CLIMATE RISK COUNTRY PROFILE

MALDIVES

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK

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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 Veronique Morin (Senior Climate Change Specialist, WBG), 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

- Maldives experiences a consistently warm climate and has already experienced warming trends, with increases of 0.8°C between 1978 and 2018.
- Future projections are clouded by the inability of current climate models to simulate changes over very small island states. However, warming under the highest emissions pathway is likely to be slightly less than the global average of 3.7°C by the 2090s, but still over 3°C.
- Warming of this magnitude would push the combined temperature and humidity conditions in Maldives to levels which are dangerous for the human body over sustained periods. This highlights the very significant benefits to achieving lower global 21st century emissions pathways.
- Low-lying atoll islands in Maldives face a very significant threat from rising sea-levels. Long-term inundation is possible, but subject to adaptation efforts and geomorphological processes. The economic and human impacts of wave flooding are likely to grow in significance and threaten the viability of livelihoods on many islands.
- The dependence of the Maldives' economy on tourism represents a major vulnerability. The tourism sector is likely to come under pressure from sea-level rise, temperature extremes, and changes to global tourism behaviour and preferences.
- The natural ecosystems of Maldives, and most notably its coral reefs, are at great risk from climate change. Adaptation and conservation efforts will be required but may be limited in their scope.
- Climate change represents a major threat to ways of life on Maldives' islands. Without careful management it is likely that its impacts will be felt most strongly by the poorest, most marginalised, and most remote communities.
- The fisheries sector is critical to Maldives given the dependence on the sector for both food security and livelihoods.

COUNTRY OVERVIEW

Maldives is an archipelago of 26 low-lying coral atolls in the Indian Ocean, southwest of the Indian subcontinent. The country consists of just under 1,192 small tropical islands out of which about 358 are used for economic activities and human settlement.[1] Local inhabitants occupy around 198 of these 358 islands, with the remainder mostly known as "one-island-one-resort" or "resort-islands".[2] While the double-chain of islets is around 860 kilometers (km) long and varies from 80 to 120 km in width, the total land area of the Maldives is estimated to be approximately 298 km^2, making the country the sixth smallest in terms of land area, as well as one of the world's most geographically dispersed sovereign states.[3] Maldives is also one of the

[1] Maldives Ministry of Environment and Energy (2016). Second National Communication of Maldives to the United Nations Framework Convention on Climate Change. October 2016. URL: https://unfccc.int/files/national_reports/non-annex_i_natcom/application/pdf/mlv_2nd_nc_13_oct_2016.pdf

[2] May & Riyaza (2017). Maldives' Population Dynamics. URL: https://www.prb.org/maldives-population-dynamics/ [accessed 12/06/2019]

[3] FAO (2011). Irrigation in Southern and Eastern Asia in figures – AQUASTAT Survey – 2011: Maldives. URL: http://www.fao.org/nr/water/aquastat/countries_regions/MDV/MDV-CP_eng.pdf [accessed 12/06/2019]

lowest and flattest countries in the world,[4] as over 80% of the total land area is less than 1 meter above mean sea level. Due to its location over the equator in the Indian Ocean, Maldives experiences a typical equatorial monsoonal climate.[5] Maldives experiences warm and humid climate throughout the year, with seasonal fluctuations in temperature and rainfall due to the monsoon.

With a population of 533,900 in 2019 Maldives is also a unique society in terms of its cultural and ethnographic heritage, with its people known as the Dhivehin. The driving force of Maldives' economy is tourism, which contributes about one third of the gross domestic product (GDP) and is also the fastest growing economic sector within the country.[6] Though the contribution of fisheries and agriculture to GDP has declined to 3.5% and 1.7% respectively, these sectors are a major source of income and subsistence for rural communities.[5] Maldives' current development challenges stem from risks from climate change, disaster resilience and environmental sustainability with rising levels of solid waste.[7] Specifically, the country's economy and society are particularly sensitive to sea level rise, coastal storms and flooding, since a vast portion of the tourism industry's infrastructure, fisheries sector, population and housing structures, and over critical infrastructure (including communications, the four international airports and over 100 harbors), are primarily located in regions that are within 100 m of the coastline.[8] Economic modelling done by ADB (2014) shows that Maldives may be the hardest hit out of the 6 South Asian countries (incl. Bangladesh, Bhutan, India, Nepal, and Sri Lanka)[9] in terms of total economic loss due to climate change – the mean outcome of the simulation indicates that the economic damage may be on average 2.3% of GDP in 2050, with estimates of 12.6% of GDP by 2100.[10] At the same time Maldives still experiences challenges relating to multi-dimensional poverty and undernourishment **(Table 1)**.

Maldives published its Updated Nationally Determined Contribution (NDC) in 2020. Maldives' NDC identifies the country's significant vulnerability to the impacts of climate change to the country's population and economic activities; most notably its fisheries, tourism, agriculture, infrastructure and health sectors. Maldives submitted its Second National Communication to the UNFCCC in 2016 (NC2). The country has high vulnerability due to extreme weather events, temperature increases, flooding, and sea level rise. The country has committed to increasing its adaptive capacity, reduce beach erosion and land lost from uncontrolled human settlements.[11]

[4] Union of Concerned Scientists (2011). Maldives hot spot. URL: https://www.climatehotmap.org/global-warming-locations/republic-of-maldives.html [accessed 12/06/2019]

[5] Maldives Ministry of Environment and Energy (2016). Second National Communication of Maldives to the United Nations Framework Convention on Climate Change. October 2016. URL: https://unfccc.int/files/national_reports/non-annex_i_natcom/application/pdf/mlv_2nd_nc_13_oct_2016.pdf

[6] Maldives Ministry of Tourism (2018). Tourism Yearbook 2018. URL: https://www.tourism.gov.mv/downloads/stats/Tourism-Yearbook-2018.pdf [accessed 05/07/2019]

[7] World Bank (2021). The World Bank in Maldives. URL: http://www.worldbank.org/en/country/maldives/overview]

[8] Ministry of Environment and Energy (2015). Maldives Climate Change Policy Framework. URL: http://extwprlegs1.fao.org/docs/pdf/mdv172920.pdf. [accessed 30/06/2019]

[9] Government of the Maldives (2016). Maldives' Nationally Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Maldives%20First/Maldives%20INDC.pdf

[10] ADB (2014). Assessing the Costs of Climate Change and Adaptation in South Asia. URL: https://www.adb.org/publications/assessing-costs-climate-change-and-adaptation-south-asia [accessed 10/07/2019]

[11] Maldives Ministry of Environment and Energy (2016). Second National Communication of Maldives to the United Nations Framework Convention on Climate Change. October 2016. URL: https://unfccc.int/files/national_reports/non-annex_i_natcom/application/pdf/mlv_2nd_nc_13_oct_2016.pdf

This document aims to succinctly summarize the climate risks faced by Maldives. 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 Maldives, 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. Additionally, in March 2020, ADB published the Multihazard Risk Atlas of Maldives. This resource provides an extensive library maps with comprehensive detail on geographic characteristics, historical climate, and projected climate changes.[12]

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished[13]	10.3% (2016–2018)	FAO, 2019
National Poverty Rate[14]	8.2% (2016)	ADB, 2021
Share of Wealth Held by Bottom 20%[15]	8.3% (2016)	World Bank, 2020
Net Migration Rate[16]	2.3% (2015–2020)	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1)[16]	0.7% (2015–2020)	UNDESA, 2019
Average Annual Change in Urban Population[17]	2.9% (2015–2020)	UNDESA, 2018
Dependents per 100 Independent Adults[16]	30.2 (2020)	UNDESA, 2019
Urban Population as % of Total Population[18]	41.1% (2021)	CIA, 2021
External Debt Ratio to GNI[19]	48.0% (2018)	ADB, 2020
Government Expenditure Ratio to GDP[19]	30.1% (2019)	ADB, 2020

Due to a combination of political, geographic, and social factors, Maldives is recognized as highly vulnerable to climate change impacts, ranked 113th out of 181 countries in the 2020 ND-GAIN Index.[20] 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

[12] ADB (2020). Multihazard Risk Atlas of Maldives. Asian Development Bank. URL: https://www.adb.org/publications/multihazard-risk-atlas-maldives

[13] FAO, IFAD, UNICEF, WFP, WHO (2019). The state of food security and nutrition in the world. FAO. Rome. URL: http://www.fao.org/3/ca5162en/ca5162en.pdf

[14] ADB (2021). Basic Statistics 2021. URL: https://www.adb.org/publications/basic-statistics-2021 [accessed 25/05/2021]

[15] World Bank (2020). Income share held by lowest 20%. URL: https://data.worldbank.org/indicator/SI.DST.FRST.20 [accessed 18/05/21]

[16] UNDESA (2019). World Population Prospects 2019. URL: https://population.un.org/wpp/ [accessed 18/05/21]

[17] UNDESA (2019). World Urbanization Prospects 2018. URL: https://population.un.org/wup/ [accessed 18/05/2021]

[18] CIA (2021). The World Factbook. Central Intelligence Agency. Washington DC. URL: https://www.cia.gov/the-world-factbook/

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

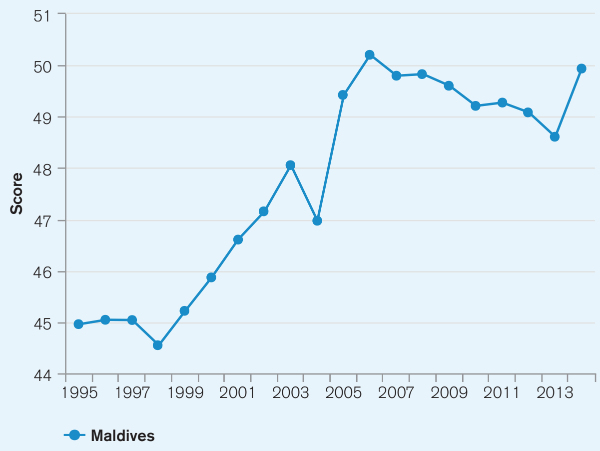
[20] University of Notre Dame (2020). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/

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 progress of Maldives.

Green, Inclusive and Resilient Recovery

The coronavirus disease (COVID-19) pandemic has led to unprecedented adverse social and economic impacts. Further, the pandemic has demonstrated the compounding impacts of adding yet another shock on top of the multiple challenges that vulnerable populations already face in day-to-day life, with the potential to create devastating health, social, economic and environmental crises that can leave a deep, long-lasting mark. However, as governments take urgent action and lay the foundations for their financial, economic, and social recovery, they have a unique opportunity to create economies that are more sustainable, inclusive and resilient. Short and long-term recovery efforts should prioritize investments that boost jobs and economic activity; have positive impacts on human, social and natural capital; protect biodiversity and ecosystems services; boost resilience; and advance the decarbonization of economies.

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.



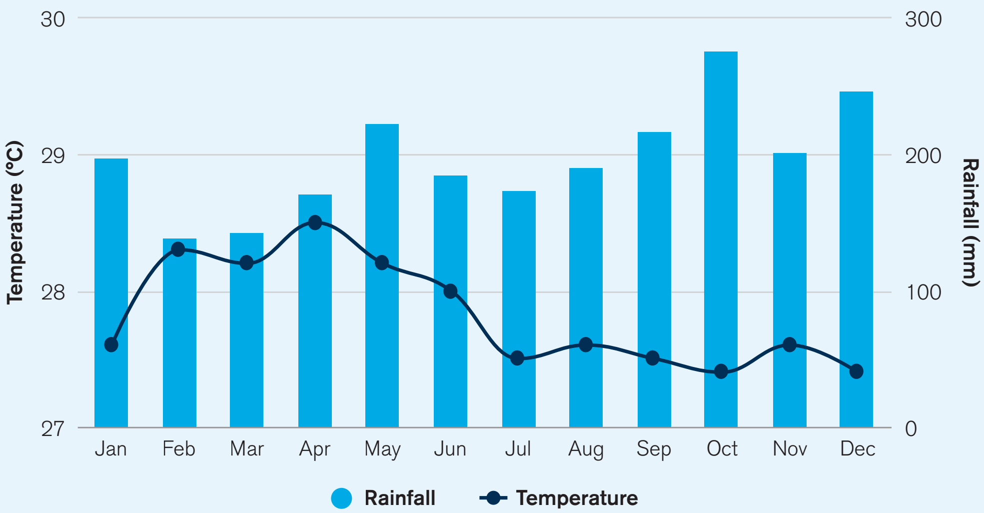
CLIMATOLOGY

Climate Baseline

Overview

The climate of Maldives is greatly influenced by its tropical monsoon weather and the islands experience a warm and humid climate throughout the year. The historical mean annual temperature was 27.6°C with little inter-seasonal variability — average monthly temperatures vary by at most 1°C throughout the year and the country has relatively high rates of precipitation, **Figure 2**, showing the latest climatology, 1991–2020. The seasonal cycle is strongest in the northern atolls recording an average maximum temperature of around 29.3°C just prior to the onset of the southwest monsoons (April–May) and an average minimum temperature of around 27.4°C prior to the onset of the northeast monsoons (December–January). The southern equatorial regions experience precipitation throughout the year and do not experience a very significant dry spell related to the northeast monsoons.

FIGURE 2. Average monthly temperature and rainfall in Maldives, 1991–2020[21]



Key Trends

Temperature

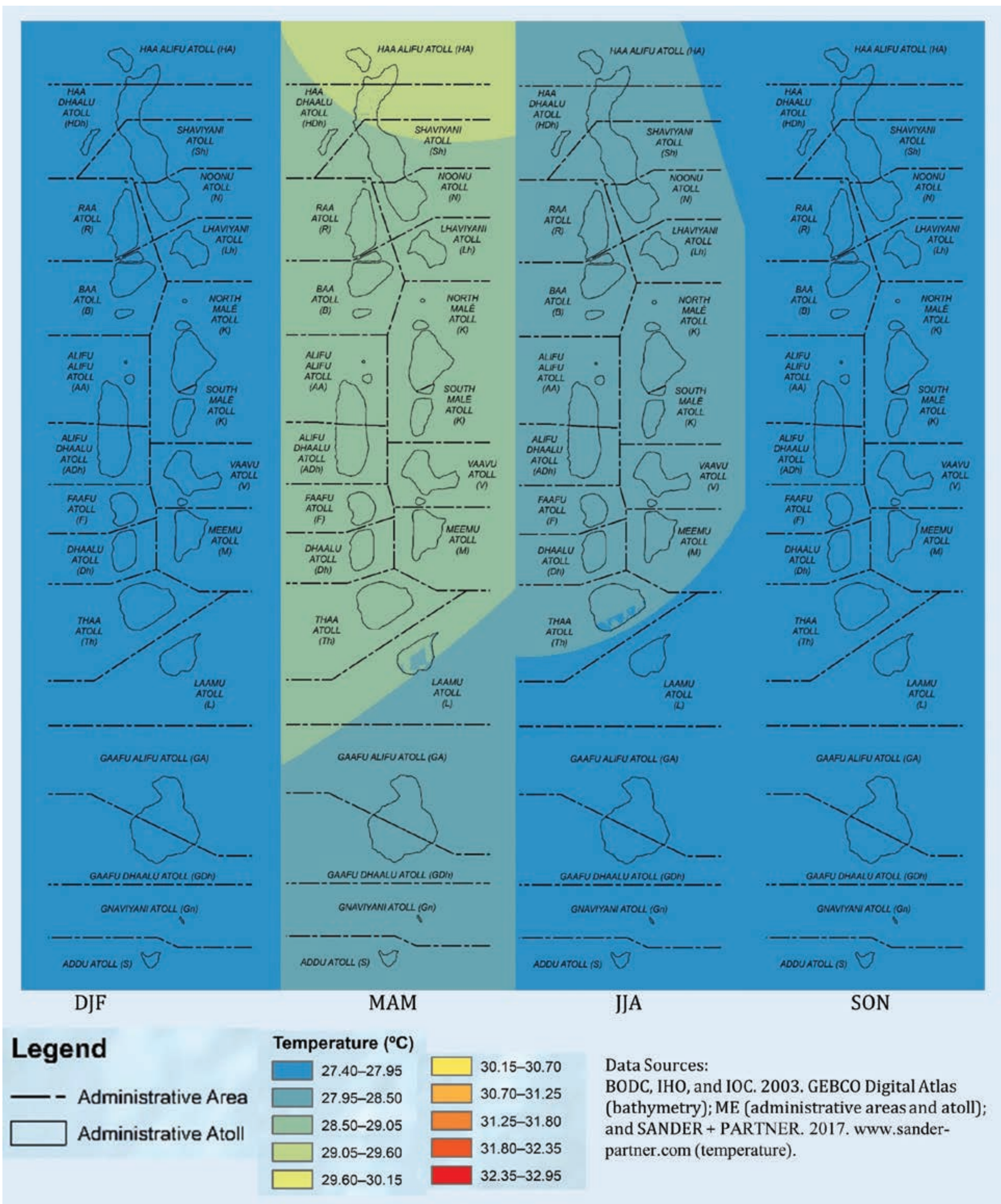
Generally, temperatures in Maldives range from 25°C to 31°C, with higher temperatures in the north, and seasonal fluctuations due to the influence of the monsoon (**Figure 3**).[5] Inter-annual temperature and precipitation trends in the vicinity of Maldives have a very complex relationship with global climate circulation phenomena such as El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD).[22] Data from the World Bank Group's CCKP shows that over 1969–1999, the annual average maximum and annual average minimum temperatures in Malé (central region) show a rising trend of 0.17°C and 0.07°C per decade, respectively. A more recent temperature record from 1995–2004 compares the trend in annual average maximum temperatures between the northern, central and southern atolls, and shows an increasing trend for central and northern regions, with the northern atolls showing a more pronounced increase. The southern atolls do not show any visible trend in the short-term record of annual average maximum temperatures. The Berkeley Earth Dataset on historical warming shows a significant increase in the rate of warming post-1977, suggesting that the over the subsequent 40-year period the climate in the vicinity of Maldives warmed by approximately 0.8°C.[23]

[21] WBG Climate Change Knowledge Portal (CCKP, 2021). Maldives Climate Data: Historical. URL: https://climateknowledgeportal.worldbank.org/country/maldives/climate-data-historical

[22] Dong, L., & McPhaden, M. J. (2018). Unusually warm Indian Ocean sea surface temperatures help to arrest development of El Niño in 2014. Scientific Reports, 8(1), 2249. https://doi.org/10.1038/s41598-018-20294-4

[23] Carbon Brief (2018). Mapped: How every part of the world has warmed – and could continue to. Infographics, Berkeley Dataset. URL: https://www.carbonbrief.org/mapped-how-every-part-of-the-world-has-warmed-and-could-continue-to-warm [accessed 25/10/2019]

FIGURE 3. Maldives seasonal average temperature (1970–2005)[12]



Precipitation

In general, there is some annual seasonality of the rainfall over Maldives due to the two monsoon periods, and there is usually more rainfall during the southwest monsoon. The southern islands tend to receive more rainfall than the north.[5] The CCKP's respective analysis of annual rainfall totals from 1969–1998 for Malé (central) and Gan (south) show a decreasing trend of around 2.7 millimeters (mm)/year and 7.6 mm/year respectively. Further, on analyzing the seasonal average precipitation for the same period at Malé, it can be seen that the decreasing trend is visible only during the southwest monsoon season, while no significant trend is observed during the northeast monsoon. Other studies, which looked at the Indian Ocean region more broadly, do not show any statistically significant changes in precipitation trends.[24]

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.[25] 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 Maldives, these models show a trend of consistent warming and the likelihood of more frequent and intense extreme weather events.

Model Ensemble

Due to differences in the way global circulation models (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 sub-national scales. Exploring the spread of climate model outputs can assist in understanding uncertainties associated with climate models. The range of projections from

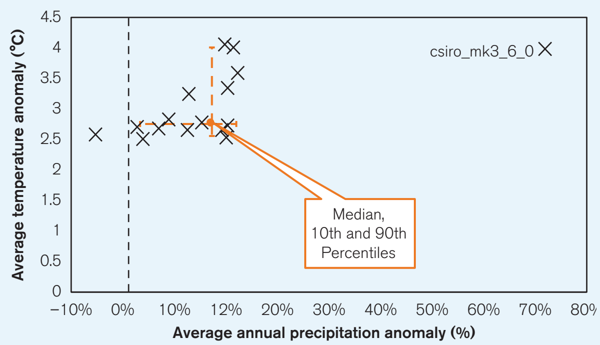
[24] Caesar, J., Alexander, L. V, Trewin, B., Tse-ring, K., Sorany, L., Vuniyayawa, V., . . . Sirabaha, S. (2011). Changes in temperature and precipitation extremes over the Indo-Pacific region from 1971 to 2005. International Journal of Climatology, 31(6), 791–801. https://doi.org/10.1002/joc.2118

[25] 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/

16 GCMs on the indicators of average temperature anomaly and annual precipitation anomaly for Maldives under RCP8.5 is shown in **Figure 4**. However, it should be noted that concerns have been raised about the realism of some of the more extreme outlier models labelled in **Figure 4**.[26]

The majority of the models from which outputs are presented in this report are from the CMIP5 round of standardization and quality assurance. Unfortunately, models of this generation operate at large spatial scales and thus are not well equipped to simulate the future climate of small islands. Typically, the changes projected will relate more to the expected changes over nearby ocean than the island itself. Caution should therefore be applied in interpreting results. This highlights a major area for future development, a research opportunity, and an urgent need from the perspective of policy makers planning for climate change.

FIGURE 4. 'Projected average temperature anomaly' and 'projected annual rainfall anomaly' in Maldives. 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. One model is labelled.

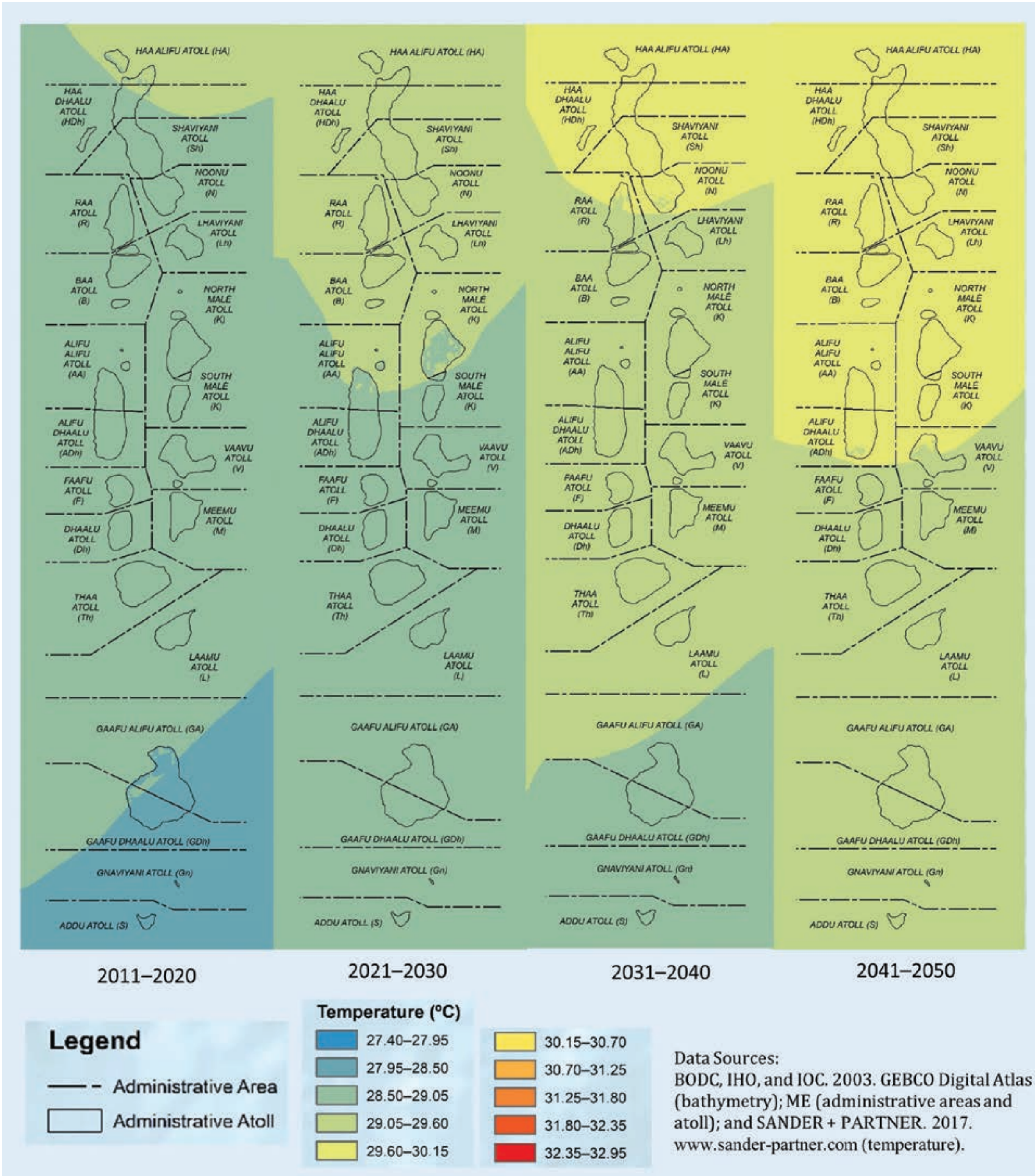


Temperature

Based on model projections, there is a likelihood that future temperature increases in Maldives may be below the global average. Under RCP8.5, the highest emission pathway, ensemble-based median annual temperatures in Maldives are projected to reach around 3.4°C by the 2090s, compared to around 3.7°C globally. In contrast, warming under the lowest emissions pathway plateaus at around 1.1°C by around 2040. A relatively lower average annual temperature perhaps reflects the moderating effect of large amounts of nearby ocean cover. But may also be a distortion of the current generation of climate models. Under lower emissions pathways (RCP4.5) average temperatures are expected to regularly exceed 30°C, particularly in northern atolls (**Figure 5**).

[26] McSweeney, C.F., Jones, R.G., Lee, R.W. and Rowell, D.P., 2015. Selecting CMIP5 GCMs for downscaling over multiple regions. Climate Dynamics, 44(11–12), pp. 3237–3260. URL: https://doi.org/10.1007/s00382-014-2418-8

FIGURE 5. Maldives average annual temperature projection under RCP4.5[12]



Precipitation

As it is for many tropical regions, considerable uncertainty clouds projections of local long-term future precipitation trends in Maldives, and little definitive trends can be offered regarding changes in average monthly or annual rainfall. As reported in AR5 (Table 14.SM.1c), regional trends for the North Indian Ocean area show a general tendency for increasing precipitation. This fits with the projections of the CCKP model ensemble shown in Figure 4, which indicate a maximum potential increase in annual precipitation of around 20%. However, median projected changes in monthly precipitation by 2100 show declines in February through June precipitation (ranging between –0.94 mm to –28.42 mm), but increases otherwise (by as much 71.03 mm in November), under the RCP8.5 multi-model ensemble. Notably, the intensity of sub-daily extreme rainfall events appears to be increasing with temperature.[27] However, as this phenomenon is highly dependent on local geographical contexts, further research is required to constrain its impact in Maldives.

In terms of climate variability within the South Asia region, according to the AR5, there is medium confidence that the Indian Monsoon will impact South Asia but with a medium confidence in the projections of Indian Monsoon, resulting in a medium level of relevance for the monsoon for this region.[28] Additionally, there is low confidence in the projection of tropical phenomena such as the Intertropical Convergence Zone (ITCZ), Madden–Julian Oscillation (MJO) and the Indian Ocean Dipole (IOD), and also a medium confidence in their impact resulting in a low level of relevance of these phenomena for South Asia. A medium level of relevance is assigned to El Niño-Southern Oscillation (ENSO) for South Asia, since there is medium confidence that ENSO will impact both the precipitation and temperature over the region but with low confidence in the projections of ENSO. Lastly, there is high confidence that rainfall extremes will impact South Asia, with a medium confidence in the projections of temperature change, and as such a high level of relevance is assigned to temperature change for South Asia.

CLIMATE RELATED NATURAL HAZARDS

The Government of Maldives has developed sound policies and plans to change its focus from a reactive approach to a more comprehensive approach to manage climate and disaster risk. In addition to the Strategic Action Plan these include: The Disaster Management Act and the 7th National Disaster Management Plan (NDMP), and the National Emergency Operations Plan (NEOP). The NDMA has been promoting a Community-based approach to disaster risk reduction through its Community Based Disaster Risk Reduction (CBDRR) Framework. The government has finalized a National Spatial Plan (NSP) which focuses on a 20-year roadmap for infrastructure, spatial development and decentralization. The NSP envisages the development of regional hubs, sub-regional centres and other islands, with basic services made available within proximity. Therefore, the NSP's focus is on development across all the islands and to reduce the overcrowding and congestion in the capital where approximately 300,000 live in an area of 8.3 square kilometres.

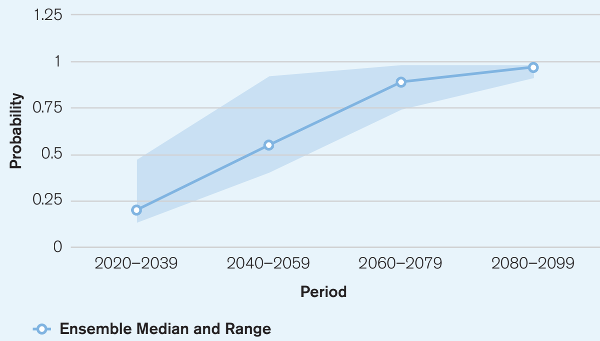
[27] Westra, S., Fowler, H. J., Evans, J. P., Alexander, L. V., Berg, P., Johnson, F., Kendon, E. J., Lenderink, G., Roberts, N. (2014). Future changes to the intensity and frequency of short-duration extreme rainfall. Reviews of Geophysics, 52, 522–555. URL: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014RG000464

[28] Christensen et al. (2013). Climate Phenomena and their Relevance for Future Regional Climate Change Supplementary Material. 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 [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. URL: http://www.climatechange2013.org

Heatwaves

Heat waves are defined as a period of 3 or more days when the daily temperature remains above the 95th percentile. **Figure 6** shows the projected change in heat wave probability (compared to 1986–2005), highlighting the daily probability of a sudden heat wave in subsequent time periods. For Maldives, this probability approaches a value of 1 by 2100. This is held within the global context in which the numbers are expected to increase, but it is noted that the tropics are particularly where systematic warming might lead to the largest increases in heat wave probability, simply because the historic baseline day-to-day and month-to-month variability are small.

FIGURE 6. Projected change in probability of heat waves in Maldives (compared to 1986–2005) under RCP8.5[30]



Generally, Maldives regularly experiences high temperatures, with a mean annual temperature of around 27.6°C and an average April temperature of 28.2°C. Ensemble-based median annual temperature rises push temperatures above 30°C on a sustained basis, with a projected ensemble median change in the maxima of daily maximum temperature of 3.24°C, compared to the historical mean (**Figure 7**). By 2100, the projected change in the Heat Index 35°C (an indicator of joint temperature and humidity) for Maldives is large. Under RCP8.5, an increase in the annual average number of days with Heat Index >35°C of 356 days is projected (**Figure 8**), when compared with the reference period (1986–2005). While instances of Heat Index 35°C may be primarily found in monsoon regions as well as some subtropical locations with high humidity (e.g., Persian Gulf region[29]), in general the values vary between 0 and +150. The projected change for Maldives likely signals the potential for extremely uncomfortable conditions, with local impacts and health repercussions. However, it is noted that further research is required to better understand the implications of climate change, and its interaction with the ENSO phenomenon, for the nation's future regime and potential heatwaves.

FIGURE 7. Projected change in maxima of daily max temperature under RCP8.5

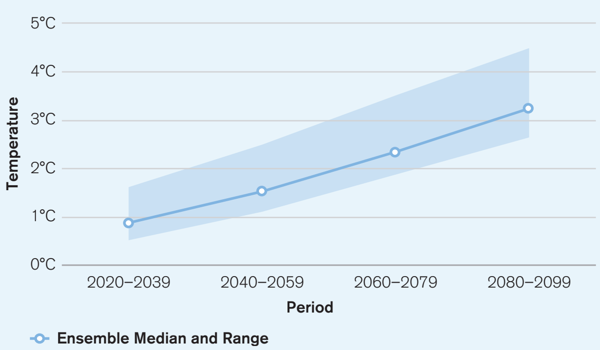
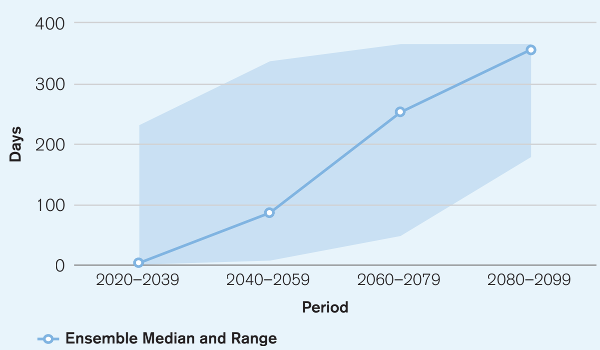


FIGURE 8. Projected change in heat index 35 under RCP8.5



[29] Im, E. S., Pal, J. S., & Eltahir, E. A. (2017). Deadly heat waves projected in the densely populated agricultural regions of South Asia. Science advances, 3(8), e1603322. URL:https://climateknowledgeportal.worldbank.org/country/maldives/climate-data-projections.

[30] WBG Climate Change Knowledge Portal (CCKP, 2021). Maldives Climate Data: Projections. URL: https://climateknowledgeportal.worldbank.org/country/maldives/climate-data-projections

An additional factor for consideration is the potential for marine heatwaves. Research has shown that "from 1925 to 2016, global average marine heatwave frequency and duration increased by 34% and 17%, respectively, resulting in a 54% increase in annual marine heatwave days globally".[31] While such research has not specifically identified Maldives under threat, the consequences of these trends may be serious for marine ecosystems in the region, which are adapted to survive under very stable temperature regimes, as well as the livelihoods dependent on them.

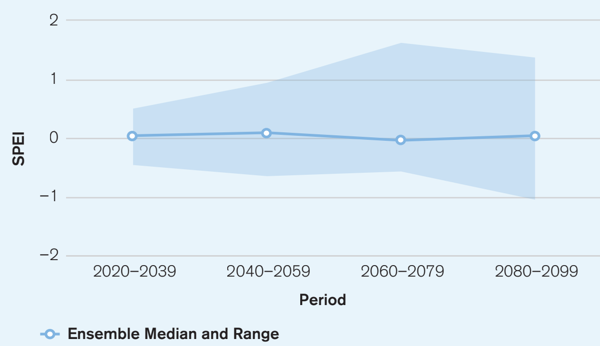
Drought

Drought can be expressed in many ways, from looking at simple precipitation deficits to complex estimates of remaining soil moisture. It is understood that drought projections are somewhat controversial because a large part of the outcome hinges on the evapo-transpiration (ET) feedback. One approach to better understanding drought is the standardised precipitation evapo-transpiration index (SPEI), which is computed over 12-month periods and captures the cumulative balance between gain and loss of water across the inter-annual time scale by incorporating both precipitation input variations as well as changes in the loss of water through evapotranspiration. It is widely used today as a global measure for drought monitoring over various cumulative time intervals.

The likelihood for severe drought analyses the frequency at which prolonged dry conditions are expected, Projections also show that southern atolls are more likely to face severe drought compared to northern atolls in Maldives in the near long term. However, projections are clouded with significant uncertainty.

Figure 9 adds further context to this likely forecast by looking at the projected changes in the annual mean drought water balance (or wet) conditions and negative values indicate negative water balance (or dry) conditions, Figure signals that SPEI trends to 2100 in Maldives are uncertain, and as such require further research.

FIGURE 9. Projected change in annual mean drought index for Maldives[32]



Flood, Cyclones, Tsunamis and Storm Surge

Floods due to rain are the most frequent natural events in Maldives.[5] Future climate projections indicate that extreme flooding events are likely to become more frequent in the future with changing climate. The return period of a daily rainfall of 150 mm for the northern region expected to change from 300 years to 23 years by the end of the century. Data on both flood events and droughts are lacking in Maldives and a proper mechanism for collecting or recording such data need to be established.

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[31] Oliver, E. C., Donat, M. G., Burrows, M. T., Moore, P. J., Smale, D. A., Alexander, L. V., . . . & Holbrook, N. J. (2018). Longer and more frequent marine heatwaves over the past century. Nature communications, 9(1), 1324. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5893591/

[32] WBG Climate Change Knowledge Portal (CCKP, 2021). Maldives Climate Data: Projections. URL: https://climateknowledgeportal.worldbank.org/country/maldives/climate-data-projections

It is noted that the most extreme rainfall episodes generally have the danger of leading to significant floods. Individual daily rainfall is often linked to flash-floods of limited spatial extent, but multi-day rainfall generally has a broader spatial footprint and thus more extensive flooding can be explained. Rare precipitation events are often referred to as events of a certain return level, and the 5-day cumulative rainfall indicator focuses on the maximum rainfall amount over any 5-day period that can be expected once in an average 25-year period. Changes in this indicator may have potentially significant impacts on infrastructure and endanger life and property through direct physical effects and perhaps through water quality issues. As such, any significant changes in their magnitudes would need to be understood.

The boxplot in **Figure 10** shows recorded 5-Day Cumulative Rainfall for 1986–2005 and projected 5-Day Cumulative Rainfall 25-yr Return Level by 2050 under all RCPs of CIMP5 ensemble modelling for Maldives. From this, it is noted that compared to the historical value, median ensemble projections seem similar, although there is some difference in the range of change under the different scenarios.

Looking at further future projections, **Figure 11** highlights the projected change in annual maximum 5-day rainfall of a 25-year return level, projected ensemble median changes seem to be close to 0, but the range of values is quite broad and needs to be further contextualized and understood.

Unlike for many other tropical small islands In the Pacific or Atlantic regions, the cyclone (hurricane or typhoon) hazard for Maldives is classified as ***low***, according to the information that is currently available, meaning that there is a 1% chance of potentially-damaging wind speeds for the islands in the next 10 years.[33] Cyclone hazard risk is highest in the north and very low in the south due to the proximity of northern latitudes to the cyclone belt. However, despite this overall low classification, there have been a few cyclones impacting on Maldives in the recent past, including Very Severe Cyclonic Storm Vayu in June 2019, and Very Severe Cyclonic Storm Ockhi in November 2017. In the case of Ockhi, while impacts were not extensive, the storm caused damage to households and property in 62 islands across Maldives. Including flooding on 36 islands, torn roofs and felled trees on 22 islands, and coastal swells on 4 islands.[34]

FIGURE 10. 5-day precipitation — historical and projected scenarios of 25-year return level in Maldives for period 2040–2059

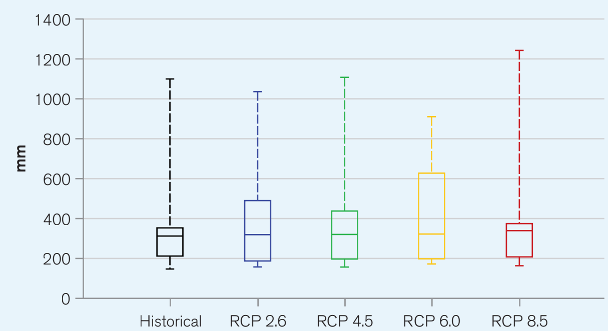
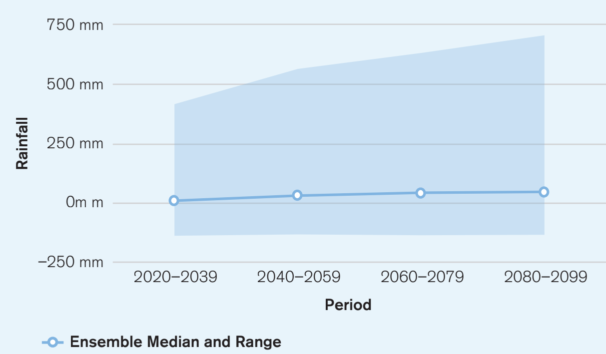


FIGURE 11. Projected Change in annual maximum 5-day rainfall (25-year return level) for the Maldives



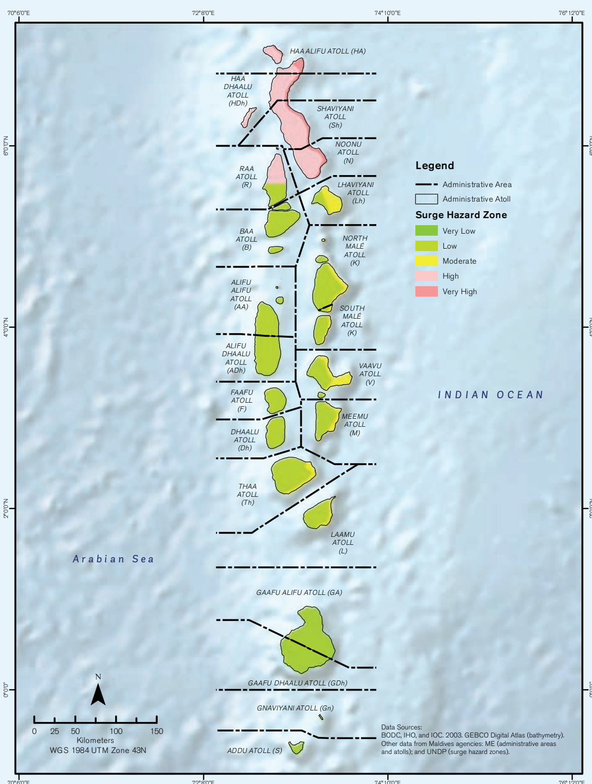
[33] GFDRR (2016). ThinkHazard! Profile for Maldives. URL http://thinkhazard.org/en/report/154-maldives
[34] Maldives Times (2017). Damage to 60 islands after extreme weather. December 3, 2017. URL:https://maldivestimes.com/damage-to-60-islands-after-extreme-weather/ [accessed 30/06/2019]

Climate change is expected to interact with cyclone hazard in complex ways which are currently 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 wind speed and precipitation intensity. Modelling of climate change impacts on cyclone intensity and frequency conducted across the globe points to a general trend of reduced (or unchanged) global average frequency of tropical cyclones, increasing global average tropical cyclone wind speed and rainfall, and increased intensity and frequency of the most extreme events.[35] Further, it is possible that the frequency of the most intense tropical cyclones will increase substantially in some ocean regions, and the present hazard level in areas currently affected by tropical cyclones may increase in the long-term. 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.

Based on available research,[36] hydrological hazards including tsunamis, storm surges, and *Udha* are among the more severe natural hazards in Maldives. According to detailed risk assessments for Maldives, tsunamis may be the most destructive natural hazard observed for Maldives, with predicted maximum wave heights between 3.2 to 4.5 meters (m) over mean sea level in parts of the country, followed by swell waves and storm surges.

It is important to note that due to the geographical layout of the islands, there is a variation of impact across the country. The 2007 UNDP risk assessment highlights that there is a higher likelihood of storm surges in the northern area due to its higher possibility of cyclones. This is confirmed in mapping by ADB shown in **Figure 12**. The southern and western islands of Maldives may experience more swell waves due to the proximity to the Southern Indian Ocean and due to the predominant south westerly approach of the swell waves, but eastern rim islands may still experience impacts due to the propagation of swell waves through reef passes within atoll lagoon.[34] Eastern rim islands are predicted to experience more frequent tsunami waves and their impacts due to the direct exposure to waves, while western rim and atoll lagoon islands are offered protection by the atoll formations. Swell and tidal waves cause flooding in Maldives islands, causing extensive damages to critical infrastructure, properties, household goods, saltwater intrusion to groundwater aquifer, coastal erosion and livelihood.[5]

FIGURE 12. Maldives surge hazard zone[12]



[35] 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/full/10.1002/wcc.371

[36] UNDP (2007). Detailed Island Risk Assessment in Maldives. Disaster Risk Management Programme UNDP Maldives. URL:https://www.geonode-gfdrrlab.org/documents/827

Natural Resources

Water

There are no rivers or streams in any of the islands of Maldives, and only a few wetlands or freshwater lakes.[37] The country's freshwater resources exist as groundwater in basal aquifers, generally unconfined in nature and extending below sea level in the form of a thin fresh water lens'. These lens' are vulnerable to saline intrusion owing to the freshwater-seawater interaction and need to be carefully managed to avoid over-exploitation. The island communities in Maldives depend primarily on rainwater for drinking purposes, and groundwater for most other domestic/non-potable uses. Rainwater is tapped from roofs and collected and stored in various types of tanks. All the islands have individual household as well as community tanks. Major urban areas like Malé and all the resort islands use desalinated water distributed through a piped network, and it is common for people to use this for drinking as well as for domestic purposes due to high contamination of groundwater, caused by human activities such as over abstraction and sewage pollution.

Although a report by Water Aid in 2018 based on WHO/UNICEF monitoring[38] estimated that 97.8% of the Maldivian population had access to at least a basic water supply, the need to consistently meet water demand through sustainable and affordable means is of critical importance to its people. In some cases, rainwater collection tanks have been provided to individual households for rainwater harvesting, making those highly vulnerable to rainfall variability. In other cases, communities rely on the expensive alternative of desalination to meet their water requirements. It is noted that resort islands — those islands set aside solely for tourists — have their own small desalination plants, which are affordable only because the islands are generating substantial revenue from the tourism.

While climate change impacts on rainfall will have pronounced effects on the islands' ability to maintain rainwater stocks, income received from tourism has so far assisted the use of desalination plants in supplying reliable and safe water sources, despite the high cost of production. It may be worthwhile to better understand the future impacts of climate change on tourism in Maldives, to see how such income flows may be affected. Two UNDP projects may offer some assistance and understanding in this regard: Supporting vulnerable communities in Maldives to manage climate change-induced water shortages (through the Green Climate Fund) 2017–2022, and the Increasing Climate Change Resilience of Maldives through Adaptation in the Tourism Sector Project (TAP) 2011–2016.

[37] Ibrahim, M. S. A., Bari, M. R., & Miles, L. (2002). Water resources management in Maldives with an emphasis on desalination. Maldives Water and Sanitation Authority Report, Male, Republic of Maldives. URL: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.113.913&rep=rep1&type=pdf [accessed 30/06/2019]

[38] Water Aid (2018). The State of the World's Water 2018. URL: https://washmatters.wateraid.org/publications/the-water-gap-state-of-the-worlds-water

Coastal Zones

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 m by the end of the 21st century by the IPCC's Fifth Assessment Report (**Table 2**)[39] but some studies published more recently have highlighted the potential for more significant rises (**Table 2**). Local sea-levels can show variation, and are influenced by the ENSO process. According to Maldives' 2007 National Adaptation Program of Action[1], the observed long term trend in relative sea level for Hulhulé (Malé International Airport Weather Station) is 1.7 mm/year, with the maximum hourly sea level increasing by approximately 7 mm/year, slightly faster than the global average. See also Palanisamy et al.[40]

TABLE 2. 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).[41]

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)

In Hulhulé, neighboring the capital Malé, an hourly sea level of 70 centimeters (cm) above mean sea level (MSL) is currently a 100-year event, and it is projected to likely be at least an annual event by 2050. Considering the South Asian region, sea-level rise is projected to be approximately 100–115 cm in a 4°C world and 60–80 cm in a 2°C world by the end of the 21st century relative to 1986–2005, with the highest values expected for Maldives.[42] Studies have shown that the extent of wave-driven flooding is impacted by coral reef height and health, highlighting the importance of coral conservation as an adaptation.[43] There is some disagreement in the academic research base regarding the extent of the inundation threat to atoll islands. Some studies have shown the potential of atoll islands to sustain and even grow despite sea-level rise thanks to geomorphological processes which build land.[44] The picture is one of a dynamic ecosystem which, at very least, will demand adaptive lifestyles and livelihoods from inhabitants.

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[39] 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 (pp. 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

[40] Palanisamy, H., Cazenave, A., Meyssignac, B., Soudarin, L., Wöppelmann, G., & Becker, M. (2014). Regional sea level variability, total relative sea level rise and its impacts on islands and coastal zones of Indian Ocean over the last sixty years. Global and Planetary Change, 116, 54–67. URL: https://www.sciencedirect.com/science/article/abs/pii/S0921818114000381

[41] 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

[42] World Bank (2013). Turn Down the Heat: Climate Extremes, Regional Impacts, and the Case for Resilience. A report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics. Washington, DC: World Bank. URL: https://www.pik-potsdam.de/members/olivias/full-report-vol-2-turn-down-the-heat.pdf

[43] Beetham, E., Kench, P. S., & Popinet, S. (2017). Future Reef Growth Can Mitigate Physical Impacts of Sea-Level Rise on Atoll Islands. Earth's Future, 5(10), 1002–1014. URL: https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2017EF000589

[44] Kench, P. S., Ford, M. R., & Owen, S. D. (2018). Patterns of island change and persistence offer alternate adaptation pathways for atoll nations. Nature Communications, 9(1), 605. URL: https://www.nature.com/articles/s41467-018-02954-1

Because of the topography and low elevation of Maldives, small changes in sea level could mean extensive land inundation, and the island nation is especially at risk. In the long run, coastal infrastructure may be threatened by permanent inundation. Rising seas pose a looming threat to homes and industries near the coast. Even small increases in sea level are likely to worsen existing environmental challenges on the islands, such as persistent flooding from waves often generated by storms far away. More than 90 of the inhabited Maldives islands already experience annual floods.[45] As well, sea level rise is also likely to place added stress on Maldives' already scarce freshwater resources. The costs of adaptation to sea-level rise in Maldives have been assessed by the government, and are estimated to be very high across a suite of different potential responses, ranging from hard infrastructure solutions to more 'ecosystem based' solutions.[46]

Some key challenges in adapting to climate change in an isolated island context include maintaining transport connectivity and supporting infrastructure which are vital to disaster recovery. Maldives has identified the need to protect island harbors from coastal hazards and long-term sea-level rise while at the same time minimizing impacts on the natural environment and particularly corals which provide natural surge protection. Past experiences have shown the dangers of poorly planned infrastructure development in sensitive coastal areas, with evidence suggesting that construction of a seaport on the island of Fuvahmulah has exacerbated coastal erosions issues hence delivering 'maladaptation'.[47]

Coral Reefs and Fisheries

The coral reef ecosystems of Maldives are significant both at international and national level for their exceptional biodiversity and cultural value. Maldives has two of the largest natural atolls in the world – Thiladhunmathi Atoll with a total surface area of 3,788 km^2 and Huvadhoo Atoll with a total surface area of 3,278 km^2. They form the seventh largest reef system, are among the richest in the world in terms of species diversity, and have a critical coastal protection function.[5] According to research from ADB, coral reefs are linked to the fisheries sector with the growing reef fishery as an important contributor to tourism, and the demand for reef fish increasing over the years.[10]

Corals are highly sensitive to changes in temperature and, as a result, the incidence of bleaching will increase in frequency and intensity with the projected rise in sea surface temperatures. Changes will be influenced by global circulation phenomena, and their interaction with climate change, notably the poorly understood interaction with El Niño. The evidence from the reefs of Maldives supports information that warming of the ocean surface leads to significant coral bleaching.[48] There have been several bleaching and coral mortality events in Maldives, including: 1977, 1983, 1987, 1991, 1995, 1997, and three global coral bleaching events in 1998, 2010, and 2016. Each of the three

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[45] Union of Concerned Scientists (2011). Maldives hot spot. URL: https://www.climatehotmap.org/global-warming-locations/republic-of-maldives.html [accessed 12/06/2019]

[46] Hosterman, H. and Smith, J. (2015). Economic costs and benefits of climate change impacts and adaptation to the Maldives tourism industry. Ministry of Tourism, Malé, Republic of Maldives. URL: http://archive.tourism.gov.mv/downloads/publicaltions/Economic.pdf

[47] David, C.G., Schlurmann, T. (2019). Coastal Infrastructure on Reef Islands – the Port of Fuvahmulah, the Maldives as Example of Maladaptation to Sea-Level Rise? In: Goseberg, Nils; Schlurmann, Torsten (Hg.): Coastal Structures 2019. Karlsruhe: Bundesanstalt für Wasserbau. URL: https://henry.baw.de/handle/20.500.11970/106703?locale-attribute=en

[48] Perry, C. T., & Morgan, K. M. (2017). Bleaching drives collapse in reef carbonate budgets and reef growth potential on southern Maldives reefs. Scientific Reports, 7(1), 40581. URL: https://www.nature.com/articles/srep40581

Global Bleaching Events was due to increased sea temperatures that coincided with El Niño events. Changes in weather patterns due to the El Niño such as reduced wind-driven mixing and increased sunlight are added on top of the steadily increasing seawater temperature due to global warming thus killing corals.[49]

Research highlights that although some areas in the Western Pacific Ocean, Coral Triangle, and Indian Ocean are likely to experience less stress and will still have large areas unaffected by annual mass coral bleaching by the end of the century, the conditions that drive mass mortality events today (Degree Heating Months > 5) will still be prevalent within the Indian Ocean region and will spread across most regions by the end of the century under RCP8.5. This risk would decrease to zero under RCP2.6, with no regions experiencing annual conditions that would cause mass mortality event. Given the time that it takes for coral reefs to recover from mass mortality events (10–20 years), there is significant risk associated with high greenhouse gas emission scenarios given the damage from these events, even in managed reef systems.[50] Reef health is also affected by sea level rise, changing ocean acidification, as well as a number of human stresses on the reef system such as coral mining, reef entrance blasting, dredging, solid waste disposal and sewage disposal which has affected the health, integrity and productivity of reefs in Maldives.

Fisheries are a critical component of the Maldivian economy. Historically, more than 20% of the population depended on fisheries as the major income earning activity.[1] Fisheries is dominant in terms of employment and subsistence of the local labor force. Fish, particularly tuna, is the primary source of dietary protein for the Maldivians and tuna is served almost daily in the local diet.[1] Although the impact of climate change on the size of overall fishing stocks is still expected to have a far smaller impact on reducing levels than the effects of over-fishing, the fisheries industry in Maldives is yet highly vulnerable to climate change. Changes in sea surface temperature and ocean pH are the main factors likely to affect fisheries in Maldives, as tuna is highly adjusted to specific biophysical conditions of the ocean environment, particularly ENSO and associated changes in SST. Given climate projections, it is possible that a greater proportion of tuna catch will need to be made in international waters as tuna species ranges shift.

Economic Sectors

Agriculture and Food

In Maldives, agriculture plays a minor role in the economy and the sector (including fisheries) contributed 5.2% to the Gross Domestic Product (GDP) in 2017.[51] Agriculture in Maldives is constrained by the small size of the islands and limited availability of cultivable land (the total cultivable land area is estimated at 27 km^2, including 18 km^2 on inhabited islands and 9 km^2 on uninhabited islands), limited freshwater availability and shortage of domestic labour.[5] As such, it is estimated that about 90% of the food consumed in the country is imported.[5]

[49] Reef Check (2017). Maldives reefs follow Great Barrier Reef down path of catastrophic decline. URL: https://reefcheck.org/reef-news/maldives-reefs-follow-great-barrier-reef-down-path-of-catastrophic-decline

[50] Hoegh-Guldberg, O., Poloczanska, E. S., Skirving, W., & Dove, S. (2017). Coral reef ecosystems under climate change and ocean acidification. Frontiers in Marine Science, 4, 158. URL: https://www.frontiersin.org/articles/10.3389/fmars.2017.00158/full

[51] Maldives Ministry of Tourism (2018). Tourism Yearbook 2018. URL: https://www.tourism.gov.mv/downloads/stats/Tourism-Yearbook-2018.pdf

Despite this small contribution to GDP, agriculture remains a crucial sector in terms of "national development goals, poverty alleviation and sustainable livelihood, nutritional status of the people, retention of foreign currency, and employment. It is also a primary sector of the economy; growth in other sectors – transport and communication, construction, financial services, and real estate – is dependent on agriculture".[10]

Such limited agricultural production, heavy import dependency (along with any impact on food production in the source countries/regions), limitations in storage, and challenges in the distribution of food across the nation are all major threats to national food security. Extreme weather events further exacerbate this vulnerability, especially considering localized flooding due to surges and disruptions in sea-based transport. Further, since most Maldivians use fish as a primary source of dietary protein, the effect of climate change on local and regional fishery systems will play a role in the impacts on the Maldivian diet.

On a global scale, 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 the submergence of coastal lands. On an international level, these impacts are expected to damage key staple crop yields, even on lower emissions pathways. Tebaldi and Lobell (2018) 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.[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. All of these phenomena threaten to drive instability and increases in global food prices which will particularly impact on nations dependent on food imports, and likely on the poorest communities within those nations.

Tourism

Tourism is the main economic activity in Maldives, accounting for 24.5% of the Gross Domestic Product (GDP) of Maldives in 2019 and more than one third of government revenue is generated from this sector.[53] This makes Maldives highly reliant on tourism and the economy thrives on the multiplier effects of the tourism industry. The tourism industry is a platform with several fields of work, providing plenty of employment opportunities to a large number of people. Based on the 2014 Census, more than a fifth of the employed are engaged in the tourism industry – of the total employed, 27,837 or 14% work in the resorts.[54] The World Travel and Tourism Council estimates that in 2017, Travel & Tourism in Maldives directly and indirectly supported 80,500 jobs (37.4% of total employment), with growth potential in years to come. It also estimated that both visitor exports and investments in the tourism sector are expected to grow over the next ten years to 2028.[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] Maldives Ministry of Tourism (2019). Tourism Yearbook 2019. URL: https://tourism.gov.mv/statistics/publications/year-2019 [accessed 05/27/2021].

[54] National Bureau of Statistics (2014). Population & Housing Census 2014. URL: http://statisticsmaldives.gov.mv/nbs/wp-content/uploads/2016/02/StatisticalReleaseIV-Employment.pdf [accessed 05/07/2019]

[55] World Travel and Tourism Council (2020). Maldives. URL: https://www.wttc.org/

Coincidentally, tourism in Maldives has been shown to be aligned with the general climate trend, with peak tourists arriving during the dry season from late October to March, and off-season during the rainy season from May till August.[5] In one critical review of the literature examining the dynamics between climate change and tourism, there appeared to be multiple indications that the tourism sectors of small island states, such as Maldives, are particularly vulnerable to climate change.[56] Already, about 45% of tourist resorts have reported varying degrees of beach erosion, affecting the "sun, sea and sand" tourism product.[8] In the long-term, the dual combination of rising sea levels and of coastal erosion will reduce the quantity and quality of available beach space without significant adaptation measures and could therefore reduce the attractiveness of the country as a tourist destination. Another potential area of vulnerability is the recreational diving sector, which is threatened by environmental degradation, loss of reefs, and coastal erosion, as has been the case in some Pacific islands.[57]

In addition to direct physical impacts, climate change may affect the tourism sector in Maldives through global efforts to mitigate climate change. One possible manifestation is in the increased cost of international flights. One study estimated that while the cost of achieving an emissions-target compatible tourism sector may be proportionately low (3.6%) the necessary increase in trip costs (estimated at $11 when averaging across every global trip but potentially higher on a long-haul destination such as Maldives) may reduce the island nation's attractiveness as a tourist destination.[58] Further research is required to better constrain the suite of potential climate change impacts on the sector.

Communities

Poverty, Inequality and Disaster Vulnerability

The official poverty headcount ratio for Maldives stood at 8.2% in 2016 (6.6% under the poverty line of $5.50 per person per day in 2011 purchasing power parity terms).[59] However, many Maldivians are clustered just above the poverty line and are vulnerable to falling into poverty. This feature, and the social vulnerability of Maldives communities, was exposed by the 2004 Indian Ocean tsunami. Documenting by ADB economists in the aftermath of the disaster suggested that the national poverty rate rose from 22% to 35% as a result.[60] The average expenditure of the bottom 40% of the population is 2.5 times lower compared to the average of the top 60% of the population. Moreover, large spatial inequalities persist with over 90% of poor Maldivians living in Atolls. Youth unemployment is high at 15.3%, with young males being 1.5 times more likely to be unemployed than young females, and 6 times more likely to be unemployed than their older counterparts. Almost one in four Maldivian youth were not in education, employment or training.

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56 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/full/10.1002/wcc.165

57 Klint, L. M., Jiang, M., Law, A., Delacy, T., Filep, S., Calgaro, E., . . . Harrison, D. (2012). Dive tourism in Luganville, Vanuatu: Shocks, stressors, and vulnerability to climate change. Tourism in Marine Environments, 8(1–2), 91–109. URL: https://researchers.mq.edu.au/en/publications/dive-tourism-in-luganville-vanuatu-shocks-stressors-and-vulnerabi

58 Scott, D., Gössling, S., Hall, C. M., & Peeters, P. (2016). Can tourism be part of the decarbonized global economy? The costs and risks of alternate carbon reduction policy pathways. Journal of Sustainable Tourism, 24(1), 52–72. URL: https://www.tandfonline.com/doi/abs/10.1080/09669582.2015.1107080

59 ADB (2019). Basic Statistics 2019. URL: https://www.adb.org/countries/maldives/poverty [accessed 30/06/2019]

60 Sugiyarto and Hagiwara (2005). Poverty impacts of the Tsunami: An initial assessment and scenario analysis. Proceeding of the 2005 CBMS Network Meeting. URL: https://www.academia.edu/1330754/Poverty_Impacts_of_the_Tsunami_An_Initial_Assessment_and_Scenario_Analysis

As the majority of the population is dependent on tourism or fisheries for livelihoods, this makes many Maldivians particularly at risk to climate-related impacts. In addition, due to problems of groundwater contamination and saltwater intrusion, there are existing challenges in accessing potable water, and as such many spend on expensive desalinated alternatives. Climate change is thus likely to disproportionately affect more deprived elements of society, as the poorest groups and communities are the least able to afford desalinated water sources or otherwise local rainwater storage options. In responding to challenges, the government has initiated the Greater Malé development strategy, involving investments in larger islands for improved basic service delivery, protection of households from the impact of climate change and natural disasters, and creation of economic opportunities. However, a specific difficulty of the country's geography leads to a dispersed population across many small islands, which makes service delivery problematic and can limit opportunities for job creation and economic diversification. This dispersed population also presents communication challenges which undermine the provision of valuable preparedness and adaptation information. Transportation continues to be a problem for Maldives with transport costs remaining high. High transport costs also continue to be a limitation for decentralized service delivery.

Gender

An increasing body of research has shown that climate-related disasters have impacted human populations in many areas including agricultural production, food security, water management and public health. The level of impacts and coping strategies of populations depends heavily on their socio-economic status, socio-cultural norms, access to resources, poverty as well as gender. Research has also provided more evidence that the effects are not gender neutral, as women and children are among the highest risk groups. Key factors that account for the differences between women's and men's vulnerability to climate change risks include: gender-based differences in time use; access to assets and credit, treatment by formal institutions, which can constrain women's opportunities, limited access to policy discussions and decision making, and a lack of sex-disaggregated data for policy change.[61]

Human Health

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.[62] Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human health. Climate change will push global temperatures closer to this temperature 'danger zone' both through slow-onset warming via an increase mean annual temperature and the intensity and frequency of heat waves. Although there are challenges of limited downscaled climate information to specify projections, it is likely that climate change will result in an increased number of people at risk of heat-related medical conditions, perhaps specifically related to the elderly, children, the chronically ill, the socially isolated and at-risk occupational groups.[62] It should be noted that the potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).[63]

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61 World Bank Group (2016). Gender Equality, Poverty Reduction, and Inclusive Growth. URL: http://documents1.worldbank.org/curated/en/820851467992505410/pdf/102114-REVISED-PUBLIC-WBG-Gender-Strategy.pdf

62 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

63 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

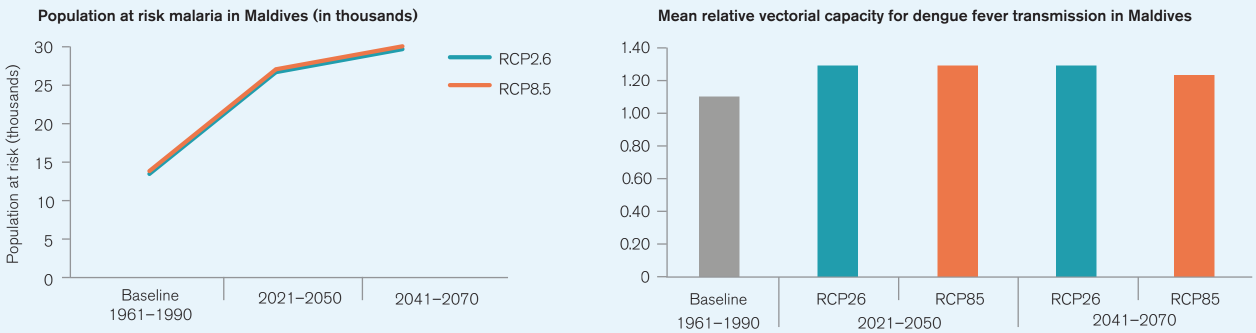
Disease and General Health

According to the WHO "some of the world's most virulent infections are also highly sensitive to climate: temperature, precipitation and humidity have a strong influence on the life-cycles of the vectors and the infectious agents they carry and influence the transmission of water and foodborne diseases". Climate change threatens to slow progress in tackling the spread of disease.[64]

While malaria has not been strongly prevalent in Maldives in the past (the number of malaria cases averaged 16 per year, with no fatalities, over 1990–2003)[10], towards 2070, under both high and low emissions scenarios, about 25,000 people are projected to be at risk of malaria as shown in **Figure 13**. Population growth can also cause increases in the population at-risk in areas where malaria presence is static in the future. As well, the mean relative vectorial capacity for dengue fever transmission is projected to increase from the baseline under both a high and low emissions scenario.

Sea-level rise also poses a serious threat to the water security of island nations due to its potential to salinate potable water sources, and further, saline intrusion to drinking water sources has been linked to the increased prevalence of hypertension during pregnancy.[65]

FIGURE 13. Climate change risk of infectious and vector-borne diseases in Maldives[62]



[64] World Health Organization (2015). Climate and Health Country Profile – 2015 Maldives. URL: https://apps.who.int/iris/bitstream/handle/10665/246134/WHO-FWC-PHE-EPE-15.25-eng.pdf;jsessionid=5651871F0A299CD7506A29CACD4403C5?sequence=1

[65] Khan, A. E., Ireson, A., Kovats, S., Mojumder, S. K., Khusru, A., Rahman, A., & Vineis, P. (2011). Drinking water salinity and maternal health in coastal Bangladesh: implications of climate change. Environmental health perspectives, 119(9), 1328–1332. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3230389/

National Adaptation Policies and Plans

TABLE 3. Key national adaptation policies, strategies and plans

Policy/Strategy/Plan	Status	Document Access
Strategic Action Plan 2019–2023	Enacted	October, 2019
Updated Nationally Determined Contribution to Paris Climate Agreement	Submitted	2020
National Communications to the UNFCCC	Two submitted	Latest: October, 2016
Maldives Climate Change Policy Framework	Enacted	August, 2015
National Adaptation Program of Action (NAPA)	Enacted	December, 2006
Disaster Management Act	Enacted	October 2007
Second National Environment Plan	Enacted	1999
National Community Based Disaster Risk Reduction Framework	Enacted	2014
Health Master Plan 2016–2025	Enacted	2014

Climate Change Priorities of ADB and the WBG

ADB Country Partnership Strategy

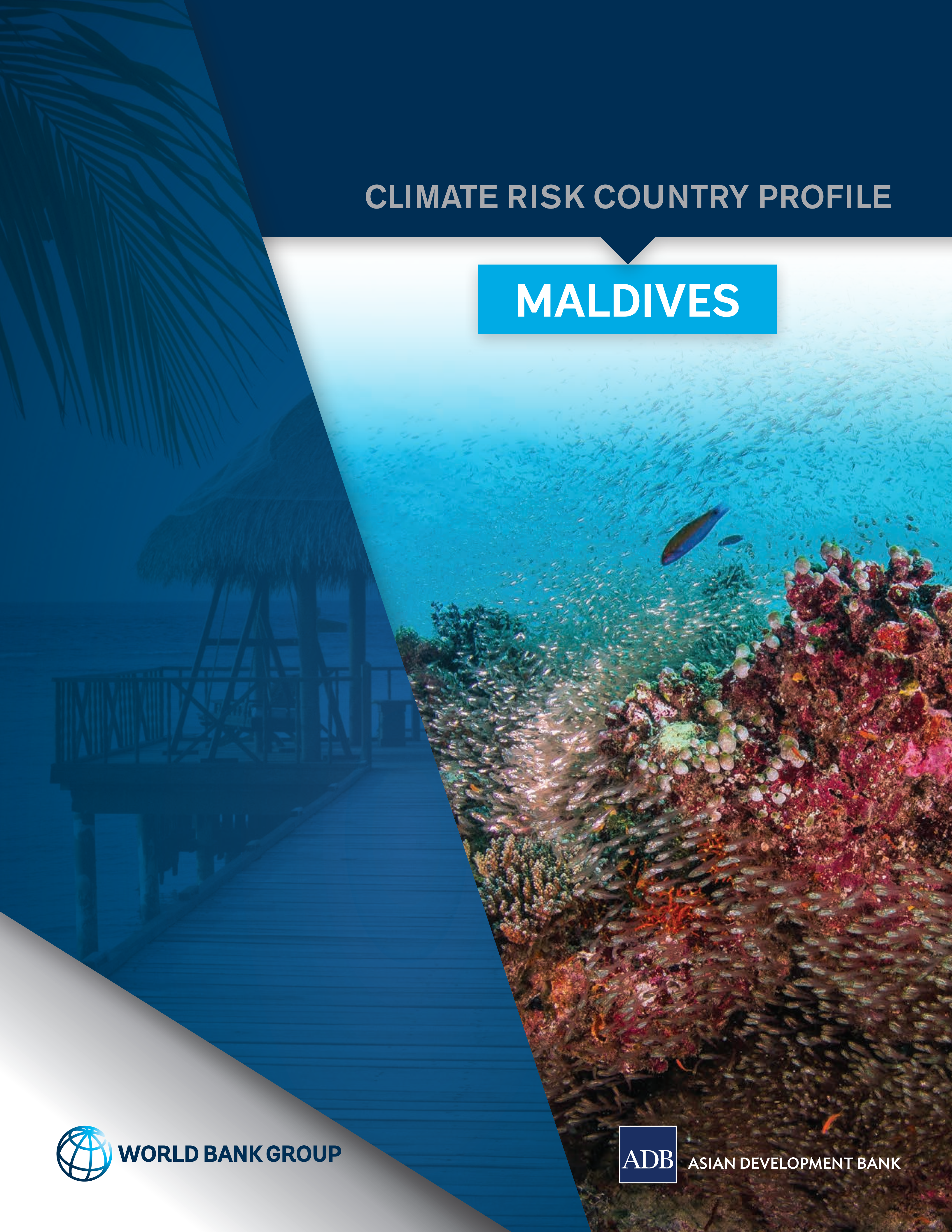
Asian Development Bank Country Partnership Strategy 2020–2024 supports the provision of a resilient and sustainable island life for all Maldivians. The CPS strategic objectives are to (i) enhance public sector efficiency and fiscal sustainability by improving the quality and efficiency of public services and SOEs, and tax administration; (ii) strengthen competitiveness and diversify the economic base by supporting private sector development, strengthening human development in health and education sectors, and improving international trade environment; and (iii) improve quality of life of island communities while ensuring environmental sustainability by investing in clean energy; solid waste management; and preservation of marine environment, climate adaptation, and disaster risk management. The CPS emphasizes the need for climate change adaptation, environmental protection and disaster risk management.

WBG Country Partnership Framework

The WBG's Country Partnership Framework (FY16–FY19) aims to contribute to the achievement of some of the government's medium-term goals in areas that are critical for the reduction of extreme poverty and the promotion of shared prosperity, and consistent with the WBG's comparative advantage. In the aftermath of the global crisis, Maldives underwent a challenging period marked by a complex political transition and substantial macroeconomic uncertainties. The findings of the 2015 systematic country diagnostic (SCD) have re-oriented the WBG program towards enhancing opportunities for the local population in tourism and fisheries (traditional growth sources), enabling opportunities for creation of new sources of growth which are inclusive, and improving management of the country's wealth-generating natural resources and financial resources to better redistribute wealth. The SCD identified the most critical constraints and opportunities facing Maldives in accelerating progress toward the goals of ending extreme poverty and promoting shared prosperity in a sustainable manner. The CPF supports the country's agenda for climate change mitigation and adaptation and mainstreaming, with specific focus on fisheries and coastal and marine ecosystems.

CLIMATE RISK COUNTRY PROFILE

MALDIVES



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