Climate information relevant for Terrestrial and Freshwater Ecosystems

Terrestrial and freshwater ecosystems encompass the forests (tropical, temperate, and boreal forests), lakes, rivers, wetlands, grasslands, savannas, deserts, mountains and polar that respond strongly to climate conditions around the world. {12.3} Freshwater fisheries and aquaculture are impacted by any changes in both terrestrial and freshwater ecosystems and marine ecosystems. {12.3}

The main climatic impact-drivers (CIDs) that are highly relevant to terrestrial and freshwater ecosystem, fisheries and aquaculture are mean air temperature, extreme heat, frost, mean precipitation, agricultural and ecological drought, and atmospheric CO_2. Additionally, cold spell; river flood; heavy precipitation and pluvial flood; aridity; fire weather; sand and dust storm; snow, glacier and ice sheet; lake, river and sea ice; and permafrost are moderately relevant {12.3}.

***Impacts** and **adaptation** options for terrestrial and freshwater ecosystems are assessed in IPCC Working Group II (WGII) Chapter 2, Chapter 5, and Cross Chapter Papers on Biodiversity hotspots (land, coasts and oceans); Deserts, semi-arid areas, and desertification; Mountains; Polar regions; and Tropical forests. **Mitigation** of climate change is assessed in IPCC WGIII Chapter 7 (AFOLU).*

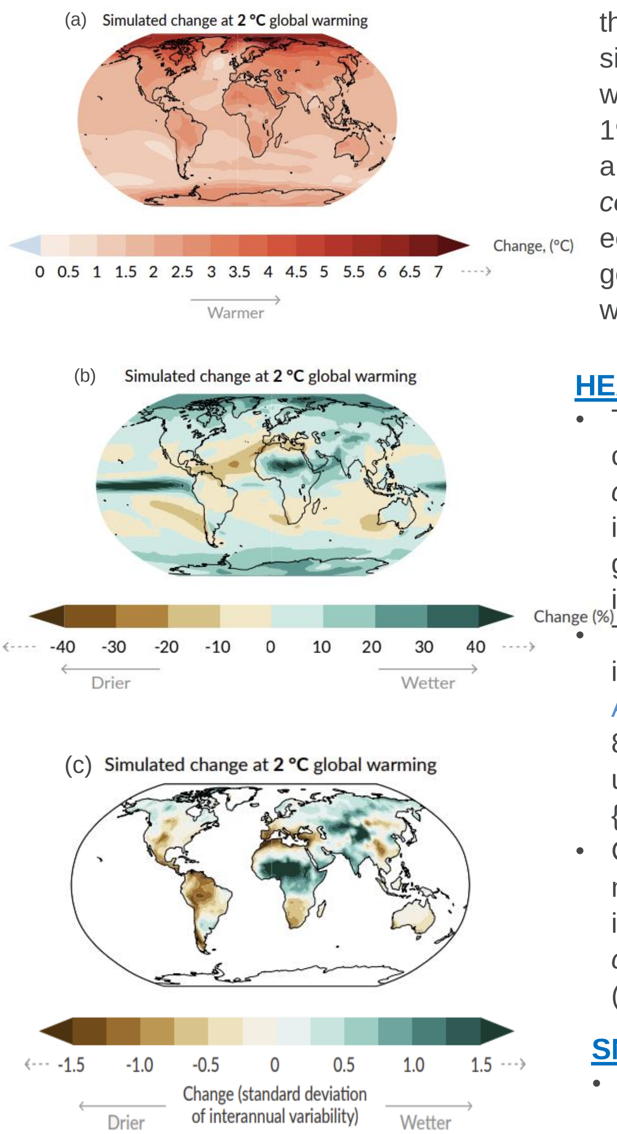

Figure 1: Simulated changes in annual (a) mean temperature, (b) precipitation and (c) soil moisture at 2℃ global warming {Figure SPM.5}

Changes in key aspects of the terrestrial biosphere, such as an increase in the growing season length in much of the Northern Hemisphere extratropics since the mid-20th century (*high confidence*), are consistent with large-scale warming. A global-scale increase in vegetation greenness since the early 1980s has been observed. Over the last century, there has been a poleward and upslope shift in the distribution of many land species (*very high confidence*) as well as increases in species turnover within many ecosystems (*high confidence*). There is *high confidence* that the geographical distribution of climate zones has shifted in many parts of the world in the last half century. {TS 2.6, 2.3.4, 3.6.1, 5.2.1, 6.4.5, 12.3.7, 12.4}

HEAT AND COLD

- The frequency and intensity of hot extremes have increased and those of cold extremes have decreased on the global scale since 1950 (*virtually certain*). The frequency and intensity of hot extremes will continue to increase and those of cold extremes will continue to decrease, at both global and continental scales and in nearly all inhabited regions with increasing global warming levels. {ES Ch 11}
- The number of days per year where temperature exceeds 35°C would increase by more than 150 days in many tropical areas, such as the Amazon basin and South East Asia by the end of the century under SSP5-8.5, while it is expected to increase by less than 60 days in these areas under SSP1-2.6 (except for the Amazon Basin) (*high confidence*). {TS.4.3.1}
- Climate challenges for biodiversity hot spots that will *very likely* see even more extreme heat and droughts, mountain areas where a projected raising in the freezing level height will alter snow and ice conditions (*high confidence*), and tropical forests that are increasingly prone to fire weather (*medium confidence*). {TS.4.3.2.10}

SNOW & ICE

- There is *high confidence* that the global warming-induced earlier onset of spring snowmelt and increased melting of glaciers have already contributed to seasonal changes in streamflow in high-latitude and low-elevation mountain catchments. {TS.4.3.1}
- Glacier volume loss and permafrost thawing will *likely* continue in the Andes Cordillera under all climate scenarios, causing important reductions in river flow and potentially high-magnitude glacial lake outburst floods. {TS.4.3.2.4}

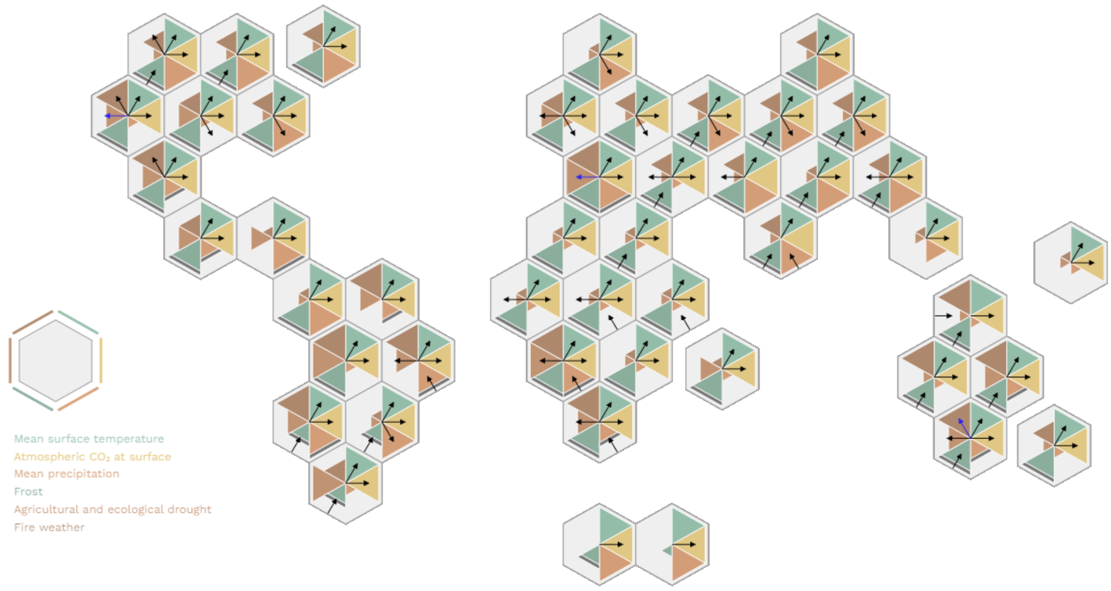

Figure 2: *Combination of select climate factors that are relevant for terrestrial ecosystems, along with their observed, attributed and projected changes for all AR6 regions (represented as hexagons in stylized world map). Changes in CIDs are projected to become more pronounced and widespread with every additional increment of global warming {SPM.B.2.2, SPM.C.2}. {Interactive Atlas}*

WET AND DRY

- Desert and semi-arid areas are strongly affected by CIDs such as extreme heat, drought and dust storms, with large-scale aridity trends contributing to expand drylands in some regions (*high confidence*). {TS.4.3.2.10}
- Increases in precipitation and rivers floods are projected over much of Asia: in the annual mean precipitation in East, North, South and South East Asia (*high confidence*); for extremes in East, South, West Central, North and South East Asia (*high confidence*) and Arabian Peninsula (*medium confidence*); and for river floods in East, South and South East Asia and East Siberia (*medium confidence*). {TS.4.3.2.2}
- In a number of regions, increases in one or more of drought, aridity and fire weather (*high confidence*) will affect a wide range of sectors, including ecosystems. {TS 4.3.2}
- Water cycle changes bring prolonged drought, longer dry seasons, and increased fire weather to many tropical forests (*medium confidence*). {TS.4.3.2.10}
- The probability of compound flooding (storm surge, extreme rainfall and/or river flow) has increased in some locations (*medium confidence*) and will continue to increase due to both sea level rise and increases in heavy precipitation, including changes in precipitation intensity associated with tropical cyclones (*high confidence*). {TS.2.6, 11 ES, 11.8}

COASTAL AND OCEANIC

- Changes in coastal and oceanic CIDs are presented in the **Marine Ecosystems, Fisheries and Aquaculture** fact sheet.

ATMOSPHERIC CARBON DIOXIDE (CO_2)

- Of the annual average anthropogenic CO_2 emissions, 46% accumulated in the atmosphere, 23% was taken up by the ocean and 31% was removed by terrestrial ecosystems (*high confidence*) {Box TS.5, 5.2.1, 5.2.2, 5.2.3}
- It is *virtually certain* that atmospheric CO_2 concentration will increase in all emissions scenarios until net zero emissions are achieved. {12.3, 12.4}
- High CO_2 concentration can increase photosynthesis rates and primary production within natural ecosystems and agricultural crops {12.3.7}.
- Ecosystem responses to warming not yet fully included in climate models, such as CO_2 and CH_4 fluxes from wetlands, permafrost thaw and wildfires, would further increase concentrations of these gases in the atmosphere (*high confidence*). {5.4, Box TS.5, TS.3.2}
- Ocean and land carbon sinks slow the rise of CO_2. Although land and ocean sinks absorb more CO_2 under high emissions than low emissions scenarios, the fraction of emissions removed from the atmosphere decreases (*high confidence*). This means that the more CO_2 that is emitted, the less efficient the ocean and land sinks become (*high confidence*).
- Under high CO_2 emissions scenarios, it is *very likely* that the land carbon sink will grow more slowly due to warming and drying from the mid-21st century, but it is *very unlikely* that it will switch from being a sink to a source before 2100. Climate change alone is expected to increase land carbon accumulation in the high latitudes (not including permafrost), but also to lead to a counteracting loss of land carbon in the tropics (*medium confidence*) {Box TS.5}

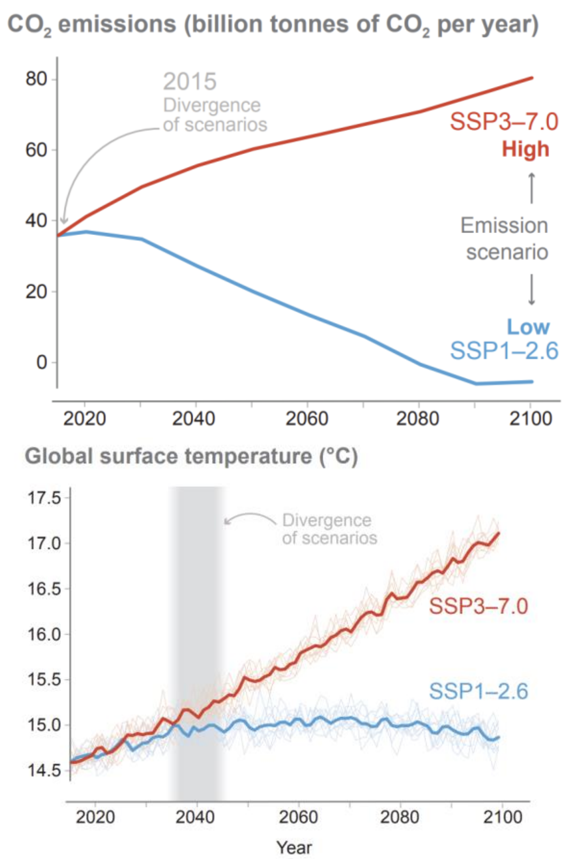

Figure 3: (top) Carbon dioxide (CO_2) emissions, and (bottom) effect on global surface temperature for two of five illustrative scenarios: a low emissions scenario (SSP1-2.6, blue) and a high emissions scenario (SSP3-7.0). {FAQ 4.2, Figure 1}