# CLIMATE RISK COUNTRY PROFILE

# NEPAL

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK

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*Graphic Design:* Circle Graphics, Reisterstown, MD

## ACKNOWLEDGEMENTS

This profile is part of a series of Climate Risk Country Profiles that are jointly developed by the World Bank Group (WBG) and the Asian Development Bank (ADB). These profiles synthesize the most relevant data and information on climate change, disaster risk reduction, and adaptation actions and policies at the country level. The profile is designed as a quick reference source for development practitioners to better integrate climate resilience in development planning and policy making. This effort is co-led by Ana E. Bucher (Senior Climate Change Specialist, WBG) and Arghya Sinha Roy (Senior Climate Change Specialist, ADB).

This profile was written by Alex Chapman (Consultant, ADB), William Davies (Consultant, ADB) and Ciaran Downey (Consultant). Technical review of the profiles was undertaken by Robert L. Wilby (Loughborough University). Additional support was provided by MacKenzie Dove (Senior Climate Change Consultant, WBG), Yunziyi Lang (Climate Change Analyst, WBG), Adele Casorla-Castillo (Consultant, ADB), and Charles Rodgers (Consultant, ADB). This profile also benefitted from inputs of WBG and ADB regional staffs.

Climate and climate-related information is largely drawn from the Climate Change Knowledge Portal (CCKP), a WBG online platform with available global climate data and analysis based on the latest Intergovernmental Panel on Climate Change (IPCC) reports and datasets. The team is grateful for all comments and suggestions received from the sector, regional, and country development specialists, as well as climate research scientists and institutions for their advice and guidance on use of climate related datasets.

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# FOREWORD

Climate change is a major risk to good development outcomes, and the World Bank Group is committed to playing an important role in helping countries integrate climate action into their core development agendas. The World Bank Group (WBG) and the Asian Development Bank (ADB) are committed to supporting client countries to invest in and build a low-carbon, climate-resilient future, helping them to be better prepared to adapt to current and future climate impacts.

Both institutions are investing in incorporating and systematically managing climate risks in development operations through their individual corporate commitments.

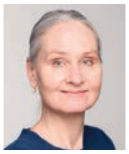
For the World Bank Group: a key aspect of the World Bank Group's Action Plan on Adaptation and Resilience (2019) is to help countries shift from addressing adaptation as an incremental cost and isolated investment to systematically incorporating climate risks and opportunities at every phase of policy planning, investment design, implementation and evaluation of development outcomes. For all International Development Association and International Bank for Reconstruction and Development operations, climate and disaster risk screening is one of the mandatory corporate climate commitments. This is supported by the World Bank Group's Climate and Disaster Risk Screening Tool which enables all Bank staff to assess short- and long-term climate and disaster risks in operations and national or sectoral planning processes. This screening tool draws up-to-date and relevant information from the World Bank's Climate Change Knowledge Portal, a comprehensive online 'one stop shop' for global, regional, and country data related to climate change and development.

For the Asian Development Bank: its Strategy 2030 identified "tackling climate change, building climate and disaster resilience, and enhancing environmental sustainability" as one of its seven operational priorities. Its Climate Change Operational Framework 2017–2030 identified mainstreaming climate considerations into corporate strategies and policies, sector and thematic operational plans, country programming, and project design, implementation, monitoring, and evaluation of climate change considerations as the foremost institutional measure to deliver its commitments under Strategy 2030. ADB's climate risk management framework requires all projects to undergo climate risk screening at the concept stage and full climate risk and adaptation assessments for projects with medium to high risk.

Recognizing the value of consistent, easy-to-use technical resources for our common client countries as well as to support respective internal climate risk assessment and adaptation planning processes, the World Bank Group's Climate Change Group and ADB's Sustainable Development and Climate Change Department have worked together to develop this content. Standardizing and pooling expertise facilitates each institution in conducting initial assessments of climate risks and opportunities across sectors within a country, within institutional portfolios across regions, and acts as a global resource for development practitioners.

For common client countries, these profiles are intended to serve as public goods to facilitate upstream country diagnostics, policy dialogue, and strategic planning by providing comprehensive overviews of trends and projected changes in key climate parameters, sector-specific implications, relevant policies and programs, adaptation priorities and opportunities for further actions.

We hope that this combined effort from our institutions will spur deepening of long-term risk management in our client countries and support further cooperation at the operational level.



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## KEY MESSAGES

- Warming in Nepal is projected to be higher than the global average. By the 2080s, Nepal is projected to warm by 1.2°C–4.2°C, under the highest emission scenario, RCP8.5, as compared to the baseline period 1986–2005. The range in possible temperature rises highlights the significantly lower rates of warming expected on lower 21st century emissions pathways.
- Rises in maximum and minimum temperatures are expected to be stronger than the rise in average temperature, likely amplifying the pressure on human health, livelihoods, and ecosystems. Temperature increase is expected to be strongest during the winter months.
- Climate change is already having significant impacts on the environment in Nepal, species' ranges are shifting to higher altitudes, glaciers are melting, and the frequency of precipitation extremes is increasing.
- Natural hazards such as drought, heatwave, river flooding, and glacial lake outburst flooding are all projected to intensify over the 21st century, potentially exacerbating disaster risk levels and putting human life at risk.
- Modelling has suggested that the number of people annually affected by river flooding could more than double by 2030 as a result of climate change. At the same time the economic impact of river flooding could triple.
- The vulnerability of Nepal's communities, particularly those living in poverty, in remote areas, and operating subsistence agriculture, increases the risk posed by climate change.
- Some important adaptation approaches, such as air conditioning, irrigation, water storage and new crop varieties, may be inaccessible to these communities, and even with adaptation they are likely to experience damage and loss. Without support to the poorest in Nepalese society inequalities are likely to widen.

## COUNTRY OVERVIEW

Nepal is a landlocked country of South Asia, located in the Himalayas between India and China. The terrain is generally mountainous and contains many of the world's highest peaks, including Mount Everest (8,848 meters [m]). The country also has low-lying areas in the south with elevations less than 100 m. About 80% of the country's 28 million inhabitants (2019) live in rural areas. Small-scale, subsistence agriculture is a mainstay of Nepal's economy, employing 69% of the country's workforce in 2015. Despite this, agriculture contributed only 25% to GDP in 2019, compared to a 60% contribution from the service sector.[1] Nepal's National Planning Commission estimated in 2018 that around 28.6% of the population experiences multidimensional poverty,[2] with a clear divide between rural areas, where the rate is 33%, and urban areas where the rate is 7%. An estimated 8% of Nepal's population are undernourished (see key indicators in **Table 1**).

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[1] World Bank (2020). DataBank – World Development Indicators. URL: https://databank.worldbank.org/source/world-development-indicators [accessed 19 September 2020].

[2] NPC (2018). Nepal Multidimensional Poverty Index 2018: Analysis Towards Action. National Planning Commission, Government of Nepal. URL: https://www.npc.gov.np/images/category/Nepal_MPI.pdf

Water and forests are Nepal's most abundant natural resources, with freshwater (derived from glaciers, snowmelt, and rainfall) accounting for an estimated 2.27% of the total world supply. This water feeds the country's major rivers: Koshi, Gandaki, and Karnali. Together, these river systems supply freshwater to a large portion of the 500 million people who live in the Ganges river basin. Nepal's varied topography and social vulnerability make the country particularly susceptible to geological and climate-related disasters. Weakness in effective response mechanisms and strategies for dealing with natural hazards has historically exacerbated this vulnerability. An increase in soil erosion, landslides, flash floods, and droughts has been reported in recent years across the country, with increased intensity and impact on the lives and livelihoods of the Nepalese. Nepal is highly vulnerable to climate change impacts and recent studies by the Asian Development Bank suggested Nepal faces losing 2.2% of annual GDP due to climate change by 2050.[3] Nepal ratified the Paris Climate Agreement and its Nationally Determined Contribution (NDC) in 2016.[4] Nepal's Second National Communication to the UNFCCC (2014) (NC2) identifies the country's energy, agriculture, water resources, forestry and biodiversity and health sectors as the most at risk to climate change.[5]

**TABLE 1.** Key indicators

| Indicator | Value | Source |
|---|---|---|
| **Population Undernourished[6]** | 6.1% (2017–2019) | FAO, 2020 |
| **National Poverty Rate[7]** | 28.6% (2018) | National Planning Commission, 2020 |
| **Share of Wealth Held by Bottom 20%** | 8.3% (2010) | World Bank, 2018 |
| **Net Annual Migration Rate[8]** | 0.15% (2015–2020) | UNDESA, 2019 |
| **Average Annual Change in Urban Population[9]** | 3.15% (2015–2020) | UNDESA, 2018 |
| **Dependents per 100 Independent Adults[10]** | 53.0 (2020) | UNDESA, 2019 |
| **Urban Population as % of Total Population[11]** | 20.6% (2020) | CIA, 2020 |
| **External Debt Ratio to GNI[12]** | 18.9% (2018) | ADB, 2020b |
| **Government Expenditure Ratio to GDP[12]** | 27.5% (2017) | ADB, 2020b |

[3] Ahmed, M., & S. Suphachalasai (2014). Assessing the costs of climate change and adaptation in South Asia. Asian Development Bank. URL: https://www.adb.org/sites/default/files/publication/42811/assessing-costs-climate-change-and-adaptation-south-asia.pdf

[4] Government of Nepal (2016). Nationally Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Nepal%20First/Nepal%20First%20NDC.pdf

[5] Nepal (2014). Second National Communications to the United Nations Framework Convention on Climate Change. URL: https://unfccc.int/sites/default/files/resource/nplnc2.pdf

[6] FAO, IFAD, UNICEF, WFP, WHO (2020). The state of food security and nutrition in the world. Transforming food systems for affordable healthy diets. FAO. Rome. URL: http://www.fao.org/documents/card/en/c/ca9692en/

[7] National Planning Commission (2020). Nepal Human Development Report 2020. URL: https://www.npc.gov.np/images/category/NHDR_2020_-_Final_-_TheSquare_compressed_final1.pdf [accessed 14/01/21]

[8] UNDESA (2019). World Population Prospects 2019: MIGR/1. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]

[9] UNDESA (2019). World Urbanization Prospects 2018. URL: https://population.un.org/wup/Download/ [accessed 28/11/18]

[10] UNDESA (2019). World Population Prospects 2019: POP/11-A. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]

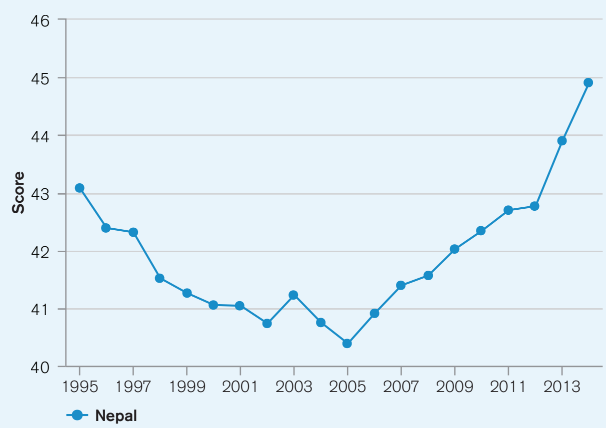
[11] CIA (2020), The World Factbook. Central Intelligence Agency. Washington DC. URL: https://www.cia.gov/the-world-factbook/

[12] ADB (2020b). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. URL: https://www.adb.org/publications/key-indicators-asia-and-pacific-2020

This document aims to succinctly summarize the climate risks faced by Nepal. This includes rapid onset and long-term changes in key climate parameters, as well as impacts of these changes on communities, livelihoods and economies, many of which are already underway. This is a high-level synthesis of existing research and analyses, focusing on the geographic domain of Nepal, therefore potentially excluding some international influences and localized impacts. The core data presented is sourced from the database sitting behind the World Bank Group's Climate Change Knowledge Portal (CCKP), incorporating climate projections from the Coupled Model Inter-comparison Project Phase 5 (CMIP5). This document is primarily meant for WBG and ADB staff to inform their climate actions. The document also aims and to direct the reader to many useful sources of secondary data and research.

Due to a combination of political, geographic, and social factors, Nepal is recognized as vulnerable to climate change impacts, ranked 128th out of 181 countries in the 2019 ND-GAIN Index.[13] The ND-GAIN Index ranks 181 countries using a score which calculates a country's vulnerability to climate change and other global challenges as well as their readiness to improve resilience. The more vulnerable a country is the lower their score, while the more ready a country is to improve its resilience the higher it will be. Norway has the highest score and is ranked 1st. **Figure 1** is a time-series plot of the ND-GAIN Index showing Nepal's progress

**FIGURE 1.** The ND-GAIN Index summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience. It aims to help businesses and the public sector better prioritize investments for a more efficient response to the immediate global challenges ahead.




[13] University of Notre Dame (2019). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/

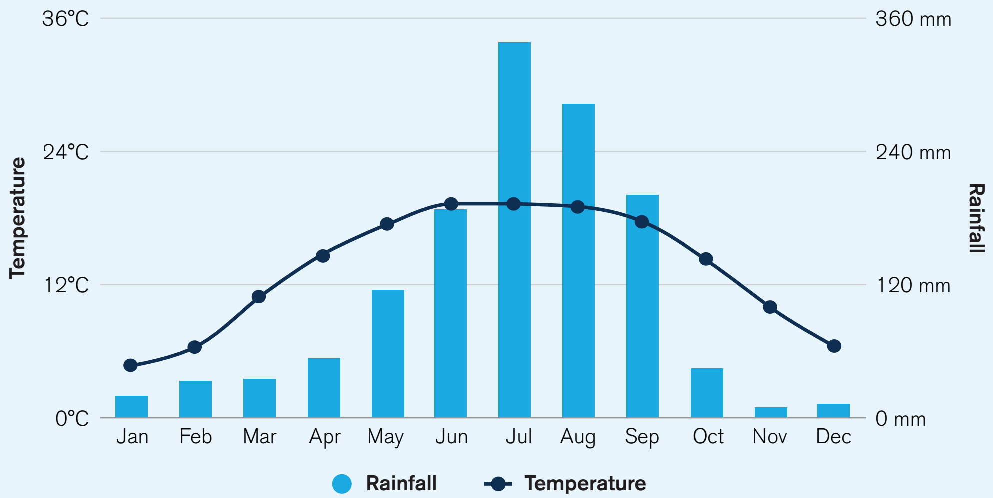
# Climate Baseline

## Overview

Nepal's climate varies considerably both seasonally (**Figure 2**) and according to altitude. Nepal can be divided into different climate zones according to altitude, ranging from the Terai region in the south at less than 500 m above sea-level to the High Himalayan region in the north at over 5,000 m. Average temperatures decline from a peak of over 24°C in the south down to sub-zero temperatures in Nepal's highest mountains. Precipitation is spatially variable with some central and northerly pockets of the country receiving more than 3,000 millimeters (mm), the central and southern plains typically receiving 1,500–2,000 mm, and some high-altitude areas in the north receiving less than 1,000 mm. **Figure 3** shows the spatial variations of observed temperature and rainfall across Nepal.

### *Annual Cycle*

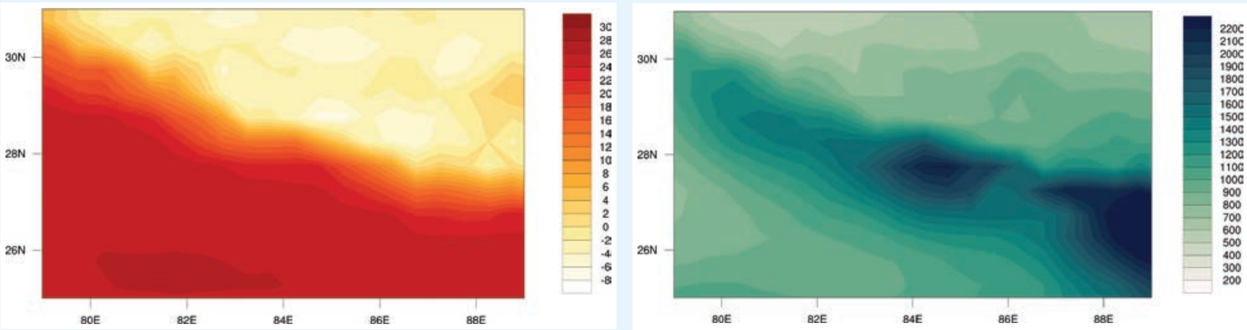
**FIGURE 2.** Average monthly temperature and rainfall in Nepal (1991–2019)[14]




[14] WBG Climate Change Knowledge Portal (CCKP, 2020). Nepal Climate Data: Historical. URL: https://climateknowledgeportal.worldbank.org/country/nepal/climate-data-historical

*Spatial Variations*

**FIGURE 3.** (Left) Annual Mean Temperature, and (Right) Annual Mean Rainfall (mm) in Nepal over the period 1901–2019.[15] Maps present the coordinates of Nepal: latitude 80°03'42"E – 88°10'10"E and 30°26'12"N – 26°21'46"N.




## Key Trends

### *Temperature*

Data from the Berkeley Earth Dataset can be used to estimate warming across Nepal over the 20th century. Based on temperature changes between the periods 1900–1917 and 2000–2017 historical warming in Nepal is estimated at between 1.0°C–1.3°C. Nepal's NC2 suggests that the spatial distribution of this warming is complex, and not homogenous across Nepal's surface area, nor defined consistently by altitude.[16] Additional studies, which focused specifically on the Himalayas region (a significantly larger area than Nepal's national territory) reports higher rates of warming, with average temperatures increasing by 1.5°C between 1982–2006.[17]

### *Precipitation*

Nepal's NC2 suggests there have been only minor changes to historical annual precipitation rates in the country and these vary spatially and include both positive and negative movements. Some regions (notably western Nepal) are believed to have experienced an increase in the frequency and intensity of extreme precipitation events.[18] One study has suggested that wet areas are becoming wetter, and dry areas are becoming drier.[19] Alongside this, another study suggested the Himalayan region has experienced increasing average annual precipitation at a rate of 6.5mm/yr between 1982–2006.[11] Other factors affecting inter-annual precipitation variability include global climate phenomena such as El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole.[20] ENSO has been shown to have complex relationships with both drought and extreme precipitation.[12]

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15 WBG Climate Change Knowledge Portal (CCKP, 2020). Nepal Climate Data: Projections. URL: https://climateknowledgeportal.worldbank.org/country/nepal/climate-data-projections

16 Nepal (2014). Second National Communications to the United Nations Framework Convention on Climate Change. URL: https://unfccc.int/sites/default/files/resource/nplnc2.pdf

17 Shrestha, U. B., Gautam, S., & Bawa, K. S. (2012). Widespread climate change in the Himalayas and associated changes in local ecosystems. PloS One, 7(5), 1–10. URL: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0036741

18 Bohlinger, P., & Sorteberg, A. (2018). A comprehensive view on trends in extreme precipitation in Nepal and their spatial distribution. International Journal of Climatology, 38(4), 1833–1845. URL: https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/joc.5299

19 Dahal, P., Shrestha, N. S., Shrestha, M. L., Krakauer, N. Y., Panthi, J., Pradhanang, S. M., . . . Lakhankar, T. (2016). Drought risk assessment in central Nepal: temporal and spatial analysis. Natural Hazards, 80(3), 1913–1932. URL: https://link.springer.com/article/10.1007/s11069-015-2055-5

20 Sigdel, M., & Ikeda, M. (2011). Spatial and Temporal Analysis of Drought in Nepal using Standardized Precipitation Index and its Relationship with Climate Indices. Journal of Hydrology and Meteorology, 7(1), 59–74. URL: https://www.nepjol.info/index.php/JHM/article/view/5617

## A Precautionary Approach

Studies published since the last iteration of the IPCC's report (AR5), such as Gasser et al. (2018), have presented evidence which suggests a greater probability that earth will experience medium and high-end warming scenarios than previously estimated.[21] Climate change projections associated with the highest emissions pathway (RCP8.5) are presented here to facilitate decision making which is robust to these risks.

# Climate Future

## Overview

The main data source for the World Bank Group's Climate Change Knowledge Portal (CCKP) is the Coupled Model Inter-comparison Project Phase 5 (CMIP5) models, which are utilized within the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), providing estimates of future temperature and precipitation. Four Representative Concentration Pathways (i.e. RCP2.6, RCP4.5, RCP6.0, and RCP8.5) were selected and defined by their total radiative forcing (cumulative measure of GHG emissions from all sources) pathway and level by 2100. In this analysis, RCP2.6 and RCP8.5, the extremes of low and high emissions pathways, are the primary focus where RCP2.6 represents a very strong mitigation scenario and RCP8.5 assumes business-as-usual scenario. For more information, please refer to the RCP Database.

For Nepal, these models show a trend of consistent warming that will be more significant for northern regions. While rainfall projections are less certain and vary by both RCP scenario as well as models, projected precipitation trends show a decrease in rainfall in the 2050s and an increase in rainfall for the 2090s. More precipitation is expected to be received through increased intensity and occurrence of extreme events. **Tables 2** and **3** below,

**TABLE 2.** Projected anomaly (changes °C) for maximum, minimum, and average daily temperatures in Nepal for 2040–2059 and 2080–2099, from the reference period of 1986–2005 for all RCPs. The table is showing the median of the CCKP model ensemble and the 10–90th percentiles in brackets[22]

| | Average Daily Maximum Temperature | | Average Daily Temperature | | Average Daily Minimum Temperature | |
|---|---|---|---|---|---|---|
| **Scenario** | **2040–2059** | **2080–2099** | **2040–2059** | **2080–2099** | **2040–2059** | **2080–2099** |
| **RCP2.6** | 1.4 (−0.7, 3.4) | 1.4 (−0.6, 3.6) | 1.4 (−0.3, 3.1) | 1.4 (0.2, 3.2) | 1.4 (−0.4, 3.5) | 1.4 (−0.5, 3.5) |
| **RCP4.5** | 1.8 (−0.4, 3.9) | 2.5 (0.3, 5.0) | 1.7 (−0.1, 3.4) | 2.5 (0.6, 4.4) | 1.7 (−0.1, 3.8) | 2.5 (0.6, 4.8) |
| **RCP6.0** | 1.5 (−0.6, 3.7) | 3.1 (0.7, 5.5) | 1.6 (−0.1, 3.4) | 3.1 (1.2, 5.1) | 1.7 (0.2, 3.5) | 3.3 (1.2, 5.4) |
| **RCP8.5** | 2.4 (0.1, 4.4) | 5.0 (2.5, 7.5) | 2.3 (0.6, 4.0) | 4.8 (2.9, 7.1) | 2.4 (0.6, 4.7) | 5.0 (2.9, 7.4) |

[21] Gasser, T., Kechiar, M., Ciais, P., Burke, E. J., Kleinen, T., Zhu, D., . . . Obersteiner, M. (2018). Path-dependent reductions in CO2 emission budgets caused by permafrost carbon release. Nature Geoscience. URL: http://pure.iiasa.ac.at/id/eprint/15453/

[22] WBG Climate Change Knowledge Portal (CCKP, 2020). Nepal Climate Data: Projections. URL: https://climateknowledgeportal.worldbank.org/country/nepal/climate-data-projections

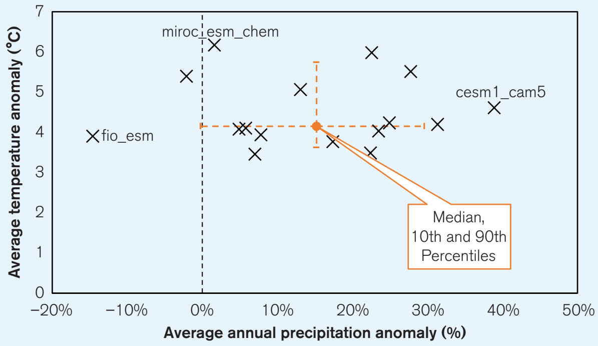
**TABLE 3.** Projections of average temperature change (°C) in Nepal for different seasons (3-monthly time slices) over different time horizons and emissions pathways, showing the median estimates of the full CCKP model ensemble and the 10th and 90th percentiles in brackets.[16]

| | 2040–2059 | | 2080–2099 | |
|---|---|---|---|---|
| **Scenario** | **Jun–Aug** | **Dec–Feb** | **Jun–Aug** | **Dec–Feb** |
| **RCP2.6** | 1.1<br>(–0.4, 3.3) | 1.5<br>(–0.3, 3.1) | 1.1<br>(–0.3, 3.5) | 1.4<br>(–0.3, 3.1) |
| **RCP4.5** | 1.3<br>(–0.2, 3.6) | 2.0<br>(0.0, 3.4) | 2.0<br>(0.4, 4.6) | 2.7<br>(0.7, 4.6) |
| **RCP6.0** | 1.2<br>(–0.3, 3.4) | 1.9<br>(–0.1, 3.3) | 2.4<br>(0.8, 4.9) | 3.6<br>(1.2, 5.3) |
| **RCP8.5** | 1.9<br>(0.4, 4.0) | 2.6<br>(1.8, 4.2) | 4.1<br>(2.5, 6.7) | 5.2<br>(3.2, 7.6) |

provide information on temperature projections and anomalies for the four RCPs over two distinct time horizons; presented against the reference period of 1986–2005.

Climate projections presented in this document are derived from datasets available through the CCKP, unless otherwise stated. These datasets are processed outputs of simulations performed by multiple General Circulation Models (GCM) (for further information see Flato et al., 2013).[23] Collectively, these different GCM simulations are referred to as the 'model ensemble'. Due to the differences in the way GCMs represent the key physical processes and interactions within the climate system, projections of future climate conditions can vary widely between different GCMs, this is particularly the case for rainfall related variables and at national and local scales. The range of projections from 16 GCMs for annual average temperature change and annual precipitation change in Nepal under RCP8.5 is shown in **Figure 4**. Spatial representation of future projections of annual temperature and precipitation for mid and late century under RCP8.5 are presented in **Figure 5**.

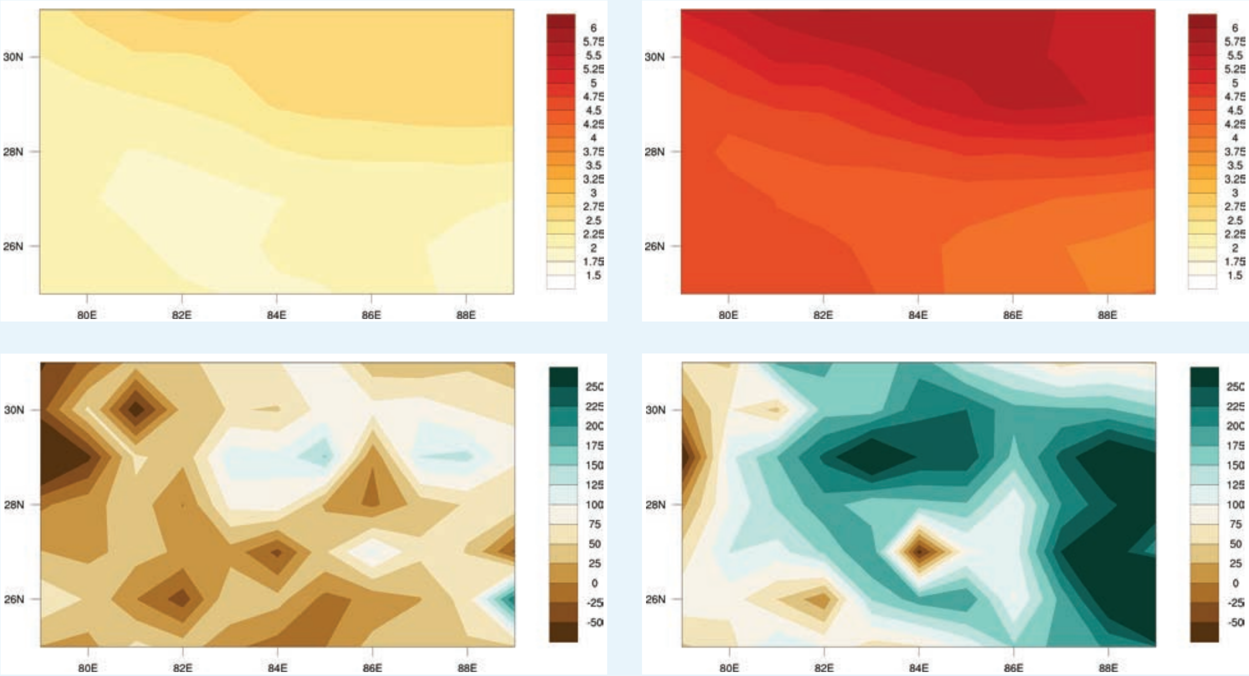
**FIGURE 4.** 'Projected average temperature anomaly' and 'projected annual rainfall anomaly' in Nepal. Outputs of 16 models within the ensemble simulating RCP8.5 over the period 2080–2099. Models shown represent the subset of models within the ensemble which provide projections across all RCPs and therefore are most robust for comparison. Three outlier models are labelled.




[23] Flato, G., Marotzke, J., Abiodun, B., Braconnot, P., Chou, S. C., Collins, W., . . . Rummukainen, M. (2013). Evaluation of Climate Models. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 741–866. URL: http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf

### *Spatial Variation*

**FIGURE 5.** CMIP5 ensemble projected change (32 GCMs) in annual temperature (top) and precipitation (bottom) by 2040–2059 (left) and by 2080–2090 (right) relative to 1986–2005 baseline under RCP8.5.[24] Maps present the coordinates of Nepal: latitude 80°03'42" E – 88°10'10" E and 30°26'12" N – 26°21'46" N.




### *Temperature*

Projections of future temperature change are presented in three primary formats. Shown in **Table 2** are the changes in daily maximum and daily minimum temperatures over the given time period, as well as changes in the average temperature. **Figures 6** and **7** display the annual and monthly average temperature projections. While similar, these three indicators can provide slightly different information. Monthly and annual average temperatures are most commonly used for general estimation of climate change, but the daily maximum and minimum can explain more about how daily life might change in a region, affecting key variables such as the viability of ecosystems, health impacts, productivity of labor, and the yield of crops, which are often disproportionately influenced by temperature extremes.

The model ensemble's median estimate of warming over the 1986–2005 baseline in Nepal is significantly above the global average. Under the highest emissions pathway (RCP8.5) warming in Nepal is projected to reach 5.0°C by the 2090s. The lowest emissions pathway (RCP2.6) ensemble mean projects warming of 1.4°C by the 2040s, followed by relatively constant temperatures up through the 2090s. Warming in monthly minimum and maximum temperatures is projected to be higher still, with minimum temperatures in Nepal projected to rise by 5.0°C by

[24] WBG Climate Change Knowledge Portal (CCKP, 2020). Nepal Climate Data: Projections. URL: https://climateknowledgeportal.worldbank.org/country/nepal/climate-data-projections

the end of the 21st century under the highest emissions pathway. The CCKP model ensemble projects a strong seasonal bias in temperature rises under higher emissions pathways, with warming strongest during the winter and spring months from November through to May (**Figure 7**). This trend reflects the stronger projected rise in minimum temperatures, which typically occur during the winter months. Spatial patterns in the warming experienced in Nepal are likely to be heavily influenced by elevation. Global research suggests warming is happening at a faster pace in higher altitude regions.[25] This trend is seen in Nepal, where night time temperatures in Nepal's highest altitude areas (over 4,000 m) have been rising at almost double the rate of temperatures in lower altitude (< 2,000 m) areas.[26] However, the complexity presented by the extreme variations in altitude seen in Nepal and the different processes which drive variation in warming (such as snow melt), may mean that model projections of future temperature rise are subject to above average levels of uncertainty.[27]

**FIGURE 6.** Historic and projected average annual temperature in Nepal under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble. Shading represents the standard deviation of the model ensemble.[28]

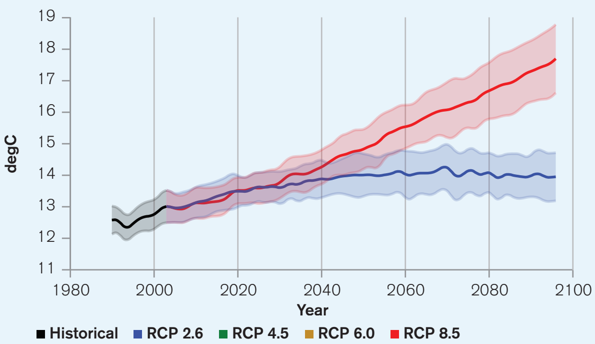
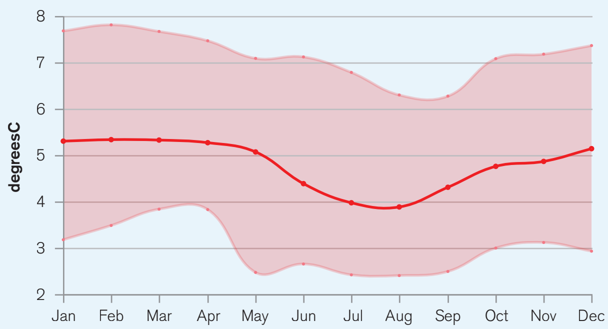



**FIGURE 7.** Projected change (°C) in monthly temperature, shown by month, for Nepal for the period 2080–2099 under RCP8.5. The value shown represents the median of the model ensemble with the shaded areas showing the 10th–90th percentiles.[19]




### *Precipitation*

The CCKP model ensemble provides minimal information on future changes in annual precipitation under all emissions pathways (**Figure 8**). The median ensemble change typically shows a small increase in annual precipitation, in the range of 5%–10% but uncertainty is very high and a minority of models also project decreases (**Figure 4**). Downscaled (i.e. localized) analysis conducted on the previous ensemble of IPCC

[25] Pepin, N., Bradley, R.S., Diaz, H.F., Baraër, M., Caceres, E.B., Forsythe, N., Fowler, H., Greenwood, G., Hashmi, M.Z., Liu, X.D. and Miller, J.R. (2015). Elevation-dependent warming in mountain regions of the world. Nature Climate Change, 5(5), p.424. URL: https://www.nature.com/articles/nclimate2563?proof=t

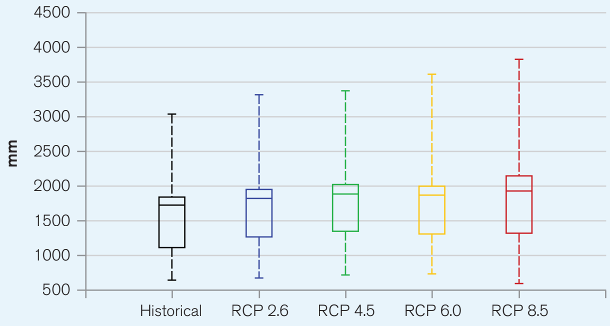
[26] Zhao, W., He, J., Wu, Y., Xiong, D., Wen, F. and Li, A. (2019). An Analysis of Land Surface Temperature Trends in the Central Himalayan Region Based on MODIS Products. Remote Sensing, 11(8), p.900. URL: https://www.researchgate.net/publication/332401472_remote_sensing_An_Analysis_of_Land_Surface_Temperature_Trends_in_the_Central_Himalayan_Region_Based_on_MODIS_Products

[27] Revadekar, J.V., Hameed, S., Collins, D., Manton, M., Sheikh, M., Borgaonkar, H.P., Kothawale, D.R., Adnan, M., Ahmed, A.U., Ashraf, J. and Baidya, S. (2013). Impact of altitude and latitude on changes in temperature extremes over South Asia during 1971–2000. International Journal of Climatology, 33(1), pp.199–209. URL: https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.3418

[28] WBG Climate Change Knowledge Portal (CCKP, 2020). Nepal Climate Data: Projections. URL: https://climateknowledgeportal.worldbank.org/country/nepal/climate-data-projections

climate models (CMIP3) pointed towards moderate increases in precipitation.[29] While considerable uncertainty surrounds projections of local long-term future precipitation trends, some global trends are evident and likely to affect Nepal. The intensity of sub-daily extreme rainfall events appears to be increasing with temperature, a finding supported by evidence from multiple regions of Asia.[30] However, as this phenomenon is highly dependent on local geographical contexts further research is required to constrain its localized impacts in Nepal. Future precipitation trends in Nepal will depend in part on how climate changes affect the ENSO phenomenon. Simulation of ENSO, however, is an area in which the CMIP5 set of models perform inconsistently.[31]

**FIGURE 8.** Historical and projected average annual precipitation for Nepal in the period 2080–2099.[19]




## CLIMATE RELATED NATURAL HAZARDS

Nepal experiences significant disaster risk, ranked 31st on the 2019 INFORM Risk Index (**Table 4**).[32] Key drivers of risk in Nepal include its high exposure to flood hazard as well as its lack of coping capacity. Nepal also holds moderate exposure to drought hazard, and moderate levels of vulnerability. However, the largest source of exposure-risk derives from earthquake. While not directly linked to climate change, earthquake exposure remains relevant in the context of a changing climate. More precipitation and higher temperatures affect

**TABLE 4.** Selected indicators from the INFORM 2019 Index for Risk Management for Nepal. For the sub-categories of risk (e.g. "Flood") higher scores represent greater risks. Conversely the most at-risk country is ranked 1st. The average score across all countries is shown in brackets.

| Flood (0–10) | Tropical Cyclone (0–10) | Drought (0–10) | Vulnerability (0–10) | Lack of Coping Capacity (0–10) | Overall Inform Risk Level (0–10) | Rank (1–191) |
|---|---|---|---|---|---|---|
| 6.7 [4.5] | 0.2 [1.7] | 2.8 [3.2] | 4.7 [3.6] | 5.8 [4.5] | 5.4 [3.8] | 31 |

29 Sigdel, M. and Ma, Y. (2016). Evaluation of future precipitation scenario using statistical downscaling model over humid, subhumid, and arid region of Nepal—a case study. Theoretical and applied climatology, 123(3–4), pp.453–460. URL: https://pubag.nal.usda.gov/catalog/4802706

30 Westra, S., Fowler, H. J., Evans, J. P., Alexander, L. V., Berg, P., Johnson, F., Kendon, E. J., Lenderink, G., Roberts, N. (2014). Future changes to the intensity and frequency of short-duration extreme rainfall. Reviews of Geophysics, 52, 522–555. URL: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014RG000464

31 Chen, C., Cane, M. A., Wittenberg, A. T., & Chen, D. (2017). ENSO in the CMIP5 Simulations: Life Cycles, Diversity, and Responses to Climate Change. Journal of Climate, 30(2), 775–801. URL: https://journals.ametsoc.org/jcli/article/30/2/775/96236/ENSO-in-the-CMIP5-Simulations-Life-Cycles

32 European Commission (2019). INFORM Index for Risk Management. Nepal Country Profile. URL:https://drmkc.jrc.ec.europa.eu/inform-index/Countries/Country-Profile-Map

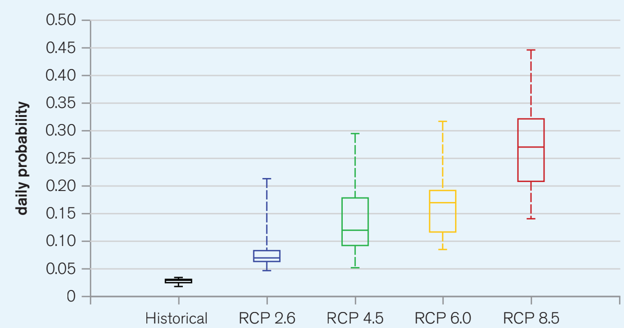
the stability of terrain and hence susceptibility to hazards from mudflows, avalanches, GLOFs and landslides that could be triggered by an earthquake. Additionally, the risk of simultaneous, multi-hazard, exposure is significant,[33] for instance hydro-climatic hazards following an earthquake have been shown to compound damages.[34]

## Heatwaves and Cold Waves

The current median probability of a heat wave (defined as a period of 3 or more days where the daily temperature is above the long-term 95th percentile of daily mean temperature) in Nepal is around 3%. The median estimated probability of cold wave also sits at around 3% (defined as a period of 3 or more days where the daily temperature is below the long-term 5th percentile of daily mean temperature).

As shown in **Figure 9**, the probability of heatwave is projected to increase significantly, potentially as high as 27% by the 2090s under the highest emissions pathway (RCP8.5). Simultaneously, the probability of cold wave is projected to decrease significantly, to less than 1% annually over the same time period. Both metrics reflect the projected rise in temperatures, which constantly moves the average away from the historical daily mean. Nonetheless, the significant increase in the potential for extreme high temperatures, particularly in Nepal's more populous lower altitude region demands both further research and disaster risk reduction efforts. Another lens through which to view the heat hazard is the annual maximum of daily maximum temperatures. The CCKP model suggests this value could increase from a baseline (1986–2005) of around 32°C, to almost 34°C by the 2030s (under all emissions pathways). Under RCP8.5 the annual maximum of daily maximum temperatures could approach 38°C by the 2080s.

**FIGURE 9.** Projected change in the probability of observing a heat wave in Nepal by 2080–2099. A 'Heat Wave' is defined as a period of 3 or more days where the daily temperature is above the long-term 95th percentile of daily mean temperature.[19]




## Drought

Two primary types of drought may affect Nepal, meteorological (usually associated with a precipitation deficit) and hydrological (usually associated with a deficit in surface and subsurface water flow, potentially originating in the region's wider river basins). At present Nepal faces an annual median probability of severe meteorological drought of around 2%, as defined by a standardized precipitation evaporation index (SPEI) of less than –2. There is some evidence that drought frequency in Nepal increased between 1981–2012.[35]

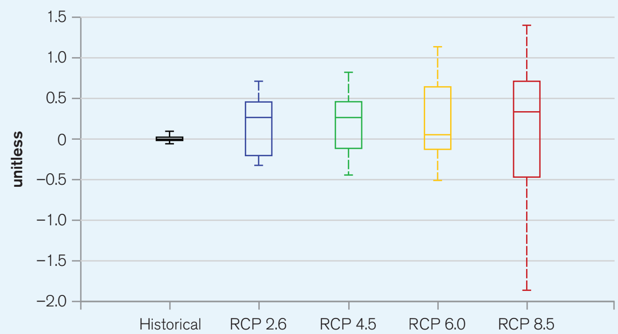
[33] Gill, J.C. and Malamud, B.D. (2017). Anthropogenic processes, natural hazards, and interactions in a multi-hazard framework. Earth-Science Reviews, 166, 246–269. URL: https://www.sciencedirect.com/science/article/pii/S0012825216302227

[34] Gautam, D. and Dong, Y. (2018). Multi-hazard vulnerability of structures and lifelines due to the 2015 Gorkha earthquake and 2017 central Nepal flash flood. Journal of Building Engineering, 17, pp.196–201. URL: http://ira.lib.polyu.edu.hk/handle/10397/77914

[35] Dahal, P., Shrestha, N. S., Shrestha, M. L., Krakauer, N. Y., Panthi, J., Pradhanang, S. M., . . . Lakhankar, T. (2016). Drought risk assessment in central Nepal: temporal and spatial analysis. Natural Hazards, 80(3), 1913–1932. URL: https://link.springer.com/article/10.1007/s11069-015-2055-5

The climate model ensemble projects an increase in drought probability over the 21st century (**Figure 10**). The ensemble projects a median annual drought probability of at least 10% by 2080–2099 under all emission pathways. However, uncertainty remains very high due to poor understanding of future ENSO behavior.

**FIGURE 10.** Annual probability of experiencing a 'severe drought' in Nepal (–2 SPEI index) in 2080–2099 under four emissions pathways.[19]




## Flood

The World Resources Institute's AQUEDUCT Global Flood Analyzer[36] can be used to establish a baseline level of flood exposure. As of 2010, assuming protection for up to a 1 in 10-year event, the population annually affected by river flooding in Nepal is estimated at 157,000 people and the expected annual impact on GDP is estimated at $218 million. This is higher than that of UNISDR who placed a figure of $143 million on average annual losses to all types of flood in 2014.[37] The difference in these values may be due to model errors and biases inherent in AQUEDUCT, however, it may also relate to the underreporting of flood impacts –a known issue with the dataset underpinning UNSIDR's estimate. Economic development, population growth and climate change are likely to increase the impacts of river flooding. The climate change component can be isolated and by 2030 is expected to increase the annually affected population by 199,000 people, and the annual impact on GDP by $574 million under the RCP8.5 emissions pathway (AQUEDUCT Scenario B). In both cases, the impact more than doubles over the 20-year reference period.

An increase in potential flooding impact is also projected by Paltan et al. (2018)[38] who demonstrate that even under lower emissions pathways coherent with the Paris Climate Agreement almost all Asian countries face an increase in the frequency of extreme river flows.[31] What would historically have been a 1 in 100-year flow, is projected to become a 1 in 50-year or 1 in 25-year event in Nepal. There is good agreement among models on this trend. This increased severity of extreme river floods can be seen in estimates by Willner et al. (2018)[39] (**Table 5**) who project that an additional 8,000–43,000 people will be affected by an extreme flood event by 2035–2044 as a result of climate change.

Nepal also faces a growing hazard from glacier lake outburst floods (GLOFs). Nepal is believed to contain well over 1,000 glacier lakes. although most do not represent a threat to Nepalese communities. Lakes such as Phoksundo Tal, Tsho Rolpa, Chamlang North Tsho, Chamlang South Tsho, and Lumding Tsho glacier lakes, could pose significant disaster risk.[40] Glacier lakes are believed to be rapidly forming in the Nepal region of the Himalayas as a result of

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36 WRI (2018). AQUEDUCT Global Flood Analyzer. URL: https://floods.wri.org/# [Accessed: 22/11/2018]

37 UNISDR (2014). PreventionWeb: Basic country statistics and indicators. URL:https://www.preventionweb.net/countries [accessed 14/08/2018]

38 Paltan, H., Allen, M., Haustein, K., Fuldauer, L., & Dadson, S. (2018). Global implications of 1.5°C and 2°C warmer worlds on extreme river flows Global implications of 1.5°C and 2°C warmer worlds on extreme river flows. Environmental Research Letters, 13. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aad985/meta

39 Willner, S., Levermann, A., Zhao, F., Frieler, K. (2018). Adaptation required to preserve future high-end river flood risk at present levels. Science Advances: 4:1. URL: https://advances.sciencemag.org/content/4/1/eaao1914

40 Rounce, D. R., Watson, C. S., & McKinney, D. C. (2017). Identification of Hazard and Risk for Glacial Lakes in the Nepal Himalaya Using Satellite Imagery from 2000–2015. Remote Sensing, 9(7). URL: https://www.mdpi.com/2072-4292/9/7/654

**TABLE 5.** Estimated number of people in Nepal affected by an extreme river flood (extreme flood is defined as being in the 90th percentile in terms of numbers of people affected) in the historic period 1971–2004 and the future period 2035–2044. Figures represent an average of all four RCPs and assume present day population distributions.[32]

| Estimate | Population Exposed to Extreme Flood (1971–2004) | Population Exposed to Extreme Flood (2035–2044) | Increase in Affected Population |
|---|---|---|---|
| **16.7 Percentile** | 350,844 | 358,940 | 8,096 |
| **Median** | 353,695 | 369,120 | 15,425 |
| **83.3 Percentile** | 356,916 | 400,498 | 43,582 |

glacier melting, with most of the existing lakes formed since the mid-20th century.[41] When a moraine that holds back the meltwater is breached, either as a result of climate or geological processes, significant flood surges can result, causing major damage to downstream communities. This risk includes a potential interaction with the significant earthquake hazard in Nepal. As increasing numbers of glacial lakes form, the risk of GLOFs during earthquake events is also believed to be increasing.[42] Potential impacts include loss of life and livelihoods, and damage to infrastructure both as a result of flooding but also through the significant transport of sediment and debris which can accompany GLOFs. Significant work is already underway in Nepal to mitigate the risk of disaster.

# CLIMATE CHANGE IMPACTS

## Natural Resources

### Water

The future of the water resources sector in Nepal depends on the management of several key pressures: notably local development, as well as hydrological climate changes and the future of Asia's high mountain glaciers in a warmer world. One study estimates that warming will result in the loss of between 36% to 64% of ice mass in Asia's high mountain glaciers by the end of the 21st century, with the higher end of the range associated with higher emissions pathways.[43] Glacial mass in the Himalayas over the coming decades will also depend on changes in the level of snowfall and the intensity of precipitation during the monsoon season, although there is less certainty among forecasts on the direction of this impact.[44] Moreover, a recent high-resolution study of Himalayan glaciers

[41] Haritashya, U. K., Kargel, J. S., Shugar, D. H., Leonard, G. J., Strattman, K., Watson, C. S., . . . Regmi, D. (2018). Evolution and Controls of Large Glacial Lakes in the Nepal Himalaya. Remote Sensing, 10(5). URL: https://www.mdpi.com/2072-4292/10/5/798

[42] Kargel, J. S., Leonard, G. J., Shugar, D. H., Haritashya, U. K., Bevington, A., Fielding, E. J., . . . Young, N. (2015). Geomorphic and geologic controls of geohazards induced by Nepal's 2015 Gorkha earthquake. Science, aac8353. URL: https://pubmed.ncbi.nlm.nih.gov/26676355/

[43] Kraaijenbrink, P. D. A., Bierkens, M. F. P., Lutz, A. F., & Immerzeel, W. W. (2017). Impact of a global temperature rise of 1.5 degrees Celsius on Asia's glaciers. Nature, 549, 257. URL: https://pubmed.ncbi.nlm.nih.gov/28905897/

[44] Bolch, T., Kulkarni, A., Kääb, A., Huggel, C., Paul, F., Cogley, J.G., Frey, H., Kargel, J.S., Fujita, K., Scheel, M. & Bajracharya, S. (2012). The state and fate of Himalayan glaciers. Science, 336(6079), pp.310–314. URL: https://science.sciencemag.org/content/336/6079/310/tab-figures-data

indicates that there is considerable localized variation in the impact of climate change on glacial mass, suggesting a need for more localized forecasts for Nepalese glacier regions.[45] A key impact of glacial melting is expected to be the disruption of the historical runoff regime. One study projects both increasing runoff volume and extreme flows, but only limited shifts in runoff seasonality in the Nepalese Himalayas as a result of climate change.[46]

These changes, along with natural hazards such as flood and drought will challenge an already vulnerable water sector. As of 2015, only 88% of Nepal's population had access to at least a basic water supply[47] and access to basic sanitation is believed to be even lower. World Bank data (2012) suggest that less than 60% of Nepal's population has access to basic sanitation, and that this is strongly biased towards higher income groups.[48] Despite a generally high national water supply, many Nepalese communities, particularly in rural and remote areas, are vulnerable to water stress. Access to water for household use can be inconsistent, as can water availability for small-scale hydropower,[49] and agriculture remains a vital part of many households' livelihoods and subsistence. In particular, rain-fed agriculture remains prominent in Nepal and is likely to be vulnerable to changes in the local precipitation regime. Many households are dependent on groundwater for subsistence and this too is under stress. Research has documented springs drying up and communities having to dig deeper and travel further to access water for consumption and basic household needs.[50] Losses in groundwater are linked primarily to declines in annual precipitation rates. Without action existing weaknesses in governance, which have failed to ensure equal access and necessary infrastructure, may be exposed by the new challenges being presented by climate change.[51]

## Forests and Biodiversity

Nepal is home to a wealth of biodiversity, many unique Himalayan ecosystems, and natural resources. As well as their intrinsic value and the cultural value these assets hold to local communities, Nepal's natural resources underpin many sectors of the country's economy. As of 2017 the World Travel and Tourism Council suggested tourism made around an 8% total contribution to Nepal's GDP and 7% total contribution to employment.[52] Studies suggest

[45] Bonekamp, P.N., de Kok, R.J., Collier, E. & Immerzeel, W.W. (2019). Contrasting meteorological drivers of the glacier mass balance between the Karakoram and central Himalaya. Frontiers in Earth Science, 7, p.107. URL: https://www.frontiersin.org/articles/10.3389/feart.2019.00107/full

[46] Ragettli, S., Immerzeel, W. W., & Pellicciotti, F. (2016). Contrasting climate change impact on river flows from high-altitude catchments in the Himalayan and Andes Mountains. Proceedings of the National Academy of Sciences, 113(33), 9222–9227. URL: https://www.pnas.org/content/113/33/9222

[47] Water Aid (2018). The State of the World's Water 2018. URL: https://washmatters.wateraid.org/sites/g/files/jkxoof256/files/The%20Water%20Gap%20State%20of%20Water%20report%20lr%20pages.pdf

[48] Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D., and Vogt-Schilb, A. (2016). Shock Waves: Managing the Impacts of Climate Change on Poverty. Climate Change and Development Series. Washington, DC: World Bank. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/22787/9781464806735.pdf?sequence=13&isAllowed=y

[49] McDowell, G., Ford, J. D., Lehner, B., Berrang-Ford, L., & Sherpa, A. (2013). Climate-related hydrological change and human vulnerability in remote mountain regions: a case study from Khumbu, Nepal. Regional Environmental Change, 13(2), 299–310. URL: https://link.springer.com/article/10.1007/s10113-012-0333-2

[50] Poudel, D.D. and Duex, T.W. (2017). Vanishing springs in Nepalese mountains: Assessment of water sources, farmers' perceptions, and climate change adaptation. Mountain Research and Development, 37(1), pp.35–46. URL: https://bioone.org/journals/mountain-research-and-development/volume-37/issue-1/MRD-JOURNAL-D-16-00039.1/Vanishing-Springs-in-Nepalese-Mountains—Assessment-of-Water-Sources/10.1659/MRD-JOURNAL-D-16-00039.1.full

[51] Biggs, E. M., Duncan, J. M. A., Atkinson, P. M., & Dash, J. (2013). Plenty of water, not enough strategy: How inadequate accessibility, poor governance and a volatile government can tip the balance against ensuring water security: The case of Nepal. Environmental Science & Policy, 33, 388–394. URL: https://research-repository.uwa.edu.au/en/publications/plenty-of-water-not-enough-strategy-how-inadequate-accessibility-

[52] World Travel and Tourism Council (2018). Travel and tourism economic impact 2018: Nepal. URL: https://wttc.org

significant changes are already under way in many Himalayan ecoregions as a result of climate changes. A key indicator of change is the increase in the length of the plant growing season which has been widely documented.[11] Earlier onset of the growing season has been documented particularly in the higher altitude areas of the Himalayas where highest rates of warming have also been measured. Indicators such as the length of the growing season, the average precipitation, precipitation as snow, and the seasonality of precipitation and temperature all signal likely shifts in the suitable geographical ranges of flora and fauna. For example, climate changes are expected to encourage the maximum altitude of the tree-line to increase, shrinking the size of the alpine ecoregion. The widespread conifer species *Abies spectabilis* has been recorded spreading upwards at around 2.6 m per year.[53] The loss of alpine habitat has been projected to reduce the area of good snow leopard habitat in Nepal by between 12.5% to 41.5%.[54] Additional pressures on biodiversity and conflicting needs in upland areas are likely to form as their viability for human use improves.[55] Eventually, it is expected that combined impact of development pressures, climate changes and the 'topographic isolation' of local species (i.e. species with limited ability shift their ranges) may result in increased rates of species endangerment and extinction.[56]

# Economic Sectors

## Agriculture

Climate change will influence food production via direct and indirect effects on crop growth processes. Direct effects include alterations to carbon dioxide availability, precipitation and temperatures. Indirect effects include through impacts on water resource availability and seasonality, soil organic matter transformation, soil erosion, changes in pest and disease profiles, the arrival of invasive species, and decline in arable areas due to dryland expansion and shifts in local hydrology. On an international level, these impacts are expected to damage key staple crop yields, even on lower emissions pathways. Tebaldi and Lobell (2018)[57] estimate 5% and 6% declines in global wheat and maize yields respectively even if the Paris Climate Agreement is met and warming is limited to 1.5°C. Shifts in the optimal and viable spatial ranges of certain crops are also inevitable, though the extent and speed of those shifts remains dependent on the emissions pathway. Both historical and projected measurement of the impacts of climate change on crop productivity in Nepal present a mixed outlook. For instance, some studies show potential for rice yield declines[58], others project yield improvements as a result of improved conditions in highland production areas[2].

[53] Gaire, N. P., Koirala, M., Bhuju, D. R., & Borgaonkar, H. P. (2014). Treeline dynamics with climate change at the central Nepal Himalaya. Climate of the Past, 10(4), 1277–1290. URL: https://cp.copernicus.org/articles/10/1277/2014/

[54] Forrest, J. L., Wikramanayake, E., Shrestha, R., Areendran, G., Gyeltshen, K., Maheshwari, A., . . . Thapa, K. (2012). Conservation and climate change: Assessing the vulnerability of snow leopard habitat to treeline shift in the Himalaya. Biological Conservation, 150(1), 129–135. URL: https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Biol.Cons.2012_Vulnerability_of_Snow_Leopard_Habitat_to_Treeline_Shift__1_.pdf

[55] Aryal, A., Brunton, D., & Raubenheimer, D. (2014). Impact of climate change on human-wildlife-ecosystem interactions in the Trans-Himalaya region of Nepal. Theoretical and Applied Climatology, 115(3), 517–529. URL: https://link.springer.com/article/10.1007/s00704-013-0902-4?shared-article-renderer

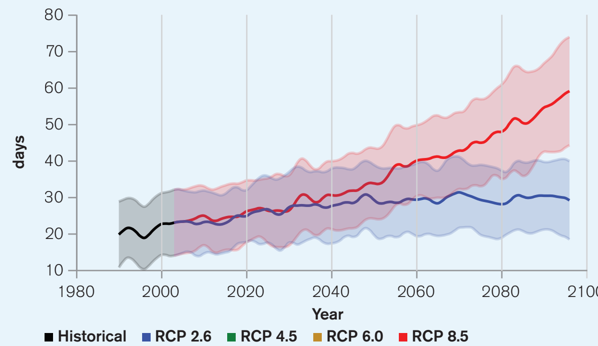
[56] Telwala, Y., Brook, B. W., Manish, K., & Pandit, M. K. (2013). Climate-Induced Elevational Range Shifts and Increase in Plant Species Richness in a Himalayan Biodiversity Epicentre. PLoS ONE, 8(2). URL: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0057103

[57] Tebaldi, C., & Lobell, D. (2018). Differences, or lack thereof, in wheat and maize yields under three low-warming scenarios. Environmental Research Letters: 13: 065001. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aaba48

[58] Palazzoli, I., Maskey, S., Uhlenbrook, S., Nana, E., & Bocchiola, D. (2015). Impact of prospective climate change on water resources and crop yields in the Indrawati basin, Nepal. Agricultural Systems, 133, 143–157. URL: https://econpapers.repec.org/article/eeeagisys/v_3a133_3ay_3a2015_3ai_3ac_3ap_3a143-157.htm

As is the case globally, there is concern that wheat and maize production may suffer in Nepal.[51] Maize is already reported to be responding adversely to increases in summer maximum temperatures.[59] and large potential increases in the frequency of very hot days (>35°C) are projected under higher emissions pathways (**Figure 11**). However, most projections suggest a large range of possible outcomes, with particular sensitivity to the climate model selected[51] highlighting the need for further research and capacity building.

**FIGURE 11.** Historic and projected annual average number of hot days (>35°C) under RCP2.6 (Blue) and RCP8.5 (Red). The values shown represents the median of 30+ GCM model ensemble with the shaded areas showing the 10–90th percentiles.[19]




Studies have shown that adaptation practices, notably adoption of new higher-yielding crop varieties, have been sustaining yield increases even when climate changes create downward pressure.[60] However, it is important to note that these adaptation practices can come at considerable economic cost. There are also barriers to entry which prevent adoption by the most vulnerable communities, many of which are dependent on farming for subsistence. It is unclear whether adaptive improvements in production efficiency will be enough to sustain production increases in the long run.

A further, and perhaps lesser appreciated influence of climate change on agricultural production is through its impact on the health and productivity of the labor force. Dunne et al. (2013) suggest that global labor productivity during peak months has already dropped by 10% as a result of warming, and that a decline of up to 20% might be expected by the 2050s under the highest emissions pathway (RCP8.5).[61] This phenomena could impact Nepal's lowland areas where extreme high heats will increasingly be experienced. Further research is required on the net effect as there may also be potential for productivity gains in upland areas where warming will make previously extremely cold environments more tolerable. In combination, it is highly likely that the above processes will have a considerable impact on national food consumption patterns both through direct impacts on internal agricultural operations, and through impacts on the global supply chain.

## Urban

The diverse climate risks documented above constitute a major threat to core infrastructure, public service provision, and economic stability in Nepal. Vulnerability extends into urban areas with risks such as flooding and extreme heat in particular. Research has established a reasonably well constrained relationship between heat and cold stress

[59] Maharjan, K. L., & Joshi, N. P. (2013). Effect of Climate Variables on Yield of Major Food-Crops in Nepal: A Time-Series Analysis. In K. L. Maharjan & N. P. Joshi (Eds.), Climate Change, Agriculture and Rural Livelihoods in Developing Countries (pp. 127–137). Springer Japan. URL: https://mpra.ub.uni-muenchen.de/35379/

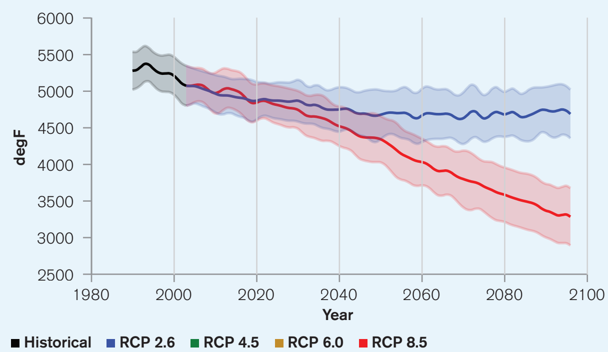
[60] Dhakal, S., Sedhain, G., & Dhakal, S. (2016). Climate Change Impact and Adaptation Practices in Agriculture: A Case Study of Rautahat District, Nepal. Climate, 4(4), 63. URL: https://www.mdpi.com/2225-1154/4/4/63

[61] Dunne, J. P., Stouffer, R. J., & John, J. G. (2013). Reductions in labor capacity from heat stress under climate warming. Nature Climate Change, 3(6), 563–566. URL: http://www.precaution.org/lib/noaa_reductions_in_labour_capacity_2013.pdf

and labor productivity, household consumption patterns, and (by proxy) household living standards.[62] In general terms the impact of an increase in temperature on these indicators depends on whether the temperature rise moves the ambient temperature closer to, or further away from, the optimum temperature range. The optimum range can vary depending on local conditions and adaptations. As well as impacting on human health (see: Communities) the temperature peaks that could result from climate change are likely to affect the productivity of the service sector economy. This may occur both through direct impacts on labor productivity and also through the additional costs of adaptation. The negative impact on service sector productivity may be exacerbated by the urban heat island effect as Nepal urbanizes.[63]

The CCKP model ensemble suggests that on a national level climate change could move Nepal into a less temperature stressed environment. The need for cooling is expected to be outweighed by the reduction in the need for heating (**Figure 12**). This view is supported by work by the World Bank, which modelled the relationship between consumption and temperature in Nepal (**Figure 13**). The analysis suggests that climate change may, over the long-term, have some positive implications for the productivity of Nepal's economy. This phenomenon represents one of the ways in which climate change might interact with the service sector economy and livelihoods in urban areas. However, given the multitude of different micro-climates found in Nepal, further research is needed on a more localised level. For instance, the changes and pressures experienced in Nepal's lowlands are likely to be very different to those experienced in its highland communities.

**FIGURE 12.** Historic and projected annual heating degree days in Nepal (cumulative degrees below 65°F) under RCP2.6 (Blue) and RCP8.5 (Red). The values shown represent the median of 30+ GCM model ensemble with the shaded areas showing the 10–90th percentiles.[19]




Research suggests that on average a 1°C movement in ambient temperature above or below comfort thresholds can result in a 0.5% to 8.5% change in electricity demand.[64] Notably this links to use of business and residential air cooling and heating systems. The net decline in the need for heating in Nepal might be expected to reduce the overall burden on energy generation systems. However, this suggestion should be approached with caution. Nepal is also projected to experience an increase in the frequency and intensity of extreme events. Hazards such as heatwaves and floods may place strain on, or damage, Nepal's energy systems and infrastructure. As such,

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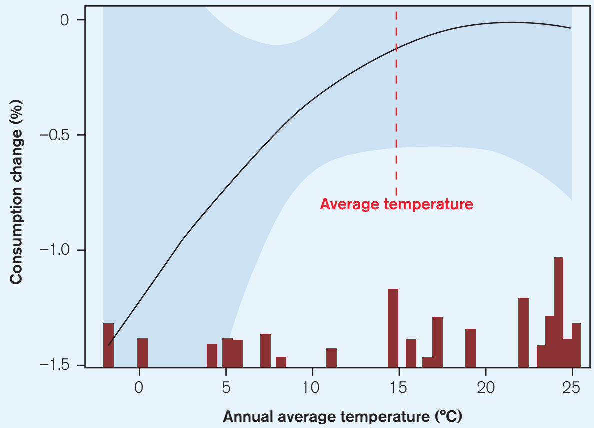
62 Mani, M., Bandyopadhyay, S., Chonabayashi, S., Markandya, A., Mosier, T. (2018). South Asia's Hotspots: The Impact of Temperature and Precipitation changes on living standards. South Asian Development Matters. World Bank, Washington DC. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/28723/9781464811555.pdf?sequence=5&isAllowed=y

63 Oleson, K. W., Monaghan, A., Wilhelmi, O., Barlage, M., Brunsell, N., Feddema, J., . . . Steinhoff, D. F. (2015). Interactions between urbanization, heat stress, and climate change. Climatic Change, 129(3), 525–541. URL: http://www.dept.ku.edu/~biomet/KU_Biometeorology_Lab/Publications_files/oleson_cc13.pdf

64 Santamouris, M., Cartalis, C., Synnefa, A., & Kolokotsa, D. (2015). On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings—A review. Energy and Buildings, 98, 119–124. URL: https://www.sciencedirect.com/science/article/abs/pii/S0378778814007907

the importance of effective disaster risk reduction initiatives remains very high. Notably, around 90% of Nepal's electricity generation is sourced from hydropower. This represents a potential vulnerability in the context of an uncertain future precipitation regime, glacial melting, and potential increases in the risks of landslides and GLOFs. Studies have shown a range of potential outcomes in terms of future hydropower productivity.[65] However, given the known exposure of Nepal's hydropower infrastructure to natural hazards there is a clear need for attention on adaptation and disaster risk reduction.[66]

**FIGURE 13.** The relationship between temperature and consumption in Nepal, shaded areas represent 90% confidence intervals. Black line shows the relationship between temperature and consumption and the optimum temperature (around 21°C) at which no consumption is lost.[55]




## Communities

### Poverty, Inequality and Disaster Vulnerability

Many of the climate changes projected are likely to disproportionately affect the poorest groups in society. For instance, heavy manual labor jobs are commonly among the lowest paid whilst also being most at risk of productivity losses due to heat stress.[67] In addition, poorer groups are proportionally most affected by natural hazards,[68] and poorer groups are also most sensitive to food price rises,[69] with the potential for food price rises to drive extreme poverty also demonstrated in Nepal.[61] While adaptations are available to reduce the negative impacts experienced in areas such as these, two key challenges present. First, the poorest groups typically have the lowest capacity and resource to access adaptation. For example, poorer businesses are least able to afford air conditioning, an increasing need given the projected increase in cooling days in Nepal's lowlands, and poorer farmers and communities are least able to afford local water storage, irrigation infrastructure, and technologies for adapting to hydrological change. Second, even where

[65] Shrestha, S., Bajracharya, A.R. and Babel, M.S. (2016). Assessment of risks due to climate change for the Upper Tamakoshi Hydropower Project in Nepal. Climate Risk Management, 14, pp.27–41. URL: https://www.sciencedirect.com/science/article/pii/S2212096316300274

[66] Shrestha, A. B., Eriksson, M., Mool, P., Ghimire, P., Mishra, B., & Khanal, N. R. (2010). Glacial lake outburst flood risk assessment of Sun Koshi basin, Nepal. Geomatics, Natural Hazards and Risk, 1(2), 157–169. URL: https://www.tandfonline.com/doi/full/10.1080/19475701003668968

[67] Kjellstrom, T., Briggs, D., Freyberg, C., Lemke, B., Otto, M., Hyatt, O. (2016). Heat, human performance, and occupational health: A key issue for the assessment of global climate change impacts. Annual Review of Public Health: 37: 97–112. URL: https://pubmed.ncbi.nlm.nih.gov/26989826/

[68] Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D., and Vogt-Schilb, A. (2016). Shock Waves: Managing the Impacts of Climate Change on Poverty. Climate Change and Development Series. Washington, DC: World Bank. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/22787/9781464806735.pdf?sequence=13&isAllowed=y

[69] Gentle, P., Thwaites, R., Race, D., & Alexander, K. (2014). Differential impacts of climate change on communities in the middle hills region of Nepal. Natural Hazards, 74(2), 815–836. URL: https://link.springer.com/article/10.1007/s11069-014-1218-0

adaptation interventions are made, either autonomously or through outside intervention, evidence from Nepal suggests they may not be enough to prevent damage and loss being experienced.[70]

Natural hazards have had a very significant impact on Nepalese society over the 20th and early 21st centuries. One study estimated that disaster events led to over 4 million casualties (killed and injured) over the period 1990–1999.[71] The largest reported contributors to human casualties over the century were disease epidemics and flooding, but major contributions were also made by earthquake, landslide, storms, and fires. In terms of the climate-linked hazards, approximately 2,000 deaths were recorded due to flood and landslides between 2000–2009 and around 250,000 families were affected.[72] Strong correlations have been found showing that households with fewer years of schooling and lower wealth levels are considerably more likely to be affected, experience casualties, and incur livelihood losses as a result of floods and landslides.[65] In absolute terms, most households exposed to flooding live in the low-lying Terai region, where population densities are higher. Large numbers of people in these regions have some exposure to flood waters, but the intensity of the hazard is lower and household capacity to take evasive action is higher. The relative risks of loss of life and livelihood are considerably higher in the other hilly and mountainous regions. Indeed, migration from disaster prone mountainous regions to the Terai region has been documented.[65] A key finding of research into disaster risk in Nepal is that hazards with low absolute impact (but potentially severe impacts for affected households) are very high in frequency. Given the projected increase in the frequency and intensity of climate extremes and the likely above-average rates of warming this trend may worsen. Nepalese communities face potentially significant yet highly uncertain challenges over coming decades.

## Human Health

### *Nutrition*

The World Food Program estimate that without adaptation the risk of hunger and child malnutrition on a global scale could increase by 20% respectively by 2050.[73] Springmann et al. assessed the potential for excess, climate-related deaths associated with malnutrition.[74] The authors identify two key risk factors that are expected to be the primary drivers: a lack of fruit and vegetables in diets, and health complications caused by increasing prevalence of people underweight. The study suggests there could be approximately 61.9 climate-related deaths per million population linked to lack of food availability in Nepal by the year 2050 under RCP8.5.

### *Heat-Related Mortality*

Research has placed a threshold of 35°C (wet bulb ambient air temperature) on the human body's ability to regulate temperature, beyond which even a very short period of exposure can present risk of serious ill-health and death

[70] Bauer, K. (2013). Are preventive and coping measures enough to avoid loss and damage from flooding in Udayapur district, Nepal? International Journal of Global Warming, 5(4), 433. URL: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.921.2497&rep=rep1&type=pdf

[71] Aryal, K. R. (2012). The history of disaster incidents and impacts in Nepal 1900–2005. International Journal of Disaster Risk Science, 3(3), 147–154. URL: https://link.springer.com/article/10.1007/s13753-012-0015-1

[72] Samir, K.C. (2013). Community Vulnerability to Floods and Landslides in Nepal. Ecology and Society, 18(1), 8. URL: https://www.ecologyandsociety.org/vol18/iss1/art8/

[73] WFP (2015). Two minutes on climate change and hunger: A zero hunger world needs climate resilience. The World Food Program. URL: https://docs.wfp.org/api/documents/WFP-0000009143/download/

[74] Springmann, M., Mason-D'Croz, D., Robinson, S., Garnett, T., Godfray, H. C. J., Gollin, D., . . . Scarborough, P. (2016). Global and regional health effects of future food production under climate change: a modelling study. The Lancet: 387: 1937–1946. URL: https://pubmed.ncbi.nlm.nih.gov/26947322/

(Im et al., 2017).[75] Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human health. Climate change could push global temperatures closer to this temperature 'danger zone' both through slow-onset warming and intensified heat waves. As shown in **Figure 11**, Nepal faces a significant increase in the annual number of days exceeding 35°C. Honda et al. (2014)[76] utilized the A1B emissions scenario from CMIP3 (most comparable to RCP6.0) to estimate that without adaptation, annual heat-related deaths in the South Asian region, could increase 149% by 2030 and 276% by 2050. The potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).[77]

### *Disease*

Many vector-borne diseases are prevalent in Nepal, including: malaria, dengue, chikungunya, Japanese encephalitis, visceral leishmaniasis, lymphatic filariasis. Most are endemic in the lowland Terai and hills of Nepal placing about 80% of the population at risk. This at-risk population is expected to increase under climate change as warming allows diseases to push further into Nepal's highlands.[78] Climate change is also expected to increase the potential for transmission of water-borne diseases. Higher temperatures have already been correlated with Diarrhea incidence in Nepal[79] and studies in other parts of the world have shown the potential for flooding and drought to drive transmission of both water and vector-borne diseases.[80]

# POLICIES AND PROGRAMS

## National Adaptation Policies and Plans

| Policy/Strategy/Plan | Status | Document Access |
|---|---|---|
| Nationally Determined Contribution (NDC) to Paris Climate Agreement | Submitted | October, 2016 |
| National Communications to the UNFCCC | Two submitted | Latest: December, 2014 |
| National Disaster Response Framework (NDRF) | Enacted | July, 2013 |
| National Adaptation Programme of Action (NAPA) to Climate Change | Enacted | September, 2010 |

75 Im, E. S., Pal, J. S., & Eltahir, E. A. B. (2017). Deadly heat waves projected in the densely populated agricultural regions of South Asia. Science Advances, 3(8), 1–8. URL: https://advances.sciencemag.org/content/3/8/e1603322

76 Honda, Y., Kondo, M., McGregor, G., Kim, H., Guo, Y-L, Hijioka, Y., Yoshikawa, M., Oka, K., Takano, S., Hales, S., Sari Kovats, R. (2014). Heat-related mortality risk model for climate change impact projection. Environmental Health and Preventive Medicine 19: 56–63. URL: https://pubmed.ncbi.nlm.nih.gov/23928946/

77 Mitchell, D., Heaviside, C., Schaller, N., Allen, M., Ebi, K. L., Fischer, E. M., . . . Vardoulakis, S. (2018). Extreme heat-related mortality avoided under Paris Agreement goals. Nature Climate Change, 8(7), 551–553. URL: https://www.nature.com/articles/s41558-018-0210-1?WT.ec_id=NCLIMATE-201807&spMailingID=56915405&spUserID=ODE0MzAwNjg5MAS2&spJobID=1440158046&spReportId=MTQ0MDE1ODA0NgS2

78 Dhimal, M., Ahrens, B., & Kuch, U. (2015). Climate Change and Spatiotemporal Distributions of Vector-Borne Diseases in Nepal – A Systematic Synthesis of Literature. PLOS ONE, 10(6), 1–31. URL: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0129869

79 Bhandari, G. P., Gurung, S., Dhimal, M., & Bhusal, C. L. (2012). Climate change and occurrence of diarrheal diseases: evolving facts from Nepal. Journal of Nepal Health Research Council, 10(22), 181–186. URL: https://europepmc.org/article/med/23281447

80 Wu, X., Lu, Y., Zhou, S., Chen, L., & Xu, B. (2016). Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. Environment International, 86, 14–23. URL: https://www.sciencedirect.com/science/article/pii/S0160412015300489

# Climate Change Priorities of ADB and the WBG

## ADB – Country Partnership Strategy

ADB agreed a Country Partnership Strategy (CPS) with the Government of Nepal covering the period 2020–2024. Support for Nepal's efforts to cope with climate are addressed under the fifth of five thematic drivers, environmental sustainability. Specifically, the CPS states that ADB assistance will focus on disaster and climate change risk management by building institutional capacities (including knowledge base and management systems), ensuring resilience of infrastructure against the risks, and applying risk-screening tools in designing projects. ADB will also help develop an integrated water resources management system.[81]

## WBG – Country Partnership Framework

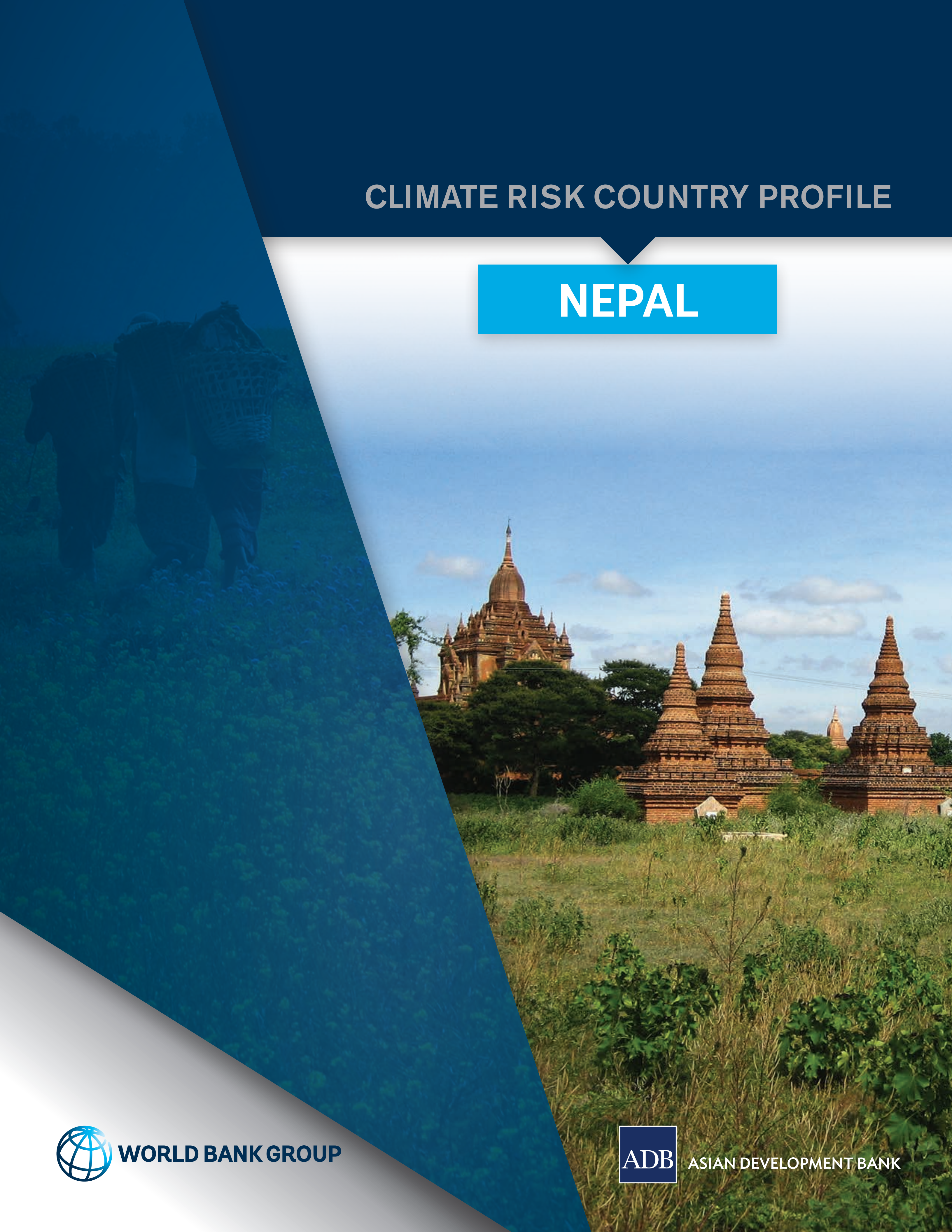
The World Bank agreed a Country Partnership Framework (CPF) with the Government of Nepal covering the period 2019–2023. Climate change is addressed in the third focus area of the CPF. Specifically, the CPF states the WBG will seek to address spatial and horizontal inequities in human development outcomes, and people's vulnerabilities to climate change, natural disasters, and health shocks. Despite the significant progress in access to education and health, there are spatial and socio-economic disparities in outcomes. Among certain pockets of the population, malnutrition and stunting persist, impacting other outcomes such as education, productivity, and longer-term human capital development. While headway is being made in empowering women and providing them with opportunities, they remain vulnerable and face unequal treatment and violence. In addition, the poor and those on the borderline of poverty remain vulnerable to a relapse in the event of an exogenous shock. The social protection system can play a significant role in mitigating this vulnerability. In parallel, the insurance sector needs to be further developed. Nepal's acute vulnerability to climate change, natural disasters and health shocks is compounded by their disproportionate impact on the crop and those on the margins of poverty. This will require enhanced preparedness to natural disasters, as well as improved natural resources management to mitigate preventable disasters.[82]

[81] ADB (2019). Nepal, 2020–2024 – Promoting Connectivity, Devolved Services, and Resilience. URL: https://www.adb.org/sites/default/files/institutional-document/531716/cps-nep-2020-2024.pdf

[82] WBG (2018). FY2019–2023 Country Partnership Framework for Nepal. URL: http://documents1.worldbank.org/curated/en/998361534181363354/pdf/Nepal-CPF-v08-07-18-Master-Copy-08092018.pdf

# CLIMATE RISK COUNTRY PROFILE

# NEPAL



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