

# CORVI: Measuring Multidimensional Climate Risks in Toamasina, Madagascar

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Cover illustration: Sunrise on the port of Toamasina (Tamatave), Madagascar. Source: Pierre-Yves Babelon (Shutterstock).

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# Summary Findings

Located on Madagascar’s eastern coast and home to the country’s principal port, Toamasina is critical to the economic security of the country. Known as “the lungs of Madagascar,” it is the country’s second-largest city, with an estimated 350,000 people in the city itself and another 275,000 living in the surrounding district. The potential for economic growth, the available vast human capital, and the ability to take advantage of the natural resources could support a strong sustainable blue economy in this coastal city and region. But first, the government needs to prioritize and fund basic infrastructure and services, poverty reduction, and disaster risk planning while building climate resilience and adaptation. Climate change is compounding challenges posed by Toamasina’s high level of poverty and rapid urbanization, as the city has already absorbed greater climate-related economic losses than any other city in Madagascar. To fully capture the intersection of climate vulnerability, urbanization, and economic and social issues as well as environmental challenges, the geographic area of this assessment includes both the Toamasina I District, which represents the core area of the city, and the surrounding Toamasina II District, in the Atsinanana region.

This CORVI assessment describes a detailed road map to help prioritize actions needed to address the greatest risks and vulnerabilities facing Toamasina. The assessment has identified four major clusters of risk and vulnerability<sup>a</sup> in Toamasina:

- 1 The frequency and intensity of flooding;
- 2 Reliance on a sustainable blue economy;
- 3 Constrained economic opportunities and limited basic services; and
- 4 Lack of coordination across government.

To address the lack of local and regional data, the CORVI methodology<sup>b</sup> builds on national-level data and fills in information gaps through extensive surveys and interviews<sup>c</sup> with local experts, providing a more complete picture of the local and regional climate risks and vulnerabilities.<sup>1</sup>

The first cluster encompasses the increasing frequency and intensity of flooding in Toamasina, and its consequences for the city’s residents, economy, and ecosystems. **Projected Sea Level Rise (SLR)** will reach a total of 11 centimeters by 2030 and 22 centimeters by 2050 under a range of emissions scenarios,<sup>2</sup> and experts rated it the second-highest risk in this assessment (score of 8.78; all scores out of 10.00). This increase in sea level rise threatens to inundate and undermine coastal communities and infrastructure. It will also increase the intensity of storm surge and coastal flooding, especially during tropical cyclones. Madagascar experiences an average of three to four cyclones per year, and experts rated the **Number of Tropical Cyclones** as the third-highest risk in this assessment (score of 8.72).

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a A complete list of the risk indicators used for this assessment is provided in Appendix 1.

b Details about the CORVI methodology are provided in Appendix 3.

c A list of organizations represented in the assessment (which included 82 expert surveys and 26 interviews) is provided in Appendix 2.

Toamasina was hit by six in a 13-month period between January 2022 and February 2023.<sup>3</sup> Inadequate management of solid waste and wastewater exacerbates the extent and duration of flooding in Toamasina. The city collects only an estimated 20% of its trash,<sup>4</sup> and 97% of the population uses latrines, most of which consist of no more than a 200-liter barrel sunk into the ground, which results in human waste flooding streets, rivers, land, and coastal areas.<sup>5</sup> The destruction and degradation of Toamasina's ecosystems, especially its coral reefs and forests, also increases the intensity of both coastal and flash flooding. Much of Toamasina's critical infrastructure is located in coastal or low-lying areas, making it vulnerable to flooding. This includes the city's roads, which are regularly inundated during rainstorms, and the airport. The city's dense informal housing is extremely vulnerable to flooding, particularly housing located in flood-prone areas, such as along the banks of the Pangalanes Canal, which runs through the center of the city.

The second cluster surrounds the eroding foundations of Toamasina's sustainable blue economy. Local experts rated the **Level of Coral Reef Coverage** (score of 8.58) and **Nearshore Fish Stock Status** (score of 8.42) as the fourth- and fifth-highest vulnerabilities in this assessment, respectively. Coral reefs and other marine ecosystems like seagrass beds provide habitat for nearshore fish. Corals also attract tourists around Nosy Alanana (Ile aux Prunes) off the coast of Toamasina. Yet these ecosystems face numerous threats from climate change and human impacts.<sup>6</sup> Climate threats include warming ocean temperatures, marine heatwaves and coral bleaching, ocean acidification, and damage from tropical cyclones. Non-climate threats include plastic debris and other solid waste that are disposed of directly offshore or are swept into the ocean by flooding. They also include runoff of untreated wastewater and sediment from deforestation. Damage to these marine ecosystems undermines the health of nearshore fisheries, which are a key source of food security and income generation. In addition to the loss of habitat, local fishers attribute the decline in coastal fisheries to overfishing, destructive fishing practices—especially from industrial shrimp trawlers—and rising ocean temperatures.<sup>7</sup> Limited fisheries management and threats to marine ecosystems and nearshore fisheries not only undermine food security and income generation, but also inhibit the growth of new industries, such as tourism.

The third cluster of risk and vulnerability relates to the limited economic opportunities and basic services in Toamasina. Madagascar is one of the poorest countries in the world, and that poverty is also present in Toamasina. The **Percent of Population Below the Poverty Line** was identified by local experts as the greatest area of vulnerability in this assessment (score of 8.82). Like much of Madagascar, Toamasina is dominated by a large informal economy, which accounts for 95% of employment nationally and 60% in urban areas like Toamasina.<sup>8</sup> Informal businesses are characterized by low levels of productivity and limited growth prospects, keeping people in poverty and pushing them toward destructive environmental activities, such as slash-and-burn agriculture, which undermines the sustainable blue economy and harms people's health. Informal businesses are also difficult to regulate and generate little tax revenue needed for city improvements. Unavailable and unreliable basic services can also hinder the success of formal businesses. Local experts rated **Adequate Access to Electricity** as high risk (score of 7.61). The electricity access rate across the Toamasina I and II Districts is 53%, and the energy grid suffers from frequent outages.<sup>9</sup> Other basic services, particularly solid waste

management (score of 6.10) and access to health care (score of 6.91), were rated as medium-high risks. Limited services coverage is in part attributed by local stakeholders to disempowered and underfunded local governments, which are dependent on the national government for most of their funding. People in poverty have few resources to protect themselves from climate impacts, a situation mirrored by overstretched government without sufficient resources to invest in robust climate adaptation.

The fourth cluster relates to the limited coordination and information sharing across the national, regional, and municipal governments. Climate change is an “all-of-society” risk that requires a “whole-of-society” response; incorporating all levels of government, the private sector, civil society, and the people of Toamasina in climate adaptation is essential. Yet local stakeholders repeatedly cited this coordination and cooperation in support of disaster risk preparedness and reduction as a key gap. The general public is perceived to have a low level of awareness around climate risks and how their actions contribute to or reduce that risk. Civil society reported that the government largely ignores their inputs. National, regional, and municipal government do not coordinate on climate adaptation projects. Those projects also often lack effective, transparent monitoring, reducing their long-term effectiveness.

## Summary of Priority Recommendations

Based on the above risks and vulnerabilities three priority areas of action were developed to build climate resilience in Toamasina. Local leaders should work with global financial institutions, international development organizations and the UN to access climate funds to implement CORVI assessment recommendations and boost Toamasina’s blue economy.

### **IMPLEMENT AN INTEGRATED FLOOD MANAGEMENT AND ADAPTATION STRATEGY**

Addressing the climate and non-climate causes of growing flooding risk in Toamasina will require an integrated approach that prioritizes the city’s most vulnerable residents. The following recommendations are designed to reduce the intensity and impacts of flooding while also strengthening flood management and response.

- Establish an emergency operations center to unify and coordinate flood response operations across government agencies and link disaster response planning to climate adaptation projects.
- Set up neighborhood disaster risk management committees to improve the reach of early warning alerts, education and the implementation of early response actions.
- Provide anticipatory cash relief for the most vulnerable residents to pay for individual and community-level preparation measures immediately prior to an extreme weather event.

- Improve solid waste management by investing in waste collection trucks, support informal waste collection workers, construct new landfills, and develop innovative projects such as waste-to-energy plants.
- Relocate residents living in the most flood-prone areas, particularly in informal settlements, through a consultative process that also provides services and land rights to less flood-prone areas.
- Identify highly flood-prone areas through a partnership between government and civil society to improve mapping of informal settlements.
- Support nature-based solutions in Toamasina’s informal settlements to reduce flooding, treat wastewater, improve food security, provide income-generation opportunities, and strengthen local communities.
- Empower local adaptation strategies by strengthening local access to climate finance, supporting coordination, and building technical expertise.

## **PROMOTE THE HEALTH OF COASTAL AND MARINE ECOSYSTEMS AND RESOURCES**

Healthy marine ecosystems, including coral reefs, mangroves, and seagrass beds, and ocean resources, including coastal and offshore fisheries, can play an outsized role in reducing the impacts of climate change, particularly for coastal cities like Toamasina. The following recommendations are designed to support the beneficial management of these ecosystems and resources.

- Invest in restoring and protecting Toamasina’s vulnerable coastal and marine ecosystems, including coral reefs, seagrass beds, and coastal forests, by adopting best practices for ecosystem restoration and management. The Western Indian Ocean Marine Science Association and UN Environment Programme (UNEP) have helpful guides for the Western Indian Ocean region.
- Create locally managed marine areas (LMMAs) and marine protected areas (MPAs) to effectively expand marine protections and restore vulnerable marine ecosystems, using a community-led approach to siting and enforcing nearshore LMMAs and MPAs.
- Develop a fishery management plan to foster a more sustainable approach to managing the shrimp trawl fishery and reduce its negative environmental impacts through practices such as turtle excluder devices, bycatch reduction devices, and area-based closures.
- Undertake science-based stock assessment to support setting fishery effort limits and provide a deeper understanding of the current state of coastal and offshore fisheries that will support longer-term marine management goals.

## **INVEST IN CLIMATE RESILIENT INFRASTRUCTURE AND ECONOMIC GROWTH**

Building climate resilience and promoting sustained economic growth are mutually dependent and reinforcing goals that require investment in infrastructure from the national government, international development organizations and financial institutions, and incentives to the local private sector. Such support should be provided to the municipal and regional governments for on-the-ground implementation in coordination with the national government. The following recommendations are designed to advance both goals and foster a virtuous cycle of sustainable and resilient economic development.

- Increase investment in renewable energy by leveraging international programs like USAID’s Power Africa to improve economic productivity, support education, and strengthen disaster management.
- Simplify national regulations for new power generation by accelerating the process to connect to the electricity grid; assist with siting new power plants, and reduce import burdens for power generation equipment.
- Protect and improve transportation infrastructure; restore natural ecosystems such as coastal forests and wetlands to protect the airport from flooding; and provide dedicated maintenance funding for the road and train network, and clear the Pangalanes Canal from debris for use as a viable waterway.
- Provide government support to local private sector businesses who offer climate adaptation products and services through affordable financing, public education, and project preparation services.

# Ecological Risk

## Toamasina: Ecological Risk

Each category score comprises multiple indicators.

Low 1 - 2.5 Medium 2.51 - 5 Medium-High 5.01 - 7.5 High 7.51 - 10

Category	Indicator	Score
Ecosystems	Level of Coral Reefs Coverage	8.58
	Percent of GDP protected by Mangroves	6.52
	Percent of GDP Protected by Sea Grass Beds	6.45
	Level of Sea Grass Bed Coverage	6.34
	Health of Existing Coral Reefs	6.31
	Health of Existing Mangroves	6.25
	Incidence of High Invasive Species Abundance	6.16
	Health of Existing Sea Grass Beds	6.10
	Level of Mangrove Coverage	6.07
	Percent of GDP protected by Coral Reefs	6.05
Climate	Rate of Occurrence of Harmful Algal Blooms	3.95
	Number of Tropical Cyclones	8.72
	Number of Wet Days	7.45
	Number of Flood Events	6.04
	Number of Droughts	4.84
	Number of Extreme Heat Events	4.57
	Change in Sea Surface Temperature	4.20
	Cases of Vector-Borne Disease Infections	4.13
Geology/Water	Number of People Affected by Extreme Weather Events	3.76
	Projected Change in Sea-Level Rise	8.78
	Percent of Bodies of Water with High Water Quality	6.09
	Degree of Soil Salinity in Arable Lands	5.74
	Piped Water Supply Continuity	5.20
	Percent of Metropolitan Area at Risk of Flooding	4.76
	Level of Geophysical Risk of Landslides	4.59
	Degree of Saltwater Intrusion in Coastal Aquifers	4.57
Fisheries	Rate of Coastal Erosion	4.39
	Percent of Landscape that is Arable Land	3.39
	Nearshore Fish Stock Status	8.42
	Fish Consumption Per Capita	6.21
	Percent of Fisheries Certified Sustainable	6.00
	Number of Fisheries Access Agreements with Foreign Nations	5.45
	Capacity of Fisheries Enforcement Institutions	5.33
	Level of Unreported Catch Estimate	4.15
OffShore Fish Stock Status	3.76	
	Number of Incidents of Foreign Vessels Fishing in EEZ	2.90

Table: Stimson Center - Created with Datawrapper

Four of the seven highest risk scores in this assessment are in the Ecological Risk Area. The number of high and medium-high ecological risk scores not only reflects the poor health of existing marine ecosystems in Toamasina, but also illustrates the essential role that healthy coral reefs, mangroves, and seagrass beds can play in reducing the impacts of climate change. This is especially the case when considering the vulnerability of Toamasina to flooding from tropical cyclones, heavy precipitation events, and sea level rise. The information on ecological vulnerability in Toamasina in this report should be used in conjunction with the detailed information on climate hazards and exposure in the “Etudes de vulnérabilités des villes côtières et proposition de mesures d’adaptations adéquates: Cas des agglomérations de Toamasina et de Mahajanga,” funded by the World Bank in cooperation with Creocéan.

- The **ECOSYSTEMS** category (expert weighted average score of 6.38) illustrated the vulnerability of the existing coral reef, mangrove, and seagrass bed ecosystems in Toamasina and the surrounding areas. For coral reefs, the highest risk score was related to the **Level of Coral Reefs Coverage** (score of 8.58), followed by the **Health of Existing Coral Reefs** (score of 6.31) and the **Percent of GDP Protected by Coral Reefs** (score of 6.05). For mangroves, the highest risk score was related to the **Percent of GDP Protected by Mangroves**, followed by the **Health of Existing Mangroves** (score of 6.25) and the **Level of Mangrove Coverage** (score of 6.07). For seagrass beds, the highest risk score was related to the **Percent of GDP Protected by Seagrass Beds** (score of 6.45), followed by the **Level of Seagrass Bed Coverage** (score of 6.34) and the **Health of Existing Seagrass Beds** (score of 6.10). **Incidence of High Invasive Species Abundance** was also scored as a medium-high risk (score of 6.16). These scores illustrate the importance of healthy, resilient marine ecosystems in reducing risk to climate change impacts.
- In the **CLIMATE CHANGE** category (expert weighted average score of 5.55), there are high and medium-high risk scores for the **Number of Tropical Cyclones** (score of 8.72), **Number of Wet Days** (score of 7.45), and **Number of Flood Events** (score of 6.04). These scores, particularly when considered together and with the high risk score for projected change in sea level rise, illustrate the outsized role that flooding plays in the vulnerability of Toamasina.
- In the **GEOLOGY/WATER** category (expert weighted average score of 5.36), there are high and medium-high risk scores for **Projected Change in Sea Level Rise** (score of 8.78), **Percent of Bodies of Water with High Water Quality** (score of 6.09), **Degree of Soil Salinity in Arable Lands** (score of 5.74), and **Piped Water Supply Continuity** (score of 5.20). These scores illustrate two contrasting realities: a Toamasina with too much (salt) water and not enough (fresh) water.
- In the **FISHERIES** category (expert weighted average score of 5.23), there are high and medium-high risk scores related to fisheries management, including **Nearshore Fish Stock Status** (score of 8.42), **Percent of Fisheries Managed Sustainably** (score of 6.00), the **Number of Fisheries Access Agreements with Foreign Nations** (score of 5.45), and the **Capacity of Fisheries Enforcement Institutions** (score of 5.33). These scores, when considered together with the medium-high risk score for **Fish Consumption Per Capita** (score of 6.21), show the importance of supporting a flexible and sustainable domestic fisheries management framework.

CORVI’s ecological risk indicators show risks for Toamasina clustered around the health of ecosystems, flood risk, and health and management of fisheries. Madagascar is in the southwestern Indian Ocean and, as a result, is highly exposed to a range of costly natural hazards, including cyclones, floods from heavy rainfall events, earthquakes, and drought. These hazards cost the country over \$100 million in

combined direct losses each year.<sup>10</sup> Although relatively small on a global scale, these losses comprise about 7% of Madagascar’s GDP and can limit the potential for sustained economic growth. Madagascar experiences an average of three to four tropical cyclones each year and has the highest risk of cyclones of any African nation<sup>11</sup>, reflected in the **Number of Tropical Cyclones** (high risk, score of 8.72). Between January 2022 and February 2023, eight tropical cyclones made landfall in Madagascar, six of which affected Toamasina directly.<sup>12</sup> The most severe storms tend to occur during the monsoon season<sup>d</sup> and cause water contamination, damage to health facilities, and increased food insecurity.<sup>13</sup> The intensity, regularity, and substantial costs of storms like these make the process of building climate resilience — particularly with respect to infrastructure — very difficult.

The number of people affected by flood events in Madagascar has increased in the past 30 years, reflected in the **Total Number of Flood Events** (medium-high risk, score of 6.04). On average, flooding costs \$13 million in total direct losses and \$3.1 million in emergency costs each year. Flooding in Madagascar is expected to increase as a result of more intense climate fueled precipitation, and cyclones. Heavy precipitation events — which are the primary drivers of flooding — in Madagascar are projected to increase in both number and intensity, particularly in the northeastern and central regions near Toamasina.<sup>14</sup> When these flood events are considered in the context of rising sea levels, Toamasina’s metropolitan area is at a significant risk for flooding, including the city’s public airport and some of the areas to the south of the city.<sup>15</sup>



Flooding in Toamasina, March 2024. Credit: Leon Marcellin

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d Monsoon season in Madagascar is between November and April and is characterized by warmer temperatures and heavy rainfall.



Nationally, **Projected Change in Sea Level Rise (SLR)** (high risk, score of 8.78) in Madagascar will reach a total of 11 centimeters by 2030 and 22 centimeters by 2050 under a range of emissions scenarios.<sup>16</sup> This indicator received the second-highest risk score in the assessment. SLR threatens the very existence of coastal communities like Toamasina, and was highlighted as a major vulnerability in local surveys as well. Coastal erosion caused by sea level rise puts existing roads and ports at risk, including those in Toamasina.<sup>17</sup> SLR may also cause saline intrusion in coastal waterways and groundwater reservoirs. Rising sea levels, increased precipitation, and tropical cyclones each contributes individually to Toamasina’s risk of flooding, but when taken together, these risks compound. As described by one interviewee, the key to understanding the full picture of climate risk and resilience in Toamasina is the combination of “[f]looding of low-lying and coastal areas, coastal erosion, intensified cyclone[s].”

Mangrove forests provide a wide range of ecosystem services, and this is especially the case in Madagascar. The **Health of Existing Mangroves** (score of 6.25), the **Level of Mangrove Coverage** (score of 6.07), and the **Percent of GDP Protected by Mangroves** (score of 6.52) were all identified as medium-high risks in this assessment. Mangroves are used for timber and fuel, provide breeding and nursery habitats, and protect communities from storms and floods and counter coastal erosion. As described by one interviewee, “forests are one of the most important ecosystems for reducing climate risks, so the key [to climate resilience in Madagascar] is to reforest and restore degraded forests.”<sup>18</sup> Mangroves are estimated to contribute \$530 million per year to Madagascar’s economy, including supporting the livelihoods of over two million people.<sup>19</sup> Mangroves cover a total of 2,776 square kilometers, covering 45% of Madagascar’s coastline.<sup>20</sup> Between 1996 and 2016, Madagascar’s mangroves experienced an overall net loss, but have since seen a significant rebound.<sup>21</sup> The primary drivers responsible for mangrove losses have been “non-productive conversion through unsustainable wood collection for charcoal production, timber and firewood (including for smoking of fish), and land clearance for agriculture and aquaculture.”<sup>22</sup>

Madagascar has roughly 2,400 square kilometers of coral reefs in its territorial waters, including nearly 400 species of stony<sup>e</sup> corals.<sup>23</sup> **The Health of Existing Coral Reefs** (score of 6.31), the **Level of Coral Reefs Coverage** (score of 8.58), and the **Percent of GDP Protected by Coral Reefs** (score of 6.05) were all identified as high or medium-high risk for this assessment. Since the 1980s, corals off the coast of Madagascar have declined as a result of large-scale disturbances, including heat-induced bleaching events, and human-induced stressors, such as overfishing.<sup>24</sup> The **Change in Sea Surface Temperature** (medium risk, score of 4.20) of the Western Indian Ocean is warming faster than for the Atlantic and Pacific Oceans, and these temperature changes have led to coral bleaching.<sup>25</sup> Heat stress events have rippling effects throughout the marine ecosystem. After the 1998 bleaching event, coral cover across the Western Indian Ocean declined by an average of 37.7%, though corals in the southwestern Indian Ocean (where Madagascar is located) showed less impact.<sup>26</sup> Although Madagascar’s eastern sea (near Toamasina) has relatively lower sea surface temperature (SST) and variation, lower temperature rises, and higher coral cover and diversity,<sup>27</sup> changes in coral coverage due to increasing SST are very likely to alter the productivity of Madagascar’s coastal fisheries.<sup>28</sup>

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e Stony corals, also called hard corals or Scleractinia, are marine animals in the phylum Cnidaria that build themselves a hard skeleton of the aragonite form of calcium carbonate.



Nearshore fisheries support food security, livelihoods, and communities throughout coastal Madagascar. Many nearshore fisheries are declining as a result of overfishing, harmful or destructive fishing practices, and habitat degradation,<sup>29</sup> reflected in **Nearshore Fish Stock Status** (high risk, score of 8.42). Many local fishers attribute the decline in Toamasina’s nearshore fisheries to industrial shrimp trawlers and tuna longline vessels,<sup>30</sup> and to degradation of the reefs. One interviewee shared, “...we can also see that fish products are diminishing because the reefs are being destroyed.” Commercial shrimp trawling has negative environmental impacts, including high levels of bycatch and the destruction of seagrass habitats.<sup>31</sup> The effects of climate change, particularly changes in SSTs, are a well-known reality for fishers in Madagascar. Higher SSTs are reducing catch and forcing a change in livelihood for some; as described by one interviewee, “...we see the reduction in fishermen’s production [that is] caused by the temperature which is not very favorable and the species are forced to move and the fishermen are unable to follow them.” By 2050, under a medium emissions scenario, the fisheries catch potential in Madagascar is projected to decrease 6.3% relative to the catch recorded in 2000.<sup>32</sup>

It is important to note that the opportunities and challenges related to fisheries are at the national and regional level, rather than at the city level. This is especially the case for offshore fisheries in Madagascar, which are targeted by foreign fleets from Japan, Taiwan, and South Korea.<sup>33</sup> A 2011 study found that catch from Madagascar in the early 2000s was underreported by at least 40%.<sup>34</sup> Foreign commercial vessels, particularly longline vessels, have had considerable environmental impacts including bycatch,<sup>f</sup> and are likely a leading culprit for the decline in catch for subsistence fishers.<sup>35</sup> Global Fishing Watch data identified 706 unique vessels flying the flags of 94 different foreign nations in Madagascar’s Exclusive Economic Zone between July 2022 and July 2023, reflected in the **Number of Fisheries Access Agreements with Foreign Nations** (medium-high risk, score of 5.45). Yet at the local level, surveys provided by Toamasina experts supported relatively low risk scores for **Offshore Fish Stock Status** (medium risk, score of 3.76), **Level of Unreported Catch Estimate** (medium risk, score of 4.15), and **Number of Incidents of Foreign Vessels Fishing in EEZ** (medium-low risk, score of 2.90). These relatively low risk scores reflect the understanding that Toamasina’s blue economy is supported primarily by the port rather than by the fishing sector.

The most recent assessment of the **Capacity of Fisheries Enforcement Institutions** (medium-high risk, score of 5.33) in Madagascar was undertaken in 2017. It found that monitoring and enforcement for industrial fisheries had improved significantly over the prior two decades, reflected in the relatively lower score for **Offshore Fish Stock Status** (medium risk, score of 3.76). The assessment suggested that additional support was needed to better manage small-scale fisheries,<sup>36</sup> reflected in the **Percent of Fisheries Managed Sustainably** (medium-high risk, score of 6.00). Madagascar established its first locally managed marine area (LMMA) in 2006 in Velondriake in the southwest.<sup>37</sup> A recent assessment found that it has had some success along both social and environmental outcomes. The five permanent reef reserves within the LMMA saw a 189% increase in fish biomass six years after implementation and have seen increased value from octopus fisheries, though progress in addressing overexploitation for species such as shark and sea cucumber has been limited.<sup>38</sup> The LMMA has also built social capital within participating communities and has supported livelihoods, improved access to housing, and access to

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f Bycatch refers to the incidental capture of non-target species. Bycatch can include non-target fish species, e.g., catching flounder when trawling for shrimp, as well as other marine creatures, like dolphins, sea turtles, and seabirds.

education.<sup>39</sup> However, local communities still rely on state authorities for enforcement and punishment of rule breaking. These authorities are often underresourced and suffer from allegations of corruption, limiting their usefulness.<sup>40</sup>

Given the role of fisheries in supporting communities and livelihoods, in 2021, Madagascar created the Ministry of Blue Economy and Fisheries and appointed Paubert Tsimanaoraty Mahatante, a scientist and civil society leader, as the Ministry's first leader. Madagascar is also a candidate for the Fisheries Transparency Initiative (FiTI). As of December 2022, Madagascar has been accepted into the FiTI as an official Candidate Country, making it the third country globally to be granted this status. after Mauritania in 2018 and Seychelles in 2020.<sup>41</sup> In December 2023, the government published its first FiTI report, making available information on fisheries laws and regulations, payments for industrial fishing activities, and a list of large-scale fishing vessels.<sup>42</sup> As part of FiTI, the Malagasy government will have to publicly disclose fisheries agreements, which would help address a lack of transparency in the fisheries industry. These changes at the national level of fisheries governance in Madagascar can support similar prioritization of sustainable fisheries management at the local level.

As described by one interviewee, "Right now, everything is linked to climate change, it's part of our daily lives."

# Economic Risk

## Toamasina: Economic Risk

Each category score comprises multiple indicators.

Low 1 - 2.5 Medium 2.51 - 5 Medium-High 5.01 - 7.5 High 7.51 - 10

Category	Indicator	Score
<b>Infrastructure</b>	Percent of Population with Adequate Access to Electricity	7.61
	Effectiveness of Solid Waste Management Procedures	6.94
	Renewable Energy Share in Total Energy Consumption	6.67
	Level of Resilience for Airports	6.47
	Level of Housing Damage from Extreme Weather Events	6.41
	Level of Resilience for Roads	6.33
	Proportion of Wastewater Safely Treated	6.10
	Level of Grid Resilience	5.97
	Level of Commercial Infrastructure Damage from Extreme Weather Events	5.96
	Percent of Low-Income Housing in Relation to Flood Zones	5.74
	Level of Water Distribution Infrastructure Resilience	5.73
	Level of Informal or Unplanned Settlement	5.37
	Level of Resilience for Ports and Shipping	5.18
	Level of Shoreline Development	4.96
	Percent of people living below 5 Meters above Sea Level	4.77
<b>Major Industries</b>	Percent of National Economy Based in Port and Shipping Industries	7.17
	Percent of National Economy Based in Agriculture	6.20
	Percent of National Economy Based in Near Shore Fishing Industry	5.95
	Diversity of Lodging Types	5.62
	Percent of National Economy Based in Tourism Industry	5.60
	Percent of National Economy Based in Off Shore Fisheries	5.03
<b>Economics</b>	National GDP Per Capita	7.99
	Level of Informal Economy	6.25
	Income Inequality	5.75
	Urban Unemployment Rate	5.64
	Market Losses from Extreme Weather Events	5.53
	Percent of GDP Generated in Coastal Cities	4.09
	National Unemployment Rate	2.81
	National Youth Unemployment Rate	2.74
Debt Ratio	2.58	

Table: Stimson Center • Created with Datawrapper

Madagascar is one of the poorest countries in the world, and its national per capita income declined 45% between 1960 and 2020.<sup>43</sup> Although Toamasina is the country's second-largest city, it suffers from many of the same economic challenges as the rest of Madagascar. These include limited coverage of basic infrastructure, lack of basic services, and a highly informal economy. The impacts of climate change further exacerbate these challenges by damaging houses, businesses, and critical infrastructure and inhibiting the circulation of goods and people.

- The **INFRASTRUCTURE** category (expert weighted average score of 6.05) highlights the limited coverage and vulnerability of Toamasina's critical built infrastructure. The highest risk score in the category is **Percent of Population with Adequate Access to Electricity** (score of 7.61); 30% of the population lacks any access at all. The **Effectiveness of Solid Waste Management Procedures** (score of 6.94) scored as a medium-high risk. Debris clogs rivers, canals, and gullies, exacerbating the impacts of flooding in the city, damaging human health, and harming the environment. Local stakeholders highlighted risks around the **Level of Resilience for Airports** (score of 6.47), the **Level of Resilience for Roads** (score of 6.33), the **Level of Grid Resilience** (score of 5.97), and the **Level of Water Distribution Infrastructure Resilience** (score of 5.73). All are medium-high risk scores, demonstrating the widespread vulnerability of Toamasina's infrastructure.
- In the **MAJOR INDUSTRIES** category (expert weighted average score of 5.98), the medium-risk score for **Percent of National Economy Based in Port and Shipping Industries** (score of 7.17) underscores the importance of Toamasina's port for Madagascar's economy. The port handles 90% of the country's container traffic, linking it to the global economy. It exports the country's major natural resources, especially agricultural, timber, and mineral products. Medium-high risk scores for **Percent of National Economy Based in Agriculture** (score of 6.20) and **Percent of National Economy Based in Nearshore Fishing Industry** (score of 5.95) highlight the importance of two sectors that are dominated by small-scale subsistence activity.
- In the **ECONOMICS** category (expert weighted average score of 4.72), **National GDP per Capita** (score of 7.99) is the highest risk score in the Economic Risk Area, reflecting Madagascar's unproductive economy. A large part of the economy is informal, as indicated in the medium-risk score for **Level of Informal Economy** (score of 6.25), much of it in the form of subsistence agriculture and fishing. Tropical cyclones and other extreme weather events inflict major losses on the economy, as shown in the medium-high risk score for **Market Losses from Extreme Weather Events** (score of 5.53).

Madagascar is the ninth poorest country in the world, reflected in the **National GDP per Capita** (high risk, score of 7.99).<sup>44</sup> It is also one of only six countries in the world that has seen national income per capita fall since gaining independence (in 1960).<sup>45</sup> The COVID-19 pandemic caused a recession that was three times as deep as in the rest of sub-Saharan Africa and drove 2.4 million people into poverty.<sup>46</sup> As a result, the government of Madagascar has limited financial resources and numerous pressing challenges, leaving it overstretched. Madagascar's cities, including Toamasina, the second-largest city, account for three-quarters of the nation's economic activity.<sup>47</sup> This economic activity, however, is also driving the fastest urbanization rates in sub-Saharan Africa, and has increased poverty in Madagascar's cities over the past decade. This increase has been especially large in the country's secondary cities, like Toamasina.<sup>48</sup> Interview respondents described internal migration to the city resulting from inland people learning of new projects in the city, like the port expansion or growth related to mining, such as

the Ambatovy refining plant. Too often, the jobs are already filled, yet the migrants remain, adding to Toamasina’s infrastructure and social challenges.

The informal sector dominates the Malagasy economy, reflected in the scores for the Level of Informal Economy (medium-high risk, score of 6.25). This sector encompasses all economic activity that is not regulated or protected by the government.<sup>49</sup> It includes those working in subsistence food production, street vendors, garment manufacturers, domestic workers, and a wide range of other workers operating without legally required permits or registration.<sup>50</sup> The informal sector accounts for 95% of national employment, according to estimates from the International Monetary Fund.<sup>51</sup> Within urban areas, an estimated 60% of jobs are informal, according World Bank estimates, driven by a lack of available formal jobs.<sup>52</sup> Interviews highlighted the rapid growth of the informal businesses in Toamasina,<sup>53</sup> as well as the persistence of slash-and-burn agriculture (locally known as Tavy) and subsistence fishing.<sup>54</sup> Interviews highlighted the lack of other options to generate income and a lack of awareness about the consequences of environmental destruction as key drivers of this kind of activity.<sup>55</sup> In addition, informal firms have limited available capital, which constrains their ability to recovery from climate impacts and invest in resilience. Since they are often untaxed, a large informal sector also limits available tax revenue. Interviews also highlighted that informal firms constrain the effectiveness of regulation.<sup>56</sup>



Roadside shops in Toamasina, August 2024. Credit: Carolyn Gruber

Although agriculture only employs less than 5% of the population in the city of Toamasina, it accounts for over a quarter of the national economy and 85% of national employment,<sup>57</sup> reflected in the score for **Percent of National Economy Based in Agriculture** (medium-high risk, score of 6.20). Agriculture does occur in the areas around the city of Toamasina, however, in the district of Toamasina II, which covers the outskirts of the city and surrounding rural areas. These inland areas are mountainous, and deforestation driven by slash-and-burn agriculture will increase the frequency and severity of rainfall-driven flooding, particularly along the Ivoloina and Ivondro Rivers, which run north and south of Toamasina, respectively.

The fisheries sector accounts for approximately 7% of Madagascar's economy,<sup>58</sup> but nearshore subsistence fishing is more important for coastal communities, such as those around Toamasina, reflected in the score for **Percent of National Economy Based in Nearshore Fishing Industry** (medium-high risk, score of 5.95). Interviewees reported that although beach seine fishing is illegal, enforcement is limited, and the practice continues in Toamasina, contributing to the decline of local fish stocks.<sup>59</sup> In addition, the government of Madagascar is working to encourage fish farming in rural areas to create employment, strengthen food security and nutrition, and reduce pressure on local ecosystems.<sup>60</sup> Interviews report that tilapia fish farming is developing in the rural areas around Toamasina.<sup>61</sup> The Ministry of Fisheries and Blue Economy also recently launched a plan to increase the country's annual production of fish by 116% by the end of 2028, driven in large part by aquaculture.<sup>62</sup>



Fish market in Toamasina, August 2024. Credit: Carolyn Gruber

In addition to their sizeable informal sectors, Madagascar’s largest cities — including Toamasina — house the majority of the country’s formal employment. In Toamasina, the most important industries are the port and the Ambatovy mineral processing plant and refinery. Both are capital intensive, which means they can only create a limited number of formal sector jobs.

Toamasina is Madagascar’s largest port, handling an estimated “75 percent of domestic cargo and 90 percent of international cargo.”<sup>63</sup> The port provided critical support during the country’s recent economic recovery following the deep recession caused by the COVID-19 pandemic. Post 2020, the economy grew more strongly than projected, driven principally by a growth in the export of mining and textile products.<sup>64</sup> The importance of Toamasina’s port, through which these exports are shipped, is reflected in the **Percent of National Economy Based in Port and Shipping Industries** (medium-high risk, score of 7.17). Shipping into and out of the port also poses risks to Madagascar’s unique biodiversity through invasive species transported in ballast water, thanks to the incomplete implementation of the Ballast Water Treaty.<sup>65</sup>

The port is currently undergoing a major expansion, funded in part by a \$411 million loan from the Japan International Cooperation Agency.<sup>66</sup> The expansion will more than triple the port’s container processing capacity, from 300,000 containers per year currently to one million containers per year by 2035.<sup>67</sup> It will also add a dedicated berth for cruise ships and protect the port complex with a new breakwater that is 11 meters high and extends 25 meters underwater, along with 30- to 50-ton wave absorbing blocks.<sup>68</sup> These measures are reflected in a comparatively lower risk score for **Level of Resilience for Ports and Shipping** (medium-high risk, score of 5.18). The port expansion, however, has allegedly destroyed some of the coral reefs around Toamasina.<sup>69</sup> The port is also a critical source of government revenue. Madagascar relies on import-export tariffs for 48% of its tax revenues, and as the country’s major port, Toamasina collects more than 75% of non-oil tax revenues. A recent World Bank study found that a single type of tax evasion scheme at the port cost Madagascar 3% of total tax revenue.<sup>70</sup>



Toamasina port, August 2024. Credit: Carolyn Gruber

Another important component of Toamasina's economy is the Ambatovy mineral processing plant and refinery. The Ambatovy mine is located 80 kilometers east of Antananarivo, outside the study area. It is connected via a 220-kilometer pipeline, most of which is buried to an average depth of 1.5 meters, to the processing plant and refinery located in Toamasina.<sup>71</sup> They process ore to produce approximately 40,000 tonnes of refined nickel and 4,000 tonnes of refined cobalt per year.<sup>72</sup> The mine tailings — leftover residue — is treated and stored at a site 10 kilometers west of the plant. Excess water from processing is discharged into the ocean. Local residents have complained of negative health effects from Ambatovy's facilities following tropical cyclones, though the company has denied these allegations.<sup>73</sup>

Tourism has been another important driver of Madagascar's economic growth in recent years,<sup>74</sup> though the sector makes up just 6.3% of the economy,<sup>75</sup> reflected in the **Percent of National Economy Based in Tourism Industry** (medium-high risk, score of 5.60). Few tourists stay in Toamasina, though the city is an important transit point for tourists going to popular attractions to the north and south.<sup>76</sup> However, the government has set the goal of attracting 500,000 tourists to the country annually,<sup>77</sup> and the construction of a cruise ship berth at Toamasina's port may help the city to attract more tourism and tourist revenues.

To attract international tourists, and to grow its economy more broadly, Toamasina will need to address the limitations and vulnerabilities of its infrastructure. An estimated 70% of the population in the city of Toamasina has access to electricity, but that figure is below 10% for the surrounding areas in Toamasina II District.<sup>78</sup> A lack of investment in aging equipment results in frequent outages and distribution losses, reflected in **Percent of Population with Adequate Access to Electricity** (high risk, score of 7.61). The lack of generation capacity is exacerbated by the failures of JIRAMA, the state-owned electric utility, to pay private generation companies. This lack of investment also makes the electricity grid more vulnerable to the impacts of extreme weather events, including tropical cyclones and heavy rainfall, which can down power lines and flood generation and transmission equipment, reflected in the **Level of Grid Resilience** (medium-high risk, score of 5.97). Two-thirds of the electricity is provided by imported fuel oil and diesel.<sup>79</sup> Ninety-five percent of the nation's gasoline is also imported through the port of Toamasina. These fuels are vulnerable to leakage and spills at the port and when they are distributed country-wide, especially during extreme weather events, which harm human and ecosystem health.

Toamasina also faces contamination risks from uncollected solid waste, reflected in **Effectiveness of Solid Waste Management Procedures** (medium-high risk, score of 6.94). Estimates of solid waste collection rates vary, but local stakeholders stated that the city collects only 60 of the 300 tonnes of solid waste produced per day,<sup>80</sup> in line with national rates.<sup>81</sup> Collection services are focused primarily on local markets and other densely populated areas.<sup>82</sup> Much of the waste that goes uncollected is disposed of illegally into the Pangalanes Canal along with other canals and drainage channels.<sup>83</sup> The Agence Portuaire Maritime et Fluviale clears the canal of waste at least twice daily, but is underresourced, and the combination of waste and sedimentation has narrowed the canal so much that boats cannot pass some points.<sup>84</sup> Obstructed drainage channels increase the intensity of flooding and slow drainage of floodwaters, which can increase the spread of mosquito- and water-borne diseases, like dengue. Uncollected or improperly stored solid waste is known to leach into and contaminate groundwater and contribute to the spread of diseases such as bubonic plague. Bubonic plague is endemic to Madagascar, and a 2017 outbreak caused more than 2,400 cases, including in Toamasina.<sup>85</sup> Uncollected solid waste also gets swept into the ocean, where it harms the health of coastal and marine ecosystems and of coastal fisheries and drives away potential tourists. The municipal government of Toamasina recognizes the urgency of improving solid waste management and is reportedly developing a solid waste

management plan.<sup>86</sup> There are also plans for a small-scale biogas project and a new waste management facility that will be able to manage 60 tonnes of waste per day, though there is reportedly no equivalent investment in waste collection systems.<sup>87</sup>



Overflowing solid waste management container, August 2024. Credit: Carolyn Gruber

Toamasina also has very limited sanitation infrastructure, reflected in the **Proportion of Wastewater Safely Treated** (medium-high risk, score of 6.10). Ninety-seven percent of the population uses latrines. Thirty-eight percent of these are septic tanks, with the remaining 62% single pit latrines, the majority of which are “tinnettes,” consisting of a 200-liter oil barrel dug in the ground.<sup>88</sup> When the latrines are full, over three-quarters of households employ informal services that manually empty the latrines, while another 13% empty the latrines themselves.<sup>89</sup> Industrial waste and maritime dumping also contributes to the challenge of untreated wastewater in Toamasina. While Madagascar is a signatory to the “London Convention,”<sup>g</sup> implementation is still in its early stages.<sup>90</sup>

Untreated wastewater contaminates groundwater and is spread throughout the city when it floods. This is a major cause of diarrheal disease, such as cholera and typhoid fever, which is the fourth leading cause of death in Malagasy children under the age of five.<sup>91</sup> The World Bank and the government of Madagascar signed a \$220 million National Water Project in 2022, but the project is targeted at the cities of Antananarivo, Antsiranana, and Mahajanga.<sup>92</sup>

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g Formally the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.

To promote economic growth, Toamasina must also address the vulnerability of its transportation infrastructure. Stakeholders rated the Level of Resilience for Airports (medium-high risk, score of 6.47) as the sixth-highest area of economic vulnerability. Toamasina Ambalamanasy Airport (TMM) is the city's primary airport, located in the northern part of the city. There is also a small private air strip located within the Ambatovy processing complex. TMM is approximately 1.2 kilometers west of the ocean and approximately 600 meters west of the Du Nord River. Another river runs to the west of the airport, between 1 (on the northern end of the runway) and 2 (on the southern end of the runway) kilometers away. TMM sits at a low elevation, making it vulnerable to flash flooding and storm surge from the ocean and the Du Nord River, particularly around the northern parts of the runway.<sup>93</sup>

Ground transportation networks are also at risk from climate impacts. Madagascar has one of the least extensive road networks in the world, with just 11.4% of the rural population living within 2 kilometers of an all-season road, reducing access to health care, stunting agricultural productivity, and increasing insecurity, which together help drive rural-to-urban migration.<sup>94</sup> Although road networks are more developed within Toamasina, they suffer from frequent damage from overloaded trucks traveling to and from the port. They are also increasingly vulnerable to sea level rise, coastal erosion, and flooding, reflected in the **Level of Resilience for Roads** (medium-high risk, score of 6.33). These challenges are compounded by limited maintenance.<sup>95</sup> Regular road maintenance has fallen sharply in recent years as a result of the diversion of revenue from fuel taxes away from the Road Maintenance Fund (FER) to the national treasury.<sup>96</sup>

Only a single road, RN2, connects Toamasina to Antananarivo and the rest of the country, with another major road, RN5, extending north from the city and running north along Madagascar's eastern coast before terminating at the town of Maroantsetra. Sinohidro is improving the road connection between Toamasina's port and RN2, and the World Bank has invested \$740 million in improving roads and other transportation infrastructure in FY20-FY22.<sup>97</sup> Toamasina also has a rail line that runs south of the city, to the town of Ambila Lemaitso, where it turns west toward Antananarivo and other inland locations. South of the town of Tampina, the line runs across a narrow spit of land between the Indian Ocean (just over 100 meters away) and Lake Farihy Ampitabe (less than 20 meters away at the closest point). Rapid sea level rise, compounded by coastal erosion, threatens this connection.

Rapid urbanization has given rise to large informal settlements in Toamasina, just as it has in other cities in Madagascar. Nationally, over 60% of urban residents live in informal settlements, over 90% of which is built with fragile materials prone to damage from extreme weather events.<sup>98</sup> These dynamics are replicated in Toamasina, contributing to the Level of Housing Damage from Extreme Weather Events (medium-high risk, score of 6.41), the seventh-highest score in the Economic Risk Area. Informal settlements are often characterized by a lack of secure tenure and land rights, which limits investments in both services, such as waste management, and resilient construction materials. Many of Toamasina's densest informal settlements lie along the Pangalanes Canal, in settlements like Ambolomadinika, Ambalakisoa, and Morarano. These settlements' proximity to the canal, combined with the lack of services, contributes to the contamination of the canal with plastic, other solid waste, and untreated wastewater.



# Social/Political Risk

## Toamasina: Social/Political Risk

Each category score comprises multiple indicators.

Low 1 - 2.5 Medium 2.51 - 5 Medium-High 5.01 - 7.5 High 7.51 - 10

Category	Indicator	Score
Governance	Investment in Climate Resiliency Development Projects	7.07
	Access to Healthcare	6.91
	Level of Perceived Transparency within Government	6.38
	Rule of Law	5.86
	Capacity of Ethics Enforcement Bodies	5.60
	Civil Society Participation	5.59
	National Climate Adaptation Plan	5.31
	Capacity of Current Disaster Response	4.49
	Voter Turnout	4.16
Social/Demographics	Percent of Population Below Poverty Line	8.82
	Percent of Urban Population Below 30 Years of Age	6.79
	Urban Population Density	6.55
	Urbanization Rate	6.36
	Dependency Ratio	6.33
	Percent of Population Engaged in Seasonal/Cyclical Migration	6.14
	Percent of Population Achieving Proficiency in Literacy and Numeracy	5.65
	National Population	5.57
	Percent of Adult Citizens Living Outside of the Country	5.57
	National Population Density	3.21
	Urban Population	2.95
Stability	Number of Years that the Current Government Structure Has Been in Place	7.20
	Percent of People Employed in Agriculture	6.83
	Percent of People Employed in Port and Shipping Industries	5.75
	Percent of People Employed in Tourism	5.47
	Percent of People Employed in Artisanal and Subsistence Fishing	5.46
	Percent of People Employed in the Commercial Fishing Industry	5.10
	Number of Incidences of Civil Unrest or Instability	4.76
Level of Social Tension	2.75	

Table: Stimson Center • Created with Datawrapper

Many of Toamasina's highest social and political risks are associated with the high levels of poverty and rapid population growth. The city also faces medium-high risk from limited investment in climate resiliency projects, political instability, and inadequate access to health care.

- The **GOVERNANCE** category (expert weighted average score of 5.84) has medium-high risk scores for **Investment in Climate Resiliency Development Projects** (score of 7.07), **Access to Health Care** (score of 6.91), and **Level of Perceived Transparency within Government** (score of 6.38), highlighting concerns of weak rule of law, and slow efforts to strengthen adaptation plans.
- In the **SOCIAL/DEMOGRAPHICS** category (expert weighted average score of 5.77), the high risk score for **Percent of Population Below Poverty Line** (score of 8.82) and medium-high risk scores for **Percent of Urban Population Below 30 Years of Age** (score of 6.79) and **Urban Population Density** (score of 6.55) show the risks associated with an increase in rural-urban migration combined with a lack of formal employment opportunities.
- The **STABILITY** category (expert weighted average score of 5.52) shows medium-high risk scores for the **Number of Years that the Current Government Structure Has Been in Place** (score of 7.20) and **Percent of People Employed in Agriculture** (score of 6.83), in **Port and Shipping Industries** (score of 5.75), and in **Tourism** (score of 5.47). These scores highlight the risks associated with the country's history of political instability since their independence, and economic dependence on the shipping, tourism, and agriculture sectors.

Toamasina is the second-largest city in Madagascar and continues to grow rapidly, reflected in a medium-high risk score for **Urbanization Rate** (score of 6.36). Home to an estimated 350,000 people in the city itself and another 275,000 in the surrounding province, Toamasina accounts for roughly 15% of the total population of Madagascar. Other estimates put the city's population at 800,000 or more. The city's population growth rate is 4.9% per year,<sup>99</sup> and the **Urban Population Density** (medium-high risk, score of 6.55) has doubled from 27.7/km<sup>2</sup> in 1993 to 54.2/km<sup>2</sup> in 2018.<sup>100</sup> A very young population, reflected in **Percent of Urban Population Below 30 Years of Age** (medium-high risk, score of 6.79), means that population growth will continue to be rapid in the coming years. This rapid growth puts additional strain on already underdeveloped and highly vulnerable infrastructure, including the poor conditions of roads, limited clean drinking water resources, and minimal access to basic sanitation infrastructure. Interviewees highlighted the lack of a sufficient wastewater system in the city and the continued stress on solid waste management, leading to health and climate risks.<sup>101</sup> Continued growth, compounded by a lack of urban planning, will likely result in the expansion of the highly congested informal settlements in the neighborhoods of Ambalakisoa and Morarano along the Pangalanes Canal. In the suburban areas of Toamasina, this growth will likely also lead to more frequent construction without permits.



Informal housing on the banks of the Pangalanes Canal, August 2024. Credit: Natalie Fiertz

Madagascar's public health system is characterized by fragmentation and instability. A 2018 World Bank report noted that the country saw four different Ministers of Health between 2009 and 2014 and that following the end of the National Health Strategy in 2011, it was informally extended with no updated strategy. The system also suffers from a lack of financing, inequitable service delivery, and poor quality of service.<sup>102</sup> Domestic health spending rose from 2013 to 2017 before falling sharply in the following years before the pandemic. Even after a small increase in 2020, domestic government spending on health care per capita was below the 2013 level,<sup>103</sup> when external support accounted for 83% of public health expenditures.<sup>104</sup> As a result, there is an increasing reliance on private (both nonprofit and for-profit) health services.

As a result of the constraints it faces, Madagascar's health infrastructure is extremely limited. According to the most recent data available, Madagascar has the second-smallest number of hospital beds per capita (2010 data)<sup>105</sup> and the 27th-smallest number of physicians per capita (2018 data).<sup>106</sup> More than 66% of health facilities report missing at least one essential medicine, over 40% of the population lives more than 5 kilometers from a health center, and only 50% of the population makes use of health facilities for reasons related to either availability or cost,<sup>107</sup> reflected in **Access to Healthcare** (medium-high risk, score of 6.91). The prevalence of long-term, chronic malnutrition among children under age five is the ninth highest in the world, although the rate has been steadily falling over time.<sup>108</sup> Similar steady improvements have been made in maternal mortality<sup>109</sup> and infant mortality.<sup>110</sup>

The majority of Malagasy people live in rural areas, reflected in the relatively low risk score of **Urban Population** (medium risk, score of 2.95). Population density is highest in Antananarivo and along the eastern coast of Madagascar.<sup>111</sup> The **Percent of Population Below Poverty Line** (high risk, score of 8.82), which had fallen modestly before the pandemic, increased to 81.5% in 2021, almost twice the

sub-Saharan Africa average rate.<sup>112</sup> People in poverty without access to electricity are dependent on wood harvesting for coal, timber, and firewood.<sup>113</sup> This reliance drives illegal deforestation and poaching activities and threatens Madagascar's fragile ecosystems.<sup>114</sup> Local expert interviewees highlighted this reliance on harmful subsistence practices as a recurring challenge to reducing climate vulnerability.<sup>115</sup> Illicitly harvested timber is transported via the Pangalanes Canal from upstream to the city.<sup>116</sup> The World Bank specifically notes the increase in poverty in urban areas, attributing it to rural-urban migration, a lack of employment opportunities in cities, and a decline in the productivity of private enterprises.<sup>117</sup>

Across many of the expert interviews, an overarching concern expressed by interviewees was the lack of education and awareness of the local population on how their actions impact the environment. Interviewees highlighted lack of education around oil spills and other marine pollution,<sup>118</sup> protection of natural resources,<sup>119</sup> climate-resilient agricultural practices,<sup>120</sup> and water quality and hygiene.<sup>121</sup> Interviewees indicated that there are some campaigns run by NGOs and regional departments to raise awareness of a few of these topics but overall, more education is needed.

Madagascar has a history of political instability, reflected in the **Number of Years that the Current Government Structure Has Been in Place** (medium-high risk, score of 7.20). Since independence from France in 1960, the country has seen four major political crises, in 1972, 1991, 2002, and 2009, each with a change in regime and constitution and serious economic impacts. The crises usually involve urban protests and strikes, but most analysts believe they are typically driven by the elite.<sup>122</sup> Although the country has not seen a major political crisis since 2009, there are recent signs of political instability. An alleged assassination plot against President Rajoelina in 2021 resulted in the arrest of 21 people, including five generals.<sup>123</sup> In December 2021, Rajoelina sacked all of his ministers.<sup>124</sup> There was another cabinet reshuffle in March 2022, the fifth in three years, though Rajoelina has retained most of his key ministers.<sup>125</sup>

Perceptions of widespread corruption and challenges around the weak **Rule of Law** (medium-high risk, score of 5.86) exacerbate the country's challenges related to the illicit trafficking of natural resources. Despite Madagascar being an island nation, its porous borders and abundant valuable natural resources have given rise to organized criminal trafficking networks. The two most studied trafficked commodities are rosewood and tortoises, though gold, wildlife, precious stones, cannabis, and other timber trafficking also exist. In addition, the impacts of the COVID-19 pandemic have exacerbated environmental crimes.<sup>126</sup> Containment measures drove rural populations toward illicit activities such as trafficking of precious wood, sale of endangered animals, and farming in protected areas to earn a living.<sup>127</sup>

A limited **Level of Perceived Transparency within Government** (medium-high risk, score of 6.38) impedes the regulation of these practices. Madagascar relies on border tariffs for 48% of its tax revenues, and as the country's major port, Toamasina collects more than 75% of non-oil tax revenues. A recent World Bank study found that a single type of tax evasion scheme at the port has cost Madagascar's central government 3% of total tax revenue.<sup>128</sup> Further public incidents of corruption included the implication of the former Minister of Justice in a racketeering case and the exposure of a powerful businessman for allegedly bribing high-ranking civil servants and manipulating court decisions.<sup>129</sup>

Agriculture, forestry, and fishing account for at least 70% of employment in Madagascar<sup>130</sup> and approximately a quarter of GDP.<sup>131</sup> The majority of the country's agriculture is subsistence based,<sup>132</sup> with many Malagasy farmers being smallholders who rely on the rainy season to grow crops.<sup>133</sup> Climate change is projected to extend the dry season across the island and increase the vulnerability of Madagascar's food supply.<sup>134</sup> In Toamasina, Tavy (slash-and-burn agriculture) is still widely practiced.<sup>135</sup> These risks,

along with the potential inundation of agricultural land from SLR and heavy rainfall, are reflected in the risk score for Percent of Population Employed in Agriculture (medium-high risk, score of 6.83). The country also remains a food importer, with rice accounting for 5% of imports by value in 2021, the second-most of any product.<sup>136</sup> This makes the country vulnerable to price swings, with poor residents who are unable to afford market-price rice pushed into slash-and-burn agriculture.<sup>137</sup>



Transporting goods via the Pangalanes Canal, August 2024. Credit: Carolyn Gruber

Concerns around food insecurity played a role in the coup in 2009. In November 2008, amidst the 2007-2008 global food price crisis, the government signed a deal with Daewoo Logistics in which the company was given a 99-year lease on 1.3 million hectares — almost half Madagascar’s total arable land — to farm maize and palm oil for export at no cost.<sup>138</sup> The revelation of the deal sparked widespread protests, and one of President Rajoelina’s first actions upon taking office in 2009 was to cancel the deal.<sup>139</sup> A law passed in June 2023 and under review by the High Constitutional Court, however, allows foreign companies and investors to secure 99-year renewable land leases, and has drawn significant criticism.<sup>140</sup>

Madagascar published its National Adaptation Plan (NAP) in May 2022. The NAP includes 12 “structuring programs,” including goals to strengthen resilience and adaptation efforts in Madagascar’s key economic sectors of fisheries, agriculture, and tourism.<sup>141</sup> However, national-level planning does not always translate into effective planning and implementation at the local level, reflected in the medium-high risk for **National Climate Adaptation Plan** (score of 5.31). There has been weak coordination in climate adaptation planning between the national, regional, and municipal governments. Limited technical capacity also inhibits the government’s ability to provide early warning services for weather emergencies. The Meteorological Department has suffered a major reduction in the available weather equipment; rain gauges have fallen from 340 at independence to just 60 today.<sup>142</sup> The communication

channel for relaying weather and climate data from local stations to the national meteorological agency in Antananarivo also faces technical constraints.

Furthermore, the lack of deep local technical expertise means that development planning in Toamasina is often conducted by consultants and not focused locally nor designed with local partners, resulting in plans that are too vague to be useful. Disaster risk management, community development, and service provision are often delegated to development partners, with minimal government oversight. Furthermore, tax revenues go primarily to the national government.<sup>143</sup> Local stakeholders highlighted how this limited the funding available for local priorities.<sup>144</sup> This constrains their capacity and ability to provide essential services to the city, including disaster risk management, development planning, and preparing for climate change.

There have been three recent significant investments in resilience projects in Madagascar, including projects funded by the Adaptation Fund,<sup>145</sup> the Green Climate Fund,<sup>146</sup> and the Global Facility for Disaster Reduction and Recovery.<sup>147</sup> Yet none of the three projects focus on the city of Toamasina, the second-largest city in the country, as reflected in **Investment in Climate Resiliency Development Projects** (medium-high risk, score of 7.07), which is the third highest risk indicator in the social risk category. This can be attributed to the control by the central government, wherein local and municipal authorities like Toamasina have not had sufficient access to this type of climate finance.

# The Status of Resilience Planning

The principal framework that guides climate adaptation planning in Madagascar is the country's National Adaptation Plan, which was published in May 2022.<sup>148</sup> The Plan establishes twelve “structuring programs,” of which four are the most relevant to the climate risks and vulnerabilities of Toamasina identified in this CORVI assessment:

- Strengthening the adaptation of the fishing industry by developing warning systems and associated action plans,
- Improving access to drinking water in urban and rural areas,
- Bolstering protection of coastal infrastructure and economic activities (including tourism) against sea level rise, and
- Improving cyclone early warning systems, as part of a regional effort in the Indian Ocean.

Over the past several years, the government of Madagascar has taken several important steps toward the implementation of these programs, with the support of international partners. In 2021, the government established the Ministry of Fisheries and Blue Economy and issued a regulation prohibiting industrial fishing within two nautical miles of the shoreline.<sup>149</sup> That same year, the government announced its commitment to join FiTI. In 2022, Madagascar was accepted as an official Candidate Country, the third country to gain that status with FiTI.<sup>150</sup> In December 2023, the government published its first FiTI report, making available information on fisheries laws and regulations, payments for industrial fishing activities, and a list of large-scale fishing vessels.<sup>151</sup>

To help strengthen the resilience of Madagascar's coastal zones, the Global Environment Facility is supporting the country's National Office for Climate Change, part of the Ministry of the Environment and Sustainable Development to implement the “project of adaptation of coastal zone management to climate change, taking into account ecosystems and livelihoods” (PAZC). In the Atsinanana region, PAZC is focused primarily on fisheries and aquaculture, particularly in Lake Ankotobona. The project is creating a community management structure, re-stocking the lake, and providing fishing and aquaculture equipment.<sup>152</sup>

The government of Madagascar, along with international partners, has initiated several projects to strengthen infrastructure threatened by tropical cyclones, flash flooding, and sea level rise. Together with the Japanese International Cooperation Agency, the government is undertaking a major expansion of Toamasina's port, which will increase the port's capacity and enhance its protection against sea level rise and storm surge.<sup>153</sup> Some stakeholders in Toamasina, however, expressed concerns that the port expansion has destroyed local coral reefs and narrowed the opening between the ocean and Toamasina's coastline, potentially increasing incoming wave energy.<sup>154</sup> Sinohidro is strengthening the road connection between the port and National Road 2, the highway that connects Toamasina to the rest of Madagascar.<sup>155</sup> The World Bank's Road Sector and Sustainability Project is rehabilitating and improving

important sections of Madagascar's road and rail network, including National Road 2, along with parts of the electricity distribution network owned by JIRAMA, the state-owned electric utility and water services company.<sup>156</sup> Another World Bank project, the Madagascar National Water Project, is increasing access to clean water in and around Antananarivo,<sup>157</sup> and a project funded by the Global Facility for Disaster Reduction and Recovery is integrating nature-based solutions and risk-informed design in Antananarivo.<sup>158</sup>

Climate adaptation efforts are not limited to the government of Madagascar. The Green Climate Fund supported a project to engage the private sector in the agriculture, health, coastal and ecosystem management, and water sectors in southern Madagascar.<sup>159</sup> Local stakeholders also highlighted the work of NGOs in improving climate resilience in Toamasina, such as Tany Ifandova, which is working to promote nature-based solutions and raise awareness of the threats posed by climate change.

# Priority Recommendations to Build Resilience

Toamasina faces high and growing risks from flooding, with threats from frequent tropical cyclones, rapid sea level rise, and flash flooding from extreme rainfall. This CORVI assessment highlights how these threats are exacerbated by high levels of poverty, loss of coral reef coverage, and inadequate infrastructure, especially for electricity provision and solid waste management. Flooding damages homes and businesses, makes it more difficult to access health care and other services, and impedes the circulation of people and goods.

Frequent and severe flooding, compounded by both climate hazards like warming oceans and non-climate hazards including habitat destruction and runoff of plastic debris and untreated wastewater, undermines economic growth, food security, and income generation in Toamasina. This assessment highlighted the high level of vulnerability of coral reefs and coastal fisheries, and local stakeholders also emphasized deforestation around the city. Degraded terrestrial and marine ecosystems also further increase flooding risk, creating a vicious cycle. The following recommendations provide a pathway for Toamasina to escape this cycle and foster durable, climate-resilient growth that can pull the people of this rapidly urbanizing city out of poverty.

## Implement an integrated flood management and adaptation strategy

Toamasina will continue to face increasing threats from flooding in the coming years. Local experts identified tropical cyclones, sea level rise, and incidents of heavy rainfall as some of the highest-priority risks facing the city. In response, Toamasina should implement an integrated flood management and adaptation strategy that strengthens its response to major flood events and addresses the compounding drivers of flood risk in the city. This strategy would include key steps to improve the Toamasina's response to, and management of, major flood events:

- **Establish a unified emergency operations center** to unify the national, regional, and district-level agencies that have responsibilities relevant to flood planning, response, and recovery. This would help coordinate operations, reduce the time between early warning and response, and help link disaster response planning to efforts to address the multiple structural factors that worsen flooding in the city. These results, in turn, could help address the lack of solid waste management and the debris clogging canals, rivers, and gullies. For example, disaster response personnel could identify specific obstructed drainage channels that play a major role in exacerbating flooding, and this could inform which areas are prioritized for improved waste collection, particularly of harmful plastics. A useful and replicable example is the Lamu County Emergency Operations Center in Kenya, which was recently awarded the Averted Disaster Award.<sup>160</sup>
- **Create neighborhood disaster risk management committees** to strengthen early warning and response systems and reduce damages from flooding. Such committees have been effectively employed in Maputo, Mozambique.<sup>161</sup> These types of committees would be especially useful in Toamasina's dense informal settlements, where government authorities have limited information and local residents can play an important role in communicating critical real-time information.

- **Implement an anticipatory cash relief program.** Anticipatory cash relief has been very effective in reducing the harm suffered by the most vulnerable residents during disasters in other countries throughout sub-Saharan Africa.<sup>162</sup> Anticipatory cash relief entails sending small payments before an extreme weather event hits, which can pay for preparatory measures like evacuating people and property, and have helped reduce food insecurity, lives lost, and loss of livelihoods after disasters like cyclones and extreme rainfall.<sup>163</sup> This type of cash relief could be funded by innovative insurance products, potentially in partnership with international initiatives like the Global Shield against Climate Risks.
- **Increase nature-based projects to address flooding.** To reduce the impacts of flooding in Toamasina's informal settlements, the government and international partners should support and implement nature-based solutions (NbS) in these neighborhoods. Good lessons can be learned from similar projects in highly dense cities in Southeast Asia.<sup>164</sup> NbS such as constructed wetlands, community gardens, restoration of riparian vegetation, and swales — shallow channels to absorb water runoff — have helped reduce flooding, clean wastewater, and support ecosystems in low-lying, flood-prone informal settlements in countries like Indonesia. Involving the residents of informal settlements in decision-making around solution design and location has improved the successful implementation of these types of solutions. So too has emphasizing their benefits to food security, income generation, and community building, in addition to how they can improve climate resilience.<sup>165</sup>
- **Improve solid waste management** to help ensure the success of NbS in informal settlements, reduce the extent and persistence of flooding throughout the city, and reduce the secondary impacts, such as the spread of disease. This will require increased investment in waste collection trucks, financial and social support for informal waste collection workers,<sup>166</sup> and construction of new waste management facilities and landfills with appropriate measures taken to prevent chemical leaching into Toamasina's groundwater. It should also include the development of waste-to-worth projects, including waste-to-energy plants,<sup>167</sup> biodigesters,<sup>168</sup> and factories that can convert PET bottles into plastic pellets for export.<sup>169</sup>
- **Design community-based relocation efforts away from flood-prone areas.** Some residents living in the most flood-prone areas, such as on the banks of the Pangalanes Canal, may need to be relocated out of harm's way. Such a relocation process should proceed in consultation with the residents in and around these areas, to improve buy-in and help ensure that flood-prone areas are not reoccupied. The district government should also identify low-risk areas for relocated residents to move to, and provide services (e.g., waste collection), basic infrastructure (e.g., sanitation and electricity), and secure land tenure rights to those living in low-risk areas. The government and international partners should also provide affordable financing to residents relocated out of flood-prone areas to help them rebuild.
- **Identify highly flood-prone areas** with the help of improved mapping of Toamasina's informal settlements, as the Humanitarian OpenStreetMap Team has done for informal settlements in cities like Monrovia, Liberia, and Dar es Salaam, Tanzania.<sup>170</sup> Such mapping efforts would also help strengthen disaster planning and response efforts by identifying vulnerable structures and guiding rescuers.

- **Empower local climate adaptation.** The national government of Madagascar should strengthen local access to climate finance through implementation of the LoCAL Climate Adaptive Living Facility in cooperation with the UN Capital Development Fund.<sup>171</sup> The government should support coordination between with non-government actors by reinforcing the regional blue economy committee and Madagascar’s Information Fusion Centre. The government should also invest in local technical expertise in climatology and oceanography and build connections with universities throughout Madagascar and the wider Western Indian Ocean region. International partners should support the deployment of a greater density of weather instruments and meteorological equipment.

## Invest in the health of coastal and marine ecosystems and resources

Toamasina is particularly vulnerable to climate change impacts that are outside of its realm of control; local experts identified tropical cyclones, sea level rise, and incidents of heavy rainfall as some of the most concerning and costly risks facing the city. These natural hazards cost the country over \$100 million in combined direct losses each year.<sup>172</sup> As climate change continues globally, causing more severe weather, storm surges, heat domes, drought, and sea level rise in the countries located in the Western Indian Ocean, it is imperative that cities like Toamasina work to build resilience and adapt to the impacts of natural hazards. Healthy marine ecosystems, including coral reefs, mangroves, and seagrass beds, and ocean resources, including coastal and offshore fisheries, can play an outsized role in reducing the impacts of climate change, particularly for coastal cities like Toamasina.

- **Stop destructive mangrove harvesting and plant new mangroves.** Mangrove forests and other coastal forests in Toamasina can provide essential ecosystem services to coastal communities. Healthy and resilient mangrove ecosystems can protect Toamasina from flooding and storm surge, reduce damage from tropical cyclones and other extreme weather events, reduce — and even reverse — coastal erosion, improve nearshore water quality, provide essential habitat and nursery grounds for fish, and support the growth of a sustainable blue economy.
- **Restore and protect Toamasina’s vulnerable coastal and marine ecosystems to foster and expand beneficial ecological services.** The Toamasina local government and Malagasy national government, together with international partners and local community leaders, should support coral reef restoration projects, artificial coral reefs, and the planting of seagrass beds and mangrove forests. Adopting best practices that are tailored to conditions in the Western Indian Ocean, like those described in the UNEP’s “Guidelines on Mangrove Restoration for the Western Indian Ocean Region,”<sup>173</sup> and “Seagrass Ecosystem Restoration Guidelines for the Western Indian Ocean Region,”<sup>174</sup> would be most useful.
- **Expand locally managed marine areas (LMMAs)** by replicating the success of the Velondriake LMMA in Toamasina and the surrounding coastal communities. This could effectively expand marine protections, restore vulnerable marine ecosystems, and foster local leadership in coastal and marine resource management. A recent assessment of the LMMA in Velondriake showed clear increases in fish biomass, which has resulted in better-supported coastal livelihoods. Applying an inclusive participatory or community-led approach to siting and enforcing nearshore LMMAs and marine protected areas (MPAs) has been used by other small island developing states to great effect. Many countries and regions are engaged in coastal conservation planning to expand their

networks of protected areas. Some are trying to include ecosystem services, such as the benefits of mangrove forests, seagrass beds, and coral reefs, as a driver in site selection for LMMAs and MPAs. Good examples include the Caribbean Challenge Initiative, the Seychelles Marine Spatial Plan Initiative,<sup>175</sup> and Belize's Nationally Determined Contribution.<sup>176</sup> One of the primary challenges with the Velondriake LMMA is limited enforcement capacity. Choosing LMMA and MPA sites that provide greater ecosystem services to the community can incentivize and improve the enforcement of those protected sites, highlighting benefits to the coastal communities.<sup>177</sup>

- **Prioritize becoming a full member of the Fisheries Transparency Initiative (FiTI).** In December 2022, Madagascar was accepted into FiTI as an official Candidate Country. As part of FiTI, the Malagasy government must publicly disclose the details of its fisheries access agreements. This, along with the other eleven FiTI transparency principles, including developing a public registry of fisheries laws, regulations, and policies and implementing a scientific assessment of fisheries resources, will improve fisheries management at the local and national levels.
- **Develop a sustainable management plan for nearshore fisheries.** Coastal fisheries support food security, livelihoods, and communities throughout Madagascar, including in Toamasina, but many nearshore fisheries are declining because of overfishing, destructive fishing practices, and habitat degradation, particularly of coral reef ecosystems and seagrass beds. According to interviews, shrimp trawling is a particular challenge, given the rate of bycatch and the role this gear type plays in damaging marine ecosystems. Rather than eliminate the trawl fishery altogether, which could have negative impacts on the fishing community and blue economy, the local government in Toamasina and the national-level Malagasy government should work together to develop a fishery management plan to foster a more sustainable approach to managing the shrimp trawl fishery. Examples could include using turtle excluder devices and bycatch reduction devices to help reduce bycatch of non-target fish species and marine creatures. Time-based closures linked to spawning times can support better fisheries management. Similarly, area-based closures that encompass at-risk marine ecosystems, like coral reefs, can support increases in biomass and ecosystem recovery. Sustainable nearshore fisheries management relies on community engagement and leadership, however. An inclusive approach that connects all relevant stakeholders will support the development of a locally relevant, enforceable, and achievable fishery management plan.
- **Conduct a science-based assessment of marine ecosystem health.** This would include a science-based fisheries stock assessment for coastal and offshore fisheries in the Atsinanana region area to improve fisheries management. Investing in a deeper understanding of the current state of coastal and offshore fisheries will support longer-term marine management goals and help determine fishing levels, gear types, closures, and areas for fish habitat protection. Beyond nearshore fisheries, investment is needed in restoration and protection of critical habitats and natural resources including coral reefs, mangroves, seagrass beds, and coastal and offshore fisheries. Supporting the health of existing marine ecosystems in Toamasina is paramount in building climate resilience and maintaining — and eventually growing — Toamasina's sustainable blue economy.

## Invest in climate-resilient infrastructure and economic growth

As one of the poorest and most climate-vulnerable countries in the world, Madagascar urgently needs to invest in climate-resilient infrastructure and economic growth to pull its people out of poverty. As the country's second-largest city, chief seaport, and a potential major driver of economic growth, it is critical that Toamasina be a focus of this investment.

- **Invest in the electrical grid.** A lack of access to reliable electricity is a major constraint to the growth of private enterprises, especially in the formal sector,<sup>178</sup> and was identified as one of the most important components of Toamasina's climate vulnerability in this assessment. The lack of reliable electricity harms productivity, imposes additional costs through the purchase and operation of private generators, and limits the education of students who cannot study after the sun goes down. During extreme weather events, unreliable electricity is associated with increased mortality from heat, limits the operation of pumps, and makes rescue efforts more difficult. Working with the regional and municipal governments, the government of Madagascar should leverage programs like the World Bank–African Development Bank initiative to provide electricity to 300 million people in Africa,<sup>179</sup> USAID's PowerAfrica program to double access to electricity in sub-Saharan Africa,<sup>180</sup> and the G20 goal to triple renewable energy capacity globally by 2030<sup>181</sup> in order to mobilize international support to expand and strengthen the electricity grid in Toamasina.
- **Create a supportive regulatory environment for the electricity sector,** including for private operators. This includes simplifying the process for connecting to the grid (which took an average of 75 days in 2022),<sup>182</sup> streamlining the requirements to set up new renewable energy plants (especially around securing land), and reducing import burdens for solar panels and other power generation equipment. Reforms at JIRAMA to ensure that private generators are paid fully and consistently for the electricity they generate are critical to the expansion of electricity access. Within the city of Toamasina, the government should build on the installation of solar PV at three heavy-fuel oil plants.<sup>183</sup> In rural areas, where expanded access can also reduce deforestation, the World Bank's Digital and Energy Connectivity for Inclusion in Madagascar Project can support microgrids and solar home systems.<sup>184</sup>
- **Build reliable and resilient transportation systems** to support sustainable economic growth in Toamasina and the surrounding region. The city's airport was identified as the most vulnerable such system in the city. An assessment of specific areas of the airport vulnerable to flooding could identify where the government should protect or restore natural ecosystems in adjoining land to protect the airport. The city's road and rail networks are also critical to its economic security. Funding should be dedicated for road infrastructure, including maintenance and relocation of highly flood-prone roads. Direct funding of fuel tax revenue to the Road Maintenance Fund should be restored, and investment made in keeping adjacent drainage channels clear of household debris and plastic waste to strengthen resilience to flooding.
- **Use the Pangalanes Canal as a transportation corridor.** The burden placed on Toamasina's road network could also be reduced if Pangalanes Canal could serve as a reliable transportation avenue. Regular dredging of the canal, improved collection of debris and plastic waste, and increased capacity to treat wastewater could all help open the canal to regular traffic and enhance the city's ability to manage floodwater. The Agence Portuaire Maritime et Fluviale recently dredged seven kilometers of the canal, but needs funding for further work, including at least four dredgers to maintain navigability.

- **Encourage government support for adaptation small and medium-sized enterprises (SMEs)** that provide climate change adaptation products and services, such as drip irrigation and drought-resistant seeds.<sup>185</sup> Adaptation SMEs can also foster climate-resilient economic growth and poverty alleviation. They have helped mobilize private capital for climate adaptation and address the needs of underserved communities that are highly vulnerable to climate change in Botswana, Malawi, and Zambia.<sup>186</sup> However, adaptation SMEs face challenges in expanding their operations, particularly around accessing sufficient investment capital and public misconceptions about their products. To address these challenges, the government and international partners should help such firms create a pipeline of investable opportunities for global investors and educate the public about the benefits of the adaptation products and services these firms provide. The government should also engage with these firms to identify and reduce key regulatory barriers. With sufficient support, adaptation SMEs could create jobs and foster economic growth in Toamasina and promote climate adaptation in the city, the surrounding areas in Toamasina II District, and more broadly throughout Madagascar.

# Appendices

## Appendix 1: Full list of Indicators for CORVI Toamasina

Category	Indicator
<b>Climate</b>	Cases of Vector-Borne Disease Infections
	Change in Sea Surface Temperature
	Number of Droughts
	Number of Extreme Heat Events
	Number of Flood Events
	Number of People Affected by Extreme Weather Events
	Number of Tropical Cyclones
	Number of Wet Days
<b>Ecosystems</b>	Health of Existing Coral Reefs
	Health of Existing Mangroves
	Health of Existing Sea Grass Beds
	Incidence of High Invasive Species Abundance
	Level of Coral Reefs Coverage
	Level of Mangrove Coverage
	Level of Sea Grass Bed Coverage
	Percent of GDP protected by Coral Reefs
	Percent of GDP protected by Mangroves
	Percent of GDP Protected by Sea Grass Beds
Rate of Occurrence of Harmful Algal Blooms	
<b>Fisheries</b>	Capacity of Fisheries Enforcement Institutions
	Fish Consumption Per Capita
	Level of Unreported Catch Estimate
	Nearshore Fish Stock Status
	Number of Fisheries Access Agreements with Foreign Nations
	Number of Incidents of Foreign Vessels Fishing in EEZ
	Offshore Fish Stock Status
	Percent of Fisheries Certified Sustainable
<b>Geology/Water</b>	Degree of Saltwater Intrusion in Coastal Aquifers
	Degree of Soil Salinity in Arable Lands
	Level of Geophysical Risk of Landslides
	Percent of Bodies of Water with High Water Quality
	Percent of Landscape that is Arable Land
	Percent of Metropolitan Area at Risk of Flooding
	Piped Water Supply Continuity
	Projected Change in Sea-Level Rise
Rate of Coastal Erosion	

<b>Category</b>	<b>Indicator</b>
<b>Economics</b>	Debt Ratio
	Income Inequality
	Level of Informal Economy
	Market Losses from Extreme Weather Events
	National GDP Per Capita
	National Unemployment Rate
	National Youth Unemployment Rate
	Percent of GDP Generated in Coastal Cities
Urban Unemployment Rate	
<b>Infrastructure</b>	Effectiveness of Solid Waste Management Procedures
	Level of Commercial Infrastructure Damage from Extreme Weather Events
	Level of Grid Resilience
	Level of Housing Damage from Extreme Weather Events
	Level of Informal or Unplanned Settlement
	Level of Resilience for Airports
	Level of Resilience for Ports and Shipping
	Level of Resilience for Roads
	Level of Shoreline Development
	Level of Water Distribution Infrastructure Resilience
	Percent of Low-Income Housing in Relation to Flood Zones
	Percent of people living below 5 Meters above Sea Level
	Percent of Population with Adequate Access to Electricity
	Proportion of Wastewater Safely Treated
Renewable Energy Share in Total Energy Consumption	
<b>Major Industries</b>	Diversity of Lodging Types
	Percent of National Economy Based in Agriculture
	Percent of National Economy Based in Near Shore Fishing Industry
	Percent of National Economy Based in Offshore Fisheries
	Percent of National Economy Based in Port and Shipping Industries
	Percent of National Economy Based in Tourism Industry

<b>Category</b>	<b>Indicator</b>
<b>Governance</b>	Access to Healthcare
	Capacity of Current Disaster Response
	Capacity of Ethics Enforcement Bodies
	Civil Society Participation
	Investment in Climate Resiliency Development Projects
	Level of Perceived Transparency within Government
	National Climate Adaptation Plan
	Rule of Law
	Voter Turnout
<b>Social/ Demographics</b>	Dependency Ratio
	National Population
	National Population Density
	Percent of Adult Citizens Living Outside of the Country
	Percent of Population Achieving Proficiency in Literacy and Numeracy
	Percent of Population Below Poverty Line
	Percent of Population Engaged in Seasonal/Cyclical Migration
	Percent of Urban Population Below 30 Years of Age
	Urban Population
Urban Population Density	
Urbanization Rate	
<b>Stability</b>	Level of Social Tension
	Number of Incidences of Civil Unrest or Instability
	Number of Years that the Current Government Structure Has Been in Place
	Percent of People Employed in Agriculture
	Percent of People Employed in Artisanal and Subsistence Fishing
	Percent of People Employed in Port and Shipping Industries
	Percent of People Employed in the Commercial Fishing Industry
Percent of People Employed in Tourism	

## Appendix 2: Surveyed and Interviewed Organizations

List of Organizations Surveyed and Interviewed
ADOPT - Tamatave
Agence Portuaire, Maritime et Fluviale
Association vogniala
Assurance Aro
Bureau Municipal d'Hygiène
CCIS Madagascar
Commune Urbane Tamatave
Bureau Régional du Commerce
Bureau des mines
Bureau régionale du tourisme
Direction Régionale de l'Eau, de l'Assainissement et de l'Hygiène Atsinanana
Faritra Atsinanana
GALANA
Fikambanana Indiana Misahana ny Fitsaboana Ala-Nenina (IAPC)
Mouvement Chrétien des Cadres et Professionnels (MCCP)
Ministère de l'industrie
ONG Crade
ONG Tany Ifandovana
Organe de Developpement du Diocèse de Toamasina
Pénitenciaire
Police Nationale
Gouvernement de la région Atsinanana
Bureau de tourisme
S2PC Peintures
Service Régional du Budget Atsinanana
Bureau des Travaux Public
Tsarahary sarlu
Universite de Toamasina
Mouvement pour la promotion du genre en politique et développement (VMLF)
Vondrona Miralenta ho an'ny Fampandrosoana

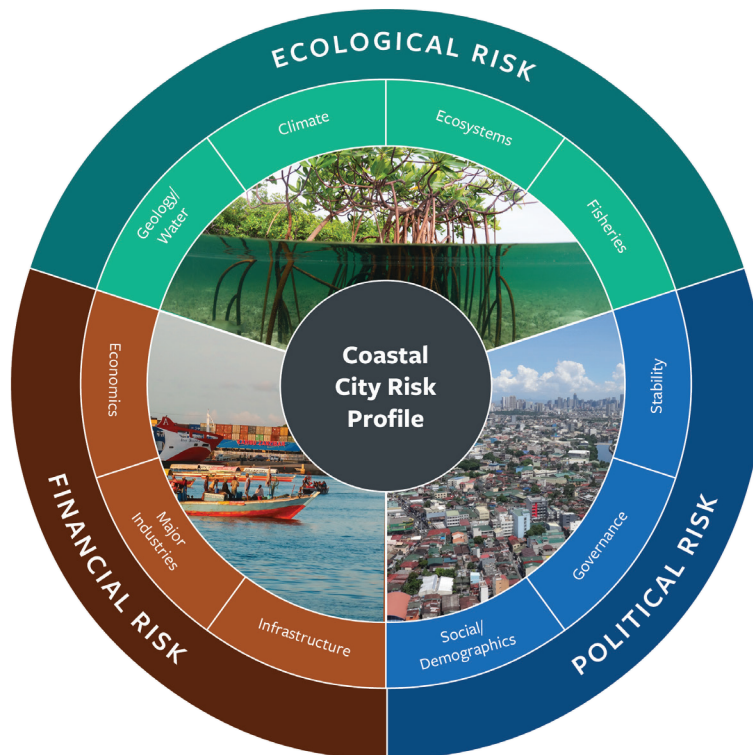
## Appendix 3: The Climate and Ocean Risk Vulnerability Initiative

It is clear that urban coastal areas are likely to experience the earliest onset and potentially most severe impacts from climate change. The risks associated with climate change for specific coastal cities, however, are much more difficult to untangle. In order for coastal cities to efficiently allocate resources and enact effective adaptation strategies, it is critical that they understand their multidimensional climate risk. However, these efforts are impeded by poor and incomplete data.<sup>187</sup> Data on climate risks is rarely available at the city level, and when it does exist, it is often poorly managed and stored in silos that make it difficult to access and use, even for city government officials.<sup>188</sup> This issue is compounded by technical, financial, and capacity gaps, trapping coastal cities in a vicious cycle where they cannot develop holistic strategies to prioritize investment and access the funds needed to implement resilience actions.

Without data at the appropriate geographic scale, decision-makers are often left with the choice of either waiting for greater data availability, or attempting to downscale national level data, neither of which are ideal solutions for effective climate change adaptation. This problem is particularly acute in small and intermediate cities, which along with absorbing the bulk of East Africa's future urban population growth, often lack the resources to gather and maintain necessary data.<sup>189</sup>

Despite these challenges, decision makers need to act now in the face of uncertainty to build resilience to the climate crisis. To do this, they need tools that will enable them to consider multidimensional climate risks, develop cohesive strategies, and utilize this information to unlock additional climate finance and implement resilience actions.

In response, the Stimson Center developed the Climate and Ocean Risk Vulnerability Initiative (CORVI). CORVI is a decision support tool which compares a diverse range of climate-related risks across the land-seascape to produce a coastal city risk profile. These risks are displayed across 10 categories, grouped under three risk areas: ecological, financial, and political (see figure 2). The 10 categories are in turn made up of close to 100 indicators, covering a range of issues including the vulnerability of vital infrastructure, the health of marine ecosystems, and urbanization dynamics in the chosen coastal city. Each indicator and category are scored using a 1-10 risk scale relative to other cities in the region, offering a simple reference point for decision-makers looking to pinpoint and categorize climate risks. The CORVI risk scores, which form the basis of a coastal city risk profile, are augmented with existing academic and grey literature, government documents, and key informant interviews to develop a comprehensive narrative and understanding of the coastal city's climate risks and identify priority policy recommendations.

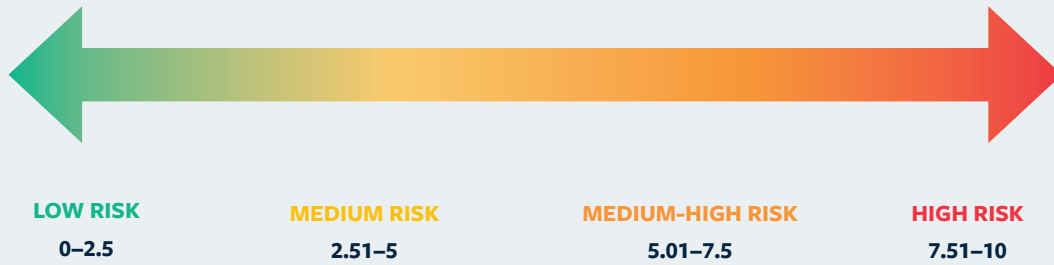


## HOW CORVI IS DIFFERENT

CORVI builds on the work of previous indices but is distinct in three ways.

- 1 **Locally-Based:** Unlike many other indices which tend to focus on the national or regional level, CORVI is city or small island based, providing sub-national level detail on the nature and impact of climate and ocean risks. This focus is based on extensive interviews with potential issuers of the CORVI tool, who noted that climate change is local and the difficulty of down-scaling national level risk and vulnerability data to inform policy action to build climate resilience in specific communities.
- 2 **Holistic:** CORVI looks across a broad set of ecological, economic, social and political risk factors connected to climate change impacts and that influence vulnerability of coastal cities and their residents. As part of the category and indicator selection process, indicator inclusion was primary based on its ability to capture and explain climate change risks in coastal cities, and not if data was available. This approach promotes a holistic understanding of climate change impacts to coastal cities.
- 3 **Data Driven:** Through using Structured Expert Judgment (SEJ), CORVI is suited to producing actionable insights in data sparse environments. By combining empirical and survey data across a wide range of indicators, CORVI fill data gaps to provide a holistic assessment, while reducing data availability bias. This approach provides a contextual and data driven assessment of climate and ocean risk vulnerability.

## CATEGORIZING RISK



### Interpreting Risk Scores

**Low risk** scores mean that either the coastal city has successfully built resilience in the issue area or the indicator is not as relevant for understanding risk in that city.

**Medium risk** scores indicate that while resilience has been built to address the specific risk, future changes could destabilize resilience gains.

**Medium-High risk** scores mean that current measures are insufficient and more attention is required to build resilience against future climate security impacts.

**High risk** scores indicate that the issue area represents a key threat to the coastal city with the potential to undermine the security of its residents.

CORVI began in 2018, with the first two assessments — of Castries, Saint Lucia and Kingston, Jamaica — completed and published in 2020. CORVI is now operating in 16 countries around the world, from the Caribbean to the South Pacific. The project now includes both full assessments, which incorporate around 100 risk indicators distributed across the 10 risk categories, along with rapid assessments, which incorporate 30-35 risk indicators across the same 10 risk categories.

## ADVANCING THE SUSTAINABLE DEVELOPMENT GOALS

CORVI also aims to contribute to the delivery of the SDGs — an essential framework to guide lasting, positive change. By providing data and information to measure climate risks in coastal cities, this project supports the delivery of the following SDGs:



CORVI operates in collaboration with national governments authorities for every assessment. As a locally driven, comprehensive assessment of ocean and climate risk and vulnerability, the CORVI team engages with a wide range of partners on the ground, including national and local government, the private sector, civil society, and academia.

#### **CORVI RAPID ASSESSMENTS COMPLETED**

- Western Province, Sri Lanka
- Southwestern Urban Corridor, Barbados
- Tarawa, Kiribati
- Dominica
- Mauritius

#### **CORVI FULL ASSESSMENTS COMPLETED**

- Basseterre, St. Kitts and Nevis
- Castries, St. Lucia
- Chattogram, Bangladesh
- Dagupan, Philippines
- Dar es Salaam, Tanzania
- Kingston, Jamaica
- Mombasa, Kenya
- Toamasina, Madagascar
- Suva, Fiji

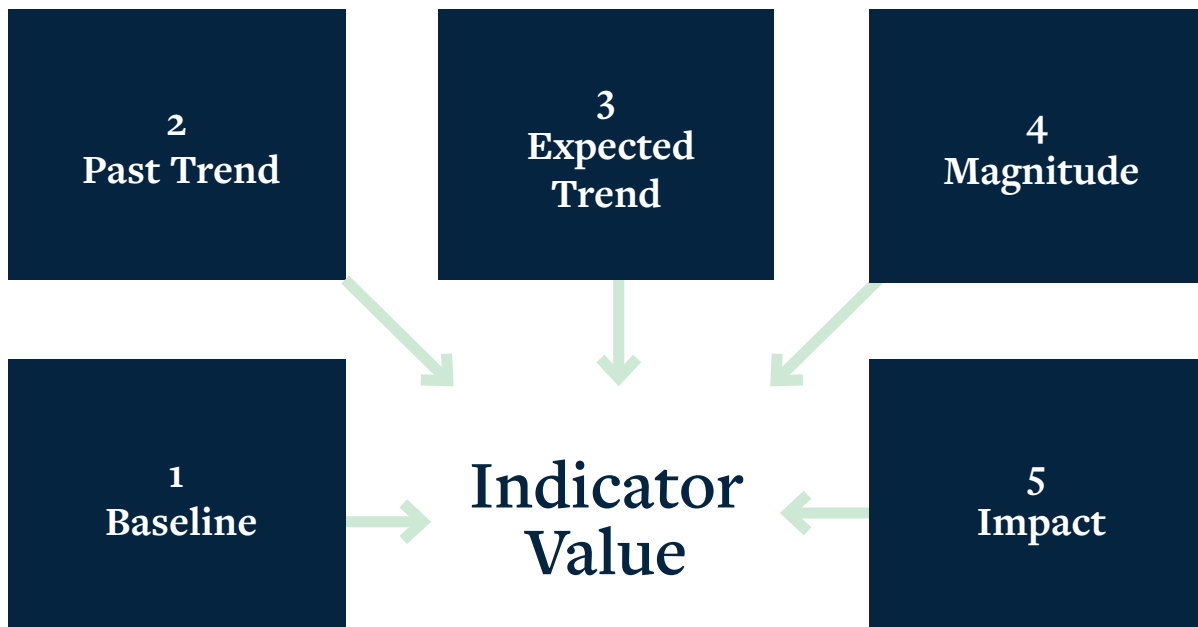
#### **CORVI ASSESSMENTS UNDERWAY**

- Aruba
- Belize City, Belize
- **End pullout box**

## INDICATORS

To ensure that the CORVI indicator scores provide a holistic risk rating, each is made up of five factors: current, past, and expected trends, the rate of change of the risk, and the impact of this risk on the coastal city.

- 1 The **BASELINE** measures the current level of risk for each indicator relative to other coastal cities in the region. Baseline data for economic and social indicators is derived from the most recent year of complete data. Climate indicators use a longer time period of 15 years.<sup>190</sup>
- 2 **PAST TREND** assesses the trend of risk for the past 10 years, measured from the baseline year. The only exception to the 10-year trend measure are the climate indicators, which use a 15-year trend horizon to account for slow onset changes.
- 3 **EXPECTED TREND** assesses the anticipated trend of risk in the next 10 years, measured from the baseline year. The only exception to the 10-year trend measure are the climate indicators, which use a 15-year trend horizon to account for slow onset changes.
- 4 **MAGNITUDE** assesses the degree of expected future trend change relative to other cities in the region. Change that happens quicker than expected is assumed to increase risk when compared to changes that take place over a longer time scale. This assumes that longer time periods of change contribute to less risk, as decision makers have more time to adapt and build resilience.
- 5 Finally, **IMPACT** assesses the importance of change for each indicator in describing future risk in the coastal city.



## DATA COLLECTION AND STRUCTURED EXPERT JUDGEMENT

To overcome data gaps, CORVI employs structured expert surveys to collect data that is otherwise unavailable. This primary data is combined with secondary data using the approach of structured expert judgement (SEJ) to produce a comparative score for each indicator in the assessment.<sup>191</sup> SEJ is well-established social science technique that seeks to quantify risk when pre-existing secondary data is inadequate. Through interviews and surveys, as well as a series of weighting procedures to ensure data is representative, SEJ allows researchers to quantify topics that might otherwise be challenging to study in such a systematic fashion.

To apply SEJ to CORVI, subject matter experts across academia, government, civil society, and the private sector are identified through research and extensive outreach to stakeholders in the target coastal cities. These experts then refer the project team to other experts and stakeholders with appropriate expertise using “snowball sampling.”<sup>192</sup> To guard against confirmation bias, survey answers are compared to a regional secondary empirical dataset to weigh the expert responses by utilizing a coherence check.<sup>193</sup> This ensures that experts whose answers do not match secondary data are not weighed as highly as those who do.

This approach has several strengths. First, CORVI incorporates the views of subject matter experts and local stakeholders at each stage of its implementation. This allows the final product to better reflect the specific context which it is seeking to measure and provide more focused information for end users. Second, pairing primary survey data with secondary data through SEJ also allows CORVI to provide insight into risks relating to urban coastal environments that existing secondary datasets do not cover. While the use of SEJ allows CORVI to assess a diverse range of risks, it should not be regarded as a substitute for empirical data collection. Rather, SEJ is best viewed as an alternative research technique specialized to analyzing topics with significant data gaps.<sup>194</sup>

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