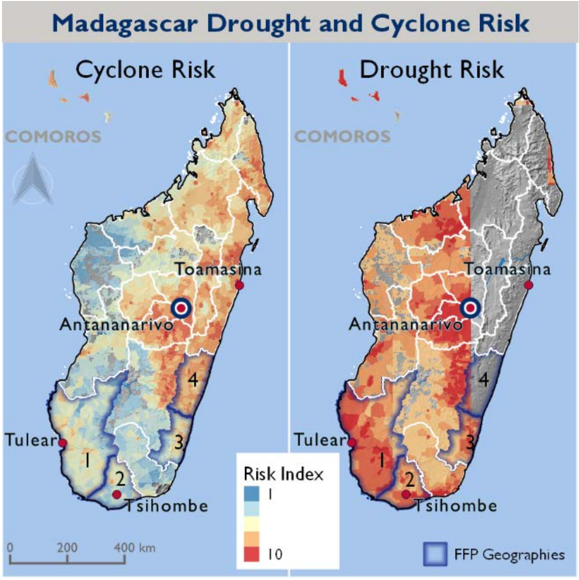
Climate Risk Profile

CLIMATE RISKS IN FOOD FOR PEACE GEOGRAPHIES
MADAGASCAR

COUNTRY OVERVIEW



Madagascar faces risks from an increasingly variable and changing climate, which add to the challenges of widespread poverty and food insecurity. The country has one of the highest poverty rates in Africa and ranks among the top five countries globally facing chronic malnutrition, with nearly half of children under five affected. The driving sectors of the economy are agriculture, livestock production and fisheries, all of which rely on climate-sensitive natural resources. Agriculture alone accounts for about 27 percent of gross domestic product (GDP) and employs 78 percent of the workforce. Rising temperatures, coupled with projected declines in rainfall as well as longer dry periods, could pose additional stress on the already vulnerable livelihoods of the country. Cyclones are particularly detrimental because the peak cyclone season (January–February) occurs during the *kere* (or lean season) when households already experience food shortages. Cyclones, in addition to droughts which affect Madagascar's southern regions, often devastate crops, leaving farmers without the means to generate income or critical food sources. Resilience remains a significant challenge for Madagascar, as recurring extreme weather events prevent households from rebuilding, replanting, recovering and ultimately moving out of poverty. (56, 9)

CLIMATE PROJECTIONS

- 1.1°C–2.6°C increase in temperatures by 2060
- Overall decrease in precipitation
- Increased intensity of cyclones
- 19 cm–47 cm rise in sea levels by 2060

KEY CLIMATE IMPACTS

Agriculture & Livelihoods

Crop loss/failure
Shifting planting/harvest seasons
Increased food spoilage
Increased presence of pests/diseases

Health & Nutrition

Persistence of malnutrition
Expanded range of disease transmission
Injury/death from extreme events

Water, Sanitation & Hygiene

Diminished water availability and quality
Increased presence of pathogens/ parasites

March 2019

This document was prepared under the Adaptation Thought Leadership and Assessments (ATLAS) Task Order No. AID-OAA-I-14-00013 and is meant to provide a brief overview of climate risk issues. The key resources at the end of the document provide more in-depth country and sectoral analysis. The contents of this report do not necessarily reflect the views of USAID.

LIVELIHOODS AND CLIMATE IN FOOD FOR PEACE PROGRAM AREAS

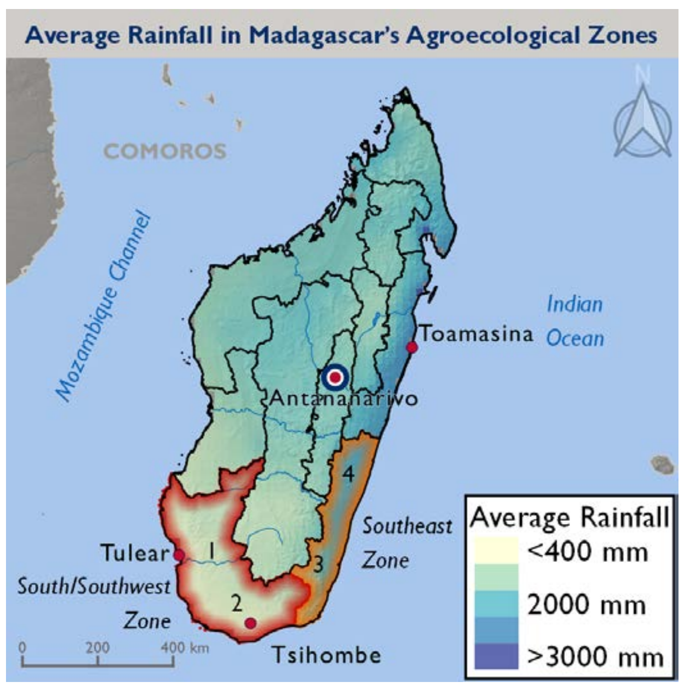
USAID Food for Peace (FFP) programs in Madagascar focus on reducing acute food insecurity for the most vulnerable populations of the southern regions of the country while also improving nutrition, increasing household and microenterprise productivity and income, and building household resilience to shocks. Target FFP investment areas include the chronically food-insecure regions of Atsimo Atsinanana and Vatovavy-Fitovinany in the southeast (numbers 3 and 4 on the map below), the Ampanihy, Betioky and Toliara (Tuléar) II districts in the Atsimo Andrefana region in the southwest (number 1 on the map), and Madagascar's southernmost region of Androy (number 2 on the map). These regions are isolated and characterized by poor access to basic services such as potable and reliable water, insufficient numbers of health care providers per capita and low incomes. (49, 50, 59)

FFP uses a multisector approach to address food insecurity and malnutrition in these areas by investing in:

- **Health and nutrition**, including community health care clinics, supplementary feeding to strengthen diets for pregnant and lactating women and children under the age of two, and improving access to water, sanitation and hygiene (WASH) infrastructure.
- **Agriculture and livelihoods**, including farmer field schools and expanded access to credit through village savings and loan associations.
- **Disaster mitigation and preparedness activities** to support local disaster management committees to design community disaster management plans. (49)

LIVELIHOOD ZONES

Agriculture (with livestock and fisheries) is the driver of Madagascar's economy. While farming is the main livelihood for most Malagasy households, at least 60 percent of agricultural households also practice livestock rearing. Crop production is strongly dictated by the country's diverse microclimates and agroecological zones. Livelihoods, in addition to irrigation systems, drinking water supply, road infrastructure and health systems, are highly sensitive to climate hazards such as cyclones, floods and droughts. Cyclones often impact food security by destroying standing crops in coastal areas and causing salinization and siltation in rice fields. In January 2018, Cyclone Ava hit eastern coastal regions, bringing heavy rains and strong winds. Localized flooding damaged transplanted rice crops, resulting in production losses. (29, 39, 13, 6)



As the climate becomes more variable and extreme events become more frequent, intense or long-lasting, food insecurity will become more acute and likely affect more people. Food insecurity affects most of the country but is chronic in the eastern zones and acute in the southern zones where FFP works. See Table 1 for more details on FFP program area livelihood zones.

CLIMATE SUMMARY

Madagascar's climate is tropical, with regional variations and two distinct seasons: (1) a hot, rainy season from November to April, with the most rainfall in December and January; and (2) a dry season from May to October, with the least rainfall between September and October. Annual average precipitation countrywide is 1,500 mm, but varies widely from region to region. The eastern region is the wettest, receiving rain almost year-round. The southwest receives less than 600 mm of rain per year. Average annual temperatures are 23°C–27°C along the coast and 16°C–19°C in the highlands. (46, 47)

Climate risk in Madagascar involves sudden onset shocks such as cyclones, floods, drought and heat waves and gradual onset stressors, such as average temperature increase, long-term changes in rainfall patterns and sea level rise. Cyclone risk is highest on the east coast; however, an estimated 12 tropical storms pass through the Mozambique Channel on the west coast of Madagascar every year, and 3–4 reach cyclone status. Between 1990 and 2015, Madagascar recorded 65 major climate-related disasters, including more than 50 cyclones and five severe droughts, with significant economic losses. On average, losses from flooding and cyclones are approximately US$40-50 million per episode. Cyclone Enawo in 2017the country's most severe cyclone in 13 years, affected 14 of the country's 22 regions. Total losses were estimated at US$400 million, equivalent to roughly 4% of Madagascar's GDP. (47, 58, 55, 57)

Table 1: Livelihood zones and climate in Madagascar's FFP program areas

Livelihood zone	Main economic activities	Rainfall and temperature	Main climate-related hazards
South East Agroecological Zone **(Atsimo Atsinanana and Vatovavy-Fitovinany)**	Atsimo Atsinanana and Vatovavy-Fitovinany fall within Madagascar's hot and humid southeast agroecological zone. Agricultural parcels are small and geographically dispersed because of topography and water availability. Poor households grow crops on *tavy* (slash-and-burn plots) due to lack of farming leases and money to buy fertilizer, and they often migrate to export centers and production basins outside of the zone during flooding periods. In the more inland regions of this agroecological zone, rainfed and irrigated agriculture includes food crops (rice, cassava and sweet potato), coffee and fruit (banana, jackfruit, litchi and sugar-apple). Rice is primarily produced in the lowlands where better-off households can use animal traction, while other rainfed crops are grown on slopes. Better-off households may rear livestock (cattle and pigs), whereas poor households generate income through agricultural activities such as gathering honey and raising poultry. They also work locally, particularly for rich households that need labor for forestry activities. There is gold mining in the zone, but production is industrialized and does not require unskilled labor. Artisanal and small-scale mining for precious and semiprecious stones is increasingly widespread.	Rainfall in this zone is high but irregular (1,700–3,500 mm per year in the easternmost half of the zone, and 1,000–2,000 mm per year in inland areas) Temperature ranges between 10°C and 32°C	Cyclones Floods

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South and Southwest Agroecological Zone **(Atsimo Andrefana and Androy)**	The Atsimo Andrefana and Androy regions align with Madagascar's south and southwest agroecological zone. The predominant crops are cassava, rice, maize and sweet potato. The portion of the zone to the north of Toliara, which receives the highest annual rainfall in this zone, is considered the rice bowl of the south, due in part to the presence of dams and irrigation canals. In spite of the zone's low population density compared with the rest of the country (5–15 inhabitants per km^2), poor soil quality and problems with water access limit the size of farms. The southernmost portion of the zone is the hottest and driest, receiving only 300 mm of rainfall per year on average. Livestock systems are more extensive in this zone compared with others. Small ruminants and poultry are raised for household consumption and marketing. Zebus (humped cattle) are raised to support agriculture but also play a significant role in meeting social obligations (especially funerals). As a result of the single crop season, seasonal labor migration is common. Between October and February, households may temporarily migrate to Toliara, Mahajanga or mining areas in the east, such as Mahaboboka and Ambinany, where artisanal and small-scale mining for precious and semiprecious stones (sapphire) is common.	The zone is characterized by its semiarid tropical climate and receives an average annual rainfall of 300–600 mm that is irregularly distributed but highly concentrated from December to March Temperatures range between 20°C and 35°C	Droughts Floods Heat waves

Sources: FEWS NET 2013; FEWS NET 2017; FAO 2010; IIED 2017

CLIMATE TRENDS AND PROJECTIONS

The climate of Madagascar is increasingly variable: dry periods are getting longer, the intensity of heavy rainfall events is increasing and maximum temperatures are increasing (see Table 2). These trends are expected to continue, with higher temperatures and reduced rainfall projected for the southern zones of Madagascar.

Table 2: Climate trends and projections

Parameter	Observed trends	Projected changes
Temperature	• Increased temperature of 0.27°C per decade for 30 years (1983–2013) • Significant increases in daily temperatures across all seasons, and pronounced increases in daily maximum temperatures during the dry season • Increased variability in temperature, with higher temperatures in the southern areas	• 1.1°C to 2.6°C increase in average annual temperature by 2060, with highest changes projected in the south • 2.5°C to 3.0°C increase by 2100 • Increase in heat wave duration of 7 to 20 days by 2050
Rainfall	• Decreased rainfall of 8 percent over 30 years (1983–2013) • Increased variability in the distribution of rainfall, with higher temperatures and increased rainfall in the southern areas • Reduction in the length of the dry season and longer periods of drought in the central and western parts of the country • Increased intensity of rainfall during cyclones	• Reduced rainfall overall, particularly during the dry season and in inland areas • Reduced rainfall in the south during the dry season (May–July and August–September) • Increased rainfall during the rainy season by 2065, particularly in the south

Sea level rise	• Sea level rise of 0.6 cm per year from 1994 to 2008	• Sea level rise of 19 cm to 47 cm by 2056 (near Ambanja in the north, high-emissions scenario)
Cyclones	• No trend detected; considerable interannual variability	• By 2100 the frequency of cyclones is projected to decrease over the Indian Ocean, particularly at the beginning of the cyclone season. However, cyclone intensity is projected to increase by almost 50 percent, with landfall tracks shifting northward.

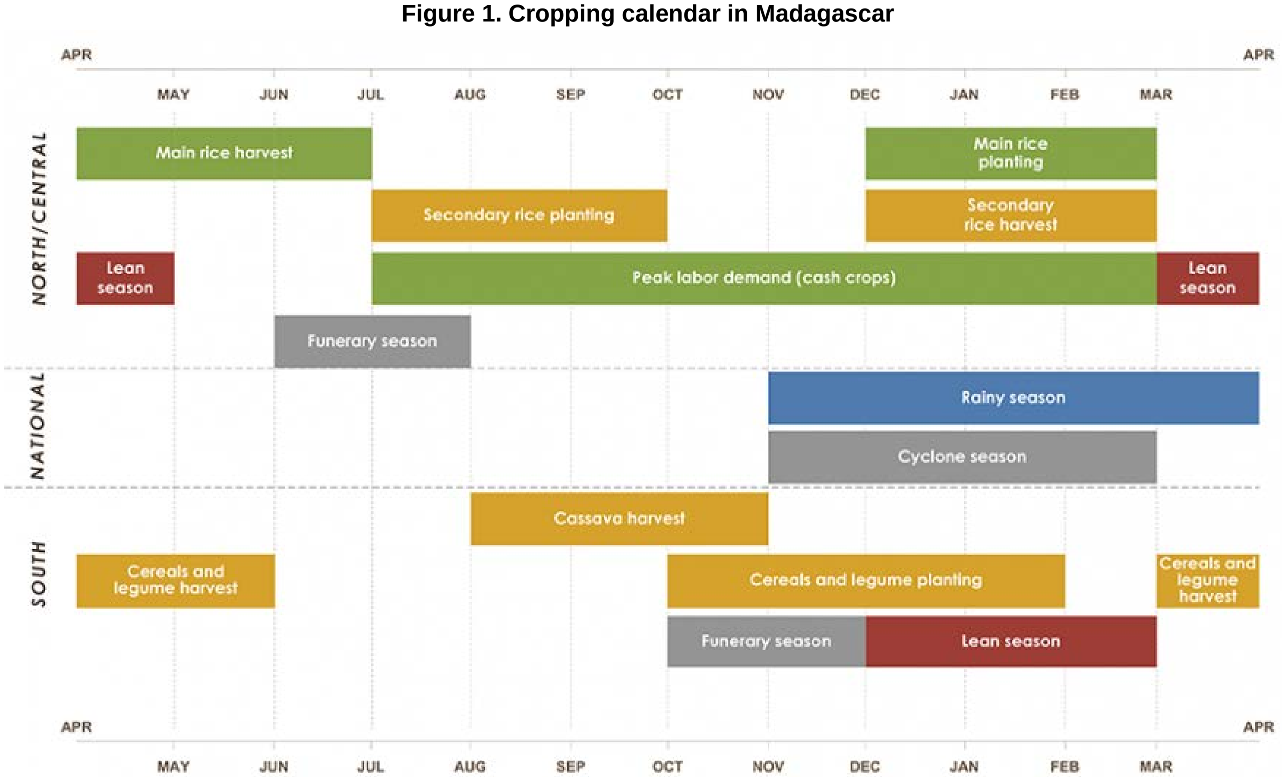
Sources: USAID 2018a

SECTOR IMPACTS AND VULNERABILITIES

CROP PRODUCTION

Crop production is mainly subsistence and dominated by smallholders working plots averaging less than two hectares. Local rice, which accounts for 70 percent of Madagascar's total agricultural production, is the staple food for the entire country and for all income groups, except in the south, where cassava dominates. Maize and sweet potato are also considered staples, especially in Madagascar's southern zones. While the main agricultural season is from October to June, cropping calendars vary from region to region (Figure 1). Projected temperature increases, however, could disrupt these unique and critical microclimates and lead to significant changes to local farming systems, with important implications for food security. (50, 8)

Figure 1. Cropping calendar in Madagascar



Source: FEWS NET 2016

Even in normal years, most farming households' harvests are unable to cover their own food requirements. Poor and very poor households often go several months without sufficient food. Rice production is largely subsistence-based, with more than two-thirds of households (68 percent) on the east coast of Madagascar growing rice at a deficit and experiencing heightened food insecurity in the months prior to the main rice harvest. When farmers experience food shortages, they respond by eating smaller meals, eating fewer times a day, changing their diet (principally from rice to cassava or maize) or supplementing their food supplies by gathering food products from nearby forests. Farmers also supplement their food supplies by purchasing rice from the market, and they routinely sell productive household assets (e.g., livestock), increase the collection and sale of firewood and charcoal, or migrate to seek off-farm employment (e.g., in mining) for income to buy food. (20, 16, 8, 9)

In addition to these challenges to food security, recurring hazards such as cyclones, droughts and locust invasions affect crop production. These hazards are localized—with cyclones affecting the east coast more than the west coast, droughts affecting the central and southern regions of the country and locust invasions mainly impacting the southwest—but their impacts on food availability are often felt on a broader scale. Half of the high-season rice crops was damaged when Cyclone Ava struck Madagascar's east coast in January 2018. Cyclones—and the associated heavy rains, storm surges, flooding and winds—disrupt the already limited transport infrastructure. Roads across Madagascar are frequently impassable during the rainiest months from November to March, and inadequate harvest, storage and processing methods lead to high rates of postharvest spoilage of root and tuber crops such as cassava and sweet potato, particularly during humid months. (43, 35)

More variable weather—delayed rains and dry conditions—are increasingly hampering crop production across Madagascar. In 2017, national rice production decreased 19 percent compared with the previous three-year average (2013–2015) due to a delayed start of the rainy season and severe midseason dry conditions affecting major rice-producing regions in the north, center and east. In the same year, national maize production was 20 percent below the 2013–2015 average, and cassava production was 4 percent below the previous year, mainly a result of dry weather conditions. (16)

More erratic rainfall and changes in temperature could also contribute to the spread of new agricultural pests, posing unprecedented threats to rice and maize. While locust invasions are frequent in the southwest agroecological zone, the fall armyworm has emerged as a new challenge. As of April 2018, 35 districts—including several in the Atsimo Andrefana and Androy regions—were affected by fall armyworm infestations. More than 50 years of data on the closely related African armyworm indicate that their population explodes after droughts. The projected lengthening dry seasons and persistence of drought conditions brought on by climate change could favor both varieties of armyworm. (14, 43, 3)

Table 3 describes common crop climate sensitivities, including sensitivities related to changes in pest and disease dynamics. Table 4 summarizes climate risks to agricultural production in Madagascar.

Table 3: CROP PRODUCTION—Climate sensitivities of key crops	
Crop	**Climate sensitivities**
Rice	• Higher temperatures can decrease rice yields because they can make rice flowers sterile, meaning no grain is produced • Higher respiration losses linked to rising temperatures also make rice less productive • Moderate salinity tolerance
Cassava	• Susceptible to cassava brown streak disease and mosaic disease transmitted by whiteflies whose proliferation is associated with increasing temperatures
Maize	• Very susceptible to rain failure • Small changes in rainfall patterns/amounts and temperatures lead to appreciable loss of yield
Sorghum	• Sensitive to moisture stress during grain-fill stage when dry periods of 2 weeks or more significantly diminish yields • Poor performance if rainfall is less than 450 mm • Temperatures more than 35°C can reduce yields • Hot dry conditions increase risk of damage from khapra beetle and striga purple witchweed; hot wet conditions increase risk of sorghum midge, anthracnose, sorghum downy mildew and zonate leaf spot

Sources: van Oort 2017; IRRI nd; Reynolds et al. 2015; Steward et al. 2018; USAID 2014

Table 4: CROP PRODUCTION—Climate stressors and risks	
Climate stressors	**Climate risks**
Rising temperatures	Reduced soil moisture and increased erosion
Increased unreliability of rainfall	Crop failure and reduced yields; increased food prices
Increased length or intensity of dry periods	Increased incidence of pests (e.g., locusts, fall armyworm) and diseases (e.g., sheath rot, bacterial blight)
Increased intensity of extreme events	Waterlogging/crop damage

Source: USAID Sector Environmental Guidelines Agriculture 2014

LIVESTOCK

At least 60 percent of households in Madagascar practice livestock rearing and depend on it for some portion of their income. While typically more resilient to climate variability and shocks than crops, livestock are susceptible to heat stress, and their viability is affected by the productivity and availability of pasture, feed production, water availability and pest and disease dynamics. (16)

Livestock production is traditional almost everywhere except for the production of broiler hens and laying hens in central Madagascar's upper plateau. Cattle and pigs make up the largest percentage of household livestock assets in Atsimo Atsinanana and Vatovavy-Fitovinany. Livestock rearing in the northwestern portion of the southern agroecological zones (Atsimo Andrefana) is dominated by small livestock (goats, sheep). Moving southward, livestock rearing becomes more widespread than agriculture and is dominated by small herds of goats and to a lesser extent, sheep. In the very south (Androy), livestock systems are extensive and involve an annual migration within Androy between May/June and October from the south to northern and western zones (e.g., from Ambanisarika commune in the Androy region to Antanimora Sud commune in the Androy region). This traditional coping strategy for addressing risks to livestock is most applicable to cattle, as small ruminants are better able to withstand the high temperatures characteristic of the south. (9, 8, 11, 50)

Poultry (local chickens, geese), small ruminants and cattle constitute important assets that households sell during periods of heightened climate stress, such as droughts. However, low rainfall or delays in rains across the country also affect pasture conditions and, in turn, animal conditions. Rising temperatures and increasing frequency of heat waves can kill livestock, particularly chickens, and are likely to impact the range, transmission rate and outbreaks of certain livestock diseases (e.g., lumpy skin disease, Newcastle disease, African swine fever, anthrax). Increased frequency of drought conditions in Madagascar's south has led more households to sell their productive assets. Furthermore, total herd sizes of Malagasy zebu—a species of humped cattle adapted to high temperatures and the major breed of the extensive cattle population throughout the country—have declined due to civil unrest and forest fires, limiting households' ability to draw on this resource. According to the Ministry of Agriculture and Livestock, cattle population fell by one-third from 9.7 million in 2005 to 6.5 million in 2016. Small ruminants and poultry are gaining importance for households, as they reproduce more quickly than large ruminants, are generally more resilient than zebu, and thus help to restore depleted herds. (7)

As populations migrating from the drought-afflicted southern zones move northward and begin to settle in more densely populated areas like Toliara in Atsimo Andrefana, livestock diseases and zoonoses associated with urbanization, like the 2008–2009 outbreak of Rift Valley Fever, are likely to become more pronounced. Climate stressors and risks for livestock are listed in Table 5. (31)

Table 5: LIVESTOCK—Climate stressors and risks

Climate stressors	Climate risks
Rising temperatures	Increased rate of development of parasites and pathogens
Increased unreliability of rainfall (more variability)	Reduced livestock reproduction and growth rates due to heat stress
Increased length or intensity of dry periods	Changes in the distribution and presence of disease vectors (e.g., mosquitoes, ticks, fleas)
Increased intensity of extreme events	Drying pasture, decreasing grazing potential
	Early drying of seasonal water or diminishing water points

Source: USAID Sector Environmental Guidelines Livestock 2015

FISHERIES

For the small percentage of households that make their living through fishing (around 3 percent), it is an economic lifeline. Marine catches in the southern zones include sardines, mackerel, tuna, shrimp and lobster. Rising sea surface temperatures and the alteration of rainfall cycles inland (which increases runoff of sediment into rivers and then into the sea) harm marine resources in Madagascar. Coupled with overfishing, climate-related stresses increase the vulnerability of coastal livelihoods, potentially compromising the long-term sustainability associated with those resources. Depletion of fish stocks in the traditional and most accessible catch sites lead fishing households to travel longer distances or to migrate inland and turn to farming for food and income. This in turn increases the pressure on arable land.

Coral reefs continue to suffer from increased warming sea temperatures, water acidity and habitat degradation from more intense cyclones. Historical aerial photographs and modern high-resolution remote sensing images confirm a continuous loss of coral habitat on Toliara's barrier reef system between 1962 and 2011, with an average loss of 65 percent and a range of 37–79 percent loss during this 50-year period. As fish species migrate, coastal communities may see their protein intake diminish, amplifying food security concerns (Table 6). (50, 56, 48, 8, 1, 12, 18)

Table 6: FISHERIES—Climate stressors and risks

Climate stressors	Climate risks
Rising surface temperatures of seas and inland ponds and lakes **Increased intensity of rains, cyclones and floods**	Altered phenology, physiology, development and yields
	Sedimentation and erosion
	Disruption to fish reproductive patterns and migratory routes
	Coral bleaching (affecting reef fisheries)
	Reduced aquatic biodiversity and productivity
	More frequent loss of fishing days due to bad weather; increased loss of nets, traps and longlines; increased damage to boats and shore facilities; increased loss of life among fishermen
	Reduced water quality
	Damage to infrastructure and transportation networks
	Loss of mangroves, a critical habitat of artisanal fisheries
	Reduced nutrition

Source: USAID Sector Environmental Guidelines Wild Caught Fisheries and Aquaculture 2018

FOREST ECOSYSTEMS

For the poorest people in the southeastern regions of Vatovavy-Fitovinany and Atsimo-Atsinanana, Madagascar's forests and natural resources provide food from hunting and foraging, and supplemental incomes from collecting firewood and producing charcoal . These ecosystems are crucial for soil protection and climate regulation, acting as carbon sinks. However, deforestation, coupled with climate variability, challenge food security in the FFP program areas (Table 7). Vatovavy-Fitovinany and Atsimo-Atsinanana, for example, lost 16.9 percent and 11.2 percent of their forested land, respectively, between 2000 and 2016. The degradation and harvesting of forestry resources is exacerbated by increasingly frequent intense rainfall events and higher temperatures. Intense rains can create floods that damage or destroy forests, and through erosion, reduce the soil cover on which the forest ecosystems depend. The decline in forest health and productivity in turn puts even more pressure on nonforested arable land that already is overused and highly susceptible to erosion and degradation. (8, 54, 48, 57, 58)

Deforestation is also linked to reduced rainfall and reduced soil fertility. Unsustainable slash–and-burn (*tavy*) agricultural production techniques are the main cause of habitat reduction, deforestation and subsequent degradation of high-altitude forest ecosystems. In the Atsimo Andrefana region, 31,000 hectares of forest were burned between 2000 and 2011 as a result of tavy. Faced with crop shortages, farming households turn to the forest to supplement their food supply, gathering wild fruits, breadfruit, cactus, yams and other tubers. As noted above, in order to recoup their lost income, some farmers also collect wood for charcoal production. Therefore, human-induced deforestation coupled with more variable weather may decrease the availability of farmers' secondary sources of food produce. Table 7 describes common forest ecosystem climate sensitivities. (41, 46, 53, 10)

Table 7: FOREST ECOSYSTEMS—Climate stressors and risks	
Climate stressors	**Climate risks**
Rising temperatures **Increased intensity and frequency of rains, cyclones and floods** **More variable precipitation**	Reduced soil moisture and soil quality
	Sedimentation and erosion of large watersheds
	Increased run-off and siltation of rice paddies
	Reduced terrestrial biodiversity and productivity
	Reduced carbon absorption capacity

Source: USAID Sector Environment Guidelines Forestry 2015; World Bank 2017d; UNDP 2015; Shriver, J. 2013; World Bank 2011

HUMAN HEALTH AND NUTRITION

Diarrheal diseases, infectious respiratory diseases (e.g., tuberculosis) and malaria are some of the largest contributors to the disease burden in Madagascar. Infectious respiratory diseases, the primary cause of mortality in children under five, have been associated with increasing temperatures, and will likely worsen as a result of climate change (Table 8). (18)

Vector- and waterborne diseases

With climate change, more areas of Madagascar are likely to see an increase in malaria transmission and prevalence. The east coast has perennial transmission and the west coast has seasonal transmission typically from October to May, with reduced transmission in July and August. In both regions, malaria morbidity and mortality are primarily among children under 15 years of age. Increases in malaria transmission, already the case in areas of the country where malaria transmission had been low, are expected to continue. This will be driven by a broadening of the temperature envelope (which has limited malaria in these areas), increased flooding and standing water sources and human migration. (32, 59)

Mass migration in response to successive drought years has increased the number and density of poorly constructed urban slums, which suffer from a lack of sanitation and have increased pressure on already limited urban infrastructure. Infected livestock that end up near water sources around densely populated areas may also attract mosquitoes and thus contribute to the transmission to humans of diseases such as Rift Valley Fever. (25)

Nutrition

Malnutrition is a widespread concern in Madagascar and renders the population vulnerable to other diseases. People living with tuberculosis, a major contributor to Madagascar's overall disease burden, are at major risk of malnutrition. One-third of all child deaths in Madagascar—18,000 a year—are linked to poor nutrition. In 2016, the El Niño weather phenomenon amplified drought conditions, leading to a 75-percent drop in rainfall compared with a 20-year average. In turn, this led to harvest losses of up to 95 percent, food insecurity for more than 1 million people, moderate acute malnutrition for 35,000 children under five and severe acute malnutrition for another 12,000 children under five. In addition to reduced yields, higher CO_2 levels and associated climate impacts could affect the nutritional content of major staples, most notably rice. New research suggests that elevated levels of CO_2 will alter the protein, micronutrients and vitamin content of rice. Maize will be less affected by higher levels of CO_2 but may face increasing risk from aflatoxin. (27, 59, 60, 61, 37, 62)

Impacts of extreme events on health and well-being
Cyclones, floods and landslides bring devastating consequences. In March 2017, more than 70 people died and at least 183 were injured as Cyclone Enawo swept through the country. Similarly, Cyclone Ava hit Madagascar's east coast in January 2018 with wind speeds between 140 and 190 kph, claiming at least 50 lives. In both cases, thousands were displaced from their homes and a number of basic health care centers were damaged, further constraining service provision and emergency response. (52)

Table 8: HEALTH AND NUTRITION—Climate stressors and risks

Climate stressors	Climate risks
Rising temperatures **Increased intensity of rains, cyclones and floods**	Increased incidence of infectious diseases from flooding and standing water
	Increased food insecurity, hunger and malnutrition
	Increased flood-related injury and mortality
	Reduced access to health services due to interruptions in transport infrastructure
	Extended range of disease-carrying vectors (e.g., mosquitoes, ticks, fleas)

Source: USAID Sector Environmental Guidelines Small Healthcare Facilities2014

WASH

Longer dry periods, sea level rise and higher temperatures will pose additional WASH risks where access to water and improved sanitation is already lacking (Table 9). The percentage of rural households with access to safe water and safe sanitation is estimated at 35 percent and 12 percent, respectively. Traditional hand-dug wells along river banks are common throughout the country. For example, in Tsihombe (Androy region in southern Madagascar), the majority of residents source water directly from the Manambovo River or its riverbed by digging shallow wells in the floodplain. (19, 47, 53)

Extended dry periods may cause water sources to dry up or become intermittent, reduce good hygiene practices that prevent the spread of diseases and infections (e.g., roundworm) and accelerate airborne fecal dust in open defecation zones, all while reducing the performance of drainage systems, where they exist. Many traditional water sources, for example, were dry during the successive droughts in southern Madagascar (2013–2016). In Tsihombe, rivers, wells and water tanks regularly fail during droughts, creating major water supply and sanitation challenges. Commercial water and sanitation service, provided by the national water and electricity utility, JIRAMA, is limited in reach and relies on groundwater underflow captured from the Manambovo

River. Alimentation en Eau dans le Sud (AES), the allied water operator for southern Madagascar, operates a water cistern that relies on water piped from a pumping station in Ampotaka in Beloha commune to fill a 100 m^3 reservoir. When either the diesel-operated water pump in Ampotaka or the 142-kilometer pipeline is not functioning, AES delivers water to Tsihombe by truck, increasing costs and further disrupting service delivery. (47)

Coastal aquifers already experience substantial saline intrusion that could be exacerbated by sea level rise and reduced rainfall or longer dry periods, leading to increased withdrawals and reduced recharge. Coastal populations in the south are particularly dependent on coastal aquifers due to the lack of surface water. Cyclones may damage water- and sanitation-related infrastructure, while flooding may result in the contamination of water supplies. For example, in February 2013, Cyclone Haruna caused a dike along on the Fiherenana River in Toliara (Atsimo Andrefana region) to rupture, leading to severe flooding that damaged roads, schools, agricultural infrastructure, water supplies and more than 15,000 homes within a 70-mile radius. Uncollected solid waste disturbed and dispersed by heavy rain and high winds leads to air and water pollution and can attract disease-carrying insects and rodents. In addition, rising water temperatures lead to increased pathogen growth (bacteria and viruses) that diminishes water quality. As a result, it is highly likely that the incidence of diarrheal diseases will rise. (46, 47, 59)

Table 9: WASH—Climate stressors and risks

Climate stressors	Climate risks
Rising temperatures **More variable rainfall** **Increased intensity of rains, cyclones and floods** **Sea level rise**	Water sources dry up or become intermittent, reducing good hygiene practices and increasing incidence of water-washed diseases (e.g., roundworm, hookworm, scabies)
	Reduced water quality and increased incidence of diarrheal and other waterborne diseases (e.g., cholera, giardiasis)
	Saline intrusion into coastal aquifers

Source: USAID Sector Environmental Guidelines Water Supply and Sanitation 2015

WETLAND ECOSYSTEMS

Madagascar's 5,000 plus kilometers of coastline sustain valuable ecosystems such as coral reefs, littoral forests, mangroves and wetlands. Mangroves, littoral forests, and wetlands serve as carbon sinks and provide a natural buffer against coastal erosion and storm surge. Mangrove forests in the southwest, in particular, provide products for domestic use (e.g., fencing, housing), as well as shelter and nursery grounds for fish species. They also serve as barriers protecting lives and property from hydrometeorological disasters such as cyclones and flooding. Charcoal production, shrimp fishing and tourism development render mangrove forests more vulnerable to climate variability. Madagascar's unique range of species and ecosystems—including its 20 Ramsar sites—are vulnerable to current and future climate patterns. The country is losing wetlands faster than forests as a result of marsh clearance for rice farming and siltation caused by high rates of soil erosion from deforested lands. Future threats to wetlands include alterations in the hydrological regime, more extreme weather events and changes in the quantity and quality of surface water (Table 10). The projected reductions in rainfall overall, particularly in inland areas of Madagascar, may also affect freshwater wetlands like the Nosivolo River and its tributaries within the Atsinanana region. (46, 17, 4, 2, 5, 33)

The Atsimo Andrefana region is home to a cluster of coral reefs and marine habitats collectively recognized as the Nosy Ve Androka barrier reef Ramsar site. These ecosystems host an estimated 140 species of corals and 240 species of fish, shellfish and marine plants, and five species of marine turtle, providing income to local populations through fishing and tourism. In addition to warming sea surface temperatures that contribute to coral bleaching and degradation of fish habitat, prolonged droughts in southern Madagascar have led more agropastoralists to take up fishing as an alternative livelihood, putting additional pressure on the site. (33)

Table 10: WETLAND ECOSYSTEMS—Climate stressors and risks

Climate stressors	Climate risks
Rising surface temperatures of seas and inland ponds and lakes **More variable rainfall** **Increased intensity of rains, cyclones and floods** **Sea level rise**	Increased sea surface temperatures and ocean acidification, impacting coral reefs and undersea coastal ecosystems
	Higher flood peaks, resulting in wetland expansion and more extensive flooding
	Improved habitat for disease vectors
	Destruction of marine habitats and biodiversity loss
	Saline intrusion and reduced water quality

Source: United Nations Economic Commission for Africa 2011; USAID 2016; USAID 2017; US EPA 2016

PESTICIDE USE

Increased intensity of heavy rainfall could increase the risk of pesticide contamination and reduce pesticide effectiveness. In areas with poor soils exposed to heavy rainfall events, like Madagascar's south and southwest agroecological zone (Atsimo Andrefana and Androy), vulnerability to pesticide contamination is heightened. Therefore, it is important to be aware of climate risks that may have implications for pesticide use in the agriculture sector (Table 11).

Large-scale application of insecticides has been the main method of controlling hazards to agricultural (e.g., locusts) and public health (e.g., vector-borne diseases). In September 2013 the Ministry of Agriculture and Livestock launched a three-year locust campaign which relied on chlorpyrifos 240 ULV, teflubenzuron (an Insect Growth Regulator or IRG), Green Muscle (a fungal biopesticide) and imidacloprid (Gaucho 70 WS). Similarly, the National Plague Control Program in Madagascar has adopted a strategy of insecticide dusting in households to control vectors and to limit the expansion of plague epidemics, with deltamethrin as the preferred insecticide for flea control. (15, 28)

An estimated 16 percent of cultivated land is fertilized (2 percent with mineral fertilizers and 14 percent with organic manure). Few formal studies have been done on household pesticide and chemical fertilizer use in Madagascar, though many speculate that an increase in the use of agricultural inputs combined with the low purchasing power of Madagascar's producers has led to an increase in the number of street vendors selling chemical inputs in recent years. Limited oversight and regulation have allowed the proliferation of dangerous or outdated products on the market. Apart from acute poisoning, there is high risk of pesticide exposure through soil, air and water due to inefficient application and unsafe disposal, and runoff caused by extreme events. (34)

Table 11: PESTICIDE USE—– Climate stressors and risks	
Climate stressors	**Climate risks**
More intense rains **Longer dry periods** **Rising temperatures**	Increased surface runoff
	Increased percolation/groundwater infiltration
	Increased threat from current pests/introduction of new pests
	Reduced effectiveness of pesticides applied topically
	Reduced effectiveness of pesticides that are activated/distributed by water
	Farmers' reduced willingness to use Personal Protective Equipment (PPE) due to increased temperatures

Source: USAID Sector Environmental Guidelines for Small-Scale Activities in Africa 2009

INVASIVE SPECIES

Invasive species, both plants and pests, can reduce crop and livestock production, encroach on native biodiversity and increase production costs. Considerable evidence globally suggests that climate change will further increase the likelihood of invasive species gaining a foothold and/or expanding their range in forests and rangelands (Table 12). Many invasive species are, by nature, highly adaptable and are likely to thrive in a more variable climate compared with native species. Additionally, invasive species can often establish in degraded lands. Converting native vegetation to agricultural land disturbs the soil and disrupts plant communities, giving invasive species an opportunity to proliferate.

Some non-native species introduced to Madagascar by humans have rapidly expanded their range with both negative and positive effects on landscapes, native biodiversity and livelihoods. Examples from southern Madagascar include several varieties of *Opuntia* (prickly pear, known in Madagascar as *raketa*) and *Acacia dealbata*. *Opuntia,* on the one hand, is used to create live fences or enclosures, and its fruit is often eaten during droughts. On the other hand, its encroachment into agricultural land and pasture hinders productivity. (23)

Eichhornia crassipes (water hyacinth) clogs many lakes and waterways, including the Pangalanes Canal—which extends more than 645 kilometers along the east coast from Mahavelona in Atsinanana to Farafangana in Atsimo Atsinanana—and Lake Alaotra (Alaotra-Mangoro region), as well as rice fields throughout Madagascar. (24)

Table 12: INVASIVE SPECIES—Characteristics and link to climate		
Species	**Characteristics**	**Link to climate**
Eichhornia crassipes Water hyacinth	A fast-growing flowering plant; populations can double in 12 days; a weed that obstructs waterways	Adapted to temperature range of 12°C–35°C; seeds can germinate in a few days or remain dormant for 15–20 years to survive variable conditions

Table 12: INVASIVE SPECIES—Characteristics and link to climate		
Species	**Characteristics**	**Link to climate**
Spodoptera frugiperda Fall armyworm	A transboundary, fast-multiplying pest that, in its larval stage, feeds on more than 80 plant species, including maize, rice and vegetable crops	Uncertain; however, more than 50 years of data on the closely related African armyworm indicate that populations explode after droughts
Opuntia stricta/ Optunia ficus-indica Cactus	A fast-growing cactus that encroaches on agricultural land and pasture	Tolerant of high temperatures up to 65°C

Sources: Nobel et al. 2003; Larsson 2004; Kull and Tassin 2014; USAID Sector Environmental Guidelines for Small-Scale Activities in Africa 2009

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