000 metres in Gabon with important forests.

Montane regions
Cameroon Highlands

Mount Cameroon is 4040 metres and marks the highest point in western Africa and on the Cameroon Volcanic Line. This is a mountain range stretching some 1600 kilometres from the Gulf of Guinea to the Mandara Mountains in the north, near Lake Chad. The climate risks to the Cameroon highlands include ecosystem disturbance from increased heat. This includes the potential for forest fires in the dry season. The climate models do not give a clear indication of rainfall trends, but if there was a reduction in rainfall it would impact the montane forests of the highlands, which thrive in moist conditions. This includes protected areas such as Mount Oku (3011 metres), which rises above the Grassfields in the north-west region of Cameroon and has montane forest and diverse flora and fauna.

Eastern DRC

Eastern DRC has mountain ecosystems forming part of the Western Rift Valley, the Albertine Rift. This area is considered a biodiversity hotspot, with endemic flora and fauna and critically endangered megafauna, including eastern mountain gorillas, that depend on the forests. The Rwenzori Mountains National Park and the Virunga National Park are both UNESCO World Heritage Sites. The Albertine Rift and its unique ecosystems are vulnerable to climate change, with one study forecasting a 75 per cent reduction in habitats for endemic species by 2080 (Ayebare et al, 2018).

Rwenzori Mountains

The Rwenzori Mountains on the DRC-Uganda border have a multitude of diverse ecosystems, following an upward gradient that reaches remarkable snow-capped peaks and glaciers. Along with Mt. Kilimanjaro and Mt. Kenya, the Rwenzori have the only glaciers in equatorial Africa. The glaciers and Alpine ecology of the Rwenzori are the largest on the continent (Russell et al., 2008). Unlike Mt. Kilimanjaro and Mt. Kenya, which are free-standing volcanic cones, the Rwenzori is a mountain range 110 kilometres in length covering an area of 3000km2, with a series of distinct high mountains and deep valleys (Osmaston, 2006; Russell et al., 2008). The highest mountain in the Rwenzori range is Mt. Stanley, at 5109m, but there are five other peaks more than 4600m asl and until recently (the 1990s or so) had glaciers on them (Osmaston, 2006). Now only the highest three peaks have glaciers, which continue to retreat (Oyana and Nakileza, 2016).

The glaciers are very sensitive to changes in temperature and retreated from 6.5km2 in 1906 to about 2km2 in 1987 and less than 1.0 km2 in 2003, caused by rising air temperatures (Taylor et al., 2006). It is expected that as global warming continues all the remaining glaciers and snowfields in the Rwenzori Mountains will disappear entirely in the next decades (Mackay et al., 2020). This will alter terrestrial and aquatic montane ecosystems, especially at higher altitudes, and as glacial lakes will no longer have glaciers to feed them their biology and geochemistry will change -- although exactly how will need to be researched (Mackay et al., 2020). However, the evidence does indicate that glacial retreat in the Rwenzori will not substantially reduce riverflow in the mountains or change the hydrology, as glaciers contribute only a small amount to river discharge, most of which comes from precipitation (Taylor et al., 2009).

The Rwenzori are famous for their flora, especially the Afro-Alpine vegetation, with four iconic species of giant Lobelia (*Lobeliaceae*) and several *Senecio* (groundsel) species (Osmaston, 2006). A redistribution of some plant species as a result of glacial recession has already been observed (Oyana and Nakileza, 2016). Some mosses, algae and lichen could be threatened by glacial retreat, even as other plants colonise ice-free areas. The loss of species adapted to Afro-alpine conditions is possible if continuing temperature increases lead to the disappearance of alpine conditions, as plants there have evolved to cope with freezing temperatures. That is their present advantage. Plants and animals are adapted to the distinct ecotones of the mountains, and if these change, some of the endemic species that live in these unique niches could be lost.

The succession and range of vegetation belts and niches is: grassy foothills (1000-2000m); montane, evergreen forest (1500-2500m); bamboo zone (2500-3000m), heather – rapanea zone (3000-4000m); Alpine zone (3800-4500m); bogs; dendrosenecio (groundsel) woodland; scree slopes; and the nival zone (above the snow line), which reaches 5000m (Linder & Gehrke, 2006; Osmaston, 2006). Montane climates are sensitive and the impacts of higher temperatures if global greenhouse gas emissions are not reduced could be amplified in the Rwenzori, leading to changes in the ecotones and biodiversity loss. Even though fires have been observed in the Rwenzori Mountains since the early twentieth century (Osmaston, 2006), they are destructive and the damage they cause would increase if there are higher temperatures during the dry months. This unique tropical mountain ecosystem is vulnerable to ongoing rapid changes in the climate.

Virunga National Park

Virunga National Park was founded in 1925, this is the oldest national park in Africa and has been the focus of intense conservation efforts to save the endangered eastern mountain gorillas (*Gorilla beringei beringei*). Virunga has a unique volcanic landscape and high biodiversity and endemicity, but it is the habitat of the mountain gorillas that has galvanised the park's conservation. Mountain gorillas were brought to the attention of a global public by the primatologist Dian Fossey during her research and conservation work from 1967-1985. By 1981, due to poaching and habitat loss, the mountain gorilla population had plummeted to only about 250 individuals in the Virunga Massif. Since then, despite very challenging circumstances with war and displacement in eastern DRC, strict conservation and improved management of the park has enabled an increase in the mountain gorilla population to over 1000 individuals, including 580 in Virunga National Park (UNEP, 2021).[11]

There are direct and indirect climate risks to Virunga and the still endangered mountain gorillas. The rural population density in the area is very high for rural Africa, with over 600 people / km2 (UNEP, 2020), which puts considerable pressure on the park, with land cultivated right up to the park boundaries. Climate change is likely to be a challenge because higher temperatures and erratic rainfall will increase the pressure on local livelihoods, especially on farmers. If local agriculture is compromised by

[11] 'Covid-19, climate change threaten last refuge of mountain gorilla': https://www.unep.org/news-and-stories/story/covid-19-climate-change-threaten-last-refuge-mountain-gorilla

changes in climate, the pressure on the park will increase as people either seek new farmland or intensify exploitation of natural resources in the protected area. It is necessary therefore to improve local livelihoods and the protection of Virunga National Park by increasing food security, clean water, switching to more efficient energy sources, and protect the buffer zone (UNEP, 2020).

Climate change could also have a direct negative impact on the vegetation and habitats of mountain gorillas. Some live at altitudes above 3000m, showing a preference for cooler conditions. Mountain gorillas are probably quite resilient to climatic variability, but this needs further research, as do their specific vulnerabilities (UNEP, 2020). For example, there are signs that more gorillas could seek to move into the higher areas of the forest in response to elevated temperatures. However, they would be constrained by the size of the park and human pressure at the boundaries. Indications are that mountain gorillas are reaching the carrying capacity of the park (UNEP, 2020), which would make it difficult for them to shift their range in response to climate change. The climate impacts on Virunga and on mountain gorillas will depend on the severity of climate change and on the continued protection of the park. The former depends on cutting greenhouse gas emissions while the latter hinges on improving the productivity and sustainability of agricultural livelihoods outside the park.

Freshwater ecosystems

Some 1327 species of freshwater fish have been identified (IUCN, 2015). There are more to be discovered, e.g., the possible identification of new fish species in Salonga National Park in DRC. Some 933 of these 1327 fish species are endemic to the region, while in 2015 180 (14.9%) were listed as threated (IUCN, 2015). The diversity of fish is found in the principal rivers – especially the Congo, Ubangui and Sangha rivers – and in lakes. There is high diversity in the Western Equatorial Lakes of the Cameroon Highlands and hyper-diversity of fishes in the Great Lakes of the Rift Valley which border eastern DRC – Lake Albert, Lake Edward, Lake Tanganyika.

Animals of the savannah Woodlands

Large carnivores include lion (*Panthera leo*), spotted hyena (*Crocuta crocuta*), leopard (*Pantera pardus*), cheetah (*Acinonyx jubatus*), wild dog (*Lycaon pictus*), and many other species (Kingdon, 2015). The range and populations of these carnivores have been substantially reduced, especially in the case of lions, cheetahs and wild dogs, due to habitat loss and hunting (Brugière et al., 2015). Other African megafauna including elephant, rhinoceros, giraffe, hippopotamus, buffalo, were historically present across Central Africa's savannahs, but their range has been reduced, mainly to protected areas. The northern white rhinoceros, whose remaining population was in Garamba National Park in north-east DRC, is now functionally extinct as there are only two females left (Wikipedia commons, 2022). The last refuge of the Western black rhinoceros (*Diceros bicornis longipes*) was in the Cameroonian savannah, but it was last sighted in 2006 and declared extinct by the IUCN in 2011.[12] Both of these rhino populations were wiped out by poachers.

Protected Areas of Savannah

The following areas are protected:

- Garamba National Park in north-eastern DRC: a UNESCO World Heritage Site since 1980 with endangered megafauna.
- Manovo-Gounda St Floris National Park in the CAR is the largest park in the Central African Savannahs and inscribed as a UNESCO World Heritage Site in Danger.[13]
- Other important conservation areas in the Savannahs of the CAR include Bamingui-Bangoran National Park and several others[14].
- A chain of national parks in Cameroon with an important diversity of wildlife: Faro National Park (adjoining Gashaka Gumti National Park in Nigeria), Benoué National Park, Bouba Ndjida National Park – Bouba Ndjida being part of the binational BSB Yamoussa transnational boundary complex that includes Sena Oura National Park in Chad.[15] Further north in Cameroon, Waza National Park supports diverse landscapes and wildlife, including herds of elephants.

Animals and Fungi of the tropical rainforests

The mammals vary from endemic megafauna such as forest elephants, great apes (eastern and western lowland gorillas, eastern mountain gorillas, chimpanzees, bonobos) and ungulates (ranging from hippopotamuses and varied species of pigs to buffalos, duikers, and many more). Mammals also include carnivores such as leopards, African golden cats, genets and civets; diverse species of monkeys, galagos (bushbabies), and other primates; varied pangolins, rodents (including many species of squirrel), bats, and lots more genera and species (Kingdon, 2015). Many of these orders are highly speciose. Central Africa also has biodiverse and endemic birds, fish, amphibians, reptiles, and invertebrates, the latter including millions of insects, nematodes, and worms. There are still a great number of species in Central Africa that are not known to science, and there is much to learn about the functioning of forest ecosystems and how they will be affected by climate change.

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[12] BBC News, 'Western black rhino declared extinct', 10 November 2011. https://www.bbc.co.uk/news/science-environment-15663982 (accessed 29 June 2022).
[13] https://whc.unesco.org/en/list/475/
[14] See: https://en.wikipedia.org/wiki/List_of_protected_areas_of_the_Central_African_Republic
[15] Wildlife Conservation Society (WCS), 'Bouba Ndjida National Park', https://cameroon.wcs.org/Wild-Places/Bouba-Ndjida-National-Park1.aspx (accessed 29 June 2022).

Mycorrhizal (fungi-plant) associations are fundamental for ecosystem function, including retaining water and nutrients in the soil, which provides resilience to climate impacts (Sheldrake, 2020; Tudge, 2005). Central Africa has the highest number of confirmed ectomycorrhizal plant species (120) of any tropical forest region (Corrales et al, 2018). Fungi in addition have a climatic role in stimulating rainfall in tropical forests, through aerial dispersal of billions of spores.

E: Agricultural sector indicators in Central Africa

Table E1: Agricultural sector indicators in Central Africa

	Agriculture as a proportion of GDP, 2020 (%)	Agriculture as a proportion of total employment, 2019 (%)	Agriculture as a proportion of female employment, 2019 (%)
Cameroon	17	43	48
CAR	32	70	73
Republic of Congo	10	34	32
DRC	21	64	72
E. Guinea	3	40	43
Gabon	7	30	46

Source: World Bank (2022). 'World Development Indicators DataBank', https://databank.worldbank.org/source/world-development-indicators

F: Farming systems in Central Africa

This report draws on the Dixon et al. (2020) farm systems approach to understanding and categorizing livelihoods in the region. Each livelihood system is diverse, but these categories correspond to households with similar livelihood patterns and development constraints and opportunities, often within broadly similar agroecological conditions (Dixon et al., 2020).

Table F1: Key characteristics of farming systems referenced in this report

Farming system	Key characteristics
Agropastoral	Mixed crop-livestock farming found in semi-arid (medium rainfall) areas of Africa, typically with low access to services. It includes the dryland mixed farming system of North Africa, often depending on wheat, barley and sheep. The main food crops are sorghum and millet, and livestock are cattle, sheep and goats. In both cases, livelihoods include pulses, sesame, poultry and off-farm work.
Cereal-root crop mixed	Mixed farming with medium-high access to services dominated by at least two starchy staples (typically maize and sorghum) alongside roots and tubers (typically cassava) found in the subhumid savannah zone in West and Central Africa. Other livelihood sources include legumes, cattle and off-farm work.
Tree crop	Lowland farming dominated by tree crops (> 25% cash income from cocoa, coffee, oil palm or rubber) found in humid areas of West and Central Africa. Other livelihood sources include citrus, yams, cassava, maize and off-farm work
Forest-based	Lowland, heavily forested humid areas in Central Africa with low access to services and subsistence food crops (cassava, maize, beans, cocoa-yam and taro). Other livelihood sources include forest products and off-farm work.
Root and tuber crop	Lowland farming dominated by roots and tubers (yams, cassava) found in humid areas of West and Central Africa. Other livelihood sources include legumes, cereals and off-farm work.
Highland perennial	Highland mixed farming is characterized by a dominant perennial crop (banana, plantains, enset or coffee) and good market access, and is found in humid East African highlands. Other livelihoods derive from diversified cropping including maize, cassava, sweet potato, beans, cereals, livestock and poultry augmented by off-farm work.

Maize mixed	Mixed farming dominated by maize with medium access to services in subhumid areas of East, Central and Southern Africa. Other livelihood sources include legumes, cassava, tobacco, cotton, cattle, shoats, poultry and off-farm work.
Fish-based	Found along coasts, lakes and rivers across Africa with medium-high access to services, with fish a major livelihood. Other livelihood sources include coconuts, cashew, banana, yams, fruit, goats, poultry and off-farm work.

Source: Dixon, J. et al. (2020). ‘Africa through the farming systems lens: context and approach’ in J. Dixon et al. (eds) *Farming Systems and Food Security in Africa: Priorities for Science and Policy under Global Change.* London and New York: Routledge, pp. 3-36

G. Demographic, Economic, Water Resources, Service Coverage and Energy Data

	Demographics						Economics				Climate Readiness, Poverty			
Country	**Total pop (M)**	**Pop growth/ yr (%)**	**Pop project 2050**	**Rural pop (%)**	**Urban slum (%)**	**Largest city (%)**	**GDP/ cap (US$)**	**GDP growth/ year %**	**Agric (%)**	**Cereal import ratio %**	**ND-GAIN and (rank)**	**ND-GAIN Vuln**	**Below US$1.9/ day (%)**	**Food insec (%)**
Central African Republic	4.8	1.8	8.2	58	95	43	493	0.8	32	40	28.9 (181)	165	71	81
Cameroon	26	2.5	55.5	42	34	26	1537	0.5	17	29	39.2 (145)	124	26	56
Equatorial Guinea	1.4	3.4	3.8	28	65	41	7143	-4.9	3	100	39.7 (142)	106	ND	ND
Gabon	2.2	2.4	4.5	10	37	41	6882	-1.8	7	91	43.2 (118)	89	3	ND
Republic of Congo	5.5	2.5	11.5	32	48	64	1846	-7.9	9.5	83	35.6 (166)	137	40	88
Democratic Rep of Congo	89.5	3.1	224.7	54	78	35	544	1.7	21	22	32.3 (178)	175	77	69
Angola	32.9	3.2	84.6	33	49	38	1776	-5.4	9.5	42	37.4 (160)	134	50	74
Reg %	–	*2.7*	–	*46*	*61*	–	–	*-2.4*	–	–	–	–	–	–
Reg % excl UMI	–	–	–	*47*	*62*	–	–	–	–	–	–	–	62	–
Total number	*162*	–	*393*	–	–	–	–	–	–	–	–	–	–	–

Data sources and notes:

<u>Demographics</u>
Total population, rural population, population growth rate, largest city: World Development Indicators, 2020 data (accessed May 2022).
Slum population: World Development Indicators, 2018 data (accessed May 2022). Note: represents proportion of urban pop living in slum households, defined as households lacking >1 basic conditions (improved water & sanitation, sufficient living area, housing durability, secure tenure). Original data from UN-HABITAT.
Pop projection to 2050: authors' own calculation applying growth rate to initial 2020 population and compounding to 2050.
<u>Economics</u>

GDP/capita, growth and agric as a % GDP: World Development Indicators, 2020 data (accessed May 2022). Note: countries shaded red defined a low income (<USD1085), orange lower-middle income (USD1086 – USD 4255) and yellow upper-middle income (USD 4256 – USD 13,205 by World Bank, 2023 fiscal year update.
Cereal import dependency ratio %: FAO/WFP estimate 2017-21 five-year average (FAOSTAT accessed May 2022). Note: provides a measure of dependence on cereal imports; the bigger the number, the higher the dependence (cereals include wheat, rice, and coarse grains - maize, barley, sorghum, millet, rye and oats).
Climate readiness, poverty
ND GAIN score & rank: Notre Dame Global Adaptation Initiative, Index of 182 countries using a score indicating a country's vulnerability to climate change and other env pressures plus readiness to improve resilience. Data from July 2021 update, accessed May 2022. See https://gain.nd.edu/
Food insecure % population: Prevalence of moderate or severe food insecurity in the population, FAO estimates 2018-20 (3 yr average). FAOSTAT accessed May 2022. Note: Indicator 2.1.2 in SDG framework to monitor target 2.1: 'By 2030 end hunger and ensure access by all people…to safe, nutritious and sufficient food year-round'
% living below USD1.90/day poverty line (2011 PPP): World Development Indicators citing most recent data various years (accessed May 2020). Data for CAR (2020); Cameroon (2014), Gabon (2017), Republic of Congo (2011), DRC (2012), Angola (2018). Note: poverty headcount ratio at current <USD1.90 threshold of extreme poverty defined by World Bank.
Regional (Reg) total and %
Excl UMI: excluding upper-middle income countries, i.e. low and lower-middle income countries only (see Economics above). Note: % calculations adjusted for different country populations.

	Water resources, withdrawals									**Access to basic services: water, sanitation, electricity**						**Hydro**
Country	**Water/ cap (m^3)**	**Int water/ cap (m^3)**	**Dep ratio (%)**	**Water stress (%)**	**Water with/ cap (m^3)**	**Irrig area (%)**	**Agric with (%)**	**Indust with (%)**	**Munic with (%)**	**Basic water all (%)**	**Basic water rural %**	**Basic san all (%)**	**Basic san rural %**	**Elec all (%)**	**Elec rural (%)**	**Hydro (%)**
Central African Republic	30,216	30,216	0.0	0.3	16	0	0.6	17	83	37	28	14	6	15	2	88
Cameroon	11,229	10,826	3.6	1.6	43	0.3	68	10	23	66	44	45	23	65	25	54
Equatorial Guinea	19,863	19,863	0.0	0.2	15	ND	5	15	80	64	31	66	57	67	1	20
Gabon	78,329	77,385	1.2	0.5	66	1.2	29	10	61	85	45	50	40	92	28	40-50
Republic of Congo	158,647	42,331	73.3	0.03	17	0.3	4	26	69	74	46	20	6	50	15	ND
Democratic Rep of Congo	15,261	10,705	29.9	0.2	8	0.1	11	21	68	46	22	15	11	19	1	98
Angola	4817	4804	0.3	1.9	23	1.6	21	34	45	57	28	52	24	47	7	56
Reg %	_	_	_	_	_	_	_	_	_	*53*	*27*	*28*	*15*	*34*	*6*	_
Reg % excl UMI	_	_	_	_	_	_	_	_	_	*52*	*27*	*28*	*14*	*33*	*6*	_

Data sources and notes:

Water resources, withdrawals

Water avail/capita: total renewable water resources (internal & external sources) per capita, 2018 estimates (m^3/person/year) (FAO-AQUASTAT, accessed May 2022).

Int water/cap: total internal renewable water resources (excluding inflows from neighbouring countries) per capita, 2018 estimates (m^3/person/year) (FAO-AQUASTAT, accessed May 2022).

Dep ratio %: percentage of renewable water originating outside country, 2018 estimates (FAO-AQUASTAT, accessed May 2022.

Water stress %: SDG 6.4.2 water withdrawals as a percentage of renewable freshwater, 2018 estimates (FAO-AQUASTAT, accessed May 2022). Note: countries where this % falls in the 0-25% bracket are classified as 'no stress' (blue colour) in the SDG 6.4.2 monitoring framework.

Water with/cap: total water withdrawals per capita, 2018 estimates (m^3/year/person) (FAO AQUASTAT, accessed May 2022).

Irrigated area %: percentage of arable land equipped for irrigation, 2016-18 average (FAOSTAT, accessed May 2022). Note: includes full and partial control irrigation, including pastures and spate irrigation.

Agric, Indus and Munic with %: water withdrawals by sector as a % of total withdrawals (agriculture (A), industrial (I), municipal (M)), 2018 estimates (FAO-AQUASTAT, accessed May 2022).

Access to basic services: water, sanitation, electricity

Access basic water: % of population with access to at least basic water services, 2020 data (WHO/UNICEF 2021). Note: basic means from an improved source, collection time <30 mins.

Rural water %: as above, rural only.

Access basic san: % of population with access to at least basic sanitation, 2020 data (WHO/UNICEF 2021). Note: improved facilities i.e. not shared with other households.

Rural san: as above, rural only.

Access electric: % of population with access to electricity, 2020 data except for Angola (2018) (World Development Indicators, accessed May 2022).

Hydropower

Hydro %: contribution of hydropower to total installed capacity. Various sources for period 2015-20, including International Hydropower Association (IHA) annual reports, World Bank Country Profiles, USAID-Power Africa fact sheets. Note: a measure of hydro % of total installed capacity, i.e. the max design output of a project/scheme (on grid).

Regional (Reg) total and %

Excl UMI: excluding upper-middle income countries, i.e. low and lower-middle income countries only (see Economics above). Note: % calculations adjusted for different country populations.

H: Glossary

Acronyms

Table F1: A table of acronyms used in this report is provided below.

AR5	IPCC 5th Assessment Report
AR6	IPCC 6th Assessment Report
CMIP5	Coupled Model Intercomparison Project Phase 5
CMIP6	Coupled Model Intercomparison Project Phase 6
CORDEX	CoOrdinated Regional climate modelling Downscaling EXperiment
ENSO	El Niño Southern Oscillation
FCDO	Foreign, Commonwealth & Development Office (UK Government)
GCM	Global Climate Model
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GMST	Global Mean Surface Temperature
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
MHW	Marine Heat Waves
MJO	Madden-Julian Oscillation
NAO	North Atlantic Oscillation
NBS	Nature-Based Solutions
NCD	Non-Communicable Diseases
ODI	Overseas Development Institute
QBO	Quasi-Biennial Oscillation
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RVF	Rift Valley Fever
SDG	Sustainable Development Goal
SES	Semi-Enclosed Seas
SLR	Sea Level Rise
SSP	Shared Socio-economic Pathway
SST	Sea Surface Temperature
SSA	sub-Saharan Africa
SWI	Saltwater Intrusion
UHI	Urban Heat Island
UNFCCC	United Nations Framework Convention on Climate Change
WASH	Water, Sanitation and Hygiene
WCRP	World Climate Research Project
WHO	World Health Organisation

Technical terms

Term	Definition
Adaptation	In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.
Aerosols	A suspension of airborne solid or liquid particles, with a typical size between a few nanometres and 10 μm that reside in the atmosphere for at least several hours. Aerosols may be of either natural or anthropogenic origin. Aerosols may influence climate in several ways: through both interactions that scatter and/or absorb radiation and through interactions with cloud microphysics and other cloud properties, or upon deposition on snow- or ice-covered surfaces thereby altering their albedo and contributing to climate feedback.
Agropastoral [livelihood]	Mixed crop-livestock farming found in semi-arid (medium rainfall) areas of Africa, typically with low access to services. It includes the dryland mixed farming system of North Africa, often depending on wheat, barley and sheep. In SSA the main food crops are sorghum and millet, and livestock are cattle, sheep and goats. In both cases, livelihoods include pulses, sesame, poultry and off-farm work.
Anomaly	The deviation of a variable from its value averaged over a reference period.
Anthropogenic	Resulting from or produced by human activities.
Atlantic Multi-decadal Variability (AMV)	Large-scale fluctuations observed from one decade to the next in a variety of instrumental records and proxy reconstructions over the entire North Atlantic Ocean and surrounding continents. Fingerprints of AMV can be found at the surface ocean, which is characterized by swings in basin-scale sea surface temperature anomalies reflecting the interaction with the atmosphere. The positive phase of the AMV is characterized by anomalous warming over the entire North Atlantic, with the strongest amplitude in the subpolar gyre and along sea ice margin zones in the Labrador Sea and Greenland/Barents Sea and in the subtropical North Atlantic basin to a lower extent.
Atmosphere	The gaseous envelope surrounding the earth, divided into five layers – the *troposphere* which contains half of the Earth's atmosphere, the *stratosphere*, the mesosphere, the thermosphere, and the exosphere, which is the outer limit of the atmosphere.
Arid pastoral and oasis [livelihood]	Extensive pastoralism and scattered oasis farming associated with sparsely settled arid zones across Africa, generally with very poor access to

	services. Livelihoods include date palms, cattle, small ruminants and off-farm work, irrigated crops and vegetables.
Baseline	The state against which change is measured. It might be a 'current baseline,' in which case it represents observable, present-day conditions. It might also be a 'future baseline,' which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines.
Biodiversity	The variability among living organisms from terrestrial, marine, and other ecosystems. Biodiversity includes variability at the genetic, species, and ecosystem levels.
Carbon Dioxide (CO2)	A naturally occurring gas, CO2 is also a by-product of burning fossil fuels (such as oil, gas and coal), of burning biomass, of land-use changes (LUC) and of industrial processes (e.g., cement production). It is the principal anthropogenic greenhouse gas (GHG) that affects the Earth's radiative balance.
Catchment	An area that collects and drains precipitation.
Cereal-root crop mixed [livelihood]	Mixed farming with medium-high access to services dominated by at least two starchy staples (typically maize and sorghum) alongside roots and tubers (typically cassava) found in the subhumid savannah zone in West and Central Africa. Other livelihood sources include legumes, cattle and off-farm work.
Climate	In a narrow sense, climate is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization.
Climate Change	A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer.
Climate Feedback	An interaction in which a perturbation in one climate quantity causes a change in a second and the change in the second quantity ultimately leads to an additional change in the first. A negative feedback is one in which the initial perturbation is weakened by the changes it causes; a positive feedback is one in which the initial perturbation is enhanced.
Climate Information	Information about the past, current state, or future of the climate system that is relevant for mitigation, adaptation and risk management. It may be tailored or "co-produced" for specific contexts, taking into account users' needs and values.
Climate Impacts	

	Impacts describe the consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability.
Climate Indicator	Measures of the climate system including large-scale variables and climate proxies.
Climate Mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
Climate Model	A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties.
Climate Projection	The simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHG) and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.
Climate Risk	The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence.
Climate System	The highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere and the interactions between them.
Climate Variability	Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate at all spatial and temporal scales beyond that of individual weather events.
Communicable Disease	Refers to an illness caused by an infectious agent or its toxins that occurs through the direct or indirect transmission of the infectious agent or its products from an infected individual or via an animal, vector or the inanimate environment to a susceptible animal or human host (CDC, 2012).
Confidence	The robustness of a finding based on the type, amount, quality and consistency of evidence (e.g., mechanistic understanding, theory, data,

	models, expert judgment) and on the degree of agreement across multiple lines of evidence.
Crop Water Deficit	A water deficit occurs whenever water loss exceeds absorption. The use of total water potential as the best single indicator of plant water status has its limitations while attempting to understand the effect of water deficits on the various physiological processes involved in plant growth. Water deficits reduce photosynthesis by closing stomata, decreasing the efficiency of the carbon fixation process, suppressing leaf formation and expansion, and inducing shedding of leaves.
Disaster	A 'serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts' (UNGA, 2016).
Deltaic	Of or pertaining to a river delta.
Downscaling	A method that derives local- to regional-scale (up to 100 km) information from larger-scale models or data analyses.
El Niño Southern Oscillation (ENSO)	The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. It has since become identified with warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere–ocean phenomenon, with preferred time scales of two to about seven years, is known as the El Niño-Southern Oscillation (ENSO). The cold phase of ENSO is called La Niña.
Emissions Scenario	A plausible representation of the future development of emissions of substances that are radiatively active (e.g., greenhouse gases (GHGs), aerosols) based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological change, energy and land use) and their key relationships.
Enhanced Greenhouse Effect	The process in which human activities have added additional greenhouse gases into the atmosphere, this has resulted in a 'stronger' greenhouse gas effect as there are more gases available to trap outgoing radiation.
Evaporation	The physical process by which a liquid (e.g., water) becomes a gas (e.g., water vapour).
Evapotranspiration	The process in which water moves from the earth to the air from evaporation (= water changing to a gas) and from transpiration (= water lost from plants).

Exposure	Exposure describes the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.
Extreme/heavy precipitation event	An extreme/heavy precipitation event is an event that is of very high magnitude with a very rare occurrence at a particular place. Types of extreme precipitation may vary depending on its duration, hourly, daily or multi-days (e.g., 5 days), though all of them qualitatively represent high magnitude. The intensity of such events may be defined with block maxima approach such as annual maxima or with peak over threshold approach, such as rainfall above 95th or 99th percentile at a particular space.
Fifth Assessment Report (AR5)	A series of IPCC reports published in 2013-2014, reports are divided into publications by three working groups.
Fish-based [livelihood]	Found along coasts, lakes and rivers across Africa with medium-high access to services, with fish a major livelihood. Other livelihood sources include coconuts, cashew, banana, yams, fruit, goats, poultry and off-farm work.
Fossil Fuels	Carbon-based fuels from fossil hydrocarbon deposits, including coal, oil, and natural gas.
Global Breadbasket	The term "breadbasket" is used to refer to an area with highly arable land. The breadbaskets of the world are the regions in the world that produce food, particularly grains to feed their people as well as for export to other places.
Global Warming	The estimated increase in global mean surface temperature (GMST) averaged over a 30-year period, or the 30-year period centred on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year periods that span past and future years, the current multi-decadal warming trend is assumed to continue.
Greenhouse Effect	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect.
Greenhouse Gas (GHG) Concentrations	Lead to an increased infrared opacity of the atmosphere and therefore to an effective radiation into space from a higher altitude at a lower temperature. This causes a radiative forcing that leads to an enhancement of the greenhouse effect, the so-called enhanced greenhouse effect.
Greenhouse Gases (GHGs)	The gaseous constituents of the atmosphere. both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes

	the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHGs in the Earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). [IPCC, 2018].
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.
Heat Stress	A range of conditions in, e.g., terrestrial or aquatic organisms when the body absorbs heat during overexposure to high air or water temperatures or thermal radiation. In aquatic water breathing animals, hypoxia and acidification can exacerbate vulnerability to heat. Heat stress in mammals (including humans) and birds, both in air, is exacerbated by a detrimental combination of ambient heat, high humidity and low wind-speeds, causing regulation of body temperature to fail.
Heatwave	A period of abnormally hot weather often defined with reference to a relative temperature threshold, lasting from two days to months. Heatwaves and warm spells have various and, in some cases, overlapping definitions.
Highland mixed [livelihood]	Highland mixed farming above 1700 m dominated by wheat and barley, found predominantly in subhumid north-east Africa with pockets in Southern, West and North Africa. Other livelihood sources include teff, peas, lentils, broad beans, rape, potatoes, sheep, goats, cattle, poultry and off-farm work.
Highland perenniall [livelihood]	Highland perennial farming is characterized by a dominant perennial crop (banana, plantains, enset or coffee) and good market access, and is found in humid East African highlands. Other livelihoods derive from diversified cropping including maize, cassava, sweet potato, beans, cereals, livestock and poultry augmented by off-farm work.
Ice sheet	An ice body originating on land that covers an area of continental size, generally defined as covering >50,000km^2, and that has formed over thousands of years through accumulation and compaction of snow. [IPCC, 2019].
Impacts	Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system.
Indian Ocean Basin Mode (IOB)	The Indian Ocean basin (IOB) mode is a mode of interannual variability characterized by a temporal alternation of basin-wide warming and cooling

	of the Indian Ocean sea surface. It mostly develops in response to El Niño–Southern Oscillation (ENSO), but often persists after ENSO's equatorial eastern Pacific signal has dissipated. The IOB affects atmospheric circulation, temperature, and precipitation in South, South East, and East Asia as well as Africa, and modulates tropical cyclone activity in the north-western Pacific.
Indian Ocean Dipole (IOD and SIOD)	The Indian Ocean Dipole (IOD) is an irregular oscillation of sea surface temperatures in which the western Indian Ocean becomes alternately warmer (positive phase) and then colder (negative phase) than the eastern part of the ocean. The Subtropical Indian Ocean Dipole (SIOD) is featured by the oscillation of sea surface temperatures (SST) in which the southwest Indian Ocean (i.e. south of Madagascar is warmer) and then colder than the eastern part i.e. off Australia.
Intergovernmental Panel on Climate Change (IPCC)	The leading international body for the assessment of climate change. Scientists come together approximately every six years, to assess peer-reviewed research in working groups to generate three reports including the Physical Science Basis, impact adaptation and vulnerability, and Mitigation of Climate Change.
Intertropical Convergence Zone (ITCZ)	The Intertropical Convergence Zone (ITCZ) is a band of low pressure around the Earth which generally lies near to the equator. The trade winds of the northern and southern hemispheres come together here, which leads to the development of frequent thunderstorms and heavy rain.
Irrigated [livelihood]	Large-scale irrigation schemes associated with large rivers across Africa, e.g. Nile. Often located in semi-arid and arid areas but with medium-high access to services. Includes the associated surrounding rainfed lands. Diversified cropping includes irrigated rice, cotton, wheat, faba, vegetables and berseem augmented by cattle, fish and poultry.
Maize mixed [livelihood]	Mixed farming dominated by maize with medium access to services in subhumid areas of East, Central and Southern Africa. Other livelihood sources include legumes, cassava, tobacco, cotton, cattle, goats, poultry and off-farm work.
Marine heatwave	A period during which water temperature is abnormally warm for the time of the year relative to historical temperatures with that extreme warmth persisting for days to months. The phenomenon can manifest in any place in the ocean and at scales of up to thousands of kilometres.
Mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
Nature-Based Solutions (NBS)	Nature-based solutions (NBS) refers to the sustainable management and use of nature for tackling socio-environmental challenges. The challenges include issues such as climate change, water security, water pollution, food security, human health, biodiversity loss and disaster risk management.

Ocean acidification	A reduction in the pH of the ocean, accompanied by other chemical changes (primarily in the levels of carbonate and bicarbonate ions), over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide (CO2) from the atmosphere, but can also be caused by other chemical additions or subtractions from the ocean. Anthropogenic ocean acidification refers to the component of pH reduction that is caused by human activity.
Overharvested	Refers to harvesting a renewable resource to the point of diminishing returns.
Pacific Decadal Variability (PDV)	The PDV is the coupled decadal-to-interdecadal variability of the atmospheric circulation and underlying ocean that is typically observed over the entire Pacific Basin beyond the El Niño–Southern Oscillation (ENSO) time scale. Typically, the positive phase of the PDV is characterized by anomalously high sea surface temperatures in the central-eastern tropical Pacific that extend to the extratropical North and South Pacific along the American coasts, encircled to the west by cold sea surface anomalies in the mid-latitude North and South Pacific. The negative phase is accompanied by sea surface temperature anomalies of the opposite sign. Those sea surface temperature anomalies are linked to anomalies in atmospheric and oceanic circulation throughout the whole Pacific Basin. The PDV is associated with decadal modulations in the relative occurrence of El Niño and La Niña.
Paris Agreement	The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on December 2015 in Paris, France, at the 21st session of the Conference of the Parties (COP) to the UNFCCC. The agreement, adopted by 196 Parties to the UNFCCC, entered into force on 4 November 2016 and as of May 2018 had 195 Signatories and was ratified by 177 Parties. One of the goals of the Paris Agreement is 'Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels', recognising that this would significantly reduce the risks and impacts of climate change. Additionally, the Agreement aims to strengthen the ability of countries to deal with the impacts of climate change.
Pastoral [livelihood]	Extensive pastoralism (dominated by cattle), found in dry semiarid (low rainfall) areas with poor access to services. Other livestock include camels, sheep and goats alongside limited cereal cropping, augmented by off-farm work.
Pelagic Fish	Pelagic fish live in the pelagic zone of ocean or lake waters – being neither close to the bottom nor near the shore.
Projection/projected	A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are

	conditional on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised.
Radiative Forcing	The change in the net, downward minus upward, radiative flux (expressed in W m-2) at the tropopause or top of atmosphere due to a change in a driver of climate change, such as a change in the concentration of carbon dioxide (CO2) or the output of the sun.
Reanalysis	Atmospheric and oceanic analyses of temperature, wind, current and other meteorological and oceanographic quantities, created by processing past meteorological and oceanographic data using fixed state-of-the-art weather forecasting models and data assimilation techniques.
Representative Concentration Pathways (RCPs)	Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover.
Resilience	The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation.
Resolution	In climate models, this term refers to the physical distance (metres or degrees) between each point on the grid used to compute the equations. Temporal resolution refers to the time step or time elapsed between each model computation of the equations.
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure and hazard.
Root and tuber crop [livelihood]	Lowland farming dominated by roots and tubers (yams, cassava) found in humid areas of West and Central Africa. Other livelihood sources include legumes, cereals and off-farm work.
Runoff	The flow of water over the surface or through the subsurface, which typically originates from the part of liquid precipitation and/or snow/ice melt that does not evaporate or refreeze and is not transpired.
Scenario	A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g. rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts but are used to provide a view of the implications of developments and actions.
Signal	Climate signals are long-term trends and projections that carry the fingerprint of climate change.

Sixth Assessment Report (AR6)	The latest series of IPCC reports published in 2021-2022, reports are divided into publications by three working groups. At the time of writing this report only the Working Group I contribution to the Sixth Assessment Report published in 2021 was available to use.
Soil moisture	Water stored in the soil in liquid or frozen form. Root-zone soil moisture is of most relevance for plant activity.
Southern Annular Mode	Annular modes are hemispheric scale patterns of atmospheric variability characterized by opposing and synchronous fluctuations in sea level pressure between the polar caps and mid-latitudes, with a structure exhibiting a high degree of zonal symmetry, and with no real preferred time scales ranging from days to decades. In each hemisphere, these fluctuations reflect changes in the latitudinal position and strength of the mid-latitude jets and associated storm tracks. Annular modes are defined as the leading mode of variability of extratropical sea level pressure or geopotential heights and are known as the Northern Annular Mode (NAM) and Southern Annular Mode (SAM) in the two hemispheres, respectively.
Special Report on Emissions Scenarios (SRES)	A report by the Intergovernmental Panel on Climate Change (IPCC) that was published in 2000. The SRES scenarios, as they are often called, were used in the IPCC Third Assessment Report (TAR), published in 2001, and in the IPCC Fourth Assessment Report (AR4), published in 2007.
Storm surge	The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place. [IPCC, 2019].
Stream Flow	Water flow within a river channel, for example, expressed in m^3s^{-1}. A synonym for river discharge.
Teleconnection	Association between climate variables at widely separated, geographically fixed locations related to each other through physical processes and oceanic and/or atmospheric dynamical pathways. Teleconnections can be caused by several climate phenomena, such as Rossby wave-trains, mid-latitude jet and storm track displacements, fluctuations of the Atlantic Meridional Overturning Circulation, fluctuations of the Walker circulation, etc. They can be initiated by modes of climate variability thus providing the development of remote climate anomalies at various temporal lags.
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. In climate change analysis, it may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of human behaviour.

United Nations Framework Convention on Climate Change (UNFCCC)	The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in May 1992 and opened for signature at the 1992 Earth Summit in Rio de Janeiro. It entered into force in March 1994 and as of May 2018 had 197 Parties (196 States and the European Union). The Convention's ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.' The provisions of the Convention are pursued and implemented by two treaties: the *Kyoto Protocol* and the *Paris Agreement*. [IPCC, 2018].
Urban Heat Island	The relative warmth of a city compared with surrounding rural areas, associated with changes in runoff, effects on heat retention, and changes in surface albedo.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm, and lack of capacity to cope and adapt.
Weather	The conditions in the air above the earth such as wind, rain, or temperature, especially at a particular time over a particular area.

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