Climate risk report for the Middle East and North Africa (MENA) region

Supplementary Document: Appendices

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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.

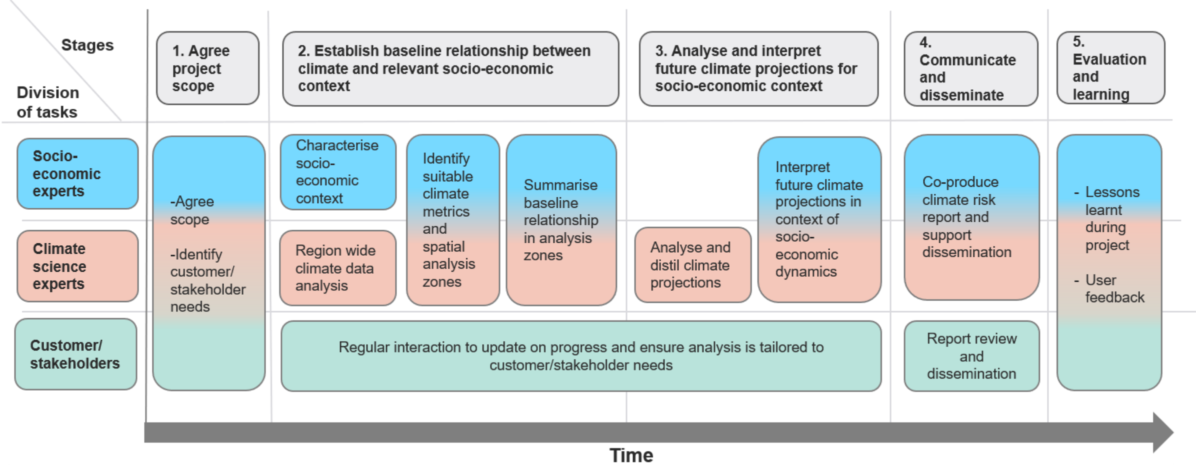

Figure A1 – Schematic diagram of the key stages of the methodology and division of tasks between the socio-economic experts (ODI), climate science experts (Met Office) and customer (FCDO) roles of the project team. This diagram is an initial draft of the Climate in Context methodology[1] currently being 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), and 7 regional climate model simulations 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 – RCM simulations from CORDEX used in the climate data analysis. These are downscaled simulations of a subset of the CMIP5 models in Table A1 at two different resolutions.

Resolution	Modelling centre	Institution	RCM	Driving GCM
50km	BOUN	Bogazici University, Turkey	RegCM4-3	HadGEM2-ES
				MPI-ESM-MR
	SMHI	Swedish Meteorological and Hydrological Institute	RCA4	CNRM-CM5
				EC-EARTH
				GFDL-ESM2M
25km	SMHI	Swedish Meteorological and Hydrological Institute	RCA4	EC-EARTH
				GFDL-ESM2M

Appendix B: Climate plots

Additional plots of the baseline climate and projected climate changes, or annual and seasonal timescales, in each spatial analysis zone are included in the following sections. Zone 1: North-West Africa and Mediterranean coast

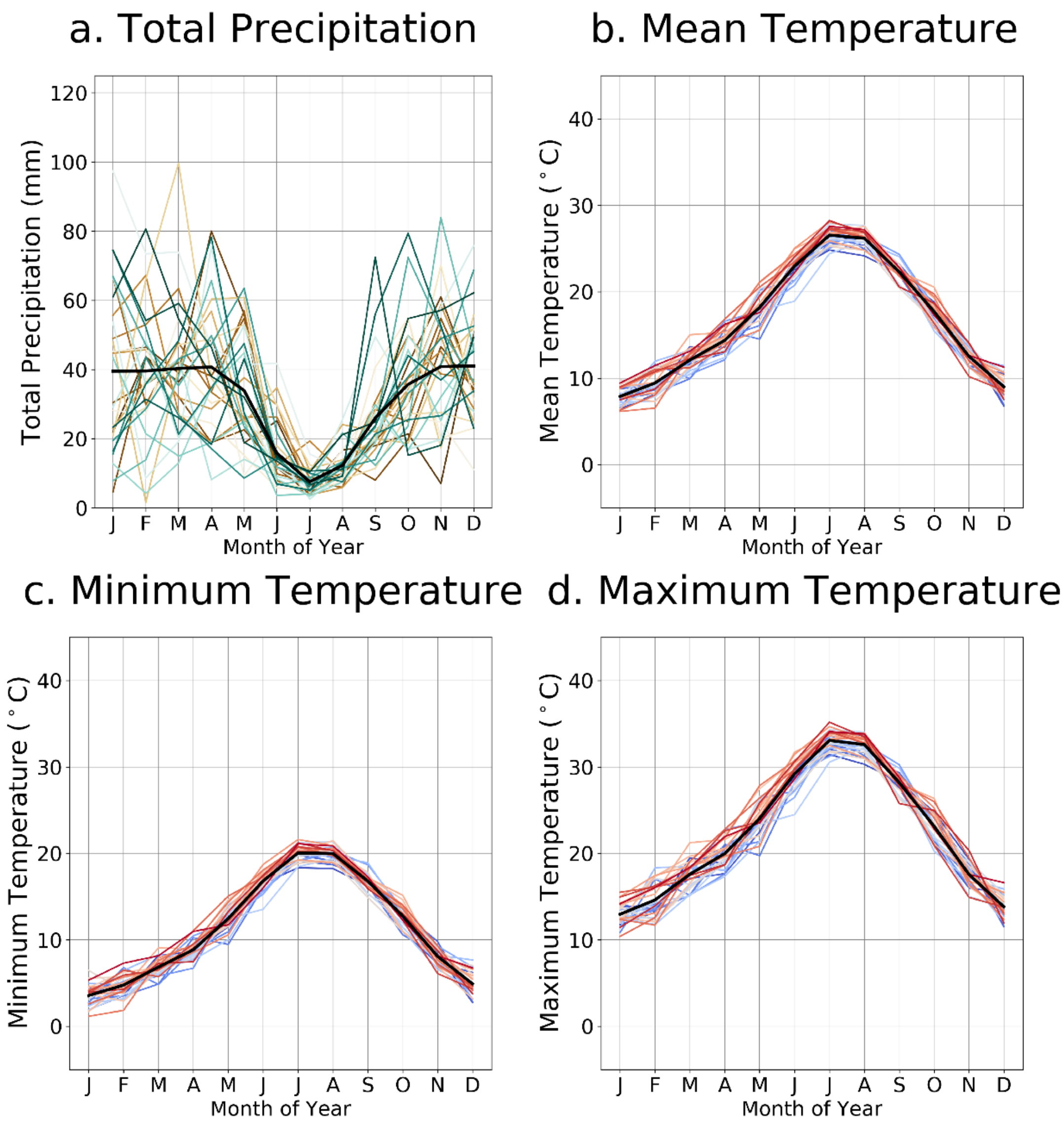

Figure B1: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 1. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean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

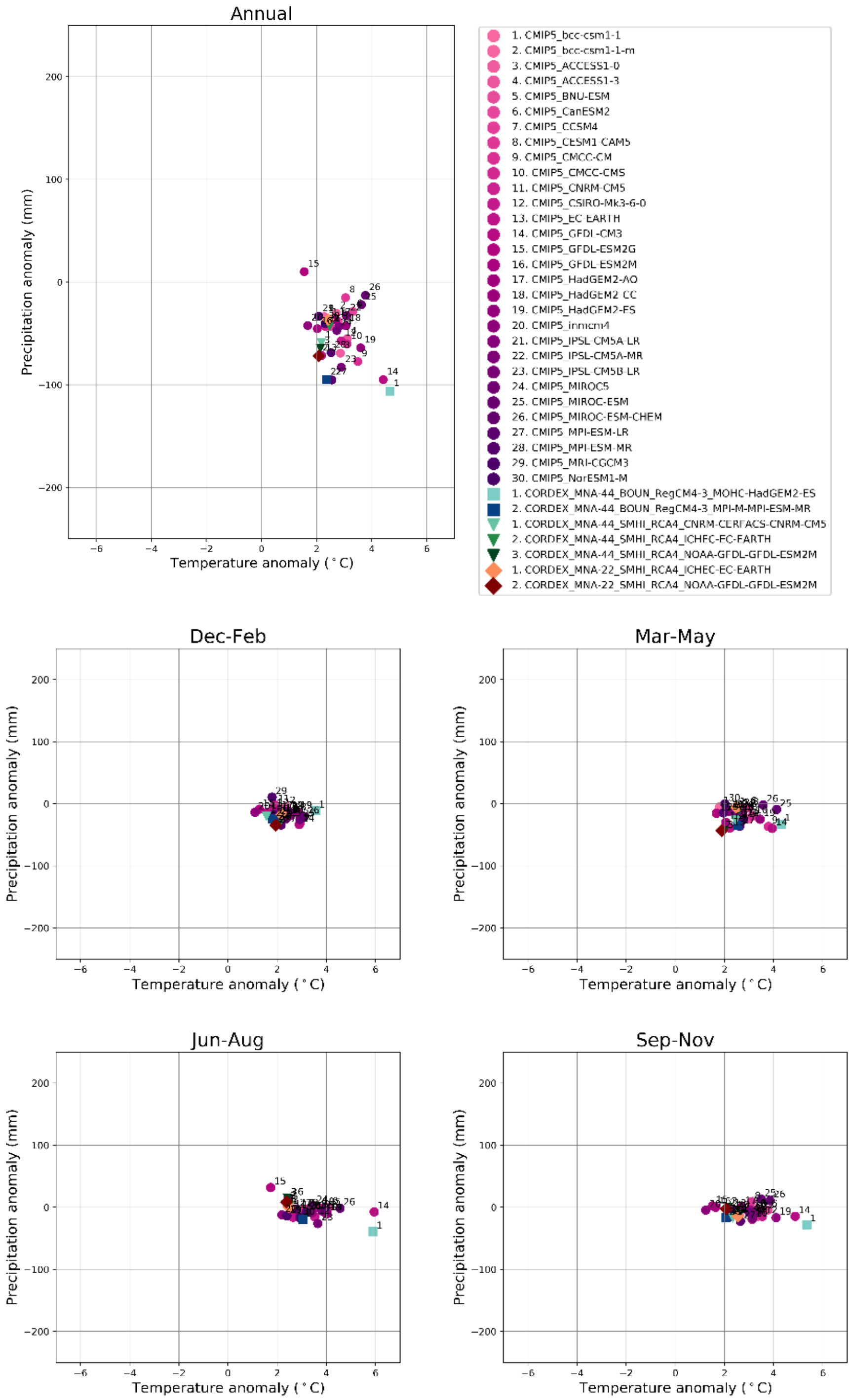

Figure B2: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 1. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are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

Zone 2: Desert regions of North Africa

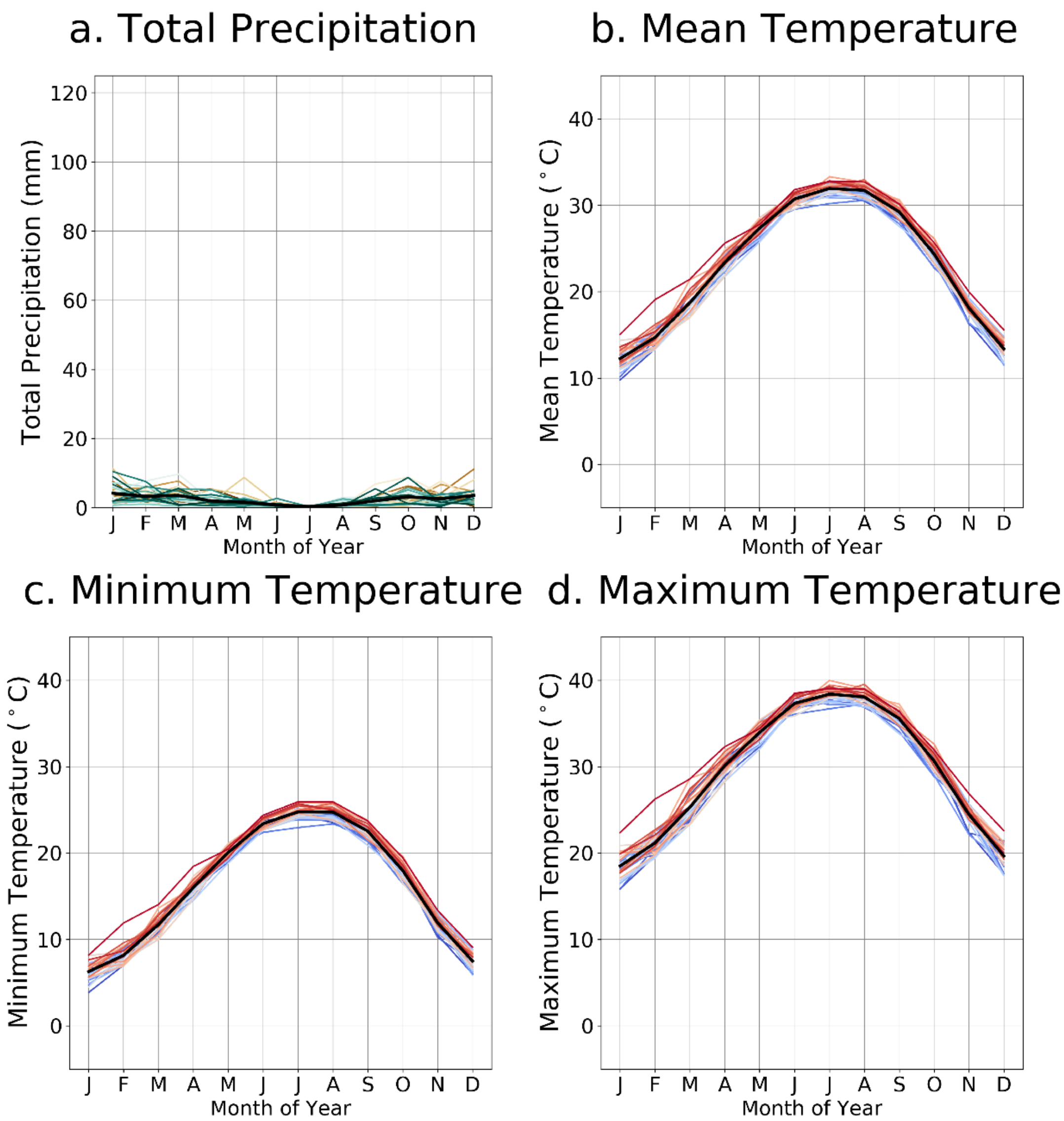

Figure B3: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 2. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean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

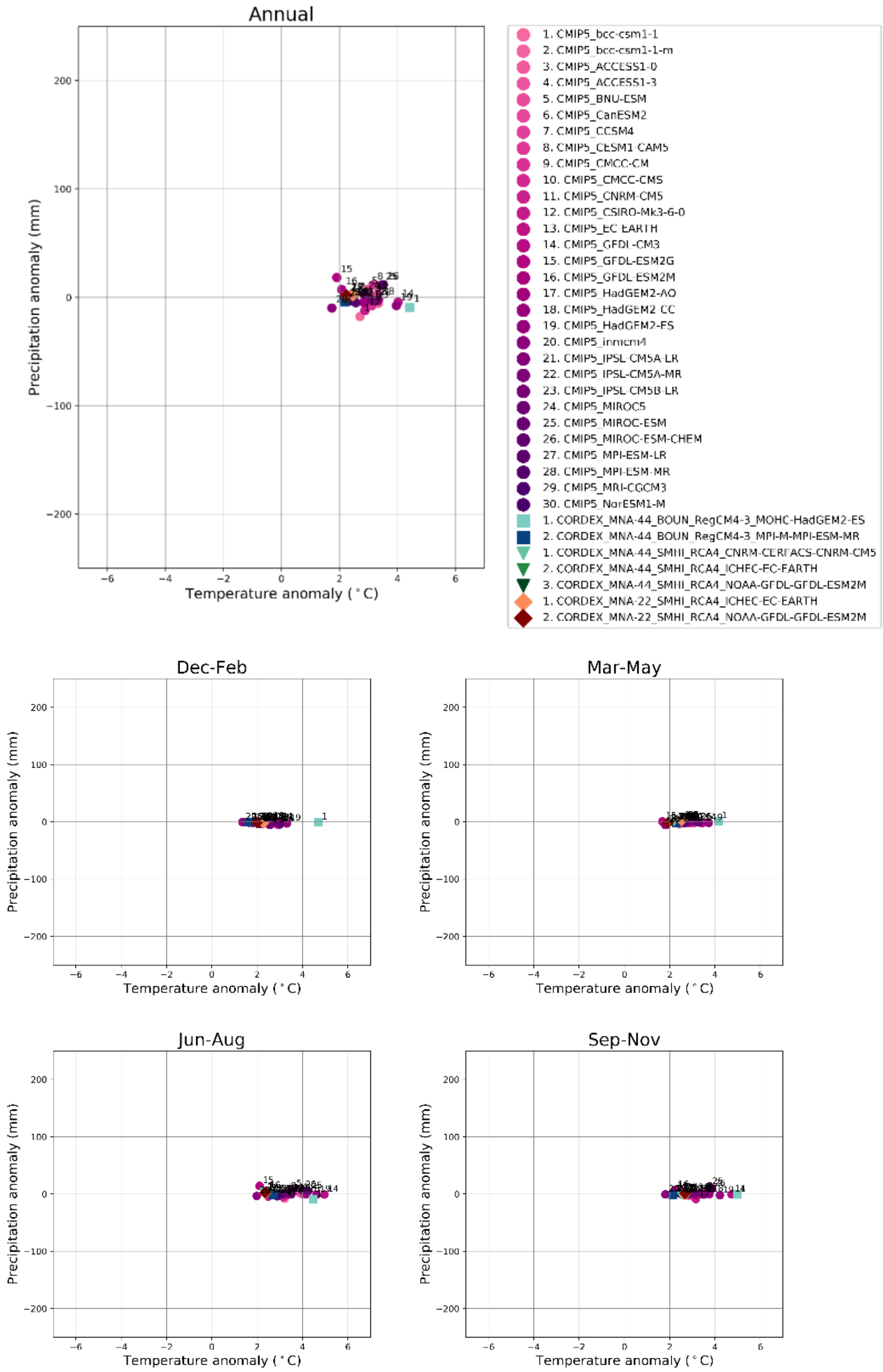

Figure B4: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 2. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are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

Zone 3: Highland regions of Iran and Iraq

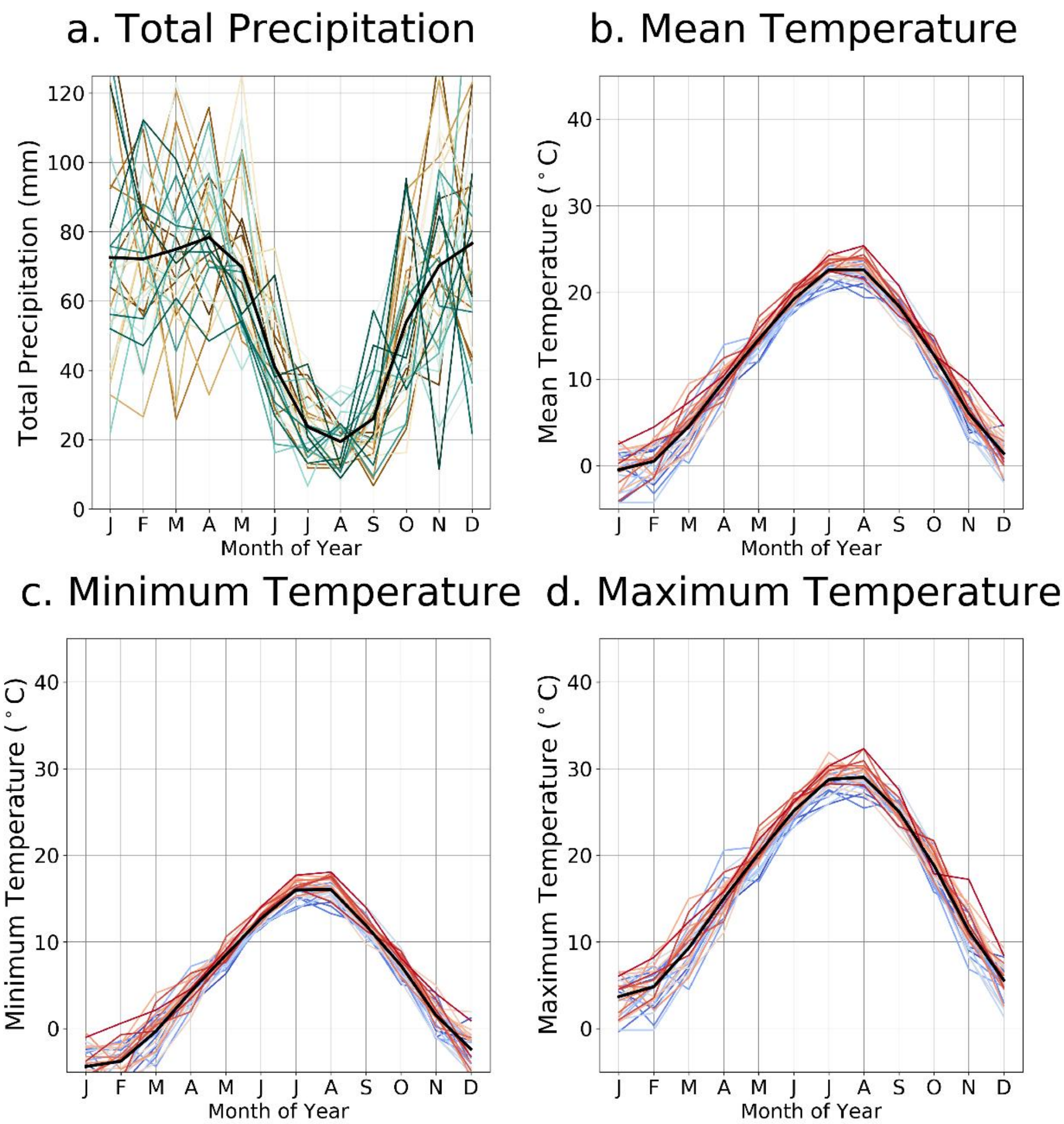

Figure B5: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 3. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean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

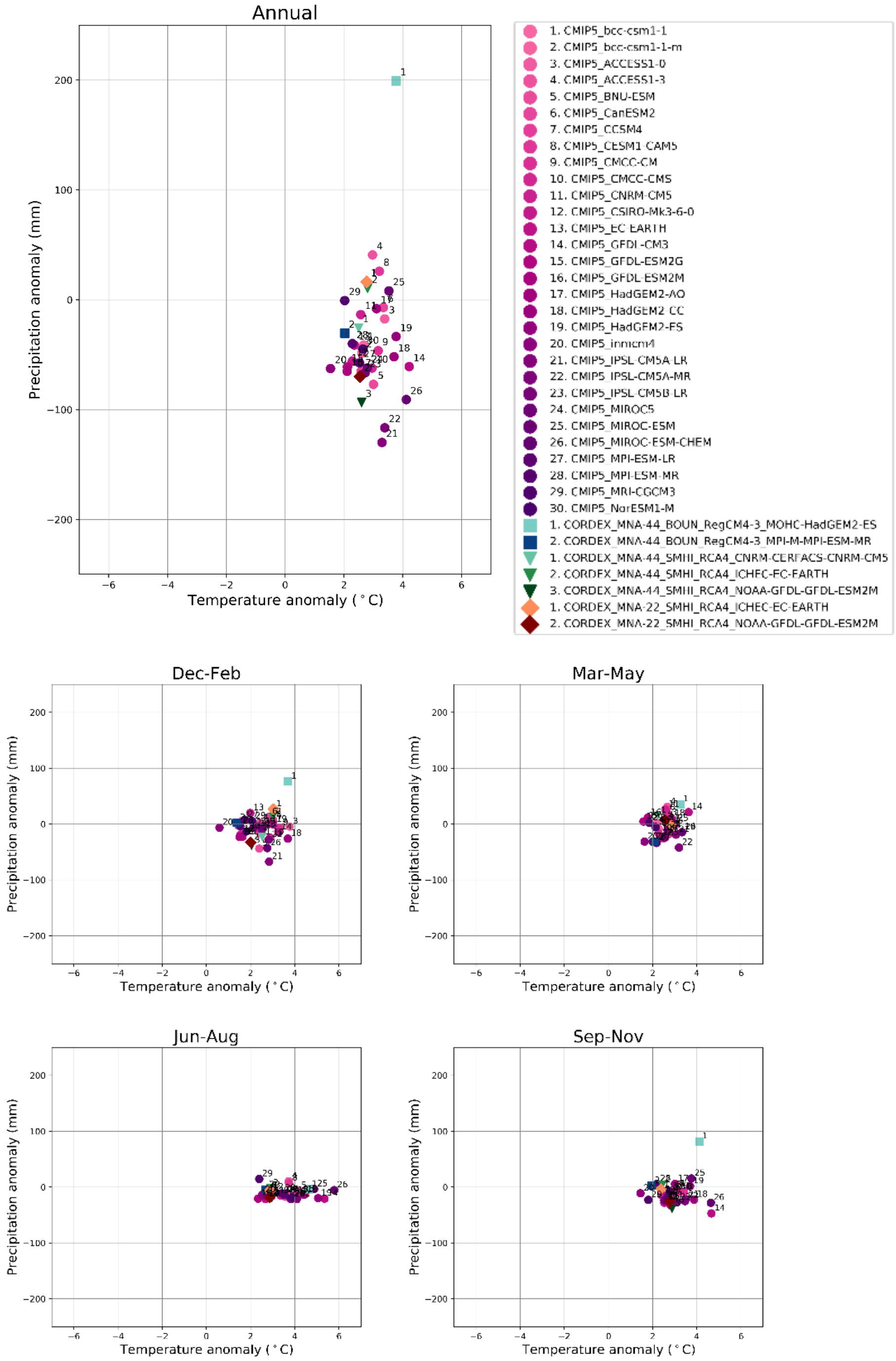

Figure B6: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 3. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are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

Zone 4: Lowlands of Iran

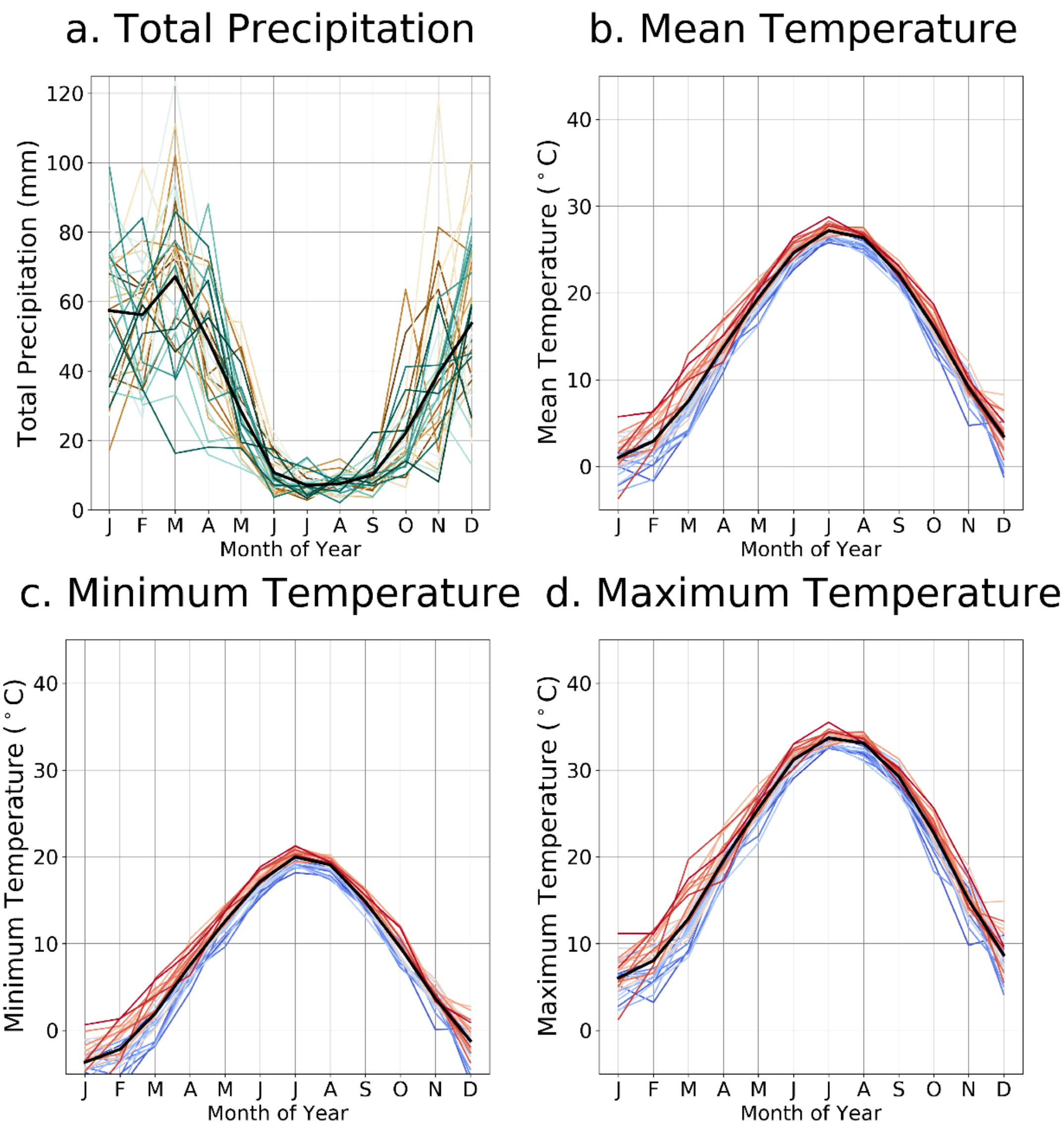

Figure B7: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 4. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean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

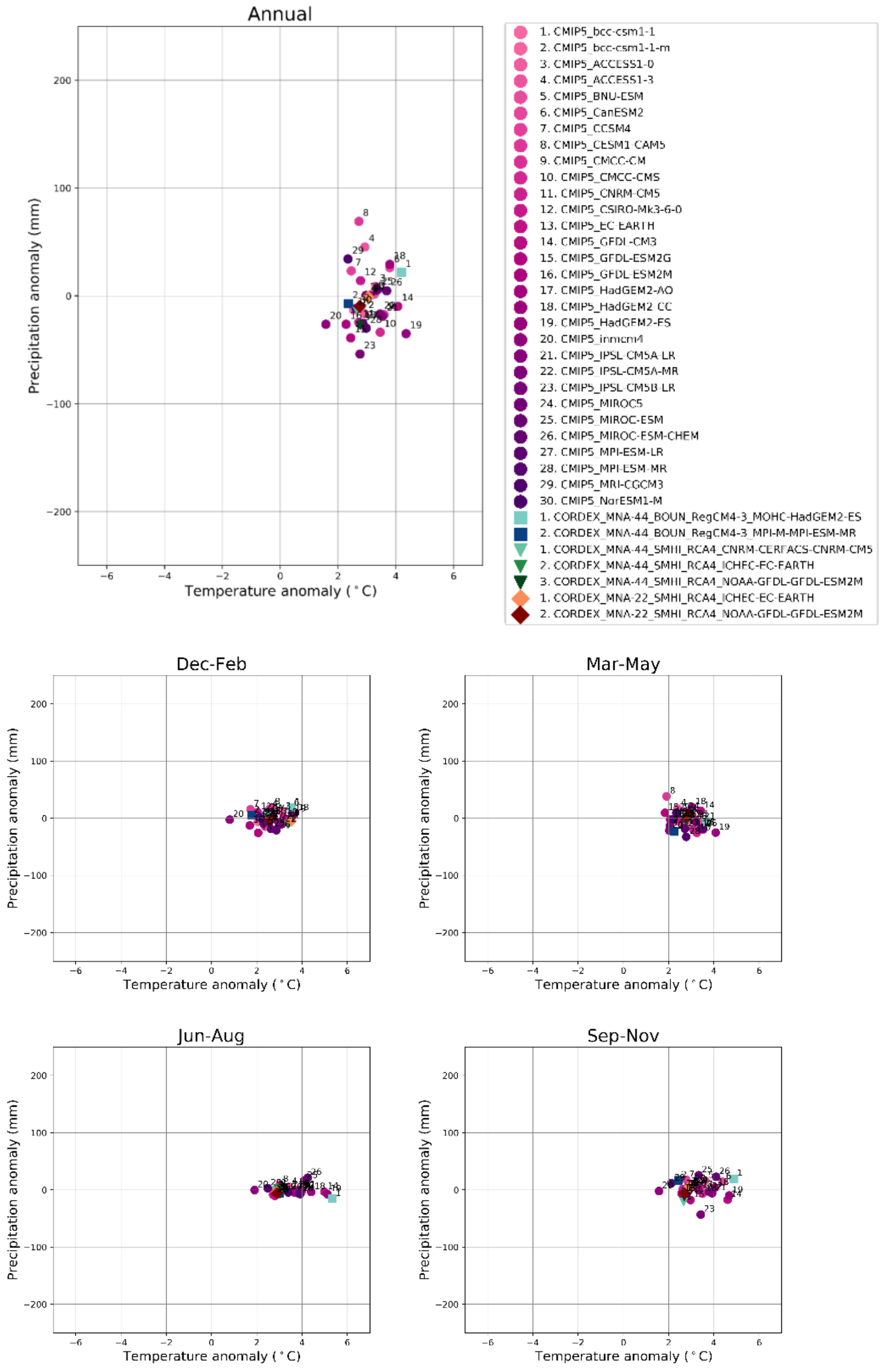

Figure B8: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 4. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are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

Zone 5: Arabian Peninsula

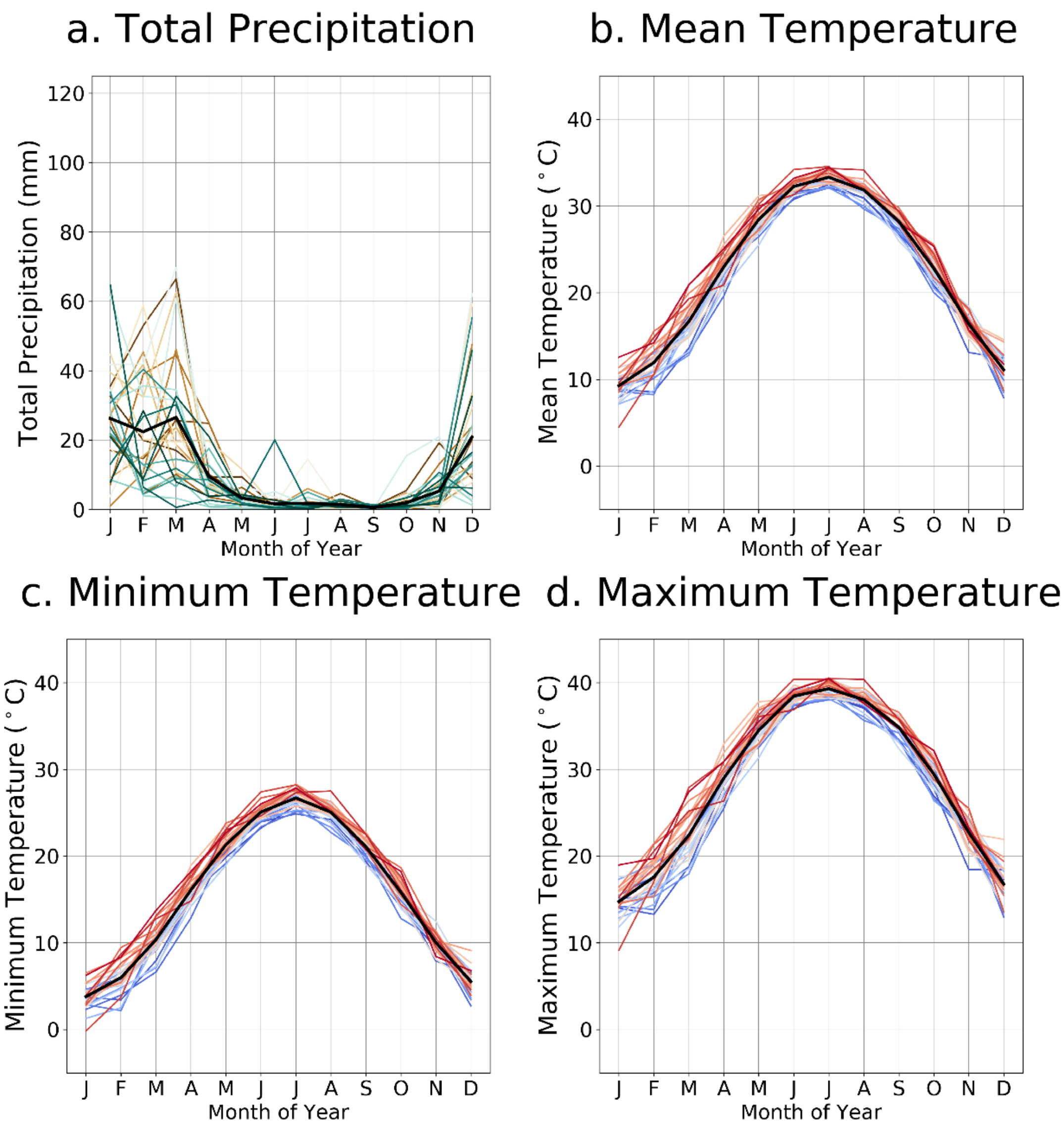

Figure B9: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 5. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean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

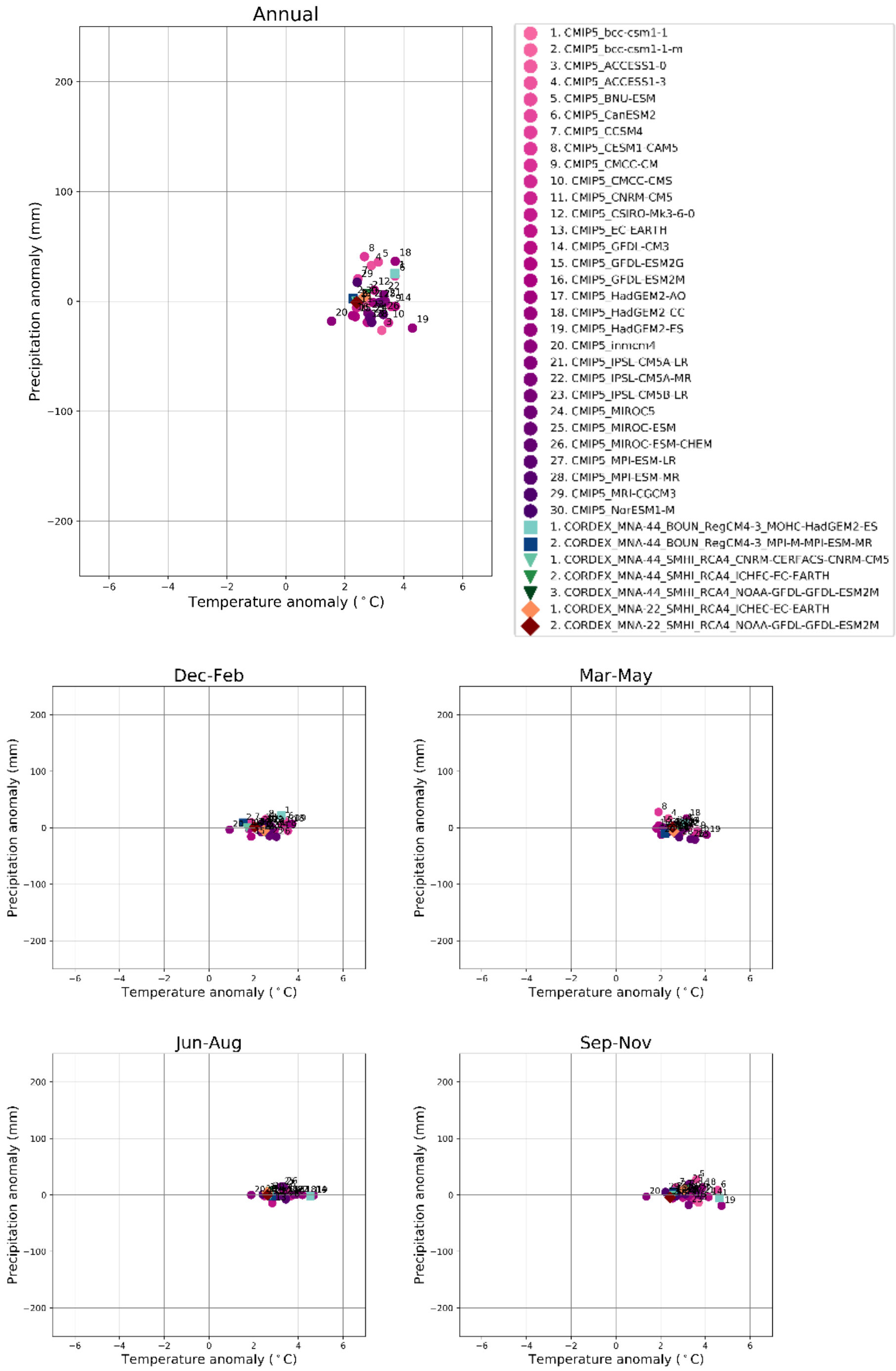

Figure B10: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 5. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are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

Zone 6: Turkey

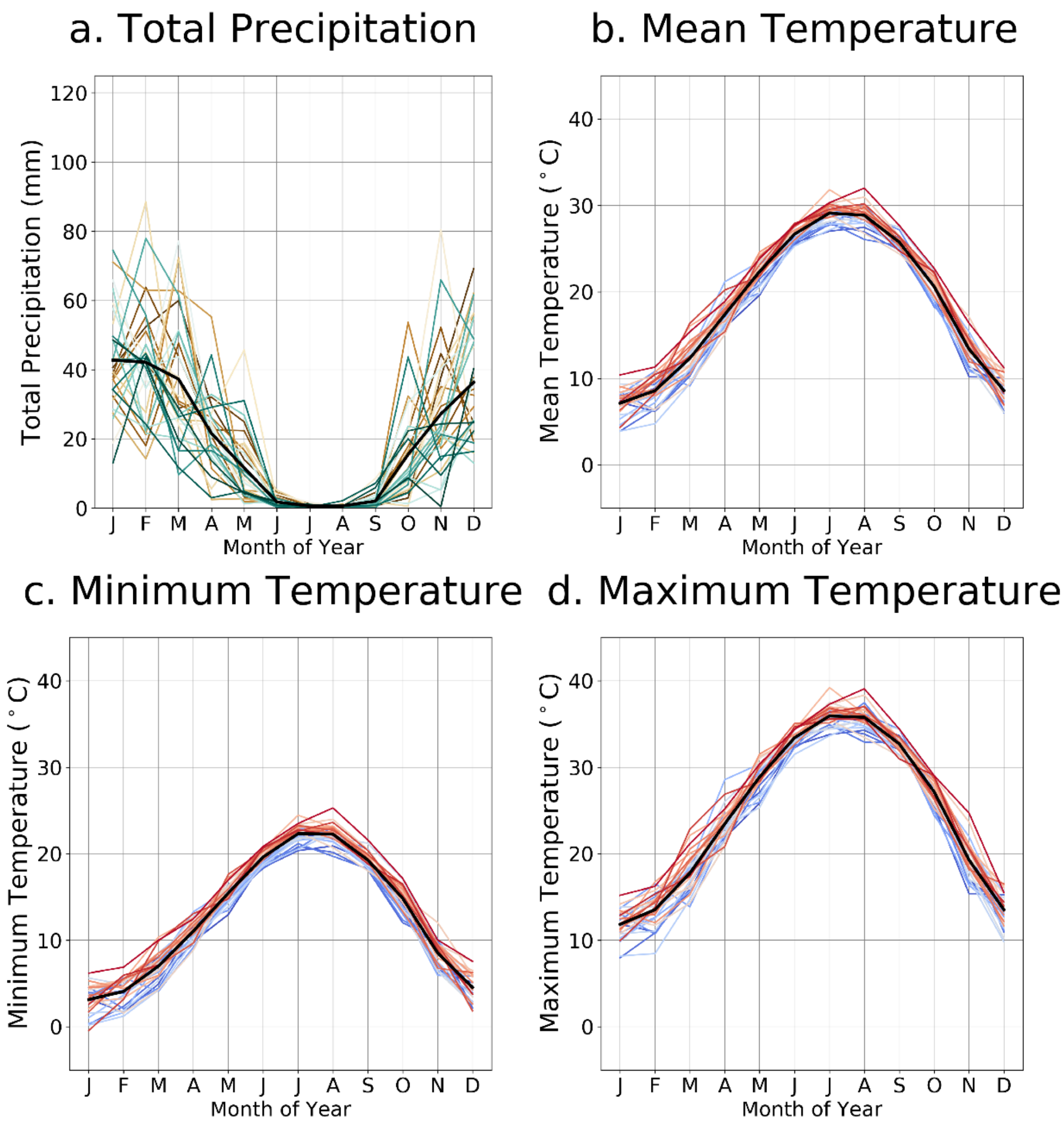

Figure B11: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline period (1981-2010) for Zone 6. Each line is one individual year. Colours show the ordering of years from brown-blue (total precipitation) and blue-red (mean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

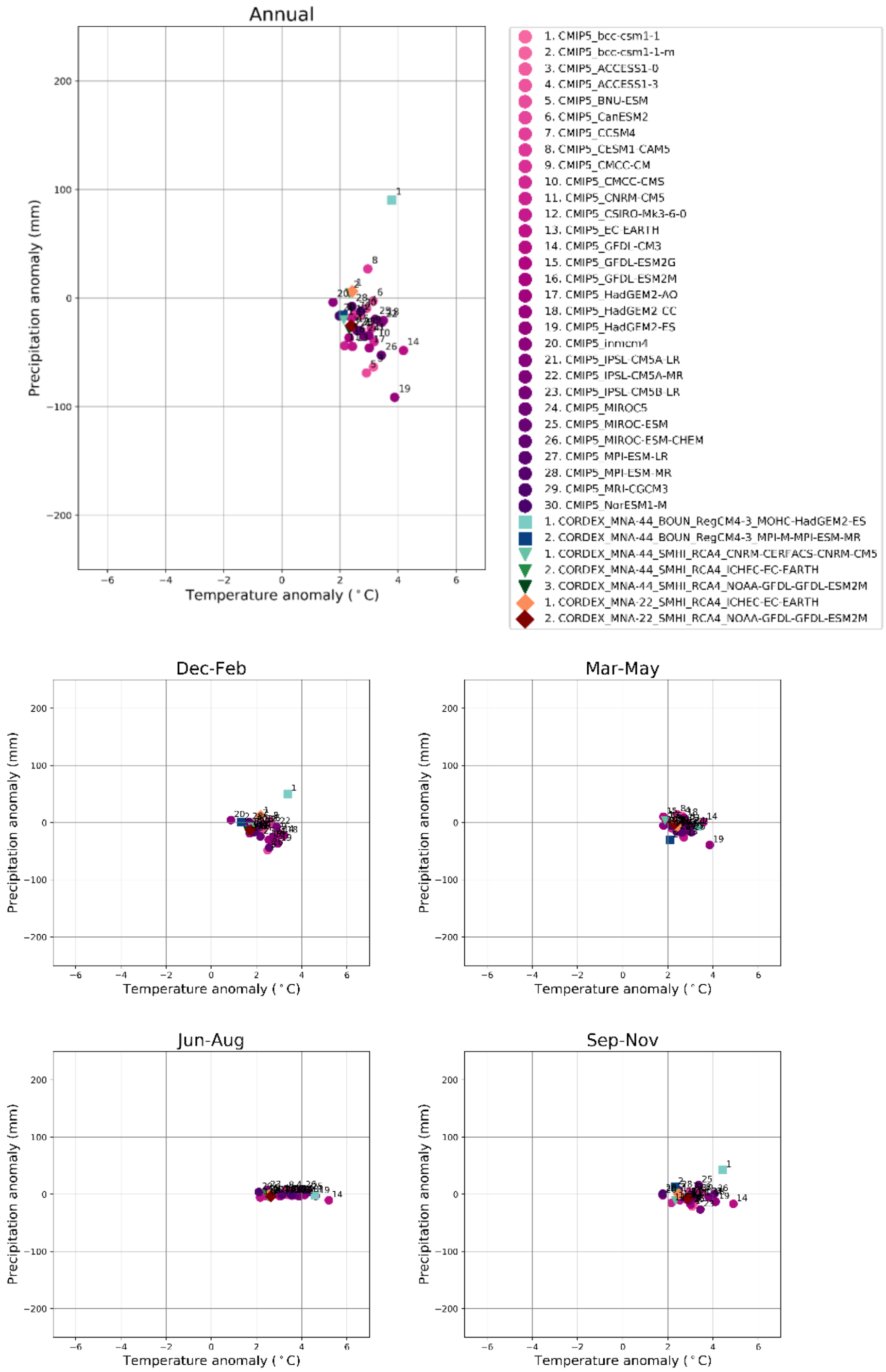

Figure B12: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 6. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are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

Zone 7: The Levant

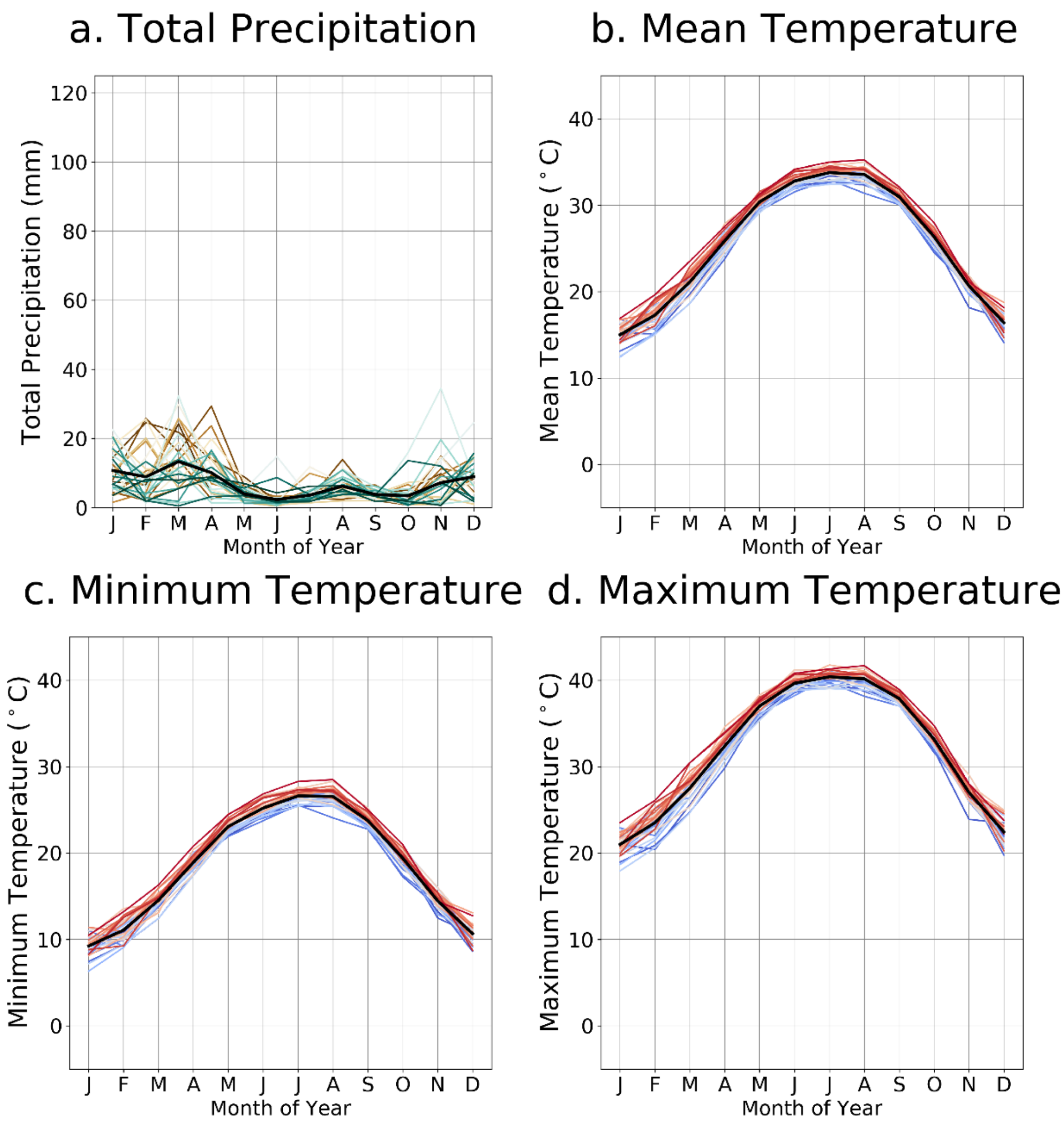

Figure B13: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 7. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

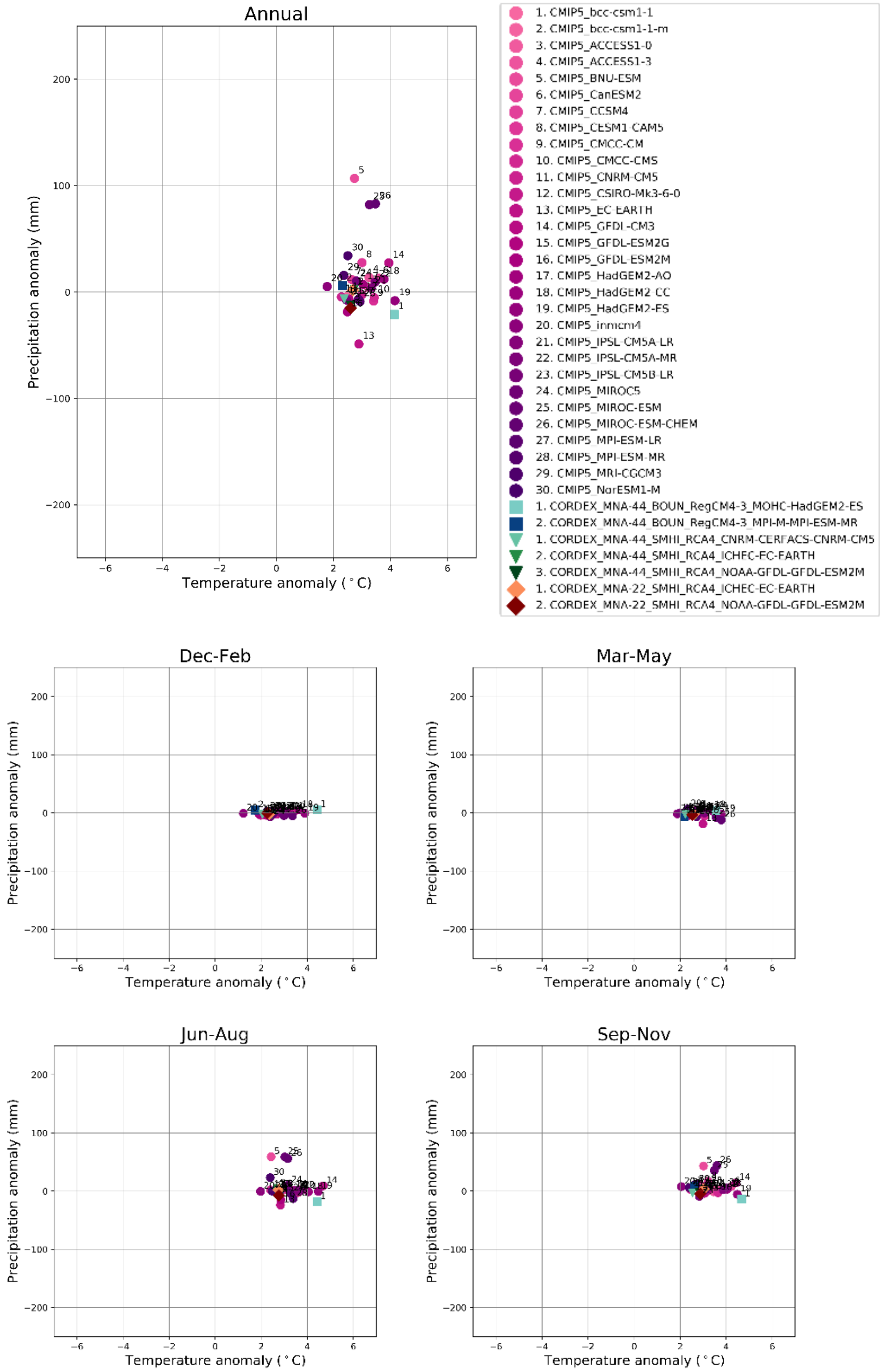

Figure B14: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 7. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Appendix C: Livelihood systems

The five main livelihood systems considered in the analysis of climate risk implications for food security presented in section 4.1 are shown in Table C1. The table summarises the relevant geography, spatial analysis zones, climate risk exposure and potential outcomes for each of the five livelihood systems. The climate risk exposure column references climate indicators relevant to agricultural production that were used in this analysis. These indicators are defined in Table C2.

Table C1: The five main livelihood systems in the MENA region, the relevant spatial analysis zones

Livelihood system	Geography	Climatic analysis zone(s)	Climate risk exposure (defined in Table C2)	Potential outcomes
Rainfed	• The Maghreb • Jordan • Palestine • Syria • Turkey • Iran • Small areas of Libya	Zone 1, Zone 5, Zone 6, Zone 3, Zone 2	A2, A4, A6, A7, A8	Risk of steadily reducing yields due to higher spring/summer temperatures and PET, and reduced water availability. May require adoption of new varieties. Increased risk of harvest failure due to increasing risk from drought and extreme heat each year. Shortening of growing season for key crops (e.g. cereals and vegetables) planted in October/November and harvested between June and August. Off-season crops - typically summer vegetables - planted during summer may no longer be viable. Warmer winter temperatures coupled with increase in drought risk mean yields may become more variable. Warm wet years could see early growth and bumper crops, while warm dry years could see harvest failure. In most areas (perhaps not zone 3), increasing temperatures and aridity implies more demand for the adoption of irrigation systems. Higher winter temperatures imply lower productivity for stone fruits such as olives, dates, apricots and peaches, which are economically, socially and culturally important. In principle rainfed farming offers good returns in bumper years, but incentives to convert to irrigation are increasing. Will need better drought tolerant varieties and access to financial services to weather drought years.

Dryland	• The Maghreb • North Libyan coast • Palestine • Jordan • Syria • Small areas of Iran	Zone 1, Zone 2, Zone 4, Zone 7, Zone 5	A2, A6, A7	Varieties of crops will already be selected for drought tolerance, but these are likely to be less viable in the future. This raises questions about the adaptation limits of dryland systems. Many dryland areas have already started depending more on the livestock production side of their system rather than the crop production aspect. Climate change may accelerate this trend to the extent that dryland areas simply transition to sedentary pastoralist production, but with greater sustainability problems due to the herd concentrations involved. These systems exposed to desertification processes, loss of fertility, etc due to increasing temperatures and aridity Some farmers will adopt groundwater irrigation systems - i.e. grow water-thirsty vegetables rather than drought tolerant barley – raising issues of sustainability with regard to groundwater supplies.
Highland	• Morocco • Turkey • Iran • Iraq • Yemen	Zone 1, Zone 6, Zone 5, Zone 3	A2, A4, A5, A6, A7	Highland agriculture usually takes place in fragile environments. However, fragile soils are likely to be disturbed by desertification, flooding and erosion, and timings of water availability disrupted by higher temperatures changing regimes of snow storage and melting Increased rates of soil erosion from higher summer temperatures and intense rainfall may leave highland soils and ecosystems more sensitive to overgrazing by herds. Higher winter temperatures may allow earlier growth or opportunities for changing to new crops that cannot tolerate current cold conditions. However, increasing temperatures and aridity pose challenges for current cultivars, especially stone fruits with higher winter temperatures limiting fruiting, and summer crops. In some areas of Iran most crops are sown during the Spring and harvested in late Summer/early Autumn; in Morocco & Lebanon, vegetables are often grown during the summer at high altitude. Higher temperatures are likely to stress production.
Pastoral	• The Maghreb • Libyan coast • Jordan • Syria • Iraq	Zone 1, Zone 2, Zone 4, Zone 5, Zone 7	A2, A6, A8	Increasing stress of aridity on plant growth and environmental carrying capacity for pastoral herds, particularly due to declining winter rains (not zone 3) and increasing spring/summer temperatures (everywhere). Drought risk increasing across zones 1, 3, 6 & 7, implying more risks of herd crashes, and needs for emergency help unless efforts taken to adapt and improve resilience.

	• Iran • Limited areas of Western Saudi Arabia • Yemen			Impacts to xeric desert ecosystems and increasing risks of soil erosion and desertification driven by increasing aridity, and less resilience to over-grazing. Greater livelihood risks to a livelihood group which already contains concentrations of poverty.
Irrigated	• River fed irrigated systems along the Nile and Tigris-Euphrates • Large surface irrigation in Morocco, Algeria, Tunisia, Jordan, Lebanon • Ground water irrigation in the majority of countries, particularly Saudi Arabia	Zone 1, Zone 2, Zone 3, Zone 4, Zone 5, Zone 6, Zone 7	A2, A4, A6, A7	Increasing irrigation water demand, which may be hard to meet either due to physical availability (e.g. river systems reliant on snowmelt) or competition from growing demand in other sectors for limited resources. Increased risk of depressed harvests due to heat stress. Shortening of growing season /earlier harvests for crops currently harvested in late Spring/Summer - e.g. irrigated wheat. Increasing heat stress on summer crops, e.g. rice, vegetables - leading to increasing water demand, downward pressure on yields.

Table C2: Definitions of the climate risk exposure indicators referenced in Table C1.

Climate risk exposure	**Description**
A1	Changes in the timing of the onset of winter rains, between September and November particularly in terms of delayed onset
A2	Average daily temperatures during spring and summer, highlighting changes in the number of days above 35˚C
A3	Changes in cumulative cold hours during autumn and winter season; or changes in minimum daily temperatures during winter
A4	Changes in cumulative cold hours during autumn and winter season; or changes in minimum daily temperatures during winter
A5	Changes in rainfall intensity, between October to April, especially looking for heavy rainfall events
A6	Changes in crop water deficit (a combination of precipitation and potential evapotranspiration)
A7	Combination of minimum daytime temperature and crop water deficit between September and February