MADAGASCAR CLIMATE CHANGE BRIEFING

Temperature

The mean temperature is predicted to increase in Madagascar. The largest increase will be in the south, while the coastal areas and north will experience less warming

Rainfall

In the tropical regions rainfall is predicted to increase and be more intense, and there will be more frequent storms; in the East and South rainfall is expected to decrease

Extreme Events

Cyclones will occur less often but be more intense, there will be more floods in the North and more droughts in the South and on the East Coast

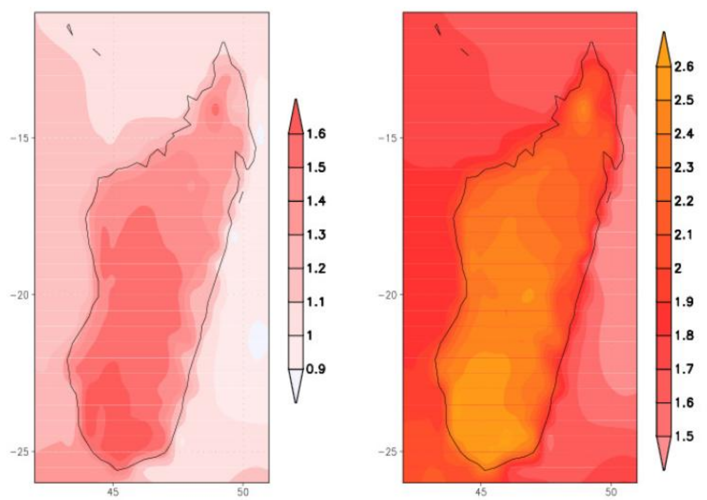
Overview

Madagascar's climate and terrain is highly varied- the South West is semi-arid while the East coast is tropical and humid. The average temperature varies between 23-27°C in the coastal areas and 16-19°C in the upland plateaux, the annual variation being around 3°C in the North and 7.5°C in the South West region. The rainfall varies from 3700 mm in the East (hot and humid) to 400 mm in the West and South West (hot and semi arid). The Highlands, the Western region and the South have two very distinct seasons - the rainy season from November to April and the dry season from May to October - while in the Eastern region it rains practically all year round and a dry season is hardly perceptible. Rainfall on the East coast is driven by the Easterly trade winds meeting the uplands, while rain in the central uplands and West is mainly due to convective activity and thunderstorms linked to the Inter-Tropical Convergence. The North and North East are affected by tropical cyclones (forming over warm waters in the South Indian Ocean) and floods, resulting in heavy rain and strong winds (the cyclone season is November to May).

Climate Change

Observational evidence from all continents and most oceans shows that many natural systems are being affected by climate change, particularly by temperature increases. The minimum temperature in Madagascar has been consistently increasing. In the South, temperatures have been steadily increasing since the 1950s (0.2°C warmer in 2000) and drought has become more frequent; in the North temperatures have started rising, but they were 0.1°C cooler in 2000 than temperatures at the beginning of the century. There has been a lower volume of rainfall but it is unclear if it is influenced by global warming, or by micro-climate changes arising from the loss of 80%-90% of forest cover in Madagascar over the last century.

The temperature changes in Madagascar were predicted using a regional climate model based on 13 global climate models (GCM) for the period 2046-2065. The model shows warming across the island and areas of both increasing and decreasing precipitation. Southern Madagascar is projected to have the greatest warming (2.6°C by 2055), while less warming is predicted in the coastal areas and the North (1.1°C). Figure 1 displays the maximum and minimum temperature changes predicted for Madagascar.



Changes in precipitation were predicted based on 6 downscaled GCMs assessing the medium value of change in precipitation for 6 emissions scenarios (the scenarios describe different economic growth and energy usage patterns) for 23 weather stations. The models project median rainfall will increase throughout the summer months (November to April). During the winter (May – October) the tropical regions are predicted to be wetter, and have more frequent storms, while the Southern half of the East coast is projected to be drier by 2050. This is significant as the South is the driest part of the country and the forests in the East are highly fragmented and vulnerable to reduced rainfall. Rainfall intensity is predicted to increase during the rainy season but decrease in the dry season. Models predicted that the likelihood of cyclones forming will decrease during the early part of the main season, but that their intensity, associated winds and destructive power are suspected to increase.

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MAIN IMPACTS OF CLIMATE CHANGE

Madagascar has severe problems with soil erosion and deforestation, which reduces soil fertility and productivity, increasing the vulnerability of agriculture and fishing-based livelihoods (livestock and fish forms 95% of national dietary requirements and 75% of exchange earnings (NAPA, 2007)). Climate change will exacerbate soil erosion and deforestation and ultimately lead to a reduction in food security, income, water quality and supply. Livelihood options will be reduced, leading to livelihood conversion or migration, which will be compounded by population pressures (USAID, 2008). Migration will typically be to urban areas, where the migrants are often more rather than less vulnerable to certain climate-related impacts. The increased populations in urban areas will increase competition over natural resources and the likelihood of conflict. In addition, resource scarcity can lead to increased capture of resources by elites exacerbating existing inequalities. The table below summarises the main impacts of climate change.

	Increased Temperature	Floods	Droughts	Cyclones
Water	• Less water for agriculture (insufficient water to improve rice farming techniques in the South) • Disappearance of some water points • Swamps and rivers drain in dry season	• Contamination of drinking water • Ingress of groundwater into pipes	• Water shortages and rivers dry up in the South • No water for irrigation or livestock • Deteriorating water quality[1] • Antananarivo plains will not have sufficient water to meet demand in 2050-2100	• Degrade water resources • Flooding
Livelihoods	• Cropping seasons no longer routine[1,3] • Reduction in soil fertility • Decrease in rice paddy productivity[4] and less income	• Soil erosion[5] • Decrease in soil cover and fertility in highlands (soil moved downstream) • No access to schools • Crop damage/loss, leading to food scarcity and hunger	• Famine • Locust swarms • Crop failure e.g. lower rice production (also caused by decreased rainfall) • Disruption of agricultural calendar[2] • Decrease in plants available for handicrafts • Increased vulnerability to fires[6]	• Increased soil erosion[4] • Flooding of crops and damage to plantations • Injured livestock • Crop failure • Sedimentation • Decreased revenue from crops if production is reduced • Disrupted education and jobs
Health	• Food shortages[7] • Malaria risk extends over whole country[8] • Other disease risk zones extend	• Cholera epidemics • Loss of life • Increase in water borne diseases	• Loss of life • Water borne diseases increasing • Less water for hygiene and cleaning	• Increased risk of epidemics • Loss of life • Damage to shelter
Biodiversity	• Loss of habitat[9] • Loss of endemic species[10] • Increase in vulnerability • Reduction of forest areas of all types	• Damage to biodiversity and habitat	• Forest loss aggravated	• Biodiversity destroyed

[1] Compounded by erratic rainfall in the North
[2] The structure of the seasons has been changed by climate change and farmers can no longer rely on the wisdom of their ancestors (cultural calendars)
[3] Most farms are inefficient and need to acquire new land each year to grow the same quantity of food, aggravating land pressures
[4] Productivity per rice paddy has decreased from 0.5 – 1.2 tonnes per capita in 1975 to 0.6 tonnes per capita in 1999 (NAPA, 2007)
[5] Splash and wind erosion of soils leads to the loss of around 7-67 tonnes per ha per year in woodland and 14-114 in the burned forest (resulting from slash and burn), while natural forest only lose 1.5-3 tonnes per ha per year (NAPA, 2007)
[6] Slash and burn and deforestation is succeeded by secondary grassland which is more prone to fires
[7] There has been an observable increase in food insecurity and malnutrition in recent years resulting from the warming in the country (USAID, 2008)
[8] Malaria is endemic in the coastal areas but does not affect the uplands; an increase in temperatures will extend its range
[9] Deforestation has claimed 90% of the island's natural forest, the remainder is highly fragmented reducing wildlife corridors and making it difficult for species to migrate to new areas. If range migrations (movement of species) is possible, Madagascar will lose 11-27% of its habitat; if they are not, it will lose 15-50% (Hannah *et al.,* 2008)
[10] Species that specialise in specific habitats are expected to do particularly badly due to reductions in their habitats

Water Resources

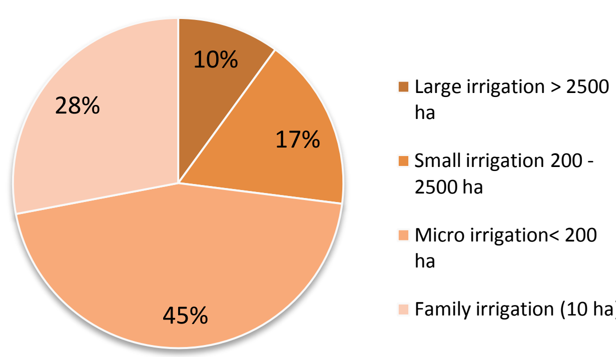
The following overviews the water resources in Madagascar based on the AQUASTAT database (2010) and Madagascar country profile (2005) (developed by the Food and Agricultural Organisation of the United Nations (FAO) Land and Water division). The renewable water resources (those that after exploitation will return to natural levels) in Madagascar are estimated at 337 $km^3 year^{-1}$ equivalent to 17,600 m^3 per person; however, despite the extensive water resources there is unequal distribution and there are shortages and droughts in the East and South of Madagascar. The main rivers drain 57% of the country and the 13 largest abstractions have a total capacity of 493 million m^3(108 million m^3 for irrigation and 385 million m^3 for hydroelectric). The vast majority of water is used for irrigation (95.6%), with a much smaller proportion for domestic consumption (2.8%) and industry (1.6%). The table opposite summarises the water resources in the country.

AQUASTAT (2010) WATER Resources	Date	Value	Unit
Water Resources			
Long-term average annual precipitation		888.2	km^3/year
Long-term average annual renewable water resources			
Internal		337	km^3/year
Surface Water		332	
Total Dam Capacity	2002	0.493	km^3
Ground Water		55	km^3/year
External		0	km^3/year
Total		337	km^3/year
Total renewable water resources per capita	2008	17634	m^3/year
Water Withdrawn			
Agricultural	2000	14.31	km^3
Municipal	2000	0.42	km^3
Industrial	2000	0.23	km^3
Total water withdrawal per capita	2002	9.24	m^3
By source			
Surface water withdrawal	2000	14.95	km^3
Groundwater withdrawal	2001	0.025	km^3
Pressure on water resources			
Total freshwater withdrawal as percentage of actual renewable water resources	2002	4.439	%
Agricultural water withdrawal as percentage of actual renewable water resources	2002	4.246	%

Irrigation

Irrigation generally uses surface water due to the higher cost of abstracting groundwater; the majority is gravity fed (0.6% is pumped) and used for micro irrigation (<200 ha) and family plots (<10 ha) (Figure 2). Family plots are characterised by rudimentary buildings, simple earthworks and simple bleeds from canals; they are not protected from flooding and need repairing at the beginning of each season (a lot are abandoned due to silting and flooding). Irrigation is mainly used for growing rice (98% of irrigated land), the staple crop of the population (114-145 kg /year per capita 2005). The government is currently trying to rehabilitate existing irrigation structures, but the capacity of the state to maintain large structures is still limited. Environmental damage (deforestation, bush fires) are also major constraints to the sustainability of irrigated areas. In recent years, rehabilitation of infrastructure has been expanded to include elements related to aquaculture, livestock, horticulture and improving hygiene in rural areas.

Figure 2: Distirbution of Irrigated Land (Total 1.1M ha)



Drinking water and sanitation

In Madagascar the utility JIRAMA provides most of the water supply and electricity. In 2005, the National Programme for Safe Water Supply and Sanitation was adopted, with the objective of meeting the Millennium Development Goals. This is now linked with the national budget for medium term water supply and sanitation improvement and increasing sector capacity. A WASH program was put in place in 2002 and a Sanitation Policy was developed in 2006. It is estimated that only about 20% of the population has access to piped sewerage or septic tanks – the remainder rely on on-site sanitation. The reform program is underway and over 50% of the population has access to safe water in the JIRAMA-served areas and 41% of the population has access nationwide (USAID, 2006).The table below summarises the improvements to water and sanitation in urban and rural Madagascar (Joint Monitoring Programme, WHO & UNICEF 2010).

Year	Urban Population (millions)	Rural Population (millions)	Improved Water Supply (%)			Improved Sanitation (%)		
			Urban population	Rural population	Total	Urban population	Rural population	Total
1990	2.6	8.6	78	16	31	14	6	8
1995	3.3	9.7	76	20	34	14	7	9
2000	4.1	11.1	73	24	37	15	8	10
2005	5.0	12.5	71	27	40	15	9	11
2008	5.6	13.4	71	29	41	15	10	11

Vulnerability Assessment

A range of global and regional studies have assessed Madagascar's vulnerability to climate change using global datasets[(1,2,3,4,5)] producing indices for each country to enable simple comparison. The table below presents the scores (measure of vulnerability) for Madagascar for 9 global indices. The indices which assess the impact of climate change on water resources indicate that Madagascar has a low vulnerability. This is due to Madagascar's relative abundance of water resources; however, this does not account for the regional variations and arid climate in the south. Madagascar has a reasonably low social vulnerability indicating that the government and economy are reasonably able to adapt to climate change. The CVI is an exception indicating that Madagascar has a medium vulnerability to climate change, probably because the CVI also assess geographic factors (such as seas level rise) that relate specific to the location.

Index	Score	Vulnerability	How it's calculated
Water Resources			
Water Scarcity Index (2004)[1]	0.0114	Very low (Abundant)	Water extracted from rivers divided by the low flow (flow exceeded 90% of the time). E.g. If ≥ 1 then consumption exceeds supply
Ground Water Dependence (2004)[1]	0.0013	Very low (Abundant)	Ground water withdrawn as a fraction of total water withdrawn in region
Total freshwater withdrawal as percentage of total renewable freshwater resources (2009)[2]	4.4%	Low	Total freshwater withdrawn in a given year, expressed in percentage of the total actual renewable water resources. It is an indication of the pressure on the renewable freshwater resources (data from 1998-2002)
Annual Renewable Water Supply (Projections for 2025)[2]	17,000 m^3pp	Abundant	Runoff (data from 1950-2000) divided by Population (2025) (prediction from UN population division)
Social Vulnerability (1st = lowest vulnerability)			
Human Vulnerability A (2007)[3]	0.691	4th /49 (Africa)	Social vulnerability to climate change (the Index consists of 5 weighted factors, each of which is scored). HVA includes: economic well being and stability (20%), demographic structure (20%), global interconnectivity (10%) and dependence on natural resources (10%); HVB also includes institutional stability and infrastructure (i.e. corruption (40%))
Human Vulnerability B (includes corruption) (2007)[3]	0.697	1st / 49 (Africa)	
Sensitivity and Adaptability (2007)[4]	0.543	145th / 182 (global)	Human Development Index (used as generic indicator for adaptive capacity)
Sensitivity Index (2004)[1]	2.33	Low	Combination of Water Scarcity Index, GW Dependence and Sensitivity and Adaptability Index
Climate Vulnerability Index (2007)[5]	-	Medium High	The index links water resources modelling with human vulnerability assessments to contribute to a meaningful assessment for generic use

[1] Petra Döll (2009) Vulnerability to the impact of climate change on renewable groundwater resources: a global-scale assessment. *Environmental Res. Letters* 4 (3)
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[4] Human Development Index (2009). Available at: hdr.undp.org/en/statistics
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