

Pacific Island Research Report

Samoa: Climate Change Impacts and Adaptation in Coastal Transport Infrastructure

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Abstract

The natural and socio-economic systems of the Pacific Islands are considerably impacted by climate change. Samoa is a Polynesian nation which is highly exposed to climate change because of its geography, coastal arrangement patterns and dependence on lifeline infrastructure concentrated along the shoreline. This report examines adaptation options and evaluates how Samoa's coastal transportation systems such as roads, bridges, ports and the international airport are affected by climate change. Rising sea levels, increasing air and ocean temperatures and changes in the variability of rainfall are examples of climate change. According to projections, high emission scenarios will result in more frequent coastal flooding, stronger tropical storms and long-term flooding of low-lying infrastructure. The focus of current adaptation programs, such as the National Adaptation Programs of Action and the Climate-Resilient Transport Program, is on policy reforms and infrastructural improvements. To ensure adaptive capacity, it will be important to strengthen community engagement, governance and funding. According to the report's findings, Climate resilient transport design is critical to Samoa's social and economic stability in the face of climate change.



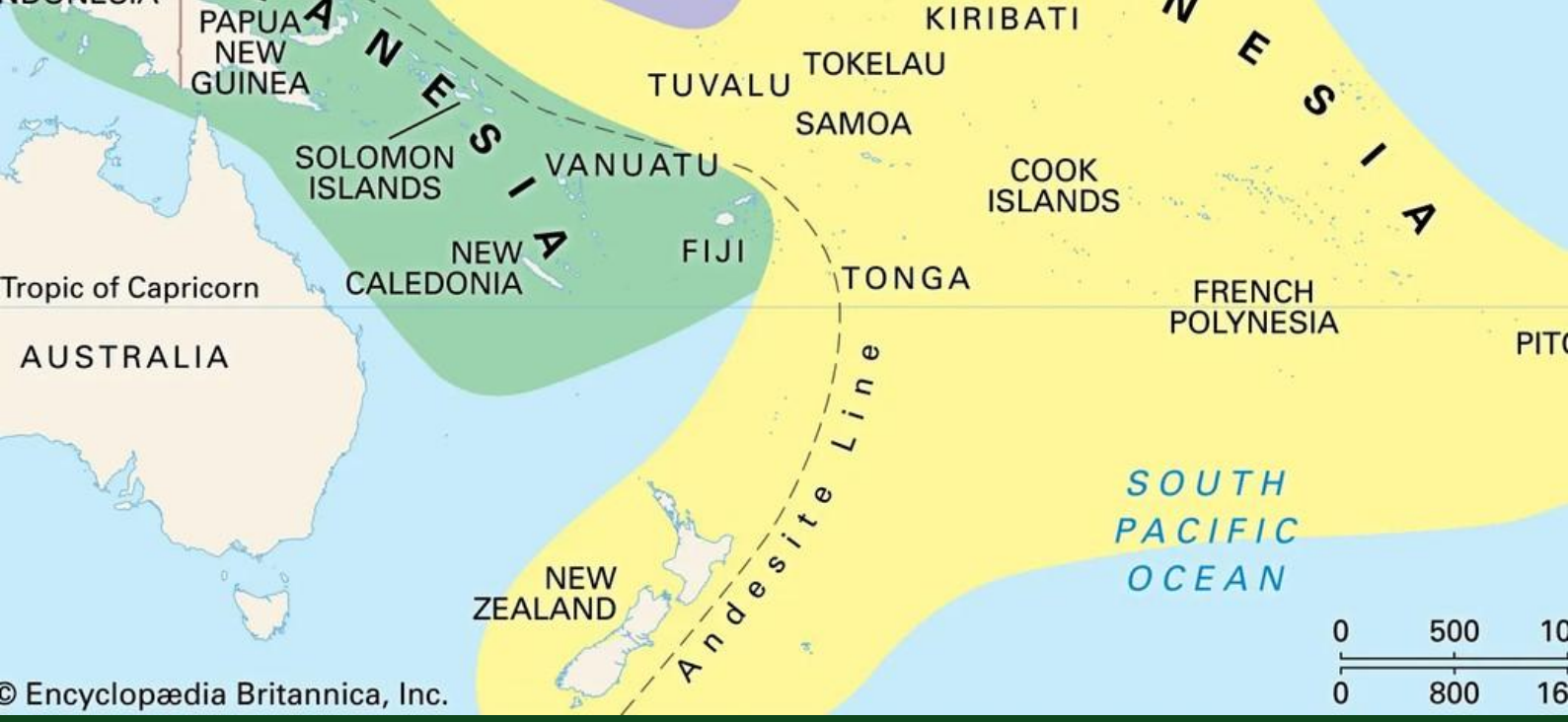
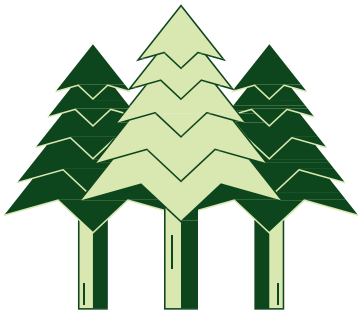


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Introduction



Figure: Samoa in the South Pacific Ocean

Countries in the Pacific Islands like Samoa, face significant vulnerability to climate change threats with documented alterations in temperature, sea levels rise, precipitation patterns, and coastal degradation (Hoegh-Guldberg & Bruno, 2010; Webb & Kench, 2010; IPCC, 2013). In developing economies, climate change exacerbates vulnerability by increasing exposure to natural hazards and disrupting livelihoods (Downing, 1991; Burton, 1993; Pelling, 2003). Three essential dimensions are used by the IPCC to determine vulnerability: exposure, sensitivity and adaptive capacity (McCarthy, 2001; Smit, 2003; Barnett & Adger, 2007). Risk is also influenced by social factors such as inequality, governance and institutional preparedness (Adger, 1999; Blaikie et al., 1994). It is essential to comprehend these drivers to evaluate Samoa's coastal transport infrastructure, which plays a key role in connectivity but is greatly vulnerable to climate hazards.

Key Characteristics of Samoa

Feature	Details
Location	Polynesia, South Pacific
Main Island	Upolu and Savai'i
Land Area	2,900 km²
Population	225,000 (Government of Samoa, 2021)
Economy	Tourism, agriculture, fisheries, remittances (World Bank, 2020)
Infrastructure	Concentrated in coastal lowlands

Observed and Projected Climate Change

Observed Climate Trends

Changes in the climate have already been observed in Samoa. In line with regional warming trends in the tropical Pacific, average air temperatures have increased by about 0.6°C since 1950 (Australian Bureau of Meteorology [BoM] & CSIRO, 2014). Since 1993, the Apia tide gauge has recorded sea level rise at an average annual rate of 4 mm, it is higher than the global average (PSMSL, 2023). This increase has led to drainage backflow during high tides and more frequent nuisance flooding of coastal roads.

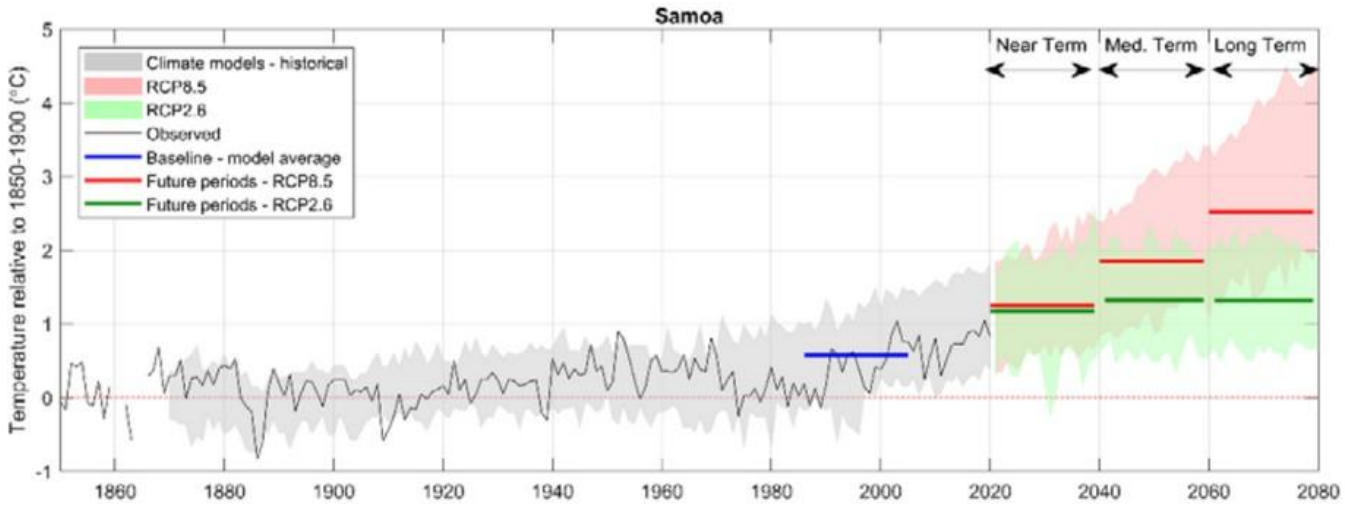


Figure: Average annual temperature in Samoa region relative to 1850-1900 (°C) derived from observations (Berkeley shown; grey solid line) and simulated in CMIP5 models, showing the range of all models for the past period (grey band), the future under a very high emissions pathway (pink band) and a very low emissions pathway (green band). Thick horizontal lines show the mean of all models in 20-year periods of the baseline 1986-2005 (blue) and future 20-year periods centered on 2030, 2050 and 2070 (RCP8.5; red horizontal lines, RCP2.6; green horizontal lines). (Source: CSIRO and SPREP (2021))

There is a growing degree of fluctuation in precipitation patterns, with landslides and flash floods caused by periods of greater rainfall. Tropical storms, such as Cyclone Evan in 2012, affect Samoa and destroy port infrastructure, roads and bridges (SPREP, 2016). Natural reef barriers which shield coastlines from wave energy have been shown to be weakened by coral bleaching related to marine heatwaves (IPCC, 2022a).

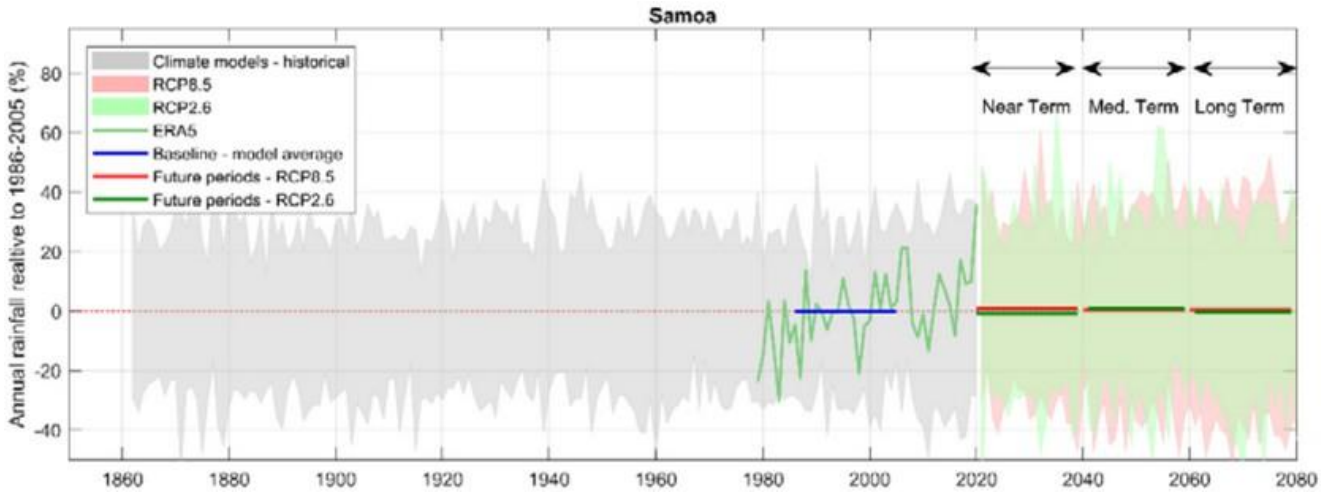


Figure: Average annual rainfall in the Samoa region relative to 1850-1900 (%) in ERA5 and simulated in CMIP5 models, showing the range of all models for the past period (grey), the future under a very high emissions pathway (pink band) and a very low emissions pathway (green band). Thick lines show the meaning of all models in 20-year periods: the baseline 1986-2005 (blue) and future 20-year periods centered on 2030, 2050 and 2070 (RCP8.5; red lines, RCP2.6; green lines). (Source: CSIRO and SPREP (2021)

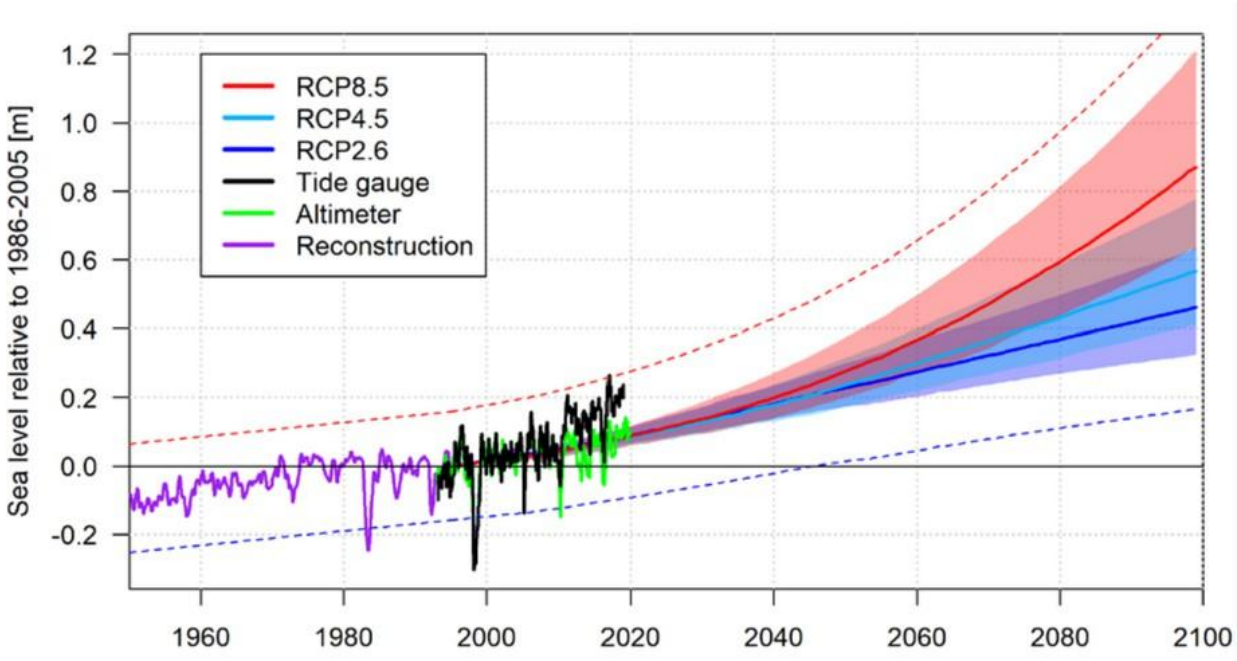


Figure: Sea level rise projections for Samoa. The tide gauge record of relative sea level at Apia is indicated in black, the satellite record in green and reconstructed sea level data is shown in purple, all are monthly means without seasonal cycles and referenced to mean sea level between 1986-2005 (note that the departure between the tide gauge and altimeter since 2009 is likely due to land subsidence after the 2009 earthquake). Multi- model-mean projections from 1995–2100 are given for the RCP8.5 (red solid line), RCP4.5 (cyan solid line) and RCP2.6 emissions scenarios (blue solid line), with the 5–95% uncertainty range for RCP8.5 and RCP2.6 shown by the red and blue shaded regions respectively. The dashed lines are an estimate of interannual variability in sea level (5–95% uncertainty range) and indicate that individual monthly averages of sea level can be above or below longer-term averages.

(Source: CSIRO and SPREP (2021))

Projected Future Climate

Projections for Samoa suggest sustained warming under all emission scenarios. According to SSP2-4.5, the mean annual temperature is predicted to rise by 1.0 to 1.5°C by 2050, while SSP5-8.5 forecast an increase of up to 2.0°C (IPCC, 2021). The amount of rainfall is still unknown, but there will be more intense precipitation that will raise the risk of landslides and floods (BoM & CSIRO, 2014).

According to SSP2-4.5 and SSP5-8.5, by 2100, the sea levels all around Samoa are expected to increase by 0.25–0.60 m and 0.45–0.85 m respectively (IPCC, 2022b). According to Vitousek et al. (2017), even slight increases of 5–10 cm by the 2030s might treble the frequency of coastal flooding occurrences in Apia. Forecasts show that tropical cyclones will become less frequent but more intense, which will increase the risk of storm surge and damage to coastal infrastructure (Knutson et al., 2020).

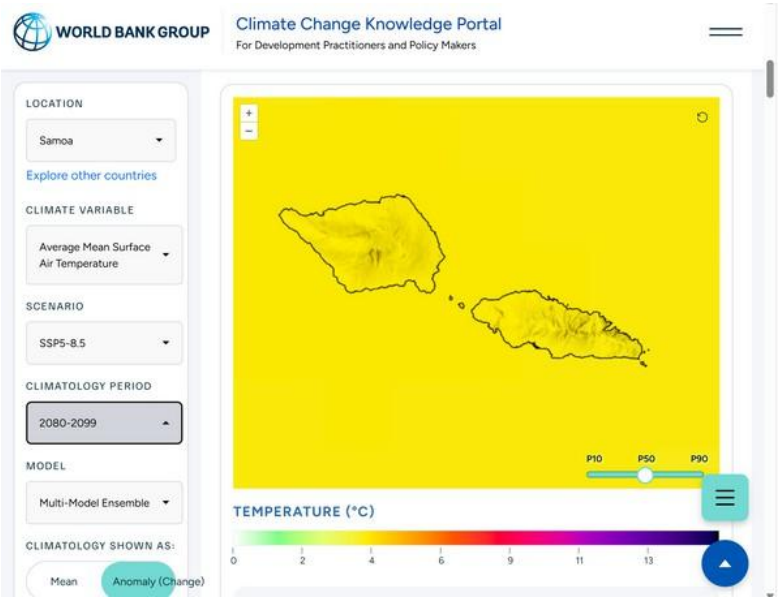


Figure: Projected Anomaly of Average Mean Surface Air Temperature (2080-2099)

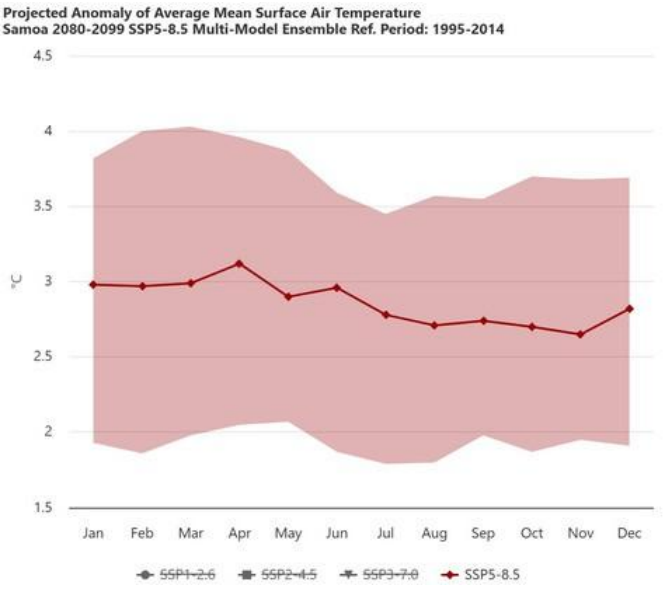


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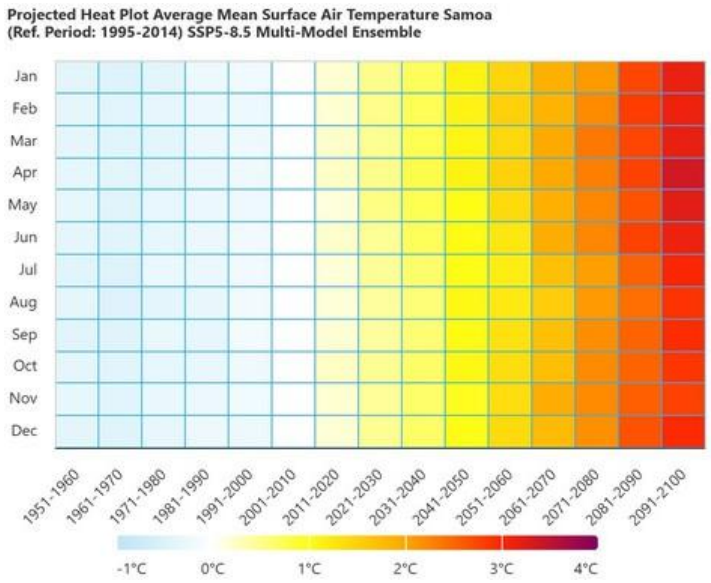


Figure: Projected Heat Plot Average Mean Surface Air Temperature

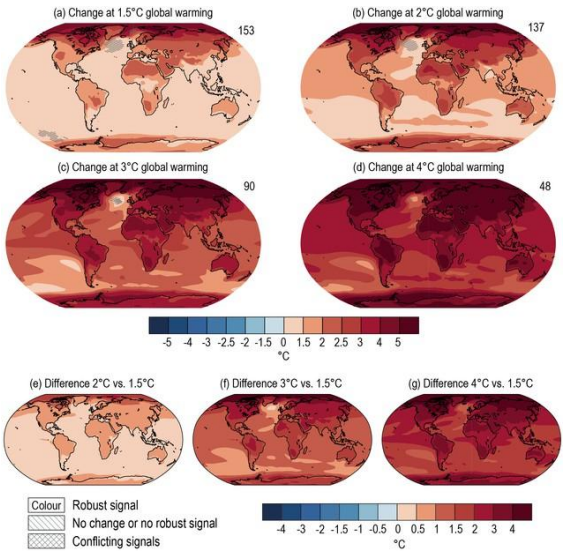
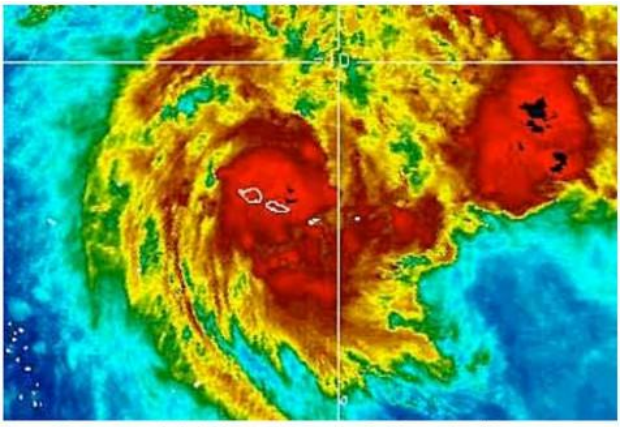


Figure: Projected spatial patterns of change in annual average near-surface temperature (°C) at different levels of global warming. (IPCC 2021)

Impacts on Coastal Transport Infrastructure

Observed Impacts

The transportation industry in Samoa has already faced severe climate related harm. About 70% of the population of Samoa resides within 1-kilometre of the coastline and essential infrastructure (such as hospitals, schools, workplaces, tourist facilities, ports, power stations, airports and roads) is mainly situated in the coastal area where road access is important (Fakhruddin, Babel & Kawasaki, 2015). An estimated $200 million was lost in infrastructure due to Cyclone Evan in 2012, which greatly damaged Apia's port, coastal roads and bridges (Government of Samoa, 2013). Connectivity between Apia and the airport is frequently damaged by erosion, drainage issues and wave overtopping on the West Coast Road (ADB, 2017). In addition, because of frequent floods, airports and port infrastructure have experienced severe service disruptions during storms.



Source: © Samoa Meteorological Division/MTSAT. Reproduced with permission of Samoa Meteorological Division/MTSAT; further permission required for reuse.

Figure: Satellite Image (Infrared) of Tropical Cyclone Evan Taken over Samoa at 1230 UTC December 13, 2012

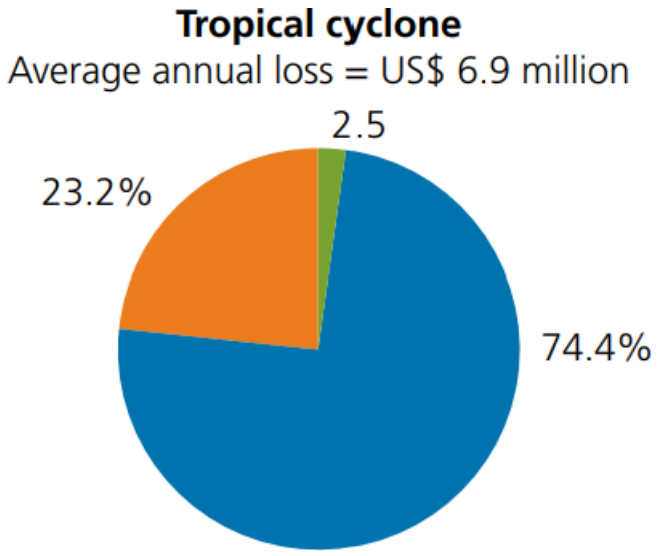
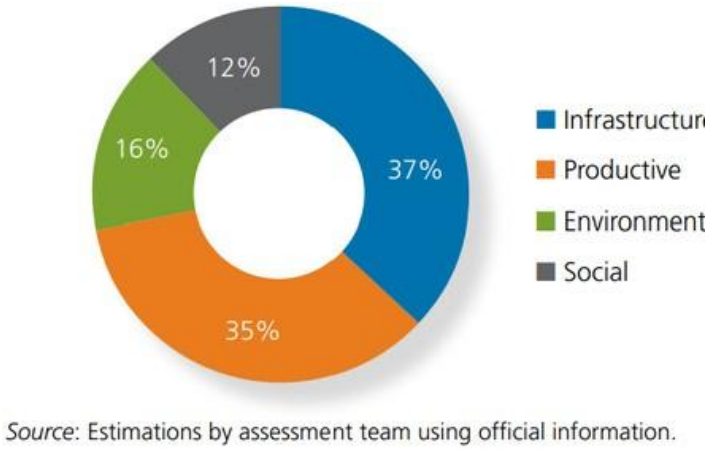


Figure: Average Annual Loss Due to Tropical Cyclones (Source: PCRAFI, "Country Risk Profile: Samoa," September 2011.)



Source: Estimations by assessment team using official information.

Figure: Breakdown of Damage and Loss, by Main Sectors of Activity (Government of Samoa, 2013)

Likely Future Impacts:

Future climate change will increase the risks to coastal transport:



2030s–2050s:

According to World Bank, 2018 and IPCC, 202, the occurrence of tidal flooding on low-lying road sections will be increased, especially along Apia's waterfront and the West Coast Road. Drainage systems are prone to increased failure rates during extreme rainfall, which will lead to localized flooding and pavement degradation.



2030s–2050s:

In the context of high-emission scenarios, chronic inundation will impact parts of coastal roads, rendering them intermittently impassable. The access roads to airports and apron facilities situated in low-lying areas will also be endangered by rising sea levels. According to IPCC, 2022 and Fakhruddin et al., 2015, intensified cyclones and storm surges will heighten the structural harm to bridges, seawalls and port infrastructure.

If no adaptation is made, these impacts could result in escalated maintenance costs, regular closures and a lack of long-term reliability in service. The economy of Samoa could be immobilized by disruptions to the West Coast Road, as they would sever supply chains and restrict access to emergency services.

Adaptation Strategies

The World Bank
Samoa Climate Resilient Transport Project (P165782)

ANNEX 6: MAP OF SAMOA WITH PROJECT SITES

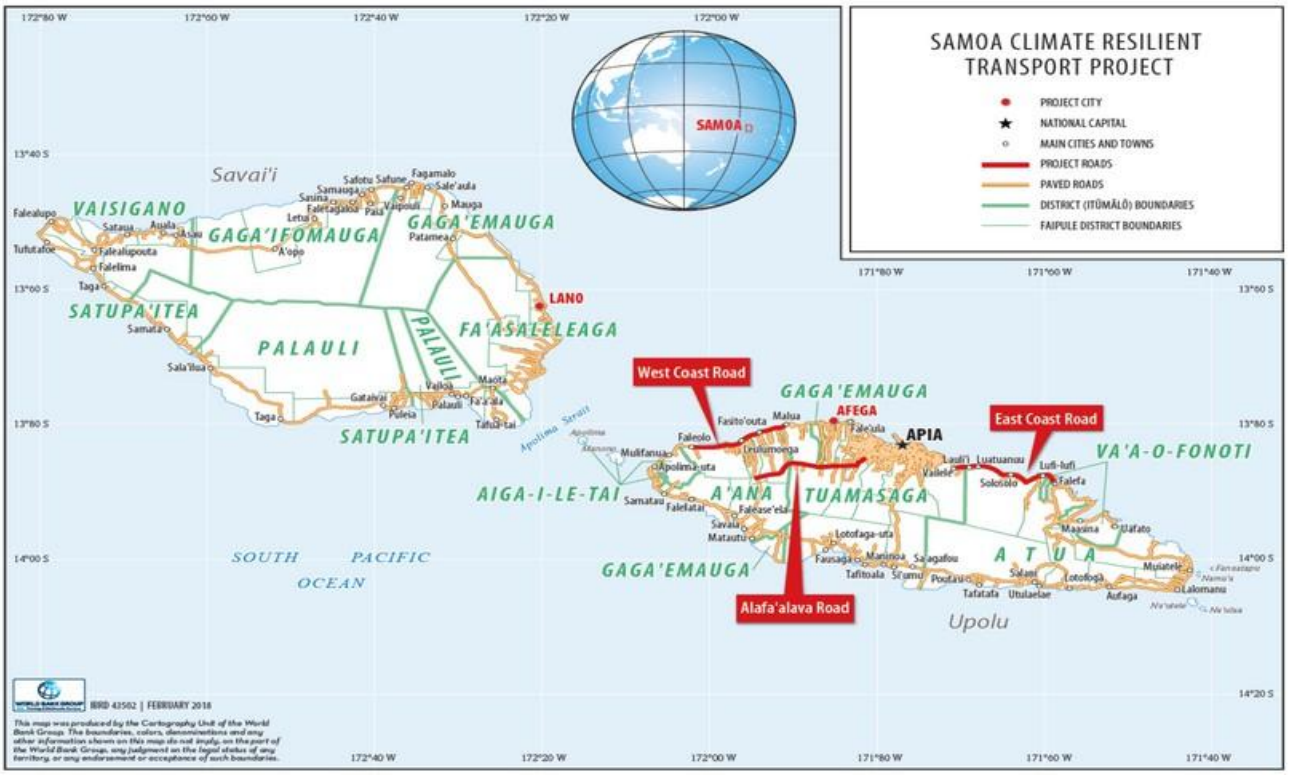


Figure: Samoa Climate Resilient Transport Project (The world bank)

Current Adaptation Efforts

In addressing climate risks in the transport sector, Samoa has made a progress. The World Bank supported Climate-Resilient Transport Program which focuses on developing key infrastructure such as the West Coast Road by elevating road sections, improving drainage and strengthening embankments (World Bank, 2020). To withstand greater flood flows, bridge rehabilitation projects have incorporated higher design standards. To mitigate flood risks, the government's National Adaptation Program of Action (NAPA) focuses on enhancing infrastructure resilience, ensuring water security, and promoting reforestation (Government of Samoa, 2005). Community-based initiatives, such as mangrove restoration and coastal vegetation planting, have also been introduced to provide natural protection against wave action (SPREP,2016).

Short Term Strategies (10 years plan)

- **Improved design standards:** Incorporating sea-level rise allowances of 0.2–0.4 m by 2050 for roads and bridges design codes.
- **Drainage enhancement:** Incorporating larger culverts, backflow preventers and sacrificial floodway to enhance stormwater management.
- **Hybrid "green-grey" approaches:** Merging seawalls with mangrove and reef restoration to absorb wave energy and reduce erosion.
- **Planning for emergency operations:** Developing Road closure protocols, using portable barriers and improved early-warning systems for transport operators.
- **Financial mechanisms:** Broadening the scope of climate risk insurance for road and port repairs and incorporating resilience costs into national budget plans.

Strategies for the Medium Term (25 years plan)

- **Progressive road elevation:** This involves elevating crucial segments of the West Coast Road and other major roads above anticipated flood levels.
- **Inland realignments:** Adjusting the position of road segments at risk to locations away from the coast, as the terrain allows, thereby reducing chronic exposure.
- **Bridge redesign:** Making spans longer and raising decks to fit higher flood levels.
- **Upgrades for ports and airports:** Enhancing platforms and fortifying areas subject to waves, all while creating redundancy in utilities and communications.

Long-Term Strategies (80 years plan)

- **Managed retreat:** Acknowledging that certain coastal road segments at low elevation might not be financially viable to upkeep; where possible, planning alternative inland transport corridors.
- **Network redundancy:** To reduce reliance on single-point corridors such as the West Coast Road, secondary inland connectors should be created.
- **Integrated land-use planning:** Implementing coastal setbacks for new constructions and ensuring transport planning is in accordance with climate forecasts.

Cross-Cutting Measures

- **Data and monitoring:** Maintaining tide and stream gauges, as well as using remote sensing for monitoring erosion and flooding.
- **Governance and standards:** Updating engineering codes to align with IPCC projections and guaranteeing that all new projects are subjected to climate screening.
- **Community involvement:** Involving local stakeholders in decision-making process and guaranteeing fair access to resilient transport.

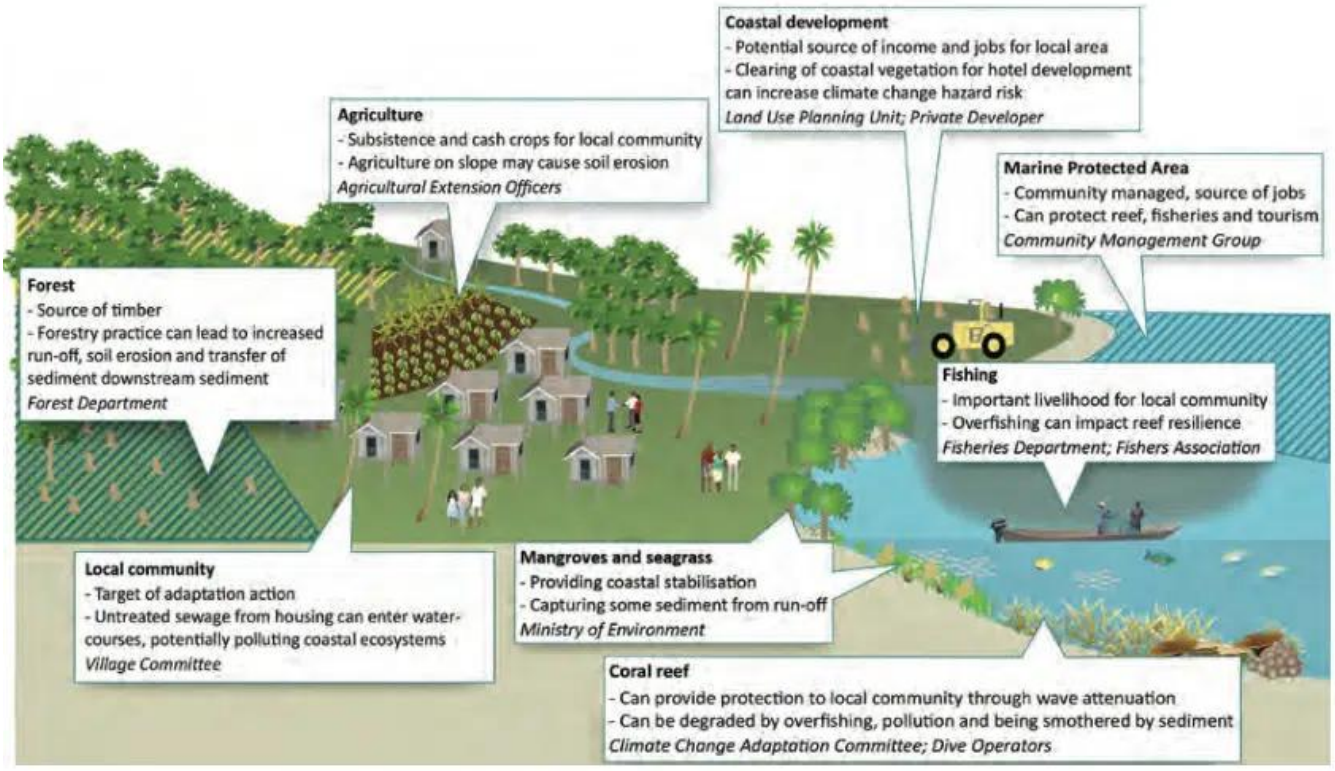


Figure: Adaptation options for islands. Source: We Adapt

Conclusion

Due to its reliance on coastal transport systems, Samoa is especially prone to the impacts of climate change. Because of rising seas, stronger cyclones and intensified rainfall, the reliability of roads, bridges, ports and airports is at risk. Samoa has started implementing significant adaptation measures, but achieving long-term resilience will necessitate a blend of engineering solutions, ecosystem-based strategies and development of institutional capacities. Progressive road raising, managed retreat and enhanced governance frameworks are among the critical strategies. To enhance Samoa's adaptive capacity, it will be important to ensure sustainable financing and community involvement. It is crucial to establish a climate-resilient transport network to ensure economic continuity and protect livelihoods and national security amid intensifying climate risks.

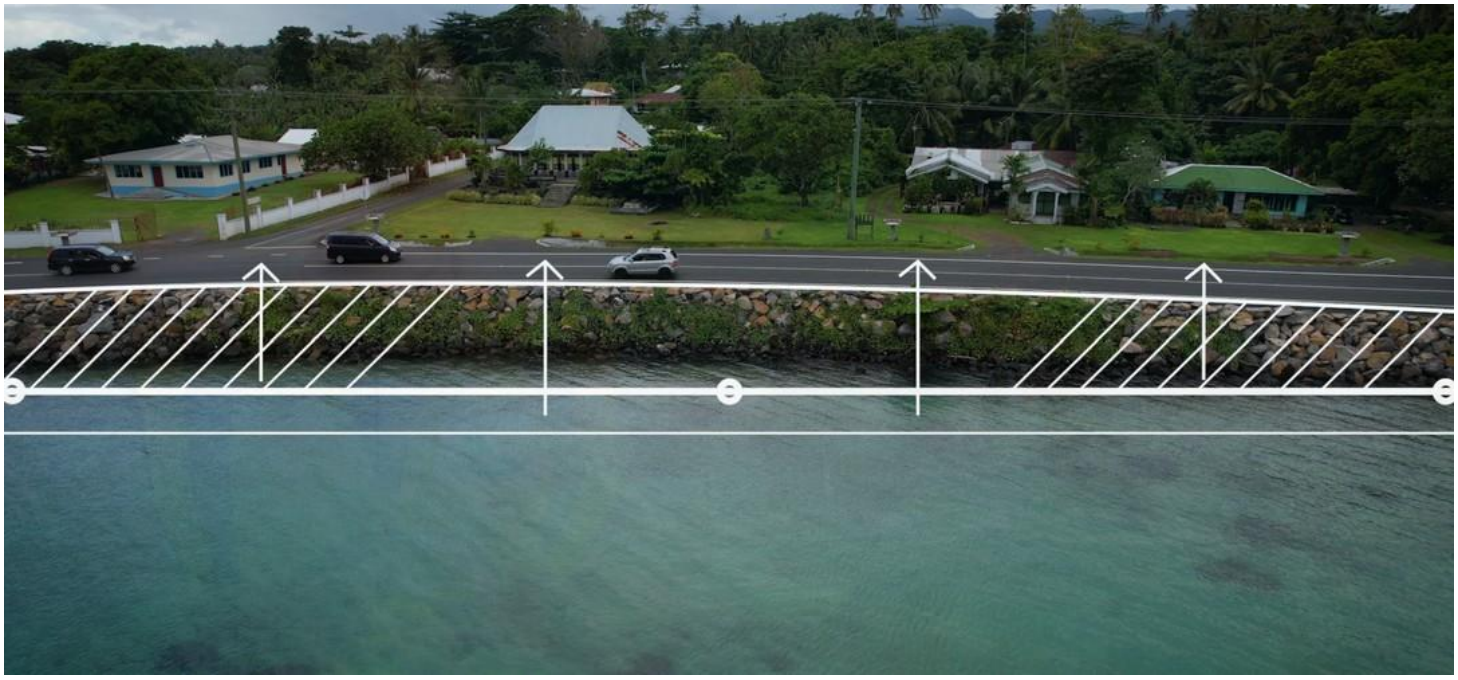


Figure: Adapting to a New Climate Reality in the Pacific (World Bank Group)

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