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FIJI

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May 30, 2025

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Asia and Pacific Department

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CONTENTS

CLIMATE CHANGE AND SEA LEVEL RISE

Fiji is an archipelagic country consisting of over 332 islands in the South Pacific Ocean, highly exposed to changes in sea level. Data shows strong positive trends in air and ocean temperatures, acidification of the oceans, and continuing sea-level rise (SLR). These trends are projected to continue in the future with high confidence. Precipitation and other climate extremes have instead remained largely unchanged over long time scales and are not projected to change significantly. SLR could cause annual losses equal to 1.8 percent of GDP, on average, from 2020 to 2099. Building coastal protection is effective at limiting SLR impacts but is expensive and may not contribute to significant net cost savings. Planned retreat from the coastline can instead reduce costs from 1.8 (i.e., without any adaptation) to 0.3 percent of GDP, but it requires careful planning and a participatory approach to ensure an orderly and equitable transition. The Government of Fiji has recognized that adaptation must entail a mix of protection and retreat from the coastline, and advanced Planned Relocation Guidelines were launched in 2018 to provide a framework for planned relocation. Relocation is financed by the innovative Climate Relocation of Communities (CROC) Trust Fund, and high-resolution data is available for planning purposes. This advanced adaptation strategy to sea-level rise is in line with principles on efficient adaptation to climate change published in IMF Staff Climate Notes and is supported by the empirical analysis presented in this Annex. With growing climate challenges ahead, the explicit consideration of costs and benefits of alternative adaptations in coastal management, as well as in all other sectors, can help contain fiscal costs, maximize the impact of international finance, and boost the overall welfare impact of adaptation for the population of Fiji.

A. Climate Trends and Projections

1. **Fiji is experiencing a positive warming trend while precipitations and other weather extremes are relatively unchanged.**[1] Mean annual temperature has increased by 0.3 °C between 1960-1990 and 1984-2014, and by an estimated additional 0.3 °C after 1984-2014, one of the slowest warming trends observed across all countries. There is no discernible trend in total annual precipitations, but variability, driven by El Niño Southern Oscillation (ENSO), is large and total annual rainfall can range between 2,000 and 4,000 mm/year. The seasonal cycle of both temperatures and precipitations has not significantly changed. Observed changes in key indicators of droughts and intense precipitations are modest and likely caused by medium-term natural cycles.

2. **Climate models project continued warming but no significant change in total annual precipitations and other weather extremes, including tropical cyclones.** Temperature is projected to rise between 0.8 and 1.1 °C in 2050 and between 0.8 and 2.0 °C in 2085, with respect to the 1985-2014 reference period, depending on the emission scenario. Median projections of precipitations and other key indicators of extreme weather indicate minor changes relatively to

[1] This assessment relies on the most recent set of IPCC scenarios and on a review of the literature and is mostly in line with the analysis in the country National Adaptation Plan (NAP) and with a comprehensive analysis of climate variability, extremes and change in the Western Topical Pacific by the Australian climate research center CSIRO (Australian Bureau of Meteorology and CSIRO, 2014). For more details, charts, and maps with climate data see Appendix I.

average total annual precipitations and models do not agree on the direction of change. Extreme temperatures are never observed in Fiji and continue not to be a risk even in fast warming scenarios. Tropical cyclones, a significant threat to the economy and population in Fiji, are predicted to decline in the future, but uncertainty is large.

3. **Sea-level rise, a risk that can be managed but not avoided, presents long-term macrocritical challenges that require effective and efficient adaptation policies.** Sea-level is increasing at approximately 4.7 mm per year and will continue to rise for centuries, even in the most optimistic emissions scenarios. In 2100, in a fast-warming and accelerated-melting scenario, sea level could be up to 1.0 m higher than in 2000, a macrocritical risk for a country in which 90 percent of the population and most economic activity are concentrated along the coastline. By proactively adapting, it is possible to substantially reduce the impacts of sea level rise on the economy and on the population. However, misguided policies can create substantial fiscal risks. The next section presents estimates of sea level rise costs and discusses how the government can maximize the impacts of its policies while minimizing macroeconomic risks. The final section extends these recommendations to adaptation spending across sectors.

B. Sea-Level Rise Impacts and Adaptation

4. **Fiji alone cannot control global sea-level, but it can minimize losses by adapting along the lines developed in the advance national adaptation strategy.** Mitigation policy is key to limiting the speed of sea-level rise (SLR) during this century and the overall extent of SLR in future centuries, but adaptation plays a crucial role to limit the unavoidable impacts of SLR.

5. **Using the state-of-the-art model of SLR costs and adaptation CIAM (Diaz, 2016), IMF staff estimates that the annual cost of SLR without adaptation is approximately equal to 1.8 percent of GDP, on average, from 2020 to 2099 (Figure 1).** This central case assumes moderate emissions and median sea-level projections.[2] Using the full range of scenarios available, costs range between 0.9 and 2.6 percent of GDP annually with the lowest SLR projection for the lowest emission scenario and the largest SLR projection for the highest emission scenario, respectively. All details on the model and scenarios are provided in Appendix II. Most of the cost is attributed to deaths and loss of capital during storms. The model does not project change in the frequency and intensity of storms - which may overestimate future risks if TCs decline in frequency - but storm surge can be more harmful due to SLR. The remaining fraction of the costs is caused by loss of land from permanent inundation and by monetized disutility losses from forced relocation. Loss of wetlands contributes modestly to total losses. These costs measure welfare losses and are the appropriate metric to estimate the full economic impact of SLR. However, they cannot be translated into GDP losses or other fiscal impacts without other models or additional assumptions. The literature uses

[2] CIAM uses sea-level rise projections derived by Kopp et al. (2014) using the older vintage of IPCC emissions scenarios. The analysis in this Annex uses median sea-level change projected using the RCP4.5 emissions scenario as a central case (+0.7 above sea-level in 2000), and the 90 percent range around the median (+0.4m to 1.11m) to illustrate uncertainty in sea-level projections. meters above the sea-level in 2000. The central case is similar to sea-level projected using the SSP2-4.5 scenario and the upper end of the range encompasses the low-likelihood worst case scenario in shown in Figure 1.

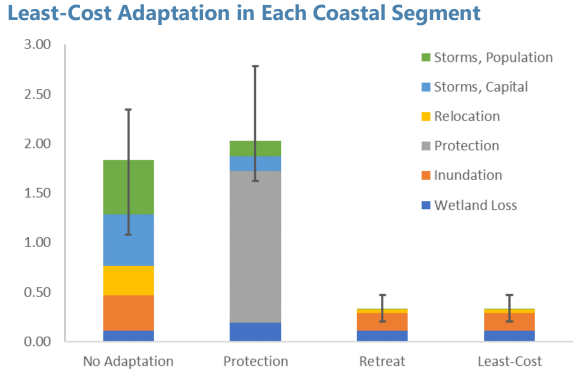
general equilibrium models to translate loss of capital and land into long-term macroeconomic impacts, including global trade effects (e.g., Bosello et al., 2012). Alternatively, it is possible to derive first-order approximations of the fiscal costs of SLR by assuming how much of the social cost of SLR is either directly borne by the public sector or compensated with public finances. Direct losses may derive from reconstruction costs of public assets and purchase of new land for public use. Losses of private capital and private land may have an impact on public finances if they affect tax revenues, or if the government compensates private losses. Increased spending on social programs aimed at easing disutility costs of relocation from inundated areas can lead to higher expenses. If the government assumes full responsibility for all losses, including the adverse effects of relocation, the costs presented in Figure 1 can be interpreted as an upper bound to government financing needs.

6. **Coastal protection can be very effective at limiting SLR impacts, but it is expensive and can result in overall costs larger than the no adaptation scenario in Fiji, even after accounting for benefits to the populations and capital saved (Figure 1).** CIAM calculates the cost of SLR and the cost of protection considering many factors, including coastal topography, distribution of population and capital, and protection costs. An investment of approximately 1.5 percent of GDP annually throughout the century is needed to protect all the coastline in a cost-effective way. In most segments this implies protection against 1/1,000-year storms (Figure 1) because these events, even if rare, can cause large human and capital losses. Protection of the coastline disrupts the natural exchange of waters between wetlands and open seas, leading to potential biodiversity losses, which are estimated to total 0.2 percent of GDP annually (higher than in the case of no adaptation). Nature-based protection, for example coastal buffer zones with mangroves, land reclamation, and vetiver grass can be cost-effective and have positive environmental externalities, as emphasized by Fiji's coastal protection strategy, but it is not considered by CIAM because more granular data is needed to assess the viability and effectiveness of this strategy. Cost-effective protection does not reduce to zero risks from rare but potentially very damaging storms. The result that protection is more costly than no adaptation may appear counterintuitive but is explained by the large cost of protection compared to the value of assets and land protected. A major study in the literature, agrees that coastal protection is expensive in Fiji and not cost-effective under all alternative model specifications (Hinkel et al., 2018).

7. **Planned retreat from the coastline is the least-cost adaptation strategy according to the CIAM model.** CIAM estimates that the cost of planned retreat is equal to 0.3 percent of GDP, on average between 2020 and 2100 (Figure 1). Planned retreat relies on a pro-active move of the population and on a long-term strategy that let assets exposed to permanent

Figure 1. Fiji: Cost of Sea-Level Rise, Annual Average 2020-2099, Percentage of GDP

Least-Cost Adaptation in Each Coastal Segment



Source: IMF Staff using the CIAM model (Diaz, 2016).
Notes: Average annual cost in percentage of GDP estimated assuming +0.7m of sea-level change with respect to the year 2000 (RCP4.5 scenario in Kopp et al., 2014). Whiskers on top of each bar indicate the range of total cost using the 5[th] (+0.4m) and 95[th] (+1.11m) percentile of the probabilistic distribution of SLR. Due to the highly non-linear nature of coastal impacts, adaptation costs, and effectiveness of adaptation measures, ranges are not always symmetric around total costs. The left panel shows sums of SLR costs in Fiji if all coastal segments adopt the same adaptation strategy.

inundation depreciate over time. In this gradual process capital losses are minimal and only bare land is lost to the sea. The opportunity cost of land in areas where the population relocates is included in cost calculations and is assumed to be equal to the value of interior agricultural or marginal land in the country (Yohe, 1990).

8. Planned retreat does not require investment in protection, but it still entails fiscal costs to finance relocation of vulnerable communities, and a long-term participatory approach is needed for an efficient and equitable retreat. The population affected does not need to move long distance to avoid sea-level rise predicted for this century in most cases (Box 2), but even limited moves can entail large direct costs, cultural losses, and emotional burden. A long-term participatory approach involving local communities is key to the viability and equity of planned relocation as long-term adaptation strategy (Box 1). A disorderly retreat can be costly, unjust, and ineffective.

9. The Government of Fiji recognizes that at least some communities and infrastructure will need to be permanently relocated and has made plans and built institutions to facilitate relocation.[3] The Government has launched Planned Relocation Guidelines (PRG) in 2018, and it has established a Relocation Taskforce (FTRD) to coordinate planned relocation in Fiji. The Climate Relocation of Communities (CROC) Trust Fund was established in 2020 to finance planned relocation and is funded by 3 percent of revenue from the Climate and Environmental Levy (ECAL) and bilateral and multilateral donor funds. This suite of policies and facilities can serve as a model for other countries.

10. Estimates of long-term costs and benefits of protection and relocation can help plan adaptation, ensure adequate financing for the CROC, and contribute to sustainable and efficient public finances.

- Protecting large parts of the coastline can be extremely expensive but also planned retreat requires a substantial increase of adaptation spending. The relocation of six communities since 2011 is estimated to have costed FJD 3.6 million, or about 0.03 percent of GDP.[4] CIAM estimates that planned relocation costs can be ten times larger as more areas are exposed to sea-level rise, including parts of the coastline with high population density and infrastructure that have been spared so far.[5]

- With many protection and relocation strategies available, the explicit consideration of costs and benefits of alternative options can help maximize the impact of public funds and of international aid, while maximizing social welfare. Cost-Benefit Analysis (CBA) can be challenging, but even

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[3] Fiji Ministry of Economy Climate Change and International Cooperation Division (2018). http://fijiclimatechangeportal.gov.fj/wp-content/uploads/2022/01/Fiji_National-Adaptation-Plan.pdf.

[4] Relocation affected 78 households, for an average cost of FJD 46,300 per household.

[5] The cost of relocation includes the opportunity cost of land where the population moves, proxied by interior agricultural land values (see Box 1).

Box 1. Fiji: Coastal Relocation

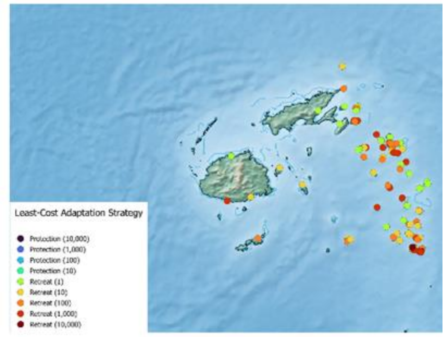
As the coastline of Fiji is very heterogeneous, adaptation plans must rely on granular data and leverage local knowledge. To provide a first approximation of this heterogeneity, CIAM has divided Fiji's coastline into 137 segments. Coastal segments vary in length from 0.4 km to 619.2 km, with a median length of 1.9 km. This allows for insights into spatial differences in the optimal extent of retreat, as shown in the figure on the right. However, much more granular data is needed to precisely identify risks and to create final adaptation plans.

For example, the Figure on the right shows a digital elevation model data map for city of Nadi. The area suitable for development within the town boundaries is as large as the area exposed to sea-level rise and with high flood risk. Relocation within the town boundaries may be an effective retreat strategy for at least one century.

The Figures below shows that half of the Lomaloma village on Vanua Balavu Island will be permanently flooded with 1 meter of sea level rise. The Authorities can start alerting the population about this unavoidable risk, allowing enough time to consider alternative adaptation options. The red arrows drawn by IMF Staff on the map show hypothetical areas of retreat within the vicinities of inundated areas.

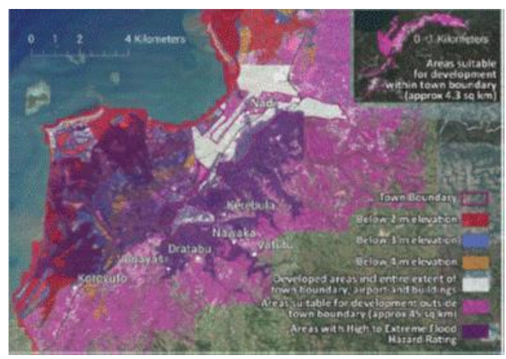
However, even relatively short-distance relocations can extoll large costs and emotional burden on the populations involved. Surveys of households in the villages of Votua, Nawaqarua, and Etatoko, located along the lower Ba River Catchment on Fiji's main island, Viti Levu, reveal mixed attitudes of the local population towards relocation after their communities have been affected by severe floods.[1] Cultural ties with

Fiji: Optimal Adaptation Strategy by Coastal Segment



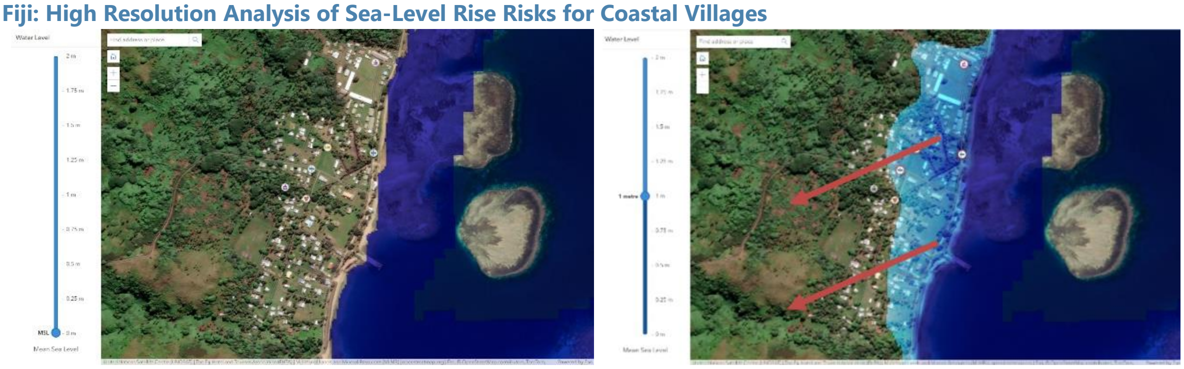
Source: IMF Staff based on coastal segment characteristics from the CIAM model (Diaz, 2016), country boundaries from EuroGeographics and UN-FAO, and free Natural Hearth vector and raster map data @ naturalearthdata.com.
Notes: Numbers in parenthesis indicate the level of protection against storm-surge floods, from 1/10 to 1/10,000 events (non-relevant categories omitted). Retreat (1) indicates a retreat perimeter that deals only with SLR and does not consider storm surge risks.

Fiji: High Resolution Analysis of Sea-Level Rise Risks in the City of Nadi



Source: Fiji Climate Vulnerability Assessment, Figure B4.1.1.
Note: Digital elevation model data for Nadi. Risk-informed urbanization planning can help accommodate growing urban population while limiting the increase in natural risks.

Fiji: High Resolution Analysis of Sea-Level Rise Risks for Coastal Villages



Source: Fiji Sea Level Rise and Critical Infrastructure tool, available at https://unosat-geodrr.cern.ch/apps/FJI/SeaLevelRise/. Elevation dataset derived from FABDEM (Forest and Buildings removed Copernicus DEM) data (Hawker, et al., 2022).
Notes: Lomaloma village, Vanua Balavu Island. Left: Present sea level. Right: 1m above present sea level. Red arrows indicate potential areas for relocation within the same area (added by IMF Staff).

Box 1. Fiji: Coastal Relocation (concluded)

the land, history, and livelihoods, as well as the lack of land with productivity and amenities like their land of origin, pose significant challenges. Existing land ownership arrangements may constrain local resettlement. For example, a long-term lease on a former sugarcane plantation was cut short to accommodate households leaving the Etatoko village.[1] Construction of new houses was entirely supported by external aid. Elders are more reluctant to move but as the younger generation moves to non-agricultural wage labor and high-skilled jobs in larger towns is more open to relocation.[1] A participatory approach in which experts and local community discussed all the available options built trust and persuaded elders to move from the Vunidogoloa village in low-lying Serua Island.[2] The new village is now located 1.5 km inland, on Vanua Levu Island, on dry grounds.

This partial and anecdotal review of relocation challenges after flood events cannot be used to draw firm conclusions about the viability of a nation-wide planned retreat from long-term sea-level rise, but it provides important insights. The government can facilitate coastal adaptation by engaging early with local communities to understand their needs and offer the most appropriate solutions. Legal and unwritten norms that regulate local land ownership may have to be revised. Financial support is likely needed to reduce direct relocation costs and compensate for the loss of amenities.

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[1] Neef et al. (2018).

[2] Rising sea levels are forcing Fiji's villagers to relocate. They want polluters to pay instead | The Wider Image | Reuters accessed on January 18, 2025

preliminary and incomplete assessments of costs and benefits of alternative adaptation options to SLR are useful to identify trade-offs and the most attractive policy options using a transparent and systematic approach (Bellon and Massetti, 2022a). In the Netherlands, a country that faces immense coastal management challenges, there is a long-standing tradition of using CBA and cost-effectiveness analysis for flood risk management and water governance. This tradition started in 1954 with the pioneering CBA of the Delta Works by Tinbergen (1954) and continues to this day (Bos and Zwaneveld, 2017).

- More granular data is necessary to exactly determine costs, protection needs, and retreat potential in a small island in which population and capital are concentrated along the coastline as in Fiji, but this preliminary analysis using CIAM establishes a useful roadmap. CIAM has information on the average coastal slope for the entire island, but it does not capture coastal characteristics that will eventually determine if specific areas will be inundated or not. Hyper-resolution maps of elevation, currents, tides, infrastructure, and population must be developed as the basis for a more accurate assessment. While the model captures baseline erosion and vertical land movement, it does not capture the interaction of sea-level rise with the ongoing coastal erosion processes. The model also does not capture the cost of infiltration of saline water into coastal aquifers. However, the model includes non-market costs such as loss of life due to storm floods, wetland loss, and disutility from relocation.

- Fiji's Government has already made substantial progress towards building a national database that can support more detailed analysis. The Sea Level Rise and Critical Infrastructure portal distributes state-of-the-art high-resolution flood maps with sea-level rise up to 2m.[6] By using data from a state-of-the-art digital elevation model (DEM) (Hawker et al., 2022), the portal interactively shows assets and population that can be flooded with sea-level rise from 0 to 2 m.[7] All this information can be combined with local estimates of protection costs, land values, value of assets at risks, population density, and value of ecosystem services.

C. Effective and Efficient Adaptation Policies

11. The Fijian government has a detailed and active climate policy agenda supported by an articulated National Adaptation Plan (NAP). Fiji was the first country to ratify the Paris Agreement in 2015, the first small island state to assume presidency of the United Nations Framework Convention on Climate Change in 2017. One of the first countries that submitted a NAP in 2018 (Singh et al., 2023) and with a new NAP in preparation, Fiji is well-positioned to implement an effective adaptation strategy.

12. The 160 adaptation Actions identified in the 2018 NAP identify important adaptation goals, but the effectiveness, efficiency, and fiscal sustainability of policies and concrete measures to achieve these goals needs additional criteria.[8] For example, Action 12.A.12 sets the goal to "enhance support for irrigation schemes which support agricultural diversification and mitigate increased drought and flooding"; Action 12.A.13 sets the goal to "maintain, adapt and construct sea wall and drainage infrastructure to reduce saltwater intrusion on agricultural land due to sea level rise and increased tidal surges"; Action 16.5 mandates to "strengthen the management an monitoring of ecosystems." These goals can be implemented in many ways and different intensity. Sea walls can be of different extension, different height, to protect against different storm surge levels, be made of concrete or nature-based solutions. Retreat perimeters can vary in extent. If protection of ecosystems requires preventing development of coastal areas for tourism, how is it possible to assess the trade-offs? For what level of water demand should irrigation schemes be sized? And, finally, how to determine the most efficient mix of public and private investment in adaptation?

13. While determining with precision what should be done, and at what cost is extremely difficult, it is possible to build a roadmap by starting from important general principles. IMF Staff has developed guidance to help countries adapt by integrating climate change in macro-fiscal

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[6] The Fiji Climate Change Information Hub serves as a model for other nations, offering comprehensive access to information on the country's climate change policies, projections, and impacts. By working closely with the United Nations, development partners, and the scientific community, the Government of Fiji has built a rich Geographic Information System (GIS) Platform with information on assets and population exposed to climate change risks and sea-level rise.

[7] The global DEM used for the portal provides the most accurate elevation data available on a global grid, but DEMs are subject to measurement error. In this case the mean vertical error is equal to +/- 1.12 m, which is larger than expected sea level rise at the end of the century. Hyper resolution local elevation maps are needed for planning purposes.

[8] Fiji Ministry of Economy Climate Change and International Cooperation Division (2018). Available at: http://fijiclimatechangeportal.gov.fj/wp-content/uploads/2022/01/Fiji_National-Adaptation-Plan.pdf.

planning (Gonguet et al. 2021; Bellon and Massetti, 2022a,b; Aligishiev, Bellon, and Massetti, 2022; Sakrak et al. 2022). These principles frame adaptation in terms familiar to economists and in the broader context of sustainable development, with the intent of guiding public investment and enabling efficient private adaptation.

14. Adaptation would be most effective if it is an integral part of development planning. In the Paris Agreement (Article 7), adaptation is established as "the global goal of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development." The 2018 NAP builds upon this principle and "adaptation is seen as synonymous with climate-resilient development."[9] This implies that investments in climate change adaptation are similar to other investments in development because their common goal is to maximize future welfare given the available resources (Bellon and Massetti, 2022a).

15. With many competing needs, the government must carefully allocate resources across all possible uses, including adaptation to climate change, while considering the distributional effects of its programs. This requires: (i) concentrating government efforts and resources in key areas; and (ii) collecting information on how effective spending is across alternative programs and how spending affects distinct groups in society (Bellon and Massetti, 2022a).

16. The government can prioritize adaptation policies with positive externalities, by removing the market imperfections and policies that hinder efficient private adaptation, and by ensuring a just transition (Box 2). Individuals and firms have strong incentives to adapt because many adaptation benefits tend to be local and private. As stated in the 2018 NAP, "it is at the local level where most adaptations take place – typically by households, communities, and businesses – and never 'to them' by outside stakeholders."[10] Even poor communities have the incentive to adapt. For example, many autonomous adaptations are observed in villages along the Ba River, in the Ba Province on the main island of Viti Levu (Singh et al., 2023). Villagers are reported having planted trees around riverbanks and shifted plantations away from coastal areas to avoid increased flooding risks. They increased planning of drought-resistant crop varieties, increased the practice of multi-cropping to reduce crop failure risks, and changed harvesting times of mussels and prawns. New houses are built on raised platforms. All these adaptations have immediate and local benefits that require, at most, community-level coordination. However, there is a clear role for government intervention when adaptation has large externalities, as in the case of coastal protection in cities, strengthening of public infrastructure, or access to climate and information services. For example, the Fiji Meteorological Service is instrumental to distribute information on weather and long-term climate change that enables private adaptation. As market inefficiencies and policy failures may limit private adaptation or create distortions, another key role for the government is to continue promoting reforms that ease the efficient use of all resources and ensure competitive access to markets (Bellon and Massetti, 2022a). For example, access to credit markets allows farmers

[9] Fiji Ministry of Economy Climate Change and International Cooperation Division (2018, p.3).

[10] Fiji Ministry of Economy Climate Change and International Cooperation Division (2018, p.3).

to invest in adaptation and efficient water pricing creates incentives to conserve water. By removing barriers to private adaptation, the government can unlock local and traditional knowledge about the most efficient adaptations (e.g., Singh et al, 2023) while preserving government funding for essential public projects.

17. Despite limitations, cost-benefit analysis (CBA) can play an important role in helping decision makers to consistently collect, aggregate, and compare information on public adaptation projects. What to do, when, how, and at what cost ultimately relies on ethical choices that should reflect the preferences of Fiji's government and population. However, cost-benefit analysis (CBA), complemented by analysis and correction of distributional impacts, can help decision makers maximize overall social welfare by avoiding wasting scarce resources. To achieve this goal, it is essential that CBA is applied to adaptation as well as to all other development programs in a consistent manner (Bellon and Massetti, 2022a). This recommendation is in line with Action 8.10 which aims at mainstreaming "cost-benefit analysis, multi-criteria analysis, and other relevant tools (such as gender analysis) into decision-making processes regarding climate change adaptation."[11] While it is not necessary to use CBA to select broad adaptation Actions,[12] the practical implementation of these lines of actions would benefit from the use of quantitative methods that rely on established welfare economics principles. The NAP Costing Methodology developed by the Government can serve as a starting point.

[11] Fiji Ministry of Economy Climate Change and International Cooperation Division (2018, p.48).

[12] Fiji Ministry of Economy Climate Change and International Cooperation Division (2018, p. vii).

Box 2. Fiji: Policies to Facilitate Private Adaptation

In imperfectly competitive markets, adaptation is inefficient, and governments should intervene mirroring standard prescriptions for public policy from economic theory.

- Some market imperfections pertain to the nature of the adaptation goods themselves. For example, markets invest sub-optimally in adaptations with large positive externalities and public goods, such as information about climate change, emergency preparedness plans, seawalls, basic research in new materials, and technologies to cope with higher temperature.

- In many instances, resilience depends on networks, such as a system of dikes, a water network, or a transportation network. As adaptation in each part of a network has impacts on the rest of the network that may not be captured, private adaptation will tend to be underprovided. Government coordination may be needed to internalize all the benefits for society.

- The extent of needed cooperation for adaptation projects depends on the extent of the externality that is addressed by the project. Building a more resilient storm water drainage system may only require cooperation at the city level. If risks from sea-level rise are localized, each locality may invest in its own system of protection. The central government can provide adaptations with local effects, but that would be equivalent to a transfer of wealth between regions when projects are financed from national resources. As risks grow in scope and complexity, cooperation might be needed at the national or even the international level, for example to manage floods in transnational rivers. In general, the optimal distribution of responsibilities across levels of government also depends on the existing allocation of responsibilities.

- Other market imperfections affect the broad functioning of the economy and make adaptation to climate change inefficient. For example, a poor business environment and inefficient credit markets hamper opportunities for farmers to invest in new capital to grow crops that are more suitable to the new climate.

- Moral hazard may cause insufficient investment in adaptation if consumers, firms, and local government expect central governments to provide relief. To avoid moral hazard, governments can implement regulations that minimize risk taking. Examples include zoning that prohibits construction in flood zones, building codes, mandatory evacuations, and mandatory insurance.

- The government may also consider correcting market distortions resulting from their own policies (policy failure). For example, subsidies to inputs can lead to inefficient use. Of particular concern is subsidized water use, which may worsen water scarcity problems due to climate change. Barriers to international trade also prevent efficient climate-change-induced reallocation of capital, land use, and other resources to maximize their productivity. The government may consider removing these distortions as part of a comprehensive plan to improve the efficiency of the economy, while taking into consideration the distributional implications of these measures.

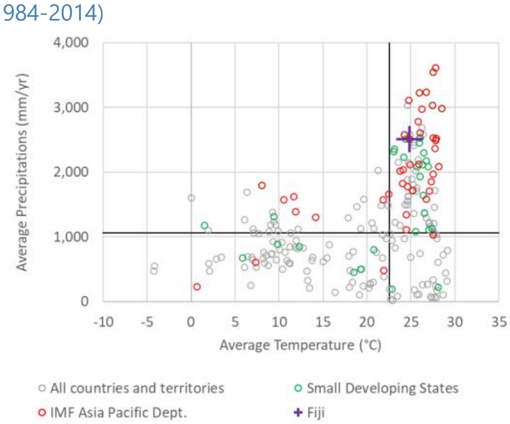
Source: Massetti and Bellon (2022a).

Appendix I. Climate Trends and Projections

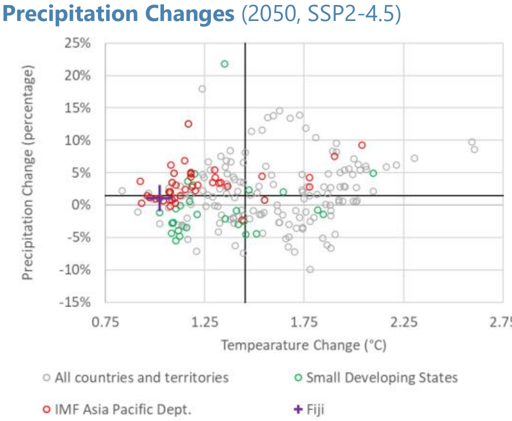
1. Fiji is an archipelagic country consisting of over 332 islands in the South Pacific Ocean with a tropical marine climate. Temperatures do not change significantly throughout the year and are mitigated by the sea. Average annual mean temperature between 1984 and 2014 was equal to 24.9 °C, above the world median, but close to the median in Asia-Pacific countries (25.1 °C) and Small Developing States (26 °C) (Appendix I. Figure 1). Total annual precipitations are equal to 2,500 mm/year on average, a considerably wetter climate than most countries (1,060 mm/year) and then geographic and development peers (Appendix I. Figure 1). Approximately two thirds of total annual rainfall are recorded during the wet season from December to April, but the dry season receives more precipitations (116 mm / month) than most countries on average during a year.

Appendix I. Figure 1. Fiji: Cross-Country Comparison of Climatic Conditions and Projections

Cross-Country Comparison of Climates (1984-2014)



Cross-Country Comparison of Projected Temperature and Precipitation Changes (2050, SSP2-4.5)

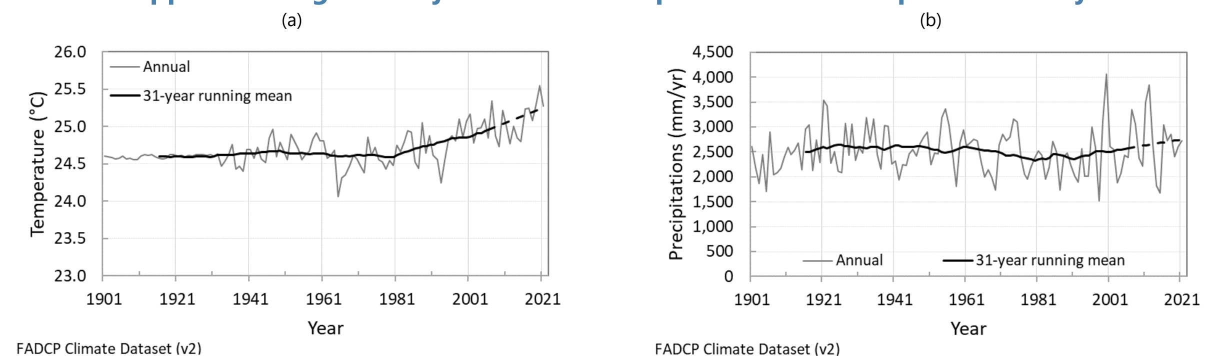


Source: FADCP Climate Dataset (Massetti and Tagklis, 2024), using CRU data (Harris et al., 2020).
Notes: Average annual temperature and precipitation during the period 1984-2014 and temperature change (1984-2014 wrt 1901-1931), using CRU. Bias-adjusted ensemble median projections of temperature and precipitation anomalies in 2036-2065 with respect to 1985-2014 data using CMIP6 data. The SSP2-4.5 scenario represents continuation of present trends. Solid lines display sample medians.

2. Fiji is experiencing a Data shows a positive warming trend since at least the 1960s while precipitations are relatively unchanged (Appendix I. Figure 2). The temperature trend is unambiguous but small compared to other countries (Appendix I. Figure 2). Mean annual temperature has increased by 0.3 °C between 1960-1990 and 1984-2014, and by an estimated additional 0.3 °C after 1984-2014. This is one of the slowest warming trends observed across all countries (13th percentile), and roughly half the size of the trend observed by the median country. Warming has been more intense from July to November than in the rest of the year, but the seasonal cycle has barely changed (Appendix I. Figure 3). There is no discernible trend in total annual precipitations, but variability, driven by El Niño Southern Oscillation (ENSO), is large and total annual rainfall can range between 2,000 and 4,000 mm/year (Appendix I. Figure 2). There is a

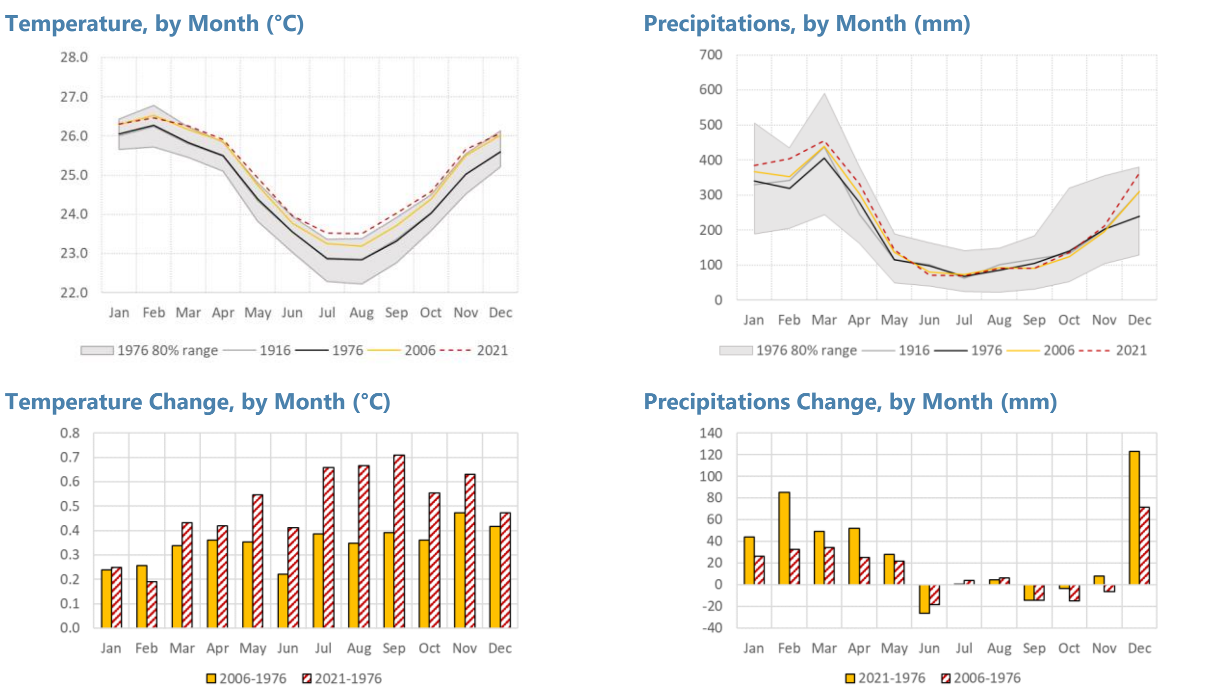
tendency to observe more rainfall during the wet season in recent decades, but changes are small compared to interannual variability and no robust trend appears from annual data (Appendix I. Figure 2).

Appendix I. Figure 2. Fiji: Historical Temperature and Precipitations in Fiji



Source: FADCP Climate Dataset (Massetti and Tagklis, 2024), using CRU data (Harris et al., 2020).
Notes: The solid gray line displays mean annual temperature (a) and total annual precipitations (b). The solid black line displays the 31-year moving average centered around each year. The first complete 15 years of the moving average are not shown because incomplete. The last 15 years show a linear trend estimated using the last 30 years of annual data (dashed). Temperatures before 1930 likely misrepresent interannual volatility due to incomplete records.

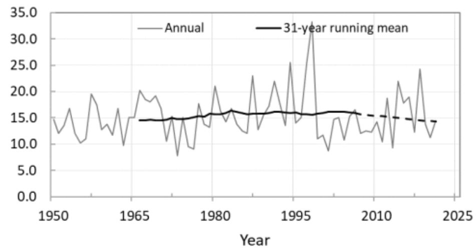
Appendix I. Figure 3. Fiji: Seasonality of Temperature and Precipitations in Fiji



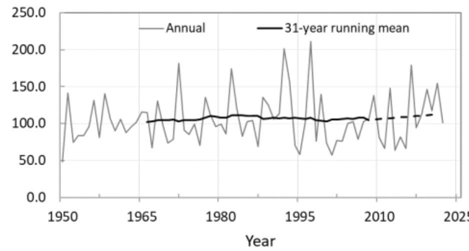
Source: FADCP Climate Dataset (Massetti and Tagklis, 2024), using CRU data (Harris et al., 2020).
Notes: The solid line displays the 30-year average centered around each 30-year period. Edge effects near the beginning and end of the time series may affect the accuracy of the mean in those regions (dashed). Change: 1991-2020 relative to 1961-1990.

Appendix I. Figure 4. Fiji: Historical Time Series of Selected Indicators of Extreme Weather in Fiji

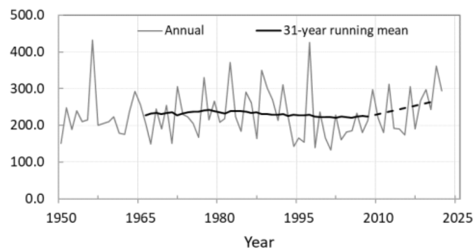
Consecutive Dry Days (Count)



Max 1-Day Precipitation (mm)

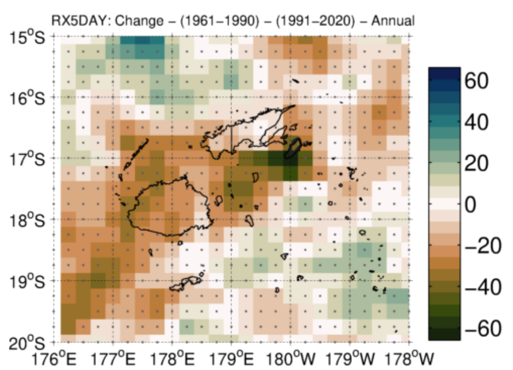


Max 5-Day Precipitation (mm)



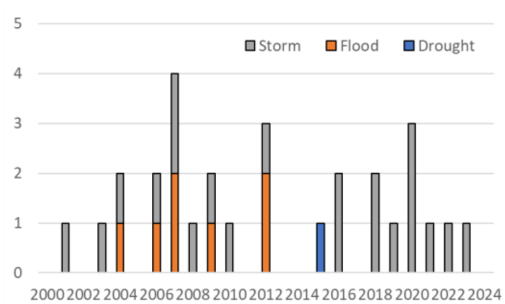
Source: FADCP Climate Dataset (Massetti and Tagklis, 2024), using CRU data (Harris et al., 2020).
Notes: The solid line displays the 30-year average centered around each 30-year period. The first complete 15 years of the moving average are not shown because incomplete. The last 15 years show a linear trend estimated using the last 30 years of annual data (dashed).

Appendix I. Figure 5. Fiji: Change of the Maximum Cumulative 5-Day Total Precipitations in a Year (RX5Day)
(1961-1990 and 1991-2020)



Source: FADCP Climate Dataset (Massetti and Tagklis, 2023), using ERA5 reanalysis data (Hersbach et al. 2023)

Appendix I. Figure 6. Fiji: Number of Climate Disasters in Fiji
(2000-2024)



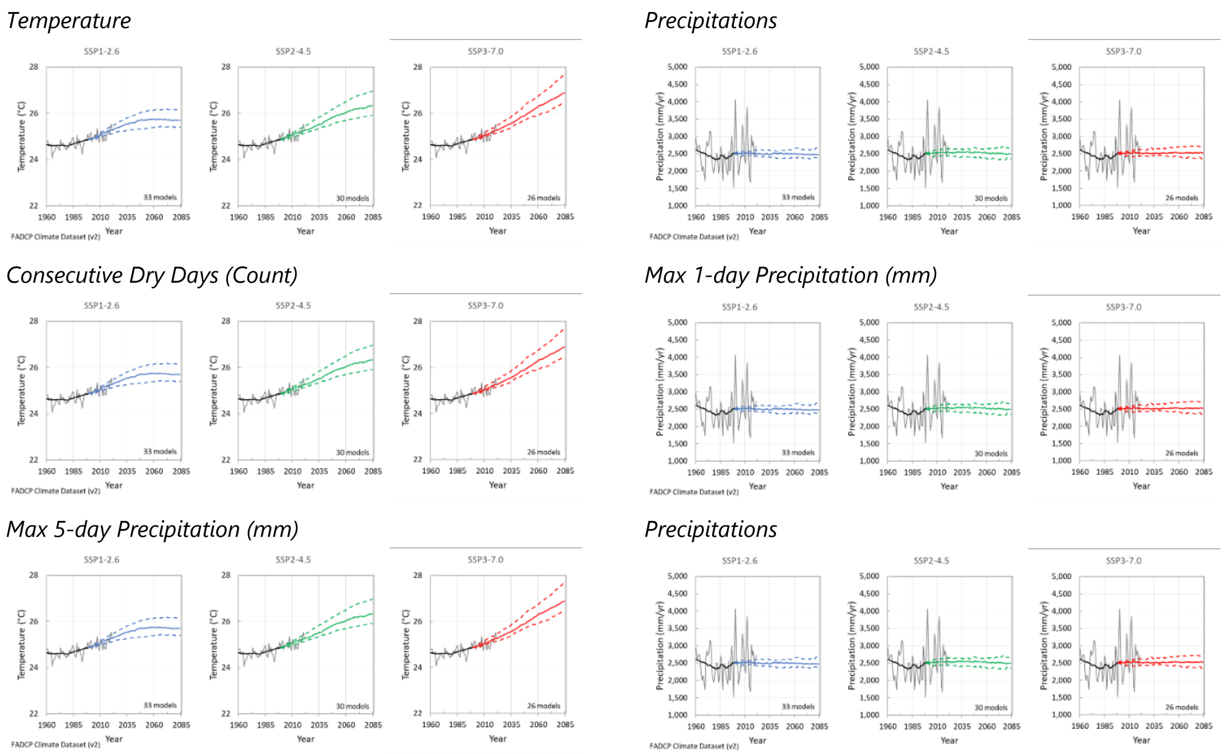
Source: IMF Staff estimates based on data from the EM-DAT database, managed by the Centre for Research on the Epidemiology of Disasters (CRED) (Delforge et al., 2023).

3. Recent years have seen a slight decline in the maximum number of consecutive dry days and an uptick in intense precipitations caused by medium-term natural cycles (Appendix I. Figure 4). There is no significant long-term trend in the maximum number of consecutive dry days in a year (CDD), and in precipitations during the 1-day (RX1Day) and 5-day (RX5Day) periods with the largest precipitation amount in a year. High-resolution analysis over an appropriately long interval does not

reveal a significant increase in the intensity of heavy precipitations anywhere in the country (Appendix I. Figure 5).[1] Analysis of disaster data from the EM-DAT dataset does not show trends in large flood events and in other climate related disasters (Appendix I. Figure 6).[2] Days with maximum daily temperature above 35 °C – a standard threshold used to identify "hot" days – are never observed in the data used for this analysis.

4. Climate models project continued warming but no significant change in total annual precipitations and other weather extremes (Appendix I. Figure 7). Median projections of warming across all climate model simulations indicate that temperature will increase between 0.8 and 1.1 °C in 2050 and between 0.8 and 2.0 °C in 2085, with respect to the 1985-2014 reference period,

Appendix I. Figure 7. Fiji: Historical and Simulated Annual Average Temperature and Total Annual Precipitations in Fiji



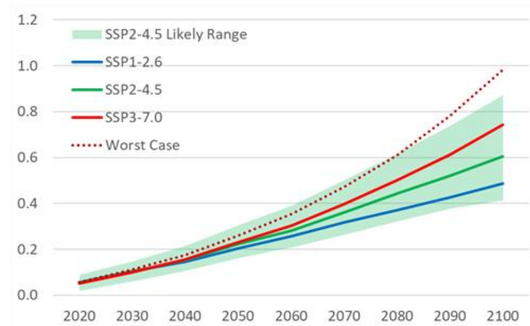
Source: FADCP Climate Dataset (Massetti and Tagklis, 2024), using CRU data (Harris et al., 2020), ERA5 data (Hersbach et al. 2023) and CMIP6 data (Copernicus Climate Change Service, Climate Data Store, 2021: CMIP6 climate projections).
Notes: The gray line describes historical average annual temperature and total annual precipitation based on observations (CRU and ERA5). The black line describes the 30-year moving average of historical data. Colored lines represent the median and the 80 percent range of CMIP6 ensemble temperature anomalies (10th and 90th percentiles) added to the CRU and ERA5 values (thick black line in the year 2000). CMIP6 extreme weather anomalies are combined with ERA5 historical time series but daily projections are not bias-adjusted. SSP1-2.6 scenario is in line with the Paris goal to keep global mean temperature increase below 2ºC with respect to pre-industrial times. SSP2-4.5 represents continuation of present trends. SSP3-7.0 is a high emission scenario.

[1] The increased intensity of 5-day heavy precipitation events from their secular minimum around the year 2000 is likely part of medium-term natural climatic cycles. Long-run projections further suggest that this is a temporary deviation from long-term expected conditions (Figure 7).

[2] Note that EM-DAT covers only major disasters, and hence underestimates the total number of events that cause economic losses and impacts on the population.

depending on the emission scenario (Appendix I. Figure 7).[3] More warming is predicted by individual models and cannot be excluded. In a high-emission, fast-warming scenario (90th percentile across models using the SSP3-7.0 emission scenario) temperature is projected to increase by 2.9 °C in 2085 (Massetti and Tagklis, 2024; Harris et al. 2020; Copernicus Climate Change Service, Climate Data Store, 2021). Median projections of precipitations indicate minor changes relatively to average total annual precipitations and models do not agree on the direction of change. There is not a clear relationship between predicted changes in precipitations and emissions scenarios, which further indicates that natural variability dominates and will continue to dominate any climate change induced changes. There are also not clear signals of changes in the number of maximum consecutive dry days and intense precipitation events.

Appendix I. Figure 8. Fiji: Sea-Level Rise Projections in Fiji Relative to Its Level in the Year 2000 (Meters)



Source: IPCC AR6 data (Fox-Kemper et al., 2021) in proximity of Fiji (latitude -19 and longitude 178) accessed using the IPCC/NASA Sea Level Projection Tool Sea Level Projection Tool – NASA Sea Level Change Portal (Garner et al., 2021). Notes: Sea level change for key SSP scenario resulting from processes in whose projection there is medium confidence. The "Worst Case" case scenario describes the potential of low-probability, high-impact ice sheet processes for which there

5. Sea-level is increasing at approximately 4.7 mm per year, faster than the global average, and will likely continue to increase for centuries, a risk that can be managed but not avoided. Median projections for Fiji using a moderate emission scenario (SSP2-4.5) indicate that by the end of the century sea-level will increase by 0.60 m with respect to its level in 2000 (Appendix I. Figure 8). With an emission scenario in line with the Paris goal of keeping global mean temperature increase below 2 °C (SSP1-2.6), sea-level is projected to increase by 0.49 m by 2100. In the worst case scenario of extremely high emissions and fast ice melting, sea-level is projected to increase by 0.98 m in 2100. Global oceanographic factors, thermal expansion, tectonic activity, and local factors like erosion and land subsidence explain why sea-level rise is faster in Fiji than the global average. With 90 percent of its total population of 900,000 living along the coastline, Fiji is very vulnerable to sea-level rise.

6. Tropical cyclones (TCs), a significant threat to the economy and population in Fiji, are predicted to decline in the future, but uncertainty is large. Approximately 30 TCs cross the Fiji Exclusive Economic Zone per decade but available data is not suitable for a long-term assessment of

[3] We consider three emission scenarios. The SSP1-2.6 scenario is in line with the Paris goal to keep global mean temperature increase below 2 °C with respect to pre-industrial times. SSP2-4.5 represents continuation of present trends. SSP3-7.0 is a high emission scenario. The 90th percentile of the SSP3-7.0 ensemble is used to provide a high-emission, fast-warming, pessimistic case and is named SSP3-7. 90th p. For a discussion of IPCC scenarios, see Bellon and Massetti (2022a) and Massetti and Tagklis (2024).

TCs trends (CSIRO, 2014). There is however consensus among models in predicting an overall decline of TCs genesis in the future because conditions favorable for TCs formation are projected to become less frequent in the region. The proportion of more severe TCs may however increase, thus leading to a limited decline in their absolute number. The CSIRO report also concludes that there is little consensus on whether El Niño and La Niña events will change in intensity or frequency in the region.

7. This assessment is in line with the analysis in the country National Adaptation Plan (NAP) and with a major study by the Australian climate research center CSIRO (Australian Bureau of Meteorology and CSIRO, 2014). Some minor differences are likely due to fact that CSIRO (2014) uses data from CMIP5, while the analysis in this annex relies on more recent CMIP6 simulations. CSIRO (2014) finds a significant change in extreme rainfall while this analysis does not find significant changes. The NAP estimates that mean air temperature has warmed by 0.9 °C over the last half century, a faster warming rate than what revealed by CRU data used for this analysis. The warming rate of 0.1 °C per decade from 1961 estimated using CRU data is similar to the warming rate measured at Nadi Airport, as reported by CSIRO (2014).

Appendix II. Estimating the Cost of Sea-Level Rise and Adaptation

1. The analysis of sea-level rise impacts, and adaptation options is done using complex models that rely on necessary simplifications but provide important insights. While there is uncertainty on the exact extent and cost of damages from SLR and on the cost of protection measures, there is consensus in this literature that long-term planning of adaptation can be highly effective at containing physical impacts and costs of SLR. For example, the large EU-funded research project PESETA IV finds that coastal protection can reduce SLR damages in the EU by approximately 90 percent (Vousdoukas et al. 2020, Table 6). Model simulations fully agree that adaptation can be highly effective but may differ on the optimal mix of adaptation measures – e.g., hard protection, nature-based solutions, planned retreat – because they use different data, use different climate scenarios, or work under different normative criteria. There is also consensus that the transformations needed to adapt to SLR, while technologically feasible and economically sound, are complex and require strong governance (Hinkel et al., 2018).

2. IMF staff uses the state-of-the-art Coastal Impact and Adaptation Model (CIAM) to estimate the cost of sea-level rise under alternative adaptation strategies. CIAM is a global model used to estimate the economic cost and benefits of adaptation to sea-level rise (Diaz, 2016). The global coastline is divided into more than 12,000 segments of different length grouped by country. Fiji's coastline is modeled using 137 separate segments in CIAM that vary in length from 0.4 Km to 619 Km. Each segment is further divided into areas of different elevation. For each segment, the model has data on capital, population, and wetland coverage at different elevations. The model has data on capital, population, and wetland coverage at different elevations for the entire coastal segment. By using projections of local sea-level rise from Kopp et al. (2014), it is possible to estimate the areas that will be inundated and the amount of capital and population at risk. Storms cause periodic inundations on top of sea-level rise. The model does not consider increased risks from river floods.

3. The model calculates the cost of SLR—protection costs plus residual losses—under alternative adaptation options:

- The **no-adaptation scenario** assumes that population does not move until the sea inundates the area where they live and then relocates to areas with higher elevation. Society keeps building and maintaining capital until inundation causes irreversible losses and capital is abandoned. The cost of sea-level rise is calculated as the sum of the residual value of capital that is abandoned, demolition costs, and the value of land that is inundated. The model uses the rental value of agricultural land in proximity of the coastline, following Yohe et al. (1990), because as SLR progresses, coastal proximity rents will shift from land that is inundated to adjacent land. Population density and development opportunity costs are assumed to be capitalized in agricultural land values. The disutility cost of reactive migration is monetized.

- At the opposite, a **protection scenario** assumes that society invests in cost-effective seawalls and other barriers along the entire coastline to avoid inundation from sea-level rise, but storms can still periodically inundate protected areas if protection is not sufficiently high. Capital and land are not lost, the population does not move, but storms periodically cause capital and human losses. The cost of SLR is equal to the cost of protection plus the expected value of the cost of storms.

- Another adaptation option relies on **planned retreat** from areas that will be subject to inundation. The goal of retreat is to keep using coastal areas without building new capital and by letting the existing capital depreciate. For example, a coastal road is used until it needs major retrofitting investment. Then, a new coastal road is built in-land on higher grounds. This strategy accepts that land and some residual value of capital will be lost, but it avoids coastal protection costs. The population gradually moves to higher grounds before areas are inundated. This usually does not require migration to distant places, but rather relocation within the same coastal area. The cost of SLR is equal to the sum of the residual cost of capital, the value of inundated land, and the disutility cost of relocation.

- The model considers variants of protection and retreat scenarios to deal with risks from storm surge floods. For example, the model calculates the height of the coastal protections to contain SLR and increasingly large storm surges (1/10-, 1/100-, 1/1,000- and 1/10,000-year events). In the base scenario (Retreat 1), the retreat perimeter is calculated to only deal with permanent inundation of land, but the retreat perimeter can be pushed to also avoid storm surges (from 1/10 to 1/10,000-year events).

- For each coastal segment, the model calculates the net present value of SLR costs for each adaptation strategy. Loss of life is monetized using the Value of Statistical Life and loss of wetland due to either SLR or protection of barriers that impede the normal circulation of tidal waters is monetized using estimates of willingness to pay for biodiversity preservation.

- The cost of building and maintaining seawalls, and other key parameters are from the literature. Storm surge costs are incremental with respect to a baseline scenario in which storms occur without SLR.

- By comparing SLR costs across all scenarios it is possible to find the least-cost adaptation strategy for each coastal segment and to calculate the lowest possible cost of SLR for the country. Coastal protection is usually the least-cost strategy in areas with large existing capital and high population density. Planned retreat is usually the least-cost strategy in areas with low capital and population density. The optimal height of coastal protection infrastructure and the optimal retreat perimeter vary on many factors, including projected incremental costs of protection, the opportunity cost of not using land that would normally not be flooded, capital and population at risk, sea-level rise scenarios.

- Despite many uncertainties and some necessary simplifying assumptions, CIAM provides a useful framework to systematically study costs and benefits of alternative adaptation strategies to SLR. More granular coastal modeling and more accurate mapping of assets can provide a more precise assessment of costs and benefits, but the key insights developed with a baseline version provide a useful starting point to deal with a complex, multidecadal challenge.

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