Sea level rise in Madagascar

Trends and vulnerabilities

This review aims to summaries some key findings from literature to provide an overview of sea level rise trends and vulnerabilities in Madagascar. However, as its scope is limited by time and available resources, the review will not cover all trends and vulnerabilities of sea level rise in Madagascar.

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1. Introduction

Sea-level rise (SLR) is primarily driven by ocean warming and the melting of glaciers and ice sheets, both of which are direct consequences of climate change. Since 1880, global mean sea levels have risen approximately 20–23 centimetres, with the rate of increase over the past decade exceedingly twice that observed during the first decade of satellite records (1993–2002). Despite this growing global concern, research focusing on the specific impacts of SLR and adaptive responses in Madagascar remains limited.

The sea-level of the coast of Madagascar is expected to rise by 2100 with between 0.5 to 0.94 meters, and under scenario SSP3-7.0, 0.73 meters (Climate Change Knowledge Portal, 2021; GIZ, 2021). With SLR projections, part of the coastal areas of Morondava and Mahajanga, in the northeast of Madagascar, might be submerged by 2100 due to SLR (Weiskopf et al., 2021). The SLR is coupled with other significant risks of the country, such as land loss, coastal erosion, inland flooding, infrastructure damage and disruption to economic activity, forced migration, and food security, creating a further strain on adaptation capacity (World Bank, 2024b).

Geography and economy

Madagascar has a population of 32,0 million (Trading Economics, 2024). The population is still growing rapidly, with an annual growth of 2.4% by 2021 (Shi, 2024). The coastline is 4.828 kilometres, and fifty-nine percent of the country's land area is considered coastal, where 38 percent of the population lives (CIA, 2025). Around 38 percent of the population live in the low-laying coastal areas, 27% of people live below 100 m in elevation, and around over 570,000 people are projected to be impacted by SLR between 2070 and 2100 under a high emissions scenario (Ballesteros & Esteves, 2021; Weiskopf et al., 2021).

Continuing, Madagascar has a highland plateau extending throughout the centre, fringed by low-lying coastal areas on all sides (GFDRR, 2011). Due to Madagascar's geographical location, the country is exposed to a multitude of climate hazards, such as droughts, floods, storms, extreme temperatures, and sea-level rise (Shi, 2024). Madagascar is facing two extremes at the opposing ends of its country. The northern and eastern regions of the country have faced devastating cyclones, flooding and heavy rain, while the south has been experiencing extreme droughts (Médecins du Monde, 2023).

Madagascar's economy is dominated by the services sector, contributing 52.1 % to the country's GDP in 2019, followed by the agricultural sector with 23.3 % and the industrial sector with 17.2 %. Coastal communities heavily depend on marine resources and agriculture (World Bank, 2024b). For example, artisanal fisheries contribute about 7% of the gross domestic product (GDP) and directly support the livelihoods of 1.5 million people (Ballesteros & Esteves, 2021). Approximately 78 percent of the population lives below the poverty line (UN Habitat, 2023).

2. Sea-level rise and associated risks

Madagascar faces significant and growing risks from sea-level rise, primarily due to its geographic location, with more than half of the island being costal, its growing population, and heavy dependence on climate-sensitive sectors like agriculture, tourism, and fisheries (World Bank, 2025). As mentioned above, sea-level rise poses significant risks for the low-lying areas, especially the northeast part of the island.

2.1 Environmental risks

SLR compounded by global warming intensifies coastal hazards such as storm surges, tsunamis, and flooding (Trisos et al., 2022). Madagascar has the highest risk of cyclones in Africa; it has around three to four cyclones per year between November and April, with the eastern, northeastern, and western regions most affected (UNDRR & CDRI, 2024). Tropical cyclones are one of the most significant disasters on the island, causing approximately 85% of the annual losses, which are expected to increase with climate change (Miklyaev & Olubamiro, 2025). Furthermore, changes in wave climate superimposed on SLR, as well as increased storm surges, will significantly increase coastal flooding (Campbell et al., 2023). The combined effect of SLR and more frequent cyclones causes economic losses through property damage, disrupted trade, and increased disaster recovery expenses (Botzen et al., 2019).

SLR will also alter biogeographical patterns, particularly threatening mangrove ecosystems and coral reefs, which provide vital coastal protection and biodiversity support (Ramarokoto et al., 2024). Madagascar has over 5,600 kilometres of coastline, with about 300,000 hectares of mangroves and 3,450 kilometres of coral reefs (GFDRR, 2011). These ecosystems are vulnerable to ocean warming and the effects of ocean acidification; for example, 70% of mangroves in the Tsiribihina delta have moderate to high vulnerability to SLR and sediment change (GFDRR, 2011; Weiskopf et al., 2021). These ecosystems are important, not only for biodiversity, but they also act as buffers, reducing the impact of storm surges and waves by breaking the energy offshore, which reduces wave impact on the coastline, and stabilising sediments, which helps prevent coastal erosion (Ballesteros & Esteves, 2021; Burke & Spalding, 2022; Sheppard et al., 2005).

More intense cyclones and rising sea levels caused by climate change directly threaten coastal communities and intensify erosion in coastal areas. Further, rising sea levels are

contributing to increased saline intrusion in low-lying coastal alluvial aquifers (USAID, 2021). Madagascar's water management system remains insufficient to meet the agricultural and consumption needs of a growing population; Madagascar is ranked one of the lowest access rates to drinking water and sanitation. Saltwater intrusion could therefore be very damaging with the already limited access in drinking water and sanitation (UNEP/GRID, 2025b).

2.2 Infrastructure

Sea level rise-induced coastal erosion poses a significant challenge for coastal infrastructure and roads in Madagascar (Miklyaev & Olubamiro, 2025). SLR, flooding, and coastal erosion can undermine foundations and disrupt transportation and communication networks, limiting access and increasing repair costs. The risk of land losses is heightened, making more people in the coastal communities vulnerable to SLR (Ballesteros & Esteves, 2021).

Madagascar's limited railway infrastructure and lack of navigable inland waterways have made the country heavily dependent on road transport. However, the road network is in poor condition, with most roads unpaved and often impassable during the rainy season. Spanning approximately 31,640 kilometres, Madagascar’s road system ranks among the lowest in terms of density worldwide (GIZ, 2021).

SLR also poses a risk for human settlements in the low-lying areas, especially in the more densely populated cities such as Toamasina and Mahajanga (GIZ, 2021). With rural-urban urbanisation, the development in low-laying areas leads to greater exposure to the growing flood risks associated with increasing intensity of heavy rainfall, cyclone events, and SLR (UN Habitat, 2023). Additionally, informal settlements are especially at risk in Madagascar during extreme weather events. According to the World Bank, over 60% of urban residents live in slums (World Bank, 2024a). The homes are usually constructed in unstable areas like steep hillsides or along riverbanks, where strong winds and floods can cause homes to be destroyed, water sources to become contaminated, and residents to suffer injuries or even loss of life (World Bank, 2024a).

Only around 15% of Madagascar’s population is connected to electricity; however, the island aims to connect 70 percent of its population to electricity by 2030 (UNDRR & CDRI, 2024). Currently, Madagascar draws around 30 % of its energy from hydropower (GIZ, 2021), where two

of six power stations are considered specifically vulnerable to rising water levels. The unpredictable river flows can reduce hydropower generation capacity, and the SLR effect on erosion can lead to an increased sediment load, which can reduce the efficiency of hydropower generation (International Energy Agency, 2020).

2.3 Economy

Sea level rise is expected to significantly affect Madagascar's economy, particularly sectors that rely heavily on a healthy ecosystem, such as tourism, fisheries, and agriculture (GIZ, 2021). However, the broader economic impacts extend beyond these sectors, with potential damage to infrastructure, public health, and essential services. For example, from 1980 to 2010, 53 natural hazards, including droughts, earthquakes, epidemics, floods, cyclones, and extreme temperatures, affected Madagascar and caused economic damages of over US$1 billion (World Bank, 2025). These events underscore the country's vulnerability, that SLR is likely to intensify.

Fisheries, tourism, and agriculture are three key sectors of Madagascar’s economy. They are, however, particularly vulnerable to the impacts of sea level rise. The sectors depend heavily on healthy coastal ecosystems, which are at increasing risk due to rising seas. SLR can lead to saltwater intrusion into freshwater systems and coastal aquifers, disrupting aquaculture operations and marine breeding grounds critical for fishery production (World Bank, 2024b). Similarly, saltwater intrusions are likely to worsen water availability, which in turn threatens agriculture (Miklyaev & Olubamiro, 2025; Weiskopf et al., 2021). At the same time, 63% of the tourism is concentrated along the coast, which will be affected negatively by shoreline erosion, habitat loss, and more frequent extreme weather events (World Bank, 2024b).

Furthermore, Toamasina port serves as the country’s most important gateway connecting Madagascar to the Indian Ocean and global markets. SLR poses a threat to port infrastructure, potentially disrupting shipping and trade. Additionally, rising sea levels and temperatures are projected to intensify coastal winds and storms, further complicating port operations and maritime navigation (Detelinova et al., 2023).

2.4 Social and health risks

Sea level rise poses significant social risks to Madagascar, particularly by threatening the livelihoods of communities that rely heavily on agriculture, fishing, and tourism while exacerbating existing vulnerabilities. These three sectors are integral to the people's livelihood and food security on the island, for example, The agricultural sector employs around 80% of the population (Miklyaev & Olubamiro, 2025). Madagascar already faces high poverty and malnutrition rates, with more than 80.7% of its population living on less than US$2.15 per day, and nearly 40% of children have chronic malnutrition, despite having a lot of natural resources (Miklyaev & Olubamiro, 2025).

As previously mentioned, saltwater intrusion increases groundwater salinity, jeopardising freshwater-dependent ecosystems on the island (Campbell et al., 2023). As a result, water availability for both human consumption and irrigation is reduced, which further threatens agricultural productivity and threatens marine ecosystems and fish stocks, threatening livelihoods and food security, which in turn face heightened risks of poverty (Debords, 2022; Miklyaev & Olubamiro, 2025; Weiskopf et al., 2021).

Beyond economic and ecological impacts, SLR also intensifies public health risks. Increased flooding and extreme weather events linked to rising sea levels exacerbate the spread of waterborne diseases such as diarrhea. These health challenges are compounded by existing vulnerabilities to diseases, disproportionately affecting poor and rural communities on the island (GIZ, 2021).

3. Adaptation measures

Research on specific adaptation strategies for SLR in Madagascar is few. Nonetheless, enhancing adaptive capacity, including climate-resilient infrastructure, is recognised as essential (UNDP, 2025). The need for effective implementation of multi-hazard early warning systems is considered vital. Additionally, the strengthening of natural protection and reduction of the vulnerability of coastal, inshore, and marine areas affected by erosion and shoreline recession (UNEP/GRID, 2025a). Many strategies are still in planning or early stages and require scaling up to match the severity of climate impacts. Some projects, supported by UNEP and other partners, aim to reduce flooding, coastal erosion, and restore ecosystem services (UNEP, 2025). However, very little domestic funding is available for climate change, and current domestic funding is insufficient to implement long-term adaptation and mitigation solutions (UNEP/GRID, 2025a).

Despite efforts, Madagascar's high poverty, limited institutional capacity, and infrastructure deficits continue to manage and adapt to climate-related risks and disasters (Miklyaev & Olubamiro, 2025; UNEP/GRID, 2025a). According to The Global Resource Information Database, current adaptation actions in Madagascar lack certain specific adaptation needs identified by the National Adaptation Action Program (UNEP/GRID, 2025a).

The government of Madagascar has initiated policy frameworks addressing climate change. These policies include the Politique Nationale de Lutte Contre le Changement Climatique (2019) (GRI, 2019), Plan National d'Adaptation Au Changement Climatique (PNA) Madagascar (2021), and Stratégie Nationale de Gestion Des Risques et Des Catastrophes 2016-2030 (2012).

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