IMPACTS OF CLIMATE CHANGE AND HAZARDS ON KEY SECTORS IN MADAGASCAR

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ABSTRACT

Madagascar is highly vulnerable to the impacts of climate change, facing a range of climate hazards such as tropical cyclones, droughts, floods, and rising sea levels. These hazards have profound effects on key sectors including agriculture, water and sanitation, health, education, and infrastructure, exacerbating poverty and food insecurity. The agricultural sector, which employs 80% of the population and contributes 25% to GDP, is particularly affected by erratic rainfall and extreme weather events, leading to significant crop losses and increased food insecurity. Water resources are under stress due to irregular rainfall patterns and contamination from cyclones, impacting both rural and urban populations. The health sector faces challenges from malnutrition, vector-borne diseases, and damage to healthcare infrastructure caused by extreme weather events. Education is disrupted by the destruction of school infrastructure and increased absenteeism due to food shortages and health issues. Infrastructure, particularly roads and energy systems, suffers from frequent damage due to cyclones and floods, hindering economic development and access to essential services.

To address these challenges, Madagascar has implemented various adaptation strategies and policies, supported by international organizations. These include enhancing agricultural resilience, improving water resource management, climate-proofing health and educational infrastructure, and strengthening road and energy systems. Despite these efforts, the country's limited economic capacity and high poverty rates continue to hinder its ability to fully adapt to the changing climate. This report underscores the urgent need for continued and enhanced support to build climate resilience and mitigate the adverse impacts of climate change on Madagascar's key sectors.

Keywords: Climate Change, Madagascar, Climate Hazards, Agriculture, Food Insecurity, Climate Resilience

JEL Classification: I15, O13, H84, R11, Q18, Q25, Q54

1. Introduction

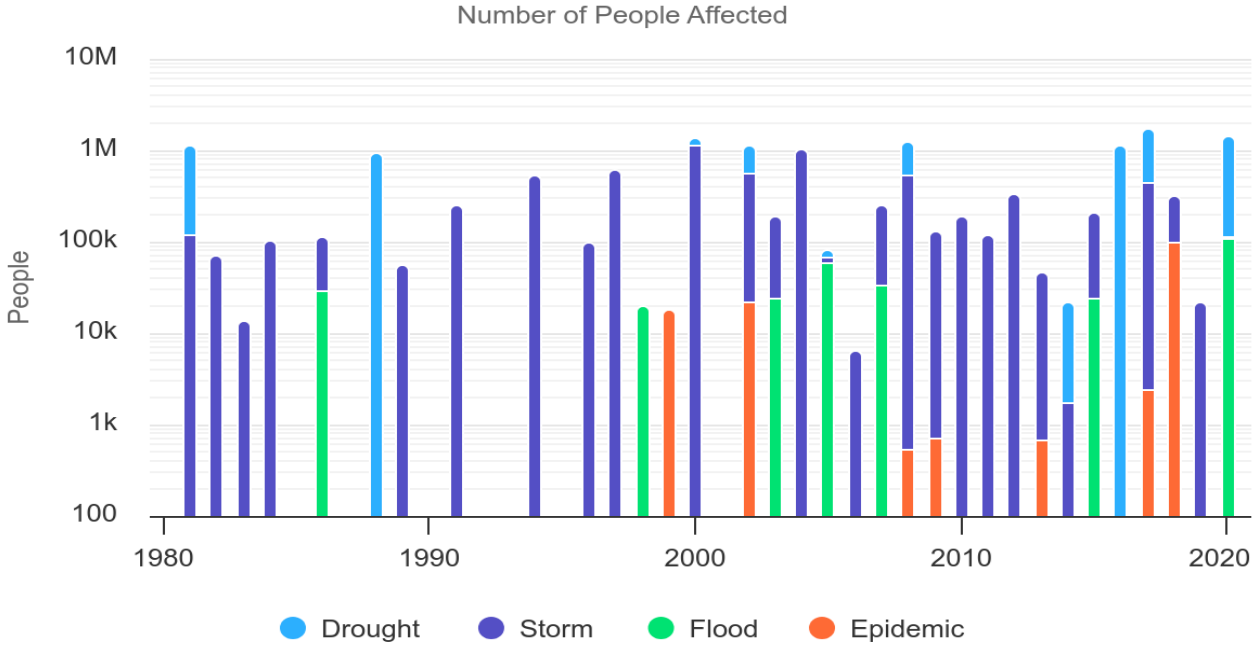
Madagascar is one of the leading countries that are vulnerable to the effects of climate change (FOA 2016). Due to its geographical location, the country is exposed to a multitude of climate hazards, particularly tropical cyclones, droughts, floods, storms, extreme temperatures, and sea level rise. Typical cyclones are by far the most significant disasters, causing approximately 85% of the annual losses among all these disasters (GFDRR 2016).

The impacts of these climate hazards on the country are profound. This includes damage to infrastructure, food security, potable water supply, irrigation, public health systems, and overall quality of life. According to the World Bank, between 1982 and 2018, Madagascar experienced economic damage and over US$1 billion loss due to climate hazards (WBG 2021). Southern Madagascar often faces drought, while the northeastern regions of the country are mostly exposed to cyclones and heavy rainfall. In early 2022, the country experienced six tropical storms, including two intense tropical cyclones (Batsiria and Emnati). Around 420,000 have been affected, and more than 169,000 people have had their homes damaged or destroyed (HI 2022). The eastern coast of Madagascar was struck by tropical Cyclone Freddy in 2023; according to preliminary estimates from the National Bureau of Risk and Disaster Management (BNGRC), 11,000 have been displaced, with more than 4,500 houses either flooded or damaged. Recent Tropical Cyclone Gamane, which hit the north and northeast of Madagascar in early 2024, has significantly impacted the region. About 535,000 people in the 33 flooded communes have been affected, including about 22,000 displaced, most sheltered in temporary sites (OCHA 2024). The area of Grand Sud in southern Madagascar is still recovering from its most acute drought in four decades. The drought is accompanied by sandstorms resulting from three consecutive years of insufficient rainfall and the increasing proliferation of worms and locusts (MDM 2023). Deforestation, soil erosion, and overexploitation of natural resources further exacerbate environmental degradation. The altering climate is also causing an increase in severe heat events and more erratic rainfall patterns. The increased frequency and severity of extreme events have resulted in significant losses in the fields of agriculture, ecosystems, water, and infrastructure (Nurse et al., 2014; Veron et al., 2019).

Madagascar faces high poverty rates, with more than 80.7% of its population living on less than US$2.15 per day despite its abundance of natural resources (WBG 2024). Chronic malnutrition affects nearly 40% of children. Food insecurity results from various factors, such as a lack of agricultural diversification, a high reliance on rain-fed agriculture, and low incomes. The frequency and severity of climate shocks are on the rise, resulting in the loss of lives and livelihoods and the destruction of agriculture, infrastructure, biodiversity, and coastal resources (WFP 2024). Madagascar's limited economic and development capacity hinders its ability to adapt to a variable and changing climate, with an annual loss of 9 to 10% of GDP due to environmental degradation (Rakotondravony et al., 2018). As of 2022, Madagascar has a GDP per capita of $505, which is the sixth lowest in the world. Additionally, the country's place on the Human Development Index has declined from 169th in 2015 to 173rd in 2021 (UNICEF 2023). Over the

last four decades, climate hazards have directly and indirectly affected over 11 million people in Madagascar.

Figure 1: Key Natural and Climate Hazards Statistics from 1980-2020



Source: Climate Change Knowledge Portal, World Bank 2021

Climate projections indicate that Madagascar will experience an increase in the severity and magnitude of climate stressors in the future, with varying degrees of certainty. A greater number of future tropical storms and cyclones is anticipated to be more severe, resulting in higher rainfall, more detrimental wind velocities, and a greater storm surge (USAID 2024). To address and mitigate these impacts, the Government of Madagascar has established laws, administrative procedures, and programs to improve its preparedness for hazards with financial support and aid from international organizations such as the World Bank, the French Development Agency, the European Union, the African Development Bank, the US Agency for International Development, the International Monetary Fund, and UN agencies. This support has led to the enactment of legislation that defines the roles and responsibilities of the National Office for Risk and Disaster Management (BNGRC) and the Emergency Prevention and Management Unit[1].

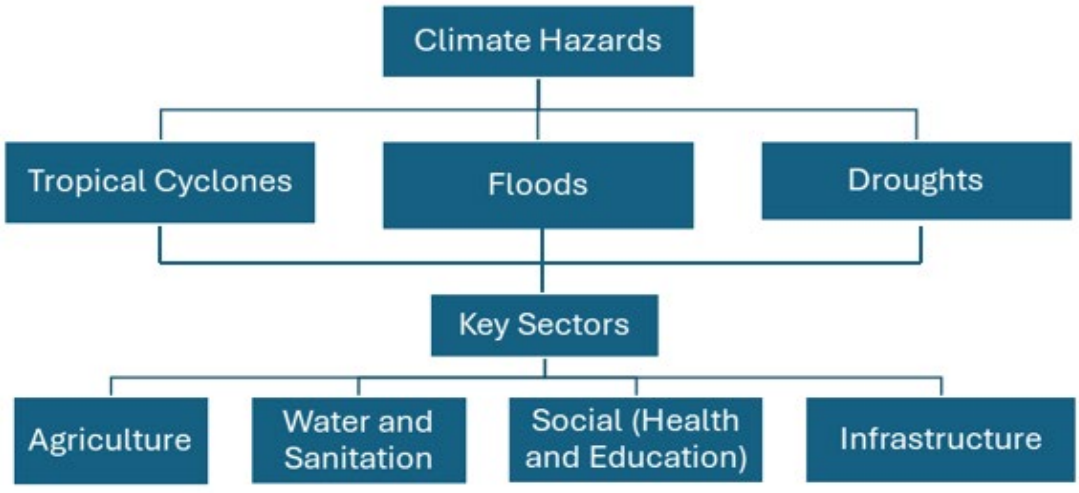
The following section describes the key sectors affected by climate change and related hazards, which are highly vulnerable to future impacts.

[1] The BNGRC is tasked with overseeing risk monitoring and disaster management in Madagascar in dealing with cyclones and floods. It also coordinates efforts related to prevention, readiness, emergency response, early recovery, and reconstruction activities.

2. Climate Change and Hazard Impacts on Key Sectors

Disruptive climate events have severely harmed major sectors in Madagascar; the extent of the damage is expected to be exacerbated by future climate change. These sectors covered in this report include agriculture, water and sanitation, social sectors (education, health), and infrastructure (road and energy).

Figure 2: Climate Hazards and Impact on Key Sectors in Madagascar

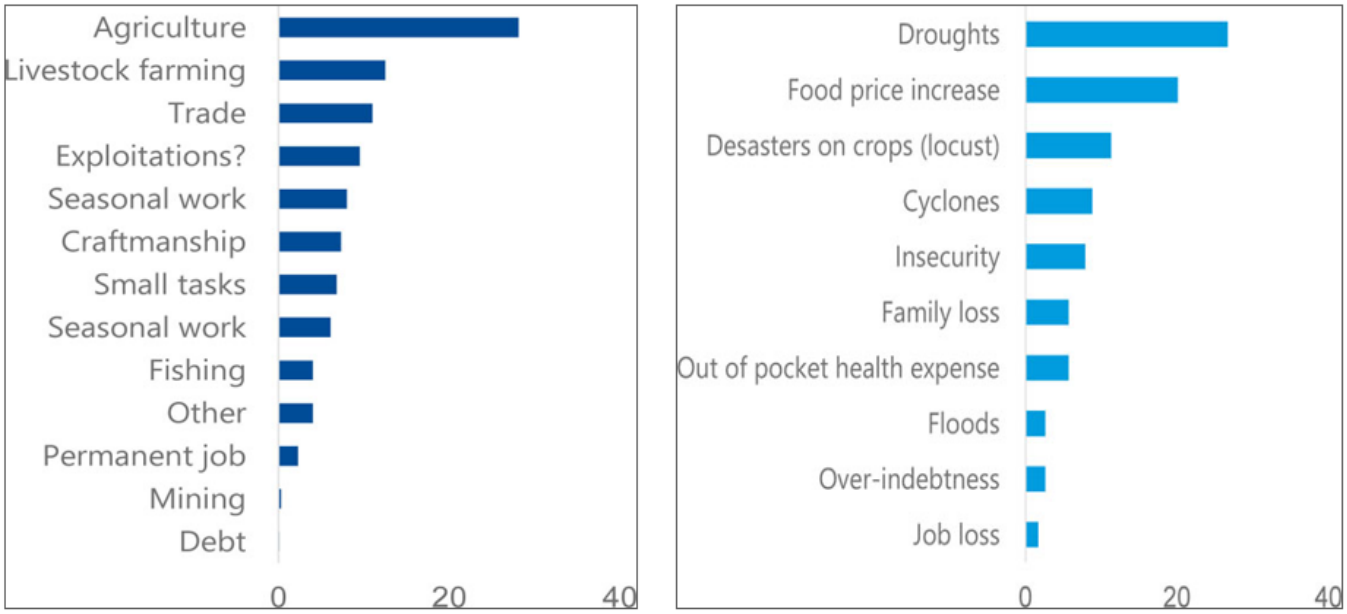


2.1 Agriculture

The agricultural sector (including raising livestock, fishing, and forestry) is the backbone of Madagascar's economy, representing 25% of the Gross Domestic Product (GDP) and providing employment for about 80% of the population (CIA 2022). Nearly 62% of Madagascar's population resides in rural regions, relying mainly on subsistence farming for food security and household income (CIA 2020). The agriculture sector in Madagascar is highly vulnerable to climate hazards, especially when compared to other sectors.

Climate change poses significant obstacles to agricultural productivity in Madagascar, particularly affecting most farmers who are particularly vulnerable due to their dependence on rainfed agriculture, limited arable land, and limited access to resources and finance to address and adjust to extreme climate events (Harvey et al., 2014; Rakotobe et al., 2016). Most farmers rely on rain-fed crops (rice, cassava, bananas, maize, and sweet potatoes). This vulnerability has intensified over the past decade, resulting in a substantial rise in food insecurity throughout the country.

Figure 3: Household Income per Activities and Types of Shocks Experienced by Households



Household Income per Activities, 2022 *(In percent of total income)*

Types of Shocks Experienced by Households, 2022 *(In percent of total households*

Source: MVAC

In the last two decades, the livelihoods and resilience of people to climate hazards have been significantly impacted by a series of droughts, insect infestations, and climate. In 2019, a prolonged period of severe drought in the southern parts of Madagascar led to a significant decrease in agricultural production. As a result, over 1 million people were pushed into a state of food insecurity, with 250,000 facing famine. As of 2021, a persistent drought has severely damaged rainfed crops and caused 1.3 million people in the southern region to experience starvation (OCHA 2021); in combination, the negative impacts of the COVID-19 pandemic further worsened the already severe food insecurity (FAO 2021). The effect of drought-induced pests, including locust outbreaks, also exacerbated the situation. Notably, in 2021, an outbreak of migratory locusts inflicted damage on over 48,000 hectares of land in the Grand Sud of Madagascar, while an outbreak of fall armyworms led to crop losses of up to 60% in severely affected areas (OCHA 2021).

The assessment[2] of production losses for food crops caused by Cyclones Batsirai and Emnati in the Great South-East of Madagascar in 2022 equals about 61 million USD, with more than 60% of the areas affected by the passage of the two cyclones. Rice and cassava crops account for 90% of these estimated losses. Production losses for cash crop agriculture are estimated at USD 78 million. Bananas (Fitovinavy and Vatovavy), coffee, and cloves account for more than 85% of the sector's losses. The reduction in production thus has consequences on the daily labor supply, which some poor and very poor households depend on to access income. According to the National Bureau of Risk and Disaster Management (BNGRC) estimate, the impact of tropical Cyclone

Source: BNGRC, CPGU

Cheneso was that the flooding affected approximately 1,400 rice fields. The recent Cyclone Gamane experience in the northeast of Madagascar in 2024 resulted in about 1,700 hectares of rice fields being flooded (ECHO 2024).

Box 1: Climate Risks and Potential Impacts on Agriculture Production

Climate Risk	Potential Impacts
Increased temperatures	Crop damage and reduced yields
	Higher rates of evapotranspiration, reducing soil moisture and increasing soil degradation
Increased precipitation during the rainy season	Increased need for irrigation, particularly for rice cultivation
	Increase in pests and diseases
	Increased sedimentation, soil erosion, and siltation, compromising flat lowland areas
Reduced rainfall in the dry season and increased drought conditions	Increased livestock mortality (especially cattle)
Increased cyclone intensity	Damage to crops, supply chains, and infrastructure from cyclones

Source: CCR Profile (2016)

The increasing temperatures and more frequent occurrence of extreme weather events associated with climate change have adversely impacted livestock health and productivity (Ravi J. et al., 2023). As a result, household income is greatly affected due to the crucial role that livestock farming plays in supporting livelihoods in Madagascar (Fayad, D. 2023). Furthermore, climate-induced hazards such as cyclones, floods, and droughts negatively impact agricultural crop production, substantially harm grazing areas, and worsen water scarcity. The production losses in the livestock sector due to Cyclones Batsirai and Emnati in 2022 reported by BNGRC were estimated at 1.5 million USD, a third of which is in the poultry sector. The fisheries sector of Madagascar accounts for over 7% of the national GDP and contributes 6.6% to the country's total exports. Increased severe weather events, rising ocean temperatures, and ocean acidification harm Madagascar's fish habitats and traditional fishing methods, reducing fish productivity, livelihoods, and food security (USAID 2024).

Almost one-third of Madagascar's population has experienced food insecurity due to the re-occurring climate shocks. Adding to the crisis, there has been a significant increase in acute malnutrition rates, reaching 8%, and chronic malnutrition affects a substantial portion of the population, precisely 40% (Fayad, D. 2023). The southern parts of Madagascar continue to struggle with food insecurity, particularly as a result of the negative effects of a lengthy drought in the Grand Sud and consecutive tropical cyclones in the Grand Sud-Est (Batsirai and Emnati in 2022 and Freddy in 2023).

2.2 Water and Sanitation

Water-and-sanitation-related illnesses are major drivers of disease in Madagascar (UNICEF 2016). Diarrheal disease is among the highest causes of morbidity and mortality in Madagascar due to a lack of clean water and poor hygiene. Additionally, 86% of the population is exposed to high rates of malaria (WHO 2015). According to the World Bank's Water and Sanitation Program (WSP) in 2012, the economic cost of healthcare connected to water, sanitation, and hygiene (WASH) in Madagascar is estimated to be as high as US$ 9 million per year. Due to inadequate sanitation, Madagascar's economy suffers an annual loss of US$103 million or 1% of GDP (WBG 2012). A survey conducted in 2018 in Madagascar revealed that 57% of the country's population does not have access to an improved water source (MCD 2022). In 2020, nearly 60% of the population had no access to clean water, and 89% had no access to sanitation (AfDB 2021). Lack of water due to climate change is one of the factors of conflict and migration, as communities and populations compete to find water resources (UNICEF 2021). The process of obtaining water is extremely difficult, as people need to walk long distances or excavate deep boreholes to access a water source. Additionally, some boreholes offer salty water as an alternative to pure drinkable water.

Climate change-induced hazards affect water supplies, leading to water stress, irregular rainfall patterns, droughts, and deficits in certain areas. This, in turn, increases the risk of malnutrition, illnesses, famine, and diseases. As a consequence of the severe contamination of potable water caused by the major cyclones that struck between 2017 and 2019, outbreaks of water-borne illnesses ensued, as determined by impact assessments (IMF 2022).

Box 2: Climate Risks and Potential Impacts on Water Resources

Climate Risk	Potential Impacts
Increased temperatures	Increased rates of evapotranspiration, potentially increasing demand for surface and groundwater resources for agriculture
Reduced rainfall and increased drought conditions	Loss of surface and groundwater for agriculture and consumption Reduced access to water supplies for drinking, sanitation, and energy generation, and reduced water quality
Increased cyclone intensity	Cyclone-induced destruction of water infrastructure and flood-induced water quality reductions due to increased sedimentation
Sea level rise	Saltwater intrusion into groundwater and aquifers in coastal regions, contaminates drinking and agricultural water

Source: CCR Profile (2016), USAID 2024

The primary climatic hazard that poses a significant danger to WASH infrastructure in the urbanized regions of Madagascar is the potential for flood damage and water supply pollution due

to the heightened severity of cyclones and high rainfall occurrences. At the end of 2016, the El Niño-induced droughts worsened the lack of water and food security, necessitating humanitarian aid for more than half of the country's population, which amounts to around 850,000 individuals (Serele et al., 2019). 2017 Cyclone Enawo damaged or destroyed 250 water systems and contaminated more than 1,300 wells (USAID & Sustainable Water Partnership, 2021). Madagascar is projected to have a relative increase in sea level ranging from 20 to 50 cm, potentially leading to saltwater infiltration into the groundwater in some coastal regions. These changes are expected to exacerbate the accessibility of water resources (Rakotondravony et al., 2018).

The southern region of Madagascar, known for its erratic rainfall patterns and arid climate, has extreme water scarcity, rendering it one of the most water-deficient regions in the country (Serele et al., 2019). The unpredictable variations in rainfall immediately affect the accessibility of groundwater and the overall welfare of the population. The challenges of water scarcity and quality in Madagascar are exacerbated by the conjunction of more frequent cyclones, reduced precipitation, and rising temperatures (USAID 2024).

2.3 Health

Madagascar's limited public health sector is vulnerable to climate change, particularly concerning the increased incidence of nutritional deficiencies and vector-borne diseases. Malnutrition is widely acknowledged as the most crucial human health concern in Madagascar; extreme weather events and temperature fluctuations further exacerbate the pre-existing health issues and diseases. With nearly half of the population experiencing stunted growth and over 40% of the population suffering from anemia, undernutrition is strongly believed to be the leading cause (Vonaesch et al., 2021).

The health sector has been affected by climate shocks in two primary ways. Firstly, through direct impact on healthcare facilities and related infrastructure. For instance, during Cyclone Enawo, flooding and landslides caused damage to health facilities across the country's northern region (BNGRC 2017). In 2022, Cyclone Batsirai destroyed a total of 93 health facilities, resulting in over 304,000 individuals in the entire country being deprived of essential health services (WHO 2022). Tropical Cyclone Freddy 2023 damaged many health centers in southeastern Madagascar, limiting access for over 100,000 people (USAID 2024). The recent Tropical Cyclone Gamane in the northeast part of the country was reported to have damaged about 22 health centers (OCHA 2024). The population's capacity to manage the effects of cyclones is significantly inhibited by the availability and accessibility of health services in Madagascar. Most of Madagascar's population, over 60%, resides in remote regions that lack communication infrastructure and roads, frequently located more than 5 kilometers from a health center (ACAPS 2024).

Secondly, through indirect impact, such as the increase in patients and disaster-related illnesses, such as infectious diseases. Madagascar not only has food insecurity but also has a high prevalence of infectious diseases. Among these diseases, several are exacerbated by the climate and rank

among the top 10 causes of death. These include diarrheal diseases, acute respiratory infections, and malaria. Madagascar recorded around 2.2 million cases of malaria, including 5,350 deaths in 2018 (BMZ 2020). In 2023, the country encountered widespread outbreaks of malaria and polio (UNICEF 2023). Tuberculosis is also a public health challenge, with an estimated incidence rate of 233 cases per 100,000 people (WHO TB database).

Box 3: Climate Risks and Potential Impacts on Human Health (WASH and Health Services)

Climate Risk	Potential Impacts
Increased temperatures and extreme heat	• Altered vector habitats, prolonging exposure and expanding vector populations to new geographies • Increased incidence of heat-related illnesses (e.g., heat exhaustion and stroke, exacerbated cardiovascular and respiratory diseases)
Increased incidence and severity of dry spells and drought	• Dehydration; reduced access to clean drinking water and associated exposure to waterborne disease • Depleted crop yield and associated food insecurity
Increased rainfall variability and severity of storms and cyclones	• Expanded mosquito habitats, increasing the risk of mosquito-borne disease • Increased exposure to waterborne disease from contaminated water • Damage to healthcare facilities or limited access to healthcare during storm events, extreme weather and flooding

Source: USAID 2024

Climate change poses ongoing challenges in the health sector, mainly through the indirect consequences of deteriorating water quality and food security concerns (Fayad, D., 2023).

2.4 Education and School Infrastructure

The human capital of Madagascar is among the lowest in the world, as demonstrated by development indicators, including infant mortality, school attendance, literacy and primary completion rates, malnutrition, etc. (IMF 2022). Education is one of the sectors that is severely affected by climate disasters. Consequently, the long-term and far-reaching consequences of climate shocks and disasters on education include the destruction and damage to schools and classrooms, lower academic performance, and increased absenteeism rates (Chuang et al., 2018).

Schools in Madagascar frequently face significant challenges due to substandard building quality and reliance on local materials. For instance, several education centers are constructed using mud and adobe, which lack durability and are susceptible to damage from climate disasters such as cyclones and floods.

Box 4: Impact of Climate Change on Education and School Infrastructure

- ❖ Climate-induced hazards are causing increasing damage to school structures, facilities, and teaching and learning materials, disrupting education
- ❖ Extreme temperatures resulting in overheated buildings causing classrooms unsuitable for learning and teaching
- ❖ Reduction in students' physical and mental health and psychosocial well-being, affecting their ability to attend school and actively engage in learning
- ❖ Increased migration and displacement disrupt educational continuity

In 2017, the coast of Madagascar was struck by Cyclone Enawo, which had gale-force winds that reached up to 180 miles per hour. An estimated 240,000 individuals were displaced due to the devastation, and the damage to educational infrastructure was unmatched. Over 3,900 classrooms were damaged, with 2,300 of them being destroyed. In the aftermath of Enawo's devastating impact, more than 120,000 children were deprived of a secure environment to learn (UNDRR 2019). In 2022, the Education Sector Group reported that a total of 6,954 classrooms were completely destroyed (all levels combined), 2,706 classrooms were partially destroyed, particularly at the roof level, and 37 administrative buildings were destroyed due to two intense cyclones (Batsiraï and Emnati). Resulting in about 423,866 pupils being deprived of classes at the primary level (ILO 2022). The recent Tropical Cyclone Gamane in the north and northeast of Madagascar was reported to damage over 165 classrooms and about 24,121 children without access to schools (OCHA 2024). During the season of cyclones, displaced people frequently use schools as emergency shelters, which disrupts the education of children.

In times of drought, families frequently experience food scarcity as a result of reduced agricultural outputs, which further exacerbates the poor rate of school enrollment. For example, in Amboarsary, in the southern part of Madagascar, the epicenter of the ten most severely affected southern districts, a WFP assessment revealed that three out of four children had stopped school, primarily to assist their parents in foraging for food (WFP 2021). It is estimated that approximately 300,000 school-age children residing in the nine districts of the Grand Sud that the drought has most significantly impacted are currently not attending school (Flash Appeal 2021). Food shortages during droughts usually lead to child malnutrition. This can impair their growth and concentration, making academic success difficult for children. Malnourished children are susceptible to illness, which can exacerbate rates of absence. School attendance is further prevented by the prevalence of illnesses stemming from poor water, sanitation, and hygiene (WASH) conditions. Over the past decade, the school completion rates have been decreasing, with primary school completion rates at 63% and lower secondary school completion rates at 35%, which are below the rate of Sub-Saharan African and low-income countries (IMF 2023).

The education sector in Madagascar remains in an unprecedented state of precariousness due to the extent of the damage caused by climate change, which has the potential to undermine the

progress that has been achieved over the past several years. Fifteen out of twenty-three regions of Madagascar have been significantly impacted (ILO 2022).

2.5 Infrastructure - Roads

Madagascar has one of the lowest road densities in the world. The country has a total of 49,800km of roads, with a mere 11% of these roads being paved (ACAPS 2024). The lack of adequate infrastructure is a significant obstacle to the economic development of most citizens. Madagascar's dependence on road transportation is heightened due to its underdeveloped railway network and limited inland waterway transportation (WFP 2022). Roads and bridges in Madagascar are especially vulnerable to the effects of climate change because the country's already fragile infrastructure is very susceptible to climate change hazards. Expected annual damages to roads and railway assets are estimated to be around 0.2% of GDP in Madagascar under the current climate (Koks et al., 2019).

Madagascar's infrastructure is anticipated to be greatly impacted by climate change, mostly due to the occurrence of severe precipitation events. High precipitation results in road flooding, while elevated temperatures accelerate the deterioration of roads, bridges, and coastal infrastructures, forming fractures. This, in turn, results in earlier replacement and leads to higher maintenance and replacement costs (AGRICA 2021).

Box 5: Climate Risks and Potential Impacts on Transport Infrastructure

Climate Risk	Potential Impacts
Increased intensity of heavy rainfall	Disruption of road, port, rail, and air transportation during cyclones and heavy rainfall
Increased cyclone intensity	Damage or destruction of roads, bridges, culverts, rail lines, and airport runways due to surface or seawater flooding, landslides, wash-outs, and coastal erosion
Sea level rise	Damage to ports due to storm surges, sea level rise, and high winds
Higher temperatures	Thermal expansion of paved surfaces and compromised pavement integrity (buckling, softening, rutting, cracking, etc.)

Source: USAID CRP (2016)

Madagascar's road network is damaged each year by extreme weather linked to climate change, especially floods and high winds associated with tropical cyclones. Sea level rise-induced coastal erosion poses a significant challenge for coastal infrastructure and roads in Madagascar as well (Interactive Country Fiches 2020). Cyclone Haruna 2013 caused a dike along the Fiherenana River, leading to severe flooding that damaged roads and other key sector infrastructures (WFP 2015). Tropical Cyclone Belna struck the north-western coast of Madagascar in 2019, causing adverse

effects on a population of 128,000 individuals. The district of Soalala was hit particularly hard, recording damage to roads and other related infrastructures (OCHA 2019). The two intense Cyclones, Batsirai and Emnati, occurred in 2022 and caused severe damage to roads, which impeded access to the affected areas (IFRC 2024). Tropical Cyclone Freddy, which occurred in 2023, caused significant damage to the road network, rendering an already inadequate transportation system inaccessible (European Investment Bank 2023). Recently, Cyclone Gamane caused substantial damage to key infrastructure, including roads and bridges (MedaFrica 2024).

2.6 Infrastructure - Energy

Madagascar's energy generation, transmission, and distribution networks face operating concerns due to a probable future decrease in rainfall coupled with increasingly intense heavy rainfall events and more frequent and severe cyclones. The country's electrical production comprises 60% hydropower and 40% thermal (fossil fuel) generation (AfDB 2016). Hydropower generation is being challenged by water constraints caused by extended periods of drought and perhaps decreased total rainfall. Thermal generation needs significant water for cooling and is vulnerable to water scarcity. Water scarcity will intensify the battle for water resources between the agriculture and energy sectors. In 2023, only 33.7% of the population had access to electricity, a low figure compared to the 2020 average of 48.4% in Sub-Saharan Africa. Madagascar is ranked 13th among the countries with the greatest unelectrified populations globally, with over 18 million individuals lacking electricity access (WB 2023).

Box 6: Climate Change Impacts on Energy Sector

Energy Sector	Climate Change Impact
Hydropower generation infrastructure	Physical and operational effects, resulting from changes to hydrological cycles, water availability, and river flow conditions
Thermal power generation infrastructure	Physical damage during storm events or flooding, or changes in the availability of input materials including water and diesel fuel
Transmission and distribution infrastructure	Increased temperatures damaging transmission lines and reducing transmission efficiencies, or flood, salinity, or storm damage to transmission lines or substations

Source: WWF (2023)

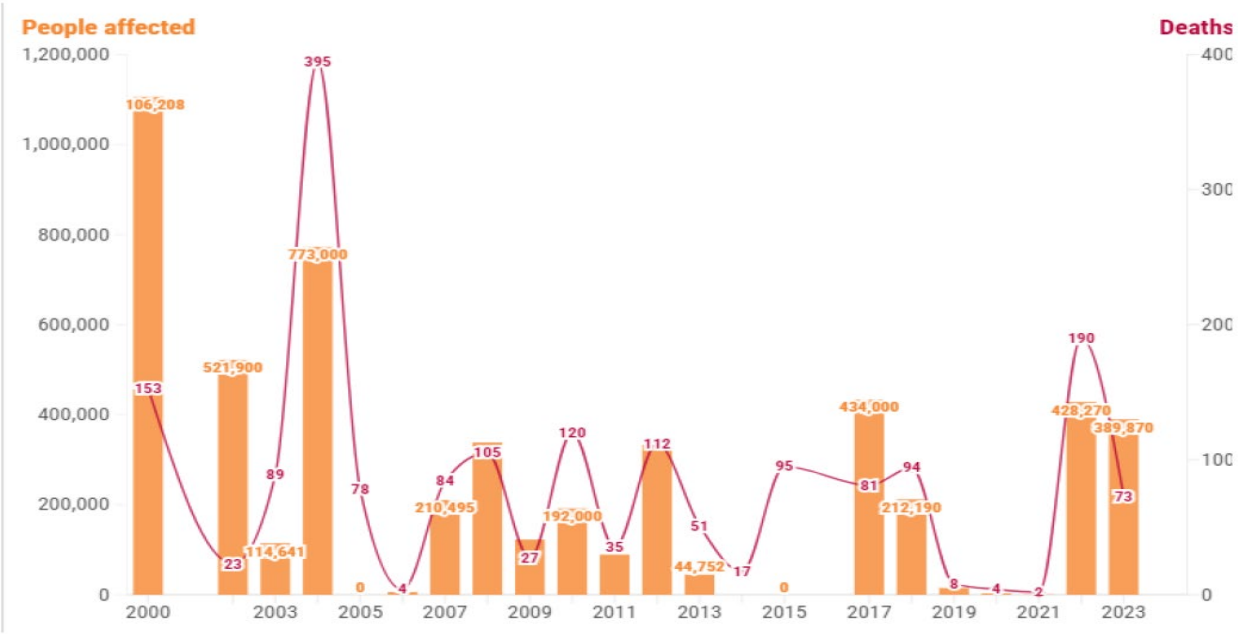
Cyclone winds also damage powerlines and other grid infrastructure, causing power outages. For example, Cyclone Enawo caused prolonged disruptions in the electricity supply across northern Madagascar, particularly in the severely affected Antalaha commune (BNGRC 2017). Cyclone Ava destroyed 90% of the Toamasina's electricity infrastructure in the port city of Toamasina. This damage causes huge losses to livelihoods and the local economy (TC 2018). Tropical Cyclone Belna made landfall on the north-western coast of Madagascar in 2019; in particular, the district of Soalala was affected severely, resulting in damage to electricity posts, roads, and wells (OCHA 2019).

Due to climate change, Madagascar's most populated area surrounding Antananarivo saw the warmest October ever in 2023. The most densely populated region in the country saw the greatest temperatures and shattered several records, affecting millions of people (World Weather Attribution, 2023). The yearly energy consumption for household cooling has steadily increased since 1975 due to the effects of climate change (Nematchoua, 2020). Charcoal is predominantly used to meet home energy demands because of its cost advantage over alternative energy sources such as gas and oil (Nematchoua, 2021). Madagascar's reliance on wood and charcoal for cooking and domestic use leads to increased deforestation, exacerbating the effects of climate change. (Velo and Zafitsara 2020).

2.7 Housing

Due to its geographic location, Madagascar has experienced several natural and climate change hazards, particularly cyclones, floods, tropical storms, and drought. The increased intensity of disasters caused by climate change has destroyed homes and caused unprecedented displacement, resulting in significantly increased humanitarian needs. From 2000 to 2023, Madagascar experienced 47 tropical storms and cyclones, causing significant destruction to the country's infrastructure, economy, and food security. These disasters impact resulted in almost 740,000 people being homeless (ACAPS 2023). In rural regions, people build their homes using less durable materials such as mud, wattle, woven matting, split bamboo, and wooden planks (Britannica 2024), making houses more vulnerable to damage and devastation caused by cyclones, floods, and disasters.

Figure 4: Number of people affected by cyclones and deaths reported from 2000–2023



Source: ACAPS 2023

The continuous event of climate hazards has affected homes and the well-being of the communities. To mention a few, between 2010 and 2018, about 456,183 houses were completely destroyed, and 213,471 houses were damaged due to cyclones, floods, and fires (BNGRC database). In early 2022, two of the most intense tropical cyclones (Batsirai and Emnati) affected a total of 423,800 individuals, and 61,489 individuals were displaced. The Malagasy National Disaster Management Agency (BNGRC) reported that 11,163 homes were destroyed, while 33,226 homes suffered varying degrees of damage. In 2023, severe tropical storm Cheneso hit Madagascar, resulting in a week of heavy rainfall and wind and widespread flooding. The impacts of Cyclone Cheneso affected about 10,807 households spread over 13 regions, 20,603 displaced people in 75 accommodation sites (4,828 households), 12,435 housing units flooded, and 523 housing units destroyed (UN-Habitat 2023). Recently, Tropical Cyclone Gamane made landfall in the northeast part of Madagascar, resulting in more than 18,830 houses being flooded and over 780 destroyed (OCHA 2024).

3. Building Climate Resilience in Madagascar: Adaptive Measures for Infrastructure Development

Given Madagascar's high susceptibility to climate change, the development of effective adaptation and mitigation strategies is crucial in addressing the specific impacts of climate change on various sectors. Key policies are implemented by the government to incorporate climate objectives with biodiversity protection, disaster management, and sustainability. Essential to these efforts are the National Disaster Risk Management Strategy 2016-2030 (2016), the National Climate Change Adaptation Plan (2019), and the National Policy to Combat Climate Change (2021), the National Adaptation Plan (2022).

Numerous international organizations, agencies and donors have been instrumental in improving climate resilience in Madagascar by implementing various programs and projects designed to mitigate the effects of climate hazards. Table 1 presents selected efforts by some organizations, such as the World Bank, USAID, AfDB, etc., as well as ongoing programs and projects in natural resource management, agriculture production and value chains, food security, and climate adaptation in Madagascar.

3.1 Agriculture

Climate change exacerbates the vulnerability of the agriculture sector in Madagascar. Adaptation is of the utmost importance for Madagascar's agricultural sector to achieve greater resilience and for its long-term development objectives, specifically food security, to be sustainable. Adaptation efforts in the agriculture sector encompass various strategies such as enhancing soil quality and conservation, increasing production of natural fertilizers, transitioning to cultivars that are more resilient to drought or have shorter growth cycles, implementing policy measures, conducting agricultural research and technology transfer, educating farmers on utilizing weather information to mitigate climate change risks, expanding reforestation activities to combat soil degradation,

promoting counter-season cropping and vegetable gardening, investing in research for adaptive seed varieties, constructing small dams for water management, and improving infrastructure and capacity-building for water management systems (WB 2011).

The National Adaptation Plan (NAP) and the sectoral investment plan outline certain sectors that are prioritized for agricultural industry investment. These expenditures encompass funding for agricultural research and investments in disaster-risk reduction technologies specifically designed for farmers. These investments amount to 157 million USD, equivalent to 1.1% of the nominal GDP yearly in 2019 (IMF 2022). In 2022, 4.7 million individuals received aid in monetary and in-kind support from humanitarian and development organizations to meet their food and subsistence needs.

The United Nations Environment Programme (UNEP) supports the government in aiding communities in restoring mangrove ecosystems and other shoreline vegetation. These habitats are natural barriers against flooding, rising sea levels, and coastal erosion. Current initiatives are being implemented to enhance the ability of local livelihoods to withstand and adapt to unexpected climatic variations while promoting diversification. These operations encompass the expansion of crop variety and the implementation of enhanced agricultural techniques. As stated by the UN Environment Programme in 2020, these activities help decrease the necessity for land clearance and the destruction of mangroves while also producing revenue and promoting food production (UNEP, 2020). On August 23, 2021, Madagascar received an SDR allocation of US$322 million. This allocation can fund the water pipeline project in the Great South region and other objectives relating to food security, climate change adaptation, and sustainable development (IMF 2023).

Madagascar received $227 million to increase productivity and strengthen the resilience of the rural livelihoods of Alaotra-Mangoro and Sofia. The funding is comprised of a $200 million credit from the World Bank and a €25 million credit from the French Development Agency. The project aimed to support community-led watershed restoration, irrigation infrastructure and service repair and management, sustainable agricultural intensification, and strengthening of priority agri-food value chains (WB, 2023). In early 2024, the USAID Agricultural Project for Enhancing Sorghum, Millet, and Peanuts Business Activity (APEMBA) was inaugurated on the occasion in partnership with FOFIFA. APEMBA aims to enhance soil conditions agricultural production, and safeguard the environment by implementing resilient crop rotations. This initiative will help Madagascar implement climate-smart agricultural practices.

3.2 Water and Sanitation

Madagascar's climate change policies and governance strategy demonstrate its determination to combat climate change. Madagascar is dedicated to implementing adaptation strategies, specifically targeting the effects of climatic hazards that disproportionately afflict the country. These hazards are made worse by the observed climate change at both the national and global scales. Several approaches encompass sustainable and integrated water resources management,

implementation of ecosystem-based adaptation measures, and restoration of natural habitats, among other strategies (Interactive Country Fiches, 2022).

In addition, the African Development Bank and Madagascar's Ministry of Water, Sanitation, and Hygiene have begun the preparation stage of a project to protect and develop water resources while also strengthening the country's climate change resilience, with funding from the African Development Fund's Project Preparation Facility totaling US$3.32 million. This project aims to increase access to drinking water, eliminate gender-based inequities, and promote sustainable, inclusive, and resilient socioeconomic development in the project regions (AfDB 2023). The Water and Sanitation for the Urban Poor (WSUP) has established long-term partnerships with the national water utility, the national government, and local communities to build creative, affordable, and financially viable water and sanitation services in select parts of the country (WSUP 2022).

Madagascar and the World Bank signed the $220 million National Water Project. The project improves JIRAMA's water and energy utility and increases water availability in Greater Antananarivo and selected minor towns. Using infrastructure investments and institutional development, this project will address sector concerns regarding water resources and services and resilient recovery requirements following the cyclones. Through the social connections initiative, 625,000 individuals will receive better water services, including 460,000 needy people whose water costs will be cut. WASH improvements will help 115,000 pupils and 70 health clinics (World Bank, 2022a).

3.3 Health

Climate change adaptation strategies are necessary to enhance the resilience of the health sector's physical components (such as hospitals and health clinics) and the institutional structures to protect the well-being of the people. Implementing measures targeting the five fundamental climate change risks to the health sector is crucial for developing a resilient health sector in Madagascar. These five cores include nutrition, water-related illness, extreme weather events, vector-borne diseases, and air pollution (WBG 2018). These measures should be accompanied by comprehensive, policy-driven recommendations that enhance the sector's capacity to handle climate-related risks effectively.

Relevant adaptation measures in health sector include i) climate-proofing health facilities, developing new infrastructure to protect existing facilities from floods and storm damage, and avoiding building new facilities in high-risk locations; ii) building institutional capacity and teaching health providers and the public to comprehend climate change's physical and mental health risks; iii) improved disease surveillance and early warning systems for outbreak response and expanded infectious disease control programs; v) ensuring enhanced accessibility to potable water and sanitation through infrastructure development or water quality protection serves to strengthen the overall resilience of populations against health risks (GFDRR 2011; World Bank 2017; WWF 2020).

3.4 Education and School Infrastructure

In Madagascar, floods and cyclones have severe effects on the continuity of education, resulting in the destruction of learning materials and infrastructure. To address these challenges, climate resilience initiatives and programs are vital in ensuring the sustainability of educational infrastructure and accessibility. Such programs include investments in climate-adapted school infrastructure and education workforce, including teachers, trainers, facilitators, counselors, staff, administrators, school leaders, and others. The Education Sector Plan (2018–2022) acknowledges the need to address climate change in the education sector, which aims to enhance the education system's ability to withstand climate-induced disasters. A non-governmental organization, Zonta International, contributed US$500,000 to UNICEF in 2023 to support climate change education for females in Madagascar. The sum is allocated for a period of three years, from 2023 to 2025, with the objective of empowering young girls to take action in the construction of climate change-resilient communities and to aid the nation in enhancing the quality of children's education (MECCE 2023).

Adding disaster risk reduction (DRR) education to the school curriculum is necessary. Educational initiatives now cover DRR and climate change adaptation, helping students grasp and prepare for climate-related risks. Training programs for teachers are also available to ensure they can teach these subjects effectively. Additionally, schools have emergency plans in place that detail evacuation procedures and collaboration with disaster response teams. Three inclusive risk and disaster management initiatives have been implemented by the CARE Madagascar and Humanity & Inclusion (HI) consortium since 2017, with the objective of improving the preparedness and response capabilities of populations that have been impacted by natural disasters. One of these interventions, the MIARO project "Disaster Risk Management is everyone's business, even children's", was funded by the European Union Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO). It employed a whole-of-school approach to enhance the capacities of students and school communities in inclusive disaster risk reduction. Overall, the objective was to enhance the safety of schools and guarantee that all students could more effectively manage disasters (HI 2023).

3.5 Infrastructure - Road

Madagascar has a very low road density compared to other countries, with a road network that covers around 31,640 km. The increasing frequency of severe weather events resulting from climate change has significant consequences for infrastructure in Madagascar. Increasing rainfall causes road flooding, while higher temperatures form cracks and faster deterioration of roads, bridges, and coastal buildings (Andrianady et al., 2023).

To enhance road networks' ability to withstand climate change impacts, it is necessary to comprehend the network's susceptibilities to weather events, evaluate how the level of risk evolves, pinpoint suitable measures to mitigate the risk and formulate a comprehensive action plan. Madagascar successfully implements existing or newly formed policies, as outlined by the Global

Transport Knowledge Partnership (2023). These policies include adopting flood-resistant land transport infrastructure standards to mitigate the impact of climate change on the country.

Through its National Adaption Plan (NAP), Madagascar aims to combat climate hazards by implementing policies that focus on developing, communicating, and implementing design and construction standards for major infrastructures. The goal is to ensure these infrastructures can withstand extreme weather events (Adaptation Partnership, 2012). As an illustration, the government of Madagascar is now enacting policies aimed at improving building practices by constructing higher resilience standards with technical expertise and cost-effective maintenance measures. These measures include the clearance of blockages under bridges and roadways. Implementing these measures and making strategic investments will result in a 50% reduction in damages to new infrastructures (Hallegatte et al., 2019).

The World Bank approved $400 million to rehabilitate important roads in rural Madagascar, especially the South, for connection, resilience, and management. Connecting Madagascar for Inclusive Growth would provide $200 million in loans and grants to rural areas to boost social and economic prospects. The project will fund the restoration and paving of 100 km of RN31 between Mangoaka and Bealalana and 400 km of RN10. The project would also maintain 500 km of minor roads around the RN10 and RN31 to access rural areas. This project brings the World Bank's Madagascar roads and transport portfolio to $740 million (World Bank 2022b).

3.6 Infrastructure - Energy

Some of the adaptive measures Madagascar aims to implement to reduce the impact of climate change on the energy sector. These measures include constructing buildings with higher resilience standards, strengthening transmission lines, stabilizing poles, and regularly maintaining power systems. These actions have the potential to reduce the risk of damage to energy infrastructure assets by 50 to 60% (Hallegatte et al., 2019; IMF, 2022).

Madagascar's objective is to decrease emissions by 13% in 2030 by raising the proportion of renewable energy from 35 to 79% while enhancing energy efficiency (IMF 2022). The government of Madagascar has revised its energy policy in accordance with the European Union. This policy promotes using renewable energy sources in the country's energy mix. By 2020, 2030, and 2050, the government seeks to achieve a minimum of 5%, 20%, and 80% of renewable energy in overall energy production. The focus will be on developing small and large-scale hydroelectric projects and exploring other renewable energy sources (Nachmany et al., 2015; Nematchoua et al., 2021).

According to WWF (2023), priority adaptation approaches that should be considered for implementation in the energy sector in Madagascar include increasing the level of rural electrification to lessen reliance on biomass as an energy source, diversifying household and community energy generation sources, climate-proofing existing and future hydropower, thermal power, and transmission and distribution infrastructures. Two recently approved projects for Madagascar, totaling $534.9 million, were recently signed by the Government of Madagascar and

the World Bank to enhance resilience against future disruptions. The World Bank contributes about $415 million to support the government's Post-Cyclone Recovery Plan, which includes improved access to energy (World Bank, 2022b).

Table 1:Selected Ongoing Climate Projects in Madagascar

Program	Amount	Donor	Year	Implementer	Implementation Regions
Fiovana Resilience and Food Security Activity (RFSA)	USD $45 million	USAID	2019-2024	USAID BHA	Vatovavy Fitovinany and Atsimo Atsinanana Regions
Maharo Resilience and Food Security Activity (RFSA)	USD $36 million	USAID	2019-2024	USAID BHA	Atsimo Andrefana and Androy Regions
Support for Resilient Livelihoods in the South of Madagascar ("Moinjo")	USD $200 million	World Bank	2021-2025	Government of Madagascar	Southern Madagascar
Integrated Urban Development and Resilience Project for Greater Antananarivo	USD $75 million	World Bank	2018-2025	Ministry of Planning and Land Management, *Fonds d'Intervention pour le Développement*	Antananarivo Region
Rapid Rural Transformation Initiative	USD > $1 million	World Food Program	2022-present	World Food Programme and Government of Madagascar	Androy and Anosy Regions
Sustainable Landscapes in Eastern Madagascar: Promoting investments in sustainable agriculture and renewable energy for smallholder farms	USD $19.3 million	Green Climate Fund	2016-2025	Conservation International Foundation	Eastern Madagascar
Project to Mobilize, Protect, Enhance Water Resources and Strengthen Resilience to Climate Change	USD $3.2 million	African Development Bank	2022-present	JIRMA, Madagascar Drinking Water and Energy Service Company	Central, Southeast, South Madagascar

Source: USAID 2024

References

Adaptation Partnership. (2012). Review of Current and Planned Adaptation Action

AFDB. (2021). Madagascar—Pair- Road Infrastructure Development Project

AFDB. (2023). Madagascar: African Development Bank and the Government join forces to secure water access and strengthen climate change resilience

AGRICA. (2021). Madagascar: Infrastructure – Agrica.

Andrianady, R. J., Randriamifidy, F., & Andrianavony, J. K. (2023). Heat and Economics: Climate Change's Influence on Madagascar's GDP. https://doi.org/10.2139/ssrn.4561001

ACAPS. (2024). Madagascar. Cyclone exposure and vulnerabilities

BNGRC. 2017. Madagascar Cyclone Enawo Situation Report No. 2.

Central Intelligence Agency (CIA) (2020). CIA World Factbook, Madagascar. In: The World Factbook

Central Intelligence Agency (CIA) (2022). CIA World Factbook, Madagascar. In: The World Factbook

Change Risk (CCR) Profile Madagascar. 2016. https://pdf.usaid.gov/pdf_docs/pa00mtz8.pdf

Cli Chuang, E., Pinchoff, J., & Psaki, S. (2018). How natural disasters undermine schooling.

ECHO. 2024. Madagascar - Tropical cyclone GAMANE

European Investment Bank. (2023). Road projects to combat climate events in Madagascar. European Investment Bank

Fayad, D. (2023). Food Insecurity and Climate Shocks in Madagascar: Republic of Madagascar. Selected Issues Papers, 2023(037).

FAO (2016). Climate-smart agriculture in Madagascar

Federal Ministry for Economic Cooperation and Development (BMZ) (2020). Climate Risk Profile: Madagascar.

Flash Appeal, Grand Sud, January – May 2021,

Food and Agriculture Organization (FAO) (2021). The Republic of Madagascar. Global Information and Early Warning System (GIEWS) Update

Global Transport Knowledge Partnership. (2023). Adaptation. IRF gTKP - Global Transport Knowledge Practice

Global Facility for Disaster Reduction and Recovery (GFDRR) (2011). Vulnerability, Risk Reduction, and Adaptation to Climate Change Madagascar

Global Facility for Disaster Reduction and Recovery (GFDRR) (2016). Disaster Risk Profile Madagascar. Building Resilience in Sub-Saharan Africa

Hallegatte, Stephane; Rentschler, Jun; Rozenberg, Julie, 2019. Lifelines: The Resilient Infrastructure Opportunity. Sustainable Infrastructure. World Bank, Washington, DC

Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., Rabarijohn, R. H., ... & MacKinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1639), 20130089

HI. 2022. Madagascar: The humanitarian impact of climate change

HI. 2023. Uninterrupted education for children with disabilities before, during, and after a crisis

IFRC. 2024. Madagascar. Tropical Storms and Cyclones

Interactive Country Fiches. (2020). Climate change / Madagascar | Interactive Country Fiches.

Interactive Country Fiches. (2022). Water / Madagascar | Interactive Country Fiches.

International Monetary Fund Fiscal Affairs. (2022). Republic of Madagascar: Technical Assistance Report-Climate Macroeconomic Assessment Program. IMF Staff Country Reports, 2022(342). https://doi.org/10.5089/9798400226212.002.A001

ILO. (2022). Rehabilitation / Construction of Primary Schools in Response to Cyclones in Madagascar

IMF. (2023a). Social Spending and Outcomes in Madagascar: Republic of Madagascar

IMF (2023b). Food Insecurity and Climate Shocks in Madagascar in: Selected Issues Papers Volume 2023 Issue 037 (2023).

Koks, E. E., Rozenberg, J., Zorn, C., Tariverdi, M., Vousdoukas, M., Fraser, S. A., ... & Hallegatte, S. (2019). A global multi-hazard risk analysis of road and railway infrastructure assets. *Nature communications*, *10*(1), 2677.

Madagascar Vulnerability Assessment Committee (MVAC). Evaluation Approfondie Multisectorielle de la Sécurité Alimentaie – Grand Sud de Madagascar, April 2022

MECCE. 2023. Madagascar. Climate Change Communication and Eduation

MCD (2022). MCD Leading UNICEF Project to Achieve Universal Access to WASH in Madagascar

MedaFrica. (2024). Madagascar Cyclone Gamane Claims Lives of 18, Displaces Thousands

MDM. 2023. Madagascar: A humanitarian emergency driven by the climate crisis

MVAC, 2022. *Evaluation Approfondie Multisectorielle de la Sécurité Alimentaire Grand Sud de Madagascar*. Antananarivo, Madagascar.

Nachmany, M., Fankhauser, S., Davidová, J., Kingsmill, N., Landesman, T., Roppongi, H., Schleifer, P., Setzer, J., Sharman, A., Singleton, C., Sundaresan, J., & Townshend, T. (2015). The 2015 Global Climate Legislation Study

Nematchoua, M. K. (2020). A study of climate change and energy consumption in Madagascar island. Health and Environment, 1(1), Article 1. https://doi.org/10.25082/HE.2019.01.002

Nematchoua, M. K. (2021). Analysis and comparison of potential resources and new energy policy of Madagascar island; A review. Renewable Energy, 171, 747–763. https://doi.org/10.1016/j.renene.2021.02.080

Nurse, L. A., R. F. McLean, J. Agard, L. P. Briguglio, V. DuvatMagnan, N. Pelesikoti, E. Tompkins, and A.Webb. 2014. Small islands. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9781107415386

OCHA. 2019 "Southern Africa: Cyclone Belna (Flash Update No. 5)," New York,

OCHA, 2024. Madagascar: Tropical Cyclone Gamane Flash Update No. 2, 4 April 2024

Rakotobe, Z. L., Harvey, C. A., Rao, N. S., Dave, R., Rakotondravelo, J. C., Randrianarisoa, J., ... & MacKinnon, J. L. (2016). Strategies of smallholder farmers for coping with the impacts of cyclones: A case study from Madagascar. *International journal of disaster risk reduction*, *17*, 114-122.

Rakotondravony, H. A., I. Abdallah, H. Andrianaivo, L. N. Andrianarison, K. Hetz, P. T. Mahatante, H. N. Masezamana, N. A. H. Rakotoarivony, R. P. Rakotonaivo, S. Ramanantsialonina, J.-F. Randrianjatovo, A. A. Rasamison, and M. S. (adelphi/ GOPA). 2018. État des lieux des études de la vulnérabilité à Madagascar: revue bibliographique. Antananarivo, Madagascar. GIZ, Bonn, Germany

Randrianarivelo, M., & Edouard, A. (2022). Changement Climatique Et Transition Enérgétique: Quel Avenir Pour Madagascar ? International Journal of Progressive Sciences and Technologies, 34, 295. https://doi.org/10.52155/ijpsat.v34.2.4621

Ravi, J., Shaw, S., Boulenger, X., & Neto, J. (2023). Sector Environmental Guideline: Livestock Production. USAID

Serele, C., Pérez-Hoyos, A., & Kayitakire, F. (2020). Mapping of groundwater potential zones in the drought-prone areas of south Madagascar using geospatial techniques. *Geoscience Frontiers*, *11*(4), 1403-1413.

The Conversation (TC). 2018. Measuring the economic impact of cyclones in Madagascar

UNDRR. (2019). Madagascar: Building back better

UNICEF. (2016). Investing in WASH in Madagascar

UNICEF. (2019). Climate Landscape Analysis for Children in Madagascar Summary Brochure

UNICEF. (2021). Fight against climate change, the challenge to accelerate the implementation of sustainable solutions for a better access to water

UNICEF. (2023). Madagascar. Country Office Annual Report 2023

United Nations Office for the Coordination of Humanitarian Affairs (OCHA). (2021). Madagascar: Madagascar: Grand Sud Humanitarian Snapshot

UN Environment Programme. (2020). *Ecosystem-based Adaptation in Madagascar | UNEP - UN Environment Programme*

UN-Habitat. (2023). Madagascar. A Better Quality of Life for all in an Urbanizing World

USAID, & Sustainable Water Partnership. (2021). Madagascar Water Resources Profile Overview.

USAID. (2014). Madagascar. Climate Risks to Resilience & Food Security in Bureau for Humanitarian Geographaies.

Velo, N. M. A., & Zafitsara, J. (2020). The management of forest and deforestation, mitigation, and adaptation of climate change in Madagascar. *Open Access Library Journal*, *7*(6), 1-19.

Veron, S., M. Mouchet, R. Govaerts, T. Haevermans, and R. Pellens. 2019. Vulnerability to climate change of islands worldwide and its impact on the tree of life. Scientific Reports 9 (1):14471. https://doi.org/10.1038/s41598-019-51107-x

Vonaesch, P., Djorie, S. G., Kandou, K. J. E., Rakotondrainipiana, M., Schaeffer, L., Andriatsalama, P. V., ... & Randremanana, R. V. (2021). Factors associated with stunted growth in children under five years in Antananarivo, Madagascar and Bangui, Central African Republic. *Maternal and Child Health Journal*, *25*(10), 1626-1637.

World Bank (2017). Estimation of Economic Losses from Tropical Cyclone Enawo

World Bank (2011). Climate Change Knowledge Portal. Vulnerability, Risk Reduction, and Adaptation to Climate Change.

World Bank. (2022a). Madagascar: $220 Million to Improve Basic Water and Sanitation Services and Supply

World Bank. (2022b). World Bank Commits to Strengthening Madagascar's Post-Cyclone Recovery Plan, Pandemic Response, and Energy and Transport Sectors

WB. 2023. Madagascar Set to Expand Access to Renewable Energy and Digital Services

World Bank Group. (2012). Poor Sanitation Costs Madagascar MGA201 Billion Each Year

World Bank Group. (2021). Climate Change Knowledge Portal. Madagascar

World Bank Group (2024). Macro Poverty Outlook. Sub-Saharan Africa

World Food Programme (WFP). 2015. Annual Evaluation Report 2015

World Food Programme (WFP). 2011. Fighting cyclones, flooding, and drought in Madagascar

World Food Programme (WFP). (2021). Humanitarian crisis looms in Southern Madagascar as drought and pandemic double number of hungry people

World Food Programme (WFP). Madagascar Country Brief May 2024

WFP. (2022). Madagascar Logistics Infrastructure.

WBG. (2018). Madagascar Climate Change and Health Diagnostic

World Health Organization (WHO). 2016. Climate and health country profile-2015 Madagascar. World Health Organization, Geneva, Switzerland.

World Weather Attribution. (2023). Extreme poverty renders Madagascar highly vulnerable to underreported extreme heat that would not have occurred without human-induced climate change – World Weather Attribution.

WSUP. (2022). Madagascar. WSUP.

WWF. (2022). Climate emergency and global energy crisis: Which way for Madagascar?

WWF. (2023). Adaptation in the energy sector