Climate risk report for the East Africa region

Supplementary Document: Appendices

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Image location: Tanzania

Appendix 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.

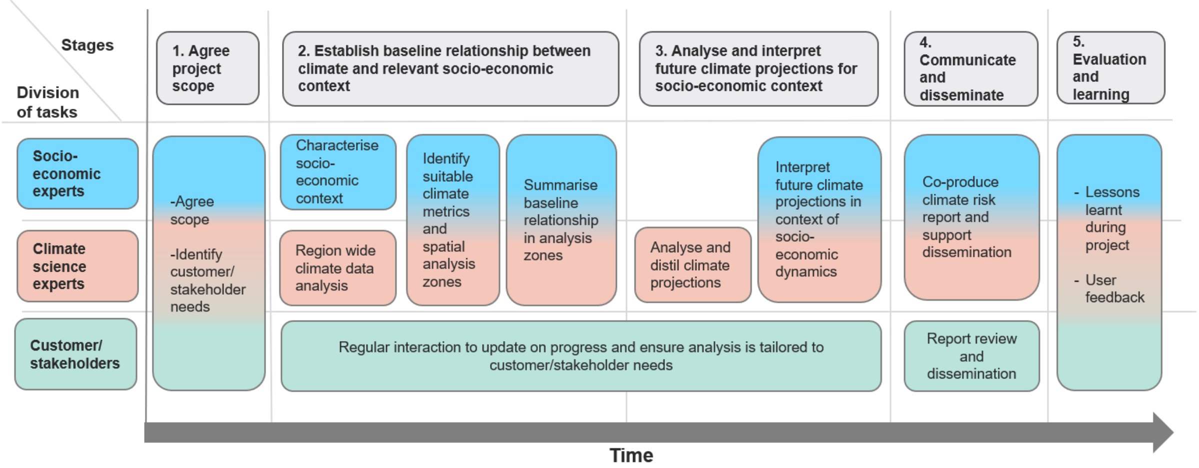

Figure A1 – Schematic diagram of the key stages of the methodology and division of tasks between the socio-economic experts (ODI), climate science experts (Met Office) and customer (FCDO) roles of the project team. This diagram is an initial draft of the Climate in Context methodology[1] currently being developed.

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:

[1] A report documenting the Met Office Climate in Context methodology is in preparation and due to be published in 2021.

- 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

The climate projections in this report came from an ensemble of 30 CMIP5 global climate model simulations (see Table A1), 20 CMIP6 global climate model simulations and 20 regional climate model simulations (see from the CORDEX project (see Table A2). 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), Ntoumos et al., (2020), Oztuek et al., (2018), Syed et al., (2019).

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

Modelling Centre	Model	Institution
BCC	BCC-CSM1-1	Beijing Climate Center, China Meteorological Administration
	BCC-CSM1-1	
CSIRO-BOM	ACCESS1-0	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)
	ACCESS1-3-m	
CCCma	CanESM2	Canadian Centre for Climate Modelling and Analysis
CMCC	CMCC-CM	Centro Euro-Mediterraneo per I Cambiamenti Climatici
	CMCC-CMS	
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	Institut Pierre-Simon Laplace
	IPSL-CM5A-MR	
	IPSL-CM5B-LR	
MIROC	MIROC5	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
	MIROC-ESM	
	MIROC-ESM-CHEM	
MOHC	HadGEM2-CC	Met Office Hadley Centre
	HadGEM2-ES	
MPI-M	MPI-ESM-LR	Max Planck Institute for Meteorology
	MPI-ESM-MR	
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	NASA Goddard Institute for Space Studies
	GFDL-ESM2G	
	GFDL-ESM2M	
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

Appendix B: Climate plots

Additional plots of the baseline climate and projected climate changes for annual and seasonal timescales, in each spatial analysis zone are included in the following sections.

Zone 1: Desert regions of Sudan and Eritrea

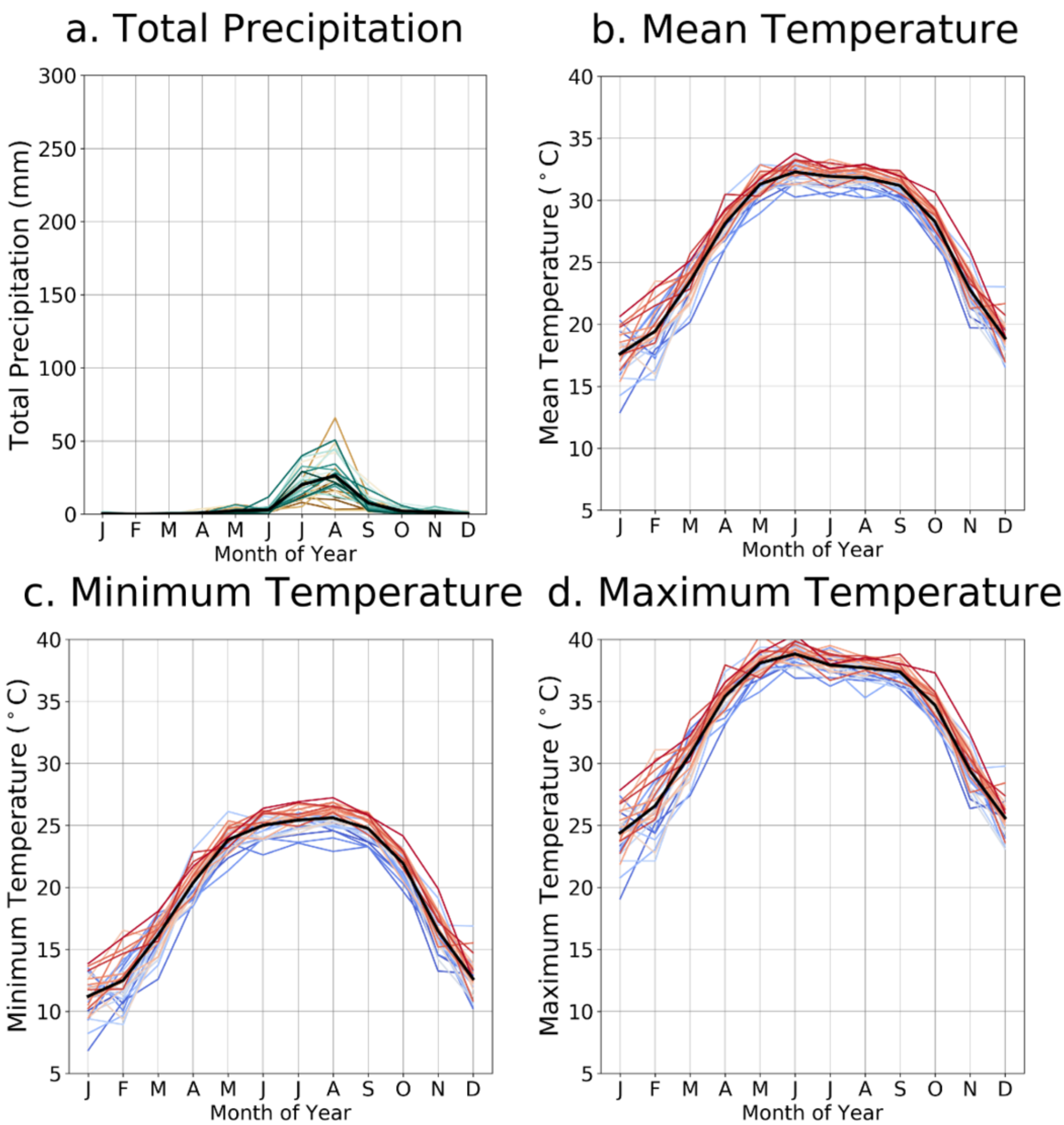

Figure B1: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 1. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean 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. Temperature and precipitation data come from ERA5 and WFDE5 reanalysis datasets respectively.

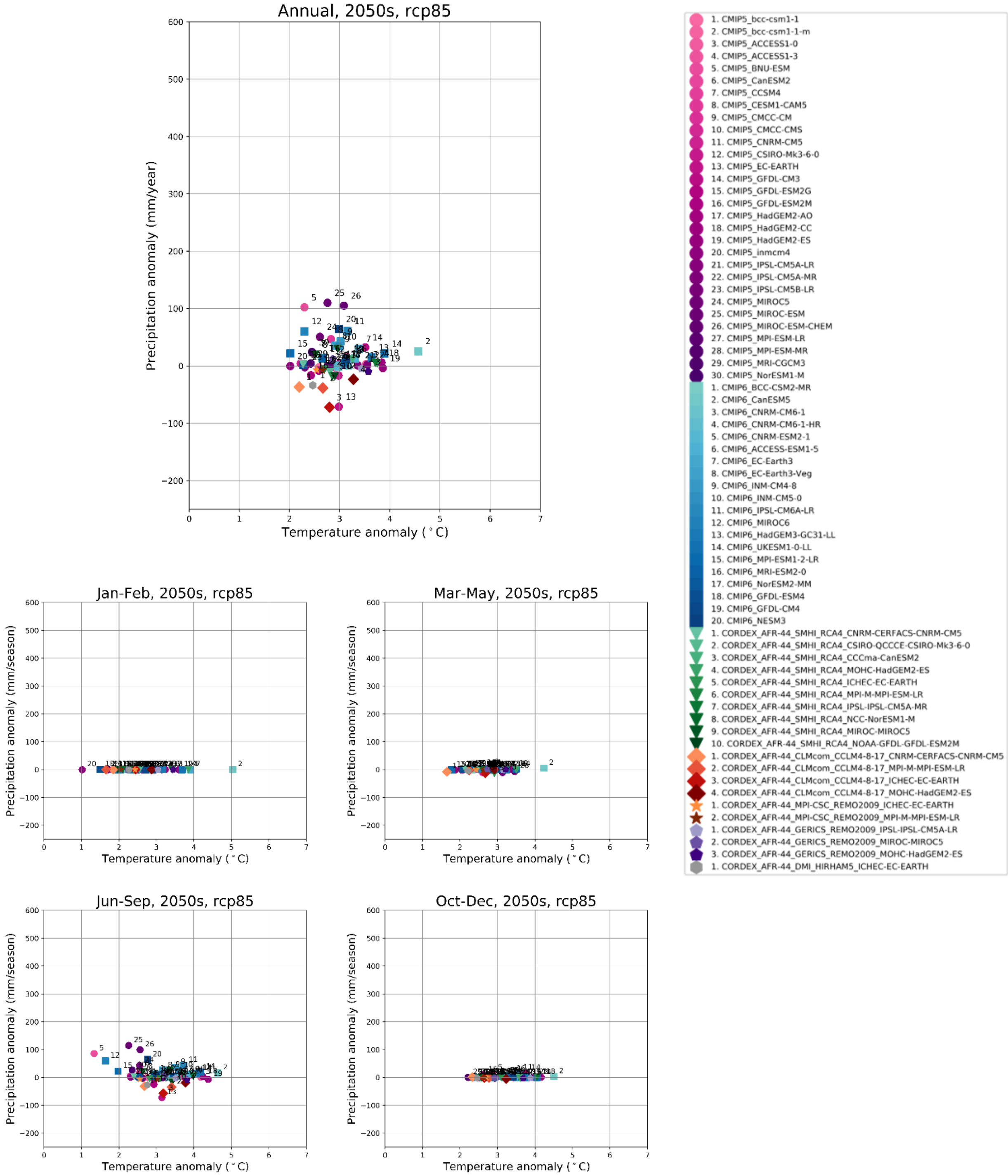

Figure B2: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 1. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Zone 2: Tropical regions of Sudan, South Sudan and Ethiopia

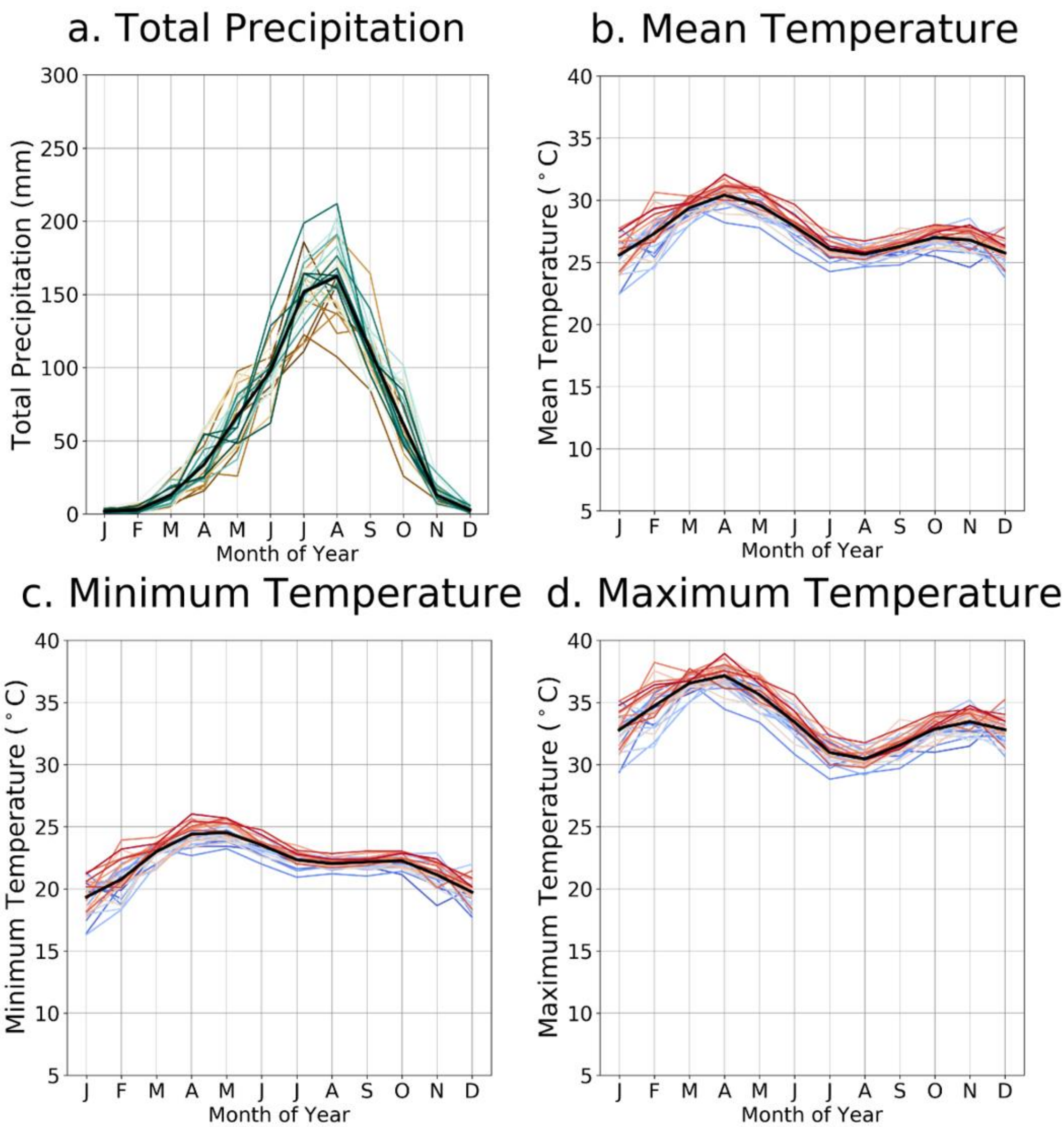

Figure B3: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 2. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean 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. Temperature and precipitation data come from ERA5 and WFDE5 reanalysis datasets respectively.

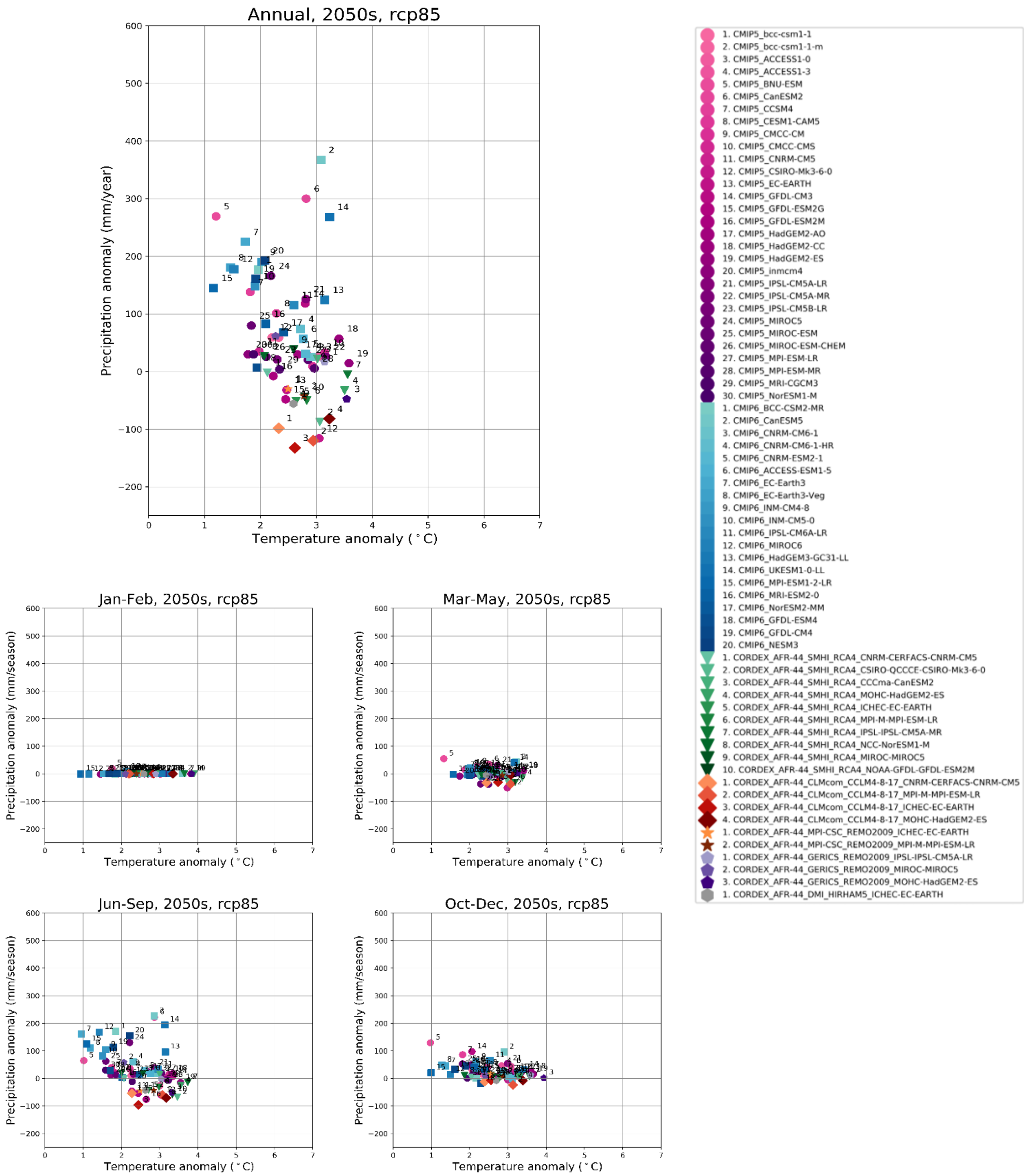

Figure B4: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 2. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Zone 3: Highland regions of Ethiopia and Eritrea

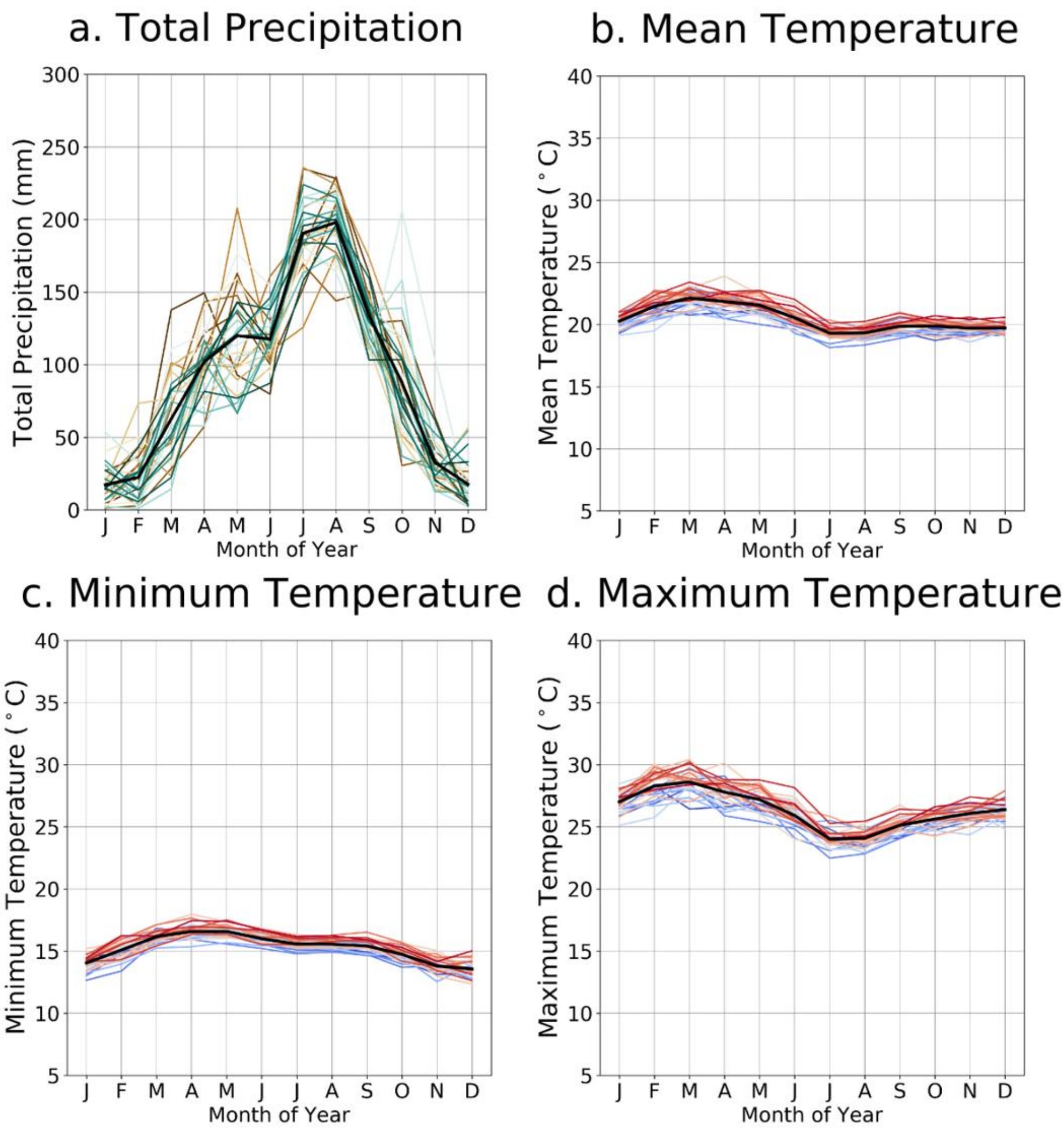

Figure B5: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 3. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean 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. Temperature and precipitation data come from ERA5 and WFDE5 reanalysis datasets respectively.

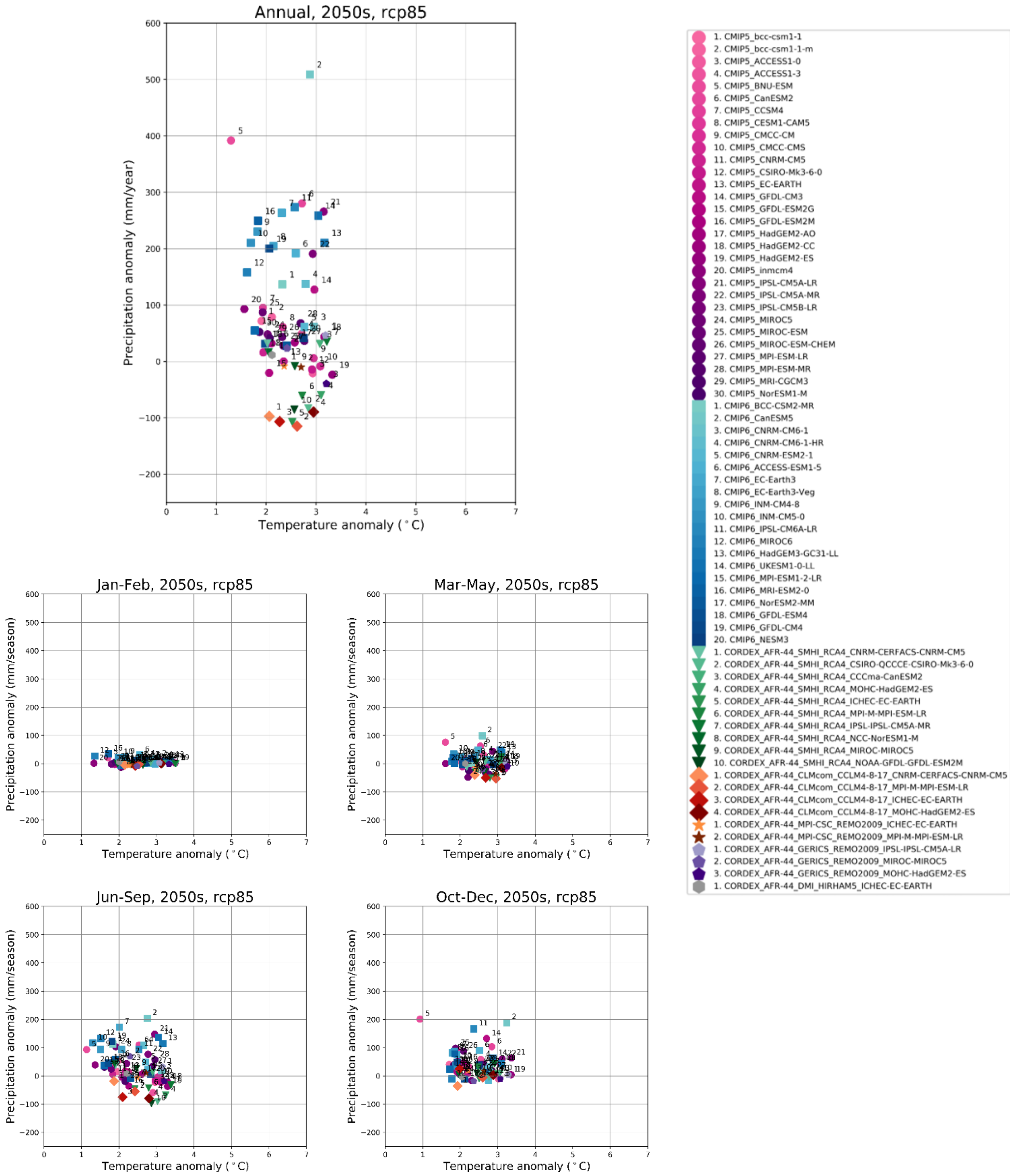

Figure B6: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 3. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Zone 4: Arid and semi-arid regions of the Horn of Africa

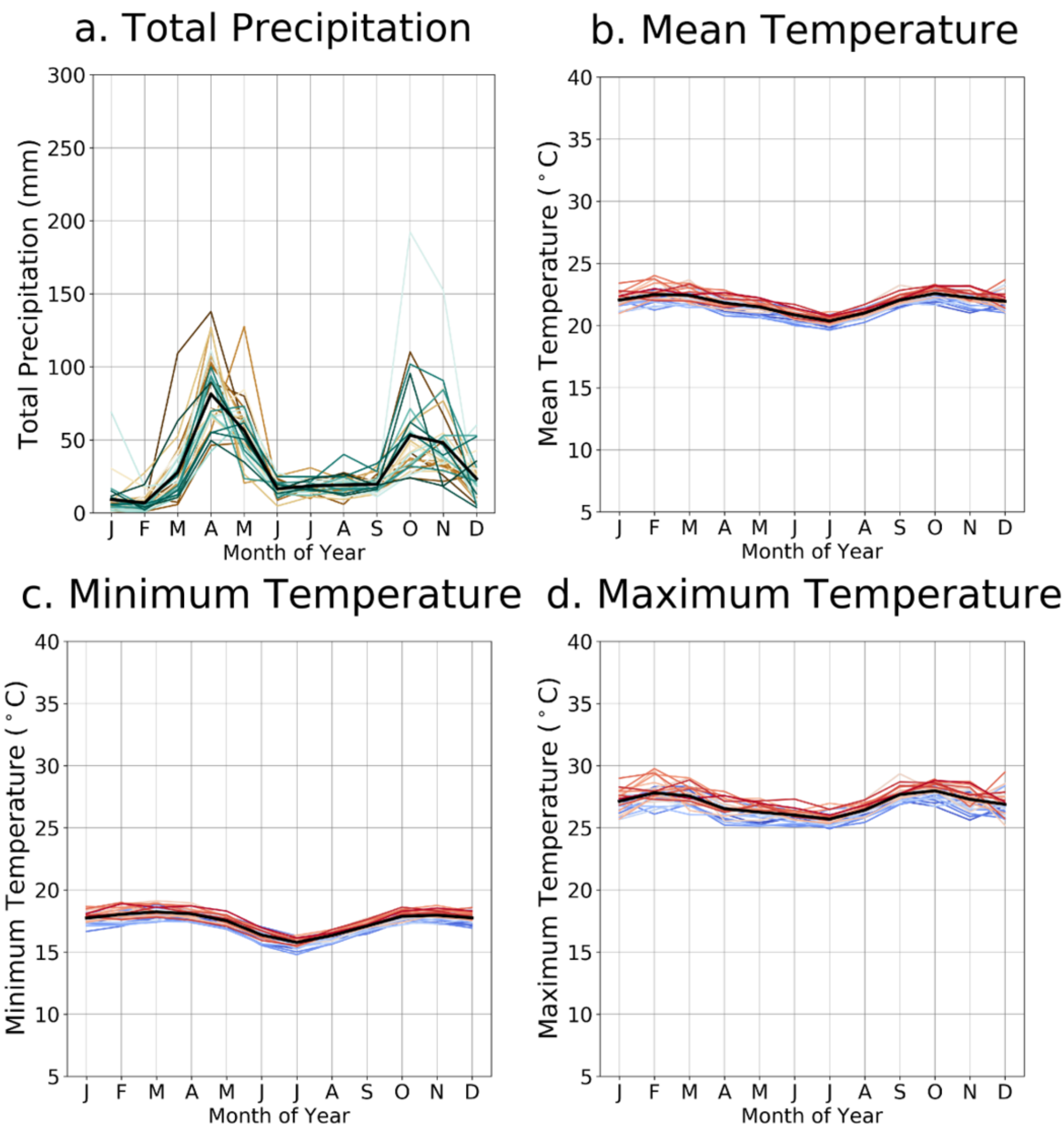

Figure B7: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 4. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean 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. Temperature and precipitation data come from ERA5 and WFDE5 reanalysis datasets respectively.

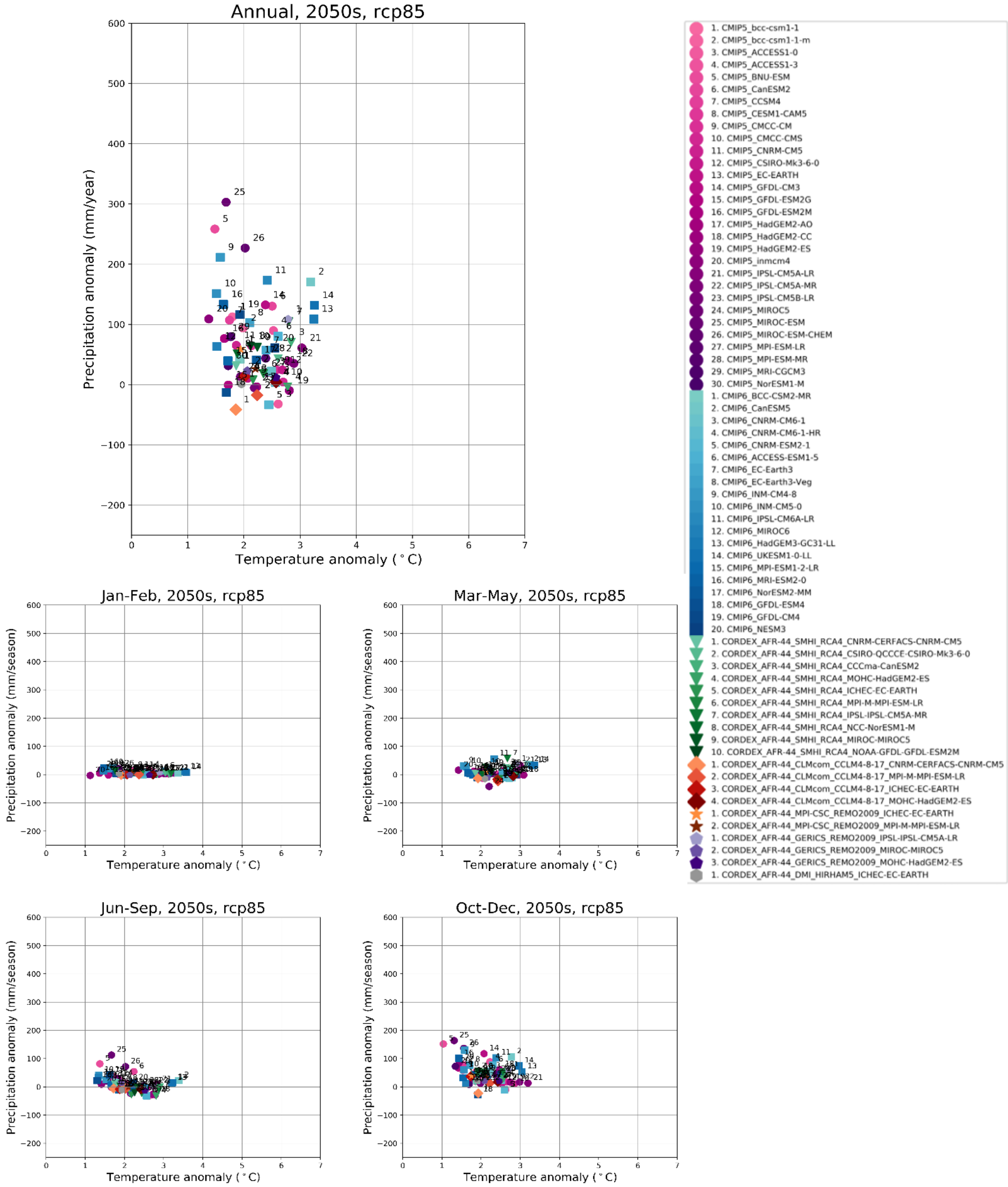

Figure B8: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 4. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Zone 5: Highland regions of the East African Rift

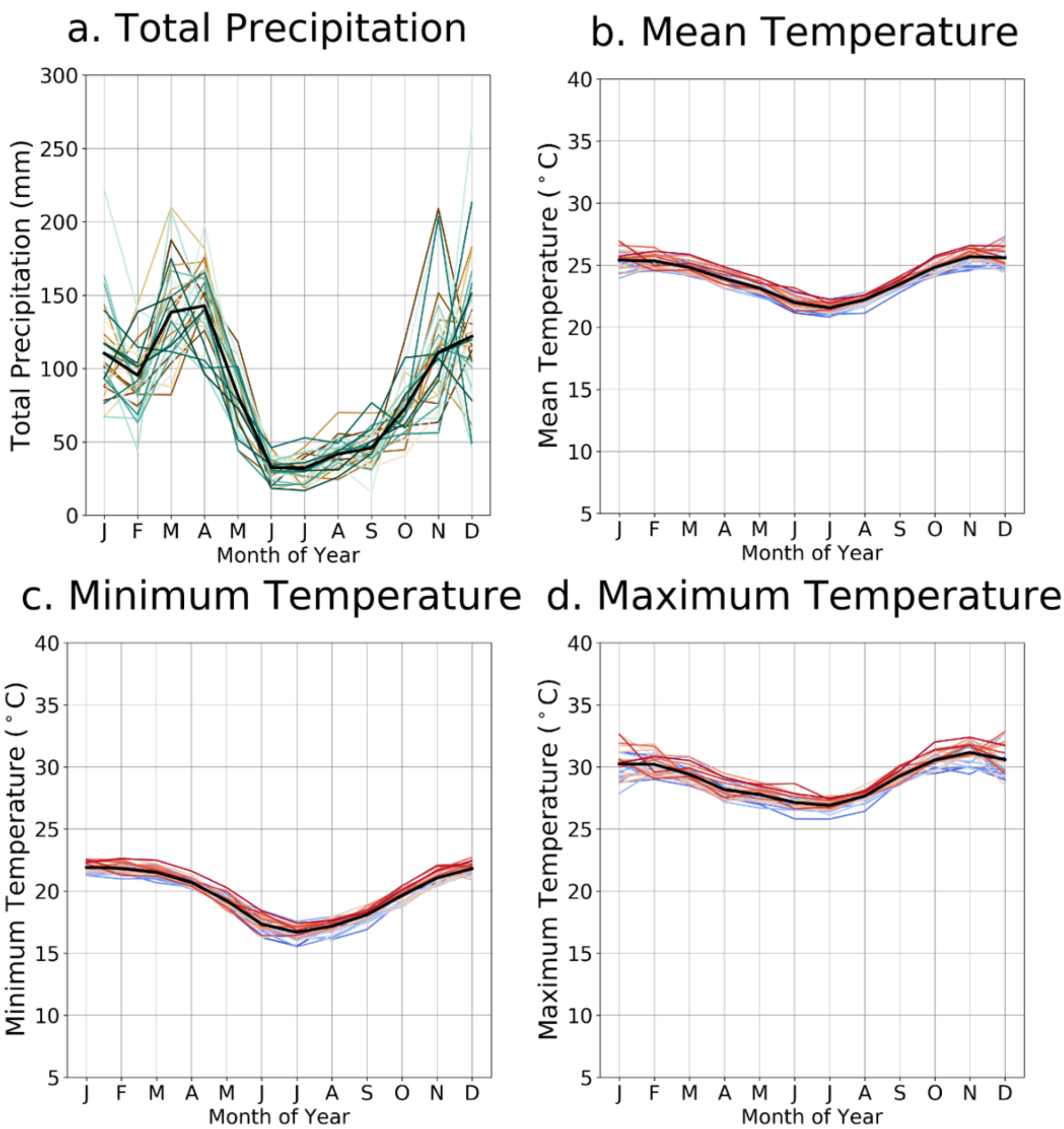

Figure B9: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 5. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean 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. Temperature and precipitation data come from ERA5 and WFDE5 reanalysis datasets respectively.

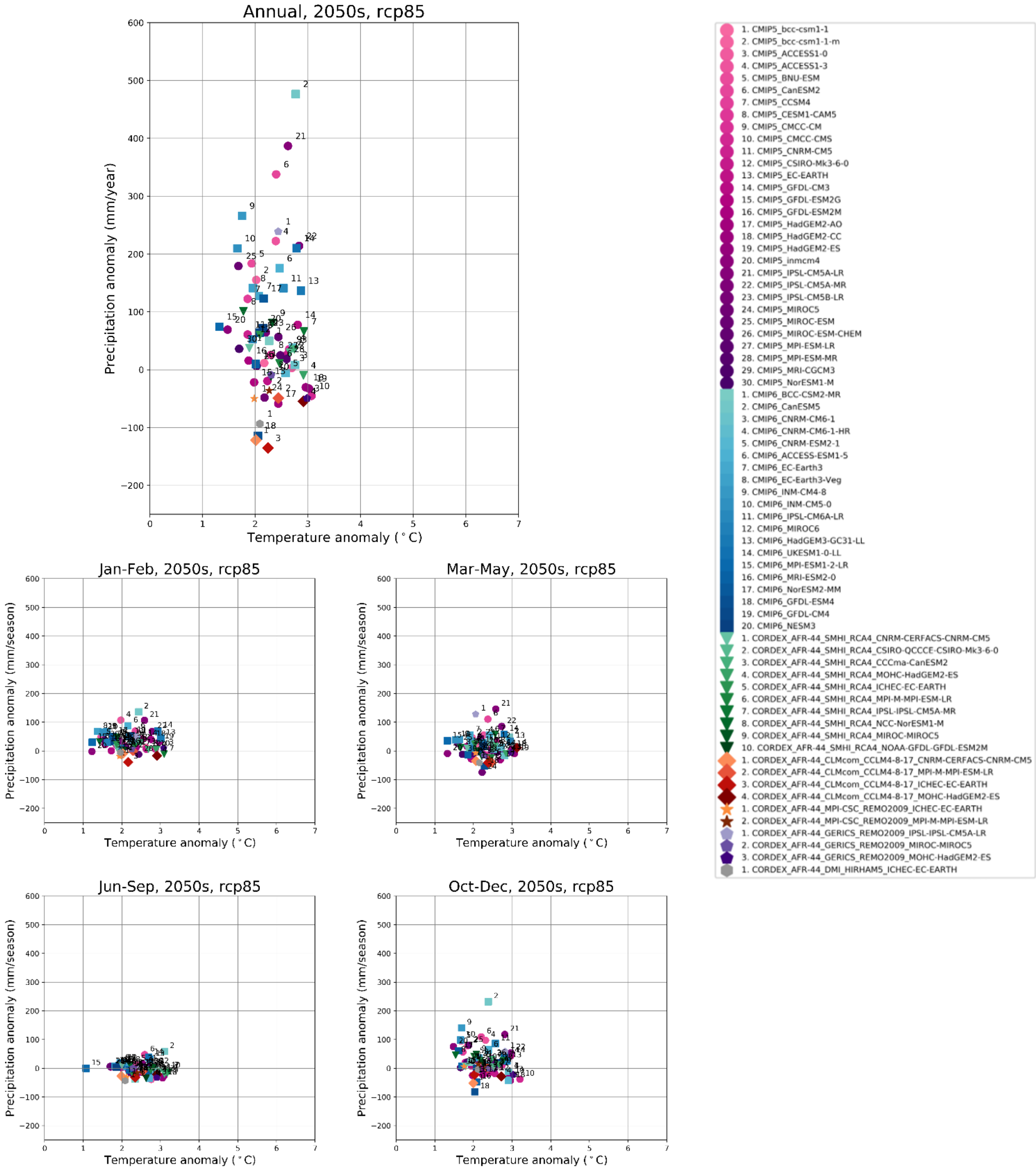

Figure B10: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 5. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Zone 6: Lowland regions of Tanzania

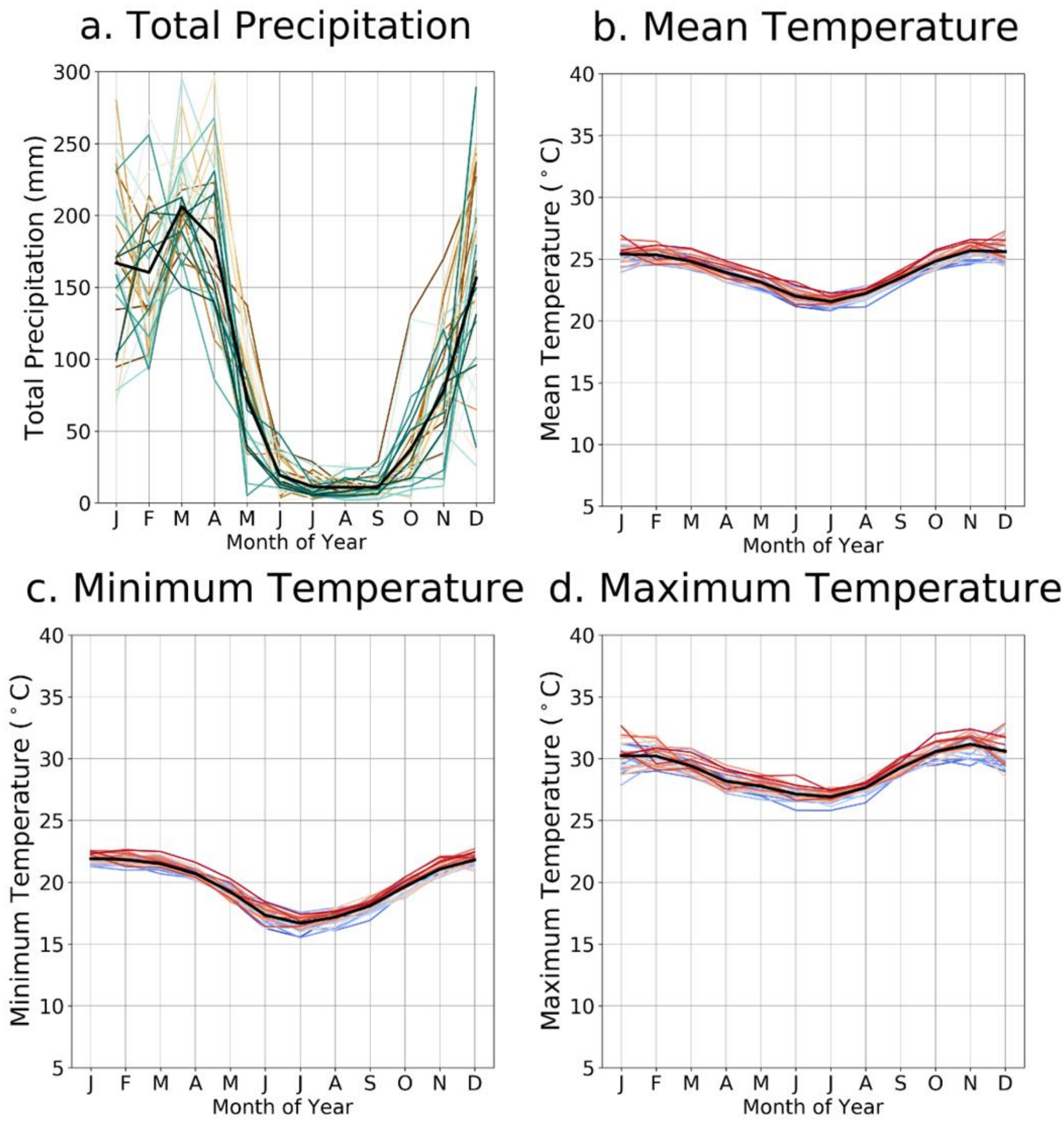

Figure B11: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 6. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean 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. Temperature and precipitation data come from ERA5 and WFDE5 reanalysis datasets respectively.

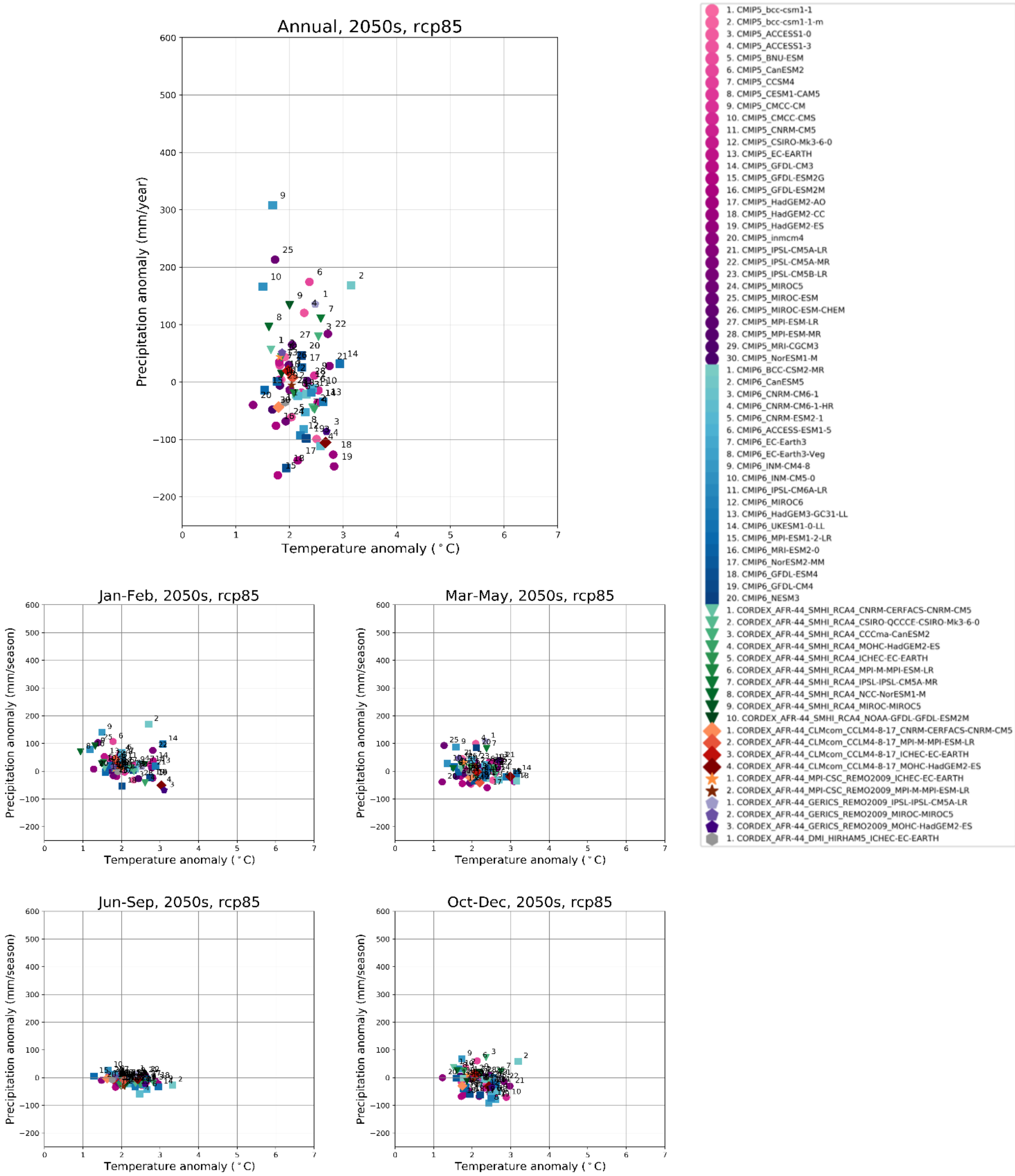

Figure B12: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 6. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Appendix C:

Farming systems in East Africa

This report draws on Dixon et al. (2020)'s 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 1: Key characteristics of farming systems referenced in this report

Farming System	**Key characteristics**
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.
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. 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.
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.
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.

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.
Highland mixed	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.
Pastoral	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.
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.
Irrigated	Large-scale irrigation schemes associated with large rivers across Africa, e.g. Nile, Volta. 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.
Arid pastoral and oasis	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.

Source: Dixon, J., Garrity, D., Boffa, J.-M., Ekberg Coulibaly, A., El-Helepi, M., Auricht, C.M. and Mburathi, G. 2020. 'Africa through the farming systems lens: Context and approach' in Dixon, J., Garrity, D., Boffa, J.-M., Williams, T., Amede, T., with Auricht, C., Lott, R. and Mburathi, G. (eds) Farming systems and food security in Africa: Priorities for science and policy under global change. London and New York: Routledge, pp. 3-36

Table 2: Evidence of climate sensitivities for key East Africa crops

Crop	Zones	Geography and cultivation conditions	Climate sensitivities
Millet	Zone 2, Zone 4, Zone 5	Cultivated mainly in the semiarid tropics and subtropics of Africa; but also cultivated in drought-prone sub-humid and medium-high altitude areas (Obilana, 2003) Hardy crop that requires few inputs, is less susceptible to pests and diseases, and can be grown in the areas that are too hot and dry for sorghum (Cagley et al., 2009) Pearl millet is grown as a dry- land crop in semiarid regions, while finger millet is generally grown in uplands and sub- humid areas (Gari, 2002). Optimum millet growing temperature is 30C	Important for food security due to its adaptation to drought and heat, high nutritive, value and ability to be stored for long periods without quality degradation. CC is expected to raise the temperature in millet-growing areas closer to the optimum temperature, leading to a general increase in millet yield. Quantitative projections show both negative and positive impacts of climate change on millet yield. The discrepancy might be attributed to the difference in scenarios and study areas Millet is more resilient to climate change than maize or wheat but less resilient than sorghum. It is expected that there will be about a 15% yield loss in East Africa by the middle of the century.
Wheat	Zone 5, Zone 1 (irrigated)	Wheat is generally cultivated as a winter rainfed crop in the highlands of Ethiopia, Kenya, Uganda, Rwanda, and Tanzania (Negassa et al. 2012). Wheat is a cool season crop and increasing temperature shortens its growth period by accelerating phonological development, resulting in reduced yield (You et al., 2005; Asseng et al., 2011)	In SSA, average annual temperature in 1990 was 20.3°C in wheat harvest areas, which already exceeded the optimum wheat-growing temperature of 15–20°C (Liu et al. 2008). The exact level of the effects of CC differ by location, but some studies suggest that a 1°C increase in temperature above norm reduces wheat yield by 10% (Brown 2009). Another study reported 3–4% reduction in wheat yield for every 1°C increase in temperature above 15°C (Wardlaw et al. 1989). As wheat has a lower optimum temperature than rice, maize, millet, cassava, and sorghum (Liu et al. 2008), many simulation

			studies have projected a greater impact on wheat yield compared to other crops in East Africa (Liu et al. 2008 ; Fischer 2009 ; Nelson et al. 2009 ; Ringler et al. 2010). The results presented above indicate that wheat is one of the most sensitive crops to climate change.
Teff	Zone 3	major crop in Ethiopian / Eritrean highlands Yumbya et al. (2014) found ideal climatic limits for teff growth to be between 13C – 25C	Distribution of suitable areas for teff likely to shift, especially as temperatures exceed 25C (Yumbya et al., 2014) teff grows better in heavy soils and requires high soil moisture during seedling germination and establishment, but very little or no rain during ripening. ''Green famines'' are caused in Ethiopia by a seasonal pattern shift with delayed rains for several weeks or starting and stopping suddenly in teff's critical germination periods. Consequently, crops are lost while the natural vegetation is able to resume normal phenological cycles, thus providing a green landscape (Evangelista, Young & Burnett, 2013).
Sorghum	Zone 2, Zone 4	Major sorghum- growing areas include much of north central, northwestern, western, and eastern mid- altitude areas of Ethiopia, Rwanda, northern and eastern Uganda, central Tanzania, and the areas in Kenya and Tanzania east of Lake Victoria (Wortmann et al. 2009). Maiti (1996) reported the optimum vegetative growth temperature of sorghum is 26–34°C and an optimum reproductive growth temperature is 25–28°C.	Inherent ability to resist drought and withstand periods of high temperatures (Taylor 2003). Currently, most sorghum in the region is grown under sub-optimum temperatures. About 54% of the sorghum is produced below 24°C (Wortmann et al., 2009). Sorghum production should increase in the region with slight increases in temperature. Water deficiency is another constraint in the region that has been cited as the most important sorghum production constraint (Wortmann et al, 2009). Water deficit may increase with increases in temperature and variability in rainfall and may offset yield gains associated with temperature increases. Being a C4 crop, sorghum may not benefit significantly from increased atmospheric CO_2 (Liu et al. 2008).

			Findings suggest that sorghum is more resilient to climate change than maize or wheat and will be minimally impacted
Maize	Zone 3, Zone 4, Zone 5, Zone 6	Maize is the most widely cultivated staple crop in SSA Primarily grown by smallholders Optimum maize- growing temperature is 25°C, though other studies report increased yields up to 29C (Liu et al., 2008)	Each day spent above 30°C has been found to reduce final maize yield by 1% even under optimal rainfed conditions (Lobell et al. 2011). Other report suggests that a 1°C increase above norm reduces maize yield by 10% (Brown, 2009). at elevated temperature, maize not only suffers from temperature stress, but also becomes sensitive to moisture availability. Rainfed agriculture combined with potential variations in rainfall distribution under climate change, available soil moisture may not be able to meet increasing water demand. (Runge, 1968) Overall, maize production will decrease under future climate scenarios, though the degree of impact differs among simulations Using the same models and scenarios, Thornton et al. (2010) predicted yield gains in Kenya and Rwanda and declines in Tanzania and Uganda in 2030 and 2050. Yield gains projected in Kenya and Rwanda were 15% and 11% by 2030 and 18% and 15% by 2050, respectively, while yield losses projected in Tanzania and Uganda were 3% and 2% by 2030 and 8% and 9% by 2050, respectively. Yield gains in Kenya and Rwanda were attributed to the beneficial temperature increases, which would bring growing season temperatures close to optimum temperature. Yield losses in

			Tanzania and Uganda occurred due to growing season temperatures rising past optimum temperatures. Despite large variations in projected impact on maize yield, there is a general consensus that CC will adversely affect maize yield in East Africa. Multiple studies indicated that East Africa could lose as much as 40% of its maize production by the end of the 21st century
Beans	Zone 3, Zone 5	Ethiopia, Kenya, Rwanda, Tanzania, and Uganda are among the major producers (Wortmann et al., 1998; Asfaw et al., 2009). Cultivation areas are concentrated in cooler highlands and warmer mid-elevation areas with altitudes greater than 1000 m above sea level. due to population pressure, the cropping area is being extended to lower elevations (Katungi et al. 2009)	Schlenker and Roberts (2009) found that increases in temperature up to 30°C gradually increased yield of soybean but temperatures beyond 30C resulted in a sharp decline in soybean yield. In E Africa, 80% of the bean- producing area has a mean annual temperature of 15–23°C, which is below the threshold temperature, favoring bean production (Wortmann et al. 1998) As a C3 crop, beans are expected to benefi t from elevated atmospheric CO 2 concentration. Ainsworth et al. (2002) reported a mean increase of 24% in soybean yield with elevated atmospheric CO2 , which was mainly due to pod number increases. Soybean yield is also affected by precipitation and subsequent moisture availability. In 65% of the bean- producing area in the region, the mean rainfall exceeds 400 mm during the three months after sowing, while in other areas yield is severely impacted by moisture deficit (Wortmann et al. 1998). When precipitation falls below 300 mm during the growing season, yield decline in beans is estimated to be 1000 kg/ha (Wortmann et al. 1998). Rainfall variability and soil moisture content, rather than rising

			temperature, are the crucial factors in determining the effect of climate change in soybean production Projections based on climate change scenarios indicate that lowland areas could lose up to 20% of the current beans production but highland areas can gain up to 57% in bean productivity by the middle of the century.
Cassava	Zone 5	In E Africa, cassava is most important staple food crop in terms of total production where it is grown Production concentrated in mid- altitude areas in the African Great Lakes region and the coastal zones of Tanzania and Kenya (Fermont, 2009)	The crop is more resilient to climate change due to its tolerance of high temperatures and intra-seasonal drought (Jarvis et al., 2012). However, if a prolonged drought period (>2 months) falls during the root thickening initiation state, a root yield reduction of up to 60% may occur (Jarvis et al., 2012). Cassava shows better yield gain than grain crops at higher CO 2 concentrations, can recover from very long drought periods, and exhibits increases in optimum growth temperature under elevated CO 2 levels (Rosenthal and Ort, 2012). Based on different projection scenarios, cassava is projected to lose up to 8% or gain up to 10% of its yield in the future. Overall, cassava yield appears to be the least impacted by the climate change.
Potato	Zone 3, Zone 5	Cultivation concentrated in highland areas. Major crop in Kenya, Rwanda, Tanzania Optimum temperature for cultivation is 17C	Optimum temperature for potato cultivation is 17°C; above which potato production is reduced through either lower plant development and productivity due to heat stress or decreased partitioning of assimilates to the tubers (Wolf et al. 1990). moisture stress reduces potato yield by shortening the growing and dormancy period and by reducing the total number and size of potato tubers (Karafyllidis et al. 1996).

			elevated atmospheric CO2 levels increase potato yield by increasing the number of tubers. Due to climate change, potato yield in most of East African countries (except Rwanda) will decrease due to heat and water stress.
Sweet Potato	Zone 5	Sweet potato is a major staple crop in Uganda, Rwanda, and parts of Tanzania, while it is a secondary food source in Kenya and most of Tanzania and Ethiopia (Smit 1997). Although crop grows from semiarid lowlands to high-altitude zones, cultivation of sweet potato is most intense in altitudes of 800–1900 m (Smit 1997). Sweet potato is a tropical or a subtropical plant, which has an optimum- growing temperature of 20–25°C, but can be grown in temperatures ranging from 15°C to 33°C (Ramirez 1992). Lower nighttime temperature is required for tuber formation, while higher temperature in the day helps vegetative growth.	Susceptibility of sweet potato to drought stress and lower nighttime temperature required for tuber formation makes the crop vulnerable to climate change (Ramirez, 1992; Agili, 2012). Being a C3 crop, sweet potato benefits from elevated atmospheric CO 2 concentration levels (Mortley et al., 1996). The studies on the impact of climate change on sweet potato in East Africa are not adequate to draw conclusions on the potential yield impact.
Rice	Zone 5	Primarily grown by smallholder farmers as a rainfed crop (excluding Kenya, where most rice is irrigated). Rice optimum growing temperature is 25°C (Liu et al., 2008)	CC expected to increase heat stress, drought, flooding + submergence, salt stress on rice In rainfed systems (majority in E Africa), drought is most important production-limiting factor due to sensitivity to moisture stress (Guan et al., 2010)

			heat stress results in high spikelet sterility, low tillering, stunting, and accelerated development, which eventually leads to reduced yield (Bimpong et al., 2011). 1°C increase in temperature above norm reduces rice yield by 10% (Brown, 2009)
Banana	Zone 5	The Great Lakes region in East Africa is the largest banana producing and consuming region in Africa (AATF 2009) Banana is the most important food crop in Uganda and Rwanda (FAO 2013). Major banana- growing areas in East Africa include southwestern and central Uganda, most parts of Rwanda, the northern, southern, and eastern highlands in Tanzania, and the central and Kisii regions in Kenya (AATF 2009)	drought stress is either the most important or the second most important constraint in banana production in the region (Van Asten et al. 2011) Optimal banana production is believed to require a constant and ample supply of water due to its permanent green vegetation and shallow root system (Robinson 1996) Though banana can survive water stress, low soil moisture and extended exposure to extreme temperatures (above 35°C) can reduce banana production (Thornton and Cramer 2012). in the East African highlands, where annual rainfall is below 1100 mm, drought- induced yield reduction on rainfed bananas can reach up to 65% compared to wetter areas (Van Asten et al. 2011) Higher temperatures may increase suitable areas, but could also result in increased water demand, limiting banana cultivation to the areas projected to receive increased rainfall (Thornton 2012). highland bananas are projected to observe significant yield loss due to increased risk of pest and diseases if the temperature increases by 2°C (Thornton and Cramer 2012). rainfall variability in lowlands will limit the suitable areas for banana cultivation in the future (Ramirez et al. 2011)

Cotton	Zone 2, Zone 1, Zone 5	Important cash crop for small holders Primarily grown in arid and semiarid regions in Kenya, northern and eastern regions in Uganda, Western and Eastern Cotton zones in Tanzania, the lowlands and mid- altitude regions in Ethiopia Optimum growing temperature ranges 23.5°C to 32°C (Burke et al. 1988).	To some extent, cotton can tolerate high temperature and drought, although it is sensitive to water availability, especially during flowering and boll formation (Ton, 2011). Cotton crop fails completely at 35°C High temps decrease boll maturation, reduce boll size, reduce number of seeds per boll, reduce fiver length, and reduce cotton yield (Ton, 2011) Increase in atmospheric CO2 expected to increase yield, as long as temperature does not exceed optimum growing range (Yoon et al., 2009) Sensitive to rainfall variability; one study in Tanzania found areas projected to receive increased precipitation by 37% were predicted to experience up to a 17% increase in cotton yield, while the areas expected to receive decreased precipitation were projected to experience up to 17% yield loss. (URT, 2003)
Tea / Coffee	Zone 5	Grown mostly by smallholders as cash crop Arabica strain dominant in high altitudes (Kenya, Ethiopia, Rwanda, Tanzania); Robusta cultivated in lowlands (Tanzania, Uganda) Optimum- growing temperature for Arabica is 18–23°C while for Robusta is 22–26°C (ICO, 2009).	Variability in precipitation is decisive factor; increase in precipitation could increase coffee yield (URT, 2003) Yet suitable growing zones will shrink; in Kenya, the optimal coffee- producing zone is predicted to move upward from 1600 m to 1700 meter above sea level by 2050 (GIZ, 2010). Similarly for tea, optimum tea- growing area is projected to shift toward higher altitudes and total suitable area for tea cultivation will shrink tea production zone (1500– 2100 m above sea level) is projected to shift to higher altitudes (2000–2300 m above sea level) by 2050 under the A2 storyline (CIAT, 2011)

Image location: Kenya

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