CLIMATE RISK COUNTRY PROFILE

SRI LANKA

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ADB ASIAN DEVELOPMENT BANK

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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).

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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.

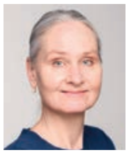
For the World Bank Group: a key aspect of the World Bank Group's Action Plan on Adaptation and Resilience (2019) is to help countries shift from addressing adaptation as an incremental cost and isolated investment to systematically incorporating climate risks and opportunities at every phase of policy 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

- Temperature rise in Sri Lanka is projected to be marginally lower than the global average. Under the highest emissions pathway (RCP8.5) temperatures are projected to rise by 2.9°C–3.5°C by the 2090s, over the 1986–2005 baseline. In contrast, warming of 0.8°C–1.2°C is projected over the same time horizon on the lowest emissions pathway (RCP2.6).
- Rises in minimum temperatures are projected to be faster than rises in average temperatures.
- Sri Lanka faces significant threat from extreme heat, with the number of days surpassing 35°C, potentially rising from a baseline of 20 days to more than 100 days by the 2090s, under emissions pathway RCP8.5.
- Extreme heat threatens human health and living standards, particularly for outdoor laborers in urban areas without adequate cooling systems; this will particularly impact communities in Sri Lanka's northern region. There is also potential for adverse implications to Sri Lanka's large tourism sector.
- Temperature rise is likely to put downward pressure on agricultural yields, including key staples such as rice. This may impact negatively on national and household food security.
- Without adaptative action, the projected increase in the frequency and intensity of extreme precipitation events may put lives, livelihoods, and infrastructure at risk through their link with riverine flooding, flash floods, and landslides.
- Increased incidence of flooding also brings the potential for enhanced disease transmission, an area demanding further research and disaster risk reduction efforts.
- Projected changes are expected to impact on Sri Lanka's poorest and most marginalized communities most strongly, exacerbating poverty and inequality.

COUNTRY OVERVIEW

Sri Lanka is a small island nation lying between 6°N and 10°N latitude and 80°E and 82°E longitude in the Indian Ocean, with a land area of approximately 65,000 square kilometers (km^2). The island consists of a mountainous area in the south-central region and a surrounding coastal plain. The climate of Sri Lanka is wet and warm, ideal for forest growth; almost all of the nation's land area was at one time covered with forests. Over the last century, more than two-thirds of this forest cover, rich in biodiversity, has been removed to accommodate human use. Nonetheless, rich natural resources remain and, alongside its vibrant cultures, contribute to the nation's successful tourism industry.

The economy of Sri Lanka is dominated by the service sector (61.7% of Gross Domestic Product [GDP] as of 2017), with major contributions from trade, transportation, and real estate activities. While the agricultural sector has shrunk in its contribution to GDP (7.8% as of 2017), it remains a significant employer (27% of the labor force as of 2016). Approximately a quarter of Sri Lanka's population are believed to live within the metropolitan area of its commercial capital, Colombo. However, official statistics suggest Sri Lanka's urban population is relatively low, reportedly 19.3% in 2016.[1] As shown in **Table 1**, a large proportion of Sri Lanka's population remains undernourished (22.1% in 2014–2016).

Sri Lanka's high temperatures, unique and complex hydrological regime, and exposure to extreme climate events make it highly vulnerable to climate change. In 2012, the Ministry of Environment submitted its Second National Communication to the UNFCCC (NC2), which highlights key vulnerabilities in the agriculture and water resources sectors, as well as significant risks to human health and in coastal zones.[2] These key climate-related risks were again emphasized in Sri Lanka's Nationally Determined Contribution (NDC) submitted after it signed and ratified the Paris Climate Agreement in 2016. Sri Lanka's NDC outlines the country's commitment to addressing its vulnerability to climate change in line with its commitments to a low carbon pathway through sustainable development efforts.[3]

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished[4]	22.1% (2014–2016)	FAO, 2017
National Poverty Rate[5]	4.1% (2016)	ADB, 2018a
Share of Wealth Held by Bottom 20%[6]	7% (2016)	World Bank Group, 2018
Net Annual Migration Rate[7]	–0.47% (2010–2015)	UNDESA, 2017
Infant Mortality Rate (Between Age 0 and 1)[7]	0.82% (2010–2015)	UNDESA, 2017
Average Annual Change in Urban Population[8]	0.03% (2010–2015)	UNDESA, 2018
Dependents per 100 Independent Adults[7]	71 (2015)	UNDESA, 2017
Urban Population as % of Total Population[9]	19.3% (2016)	CBSL, 2018
External Debt Ratio to GNI[10]	59% (2016)	ADB, 2018b
Government Expenditure Ratio to GDP[10]	19.3% (2017)	ADB, 2018b

1 CBSL (2018). Economics and social statistics of Sri Lanka 2018. Central Bank of Sri Lanka. URL: https://www.cbsl.gov.lk/en/publications/other-publications/statistical-publications/economic-and-social-statistics-of-sri-lanka

2 Ministry of Environment (2012). Sri Lanka's Second National Communication on Climate Change. URL: https://unfccc.int/sites/default/files/resource/lkanc2_0.pdf

3 Ministry of Mahaweli Development and Environment (2016). Nationally Determined Contributions, Sri Lanka. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Sri%20Lanka%20First/NDCs%20of%20Sri%20Lanka.pdf

4 FAO, IFAD, UNICEF, WFP, WHO (2017). The state of food security and nutrition in the world. Building Resilience for peace and food security. FAO. Rome. URL: http://www.fao.org/3/a-i7695e.pdf

5 ADB (2018a). Basic Statistics 2018. URL:https://www.adb.org/publications/basic-statistics-2018 [accessed 11/01/19]

6 World Bank Group (2018). Income share held by lowest 20%. URL:https://data.worldbank.org/indicator/SI.DST.FRST.20 [accessed 11/01/19]

7 UNDESA (2017). World Population Prospects 2017. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 11/01/19]

8 UNDESA (2018). World Urbanization Prospects 2018. URL: https://population.un.org/wup/Download/ [accessed 11/01/19]

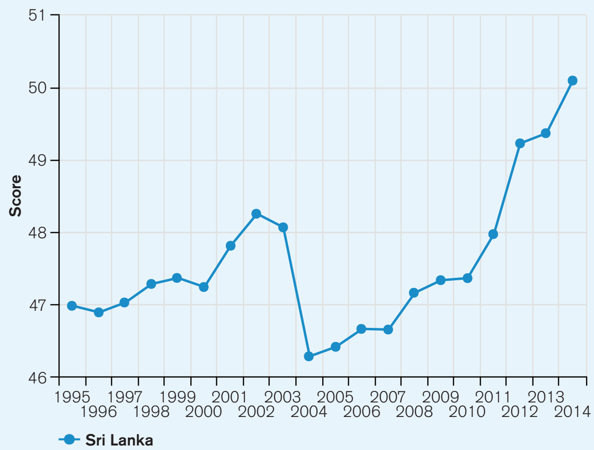
9 CIA (2018). The World Factbook. Central Intelligence Agency. Washington, DC. URL: https://www.cia.gov/library/publications/the-world-factbook/geos/ch.html

10 ADB (2018b). Key Indicators for Asia and the Pacific 2018, 49th Edition. Asian Development Bank. URL: https://www.adb.org/sites/default/files/publication/443671/ki2018.pdf

This document aims to succinctly summarize the climate risks faced by Sri Lanka. 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 Sri Lanka, therefore, potentially excluding some international influences and localized impacts. The core data 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 and to direct them to many useful sources of secondary data and research.

Due to a combination of political, geographic, and social factors, Sri Lanka is recognized as vulnerable to climate change impacts, ranked 100th out of 181 countries in the 2017 ND-GAIN Index.[11] 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 Sri Lanka'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



CLIMATOLOGY

Climate Baseline

Overview

Sri Lanka has two main seasons, the Maha season associated with the northeast monsoon (September–March) and the Yala season associated with the southwest monsoon (May–August). With an average temperature of around 27°C–28°C, Sri Lanka is one of the hottest countries in the world. Sri Lanka's commercial capital, Colombo,

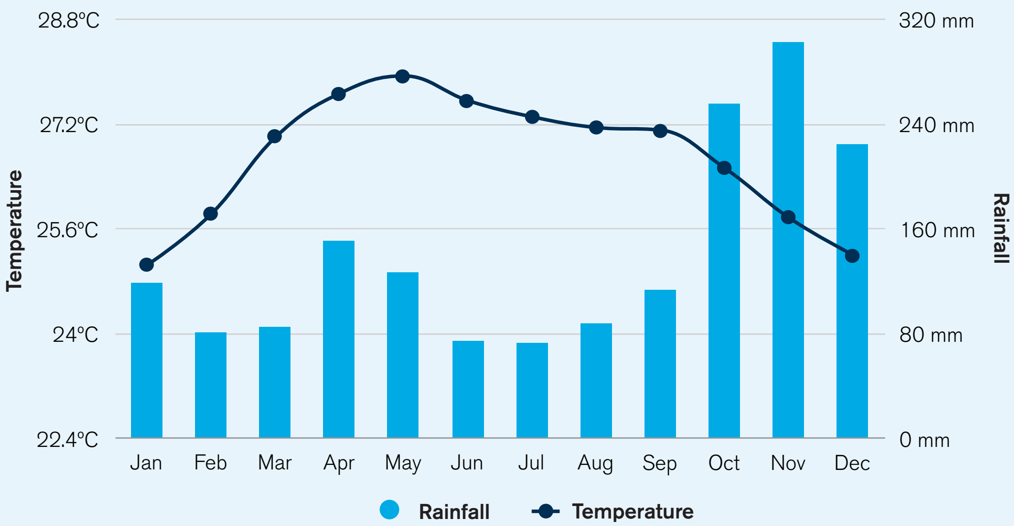
[11] University of Notre Dame (2019). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/

experiences average temperatures of 28°C–29°C and, like much of the rest of the country, has little monthly variation in temperature (**Figure 2**). Daily maximum temperatures average around 31°C all year round. The most important factor affecting temperature variations within Sri Lanka is altitude, with considerably lower temperatures experienced in its south-central mountain ranges.

Sri Lanka's topography creates unique rainfall patterns, with notable spatial variation for a country of its size. Sri Lanka's precipitation regime is divided into three zones: the wet zone, intermediate zone, and dry zone. The wet zone, found in the southwest, receives a mean annual rainfall of over 2,500 millimeters (mm), with a strong contribution from the southwest monsoon. The dry zones, found in the south and northwest, receive less than 1,750 mm. The intermediate zones found in the eastern and central regions, receive between 1,750 mm and 2,500 mm, primarily from the northeast monsoon. Areas of the southwestern slopes of the central hills are known to experience as much as 5,000 mm in a year and annual rainfall can vary by more than 1,000–2,000 mm over distances of less than 100 km. All regions receive steady rainfall during the inter-monsoon seasons. **Figure 3** shows the spatial differences of observed temperature and rainfall in Sri Lanka.

Annual Cycle

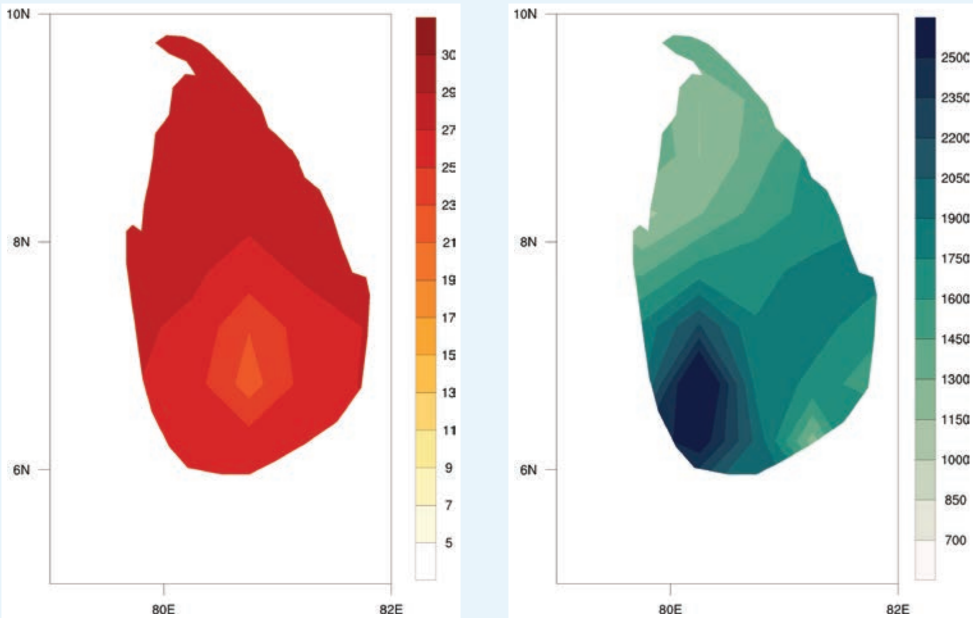
FIGURE 2. Average monthly temperature and rainfall in Sri Lanka (1901–2016)[12]



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

Spatial Variation

FIGURE 3. (Left) annual mean temperature, and (right) annual mean rainfall (mm) in Sri Lanka over the period 1901–2019[13]



Key Trends

Temperature

Analysis of the change seen between the average temperature over 1900–1917 and 2000–2017 suggests Sri Lanka experienced warming of around 0.8°C over the 20th century (based on the Berkeley Earth dataset).[14] This estimate broadly agrees with the temperature rise reported in Sri Lanka's NC2, which estimated 0.16°C of warming per decade between 1961–1990. Temperature rise has accelerated toward the end of the 20th century.[15]

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

[14] Carbon Brief (2018). Mapped: How every part of the world has warmed – and could continue to. Infographics, Berkeley Dataset. 26 September 2018]. URL: https://www.carbonbrief.org/mapped-how-every-part-of-the-world-has-warmed-and-could-continue-to-warm

[15] Esham, M., & Garforth, C. (2013). Climate change and agricultural adaptation in Sri Lanka: a review. Climate and Development, 5(1), 66–76. URL: https://rsa.tandfonline.com/doi/abs/10.1080/17565529.2012.762333?scroll=top&needAccess=true&journalCode=tcld20#.Xe_wwpNKhBw

Precipitation

Sri Lanka's complex and spatially variable precipitation regime makes estimation of change over time difficult and it should be noted that there is a need to improve the evidence base in this area. A number of studies have attempted to assess the trends in precipitation (see Eriyagama and Smakhtin, 2010).[16] A general trend of decreasing annual precipitation in the latter half of the 20th century has been observed. This decline is estimated at around 7% as compared to the period 1931–1960. This decline in precipitation has been detected during the northeast monsoon season and second inter-monsoon season and is particularly significant in the central regions of the country. It is also observed that the number of consecutive dry days experienced has increased over the 20th century, and the number of consecutive wet days has reduced. A review by Esham and Garforth (2013) also suggests that the variability of climate and the frequency of extreme events has been increasing.[15] Precipitation remains linked to the El Niño Southern Oscillation (ENSO), with El Niño events typically increasing the precipitation associated with the northeast monsoon.[17]

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.[18] 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 Green House Gas [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: RCP2.6 represents a very strong mitigation scenario, whereas RCP8.5 assumes a business-as-usual scenario. For more information, please refer to the RCP Database.

16 Eriyagama, N. and Smakhtin, V. (2010). Observed and Projected Climatic Changes, Their Impacts and Adaptation Options for Sri Lanka: A Review, in Proceedings of the National Conference on Water, Food Security and Climate Change in Sri Lanka, Volume 2, International Water Management Institute, Colombo, 99–117. URL: http://publications.iwmi.org/pdf/H042863.pdf

17 Zubair, L., & Ropelewski, C. F. (2006). The strengthening relationship between ENSO and northeast monsoon rainfall over Sri Lanka and southern India. Journal of Climate, 19(8), 1567–1575. https://doi.org/10.1175/JCLI3670.1. URL: https://journals.ametsoc.org/doi/pdf/10.1175/JCLI3670.1

18 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: https://www.nature.com/articles/s41561-018-0227-0?WT.feed_name=subjects_climate-sciences

For Sri Lanka, models show a trend of consistent warming regardless of emissions scenario. While projections for rainfall are highly variable, trends do show a likely increase in rainfall, and specifically for its central region throughout the century. An increase in intensity for extreme rainfall events is likely. **Tables 2** and **3** below, provide information on temperature projections and anomalies for the four RCPs over two distinct time horizons; presented against the reference period of 1986–2005.

TABLE 2. Projected anomaly (changes °C) for maximum, minimum, and average daily temperatures in Sri Lanka for 2040–2059 and 2080–2099, from the reference period of 1986–2005 for all RCPs. The table shows the median of the CCKP model ensemble and the 10th–90th percentiles in brackets.[19]

	Average Daily Maximum Temperature		Average Daily Temperature		Average Daily Minimum Temperature	
	2040–2059	2080–2099	2040–2059	2080–2099	2040–2059	2080–2099
RCP2.6	0.8 (–0.1, 1.8)	0.9 (0.0, 1.8)	0.9 (0.1, 1.5)	0.9 (0.1, 1.6)	0.9 (0.3, 1.6)	0.9 (0.3, 1.6)
RCP4.5	1.1 (0.1, 2.0)	1.6 (0.5, 2.7)	1.1 (0.4, 1.8)	1.6 (0.7, 2.5)	1.1 (0.5, 1.8)	1.6 (0.5, 2.5)
RCP6.0	1.0 (0.0, 2.0)	1.9 (0.8, 3.1)	1.0 (0.3, 1.7)	1.9 (1.0, 2.9)	1.0 (0.5, 1.7)	2.0 (1.2, 3.0)
RCP8.5	1.5 (0.4, 2.5)	3.2 (1.9, 4.6)	1.5 (0.7, 2.3)	3.2 (2.2, 4.5)	1.6 (0.9, 2.3)	3.4 (2.4, 4.5)

TABLE 3. Projections of average temperature anomaly (°C) in Sri Lanka 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

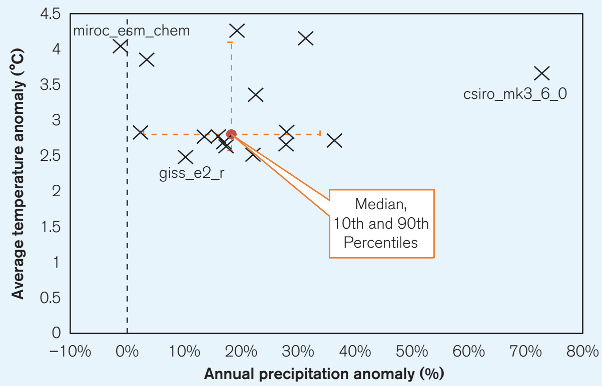
	2040–2059		2080–2099	
	Jun–Aug	Dec–Feb	Jun–Aug	Dec–Feb
RCP2.6	0.9 (0.1, 1.7)	0.8 (0.0, 1.4)	0.9 (0.1, 1.8)	0.8 (0.0, 1.5)
RCP4.5	1.2 (0.5, 1.9)	1.1 (0.3, 1.7)	1.6 (0.7, 2.6)	1.6 (0.7, 2.3)
RCP6.0	1.0 (0.3, 1.9)	1.0 (0.1, 1.5)	1.9 (1.1, 3.1)	1.9 (0.8, 2.6)
RCP8.5	1.5 (0.8, 2.3)	1.5 (0.6, 2.1)	3.4 (2.2, 4.6)	3.1 (2.1, 4.1)

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

Model Ensemble

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).[20] 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 Sri Lanka 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**.

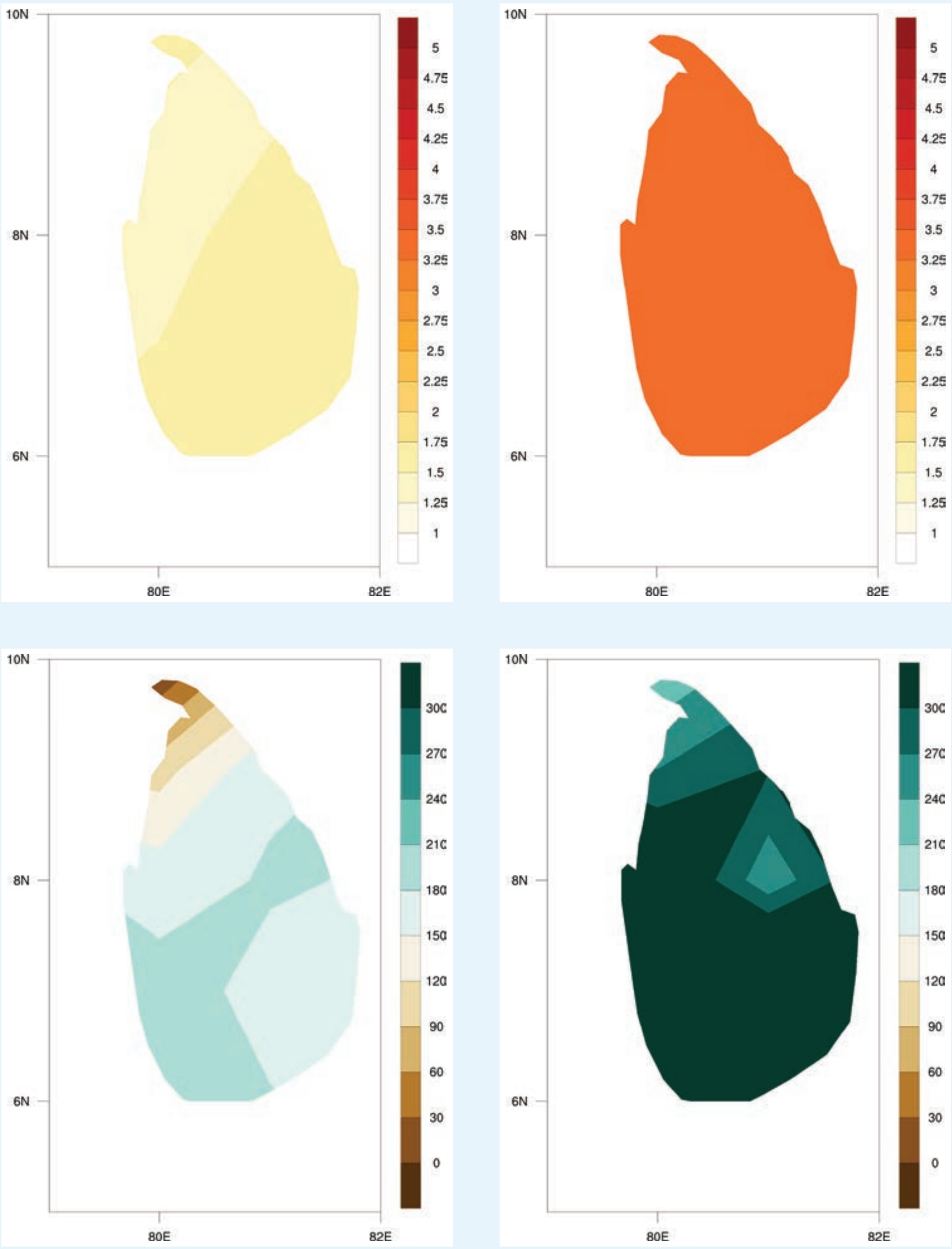
FIGURE 4. 'Projected average temperature anomaly' and 'projected annual rainfall anomaly' in Sri Lanka. Outputs of 16 models within the ensemble simulating RCP8.5 over the period 2080–2099. Models shown represent the subset of models within the ensemble which provide projections across all RCPs and,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



20 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[21]



[21] WBG Climate Change Knowledge Portal (CCKP, 2020). Sri Lanka Climate Data. Projections. URL: https://climateknowledgeportal.worldbank.org/country/sri-lanka/climate-data-projections

Temperature

Projections of future temperature change are presented in three primary formats. Shown in **Table 2** are the changes (anomalies) 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.

Average temperature rise in Sri Lanka is expected to be lower than the rise in global temperatures, and are projected to reach approximately 3.2°C by the 2090s according to the CCKP model ensemble under emissions pathway RCP8.5, compared to the projected global rise of 3.7°C. Maximum and minimum temperatures are projected to rise faster than the average, but still remain below global averages. Statistically downscaled projections from the KNMI Climate Explorer, which operate on a slightly finer spatial resolution, show a rise in the region of 3.5°C under RCP8.5, and 1.2°C under RCP2.6 by the 2090s.[22] Projected rises are very likely to push ambient temperatures over 30°C on a much more regular basis, and to considerably increase the frequency of temperatures over 35°C.

FIGURE 6. Historic and projected average annual temperature in Sri Lanka under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble. Shading represents the standard deviation of the model ensemble[23]

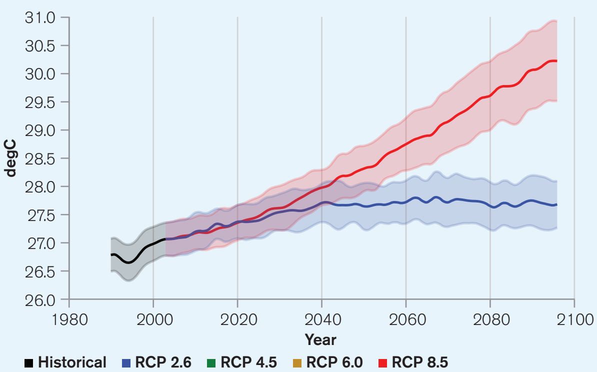
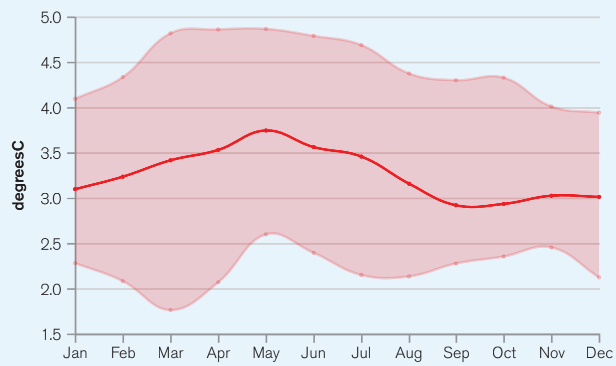


FIGURE 7. Projected change (anomaly) in monthly temperature, shown by month, for Sri Lanka for the period 2080–2099 under RCP8.5. The value shown represents the median of the model ensemble with the shaded areas showing the 10th–90th percentiles[24]



The model ensemble's projections of temperature rise are highly seasonal. Temperatures could rise faster in the months March to July than August to February. The difference in median average temperature rise between May and October being as much as 20%–25% by the 2090s under all emissions pathways.

[22] KNMI (2019). Climate Explorer CMIP5 Projections. URL: https://climexp.knmi.nl/start.cgi

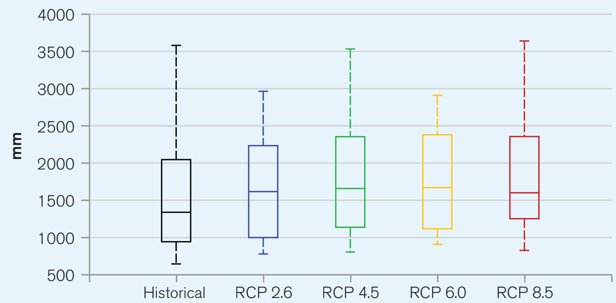
[23] WBG Climate Change Knowledge Portal (CCKP, 2020). Sri Lanka. Agriculture Interactive Indicator Dashboard: URL: https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=LKA&period=2080-2099

[24] WBG Climate Change Knowledge Portal (CCKP, 2020). Sri Lanka. Agriculture Interactive Indicator Dashboard: URL: https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=LKA&period=2080-2099

Precipitation

Climate model projections of future rainfall are generally less reliable than temperature projections, especially for island nations. This is due in part to coarse spatial resolution, which fails to capture local processes that drive rainfall dynamics such as feedbacks and convection, or the presence of land surfaces. The CCKP model ensemble suggests increases in median annual rainfall under all emissions pathways. However, uncertainty in this estimate is high (as seen in the interquartile range shown in **Figure 8**). This projected trend is counter to the observed historical drying trend. While the majority of climate models agree on this trend, the majority of projections sit within the range of historical baseline variability.

FIGURE 8. Boxplots showing the projected average annual precipitation for Sri Lanka in the period 2080–2099[23]



While considerable uncertainty surrounds projections of local, long-term future precipitation trends, some global trends are evident. The intensity of sub-daily extreme rainfall events appears to be increasing with temperature, a finding supported by evidence from different regions of Asia.[25] The volume of water deposited during future 5-day heavy rainfall events is expected to increase, but again, the variability in projections is high. Certainty is highest under RCP6.0 and RCP8.5 where increases in the range of 5%–30% are plausible by the 2080s. Precipitation changes are likely to depend on how climate change affects the dynamics of the two monsoon seasons affecting Sri Lanka. Jayasankar et al. (2015) attempt to provide more robust analysis of changes in Indian Summer Monsoon rainfall through the creation of sub-groups of GCMs and statistically analyzing the performance of those groups.[26] The best performing sub-group point toward a slight reduction in the frequency of light precipitation events which is offset by an increase in the frequency of high and extreme precipitation events, leading to a net increase in average daily monsoon precipitation of 0.74 ± 0.36 mm/day.[27] Downscaling has been conducted using a very limited set of GCMs, but has thus far pointed to either increases in, or no change to, annual rainfall, alongside increased intensity of extreme rainfall events.[28,29] Further research and model downscaling work is required to constrain and localize potential changes to Sri Lanka across a wider set of global climate models.

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25 S. Westra, H. J. Fowler, J. P. Evans, L. V. Alexander, P. Berg, F. Johnson, E. J. Kendon, G. Lenderink, N. M. R. (2014). Future changes to the intensity and frequency of short-duration extreme rainfall. Reviews of Geophysics, 52, 522–555. URL: https://www.jstage.jst.go.jp/article/hrl/10/4/10_139/_pdf

26 Jayasankar, C., Surendran, S., Rajendran, K. (2015). Robust signal of future projections of Indian Summer Monsoon rainfall by IPCC AR5 climate models: Role of seasonal cycle and interannual variability. Geophysical Research Letters: 42: 3513–3520. URL: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2015GL063659

27 Sharmila, S., Joseph, S., Sahai, A.K., Abhilash, S., Chattopadhyay, R. (2015). Future projection of Indian summer monsoon variability under climate change scenario: An assessment from CMIP5 climate models. Global and Planetary Change: 124: 62–78. URL: https://ui.adsabs.harvard.edu/abs/2015GPC . . . 124 . . . 62S/abstract

28 Dorji, S., Herath, S., & Mishra, B. K. (2017). Future Climate of Colombo Downscaled with SDSM-Neural Network. Climate, 5(1). URL: https://www.mdpi.com/2225-1154/5/1/24

29 Silva, G. De, Weerakoonb, S., & Herath, S. (2016). Event Based Flood Inundation Mapping Under the Impact of Climate Change: A Case Study in Lower Kelani River Basin, Sri Lanka. Hydrology: Current Research, 7(1), 7–10. URL: https://www.omicsonline.org/open-access/event-based-flood-inundation-mapping-under-the-impact-of-climatechange-a-case-study-in-lower-kelani-river-basin-sri-lanka-2157-7587-1000228.php?aid=69230

Sri Lanka faces moderate disaster risk levels, ranked 97th out of 191 countries by the 2019 INFORM Risk Index[30] (**Table 4**). Sri Lanka has moderate exposure to flooding (ranked 56th), including riverine and flash flooding. Sri Lanka also has some exposure to tropical cyclones and their associated hazards (ranked 45th). Drought exposure is slightly lower (ranked 76th). Sri Lanka's overall ranking on the INFORM risk index is somewhat mitigated by its comparatively high coping capacity score. Landslide hazard is present in many parts of Sri Lanka, but is not explicitly captured by the INFORM risk index. The section which follows analyzes climate change influences on the exposure component of risk in Sri Lanka. As seen in **Figure 1**, the ND-GAIN Index presents an overall picture of a country's vulnerability and capacity to improve its resilience. In contrast, the Inform Risk Index identifies specific risks across a country to support decisions on prevention, preparedness, response and a country's overall risk management.

TABLE 4. Selected indicators from the INFORM 2019 Index for Risk Management for Sri Lanka. 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)
6.1 [4.5]	3.6 [1.7]	3.6 [3.2]	3.4 [3.6]	4.1 [4.5]	3.6 [3.8]	97

Heatwaves

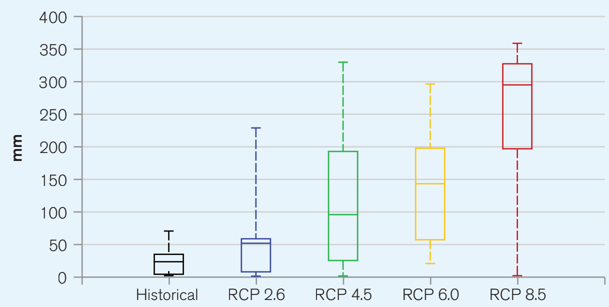
Sri Lanka regularly experiences very high maximum temperatures, with an average monthly maximum of around 30°C and an average maximum of 32°C. The current probability of a heat wave (defined as a period of 3 or more days where the daily temperature is above the long-term 95th percentile of daily mean temperature) is around 3%. One study by IWMI suggested that around 23% of Sri Lanka's population were exposed to hazardous heatwaves during the period 2001–2013 (defined here as an anomaly of +6°C).[31] The CCKP model ensemble projects significant future increases in the annual probability of a heatwave under all emissions pathways in Sri Lanka. These projected increases primarily reflect the general warming trend, as well as increasing variability in climate, both of which amplify heatwave probability when the historical period (1986–2005) is held as the baseline. While heatwaves refer to the periodic occurrence of exceptionally high temperatures, the incidence of permanent (chronic) heat stress is likely to increase significantly in Sri Lanka under all emissions pathways. This threat is highlighted in

[30] European Commission (2019). INFORM Index for Risk Management. Sri Lanka Country Profile. URL:https://drmkc.jrc.ec.europa.eu/inform-index/Countries/Country-Profile-Map

[31] Amarnath, G.; Alahacoon, N.; Smakhtin, V.; Aggarwal, P. (2017). Mapping multiple climate-related hazards in South Asia. Colombo, Sri Lanka: International Water Management Institute (IWMI). 41p. (IWMI Research Report 170). URL: http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub170/rr170.pdf

Figure 9, which shows the significant projected increase in the number of days surpassing the Heat Index of 35°C by the 2090s. Im et al. (2017) identify northern Sri Lanka as a hotspot of exposure to extreme heat even under lower emissions pathways.[32]

FIGURE 9. Historical (1986–2005) and projected (2080–2099) average annual number of days with Heat Index > 35°C under four emissions pathways[23]

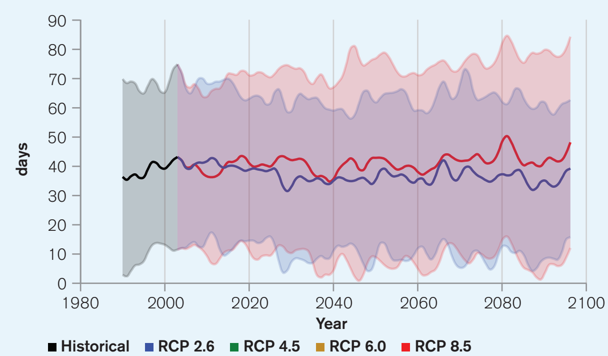


Drought

Two primary types of drought may affect Sri Lanka, 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, Sri Lanka faces an annual probability of severe meteorological drought of around 4%, as defined by the Standardized Precipitation Evaporation Index (SPEI) of less than –2. One study suggested that between 2001–2013, approximately 10% of Sri Lanka's population was exposed to drought (in this case, drought was categorized as a Normalized Difference Drought Index of >0.6).[31]

Naumann et al. (2018) provide a global overview of changes in drought conditions under different warming scenarios.[33] The research suggests that in South Asia, there could be an increase in the frequency of drought events, with what is currently a 1-in-100-year event returning approximately every 40 to 50 years under 1.5°C–2°C of warming, and every 20 years under 3°C of warming. In contrast, no significant change to severe drought probability is projected by the CCKP model ensemble. **Figure 10** shows the number of consecutive dry days through the end of the century. The difference in projections may relate to the coarse spatial resolution of the model ensemble and the model choices made by the researchers. Global models do not capture the dynamics of precipitation in Sri Lanka, which can vary dramatically over small distances. Further research and downscaling of global models are urgently required to constrain future drought projections in Sri Lanka. Future drought risk, particularly hydrological and agricultural drought, will also depend to a great extent on development, and water and land management practices in Sri Lanka over coming decades.

FIGURE 10. Time Series showing the maximum number of consecutive dry days in Sri Lanka through 2080–2099, under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble. Shading represents the standard deviation of the model ensemble[23]



[32] 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. https://advances.sciencemag.org/content/3/8/e1603322

[33] Naumann, G., Alfieri, L., Wyser, K., Mentaschi, L., Betts, R. A., Carrao, H., . . . Feyen, L. (2018). Global Changes in Drought Conditions Under Different Levels of Warming. Geophysical Research Letters, 45(7), 3285–3296. URL: https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2017GL076521

Floods

Sri Lanka is affected by multiple forms of flooding. These can be summarized as river flooding, flash (or pluvial) flooding, and coastal flooding. In addition to their direct impacts, flood events have known relationships with other hazards, such as landslides as well as the spread of disease. The World Resources Institute's AQUEDUCT Global Flood Analyzer can be used to establish a baseline level of river flood exposure.[34] As of 2010, assuming protection for up to a 1-in-25-year event, the population annually affected by river flooding in Sri Lanka is estimated at 59,000 people and the expected annual impact on GDP is estimated at $267 million. The United Nations Office for Disaster Risk Reduction (UNDRR), formerly the United Nations International Strategy for Disaster Reduction (UNISDR), suggested floods are currently the largest contributor to Sri Lanka's average annual losses from disasters of approximately $140 million per year.[35] Development and climate change are both likely to increase these figures. By the 2030s, this is expected to increase the annually affected population by 26,000 people, and annual GDP by $338 million under RCP8.5 (AQUEDUCT Scenario B).

Work by Paltan et al. (2018) demonstrates 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.[36] What would historically have been a 1-in-100-year flow, could become a 1-in-50-year or 1-in-25-year event in most of South, Southeast, and East Asia. There is good agreement among models on this trend. Willner et al. (2018) suggest this increase in flows could lead to an increase in the population affected by an extreme flood of 70,000–560,000 people (**Table 5**).[37]

TABLE 5. Estimated number of people in Sri Lanka affected by an extreme river flood (extreme river 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[37]

Estimate	Population Exposed to Extreme Flood (1971–2004)	Population Exposed to Extreme Flood (2035–2044)	Increase in Affected Population
16.7 Percentile	385,942	943,081	557,139
Median	930,866	1,111,418	180,552
83.3 Percentile	1,105,180	1,179,366	74,186

Periods of intense precipitation can result in flash flooding and landslide events in Sri Lanka, leading to loss of life, livelihoods, and infrastructure. Indeed, around 20% of the nation's surface area is estimated to be exposed to landslide events and these events are reportedly the third most frequently occurring hazard, behind flood and drought.[38] Past research has shown that shifts in the precipitation regime toward more intense extreme events

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

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

[36] 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. Environmental Research Letters, 13. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aad985/pdf

[37] 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

[38] Wickramaratne, S., Ruwanpura, J., Ranasinghe, U., Walawe-Durage, S., Adikariwattage, V., & Wirasinghe, S. C. (2012). Ranking of natural disasters in Sri Lanka for mitigation planning. International Journal of Disaster Resilience in the Built Environment, 3(2), 115–132. URL: https://www.emerald.com/insight/content/doi/10.1108/17595901211245198/full/html

have driven increased landslide risk over the late 20th and early 21st centuries.[39] While projections of future average annual precipitation hold uncertainty, there is some confidence that extremes of precipitation at the daily and sub-daily level will increase, likely leading to an increase in landslide risk. Further research is needed.

Cyclones

Climate change is expected to influence cyclone hazards in complex ways which remain poorly understood. Known risks include the action of sea-level rise to enhance the damage caused by cyclone-induced storm surges, and the possibility of increased windspeed and precipitation intensity. Modelling of climate change impacts on cyclone intensity and frequency conducted across the globe points to a general trend of reduced cyclone occurrences, but increased intensity and frequency of the most extreme events.[40] Further research is required to better understand potential changes in cyclone seasonality and routes, and the potential for cyclone hazards to be experienced in unprecedented locations. While records show cyclone frequency in Sri Lanka has a declining trend over the 20th century, Balaguru et al. (2014) report increased intensity of tropical cyclone activity in the Bay of Bengal in 1981–2010, emphasizing that disaster risk reduction remains a priority.[41]

CLIMATE CHANGE IMPACTS

Natural Resources

Water

Sri Lanka is exposed to moisture-laden winds from the southwest and the northeast. The topography of the country (the highland massif) is a major determinant of water resources of the island in the south-central region as is its location across the passage of monsoonal winds. These moisture-laden monsoonal winds are intercepted by the hills in the central region leading to a unique rainfall pattern. Despite its favorable geographic position, the country has widespread areas of water scarcity and a large part of the country experiences intermittent droughts, sometimes extending over several months. Conversely, the coastal areas often get inundated by flood-waters from the highlands.

Sri Lanka's surface water is sourced water from high watersheds and transported by 103 distinct natural river basins that cover 90% of the island, transporting approximately 3.3 million hectare-meters of water each year; the remaining 94 small coastal basins contribute only marginally to water resources. River basins originating in the wetter parts of

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39 Ratnayake, U., & Herath, S. (2005). Changing rainfall and its impact on landslides in Sri Lanka. Journal of Mountain Science, 2(3), 218–224. URL: https://link.springer.com/content/pdf/10.1007/BF02973195.pdf

40 Walsh, K., McBride, J., Klotzbach, P., Balachandran, S., Camargo, S., Holland, G., Knutson, T., Kossin, J., Lee, T., Sobel, A., Sugi, M. (2015). Tropical cyclones and climate change. WIREs Climate Change: 7: 65–89. URL: https://onlinelibrary.wiley.com/doi/epdf/10.1002/wcc.371

41 Balaguru, K., Taraphdar, S., Leung, L. R., & Foltz, G. R. (2014). Increase in the intensity of postmonsoon Bay of Bengal tropical cyclones. Geophysical Research Letters, 41(10), 3594–3601. URL: https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2014GL060197

the hill country are perennial, while the majority of those in the dry zone are seasonal.[42] The country's water resources are critical for many development sectors and for human use. Access to water sources is reasonably good, with an estimated 92.3% of the population having access to at least a basic water supply in 2015.[43] However, ADB's 2016 Water Outlook identified potential weaknesses in Sri Lanka's existing economic and household water security.[44]

The overall impacts of climate change on the water sector are likely to have adverse effects for agricultural water supply, energy generation, human health, and human settlements. As of 2019, a major hindrance to effective water governance and planning was the level of uncertainty, and lack of spatial specificity associated with all water-related projections. In what is a highly spatially variable climate, and with noteworthy social vulnerabilities, further research is urgently required to improve understanding of potential future issues.

Coastal Zone

Sea-level rise threatens significant physical changes to coastal zones around the world. Global mean sea-level rise was estimated in the range of 0.44–0.74 meters (m) by the end of the 21st century by the IPCC's Fifth Assessment Report,[45] however, some studies published more recently have highlighted the potential for more significant rises (**Table 6**). Sri Lanka has a moderate level of vulnerability to slow onset sea-level rise impacts, but has been identified as having particularly high vulnerability to the combined impacts of storm surge and sea-level rise.[46] While the total population likely to be exposed to permanent flooding by 2070–2100 is relatively low at 66,000 people without adaptation actions (**Table 7**), the population exposed to a 1-in-100-year coastal flood induced by storm surge is relatively high. It is estimated that by the 2030s, approximately 230,000–400,000 people could reside in exposed floodplains, growing to 400,000 to 500,000 by the 2060s.[47] These estimates assume modest sea-level rise of 10 centimeters (cm) by 2030 and by 21 cm by 2060.

In addition to the increased risk of rapid-onset disaster events, sea-level rise is already impacting the lives and livelihoods of Sri Lankans along the coast through the salinization of soils and groundwater in the coastal zones. Studies have documented the abandonment of coastal agriculture and degradation of water sources used for human consumption.[48]

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[42] Ministry of Environment (2012). Sri Lanka's Second National Communication on Climate Change. URL: https://unfccc.int/sites/default/files/resource/lkanc2_0.pdf

[43] 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

[44] ADB (2016). Asian Water Development Outlook 2016: Strengthening Water Security in Asia and the Pacific. Asian Development Bank. URL: https://www.adb.org/sites/default/files/publication/189411/awdo-2016.pdf

[45] Church, J. A., Clark, P. U., Cazenave, A., Gregory, J. M., Jevrejeva, S., Levermann, A., . . . Unnikrishnan, A. S. (2013). Sea level change. In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (1137–1216). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. URL: https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf

[46] Dasgupta, S., Laplante, B., Murray, S., & Wheeler, D. (2011). Exposure of developing countries to sea-level rise and storm surges. Climatic Change, 106(4), 567–579. URL: https://link.springer.com/content/pdf/10.1007/s10584-010-9959-6.pdf

[47] Neumann, B., Vafeidis, A. T., Zimmermann, J., & Nicholls, R. J. (2015). Future coastal population growth and exposure to sea-level rise and coastal flooding—A global assessment. PLOS ONE, 10(3). URL: https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0118571&type=printable

[48] Perera, M. D. N. D., Ranasinghe, T. K. G. P., Piyadasa, R. U. K., & Jayasinghe, G. Y. (2018). Risk of seawater intrusion on coastal community of Bentota river basin Sri Lanka. Procedia Engineering, 212, 699–706. URL: https://www.sciencedirect.com/science/article/pii/S1877705818301085

TABLE 6. Estimates of global mean sea-level rise by rate and total rise compared to 1986–2005 including likely range shown in brackets, data from Chapter 13 of the IPCC's Fifth Assessment Report with upper-end estimates based on higher levels of Antarctic ice-sheet loss from Le Bars et al. 2017[49]

Scenario	Rate of Global Mean Sea-Level Rise in 2100	Global Mean Sea-Level Rise in 2100 Compared to 1986–2005
RCP2.6	4.4 mm/yr (2.0–6.8)	0.44 m (0.28–0.61)
RCP4.5	6.1 mm/yr (3.5–8.8)	0.53 m (0.36–0.71)
RCP6.0	7.4 mm/yr (4.7–10.3)	0.55 m (0.38–0.73)
RCP8.5	11.2 mm/yr (7.5–15.7)	0.74 m (0.52–0.98)
Estimate Inclusive of High-End Antarctic Ice-Sheet Loss		1.84 m (0.98–2.47)

TABLE 7. The average number of people experiencing flooding per year in the coastal zone in the period 2070–2100 under different emissions pathways (assumed medium ice-melt scenario) and adaptation scenarios for Sri Lanka[50]

Scenario	Without Adaptation	With Adaptation
RCP2.6	15,290	30
RCP8.5	65,610	70

Economic Sectors

Agriculture and Fisheries

The agricultural sector in Sri Lanka includes both a domestic market and an export market. Rice is the major food crop grown, with cultivation limited to two primary seasons—Yala (May to August) and Maha (September to March). Production is highest in the Maha season, with the harvested area nearly 50% lower in the Yala season. As of 2014, approximately 74% of the harvested paddy area was supported by either a major or minor irrigation scheme, with the remaining 26% under a rainfed scheme.[51] Other key crops include tea, rubber, and coconut, which collectively are cultivated over an area comparable with paddy rice (ca. 600,000–700,000 ha). However, food crops such as pulses, oil crops, fiber crops, other cereals, yams, vegetables, and others are grown as rotation crops, for household use or for sale in local markets. The agriculture and forestry sectors rely on both traditional and modern technologies; generally, neither sector is highly mechanized.

Climate change could 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 impacts on water resource availability and seasonality, soil organic matter transformation, soil erosion, changes

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[49] Le Bars, D., Drijhout, S., de Vries, H. (2017). A high-end sea level rise probabilistic projection including rapid Antarctic ice sheet mass loss. Environmental Research Letters: 12:4. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aa6512

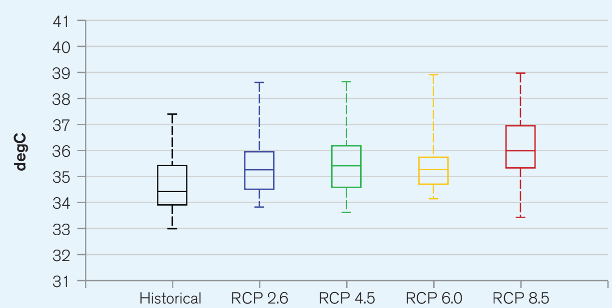
[50] UK Met Office (2014). Human dynamics of climate change: Technical Report. Met Office, UK Government. URL: https://www.metoffice.gov.uk/weather/learn-about/climate-and-climate-change/climate-change/impacts/human-dynamics/index

[51] Department of Census and Statistics (2015). Paddy: Extent sown and harvested by irrigation scheme and season, 2006–2014. URL: http://www.statistics.gov.lk/Abstract2015/CHAP5/5.3.pdf [accessed 11/12/2018]

in pest and disease profiles, the arrival of invasive species, and decline in arable areas due to the submergence of coastal lands and desertification. Globally, these impacts are also expected to damage key staple crop yields, even on lower emissions pathways. Tebaldi and Lobell (2018) estimate that 5% and 6% declines in global wheat and maize yields, respectively, are possible even if the Paris Climate Agreement is met and warming is limited to 1.5°C.[52] 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.

Rice is a staple food item in Sri Lanka, crucial to national food security and the livelihoods and nutrition of an estimated 32% of the population.[53] Increases in temperature during the rice growing season have been shown to have negative consequences for yields, outweighing the benefits of increased carbon dioxide (CO_2) concentrations. In particular, rice has been observed to have vulnerability to elevated night time minimum temperatures.[54] Sri Lanka faces very significant increases in minimum temperatures under all emissions pathways (**Figure 11**). Work by Zubair et al. (2015) based on a subset of five climate models suggests that under RCP8.5, yields could decline in both growing seasons.[53] By the 2060s, yields are projected to decline in the range of 12%–19% in the Maha season and 27%–41% in the Yala season. In the context of high local dependence on rice, this is also projected to increase poverty rates, in the range of 12%–26%. A review by Esham and Garforth (2013) also highlights the high sensitivity of other key crops, such as coconut, tea, and rubber, to temperature and precipitation variability, with notable risks to higher temperatures and periods of low rainfall.[15]

FIGURE 11. Historical and projected model ensemble estimates of daily maximum temperatures in 2040–2059 under four emissions pathways in Sri Lanka[23]



Sri Lanka has a notably high dependency on fisheries for its national protein intake. While management approaches and trade practices remain the largest influence on the health of fisheries, research also links productivity to climate change. Rising temperatures and ocean acidification are expected to restructure coastal shelf fisheries upon which many households depend. Barange et al. (2014) identify Sri Lanka as one of the most at-risk nations on earth, projecting a potential decline in fish catch due to climate change of around 20% by the 2050s (this estimate based on the SRES scenario A1B).[55]

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52 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

53 Zubair, L., Nissanka, S. P., Weerakoon, W. M. W., Herath, D. I., Karunaratne, A. S., Prabodha, A. S. M., . . . McDermid, S. P. (2015). Climate change impacts on rice farming systems in northwestern Sri Lanka. In Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project (AgMIP), Part 2. ICP Series on Climate Change Impacts, Adaptation, and Mitigation Vol. 3 (Vol. 2, 315–352). URL: https://pubs.giss.nasa.gov/abs/zu02000c.html

54 Welch, J. R., Vincent, J. R., Auffhammer, M., Moya, P. F., Dobermann, A., & Dawe, D. (2010). Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures. Proceedings of the National Academy of Sciences, 107(33), 14562–14567. URL: https://www.pnas.org/content/107/33/14562

55 Barange, M., Merino, G., Blanchard, J. L., Scholtens, J., Harle, J., Allison, E. H., . . . Jennings, S. (2014). Impacts of climate change on marine ecosystem production in societies dependent on fisheries. Nature Climate Change, 4(3). URL: https://www.nature.com/articles/nclimate2119.pdf

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. Work by Dunne et al. (2013) suggests 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 RCP8.5.[56] In combination, it is highly likely that the above processes could have a considerable impact on national food production and consumption patterns both through direct impacts on internal agricultural operations, and through impacts on the global supply chain.

Urban and Energy

Research has established a reasonably well constrained relationship between heat stress and labor productivity, household consumption patterns, and (by proxy) household living standards.[57] 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.

The effects of temperature rise and heat stress in urban areas are increasingly compounded by the phenomenon of the Urban Heat Island (UHI) effect. Dark surfaces, residential and industrial sources of heat, an absence of vegetation, and air pollution[58] can push temperatures higher than those of the rural surroundings, commonly anywhere in the range of 0.1°C–3°C in global mega-cities.[59] One estimate made on the UHI effect in Colombo, Sri Lanka suggested urbanization may have driven around a 1.6°C increase in land surface temperatures.[60] As well as impacting on human health (see Communities) the temperature peaks that will result from combined UHI and climate change, as well as future urban expansion, are likely to damage the productivity of the service sector economy, both through direct impacts on labor productivity, but also through the additional costs of adaptation.

As of 2017, just under 30% of Sri Lanka's gross electricity generation came from hydropower. Much of the country's water resources are used for hydropower generation and irrigation and the balance is discharged to the sea. Over 60% of the water that is discharged comes from the wet zone and often leads to floods and water-logged lowlands.[61] Research suggests that on average, a one degree increase in ambient temperature can result in a 0.5%–8.5% increase in electricity demand.[62] Notably, this is to support increased demand for business

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56 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

57 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

58 Cao, C., Lee, X., Liu, S., Schultz, N., Xiao, W., Zhang, M., & Zhao, L. (2016). Urban heat islands in China enhanced by haze pollution. Nature Communications, 7, 1–7. URL: https://www.nature.com/articles/ncomms12509

59 Zhou, D., Zhao, S., Liu, S., Zhang, L., & Zhu, C. (2014). Surface urban heat island in China's 32 major cities: Spatial patterns and drivers. Remote Sensing of Environment, 152, 51–61. URL: https://www.researchgate.net/publication/263283084_Surface_urban_heat_island_in_China's_32_major_cities_Spatial_patterns_and_drivers

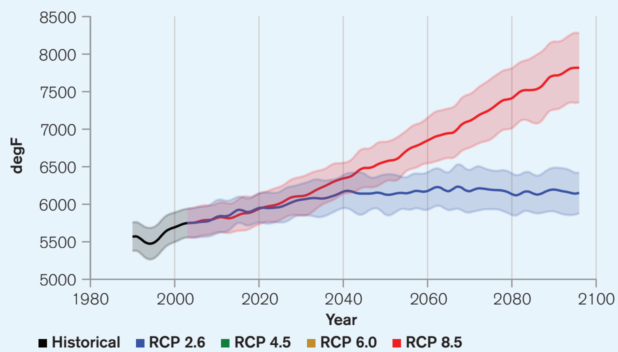
60 Ranagalage, M., Estoque, R. C., & Murayama, Y. (2017). An Urban Heat Island Study of the Colombo Metropolitan Area, Sri Lanka, Based on Landsat Data (1997–2017). ISPRS International Journal of Geo-Information, 6(7). URL: https://www.mdpi.com/2220-9964/6/7/189

61 Ministry of Environment (2012). Sri Lanka's Second National Communication on Climate Change. URL: https://unfccc.int/sites/default/files/resource/lkanc2_0.pdf

62 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://pdfs.semanticscholar.org/17f8/6e9c161542a7a5acd0ad500f5da9f45a2871.pdf

and residential air-cooling systems. The increase in demand associated with rising temperatures under climate change can be captured in the indicator. Cooling Degree Days, representing the total burden of cooling required to maintain temperatures at the optimum level for human comfort. In Sri Lanka the projected increase in cooling requirement is very significant, rising at least 10% by the 2040s under all emissions pathways (**Figure 12**). This increase in demand places strain on energy generation systems which are compounded by the heat stress on the energy generation system itself, commonly due to its own cooling requirements, which can reduce its efficiency.[63]

FIGURE 12. Historic and projected annual cooling degree days in Sri Lanka (cumulative degrees above 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[23]



Tourism

Tourism is a vital component of Sri Lanka's economy. The World Travel and Tourism Council (WTTC) suggest that tourism directly contributed 5% of total employment, and indirectly to 11% of national employment.[64] The large majority of Sri Lanka's tourism economy is located along the coastal zone and is therefore exposed to multiple climate hazards, including sea-level rise and associated enhancement of erosion and storm surge risk, river flooding, extreme rainfall, and extreme heat. Research examining the potential impacts of increased climate variability and intensified extremes of temperature and rain specific to Sri Lanka's tourism economy is lacking.[65]

It is expected that Sri Lanka will have to bear potentially very large adaptation costs to protect its tourism economy. Recent examples of this can be seen in recent activities of the Sri Lanka Tourism Development Authority related to climate change, including large investments in beach nourishment and protection.[66] One study has explored the risks and trade-offs that will be faced over the 21st century as communities and infrastructure are forced to retreat from the present-day coast as sea level rises and storm surge risk increases. An optimal retreat distance of between 37 and 262 m along Sri Lanka's east coast is proposed, a move which will be associated with significant economic costs.[67]

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63 ADB (2017). Climate Change Profile of Pakistan. Asian Development Bank. URL: https://www.adb.org/sites/default/files/publication/357876/climate-change-profile-pakistan.pdf

64 WTTC (2018). Travel and Tourism Economic Impact 2018: Sri Lanka. World Travel and Tourism Council. URL: https://www.wttc.org/economic-impact/country-analysis/country-reports/

65 Scott, D., Gössling, S., & Hall, C. M. (2012). International tourism and climate change. Wiley Interdisciplinary Reviews: Climate Change, 3(3), 213–232. URL: https://onlinelibrary.wiley.com/doi/epdf/10.1002/wcc.165

66 Su, Y.-P., & Hall, M. (2015). Climate Change and Tourism in Asia: A Review. In Responding to Climate Change – Tourism Initiatives in Asia and the Pacific (p. Chapter 2). United Nations World Tourism Organization. URL: https://www.academia.edu/7208168/Climate_Change_and_Tourism_in_Asia_A_Review

67 Dastgheib, A., Jongejan, R., Wickramanayake, M., & Ranasinghe, R. (2018). Regional Scale Risk-Informed Land-Use Planning Using Probabilistic Coastline Recession Modelling and Economical Optimization: East Coast of Sri Lanka. Journal of Marine Science and Engineering, 6(4). URL: https://www.mdpi.com/2077-1312/6/4/120

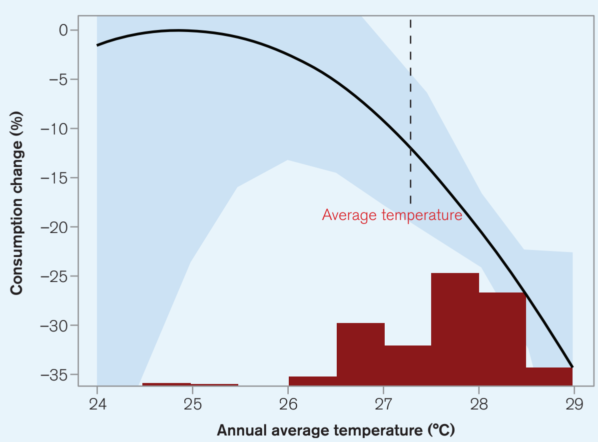
Communities

Poverty and Inequality

Many of the climate changes projected are likely to disproportionately affect the poorest groups in Sri Lanka. For example, heavy manual labor jobs are commonly among the lowest paid whilst also being most at risk of productivity losses due to heat stress.[68] Poorer businesses are least able to afford air conditioning, an increasing need given the projected rise in cooling degree days. Poorer farmers and communities are least able to afford local water storage, irrigation infrastructure, and technologies for adaptation. Sri Lanka was identified as a country with a particularly high vulnerability to food price rises, and as a nation which should expect a particularly large increase in extreme poverty in the event of any climate-driven price rise.[69] These processes are likely to amplify existing societal inequalities and vulnerabilities, for example, between rural and urban areas. As of 2015, access to improved drinking water sources was around 3.5% higher in urban areas compared to rural.[70]

One lens through which to view the impact of changes is through the correlation of consumption patterns with temperature. Work by Mani et al. (2018) describes this relationship, and particularly the way consumption (used as an indicator of living standards) declines beyond a certain threshold temperature.[57] The research suggests that Sri Lanka's average temperature is already higher than the optimal level for maximum consumption (**Figure 13**) and that further increases, manifested by impacts on the productivity of labor and human health, could reduce living standards. Sri Lanka has been identified as a particular hotspot, where declines in living standards due to temperature increases are expected to be some of the most marked in South Asia.[57] Under higher emissions pathways, northern and western regions of Sri Lanka, such as Jaffna district, are projected to see income declines of up to 10% by the 2050s. In these regions, climate changes could be compounding high levels of existing deprivation.

FIGURE 13. The relationship between temperature and consumption in Sri Lanka, shaded areas represent 90% confidence intervals. Black line shows the relationship between temperature and consumption and the optimum temperature (around 25°C) at which no consumption is lost[71]



[68] 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://www.ncbi.nlm.nih.gov/pubmed/26989826

[69] 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

[70] WHO/UNICEF (2018). Joint Monitoring Program (JMP) for Water Supply and Sanitation. URL: https://www.unwater.org/publication_categories/whounicef-joint-monitoring-programme-for-water-supply-sanitation-hygiene-jmp/

[71] 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. P. 5. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/28723/9781464811555.pdf?sequence=5&isAllowed=y

Human Health

Nutrition

The World Food Program estimates that without adaptation, the risk of hunger and child malnutrition on a global scale could increase by 20%, respectively, by 2050.[72] Work by Springmann et al. (2016) has assessed the potential for excess, climate-related deaths associated with malnutrition.[73] 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 authors' projections suggest there could be approximately 73 climate-related deaths per million population linked to lack of food availability in Sri Lanka by the 2050s 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.[32] While 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. Northern Sri Lanka is identified by Im et al. (2017) as facing a potential human health threat from temperatures approaching 35°C.[32] The region's vulnerability is driven by high ambient temperatures, but risks are amplified by the relatively high prevalence of agricultural laborers working outdoors and by low income levels. These risks are significantly mitigated by the pursuing of lower global emissions pathways. Work by Honda et al. (2014), which utilized the A1B emissions scenario from CMIP3 (most comparable to RCP6.0), estimates that without adaptation, annual heat-related deaths in the South Asian region will increase 149% by 2030 and 276% by 2050.[74] The potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).[75]

Disease

Climate change pressures, such as increased incidence of drought, extreme rainfall, and flood, as well as higher temperatures, represent environmental drivers of vector and water-borne diseases. For example, higher average, maximum and minimum temperatures all correlate with greater dengue incidence.[76] The World Health Organization (WHO) projects an increase in the capacity for dengue fever transmission under all emissions pathways.[77] A similar

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72 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/

73 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://www.sciencedirect.com/science/article/pii/S0140673615011563?via%3Dihub

74 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://link.springer.com/article/10.1007/s12199-013-0354-6

75 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.ncbi.nlm.nih.gov/pmc/articles/PMC6181199/

76 Choi, Y., Tang, C. S., McIver, L., Hashizume, M., Chan, V., Abeyasinghe, R. R., . . . Huy, R. (2016). Effects of weather factors on dengue fever incidence and implications for interventions in Cambodia. BMC Public Health, 16(1), 1–7. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4784273/

77 WHO (2015). Climate and Health Country Profiles - Sri Lanka. URL: https://apps.who.int/iris/bitstream/handle/10665/246141/WHO-FWC-PHE-EPE-15.45-eng.pdf?sequence=1

scenario is expected for transmission of malaria, with a potential increase in the at-risk population of approximately 5 million people by the 2060s. Other disease vulnerabilities include increased potential for transmission of water-borne diseases after flood events, exacerbated in urban areas by inadequate drainage and sewerage systems.

Diarrheal disease is a comparatively low health risk to children in Sri Lanka, reflecting the country's good progress tackling issues of clean water access and sanitation. United Nations Children's Fund (UNICEF) estimates that around 50 children under 5 years of age died as a result of diarrheal disease in 2016.[78] This represents around 2% of all under-5 deaths in Sri Lanka. Modelling by WHO estimates the change in the number of diarrheal deaths in under 15-year-olds attributable to climate change under the A1B scenario in the South Asia region. Climate change is projected to increase the number of deaths in the 2030s by 5%–15% and by 10%–20% in the 2050s.[79]

POLICIES AND PROGRAMS

National Adaptation Policies and Strategies

TABLE 8. Key national adaptation policies, strategies, and plans

Policy, Strategy, Plan	Status	Document Access
National Adaptation Plan (NAP) for Climate Change Impacts in Sri Lanka	Enacted	November, 2016
Nationally Determined Contribution	Submitted	November, 2016
National Communications to the UNFCCC	Two submitted	Latest: March, 2012
Technology Needs Assessment (TNA)	Completed	December, 2011
National Policy on Disaster Management	Enacted	December, 2010

Climate Change Priorities of ADB and the WBG

ADB Country Partnership Strategy

ADB's Country Partnership Strategy (CPS) (2018–2022) with Sri Lanka seeks to strengthen the country's environment, climate change, and disaster risk management. In support of these efforts, ADB will expand its assistance in clean energy (wind and solar), natural resource management, expansion of the sewerage network, improve water conservation through leakage reduction, and sustainable transport through railways network improvement. Considerations of environmental, climate, and disaster resilience will be mainstreamed in ADB operations. ADB will support the government's efforts to mitigate greenhouse gas emissions through

[78] UNICEF (2019). Data: Diarrhoeal Disease. URL: https://data.unicef.org/topic/child-health/diarrhoeal-disease/ [accessed 29/01/2019]

[79] WHO (2014). Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. World Health Organization. URL: https://apps.who.int/iris/handle/10665/134014

implementing climate change adaptation technologies and an integrated disaster risk management mechanism. Knowledge support will be provided through key studies for environmental management (conservation, adaptation, and mitigation).

(i) **Improving system efficiencies and water productivity.** This study will investigate inefficiencies in the conveyance and irrigation systems and constraints to improving water productivity, and recommend on-farm and system-wide improvements.
(ii) **Strengthening institutions with integrated water resources management.** This study will recommend programs for modernizing policy and governance frameworks, and institutional strengthening to improve national water resources planning and management, and operation and maintenance procedures.
(iii) **Water productivity assessment for improved irrigation performance.** This study will support irrigation managers to take appropriate measures during crop water stress and water shortages. Satellite remote sensing techniques will be used.

WBG Country Partnership Framework

The WBG has agreed on a Country Partnership Framework (CPF) (2017–2020) with Sri Lanka, in which climate change issues are discussed throughout the agreement, but are particularly addressed under its third pillar: seizing green growth opportunities, improving environmental management, and enhancing adaptation and mitigation potential. This agreement will target the enhanced resilience to climate-related events and disaster risk management through the implementation of a comprehensive, evidence-based, and innovative climate resilience program that addresses the physical and fiscal impacts of climate change and natural disaster, and move toward more integrated water resource management.

CLIMATE RISK COUNTRY PROFILE

SRI LANKA

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK