Federal Ministry
for Economic Cooperation
and Development

Climate Risk Profile: Madagascar

Summary

This profile provides an **overview of projected climate parameters and related impacts** on different sectors in Madagascar until 2080 **under different climate change scenarios** (called Representative Concentration Pathways, RCPs). RCP2.6 represents the low emissions scenario in line with the Paris Agreement; RCP6.0 represents a medium to high emissions scenario. **Model projections do not account for effects of future socio-economic impacts.**

Agriculture, biodiversity, health, infrastructure and water are highly vulnerable to climate change. The **need for adaptation in these sectors has been stressed in Madagascar's NDC targets and the National Adaptation Plan (NAP) and should be represented in the German development cooperation portfolio** of the country.

Depending on the scenario, **temperature** in Madagascar is projected to **rise by between 1.5 and 3.2 °C by 2080**, compared to pre-industrial levels, with higher temperatures and more temperature extremes projected for the western part of the country.

Precipitation trends are uncertain with projections indicating a **decrease in annual precipitation of up to 114 mm by 2080**. Future dry and wet periods are likely to become **more extreme**.

Under RCP6.0, the **sea level** is expected to **rise by 43 cm** until 2080. This threatens Madagascar's coastal communities and may cause saline intrusion in coastal waterways and groundwater reservoirs.

Climate change is likely to cause **severe damage to the infrastructure sector** in Madagascar including roads and bridges. As roads are the backbone of the country's transportation network, investments will need to be made into building climate-resilient roads and other infrastructure.

The models project an **increase in crop land exposure to drought**. Yields of cassava and maize are projected to decline, while yields of rice and sugar cane are projected to benefit from CO_2 fertilisation. Farmers will need to adapt to these changing conditions.

Agro-ecological zones might **shift, affecting ecosystems, biodiversity** and **crop production**. Models project decreases in species richness almost all over Madagascar, while projections of tree cover are uncertain.

Per capita water availability will decline by 2080 mostly due to population growth. Model projections indicate that **water saving measures are expected to become more important all over Madagascar after 2030**.

The **population share affected by at least one heatwave** per year is projected to **rise** from 0.2 % in 2000 to 4.8 % in 2080. This is related to 24 more very hot days per year over this period. As a consequence, **heat-related mortality** is estimated to **increase by a factor of four** by 2080.

Context

Madagascar is an **East African island state**, located in the Indian Ocean and with more than **4 800 km of coastline** [1]. The population is estimated to exceed **27 million** in 2020, given **an annual demographic growth rate of 2.7 %** [2]. The majority of the inhabitants live in the central highlands around the capital Antananarivo and along the eastern coast. With a real GDP per capita of 500 USD and an annual GDP growth rate of 2.1 %, Madagascar **counts as a least developed country (LDC)** [2]. Its economy is dominated by the services sector, contributing 52.1 % to the country's GDP in 2019, followed by the agricultural sector with 23.3 % and the industrial sector with 17.2 % [3]. **Vanilla is Madagascar's key export** (27.2 % of the total export value in 2018), followed by minerals such as nickel and cobalt [4]. Other agricultural exports include fruits and spices such as cloves, cinnamon and pepper [4]. In 2018, 41 % of the total export value of vanilla went to the United States, other destinations being France and Germany [5]. Although services have surpassed the agricultural sector, **roughly 80 % of the population** is employed in the latter, heavily **relying on agriculture** for sustaining food security and securing livelihoods [1]. Therefore, concerns are rising over the increasing effects of climate change including rising temperatures, reduced water availability through changing precipitation patterns and more extreme weather events, such as droughts, cyclones and floods. **Agricultural production in Madagascar is primarily subsistence-based and rainfed. Rice** is by far the **most important staple crop**, followed by cassava, sweet potatoes, maize and sugar cane [6]. Nevertheless, Madagascar **imports around 360 000 mt of rice** (9 % of the total production quantity in 2018) per year to meet its demand, with India and Pakistan being the main countries of origin [7], [8]. **Limited adaptive capacity in the agricultural sector**, such as limited access to agricultural inputs, formal credit or extension services, **underlines its vulnerability to climate change.** In 2013, only 60 % of the estimated irrigation potential of 1.5 million ha (42 % of total national crop land) was equipped for irrigation [6], [9]. Hence, especially smallholder farmers are directly affected by the impacts of climate variability, which can reduce their food supply and increase the risk of hunger and poverty.

While internal seasonal migration used to be common, recurring droughts, especially in southern Madagascar, continue to drive **more permanent migration** from affected areas to other parts of the country, particularly cities. As a result, Madagascar's **urban population is growing rapidly** [10].

Quality of life indicators [2], [11]–[13]

Human Development Index (HDI) 2019	ND-GAIN Vulnerability Index 2018	GINI Coefficient 2012	Real GDP per capita 2019	Poverty headcount ratio 2012	Prevalence of undernourishment 2017–2019
0.528 **164 out of 189** (0 = low, 1 = high)	**35.3** **164 out of 181** (0 = low, 100 = high)	**42.6** (0–100; 100 = perfect inequality)	**500 USD** (constant 2010 USD)	**77.4 %** (at 1.9 USD per day, 2011 PPP) [1]	**41.7 %** (of total population)

[1] Poverty headcount ratio for the year 2012 adjusted to 2011 levels of Purchasing Power Parity (PPP). PPP is used to compare different currencies by taking into account national differences in cost of living and inflation.

Topography and environment

Madagascar's topography is very diverse. Altitudes gently rise from the dry plains on the Mozambique Channel in the west towards the central highlands, reaching the highest peak at Mount Maromokotro (2 876 m), before descending more abruptly towards the eastern coastline [1]. The country has an **semi-arid to arid climate in the south-west** and a **tropical climate along the eastern coast**, while the central highlands are characterised by moderate temperature and moisture regimes. The arid climate of the south-west can be ascribed to the **trade winds** coming **from the Indian Ocean**: They lose their humidity on the eastern coast and in the highlands, leaving the western part in a so-called rain shadow [14]. Madagascar can be divided into **five major agro-ecological zones (AEZ)**[2]: Arid, Semi-arid / Savannah, Tropical Savannah, Humid Forest and the Highlands (Figure 1) [15]. Each of these zones is characterised by specific temperature and moisture regimes, and consequently, specific patterns of crop production and pastoral activities. Madagascar's major **rivers include the Mangoky, Tsiribihina, Betsiboka and the Onilahy**, all of which flow down the western side of the plateau. On the eastern side of the plateau, there are several shorter rivers, some of which discharge directly into the Indian Ocean via waterfalls. Although fairly abundant, Madagascar's **water resources are geographically unequally distributed** and threatened by reduced precipitation amounts and rising temperatures [16]. Unsustainable agricultural practices, such as **slash-and-burn agriculture and overgrazing**, have resulted in major environmental issues including deforestation and soil erosion [17]. Extreme weather events, including cyclones, heavy precipitation and severe droughts, are expected to intensify in the context of climate change, highlighting the **need for adaptation measures to protect biodiversity and maintain fragile ecosystems and their services**.

Present climate [18]

Madagascar has a very diverse climate largely influenced by its geographic location and elevation. Mean annual temperatures range from 18 °C to 26 °C with lower values in the central highlands and higher values in the west of the country.

Annual precipitation sums range from 400 mm on the south-western coast, which has a semi-arid to arid climate, to 3 300 mm on the eastern coast, which is characterised by a tropical climate.

Madagascar has a single rainy season (unimodal precipitation regime) from November to April in the northern and eastern part of the country, with decreasing length and precipitation amounts towards the south-west.

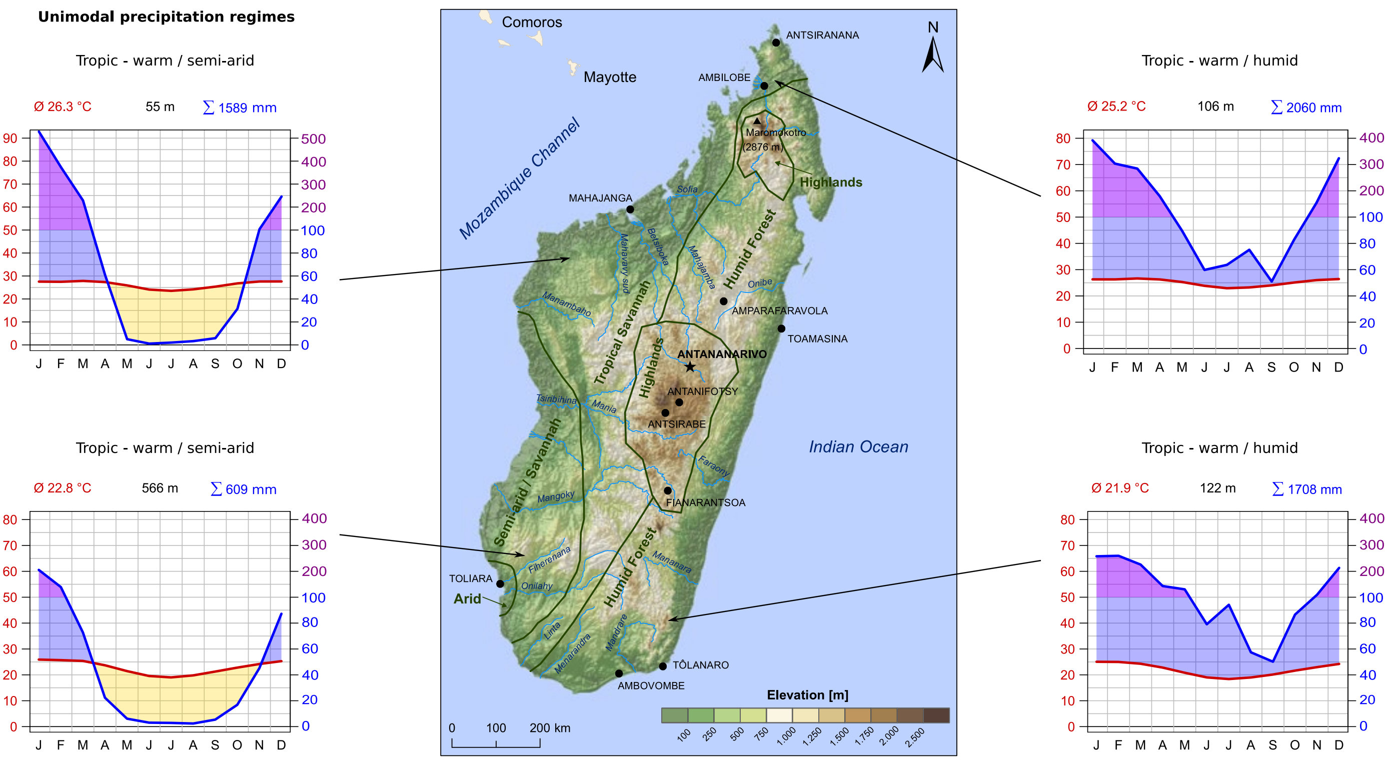

Figure 1: Topographical map of Madagascar with agro-ecological zones and existing precipitation regimes.[3]

[2] It should be noted that there are different classifications of AEZs in Madagascar.

[3] The climate diagrams display temperature and precipitation values which are averaged over an area of approximately 50 km × 50 km. Especially in areas with larger differences in elevation, the climate within this grid might vary.

Projected climate changes

How to read the line plots

- historical
- RCP2.6
- RCP6.0
- best estimate
- likely range
- very likely range

Lines and shaded areas show multi-model percentiles of 31-year running mean values under RCP2.6 (blue) and RCP6.0 (red). In particular, lines represent the best estimate (multi-model median) and shaded areas the likely range (central 66 %) and the very likely range (central 90 %) of all model projections.

How to read the map plots

Colours show multi-model medians of 31-year mean values under RCP2.6 (top row) and RCP6.0 (bottom row) for different 31-year periods (central year indicated above each column). Colours in the leftmost column show these values for a baseline period (colour bar on the left). Colours in the other columns show differences relative to this baseline period (colour bar on the right). The presence (absence) of a dot in the other columns indicates that at least (less than) 75 % of all models agree on the sign of the difference.
For further guidance and background information about the figures and analyses presented in this profile kindly refer to the supplemental information on how to read the climate risk profile.

Temperature

In response to increasing greenhouse gas (GHG) concentrations, **air temperature over Madagascar is projected to rise by 1.5 to 3.2 °C (very likely range) by 2080** relative to the year 1876, depending on the future GHG emissions scenario (Figure 2). Compared to pre-industrial levels, median climate model temperature increases over Madagascar amount to approximately 1.6 °C in 2030 and 1.8 °C in both 2050 and 2080 under the low emissions scenario RCP2.6. Under the medium/high emissions scenario RCP6.0, median climate model temperature increases amount to 1.5 °C in 2030, 2.0 °C in 2050 and 2.8 °C in 2080.

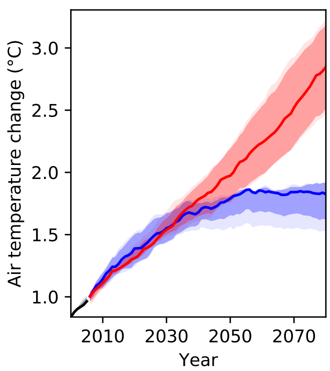

Figure 2: Air temperature projections for Madagascar for different GHG emissions scenarios.[4]

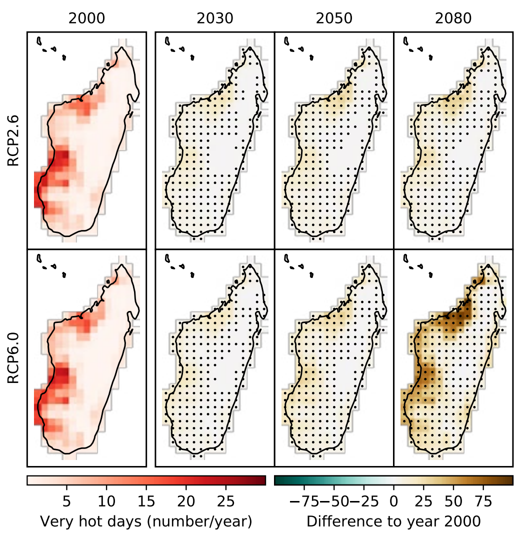

Figure 3: Projections of the annual number of very hot days (daily maximum temperature above 35 °C) for Madagascar for different GHG emissions scenarios.

Very hot days

In line with rising mean annual temperatures, the annual number of very hot days (days with daily **maximum temperature above 35 °C**) is projected to rise substantially and with high certainty, in particular over western Madagascar (Figure 3). Under the medium/high emissions scenario RCP6.0, the multi-model median, averaged over the whole country, projects **5 more very hot days per year in 2030 than in 2000**, **8 more in 2050** and **24 more in 2080**. In some parts, especially on the western coast of Madagascar, this amounts to about 90 days per year by 2080.

[4] Changes are expressed relative to year 1876 temperature levels using the multi-model median temperature change from 1876 to 2000 as a proxy for the observed historical warming over that time period.

Sea level rise

In response to globally increasing temperatures, the sea level off the coast of Madagascar is projected to rise (Figure 4). Until 2050, very similar sea levels are projected under both emissions scenarios. Under RCP6.0 and compared to year 2000 levels, the median climate model projects **a sea level rise by 11 cm in 2030, 22 cm in 2050, and 43 cm in 2080**. This threatens Madagascar's coastal communities and may cause saline intrusion in coastal waterways and groundwater reservoirs.

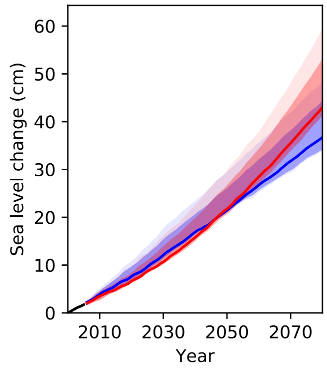

Figure 4: Projections for sea level rise off the coast of Madagascar for different GHG emissions scenarios, relative to the year 2000.

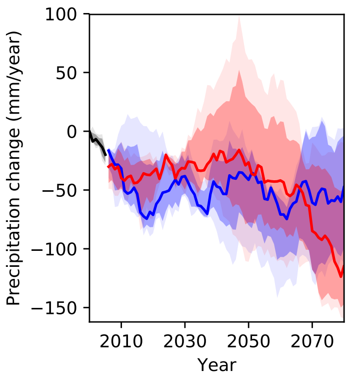

Figure 5: Annual mean precipitation projections for Madagascar for different GHG emissions scenarios, relative to the year 2000.

Precipitation

Future projections of precipitation are less certain than projections of temperature change due to high natural year-to-year variability (Figure 5). Out of the four climate models underlying this analysis, two models project a decrease in mean annual precipitation over Madagascar and two models project little change. Median model projections show **a precipitation decrease of 114 mm per year by 2080** under RCP6.0, while median model projections for RCP2.6 show a decrease at the beginning of the century, which settles at a decrease of **47 mm by 2080** compared to year 2000. Higher greenhouse gas emissions suggest an overall drier future for Madagascar.

Heavy precipitation events

In response to global warming, **heavy precipitation events are expected to become more intense** in many parts of the world due to the increased water vapour holding capacity of a warmer atmosphere. At the same time, the number of days with heavy precipitation events is expected to increase. This tendency is also reflected in climate projections for Madagascar (Figure 6), with climate models projecting **a slight increase in the number of days with heavy precipitation events**, from 7.0 days per year in 2000 to 7.5 and 7.2 days per year in 2080 under RCP2.6 and RCP6.0, respectively.

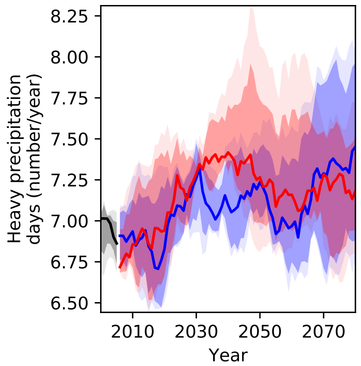

Figure 6: Projections of the number of days with heavy precipitation over Madagascar for different GHG emissions scenarios, relative to the year 2000.

Soil moisture

Soil moisture is an important indicator for drought conditions. In addition to soil parameters and management, it depends on both precipitation and temperature, as higher temperatures translate to higher potential evapotranspiration. **Projections for annual mean soil moisture** values for the topsoil (from the surface to a depth of 1 metre) **show a slight decrease under RCP2.6 and a stronger decrease of 5 % under RCP6.0** by 2080 compared to the year 2000 (Figure 7). However, looking at the different models underlying this analysis, there is large year-to-year variability and modelling uncertainty, with some models projecting a much stronger decrease in soil moisture.

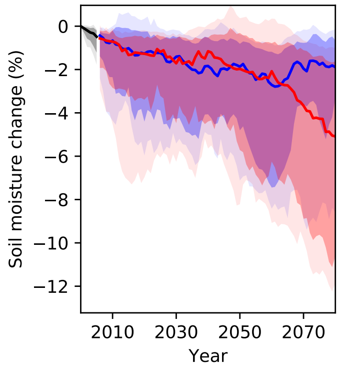

Figure 7: Soil moisture projections for Madagascar for different GHG emissions scenarios, relative to the year 2000.

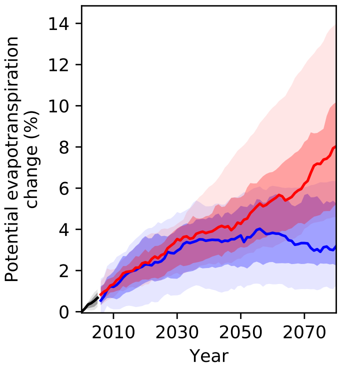

Figure 8: Potential evapotranspiration projections for Madagascar for different GHG emissions scenarios, relative to the year 2000.

Potential evapotranspiration

Potential evapotranspiration is the amount of water that would be evaporated and transpired if sufficient water was available at and below land surface. Since warmer air can hold more water vapour, **it is expected that global warming will increase potential evapotranspiration in most regions of the world.** In line with this expectation, hydrological projections for Madagascar indicate a stronger rise of potential evapotranspiration under RCP6.0 than under RCP2.6 (Figure 8). Under RCP6.0, **potential evapotranspiration is projected to increase by 3 % in 2030, 4 % in 2050 and 8 % in 2080** compared to year 2000 levels.

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Sector-specific climate change risk assessment

a. Water resources

Current projections of water availability in Madagascar display high uncertainty under both GHG emissions scenarios. Assuming a constant population level, multi-model median projections suggest a decrease of 13 % (RCP2.6) and 15 % (RCP6.0) in per capita water availability by the end of the century (Figure 9A). Yet, when accounting for population growth according to SSP2 projections[5], **per capita water availability for Madagascar is projected to decline** more dramatically, i.e. **by 78 % under both RCPs by 2080** relative to the year 2000 (Figure 9B). While this decline is primarily driven by population growth rather than climate change, it highlights the urgency to invest in water saving measures and technologies for future water consumption after 2030.

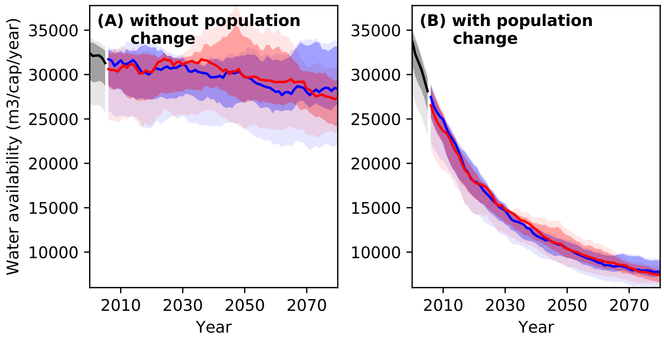

Figure 9: Projections of water availability from precipitation per capita and year with (A) national population held constant at year 2000 level and (B) changing population in line with SSP2 projections for different GHG emissions scenarios, relative to the year 2000.

Projections of future water availability from precipitation vary depending on the region and scenario (Figure 10). In line with precipitation projections, **water availability is projected to decrease by up to 25 % in the north and east of Madagascar** under RCP6.0. Under RCP2.6, models project decreases of up to 20 % for the north-east with simultaneous increases of up to 40 % in the otherwise very dry south-west of the country. The partial increase in water availability projected under RCP2.6 is based on a constant population level. Hence, **water saving measures are likely to become important** for Madagascar's rapidly growing population.

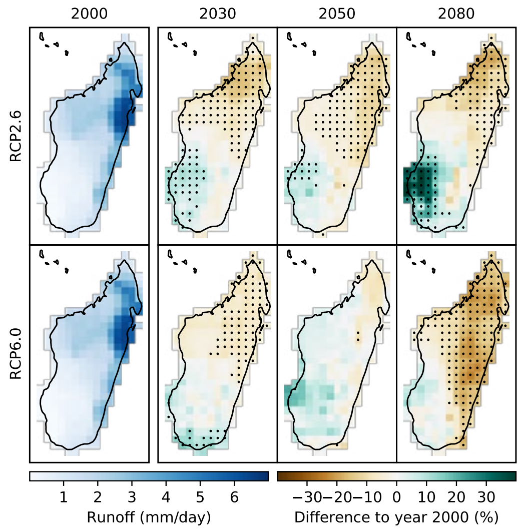

Figure 10: Water availability from precipitation (runoff) projections for Madagascar for different GHG emissions scenarios.

Madagascar is **known for its abundant water resources** from precipitation. However, these water resources are **unevenly distributed across the country**. While parts of the eastern coast of Madagascar receive more than 3,300 mm of precipitation annually, the south-west receives as little as 400 mm and is characterised by a semi-arid to arid climate [18]. For instance, in the 2019 / 2020 rainy season, the very south-west of the country, particularly northern Amboasary and parts of Ambovombe, Tsihombe and Bekily, recorded **below-average precipitation levels, threatening agricultural crops** which were just sown or at the flowering stage [8]. In contrast, northern Madagascar recorded **above-average precipitation levels**, which resulted in **flooding in several regions**, including Alaotra Mangoro, Analamanga, Betsiboka, Boeny, Melaky, and Sofia [19]. Increasingly heavy precipitation events and cyclones already have devastating impacts on smallholder farmers. In a study conducted among smallholder farmers in the aftermath of the **2012 cyclone Giovanna**, 81 % of farmers reported losing crops and 70 % reported damages to stored grains, resulting in prolonged periods with insufficient food for household consumption [20].

[5] Shared Socio-economic Pathways (SSPs) outline a narrative of potential global futures, including estimates of broad characteristics such as country level population, GDP or rate of urbanisation. Five different SSPs outline future realities according to a combination of high and low future socio-economic challenges for mitigation and adaptation. SSP2 represents the "middle of the road"-pathway.

b. Agriculture

Smallholder farmers in Madagascar are increasingly challenged by the uncertainty and variability of weather caused by climate change [21]. Since **crops are predominantly rainfed**, yields highly depend on water availability from precipitation and are prone to drought. Both the length and the intensity of the rainy season are becoming more and more unpredictable and the availability and **use of irrigation facilities remains limited**: In 2013, only 60 % of the estimated irrigation potential of 1.5 million ha (42 % of total national crop land) was equipped for irrigation [9]. Constraints to the implementation of adaptation strategies usually include limited access to technical equipment, formal credit and extension services [21]. The **main irrigated crop is rice**, and while temperature increases could be beneficial where low temperatures are currently a limiting factor to the growth of rice, prolonged periods of high temperatures in combination with strong winds could as well have devastating impacts on rice yields [22], [23]. **Drier conditions also facilitate the spread of invasive species** including the fall armyworm, which caused a yield loss of 47 % for maize in Madagascar in 2018 [8].

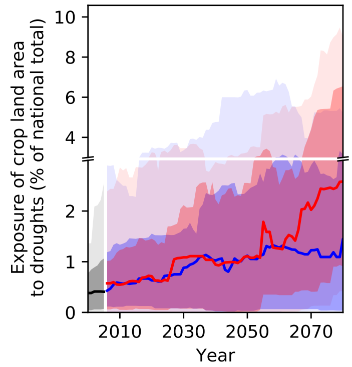

Figure 11: Projections of crop land area exposed to drought at least once a year for Madagascar for different GHG emissions scenarios.

Currently, the high uncertainty of projections regarding water availability (Figure 10) translates into high uncertainty of drought projections (Figure 11). According to the median over all models employed for this analysis, **the national crop land area exposed to at least one drought per year will increase from 0.4 % in 2000 to 1.4 % and 2.6 % in 2080 under RCP2.6 and RCP6.0, respectively.** Under RCP6.0, the likely range of drought exposure of the national crop land area per year widens from 0.04–0.8 % in 2000 to 0.9–6.5 % in 2080. The very likely range widens from 0–1.4 % in 2000 to 0.4–9 % in 2080. This means that **some models project a tenfold increase of drought exposure over this time period.**

In terms of yield projections, model results indicate a **negative trend for cassava and maize** under both RCPs (Figure 12)[6]. By 2080, compared to the year 2000, yields of cassava and maize are projected to decrease by 3.8 % and 2.7 % under RCP2.6, and by 2.6 % and 2.8 % under RCP6.0. **Yields of rice and sugar cane**, on the other hand, **are projected to increase** by 2.7 % and 9.7 % under RCP6.0 and to not change under RCP2.6. A possible explanation for the more positive results under RCP6.0 is that rice, sugar cane and cassava are so-called C3 plants, which follow a different metabolic pathway than, for example, maize (a C4 plant), and benefit more from the CO_2 fertilisation effect under higher concentration pathways. The later drop for cassava can be explained by decreasing levels of precipitation after 2050 under RCP6.0 (see Figure 5). Although some yield changes may appear small at the national level, they will likely increase more strongly in some areas and, conversely, decrease more strongly in other areas as a result of climate change impacts.

Overall, adaptation strategies such as switching to improved varieties in climate change sensitive crops need to be considered, yet should be carefully weighed against adverse outcomes, such as a resulting decline of agro-biodiversity and loss of local crop types.

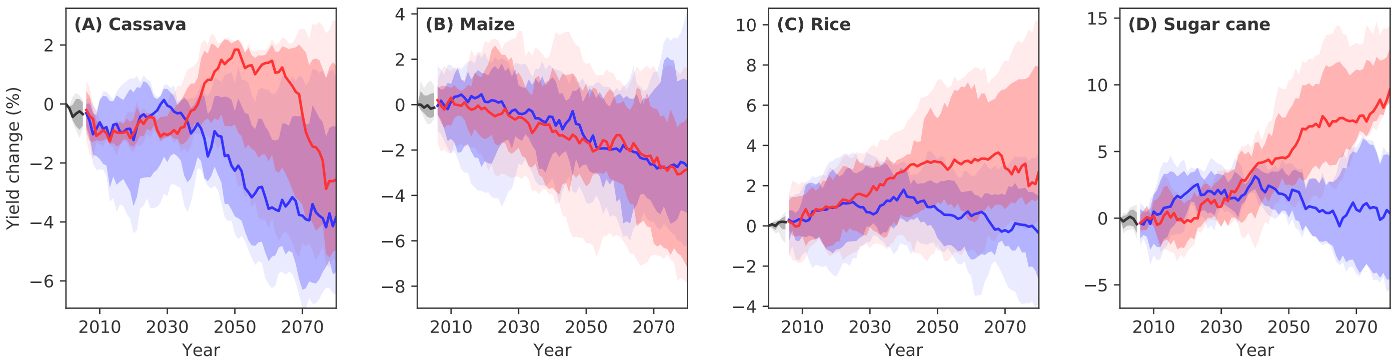

Figure 12: Projections of crop yield changes for major staple crops in Madagascar for different GHG emissions scenarios assuming constant land use and agricultural management, relative to the year 2000.

[6] Modelling data is available for a selected number of crops only. Hence, the crops listed on page 2 may differ.

c. Infrastructure

Climate change is expected to significantly affect Madagascar's infrastructure through extreme weather events. High precipitation amounts can lead to the **flooding of roads**, while high temperatures can cause **roads, bridges and coastal infrastructures to develop cracks and degrade more quickly**. This will require earlier replacement and lead to **higher maintenance and replacement costs**. The poorly developed railway network and limited inland waterway transportation increase Madagascar's reliance on road transportation [24]. Roads, however, are in very poor condition with the majority being unpaved and difficult to access, especially during the rainy season. With an estimated road network of 31 640 km, Madagascar has **one of the lowest road densities** in the world [24]. Investments will have to be made to build climate-resilient road networks.

Extreme weather events also have **devastating effects on human settlements and economic production sites**, especially in urban areas with high population densities like Antananarivo, Toamasina or Antsirabe. **Informal settlements are particularly vulnerable to extreme weather events**: Makeshift homes are often built in unstable geographical locations including steep slopes or riverbanks, where strong winds and flooding can lead to loss of housing, contamination of water, injury or death. Dwellers usually have a low adaptive capacity to respond to such events due to high levels of poverty and lack of risk-reducing infrastructures. For example, the **tropical Cyclone Belna** made landfall on the north-western coast of Madagascar in December 2019, **affecting 128 000 people** [8]. The district of Soalala was hit particularly hard, recording damages to roads, electricity posts and wells [25]. Flooding and droughts will also have an impact on hydropower generation: **Madagascar draws 29 % of its energy from hydropower,** with a total installed capacity of 162 MW in 2014 [26]. However, variability in precipitation and **climatic conditions could severely disrupt hydropower generation**.

Despite the risk of infrastructure damage being likely to increase due to climate change, precise predictions of the location and the extent of exposure are difficult to make. For example, projections of river flood events are subject to substantial modelling uncertainty, largely due to the uncertainty of future projections of precipitation amounts and their spatial distribution, affecting flood occurrence (see also Figure 4). In the case of Madagascar, median projections show **little change in national road exposure to river floods** (Figure 13). In the year 2000, 1.6 % of major roads were exposed to river floods at least once a year. By 2080, this value is projected to not change under RCP6.0 and to increase to 2.0 % under RCP2.6. This difference is in line with precipitation trends for Madagascar. The **exposure of urban land area to river floods is projected to change only slightly** under both RCP (Figure 14).

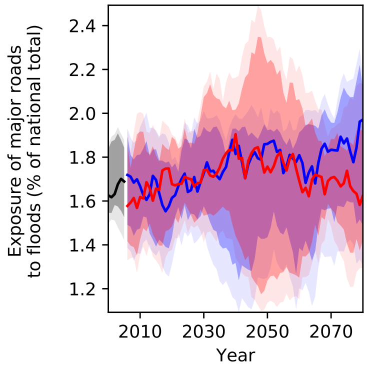

Figure 13: Projections of major roads exposed to river floods at least once a year for Madagascar for different GHG emissions scenarios.

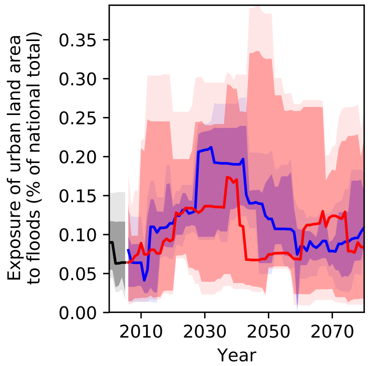

Figure 14: Projections of urban land area exposed to river floods at least once a year for Madagascar for different GHG emissions scenarios.

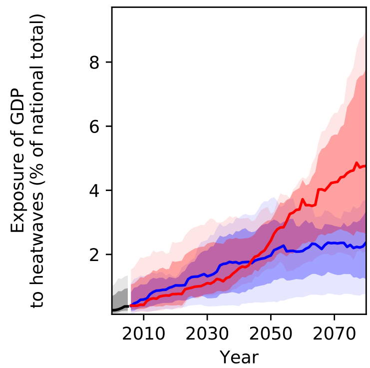

Figure 15: Exposure of GDP in Madagascar to heatwaves for different GHG emissions scenarios.

With the **exposure of the GDP to heatwaves projected to increase** from around 0.3 % in 2000 to 2.4 % (RCP2.6) and 4.8 % (RCP6.0) by 2080 (Figure 15), it is recommended that policy planners start identifying heat-sensitive economic production sites and activities, and integrating climate adaptation strategies such as improved solar-powered cooling systems, "cool roof" isolation materials or switching the operating hours from day to night [27].

d. Ecosystems

Climate change is expected to have a significant influence on the ecology and distribution of tropical ecosystems, though the magnitude, rate and direction of these changes are uncertain [28]. With rising temperatures and increased frequency and intensity of droughts, **wetlands and riverine systems are increasingly at risk of being disrupted and altered,** with structural changes in plant and animal populations. Increased temperatures and droughts can also impact succession in forest systems while concurrently increasing the risk of invasive species, all of which affect ecosystems. In addition to these climate drivers, low agricultural productivity and population growth might motivate unsustainable agricultural practices resulting in increased deforestation, fires and soil erosion. In turn, soil erosion, along with heavy precipitation and storms, facilitate the occurrence of landslides, threatening human lives, infrastructure and natural resources [29].

Model projections of species richness (including amphibians, birds and mammals) and tree cover for Madagascar are shown in Figure 16 and 17, respectively. The models applied for this analysis show particularly strong agreement on the development of species richness: Under RCP6.0, **species richness is expected to decrease almost all over Madagascar**, in some parts by up to 50 % (Figure 16). Under RCP2.6, models are far less certain, projecting slight increases in small patches across Madagascar. **With regard to tree cover, model results are very uncertain** and only small changes are projected under both RCPs (Figure 17). Hence, no clear tree cover trends can be identified.

It is important to keep in mind that the **model projections exclude any impacts on biodiversity loss from human activities such as land use**, which have been responsible for significant losses of global biodiversity in the past, and are expected to remain its main driver in the future [30]. In recent years, Madagascar's vegetation has experienced profound disturbances due to population pressure and increasing **demand for firewood** as well as agricultural land, leading to **high rates of slash-and-burn activities**, which are one of the main drivers behind deforestation [17]. The country has **lost 3.89 million ha of tree cover** between 2001 and 2019, which is equivalent to a 23 % decrease of national forest area [31].

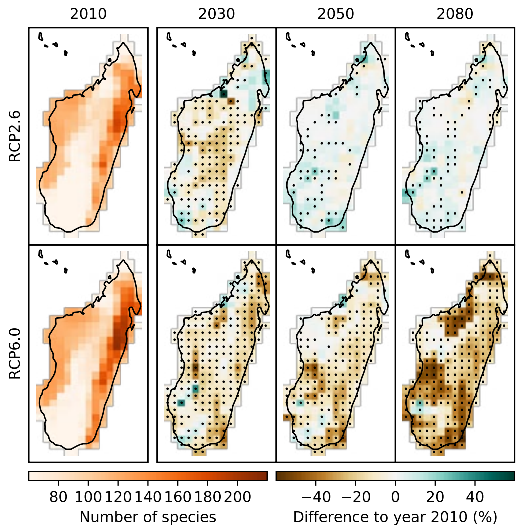

Figure 16: Projections of the aggregate number of amphibian, bird and mammal species for Madagascar for different GHG emissions scenarios.

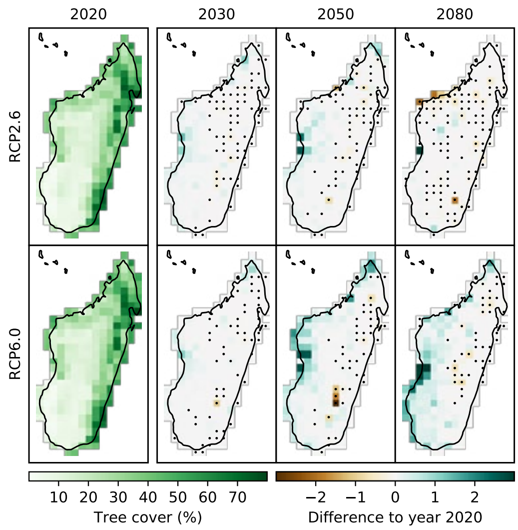

Figure 17: Tree cover projections for Madagascar for different GHG emissions scenarios.

e. Human health

Climate change threatens the health and sanitation sector through more frequent incidences of heatwaves, floods, droughts and storms, including cyclones. Among the key health challenges in Madagascar are morbidity and mortality through vector-borne diseases such as malaria, waterborne diseases related to extreme weather events (e.g. flooding) such as diarrhoea, respiratory diseases, tuberculosis and HIV [32]. **Climate change also impacts food and water supply, thereby increasing the risk of malnutrition, hunger and death by famine**. Many of these challenges are expected to become more severe under climate change. According to the World Health Organization, Madagascar recorded an estimated 2.2 million cases of malaria including 5 350 deaths in 2018 [33]. **Climate change is likely to have an impact on the geographic range of vector-borne diseases**: In Madagascar, malaria usually does not occur above 1 500 m [34]. However, temperature increases could expand occurrence to higher-lying areas. This is already the case in Antananarivo which used to be largely free of malaria but is now observing rising numbers of cases [35]. Malaria is also likely to increase in many parts of Madagascar due to flooding and stagnant waters, which provide a breeding ground for mosquitos [35]. Climate change also poses a threat to food security and malnutrition, particularly for subsistence farmers. **Chronic malnutrition is generally high with 42 %** and could further increase due to the consequences of the COVID-19 pandemic [36]. Furthermore, access to healthcare is often complicated in Madagascar: **40 % of the population live in areas far away from health centers** and have to travel for hours to seek medical treatment [35]. Access is even more difficult in the rainy season when many rural areas are cut off by impassable roads.

Rising temperatures will result in **more frequent heatwaves** in Madagascar, leading to **increased heat-related mortality.** Under RCP6.0, the population affected by at least one heatwave per year is projected to increase from 0.2 % in 2000 to 4.8 % in 2080 (Figure 18). Furthermore, under RCP6.0, **heat-related mortality will likely increase from 1.3 to 5.4 deaths per 100 000 people per year by 2080**. This translates to an increase by a factor of more than four towards the end of the century compared to year 2000 levels, provided that no adaptation to hotter conditions will take place (Figure 19). Under RCP2.6, heat-related mortality is projected to increase to 2.9 deaths per 100 000 people per year in 2080.

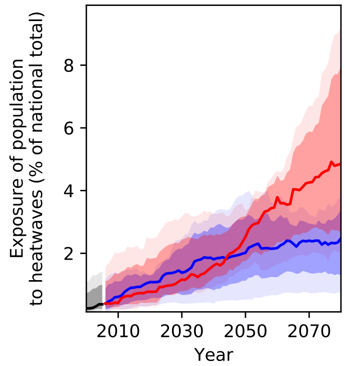

Figure 18: Projections of population exposure to heatwaves at least once a year for Madagascar for different GHG emissions scenarios.

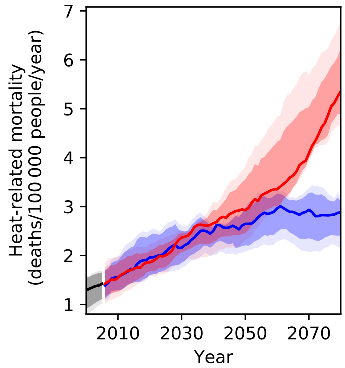

Figure 19: Projections of heat-related mortality for Madagascar for different GHG emissions scenarios assuming no adaptation to increased heat.

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Federal Ministry for Economic Cooperation and Development (BMZ)
BMZ Bonn
Dahlmannstraße 4
53113 Bonn, Germany
www.bmz.de

Scientific content developed by:
Potsdam Institute for Climate Impact Research (PIK)
Telegraphenberg A 31
14473 Potsdam, Germany
http://www.pik-potsdam.de

Scientific coordination:
Christoph Gornott (PIK)

Main authors:
Julia Tomalka (PIK),
Stefan Lange (PIK),
Felicitas Röhrig (PIK),
Christoph Gornott (PIK)

Contributors:
Paula Aschenbrenner (PIK),
Abel Chemura (PIK),
Lisa Murken (PIK),
Ylva Hauf (PIK),
Clarissa Kees (GIZ),
Enrico Grams (GIZ),
Sibylla Neer (GIZ),
Josef Haider (KfW)

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