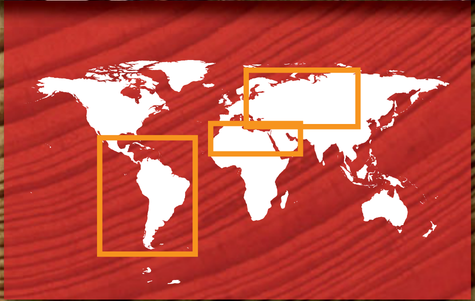
Regional Summaries

4° Turn Down the Heat

Confronting the New Climate Normal



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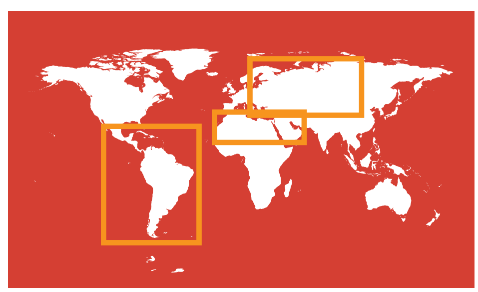

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Latin America and the Caribbean

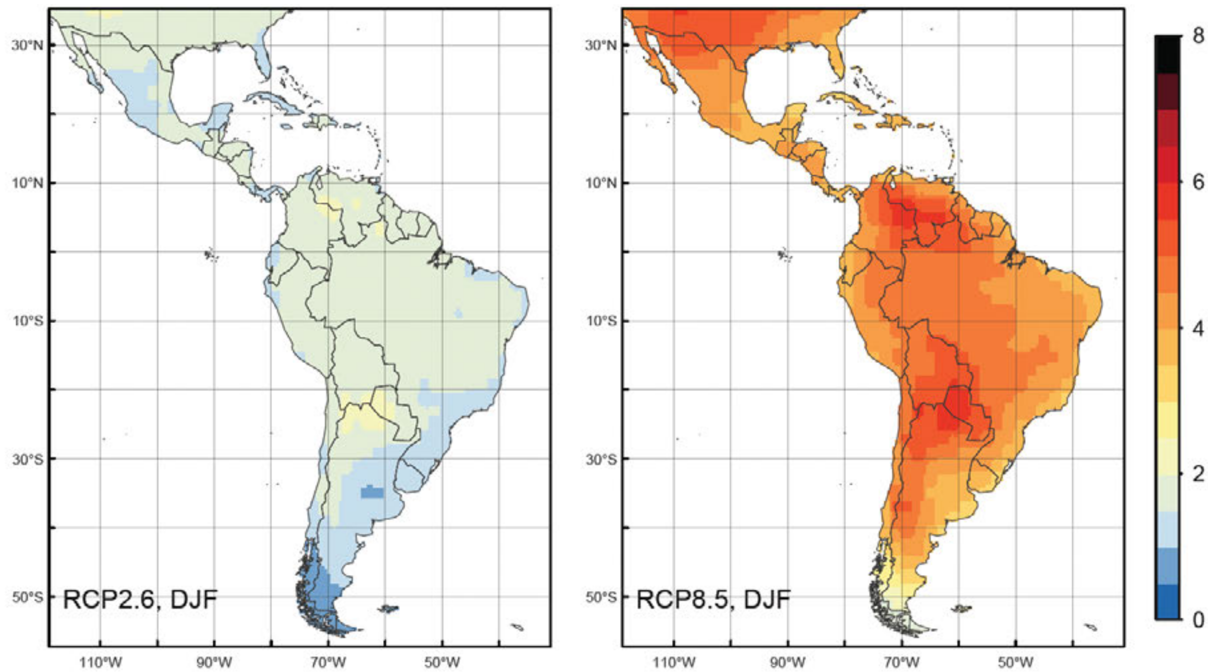
The Latin America and the Caribbean region encompasses a huge diversity of landscapes and ecosystems. The region is highly heterogeneous in terms of economic development and social and indigenous history. It is also one of the most urbanized regions in the world. In Latin America and the Caribbean, temperature and precipitation changes, heat extremes, and the melting of glaciers will have adverse effects on agricultural productivity, hydrological regimes, and biodiversity. In Brazil, without additional adaptation, crop yields could decrease by 30–70 percent for soybean and up to 50 percent for wheat at 2°C warming. Ocean acidification, sea level rise, and more intense tropical cyclones will affect coastal livelihoods and food and water security, particularly in the Caribbean. Local food security is also seriously threatened by the projected decrease in fishery catch potential. Reductions and shifts in water availability would be particularly severe for Andean cities. The Amazon rainforest may be at risk of large-scale forest degradation that contributes to increasing atmospheric carbon dioxide concentration and local and regional hydrological changes.

1.1 Regional Summary

The Latin America and Caribbean region is highly heterogeneous in terms of economic development and social and indigenous history with a population of 588 million (2013), of which almost 80 percent is urban. The current GDP is estimated at $5.655 trillion (2013) with a per capita GNI of $9,314 in 2013. In 2012, approximately 25 percent of the population was living in poverty and 12 percent in extreme poverty, representing a clear decrease compared to earlier years. Undernourishment in the region, for example, declined from 14.6 percent in 1990 to 8.3 percent in 2012. Despite considerable economic and social development progress in past decades, income inequality in the region remains high.

The region is highly susceptible to tropical cyclones and strong El Niño events, as well as to rising sea levels, melting Andean glaciers, rising temperatures and changing rainfall patterns. The rural poor who depend on a natural resource base are particularly vulnerable to climate impacts on subsistence agriculture and ecosystem services; the urban poor living along coasts, in flood plains, and on steep slopes are particularly vulnerable to extreme precipitation events and the health impacts of heat extremes. The intensive grain-producing cropping systems in the southern part

Figure 1.1: Multi-model mean temperature anomaly for Latin America and the Caribbean for RCP2.6 (2°C world, left) and RCP8.5 (4°C world, right) for the austral summer months (DJF).



Temperature anomalies in degrees Celsius are averaged over the time period 2071–2099 relative to 1951–1980.

of the region are mainly rain-fed and, as a result, susceptible to variable rainfall and temperatures. In the Andean regions, houses built on the often steep terrain are critically exposed to storm surface flows, glacial lake outbursts, and landslides. Coastal residents, particularly in the Caribbean region, face the risks of loss of ecosystem services and livelihoods from degrading marine ecosystems, loss of physical protection from degrading reefs, and coastal flooding, as well as from damages to critical infrastructure (especially in the beach front tourism sector) and threats to freshwater from sea water intrusion due to sea level rise.

1.1.1 Regional Patterns of Climate Change

1.1.1.1 Temperatures and Heat Extremes

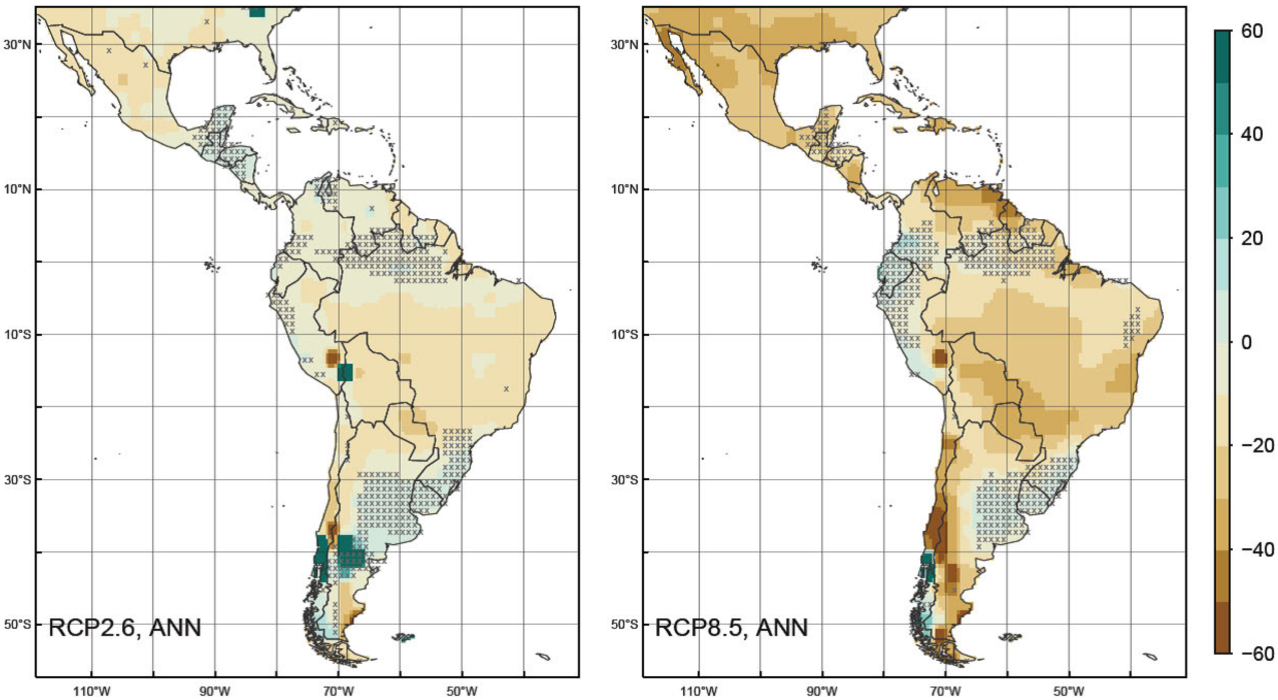
By 2100, summer temperatures over the region will increase by approximately 1.5°C under the low-emissions scenario (a 2°C world) and by about 5.5°C under the high-emissions scenario (a 4°C world) compared to the 1951–1980 baseline (Figure 1.1). Along the Atlantic coast of Brazil, Uruguay, and Argentina, the warming is projected to be less than the global average, ranging between 0.5–1.5°C in a 2°C world and 2–4°C in a 4°C world. In the central South American region of Paraguay, in northern Argentina, and in southern Bolivia, warming is likely to be more pronounced, up to 2.5°C in a 2°C world and up to 6°C in a 4°C world by 2071–2099. Similar levels of warming are projected for the equatorial region, including eastern Colombia and southern Venezuela. Projections indicate that in a 4°C world almost all land area (approximately 90 percent) will be affected by *highly unusual,*[1] and more than half of the land area (approximately 70 percent) by *unprecedented*, summer heat extremes.

1.1.1.2 Precipitation, Drought, and Aridity

In general, in a 2°C world, precipitation changes are relatively small (+/–10 percent) and models exhibit substantial disagreement on the direction of change over most land regions. In a 4°C world, the models converge in their projections over most regions, but inter-model uncertainty remains over some areas (such as northern Argentina and Paraguay) (Figure 1.2). Tropical countries on the Pacific coast (Peru, Ecuador, and Colombia) are projected to see an increase in annual mean precipitation of about 30 percent. Similarly, Uruguay on the Atlantic coast (and bordering regions in Brazil and Argentina) will get wetter. Regions which are projected to become drier include Patagonia (southern Argentina and Chile), Mexico, and central Brazil. These patterns indicate that, under climate change, most dry regions will get drier and most

[1] In this report, *highly unusual* heat extremes refer to 3-sigma events and unprecedented heat extremes to 5-sigma events (see Appendix).

Figure 1.2: Multi-model mean of the percentage change in the aridity index under RCP2.6 (2°C world, left) and RCP8.5 (4°C world, right) for Latin America and the Caribbean by 2071–2099 relative to 1951–1980.



Hatched areas indicate uncertain results, with two or more out of five models disagreeing on the direction of change. Note that a negative change corresponds to a shift to more arid conditions.[2]

wet regions will get wetter. The exception is central Brazil. The annual mean precipitation here is projected to drop by 20 percent in a 4°C world by the end of the century. In general, more intense and frequent extreme precipitation events also become more likely.

In a 4°C world, the Amazon basin, the full land area of Brazil except the southern coast, southern Chile, the Caribbean, Central America, and northern Mexico, are expected to be under severe to extreme drought conditions relative to the present climate by the end of the 21st century. The total area of land classified as hyper-arid, arid, or semi-arid is projected to grow from about 33 percent in 1951–1980 to 36 percent in a 2°C world, and to 41 percent in a 4°C world.

1.1.1.3 Tropical Cyclones

Observations over the last 20–30 years show positive trends in tropical cyclone frequency and strength over the North Atlantic but not over the eastern North Pacific. While Atlantic tropical cyclones are suppressed by the El Niño phase of ENSO, they are enhanced in the eastern North Pacific. Under further anthropogenic climate change, the frequency of high-intensity tropical cyclones is generally projected to increase over the western North Atlantic by 40 percent for 1.5–2.5°C global warming and by 80 percent in a 4°C world. Global warming of around 3°C is associated with an average 10 percent increase in rainfall intensity averaged over a 200 km radius from a tropical cyclone's center. Although there is some evidence from multiple-model studies for a projected increase in frequency of tropical cyclones along the Pacific coast of Central America, overall projections in this region are currently inconclusive. Despite these inconclusive projections, however, any increase in Pacific and Atlantic storms (not necessarily cyclones) making landfall simultaneously would potentially entail more damaging impacts than increasing frequency of any individual Pacific or Atlantic cyclone.

1.1.2 Regional Sea-Level Rise

Sea-level rise is projected to be higher at the Atlantic coast than at the Pacific coast. Valparaiso (median estimate: 0.55 m for a 4°C world) is projected to benefit from southeasterly trade wind intensification

[2] Some individual grid cells have noticeably different values than their direct neighbors (e.g., on the border between Peru and Bolivia). This is due to the fact that the Aridity index is defined as a fraction of total annual precipitation divided by potential evapotranspiration (see Appendix). It therefore behaves in a strongly non-linear way, and thus year-to-year fluctuations can be large. Since averages are calculated over a relatively small number of model simulations, this can result in these local jumps.

over the Southern Pacific and associated upwelling of cold water leading to below-average thermosteric (due to ocean temperature rise) sea-level rise. In contrast, the Atlantic coast of Brazil is projected to experience above-average sea-level rise (Recife: median estimate: 0.63 m, low estimate: 0.41 m, high estimate: 1.14 m; Rio de Janeiro: median estimate: 0.62 m, low estimate: 0.46 m, high estimate: 1.11 m). Sea-level rise is exacerbated at low latitudes due to both increased ocean heat uptake and the gravity-induced pattern of ice sheets and glaciers. As an example, Guayaquil on the Pacific Coast of Ecuador is projected to experience 0.62 m (low estimate: 0.46 m, high estimate: 1.04 m) of sea-level rise in a 4°C world. In contrast, Puerto Williams (Chile) at the southern tip of the South American continent is projected to experience only 0.46 m (low estimate: 0.38 m; high estimate: 0.65 m). Port-Au-Prince (Haiti) is projected to experience 0.61 m (low estimate: 0.41 m, high estimate: 1.04 m) of sea-level rise in a 4°C world (Figure 1.11); it serves as a typical example for sea-level rise in other Caribbean islands.

1.1.3 Sector-based and Thematic Impacts

1.1.3.1 Glaciers and Snowpack Changes

Glacial recession in South America has been significant. The tropical glaciers in the Central Andes in particular have lost major portions of their volume in the course of the 20th century. A clear trend of glacial retreat is also visible for glaciers in the southern Andes, which have lost about 20 percent of their volume.

The recession of the tropical glaciers in the Central Andes will continue as rapidly as it has in recent decades. Even for low or intermediate emissions scenarios inducing a global warming of 2–3°C above pre-industrial levels, two comprehensive studies consistently project a glacial volume loss of 78–97 percent. Both studies predict an almost complete deglaciation (93–100 percent) for a 4°C world. Other studies are slightly less dramatic; irrespective of the temperature evolution in the next decades, however, large parts of the glaciers of the tropical Andes will be gone long before the end of the century. In the Southern Andes, the model spread for the 2–3°C global warming ranges from 22–59 percent glacier volume loss; a comparison for individual scenarios is difficult. In a 4°C world, models project a glacier volume retreat of 44–74 percent by 2100.

Monitoring of snow cover in the high altitudes of Chile and Argentina since 1950 shows no significant trend (possible trends are hard to identify in the records, since the inter-annual variability is large and clearly modulated by ENSO). The lack of reliable projections for snowpack and snow cover changes in the Andes is an important research gap.

1.1.3.2 Water Resources, Water Security, and Floods

Although the magnitude of the change varies, there is a high agreement on decreasing mean annual runoff and discharge in Central America. Water stress may increase, especially in arid areas with high population densities and during the dry season. In the Caribbean, runoff projections are of low confidence due to lack of data. However, freshwater availability may decrease for several reasons, such as sea-level rise leading to an intrusion of sea water into coastal aquifers. Regionally, the risk of flooding and mudslides with high mortality rates is high. Although floods often seem to be associated with land-use change, more severe flooding events may also occur in the context of climate change.

Higher variability of seasonal discharge is projected for the Tropical Andes. Decreased streamflow during the dry season has already been observed, and may decrease further as a result of ongoing glacier retreat. However, streamflow during the wet season may increase. The Andean region could experience a higher flood risk in a 4°C world (e.g. due to accelerated glacier melting). In the Amazon Basin, runoff and discharge projections for most parts of the Amazon basin are diverging. For the western part of the basin a likely increase in streamflow, runoff, flood zone, and inundation time are projected. In southern most South America, a decrease in mean runoff is projected.

Although the Latin America and Caribbean region has an abundance of freshwater resources, many cities depend on local rivers, aquifers, lakes, and glaciers that may be affected by climate change—and freshwater supplies might not be enough to meet demand. For example, Guadalajara (Mexico) and many Andean cities are expected to face increasing water stress and, if the current demand continues, low-income groups who already lack adequate access to water will face more challenges.

1.1.3.3 Climate Change Impacts on Agriculture, Livestock, and Food Security

The results of the climate change impact projections on crop yields differ among studies, but most authors agree that climate change will very likely decrease agricultural yields of important food crops in the Latin America and Caribbean region. An exception is the projected increase in yield of irrigated/flooded rice in some regions. The few available studies on climate change impacts on livestock indicate that beef and dairy cattle production will decline under increasing temperatures, as heat stress is a major influencing factor of cattle productivity. Sheep seem to cope better with warmer and drier conditions than cattle and pigs.

1.1.3.4 Climate Change Impacts on Biodiversity

Climate change-induced negative effects on biodiversity, from range contractions to extinctions, are very likely in a warmer than 2°C world. As the adaptive capacity of affected species and ecosystems is hard to project or quantify, models need to use simplified approaches as implemented in bioclimatic envelope models, species-distribution models, and dynamic global vegetation models.

One clear trend regarding future warming levels is that the more temperature is projected to increase, the more species diversity is affected. Mountainous regions in the tropics (e.g., cloud forests) are projected to become very vulnerable due to the high number of endemic and highly specialized species which might face mountaintop extinction. Most models do not take biotic interactions (e.g., food-web interactions, species competition) or resource limitations into account. Therefore, the realized ecological niche of species within an ecosystem might become much smaller than what is potentially possible according to climatic and other environmental conditions, leading to shifts in ecological zones.

1.1.3.5 Amazon Rainforest Degradation, Dieback, and Tipping Point

Overall, the most recent studies suggest that the Amazon dieback is an unlikely, but possible, future for the Amazon region. Projected future precipitation and the effects of CO_2 fertilization on tropical tree growth remain the processes with the highest uncertainty. Climate-driven changes in dry season length and recurrence of extreme drought years, as well as the impact of fires on forest degradation, add to the list of unknowns for which combined effects still remain to be investigated in an integrative study across the Amazon. A critical tipping point has been identified at around 40 percent deforestation, when altered water and energy feedbacks between remaining tropical forest and climate may lead to a decrease in precipitation.

A basin-wide Amazon forest dieback caused by feedbacks between climate and the global carbon cycle is a potential tipping point of high impact if regional temperatures increase by more than 4°C and global mean temperatures increase by more than 3°C toward the end of the 21st century. Recent analyses have, however, downgraded this probability from 21 percent to 0.24 percent for the 4°C regional warming level when coupled carbon-cycle climate models are adjusted to better represent the inter-annual variability of tropical temperatures and related CO_2 emissions. This holds true, however, only when the CO_2 fertilization effect is realized as implemented in current vegetation models. Moreover, large-scale forest degradation as a result of increasing drought may impair ecosystem services and functions, including the regional hydrological cycle, even without a forest dieback.

1.1.3.6 Fisheries and Coral Reefs

Together with ocean acidification and hypoxia, which are very likely to become more pronounced under high-emissions scenarios, the possibility of more extreme El Niño events poses substantial risks to the world's richest fishery grounds. Irrespective of single events, the gradual warming of ocean waters has been observed and is further expected to affect fisheries (particularly at a local scale).

Generally, fish populations are migrating poleward toward colder waters. Projections indicate an increase in catch potential of up to 100 percent in the south of Latin America. Off the coast of Uruguay, the southern tip of Baja California, and southern Brazil the maximum catch potential is projected to decrease by more than 50 percent. Caribbean waters and parts of the Atlantic coast of Central America may see declines in the range of 5–50 percent. Along the coasts of Peru and Chile, fish catches are projected to decrease by up to 30°percent, but there are increases expected toward the south.

Irrespective of the sensitivity threshold chosen, and irrespective of the emissions scenario, by the year 2040, Caribbean coral reefs are expected to experience annual bleaching events. While some species and particular locations appear to be more resilient to such events, it is clear that the marine ecosystems of the Caribbean are facing large-scale changes with far-reaching consequences for associated livelihood activities as well as for the coastal protection provided by healthy coral reefs.

1.1.3.7 Health

The Latin America and Caribbean region faces increased risks of morbidity and mortality caused by infectious diseases and extreme weather events. Observed patterns of disease transmission associated with different parts of the ENSO cycle offer clues as to how changes in temperature and precipitation might affect the incidence of a particular disease in a particular location. Projections of how malaria incidence in the region could be affected by climate change over the rest of the century are somewhat inconsistent, with some studies pointing to increased incidence and others to decreased incidence. Such uncertainty also characterizes studies of the relationship between climate change and malaria globally and reflects the complexity of the environmental factors influencing the disease.

1.1.3.8 Migration and Security

While migration is not a new phenomenon in the region, it is expected to accelerate under climate change. There are many areas in the Latin America and Caribbean Region prone to extreme events, including droughts, floods, landslides, and tropical cyclones; all of these extreme events can induce migration.

Examples indicate that drought-induced migration is already occurring in some regions. The largest level of climate migration is likely to occur in areas where non-environmental factors (e.g., poor governance, political persecution, population pressures, and poverty) are already present and putting migratory pressures on local populations.

The region is considered to be at low risk of armed conflict. However, in the context of high social and economic inequality and migration flows across countries, disputes regarding access to resources, land, and wealth are persistent. Climate change could increase the risk of conflict in the region through more resource scarcity, more migration, increasing instability, and increasing frequency and intensity of natural disasters.

1.1.3.9 Coastal Infrastructure

By 2050, coastal flooding with a sea-level rise of 20 cm could generate approximately $940 million of mean annual losses in the 22 largest coastal cities in the Latin America and Caribbean region, and about $1.2 billion with a sea-level rise of 40 cm. The Caribbean region is particularly vulnerable to climate change due to its low-lying areas and the population's dependence on coastal and marine economic activity. In a scenario leading to a 4°C world and featuring 0.89–1.4 m of sea-level rise, tropical cyclones in the Caribbean alone could generate an extra $22 billion by 2050 (and $46 billion by 2100) in storm and infrastructure damages and tourism losses, compared to a scenario leading to a 2°C world. The potential increase in tropical cyclone intensity may increase port downtime for ships and, therefore, increase shipping costs. Beach tourism is particularly exposed to direct and indirect climate change stressors, including sea-level rise, modified tropical storm patterns, heightened storm surges, and coastal erosion. Coastal tourist resorts are potentially two-to-three times more exposed to climate change-related stressors than inland touristic resorts.

1.1.3.10 Energy

The assessment of the current literature on climate change impacts on energy in Latin America and the Caribbean shows that there are only a few studies, most of which make strong assumptions about such key issues as seasonality of water supply for hydropower. These studies are more qualitative than quantitative and important gaps remain. There is also a lack of studies with respect to the impacts of climate change impacts on renewable energies.

In general, the impacts of climate change on energy demand are less well studied than those on energy supply—and, yet, demand and supply interact in a dynamic way. For example, the concomitant increase in energy demand during heat extremes and the decrease in energy supply through reduced river flow and low efficiencies may put existing energy systems under increasing pressure in the future.

1.1.4 Overview of Regional Development Narratives

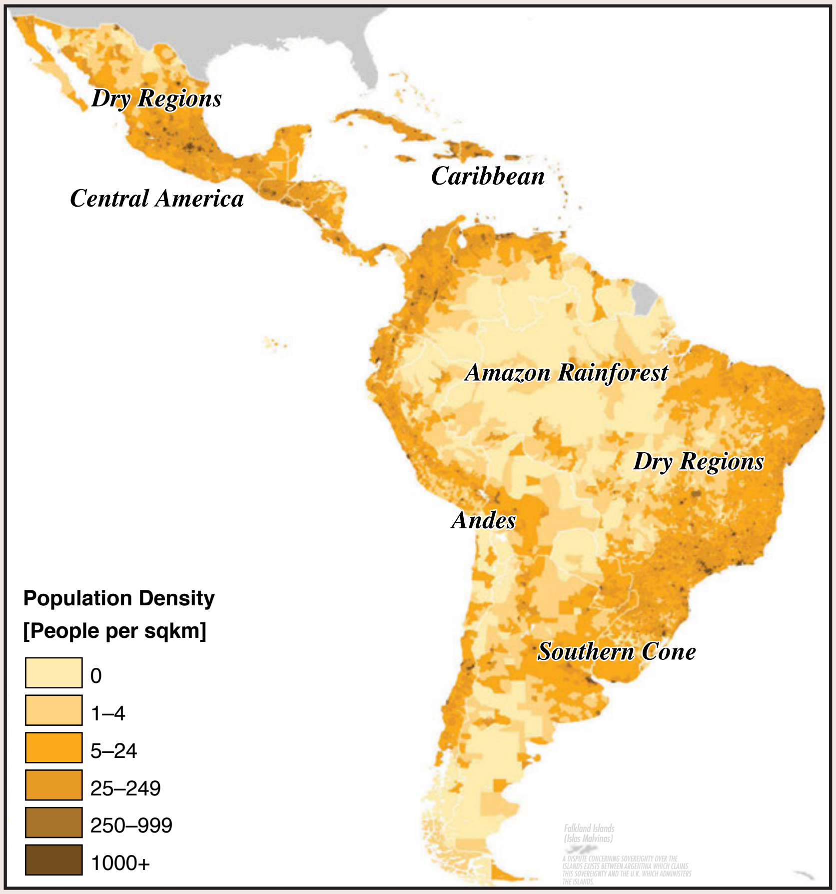
Box 1.1 gives an overview of the key climate risks in the region. The development narratives build on the climate change impacts analyzed in the Main report (cf. Table 3.15, Section 3.5). Climate change impacts have manifold direct and indirect implications for development in the region. These impacts occur on a continuum from rural to urban; not only are there many climate impacts directly affecting rural spaces leading for example to reduced agricultural productivity or altered hydrological regimes, but these impacts also affect urban areas through changing ecosystem services, migration flows, and so forth. Development will likewise be impacted as the challenges of a changing climate mount and interact with socioeconomic factors. In particular, glacial melt and changing river flows, extreme events, and risks to food production systems will put human livelihoods under pressure.

Climate change impacts are and will continue to affect development across the region in several ways. First, changes to the hydrological cycle endanger the stability of freshwater supplies and ecosystem services. An altered hydrological system due to changing runoff, glacial melt, and snowpack changes will affect the ecosystem services that the rural population depends on, freshwater supplies in cities, and such major economic activities as mining and hydropower. Second, climate change places at risk both large-scale agricultural production for export and small-scale agriculture for regional food production. Third, a stronger prevalence of extreme events affects both rural and urban communities, particularly in coastal regions.

At the sub-regional level, the following climate-development interactions are particularly important. In Central America and the Caribbean, extreme events threaten livelihoods and damage infrastructure. In the Andes, changes in water resource availability challenge the rural and urban poor. In the Amazon, the risks of a tipping point, forest degradation, and biodiversity loss threaten local communities. Hydrological changes may affect the wider region. The Southern Cone faces risks to export commodities from loss of production from intensive agriculture. In the Mexican dry subtropical regions and northeastern Brazil, increasing drought stress threatens rural livelihoods and health.

A summary of projected impacts of climate change in key sectors for the region is provided in Box 1.2

Box 1.1: Sub-regional risks for development in Latin America and the Caribbean (LAC) under 4°C warming in 2100 compared to pre-industrial temperatures



Data sources: Center for International Earth Science Information Network, Columbia University; United Nations Food and Agriculture Programme; and Centro Internacional de Agricultura Tropical—(2005). Gridded Population of the World, Version 3 (GPWv3): Population Count Grid. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). This map was reproduced by the Map Design Unit of The World Bank. The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.

Central America & the Caribbean

Higher ENSO and tropical cyclone frequency, precipitation extremes, drought, and heat waves. Risks of reduced water availability, crop yields, food security, and coastal safety.

Poor exposed to landslides, coastal erosion with risk of higher mortality rates and migration, negative impacts on GDP where share of coastal tourism is high.

Amazon Rainforest

Increase in extreme heat and aridity, risk of forest fires, degradation, and biodiversity loss.

Risk of rainforest turning into carbon source. Shifting agricultural zones may lead to conflict over land. Risks of species extinction threatening traditional livelihoods and cultural losses.

Andes

Glacial melt, snow pack changes, risks of flooding, and freshwater shortages.

In high altitudes women, children, and indigenous people particularly vulnerable; and agriculture at risk. In urban areas the poor living on steeper slopes more exposed to flooding.

Dry Regions

Increasing drought and extreme heat events leading to cattle death, crop yield declines, and challenges for freshwater resources.

Risks of localized famines among remote indigenous communities, water-related health problems. Stress on resources may lead to conflict and urban migration.

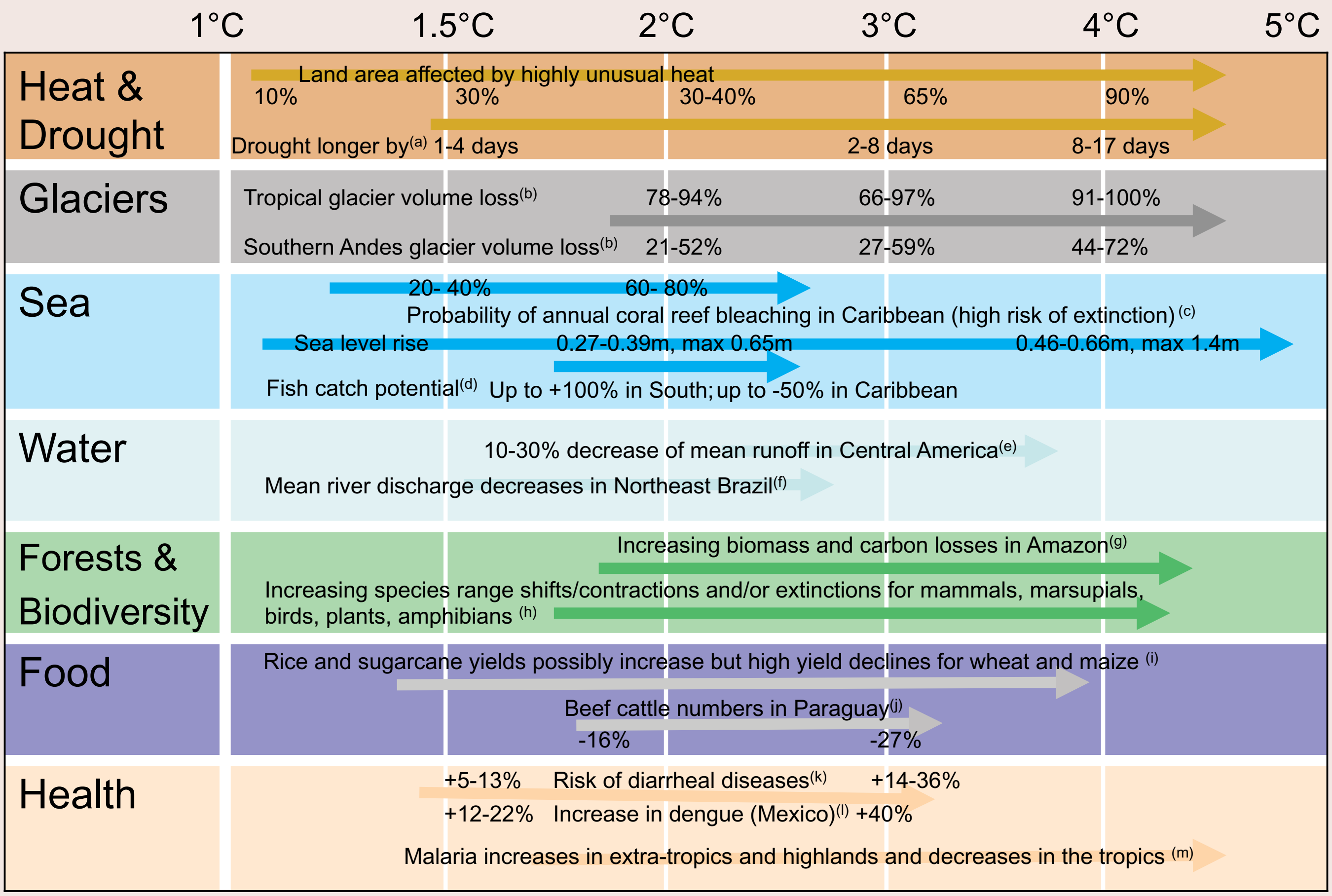
Southern Cone

Decreasing agricultural yields and pasture productivity, northward migration of agro-ecozones.

Risks for nutritious status of the local poor. Risks for food price increases and cascading impacts beyond the region due to high export share of agriculture.

Box 1.2: Projected Impacts of Climate Change in Key Sectors in the Latin America and Caribbean Region

Warming levels are relative to pre-industrial temperatures. The impacts shown here are a subset of those summarized in Table 3.15 of the Main report. The arrows indicate solely the range of warming levels assessed in the underlying studies, but do not imply any graduation of risk unless noted explicitly. In addition, observed impacts or impacts occurring at lower or higher levels of warming that are not covered by the key studies highlighted here are not presented (e.g., coral bleaching already occurs earlier than 1.5°C warming but the studies presented here only start at 1.5°C). Adaptation measures are not assessed here although they can be crucial to alleviate impacts of climate change. The layout of the figure is adapted from Parry (2010). The lower-case superscript letters indicate the relevant references for each impact.[3] If there is no letter, the results are based on additional analyses for this report.



[3] a) Sillmann et al. (2013b); (b) Marzeion et al. (2012); Giesen and Oerlemans (2013); Radic et al. (2013); (c) Meissner et al. (2012); (d) Cheung et al. (2010); (e) Hidalgo et al. (2013); (f) Döll and Schmied (2012); (g) several studies without considering $C0_2$-fertilization, see Table 3.1; (h) several studies, see Table 3.1; (i) several studies, see Table 3.1; (j) ECLAC (2010); (k) Kolstad and Johansson (2011); (l) Colon-Gonzalez et al. (2013); (m) Beguin et al. (2011); Caminade et al. (2014); Van Lieshout et al. (2004).

Middle East and North Africa

The Middle East and North Africa region is one of the most diverse in the world in economic terms, with per-capita annual GDP ranging from $1,000 in Yemen to more than $20,000 in the Arab Gulf States. As a consequence, adaptive capacity and vulnerability to climate risks varies enormously within the region. The region will be severely affected at both 2°C and 4°C warming, particularly because of the large increase in projected heat extremes, the substantial reduction in water availability and expected consequences for regional food security. In some countries, crop yields could decrease by up to 30 percent at 1.5–2°C and by almost 60 percent at 3–4°C in parts of the region. Deteriorating rural livelihoods may contribute to internal and international migration, adding further stresses on particularly urban infrastructure with associated health risks for poor migrants. Migration and climate-related pressure on resources might increase the risk of conflict.

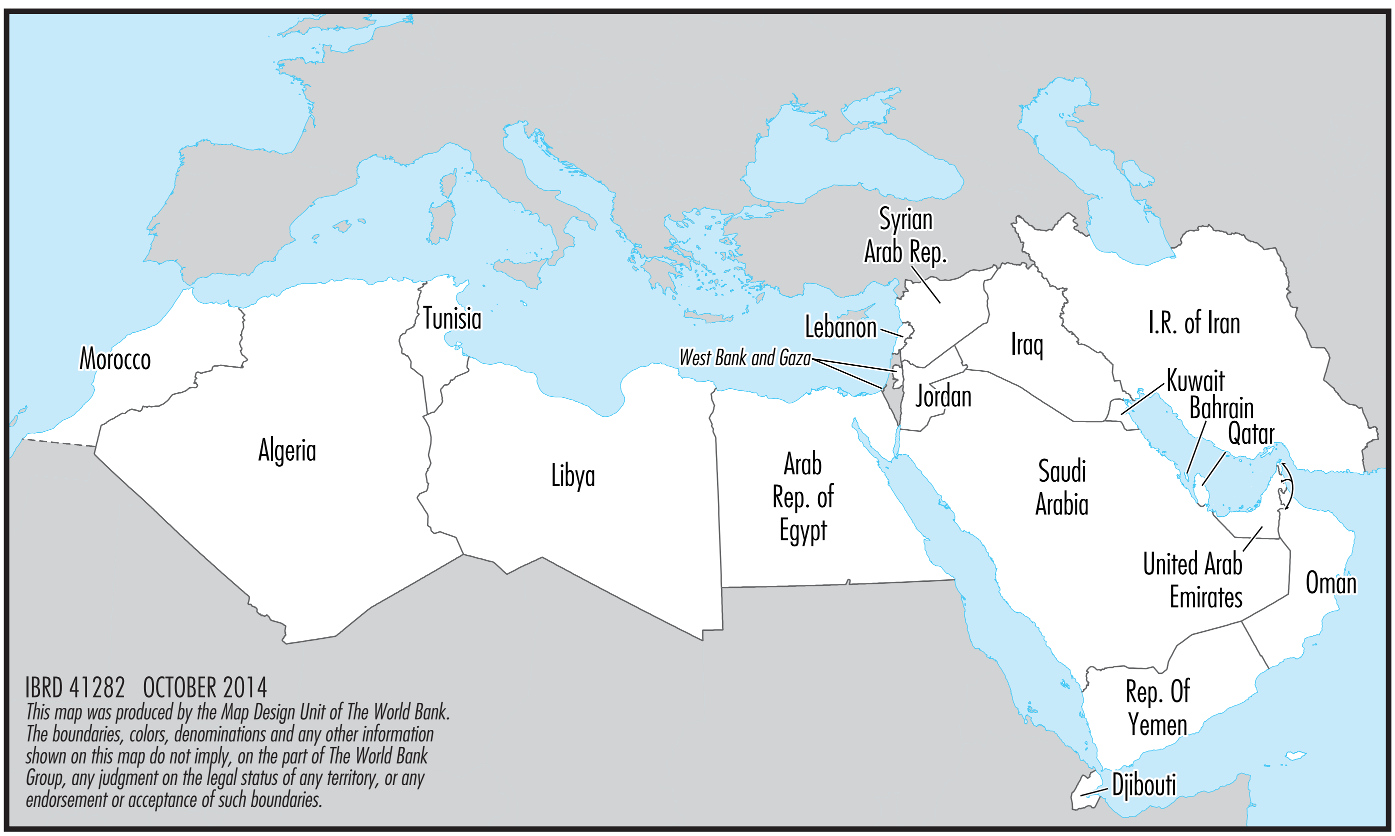
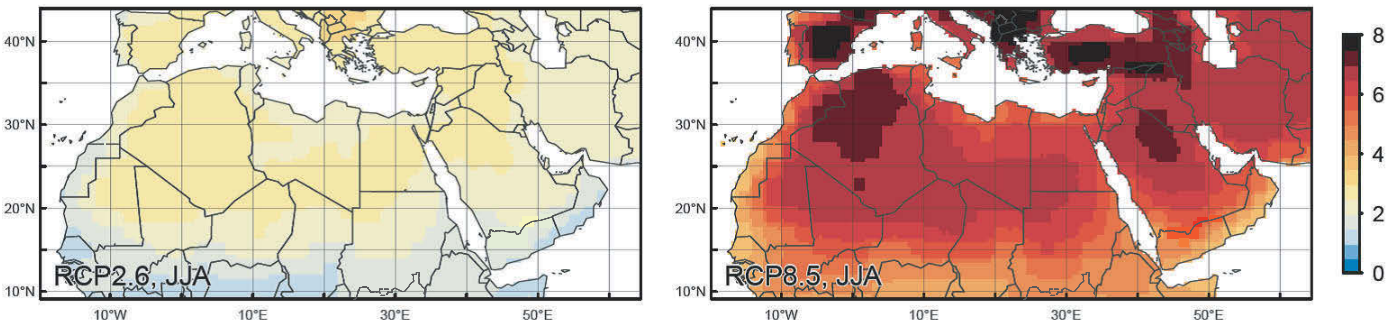


Figure 2.1: Multi-model mean temperature anomaly for RCP2.6 (2°C world, left) and RCP8.5 (4°C world, right) for the months of June-July-August for the Middle East and North African region.



Temperature anomalies in degrees Celsius are averaged over the time period 2071–2099 relative to 1951–1980.

2.1 Regional Summary

The population in Middle East and North Africa is projected to double by 2050, which together with projected climate impacts, puts the region under enormous pressure for water and other resources. The region is already highly dependent on food imports. Approximately 50 percent of regional wheat and barley consumption, 40 percent of rice consumption, and nearly 70 percent of maize consumption is met through imports. The region has coped with its inherent water scarcity through a variety of means: abstraction of groundwater, desalinization, and local community coping strategies. Despite its extreme water scarcity, the Gulf countries use more water per capita than the global average, with Arab residential water and energy markets among the most heavily subsidized in the world. The region is very diverse in terms of socio-economic and political conditions. Thus, adaptive capacity and vulnerability to climate risks varies enormously, especially between the Arab Gulf States and the other countries in the region.

Middle East and Northern Africa heavily relies on agriculture as a source of food and income, not only in the historically important "fertile crescent" of the Euphrates and Tigris region, but also at the Mediterranean coast and the Nile, while at the same time being largely covered by drylands and deserts. Seventy percent of the region's agricultural production is currently rain-fed, which leaves the region highly vulnerable to temperature and precipitation changes, and the associated implications for food security, social security, and rural livelihoods. This, in combination with social changes and strong urbanization rates, indicates a very vulnerable future for the Middle East and North Africa, particularly for the urban and rural poor. All countries in the region face a severe and fast growing resource squeeze, especially relating to severe water and land scarcity. The region is very diverse in terms of socio-economic and political conditions. Thus, adaptive capacity and vulnerability to climate risks varies enormously, especially between the Arab Gulf States and the other countries.

2.1.1 Regional Patterns of Climate Change

2.1.1.1 Temperatures and Heat Extremes

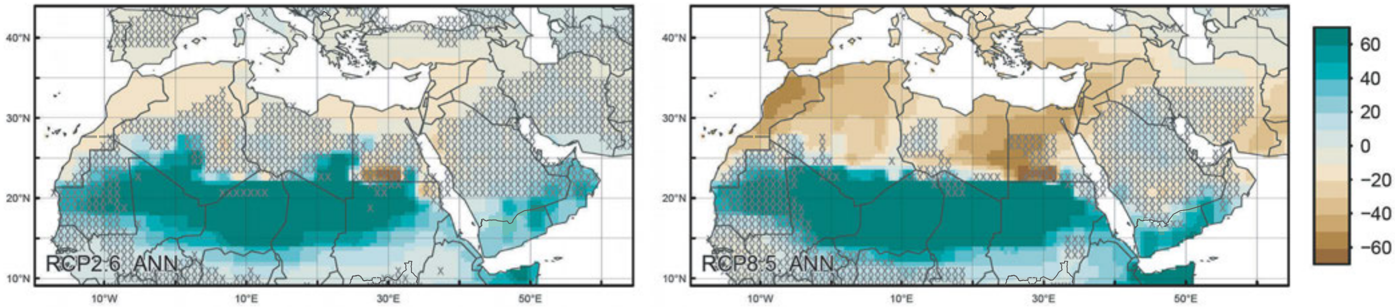
Warming of about 0.2° per decade has been observed in the region from 1961–1990, and at even faster rate since then, which in line with an increase in frequency in temperature extremes. Geographically, the strongest warming is projected to take place close to the Mediterranean coast. Here, but also in inland Algeria, Libya and large parts of Egypt, warming by 3°C in a 2°C world is projected by the end of the century. In a 4°C world, mean summer temperatures are expected to be up to 8°C warmer in parts of Algeria, Saudi Arabia and Iraq by the end of the century (see Figure 2.1).

By the end of the century, in a 2°C world, *highly unusual*[4] heat extremes will occur in about 30 percent of summer months almost everywhere in the MENA region. This implies that on average one of the summer months each year will exceed temperatures warmer than three standard deviations beyond the baseline average. *Unprecedented* heat extremes, however, will remain largely absent in a 2°C world, except for in some isolated coastal regions including the Mediterranean coasts of Egypt, and in Yemen, Djibouti and Oman. Here these events are projected to be relatively rare in a 2°C world, but are nevertheless expected to occur in 5–10 percent of summer months.

Whereas the increase in frequency of heat extremes is expected to level off by mid-century in a 2°C world, in a 4°C world it will continue increasing until the end of the century. in a 4°C world,

[4] In this report, *highly unusual* heat extremes refer to 3-sigma events and *unprecedented* heat extremes to 5-sigma events (see Appendix).

Figure 2.2: Multi-model mean of the percentage change in the aridity index in a 2°C world (left) and a 4°C world (right) for the Middle East and North Africa by 2071–2099 relative to 1951–1980.



Hatched areas indicate uncertain results, with two or more out of five models disagreeing on the direction of change. Note that a *negative* change corresponds to a shift to *more arid* conditions (see Appendix).[5]

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80 percent of summer months are projected to be hotter than 5-sigma (*unprecedented* heat extremes) by 2100, and about 65 percent are projected to be hotter than 5-sigma during the 2071–2099 period.

2.1.1.2 Precipitation and Aridity

Future northward shifts of air moisture associated with a stronger North Atlantic Oscillation (NAO) anomaly are projected to reduce rainfall in North Africa, Maghreb, and Mashrek. In a 4°C world, countries along the Mediterranean shore, notably Morocco, Algeria, and Egypt, are projected to receive substantially less rain. However, a projected northward shift of the Inter-Tropical Convergence Zone (ITCZ) is expected to increase moisture delivery to the southern parts of the region (which are already under the influence of monsoon systems), in particular to the southern Arabian Peninsula (Yemen, Oman). Consequently, projected annual mean precipitation changes show a clear North-South dipole pattern, with regions north of 25°N becoming relatively drier and regions to the south becoming wetter. The absolute increase in precipitation in the southern regions, however, will be very small, because these regions (with the exception of Yemen) are already very dry today. Furthermore, the effect of an increase in precipitation on water availability should be counteracted by a simultaneous increase in temperature, resulting in a higher rate of evaporation. Lastly, an increase in precipitation in the southern part of the region may be associated with more intense and extreme precipitation events.

[5] Some individual grid cells have noticeably different values than their direct neighbors (e.g., on Turkey's Black Sea coast under RCP8.5). This is due to the fact that the aridity index is defined as a fraction of total annual precipitation divided by potential evapotranspiration (see Appendix). It therefore behaves in a strongly nonlinear fashion and year-to-year fluctuations can be large. As the results are averaged over a relatively small number of model simulations, this can result in local jumps.

There is a close match between the pattern of change in the annual mean aridity index (AI) and projected precipitation changes. Changes in the aridity are primarily driven by changes in precipitation, with wetter conditions south of 25°N and in most southern parts of the Arabian Peninsula causing a drop in aridity, and drier conditions north of 25°N causing aridity there to increase. In the Mediterranean coastal region, the relative increase in aridity is more pronounced than would be expected from the drop in precipitation, because there is a substantial increase in evapotranspiration here due to enhanced warming.

2.1.2 Regional Sea-Level Rise

In the Mediterranean area, tide gauges recorded below-average sea-level rise during the 20th century, with average rise of 1.1–1.3 mm per year (slower than the global average of 1.8 mm per year). There has been significant interdecadal variability, however, with a slow gradual rise from 1960–1990, and rapid (above-average) rise after 1990.

Analysis for the 21st century indicates slightly below-average rise in the Mediterranean basin mostly as a result of the gravitational influence of Greenland ice sheet. Tunis, on the Mediterranean Sea coast, is projected to experience a median sea-level rise of 0.56 m (with a maximum of 0.96 m) by the end of the century in a 4°C world. This is 8 cm less than in Muscat, on the Arabian Sea coast, where a median 0.64 m (low estimate: 0.44 m, high estimate: 1.04 m) sea-level rise is projected. On the Atlantic coast, a 0.58 m sea-level rise is projected for Tangier (low estimate: 0.39 m, high estimate: 0.98 m). In a 1.5°C world, median sea level rises of 0.34 m, 0.35 m and 0.39 m are projected for Tunis, Tangier, and Muscat.

2.1.3 Sector-based and Thematic Impacts

2.1.3.1 The Agriculture-Water-Food Security Nexus

The Middle East and North Africa region is water scarce, with most of the land area receiving less than 300 mm of annual rainfall (200–300 mm represents the lower limit of rain-fed agriculture). Semi-arid belts along the coasts and mountains are the only water source areas and provide productive land for rain-fed agriculture. The annual availability of renewable water resources in most countries is below 1000 m^3 per capita (except for Iraq, Oman, Syria and Lebanon) and as low as 50 m^3 per capita for Kuwait. This water scarcity prevents countries from producing all required food domestically and makes the region dependent on food imports. From the current situation of critical water and arable land scarcity, both the 2°C and 4°C warming scenarios would put further pressure on water resources and agriculture.

- **Cropland:** Warmer and drier climate is projected to shift vegetation and agricultural zones northward (e.g., by 75 km for 2090–2099 relative to 2000–2009 in a 4°C world).
- **Length of growing period:** Lower rainfalls and higher temperatures will shorten growing periods for wheat in large parts of the region by about two weeks by mid-century (2031–2050). The wheat growing period in Tunisia is expected to be shortened by 10 days for 1.3°C warming, by 16 days for 2°C, by 20 days for 2.5°C and by 30 days for 4°C warming.
- **Crop yields:** Crop yields are expected to decline by 30 percent with 1.5–2°C warming and up to 60 percent with 3–4°C warming, with regional variation and without considering adaptation. Reductions in crop productivity of 1.5–24 percent are expected for the western Maghreb and 4–30 percent in parts of the Mashrek, by mid-century. Legumes and maize crops are expected to be worst affected in both areas as they are grown during the summer period.
- **Livestock:** Climate change will impact livestock production through various pathways, including changes in the quantity and quality of available feeds, changes in the length of the grazing season, additional heat stress, reduced drinking water, and changes in livestock diseases and disease vectors.

Uncertainty in projections arises from different approaches, different climate models, and the persistence of CO_2-effects because increasing atmospheric CO_2 concentration can potentially increase plant water-use efficiency (and thus crop productivity).

As a result of regional warming and changes in precipitation patterns, water availability is projected to decrease in most parts of the region throughout the 21st century. For example, in the eastern Anatolian mountains (headwaters of Euphrates and Tigris rivers) a runoff decrease of 25 percent to 55 percent is projected with 4°C warming.

Mountain areas in Morocco, Algeria, Lebanon, Syria, Iraq, Iran and Turkey play an important role in the water supply of the region, as they store a fraction of precipitation as snow. With projected reduction in snowfall and snow water storage, peak flows of melt water will shift towards earlier months, with negative impacts for downstream river systems and water availability in distant regions. For example, snowpack in the upper Nahr el Kalb basin in Lebanon was projected to shrink by 40 percent with 2°C warming, and 70 percent with 4°C warming. Hence, drought periods would occur 15–20 days earlier under a 2°C warming scenario, and more than a month earlier under a 4°C warming scenario.

2.1.3.2 Desertification, Salinization, and Dust Storms

The importance of climate change for desertification varies depending on local conditions, and interactions between drivers can be multifaceted. An increase in temperatures and evapotranspiration, change of precipitation regime, and the intensification or change in frequency of extreme events can directly trigger or enhance the desertification processes. Being covered mostly by drylands, the region is frequently threatened by dust storms, causing damage and disruption to people, agriculture and the economy. While there are no direct projection studies on dust storms in the region, wind as a driving factor can be projected from climate models. However, there are no regional studies on changing wind patterns under climate change in the region as yet, and future trends have to be derived from global studies.

An increase in salinization under climate change holds for all water resources in the region. The densely populated coastal areas in the region are most affected by climate-change-induced salinization (seawater intrusion), which is accelerated by climate-induced sea level rise. River salinization, meanwhile, is documented in studies of the Euphrates and Tigris, the Jordan River, and the Nile.

The salinization process is complex, however, and climate change is but one important factor among others (including irrigation, water uptake and land subsidence). Climate change and, in particular, projected drier conditions in the region, are expected to compound these other drivers (e.g., as more irrigation is needed for agriculture).

2.1.3.3 Human Health

The region is currently experiencing a resurgence of several vector-borne and viral diseases that had previously been in decline. Climate change may compound the challenge of managing these diseases, including such vector-board diseases as malaria, lymphatic filariasis, and leishmaniasis. In addition, outbreaks of cholera (which correlate with high temperatures and can follow extreme weather events that disrupt water supply) have in recent years caused deaths in Iraq, the Islamic Republic of Iran and the Republic of Yemen.

The Middle East and North Africa region is already characterized by very high summer temperatures, making the populations of the region highly susceptible to further temperature increases. In a 2°C world, the annual number of hot days with exceptionally high temperatures and high thermal discomfort is expected to increase in several capital cities, from 4 to 62 days in Amman (Jordan), from 8 to 90 days in Baghdad (Iraq) and from 1 to 71 days in Damascus (Syria). The greatest increase is expected in Riyadh (Saudi Arabia) where the number of hot days is projected to rise from 3 to 132 days per year. In a 4°C world, the average number of hot days is projected to exceed 115 days per year in all of these cities.

2.1.3.4 Migration and Security

The literature review revealed a link between climate change and migration in the region. It is expected that migration options will be more limited in a warmer world. Internal migration will continue to be important, but traditional patterns of mobility might be disrupted. Many people will be forced to move, while others trapped in poverty will be forced to stay. This indicates that climate-induced migration should be addressed not only within the context of climate change but also within economic, cultural, technological, and political frameworks.

Climate change could act as a threat multiplier in the region by placing additional pressure on already scarce resources and reinforcing preexisting threats as political instability, poverty, and unemployment. This can create the conditions for social uprising and violent conflict. Establishing a direct link between climate change and conflicts is challenging due to contradictory conclusions and methods. The findings are in some cases based on a single extreme event; others use rainfall or temperature variability as proxies for long-term changes; and some examine short-term warming. Further research is needed to investigate and establish the link between climate change and conflict and to relate long-term climate change, instead of single climatologic hazards, to migration and to conflicts.

2.1.3.5 Coastal Infrastructure and Tourism

Middle East and in North Africa countries are vulnerable to the impacts of sea-level rise. The population at risk in coastal cities numbered approximately 60 million in 2010; that number is expected to rise to 100 million by 2030. Separating out the socioeconomic drivers of vulnerability from the effects of sea-level rise, a study of 136 coastal cities identified Alexandria, Benghazi, and Algiers as particularly vulnerable to a 0.2 m sea-level rise by 2050. The study projected that, in the event of the failure of flood defenses, the effects of sea-level rise would increase damages from $16.5 billion to $50.5 billion in Alexandria, from $1.2 billion to $2 billion in Benghazi, and from $0.3 billion to $0.4 billion in Algiers. Annual losses would increase to $58 billion, $2.7 billion and $0.6 billion with 0.4 m of sea-level rise for these three cities respectively. A sea-level rise of one meter could impact 10 percent of Egypt's population, five percent of its urban area, and decrease the country's GDP by six percent. One study estimated that a sea-level rise of 0.30 m (projected for 2025 in this study) would flood 30 percent of metropolitan Alexandria, forcing about 545,000 people to abandon their homes and land, and leading to the loss of 70,500 jobs. With a sea-level rise of 0.5 m, projected for 2050, the same study calculated that about 1.5 million people would be displaced and about 195,500 jobs lost.

The impacts of climate change on tourism are unclear due to other non-climatic aspects of tourism, such as changes in travel costs, demand, and options for tourism destinations.

2.1.3.6 Energy Systems

Three types of climate-change-related stressors could potentially affect thermal power generation and hydropower generation: (1) Increased air temperatures could reduce thermal conversion efficiency; (2) changes in the water regime and water temperatures may decrease the available volume and decrease efficiency of water for cooling; and (3) extreme weather events could affect the production plants and the distribution systems. Regional studies published in English that quantify the impacts of climate change on thermoelectricity generation in the Middle East and in North Africa appear to be lacking. For North Africa, one study projects that hydropower production will decrease by almost 0.5 percent with 2°C warming compared to 2005 production levels due to changes in river runoff. In the same study the production is projected to decrease by 1.4 percent in the Middle East.

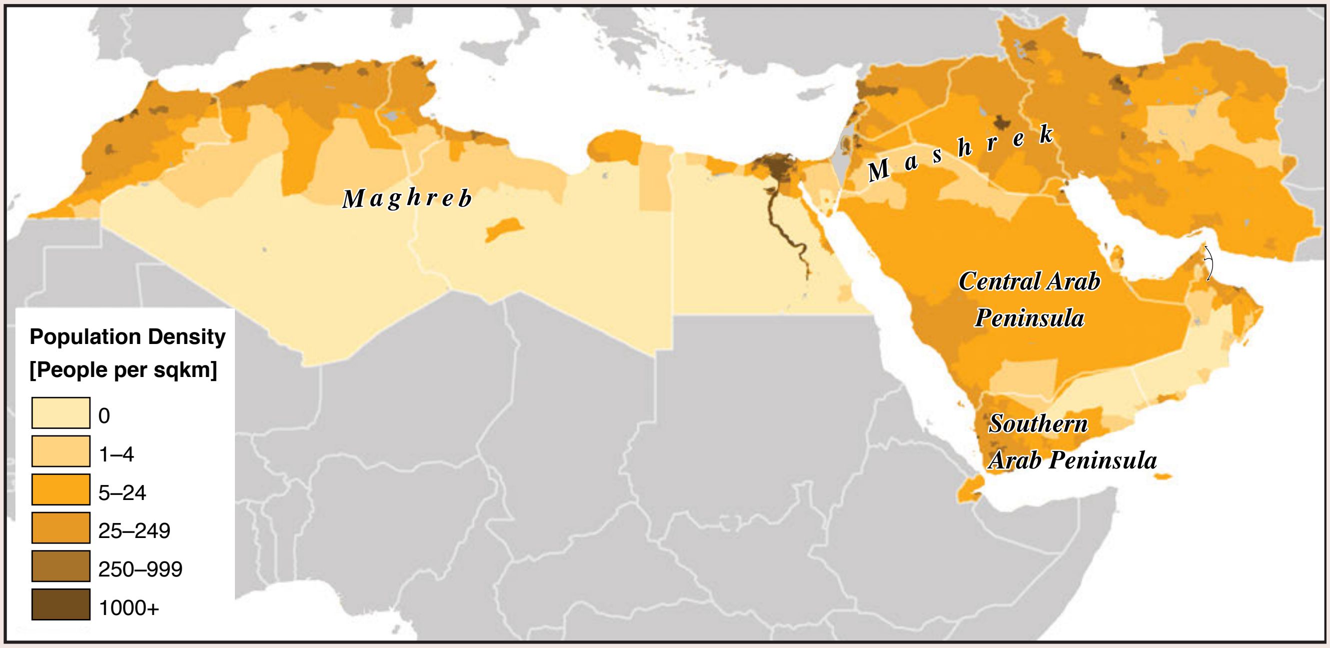
2.1.4 Overview of Regional Development Narratives

Box 2.1 gives an overview of the key climate risks in the region. The development narratives build on the climate change impacts analyzed in the Main report (cf. Table 4.10, Section 4.5). The Middle East and North Africa region is one of the world's most climate vulnerable regions. With its high and growing import dependency, the region is particularly vulnerable to worldwide and domestic agricultural impacts and related spikes in food prices. While never mono-causal, such climate-related market signals may fuel the potential for social unrest and migration and have a lasting effect on poverty in the region. Both the rural poor and the urban poor would be hard hit by agricultural impacts, as poor farmers in rural areas are particularly vulnerable to hunger and malnutrition and the urban poor are hit hard by rising food prices.

While biophysical impacts vary only slightly across the region, there is also a clear division in vulnerabilities and socioeconomic impacts between the (oil-) rich Arab Gulf States and other countries in the region. The former have the financial means to afford adaptation options, such as desalination technology and food imports.

A summary of projected impacts of climate change in key sectors for the region is provided in Box 2.2.

Box 2.1: Sub-regional risks for development in the Middle East and Northern Africa under 4°C warming in 2100 compared to pre-industrial temperatures



Maghreb

Strong warming reduction in annual precipitation, increased water stress and reduced agricultural productivity. Large coastal cities exposed to sea level rise.

Climate change risks will have severe implications on farmers' livelihoods, country economy, and food security. Exposure of critical coastal assets would have impact on the economy, including tourism. There is risk for accelerated migration flows to urban areas and social conflict.

Mashrek and Eastern Parts

Highly unusual heat and decrease in annual precipitation will increase aridity, decrease in snow water storage and river runoff for example in Jordon, Euphrates and Tigris. Adverse consequences for mostly rain-fed agricultural and food production.

Climate change risks will have severe implications on farmers' livelihoods, country economy, and food security. There is a risk for accelerated migration flows to urban areas and social conflict.

Arabian Peninsula

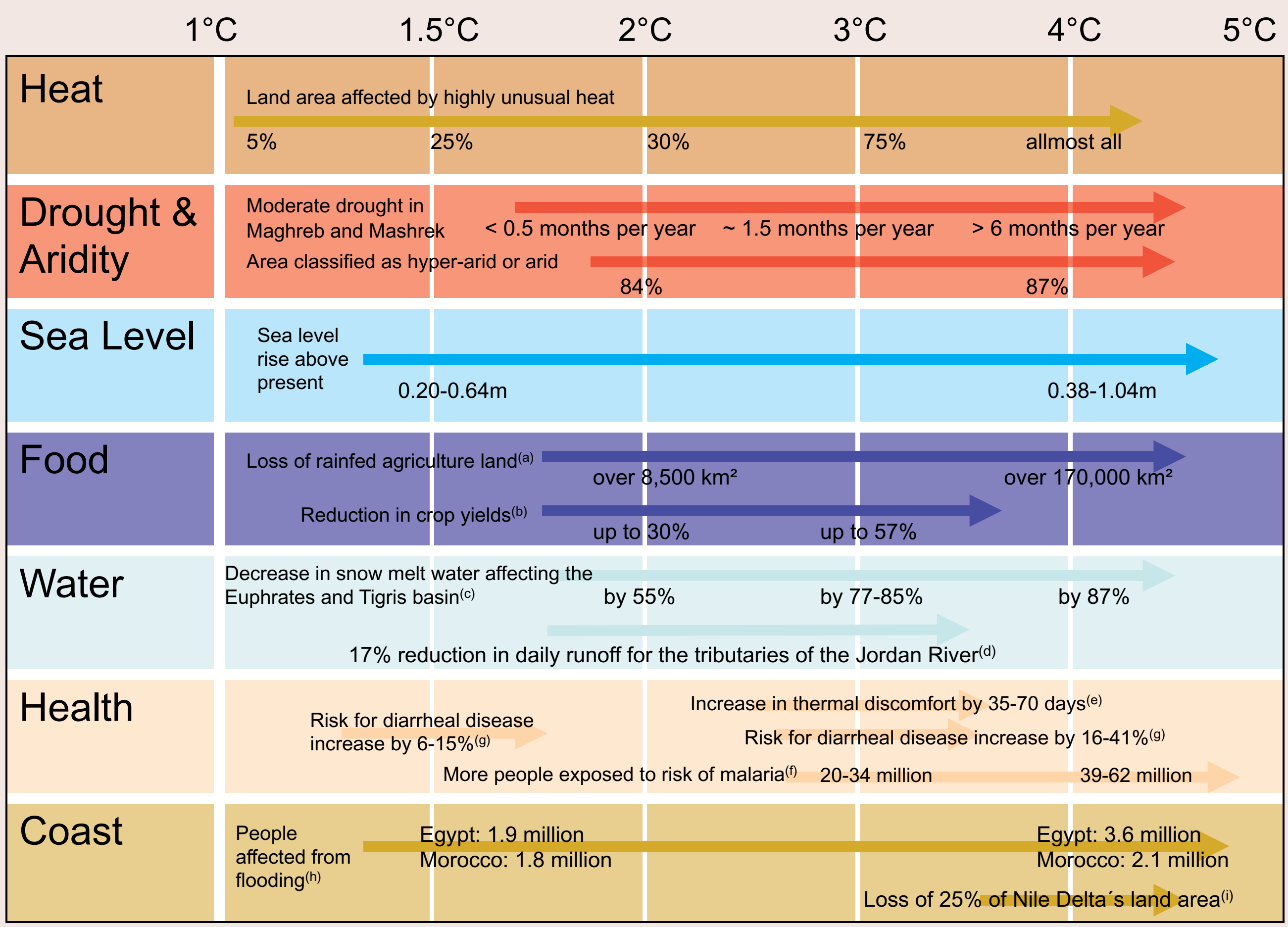
Highly unusual heat extremes in central Arabian Peninsula. In southern parts relative increase in annual precipitation, but uncertain trend of annual precipitation in central part. Sea level rise in the Arabian Sea likely higher than in Mediterranean and Atlantic coasts with risk of storm surges and adverse consequences for infrastructure.

More heat extremes expected to increase thermal discomfort, posing risk to labor productivity and health.

Data sources: Center for International Earth Science Information Network, Columbia University; United Nations Food and Agriculture Programme; and Centro Internacional de Agricultura Tropical—(2005). Gridded Population of the World, Version 3 (GPWv3): Population Count Grid. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). This map was reproduced by the Map Design Unit of The World Bank. The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.

Box 2.2: Projected Impacts of Climate Change in Key Sectors in the Middle East and North Africa Region

Warming levels are relative to pre-industrial temperatures. The impacts shown here are a subset of those summarized in Table 4.10 of the Main report. The arrows solely indicate the range of warming levels assessed in the underlying studies; but do not imply any graduation of risk unless noted explicitly. In addition, observed impacts or impacts occurring at lower or higher levels of warming that are not covered by the key studies highlighted here are not presented (e.g., increase in drought and aridity is already observed, but the respective study does not assess impacts below 1.5°C). Adaptation measures are not assessed here although they can be crucial to alleviating the impacts of climate change. The layout of the figure is adapted from Parry (2010). The lower-case superscript letters indicate the relevant references for each impact.[6] If there is no letter, the results are based on additional analyses for this report.

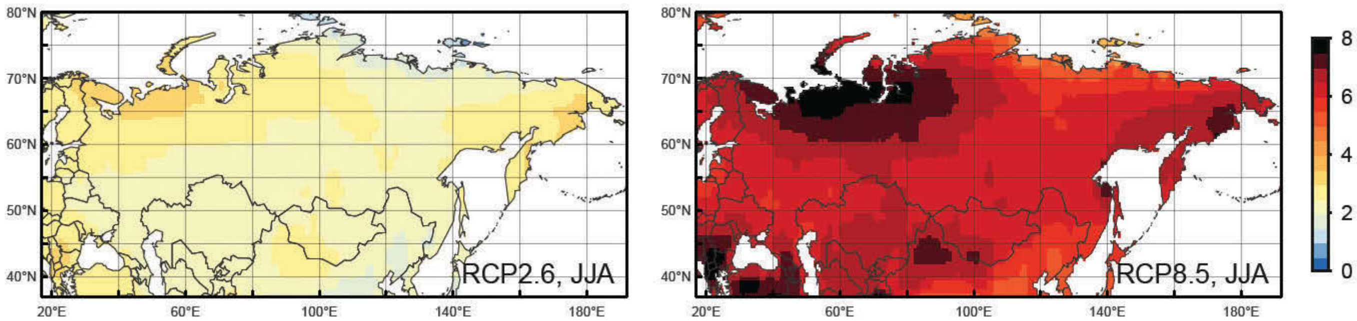


[6] (a) Evans (2008); (b) several studies, see Table 4.1; (c) Bokurt and Sen (2013); (d) Samuels et al. (2010); (e) Giannakopoulos et al. (2013); (f) van Lieshout et al. (2004); (g) Kolstad and Johansson (2011); (h) Brown et al. (2011); (i) Dasgupta et al. (2009).

Europe and Central Asia

The Europe and Central Asia region encompasses a wide range of geographic features ranging from the mountains to coasts in the Western Balkans and from the vast plains of Central Asia to Russia's boreal forests. In the Western Balkans and Central Asia, heat extremes and reduced water availability become threats as temperatures rise toward 4°C. This includes earlier glacier melt in Central Asia and shifts in the timing of water flows, and a higher risk of drought in the Western Balkans, with potential declines for crop yields, urban health, and energy generation. In Macedonia, for example, yield losses are projected of up to 50 percent for maize, wheat, vegetables and grapes at 2°C warming. Flood risk is expected to increase slightly along the Danube, Sava and Tisza rivers, and a slight decrease in 100-year flood events is projected in the southern parts of the Western Balkans. At 2°C warming, methane emissions from melting permafrost could increase by 20–30 percent across Russia in the mid-21st century.

Figure 3.1: Multi-model mean temperature anomaly for RCP2.6 (2°C world, left) and RCP8.5 (4°C world, right) for the months of June-July-August for the Europe and Central Asia region.



Temperature anomalies in degrees Celsius are averaged over the time period 2071–2099 relative to 1951–1980.

3.1 Regional Summary

The Europe and Central Asia region in this report covers 12 countries[7] within Central Asia, the Western Balkans, and the Russian Federation. The region encompasses a wide range of geographic features ranging from the mountainous and partly coastal Western Balkans to the vast plains of Central Asia and Russia's boreal forests. The region is inhabited by 226 million people; the population is, however, unequally distributed, with Kazakhstan having only six inhabitants per square kilometer and Kosovo as many as 166 inhabitants per square kilometer. The urbanization rate is about 50 percent. The population in Russia and the Western Balkans is projected to decline slightly, while the population of Central Asia is projected to increase sharply by 2050.

The region's importance is closely related to its rich natural resources, including gas and oil reserves as well as carbon stored in the boreal forests (the extraction and maintenance of which affect worldwide climate mitigation goals). Due to the geographical exposure as well as a relatively high share of agriculture in regional GDP, poverty rates that are increasing in recent years, inequalities and relatively poor social services and public infrastructure, the region is highly vulnerable to climate change impacts.

In climatic terms, the region displays a clear dipole: regions in the southwest become drier and regions in the northeast become wetter as the world warms toward 4°C. These warming conditions lead to a high risk of drought in the west and challenges to stable freshwater supplies in the east, where changes in precipitation combine with glacial melt to affect the seasonality of river discharge.

3.1.1 Regional Patterns of Climate Change

3.1.1.1 Temperature

Warming over Europe and Central Asia is projected to be above the global mean land warming. In a 2°C world, the multi-model mean warming by the end of the century is about 2.5°C above the 1951–1980 base period. This level of warming is reached by mid-century and then remains constant until the end of the century in a 2°C world. In contrast, in a 4°C world, summer warming continues almost linearly until the end of the century, reaching about 8.5°C above the 1951–1980 baseline by 2100 for the region's land area (Figure 3.1). The most pronounced warming is projected to occur in Northern Russia in the region bordering the Barents-Kara Sea, along the Black Sea coast (including the Balkans), and in Northern China and Mongolia. In these areas, mean summer temperatures by 2071–2099 will increase by about 3.5°C in a 2°C world and by about 7.5°C in a 4°C world.

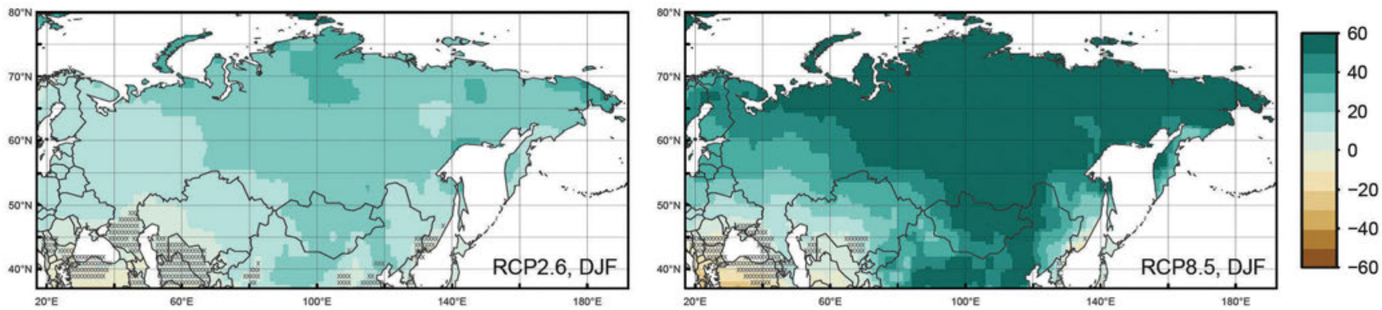
3.1.1.2 Heat Extremes

One of the clearest climate change signals is the strong increase in threshold-exceeding heat extremes[8] in the region surrounding the Black Sea, (and, in particular, the Balkans). Here, even in a 2°C world, *highly unusual* heat extremes, with temperatures warmer than three standard deviations beyond the baseline average, will occur in about 20–30 percent of summer months by 2100, and *unprecedented* heat extremes will occur between 5–10 percent of

[7] The Europe and Central Asia region in this report includes the following countries: Albania, Bosnia and Herzegovina, Kazakhstan, Kosovo, the Kyrgyz Republic, the Former Yugoslav Republic of Macedonia, Montenegro, the Russian Federation, Serbia, Tajikistan, Turkmenistan, and Uzbekistan.

[8] In this report, *highly unusual* heat extremes refer to 3-sigma events and *unprecedented* heat extremes to 5-sigma events (see Appendix).

Figure 3.2: Multi-model mean of the percentage change in the aridity index (AI) for RCP2.6 (2°C world) (left) and RCP8.5 (4°C world) (right) for the Europe and Central Asia region by 2071–2099 relative to 1951–1980.



Hatched areas indicate uncertain results, with two or more out of five models disagreeing on the direction of change. Note that a negative change corresponds to a shift to more arid conditions.[9]

summer months. For the whole region, about 15 percent of the land area is projected to be affected by *highly unusual* heat extremes in a 2°C world by the end of the century, while *unprecedented* heat extremes will remain almost absent. In contrast, in a 4°C world, 85 percent of land area in the region is projected to be affected by *highly unusual* heat extremes; 55 percent of the area is projected to be affected by *unprecedented* heat extremes by 2100. Most of the heat extremes will occur south of approximately 50°N, stretching from the Balkans all the way to Japan. The number of tropical nights south of approximately 50°N is expected to increase by 20–30 days in a 2°C world and by 50–60 days in a 4°C world.

3.1.1.3 Precipitation

The basic concept of the "dry-getting-drier and wet-getting wetter" under climate change is a good first order estimate for Europe and Central Asia. The relative wetting of the Northeast, (i.e., Siberia) is the most pronounced signal, possibly associated with a shift in storm tracks. The increase in precipitation is far more pronounced during the winter than during the summer.

Despite an overall negative trend in extreme precipitation events, regional and seasonal projections for the Balkans remain inconclusive in a 2°C world. However, 20–30 percent reductions are projected for a 4°C world. Although projections of precipitation for the Central Asian countries suffer from substantial model uncertainties, the overall trend for heavy precipitation intensity is below the global average.

Central and Eastern Siberia is one of the regions expected to experience the strongest increase in heavy precipitation events. Heavy precipitation events with a 20-year return time are projected to intensify by over 30 percent in this region and the return time of such extremes from the 20-year reference period (1986–2005) in a 4°C world is projected to fall below five years by the end of the 21st century. Changes are much weaker (greater than 10 percent increase in intensity and 10–15 year return times) in a 2°C world.

3.1.1.4 Drought and Aridity

In a 2°C world around five percent more land in the region will be affected by aridity; in a 4°C world, the land area classified as hyper-arid, arid, or semi-arid will increase by more than 30 percent (Figure 3.2). The Western Balkans is projected to suffer from increased drought conditions. Though changes in annual precipitation are weak, the Balkans and the region surrounding the Caspian Sea are projected to become more arid due to warming-induced drying.

Projections for future drought also mimic the overall trend toward a wetter climate. Some projections even show a negative change in drought risk for the eastern Siberia under a 4°C world. Projections for central and eastern Russia, meanwhile, are inconclusive.

3.1.2 Regional Sea-level Rise

The countries of the ECA region considered here (excluding Russia) cover a relatively short stretch of coast that is affected by sea level rise. The sea-level rise in the region is projected to reach 0.52 m on average (0.37–0.9 m) in a 4°C world from 2081–2100 above the 1986–2005 baseline, with rates of increase of 10.1 mm per year (5.9–19.6 mm/yr) from 2081–2100. This is slightly below the global mean. One of the most vulnerable coasts in the region is the Drini-Mati River Delta in Albania. The sea level in the Caspian Sea, that is completely isolated from the global ocean, is projected to fall by 4.5 m by the end of the century due to increased evaporation.

[9] Some individual grid cells have noticeably different values than their direct neighbors. This is due to the fact that the aridity index is defined as a fraction of total annual precipitation divided by potential evapotranspiration (see Appendix). It therefore behaves in a strongly non-linear fashion and year-to-year fluctuations can be large. As the results are averaged over a relatively small number of model simulations, this can result in local jumps.

3.1.3 Sector-based and Thematic Impacts

3.1.3.1 Glaciers and Snow

The enhanced runoff from the glaciers is expected to continue over the 21st century. Projections of glacier change use different scenarios applied to different geographical regions for different reference periods, making direct scenario comparisons rather difficult. In all projections, however, glaciers are expected to lose more than half of their volume by 2100. The loss of stored water implies increased runoff in the coming decades, followed by a significant shortage until the store is completely emptied.

The principal driver behind the glacier volume and snow cover change is air temperature. Projections show approximately 50 percent (31–66 percent) glacier volume loss in Central Asia in a 2°C world and approximately 67 percent (50–78 percent) glacier volume loss in a 4°C world. A temperature rise higher than 1.1°C will cause the small glaciers of the Balkans (Albanian Alps and Montenegrin Durmitor) to melt completely within decades.

3.1.3.2 Water

River flows in Central Asia will in general be lower during the summer months when the vegetation is present, while winter runoff may increase. Climate change in the region is likely to have consequences for runoff seasonality, and a shift in the peak flows from summer to spring can be expected due to earlier snow melt. This may increase water stress in summer, in particular in unregulated catchments. The annual amount of water in rivers is not likely to decrease considerably, at least until the middle of the century when glacier depletion will cause a distinct decrease in water volume of Central Asian rivers. Over the short-term, enhanced glacier melt rates will provide an inflow of additional water into the rivers, though in the more remote future, when glaciers are shrinking, their buffer effect will disappear. This effect will be more pronounced for the Amu Darya, because of its actual higher share of glacier melt water, than for the Syr Darya.

Very few scientific studies about regional impacts on water resources and river runoff levels are available for the Western Balkan countries, with most projections done on a broader European level. In particular, there is a lack of area-wide hydrological data, especially since the 1990s. Water availability over summer months In the Balkans is assumed to decrease considerably until the end of the century. In the northern parts of the Balkans, spring and winter riverine flood risk can increase. Results from a global study show severe decreases in annual discharge in the Western Balkans of more than 45 percent in a 4°C world.

3.1.3.3 Agriculture

Central Asia's agricultural sector is highly dependent on irrigation water availability, and the impact climate change will have on agriculture in both Central Asia and the Western Balkans is significant. Changing precipitation patterns, reduced runoff in the major river basins, and increasing temperatures will put additional pressure on available water resources (and, at the same time, increase agricultural water demand). Prolonged periods of above average temperatures will exacerbate heat stress of agricultural crops, leading to decreasing plant productivity. Droughts, meanwhile, are very likely to increase desertification in the Kyrgyz Republic and Kazakhstan.

- **Yields.** Yields for a few crops, including alfalfa, grasslands, and wheat in parts of the region are projected to increase in parts of the region. The overwhelming majority of results, however, point toward decreasing crop yields. Climate change is also likely to increase heat stress and change river runoff reducing agricultural yields in the long term. In the Western Balkans, the increasing occurrence of droughts will be a major threat to agricultural production under climate change; conversely so will the increasing appearance of extreme rain and flood events.
- **Livestock.** Increasing temperatures and reduced water availability will negatively impact livestock production. Pasture growth and regeneration rates are expected to decline in parts of Central Asia. If producers react to the changes by increasing livestock numbers, pastures might be at added risk from overgrazing and erosion. In the areas where productivity of alfalfa and grasslands is projected to increase (e.g., in Uzbekistan), the indirect effect of climate change on livestock production might be positive.
- **Food Security.** The rural population in Central Asia is at a particular risk of food insecurity, and there have been recent cases of a direct hunger threat. Rising food prices that might follow production declines will affect the poorest social groups (i.e., people who spend a large portion of their income on food). There are, however, opportunities to increase regional agricultural production efficiency by, for example, improving agricultural policies and institutions as well as by improving production infrastructure and technology. Finally, while access to international food markets could lead to higher food security and lower prices, the region is not well integrated into international trade networks.

3.1.3.4 Human Health

A number of diseases and adverse health conditions are already present across Eastern Europe and Central Asia, and it is anticipated that some of these will be affected by such climatic changes as increased temperatures and more frequent and intense rainfall and drought events. A lack of certainty about the mechanisms through which climate change affects the incidence of diseases, however, prevents strong claims about future trends. In general, however, higher temperatures correlate to an increased occurrence of tick-borne encephalitis and mosquito transmitted malaria and dengue fever. Malaria is endemic in Tajikistan; since the 1990s, it has reoccurred in Uzbekistan, the Kyrgyz Republic, and Turkmenistan. Furthermore, there is evidence providing stronger indications of an increased risk of dengue in the Western Balkans.

Historical observations show that increased temperatures, as well as extreme weather events such as floods can lead to drinking water contamination, salmonellosis, cholera, typhoid, and dysentery. Evidence from Albania and Macedonia in the Western Balkans, as well as Tajikistan and Kazakhstan in Central Asia, show an increased vulnerability of heat related strokes and mortalities. Severe floods, like those that occurred in recent years in Serbia, as well as glacial outbursts in the mountains of Tajikistan, Uzbekistan and the Kyrgyz Republic, increase vulnerability to injuries and drowning.

3.1.3.5 Energy

Climate change will have a strong impact on the region's energy sector. In Central Asia, the demand for electricity is expected to rise as a consequence of population growth, and current and projected economic growth. Hydroelectricity can play a major role in the future energy mix of the Central Asian countries, as only 8 percent of the hydropower potential of the region has been developed. Changes in climate and melting of glaciers generally mean that the amount of water available for power generation could increase, but the new pattern of intra-annual runoff distribution means that less water will be available for energy generation in the summer. Changes in reservoir management and the need to balance water requirements for agriculture may also have a negative impact on energy availability over the summer months.

Due to changes in river water temperatures and river flows, the capacity of nuclear and fossil-fueled power plants in Southern and Eastern Europe could decrease from 6.3 percent to 19 percent in Europe from 2031–2060 compared to the production levels observed from 1971–2000. Furthermore, due to the increased incidence of droughts and extreme river low flows, the mean number of days during which electricity production will be reduced by more than 90 percent is projected to increase threefold; from 0.5 days per year (in present days) to 1.5 days per year from 2031–2060 under 1.5˚C global warming. The challenge to meet growing energy demands in the Western Balkans will be further intensified by a reduction in energy generation from hydropower sources as the result of decreases in precipitation.

3.1.3.6 Security and Migration

Climate change impacts will intensify in Central Asia and contribute to increasing the population's overall physical, economic, and environmental insecurity. A key vulnerability is the high exposure of the densely populated, agriculturally productive Fergana Valley region to catastrophic floods and mudflows as a result of glacial lake outbursts.

Forecasting migration patterns is a challenge because of both the complexity of these phenomena and the low reliability of and significant gaps in existing datasets particularly with respect to information on environmental problems (including disasters) and environmentally induced migration.

The Western Balkans, especially those nations bordering the sea, are projected to experience sea-level rise and hotter temperatures; this is expected to result in growing numbers of people moving from coastal zones to cooler mountainous zones. Migration in the Western Balkans has already led to severe demographic changes, which coupled with an aging population is expected to lead to further increased regional climate change sensitivity as a result of decreased adaptive capacity.

In Central Asia, the majority of the population lives in climate hotspot areas, with projected increase in the intensity and frequency of extreme events (e.g. forest fires, heat waves, floods). The rural population is among those that is the most vulnerable, and an increased rural-to-urban migration could be expected. Women are particularly vulnerable, since they typically remain behind in the countryside to manage their households as men migrate to urban areas. Taking into account the urbanization trends in Central Asia, the vulnerability of cities to catastrophes might increase.

3.1.3.7 Forests of the Russian Federation

Russia's forest covers a large area with a huge amount of carbon stored in the soil and vegetation. Future projections highlight changes in productivity (both increasing and decreasing, depending on species, region, site and so forth) and vegetation composition which will typically be stronger under a 4°C world than a 2°C world. Changes in species composition toward better-adapted tree species may buffer productivity losses, but they will also lead to a change in the forest structure and biodiversity.

The region includes a large forest area affected by permafrost which contains large stock of carbon and methane. In general, changes in the carbon, water and energy fluxes of Russia's forests may strongly affect local, regional, and global forest resource availability, ecosystem functioning, services such as carbon storage and biodiversity, and even feedback on the global climate system. Substantial research gaps exist, for example, regarding the effect of disturbances such as fire and insect outbreaks on vegetation cover or carbon stocks and how climate change will change forest productivity under concomitant changes of growing conditions, disturbance regimes, and forest management practices.

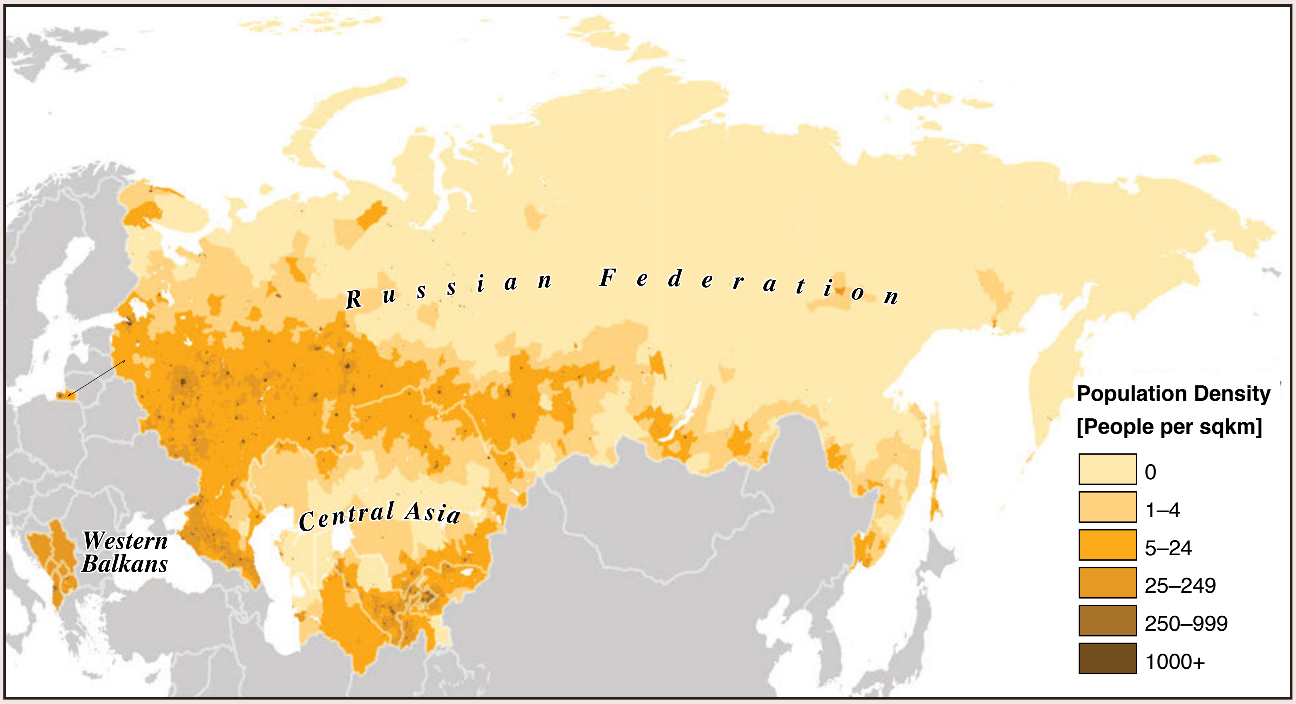
3.1.4 Overview of Regional Development Narratives

Box 3.1 gives an overview of the key climate risks in the region. The development narratives build on the climate change impacts analyzed in the Main report (cf. Table 5.7, Section 5.5). Increasing climate variability and changing climate are expected to threaten agricultural and energy production in the region by changing the hydrological snow, and glacial regimes. Furthermore, climate change in interaction with vegetation shifts and fires threaten forest productivity and carbon storage in the Eurasian forests. The exposure to climatic changes in combination with the regional social vulnerability patterns could have negative consequences on key development trends.

- **Water resources in Central Asia are projected to increase during the first half of the century and decline thereafter, amplifying the challenge of accommodating competing water demands for agricultural production and hydropower generation.** The timing of river flows is projected to shift from summer to spring, with adverse consequences for water availability in critical crop-growing periods. An intensification of the runoff variability is expected to increase in all river basins in the region. The competition for water resources between key sectors (e.g., agriculture and energy), as well as between upstream and downstream water users, can therefore be expected to intensify. Until 2030 the contribution of glacial melt water to river runoff might lead to an increase in river runoff and partially offset the runoff variability. In the second half of the century, however, runoff generation of melt water in the mountainous parts of the river basins is likely to decline substantially. An increasing population, followed by increased water and energy demand, will put an additional pressure on scarce resources. Improving irrigation water management and efficiency of irrigation infrastructure, institutional and technical advancements in agriculture, integrated transboundary river management, and new employment opportunities outside agriculture could counterbalance the negative impacts of these environmental changes.
- **Climate extremes in the Western Balkans pose major risks to agricultural systems, energy and human health.** The vulnerability of the Western Balkans to climatic changes is mainly related to rain-fed agricultural production and the high share of the population that is dependent on income from agriculture. There are, however, projections showing production increases for irrigated crops in parts of the region (for example, C4 summer crops and tubers in Serbia). Increased temperatures as well as both droughts and extreme river flows could pose further challenges to energy production. Recent floods and landslides illustrate the threats of extreme events to human health and well-being. In addition, the climatic conditions in the region are becoming increasingly suitable to dengue fever and other vector-transmitted diseases such as dengue fever.
- **The responses of the permafrost and the boreal forests of Russia to climate change have consequences for timber productivity and global carbon stocks.** Changes to carbon fluxes in response to rising temperatures, changing precipitation patterns, and interactions with disturbance regimes in the forest and permafrost areas in the region can have far-reaching repercussions—affecting the global carbon stock and having an effect on albedo in the northern hemisphere. While climate change can increase the productivity of some tree species, heat waves, water stress, forest fires, and an increased incidence of tree pests and diseases could counterbalance any positive effects. Improving forest management and sustainable wood extraction are of key importance as is sustainable and far-sighted management of Russian forest ecosystems, including addressing key research gaps.

A summary of projected impacts of climate change in key sectors for the region is provided in Box 3.2.

Box 3.1: Sub-regional risks for development for Europe and Central Asia at 4°C warming in 2100 compared to pre-industrial temperatures



Western Balkans

Increase in droughts, unusual heat extremes and flooding. High risks for agriculture, human health and stable hydropower generation.

Risks for human health, food and energy security.

Central Asia

Increasing glacial melt alters river runoff. Risks of glacial lake outbursts, flooding and seasonal water shortages. Increasing competition for water resources due to rising agricultural water demand and demand for energy production.

Risks for poor through rising food prices particularly affecting women, children and the urban poor. Risks for human health due to spreading disease, heat waves and flooding.

Boreal Forests of the Russian Federation

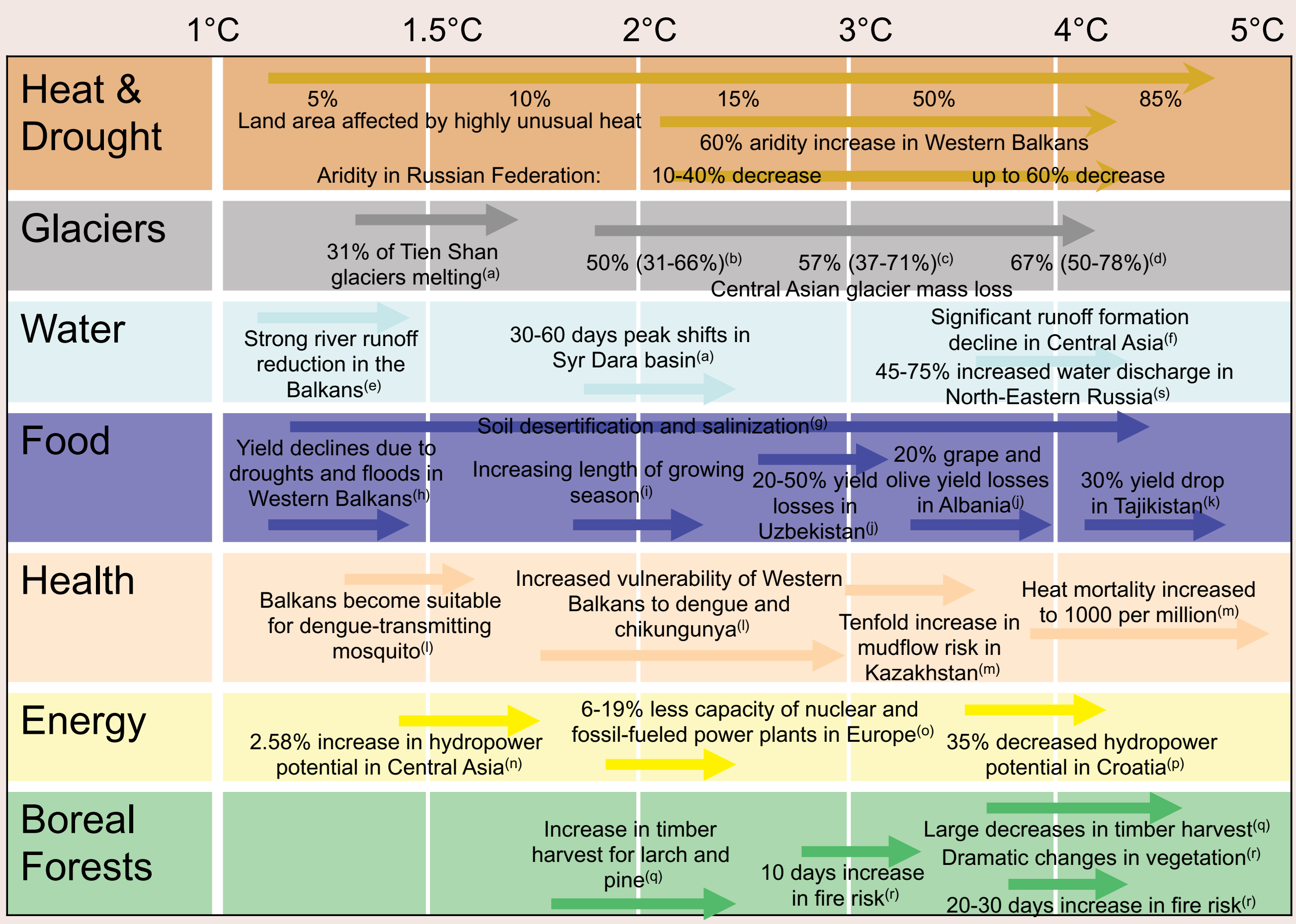
Unusual heat extremes and annual precipitation increase, rising risks of forest fires and spread of pests leading to tree mortality and decreasing forest productivity. Possible northward shift of treeline and changes in species composition. Risks of permafrost melt and methane release.

Risk for timber production and ecosystem services, including carbon capture. Risks of substantial carbon and methane emissions.

Data sources: Center for International Earth Science Information Network, Columbia University; United Nations Food and Agriculture Programme; and Centro Internacional de Agricultura Tropical—(2005). Gridded Population of the World, Version 3 (GPWv3): Population Count Grid. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). This map was reproduced by the Map Design Unit of The World Bank. The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.

Box 3.2: Projected Impacts of Climate Change in Key Sectors in the Europe and Central Asia Region

Warming levels are relative to pre–industrial temperatures. The impacts shown here are a subset of those summarized in Table 5.7 of the Main report. The arrows solely indicate the range of warming levels assessed in the underlying studies but do not imply any graduation of risk unless noted explicitly. In addition, observed impacts or impacts occurring at lower or higher levels of warming that are not covered by the key studies highlighted here are not presented (e.g., an increase in Tien Shan glacier melt is already observed, but the respective study does not assess the observed impacts). Adaptation measures are not assessed here, although they can be crucial to alleviating the impacts of climate change. The layout of the figure is adapted from Parry (2010). The lower-case superscript letters indicate the relevant references for each impact.[10] If there is no letter, the results are based on additional analyses conducted for this report.



[10] (a) Siegfried et al. (2012); (b) Marzeion et al. (2012); (c) Marzeion et al. (2012); Giesen and Oerlemans (2013); Radic et al. (2013); (d) Marzeion et al. (2012); Giesen and Oerlemans (2013); Radic et al. (2013); (e) Dimkic and Despotovic (2012); (f) Hagg et al. (2013); (g) Thurmann (2011); World Bank (2013f); World Bank (2013d); World Bank (2013a); (h) Maslac (2012); UNDP (2014); (i) Sutton et al. (2013a); Sommer et al. (2013); (j) Sutton et al. (2013a); (k) World Bank (2013m); (l) Caminade et al. (2012); (m) BMU and WHO-Europe (2009); (n) Hamududu and Killingtveit (2012); (o) van Vilet et al. (2012); (p) Pasicko et al. (2012); (q) Lutz et al. (2013b); (r) Tchebakova et al. (2009); (s) Schewe et al. (2013).

Abbreviations

°C	degrees Celsius
$	United States Dollars
AI	Aridity Index
AOGCM	Atmosphere-Ocean General Circulation Model
AR4	Fourth Assessment Report of the Intergovernmental Panel on Climate Change
AR5	Fifth Assessment Report of the Intergovernmental Panel on Climate Change
BAU	Business as Usual
$CaCO_3$	Calcium Carbonate
CAT	Climate Action Tracker
CMIP5	Coupled Model Intercomparison Project Phase 5
CO_2	Carbon Dioxide
DGVM	Dynamic Global Vegetation Model
DIVA	Dynamic Interactive Vulnerability Assessment
DJF	December, January, and February (the winter season of the northern hemisphere)
ECA	Europe and Central Asia
ECS	Equilibrium Climate Sensitivity
ENSO	El-Niño/Southern Oscillation
FAO	Food and Agricultural Organization
FPU	Food Productivity Units
GCM	General Circulation Model
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GLOF	Glacial Lake Outburst Flood
HCS	Humboldt Current System
IAM	Integrated Assessment Model
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISI-MIP	Inter-Sectoral Impact Model Intercomparison Project
ITCZ	Intertropical Convergence Zone
JJA	June, July, and August (the summer season of the northern hemisphere; also known as the boreal summer)
LAC	Latin America and the Caribbean
LDC	Least Developed Countries
MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change
MCMA	The Mexico City Metropolitan Area
MENA	Middle East and North Africa
MGIC	Mountain Glaciers and Ice Caps
NAO	North Atlantic Oscillation
NDVI	Normalized Differenced Vegetation Index (used as a proxy for terrestrial gross primary production)
NH	Northern Hemisphere
NPP	Net Primary Production
OECD	Organization for Economic Cooperation and Development
PDSI	Palmer Drought Severity Index
PgC	Petagrams of Carbon (1 PgC = 1 billion tons of carbon)
ppm	Parts Per Million
PPP	Purchasing Power Parity (a weighted currency based on the price of a basket of basic goods, typically given in US dollars)
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
SCM	Simple Climate Model
SLR	Sea-level Rise
SRES IPCC	Special Report on Emissions Scenarios
SREX IPCC	Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation

TgC Teragrams of Carbon (1 TgC = 1 million tons of carbon)
UNCCD United Nations Convention to Combat Desertification
UNDP United Nations Development Programme
UNEP United Nations Environment Programme
UNFCCC United Nations Framework Convention on Climate Change
UNHCR United Nations High Commissioner for Refugees
USAID United States Agency for International Development
WBG World Bank Group
WGI Working Group I (also WGII, WGIII)
WHO World Health Organization

Glossary

Aridity Index: The Aridity Index (AI) is an indicator designed for identifying structurally arid regions; that is, regions with a long-term average precipitation deficit. AI is defined as total annual precipitation divided by potential evapotranspiration, with the latter a measure of the amount of water a representative crop type would need as a function of local conditions such as temperature, incoming radiation, and wind speed, over a year to grow, which is a standardized measure of water demand.

Biome: A biome is a large geographical area of distinct plant and animal groups, one of a limited set of major habitats classified by climatic and predominant vegetative types. Biomes include, for example, grasslands, deserts, evergreen or deciduous forests, and tundra. Many different ecosystems exist within each broadly defined biome, all of which share the limited range of climatic and environmental conditions within that biome.

C3/C4 plants: C3 and C4 refer to two types of photosynthetic biochemical pathways. C3 plants include more than 85 percent of plants (e.g., most trees, wheat, rice, yams, and potatoes) and respond well to moist conditions and to additional CO_2 in the atmosphere. C4 plants (e.g., savanna grasses, maize, sorghum, millet, and sugarcane) are more efficient in water and energy use and outperform C3 plants in hot and dry conditions.

CAT: The Climate Action Tracker is an independent, science-based assessment that tracks the emissions commitments of and actions by individual countries. The estimates of future emissions deducted from this assessment serve to analyze warming scenarios that could result from current policy: (i) *CAT Reference BAU*: a lower reference business-as-usual scenario that includes existing climate policies but not pledged emissions reductions; and (ii) CAT Current Pledges: a scenario additionally incorporating reductions currently pledged internationally by countries.

CO_2 fertilization: The CO_2 fertilization effect refers to the effect of increased levels of atmospheric CO_2 on plant growth. It may increase the rate of photosynthesis mainly in C3 plants and increase water use efficiency, thereby causing increases in agricultural productivity in grain mass and/or number. This effect may to some extent offset the negative impacts of climate change on crop yields, although grain protein content may decline. Long-term effects are uncertain as they heavily depend on a potential physiological long-term acclimation to elevated CO_2 and other limiting factors, including soil nutrients, water, and light. (See also Box 2.4 on the CO_2 fertilization effect on crop productivity.)

CMIP5: The Coupled Model Intercomparison Project Phase 5 (CMIP5) brought together 20 state-of-the-art GCM groups, which generated a large set of comparable climate-projection data. The project provided a framework for coordinated climate change experiments and includes simulations for assessment in the IPCC AR5.

Development narratives: Development narratives highlight the implications of climate change impacts on regional development. The *Turn Down the Heat* series, and in particular this report, discuss the potential climate change impacts on particularly vulnerable groups along distinct storylines—the so called development narratives. These development narratives were developed for each region in close cooperation with regional World Bank specialists. They provide an integrated, often cross-sectoral analysis of climate change impacts and development implications at the sub-regional or regional level. Furthermore, the development narratives add to the report by allowing the science-based evidence of physical and biophysical impacts to be drawn out into robust development storylines to characterize the plausible scenarios of risks and opportunities—showcasing how science and policy interface.

GCM: A General Circulation Model is the most advanced type of climate model used for projecting changes in climate due to increasing greenhouse gas concentrations, aerosols, and external forcing (like changes in solar activity and volcanic eruptions). These models contain numerical representations of physical processes in the atmosphere, ocean, cryosphere, and land surface on a global three-dimensional grid, with the current generation of GCMs having a typical horizontal resolution of 100–300 km.

GDP: Gross Domestic Product is the sum of the gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the product. It is calculated without deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.

GDP PPP: This is GDP on a purchasing power parity basis divided by population. Whereas PPP estimates for OECD countries are quite reliable, PPP estimates for developing countries are often rough approximations.

Highly unusual and Unprecedented: In this report, *highly unusual* and *unprecedented* heat extremes are defined using thresholds based on the historical variability of the current local climate. The absolute level of the threshold depends on the natural year-to-year variability in the base period (1951–1980), which is captured by the standard deviation (sigma). Highly unusual heat extremes are defined as 3-sigma events. For a normal distribution, 3-sigma events have a return time of 740 years. The 2012 U.S. heat wave and the 2010 Russian heat wave classify as 3-sigma and thus highly unusual events. Unprecedented heat extremes are defined as 5-sigma events. They have a return time of several million years. Monthly temperature data do not necessarily follow a normal distribution (for example, the distribution can have long tails, making warm events more likely) and the return times can be different from the ones expected in a normal distribution. Nevertheless, 3-sigma events are extremely unlikely and 5-sigma events have almost certainly never occurred over the lifetime of key ecosystems and human infrastructure.

Hyper-aridity: This refers to land areas with very low Aridity Index (AI) scores, generally coinciding with the great deserts. There is no universally standardized value for hyper-aridity, and values between 0 and 0.05 are classified in this report as hyper-arid.

IPCC AR4, AR5: The Intergovernmental Panel on Climate Change (IPCC) is the leading body of global climate change assessments. It comprises hundreds of leading scientists worldwide and on a regular basis publishes assessment reports which provide a comprehensive overview of the most recent scientific, technical, and socioeconomic information on climate change and its implications. The Fourth Assessment Report (AR4) was published in 2007. The Fifth Assessment Report (AR5) was published in 2013/2014.

ISI-MIP: The first Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) is a community-driven modeling effort which provides cross-sectoral global impact assessments based on the newly developed climate Representative Concentration Pathways and socioeconomic scenarios. More than 30 models across five sectors (agriculture, water resources, biomes, health, and infrastructure) were incorporated in this modeling exercise.

Pre-industrial Level (what it means to have present 0.8°C warming): Pre-industrial level refers to the level of warming before/at the onset of industrialization. The instrumental temperature records show that the 20-year average of global-mean, near-surface air temperature in 1986–2005 was about 0.6°C higher than the average over 1851–1879. There are, however, considerable year-to-year variations and uncertainties in the data. In addition, the 20-year average warming over 1986–2005 is not necessarily representative of present-day warming. Fitting a linear trend over the period 1901–2010 gives a warming of 0.8°C since "early industrialization." Global mean, near-surface air temperatures in the instrumental records of surface-air temperature have been assembled dating back to about 1850. The number of measurement stations in the early years is small and increases rapidly with time. Industrialization was well on its way by 1850 and 1900, which implies using 1851–1879 as a base period, or 1901 as a start for linear trend analysis might lead to an underestimate of current and future warming. However, global greenhouse-gas emissions at the end of the 19th century were still small and uncertainties in temperature reconstructions before this time are considerably larger.

RCP: Representative Concentration Pathways are based on carefully selected scenarios for work on integrated assessment modeling, climate modeling, and modeling and analysis of impacts. Nearly a decade of new economic data, information about emerging technologies, and observations of such environmental factors as land use and land cover change are reflected in this work. Rather than starting with detailed socioeconomic storylines to generate emissions scenarios, the RCPs are consistent sets of projections of only the components of radiative forcing (the change in the balance between incoming and outgoing radiation to the atmosphere caused primarily by changes in atmospheric composition) that are meant to serve as inputs for climate modeling. These radiative forcing trajectories are not associated with unique socioeconomic or emissions scenarios; instead, they can result from different combinations of economic, technological, demographic, policy, and institutional futures. RCP2.6, RCP4.5, RCP6 and RCP8.5 refer, respectively, to a radiative forcing of +2.6 W/m², +4.5 W/m², +6 W/m² and +8.5 W/m² in the year 2100 relative to pre-industrial conditions.

RCP2.6: RCP2.6 refers to a scenario which is representative of the literature on mitigation scenarios aiming to limit the increase of global mean temperature to 2°C above pre-industrial levels. This emissions path is used by many studies that have been assessed for the IPCC 5th Assessment Report and is the underlying low emissions scenario for impacts assessed in other parts of this report. In this report, the RCP2.6 is referred to as a 2°C world (with the exception of sea-level rise, where the subset of model used actually leads to 1.5°C world—see Box 2.1, Definition of Warming Levels and Base Period in this Report).

RCP8.5: RCP8.5 refers to a scenario with a no-climate-policy baseline with comparatively high greenhouse gas emissions which is used by many studies that have been assessed for the IPCC Fifth Assessment Report (AR5). This scenario is also the underlying high-emissions scenario for impacts assessed in other parts of this report. In this report, the RCP8.5 is referred to as a 4°C world above the pre-industrial baseline period.

Severe and extreme: These terms indicate uncommon (negative) consequences. These terms are often associated with an additional qualifier like "highly unusual" or "unprecedented" that has a specific quantified meaning.

SRES: The Special Report on Emissions Scenarios, published by the IPCC in 2000, has provided the climate projections for the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change. The scenarios do not include mitigation assumptions. The SRES study included consideration of 40 different scenarios, each making different assumptions about the driving forces determining future greenhouse gas emissions. Scenarios were grouped into four families (A1FI, A2, B1 and B2), corresponding to a wide range of high- and low-emissions scenarios.

SREX: The IPCC published a special report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) in 2012. The report provides an assessment of the physical and social factors shaping vulnerability to climate-related disasters and gives an overview of the potential for effective disaster risk management.

Tipping element: Following Lenton et al. (2008), the term tipping element describes large scale components of the Earth system possibly passing a tipping point. A tipping point "commonly refers to a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system" (Lenton et al. 2008). The consequences of such shifts for societies and ecosystems are likely to be severe.

Virtual water: A measure of the water resources used in the production of agricultural commodities. International trade in such commodities thereby implies a transfer of virtual water resources from one country to another embedded in the products.

WGI, WGII, WG III: IPCC Working Group I assesses the physical scientific aspects of the climate system and climate change. IPCC Working Group II assesses the vulnerability of socio-economic and natural systems to climate change, negative and positive consequences of climate change, and options for adapting to it. IPCC Working Group III assesses the options for mitigating climate change through limiting or preventing greenhouse gas emissions and enhancing activities that remove them from the atmosphere.

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