Federal Ministry
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Climate Risk Profile for Pakistan
Supplemental Information

The Climate Risk Profile (CRP) for Pakistan has been developed by the Potsdam Institute for Climate Impact Research (PIK) in close cooperation with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). This CRP presents a condensed overview of present and future climate impacts and risks at the national level for relevant sectors in Pakistan. This document will help readers better understand the analyses by providing more detailed information on the data base, models and indicators used.

Section 1: Data base

The CRP is largely based on climate data and climate impact simulations carried out in phase 2b of the Intersectoral Impact Model Intercomparison Project (ISIMIP2b; see www.isimip.org and Frieler et al., 2017). All impact model simulations are based on the same harmonized input data including climate data from four global climate models (GCMs). These four GCMs were selected from the larger CMIP5 (phase 5 of the Coupled Model Intercomparison Project) ensemble, based on criteria including data availability, model performance and climate sensitivity (Frieler et al., 2017).

Future climate impact projections in ISIMIP2b were made for two future greenhouse gas emissions scenarios (called Representative Concentration Pathways, RCPs) under the SSP2 socio-economic pathway[1]. RCP2.6 represents a low emissions scenario, which aims to keep global warming below 2 °C, whereas RCP6.0 represents a medium to high emissions scenario.

Section 2: Models

The following overview lists the number of models whose output data was used to carry out simulations of the different indicators presented in more detail in Section 3.

4 Global Climate Models (GCMs)

IPSL-CM5A-LR, GFDL-ESM2M, MIROC5, HadGEM2-ES

GCMs simulate the physical, chemical and biological dynamics of the climate system.

6 Global Hydrological Models (GHMs)

CLM45, H08, LPJmL, MPI-HM, PCR-GLOBWB, WaterGAP2

GHMs simulate the hydrological cycle at the land surface of continental-scale river basins.

3 Global Gridded Crop Models (GGCMs)

GEPIC, LPJmL, PEPIC

GGCMs simulate crop growth at the grid scale for a selected number of crop functional types.

3 Global Vegetation Models (GVMs)

LPJ-GUESS, LPJmL, ORCHIDEE-DGVM

GVMs simulate the dynamics of terrestrial vegetation and soil as well as the associated carbon pools and fluxes.

2 Global Species Distribution Models (GSDMs)

BioScen1.5-SDM-GAM, BioScen1.5-SDM-GBM

GSDMs simulate species distribution based on known locations of a species and information on environmental conditions.

1 Temperature Related Mortality Model (TRMM)

TRM-Tsukuba

TRMMs simulate excess mortality attributable to non-optimal temperature based on statistical relationships between temperature and mortality.

[1] Shared Socio-economic Pathways (SSPs) outline a narrative of potential global futures, including estimations of broad characteristics such as country level population, GDP or rate of urbanisation. Five different SSPs outline future realities according to a combination of high and low future socio-economic challenges for mitigation and adaptation. SSP2 represents the "middle of the road"-pathway.

Section 3: Indicators

This overview provides detailed information about each indicator with the type and number of models indicated in brackets. Climate projections used in this analysis are based on data from the GCMs and shown at the 0.5 ° grid-cell level, which corresponds to approximately 50 × 50 km near the equator.

Temperature (4 GCMs)

Temperature change projections are based on daily mean near surface air temperature data from the GCMs. Changes are averaged over the whole country.

Very hot days (4 GCMs)

Very hot days refer to days with a maximum near-surface air temperature above 35 °C.

Sea level rise (4 GCMs)

National sea level rise projections were obtained from total sea level rise data averaged along the coastline of a country. Total sea level rise in ISIMIP2b was computed as the sum of contributions from thermal expansion, melting of mountain glaciers, ice caps and the large ice sheets on Greenland and Antarctica, as well as changes in land water storage. Due to GCM-dependent warming patterns, sea level rise projections are also GCM-dependent and vary at different locations.

Precipitation (4 GCMs)

Precipitation change projections are based on daily precipitation sums from the GCMs and shown as averages over the whole country.

Heavy precipitation events (4 GCMs)

The precipitation event analysis is based on daily precipitation sums from the GCMs and national averages. A heavy precipitation event is defined as a day on which the precipitation sum exceeds the 98^{th} percentile of the daily precipitation sums of all wet days from 1861 to 1983, where a wet day is a day with a precipitation sum of at least 0.1 mm. Projections show national averages of the annual number of heavy precipitation events.

Extremely dry months (4 GCMs)

Extremely dry months are defined as months with a standardized precipitation-evapotranspiration index (SPEI) of less than −2. The SPEI describes the deviation of the precipitation-evapotranspiration difference from the long-term conditions (1986 to 2014). The calculation of the SPEI is based on monthly precipitation anomalies and evapotranspiration, which are accumulated over six months. Evapotranspiration is approximated by the Thornthwaite method from monthly temperature data.

Soil moisture (4 GCMs, 6 GHMs)

Soil moisture projections are based on root-zone soil moisture estimates (the portion of soil moisture that is found within the rooting depth of plants) from the GHMs. For GHMs that do not directly provide root-zone soil moisture (CLM45, LPJmL), this variable was approximated by integrating soil moisture across multiple soil water layers in order to reach a depth of approximately 1 metre. Projected changes are country-level averages of these root-zone soil moisture estimates.

Potential evapotranspiration (4 GCMs, 5 GHMs)

Evapotranspiration is the combined evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. Potential evapotranspiration is the amount of evapotranspiration that would occur if sufficient water was available. Projections are based on five GHMs and shown as national averages.

Water availability (4 GCMs, 6 GHMs)

Water availability at the national level is projected using the Falkenmark Water Stress Indicator (FWSI) and total runoff from the GHMs. The FWSI represents the annual amount of water from rainfall that is available to each person. It is computed by first summing up runoff over the entire country and year and then dividing the amount of water by the national population. FWSI projections are provided including and excluding the effects of population change. For this purpose, SSP2 population projections from the ISIMIP2b database are used. A country is said to be under water stress (face water scarcity) when water supplies drop below 1700 (1000) cubic metres per person per year.

Runoff (4 GCMs, 6 GHMs)

Runoff is defined as the amount of water discharged through surface and subsurface streams, including all precipitation, snow melt and irrigation water that is neither absorbed by the soil nor evaporated. Projections are based on total runoff from the GHMs. Total runoff is computed as the sum of surface runoff and subsurface runoff. Projections are shown at the 0.5° grid-cell level.

Exposure to droughts (4 GCMs, 6 GHMs)

For projections of the crop land area exposed to drought at least once a year, a drought index based on soil moisture projections from the GHMs is used (Lange et al., 2020). A grid cell is considered to be exposed to drought in a given year if monthly mean soil moisture drops below monthly threshold values for at least seven consecutive months, with at least four of those months belonging to the given year. The monthly threshold values are the 2.5th percentiles of monthly mean soil moisture under pre-industrial climate conditions. Land use patterns from ISIMIP2b are then used to compute the crop land area exposed to drought. Constant land use patterns representing conditions from 2005 are used. The profile shows the fraction of the national crop land area that is exposed to at least one drought in a given year.

Crop yields (4 GCMs, 3 GGCMs)

Crop yield projections are based on the GGCMs and constant year 2005 level land use patterns and agricultural management (irrigation, fertiliser use, growing seasons). All GGCMs simulate effects of CO_2 fertilisation. The profile shows projected changes in national production for all relevant crop types covered by these models.

Exposure to river floods (4 GCMs, 6 GHMs)

The exposure of the national major road network to river floods is projected based on runoff projections from the GHMs (Lange et al., 2020). Simulated daily runoff is translated into annual maximum daily discharge by the global river model CaMa-Flood (Yamazaki et al., 2013; Yamazaki et al., 2011). A grid cell is considered to be exposed to river flooding at least once a year if the maximum annual discharge exceeds the 100-year return level under preindustrial conditions. Road network data from OpenStreetMap are used to estimate which major roads[2] are exposed to at least one river flood per year. Projections show the fraction of the national network of major roads that is exposed to at least one river flood per year.

Species richness (4 GCMs, 2 GSDMs)

Projections of species richness are based on probabilities of occurrence of amphibian, bird and mammal species projected by the GSDMs (Hof et al., 2018). The probabilities are summed over the three taxa to obtain an aggregate metric of species richness. Results of projections under a no-dispersal scenario were used, which means that for all species, it is assumed that they can only occur where they have occurred in the past. Results are shown at the 0.5° grid-cell level.

Tree cover (4 GCMs, 3 GVMs)

Projections are based on the GVMs considering the effects of CO_2 fertilisation and using constant year 2005 level land use patterns. Tree cover is calculated as the sum of the land area fractions vegetated by forestal plant functional types and shown at the 0.5° grid-cell level. The profile uses 2020 as the reference year for tree cover projections to ensure that the depicted changes reflect the pure effect of future climate change.

Exposure to heatwaves (4 GCMs)

Projections of population exposure to heatwaves are based on daily mean near-surface relative humidity and daily mean and maximum near-surface air temperature data from the GCMs (Lange et al., 2020). A grid cell is considered to be exposed to at least one heatwave per year if both the Heat Wave Magnitude Index daily (HWMId; Russo et al., 2015; Russo at al., 2017) of that year exceeds the 97.5th percentile of the HWMId distribution under pre-industrial climate conditions and the humidex (Masterton & Richardson, 1979) exceeds 45 on all days of the corresponding heatwave period. Projections show the fraction of the national population exposed to at least one heatwave per year.

Heat-related mortality (4 GCMs, 1 TRMM):

Excess mortality attributable to heat is projected using the corresponding TRMM output. The TRMM was run using constant year 2005 population data. Results are shown at the national level.

[2] OpenStreetMap key highway with value motorway, trunk, primary, secondary, tertiary, motorway_link, trunk_link, primary_link, or secondary_link.

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