MADAGASCAR

AFRICAN DEVELOPMENT BANK

NATIONAL CLIMATE CHANGE PROFILE

PRODUCED IN COLLABORATION WITH:
African Climate & Development Initiative, University of Cape Town;
Climate Systems Analysis Group, University of Cape Town;
Energy Research Centre, University of Cape Town; Cirrus Group.

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ACKNOWLEDGEMENT

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1. BACKGROUND

1.1 Geographic and socio-economic context

The Republic of Madagascar (henceforth 'Madagascar' and shown below in Figure 1-1) is an island nation off the southeast coast of Africa. The country has a population of ~25,600,000 people, of which ~35% are urban and ~77% of the urban population are living in slums. Madagascar is one of the poorest and most ruralised of African countries, having the seventh highest proportion of population working in agriculture (~74%) the highest proportion of people living below the poverty line of USD 1.90/day (~77%) and the 6th highest percentage of the population undernourished (~33%). As Madagascar is situated in the tropics, the country is exposed to tropical cyclones and heavy rainfall events that result in impacts such as flooding and a cumulative total of ~160,000 people were affected by floods in the period 1996-2016. Madagascar is also prone to droughts and as a result a cumulative total of ~10,200,000 people were affected by drought in the same period. Madagascar has a GINI coefficient of 42.7 and a human development index of 0.51. The ND-GAIN index summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience. Madagascar's ND-GAIN index is 36.0 and is composed of a low readiness score and a high vulnerability score and is one of the lower scores in Africa. This indicates that the country has both a great need for investment and innovations to improve readiness and a great urgency for action. Key socio-economic and demographic indicators of Madagascar are further presented and summarised in Table 1-1, below.

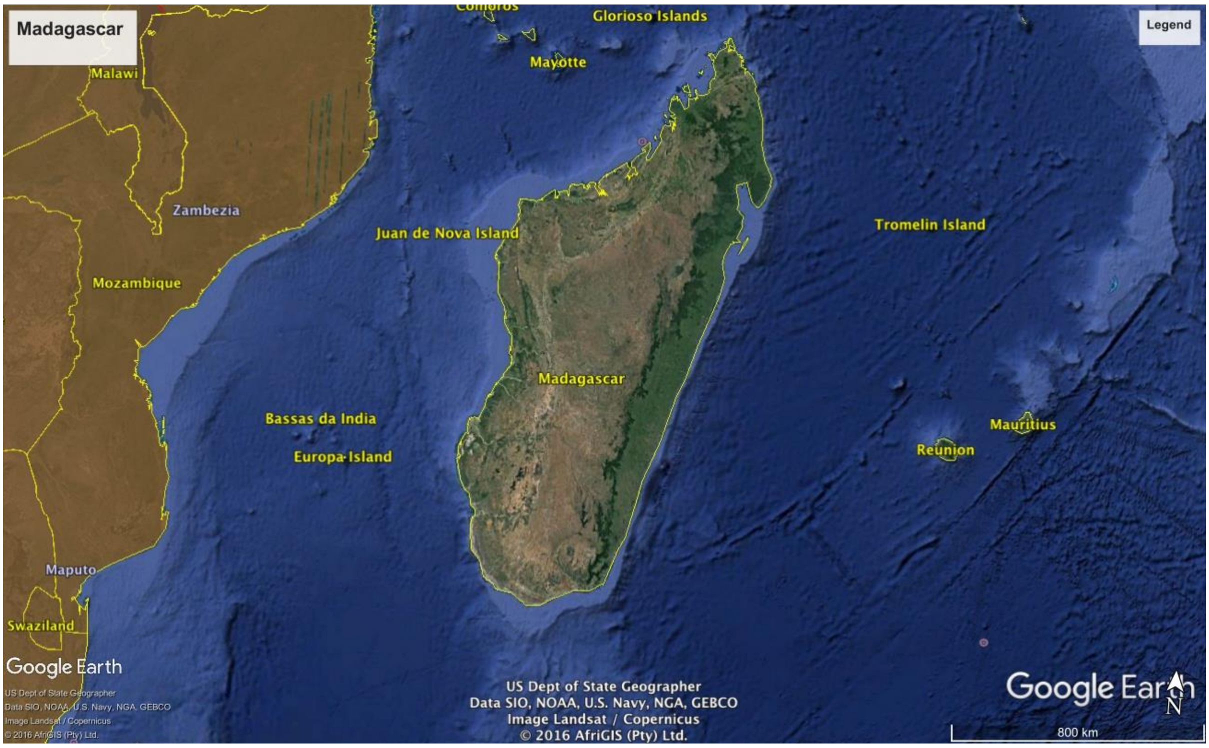

Figure 1-1: Map of Madagascar

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Table 1-1: Socio-Economic Context of Madagascar (reference year ranges from 2014 - 2017)

VARIABLE		SCORE/TOTAL	UNIT	RANK (OUT OF 54)
Geography, Socio-Economy and Demographics				
Population[1]		25,612,972	people	15
Population growth rate[1]		2.8	% population. yr-1	17
Population density[1]		44	People/km2	33
Land area[1]		582,113	km2	21
% Urban population[1]		34.8	% population	37
% Urbanisation rate[2]		4.5	% population. yr-1	11
Economy: total GDP[2]		10.0	USD billions. yr-1	28
Economy: GDP by PPP[2]		37	billion international dollars. yr-1	21
Economy: GDP/capita[2]		401	USD per capita/yr.	45
Population below the poverty line[3]		77.8	% below USD 1.90 per day	1
GINI co-efficient[3]		42.7		29
HDI[4]		0.51		26
Access to electricity[5]		16.8	% population	44
Population[1]		25,612,972	people	15
Summary indicators of climate change vulnerability				
Workforce in agriculture[6]		74.5	% workforce	7
Population undernourished[6]		33.0	% population	6
Number of people affected by drought[7]		2,725,290	people	18
Number of people affected by flood events[7]		159,987	people	33
Population living within 100 km of coast[8]		10,210,947	people	8
Population living in informal settlements[5]		77.2	% urban population	9
Incidence of malaria[6]		104	cases per 1000 population at risk	31
ND-Gain Vulnerability Index[11]	Total	36.0		40
	Readiness	0.31		38
	Vulnerability	0.59		15

2. CLIMATE AND WEATHER

Madagascar's climate is tropical and characterized by two seasons: the hot, rainy season from November to April and a cooler, dryer season from May to October. The topography along with the predominant wind direction results in diverse climates over the island.

Madagascar can be divided into four climatic regions based on annual total rainfall as well as variations in the seasonal cycle of rainfall. These regions are illustrated in Figures 2-1 and 2-2, below, and summary descriptions can be found in Table 2-1 below.

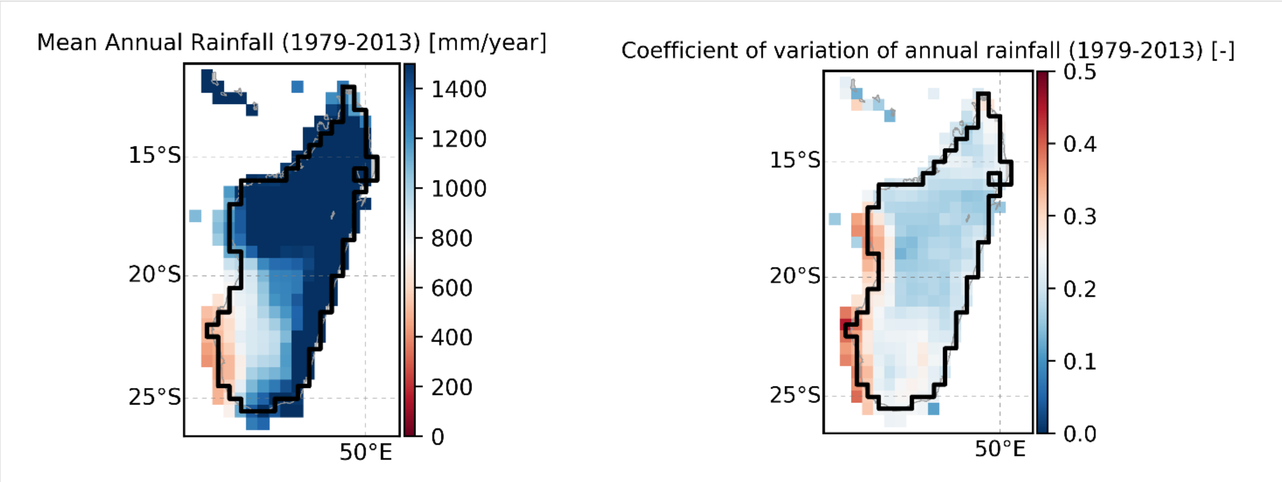
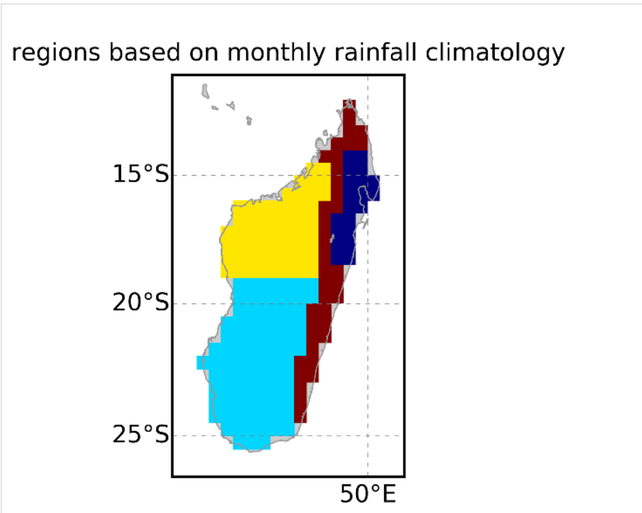


Figure 2-1: Main characteristics (magnitude and variability) of rainfall in Madagascar and its region



Coloured regions on the map (above) correspond to the colours used in rainfall and temperature graphs (below)

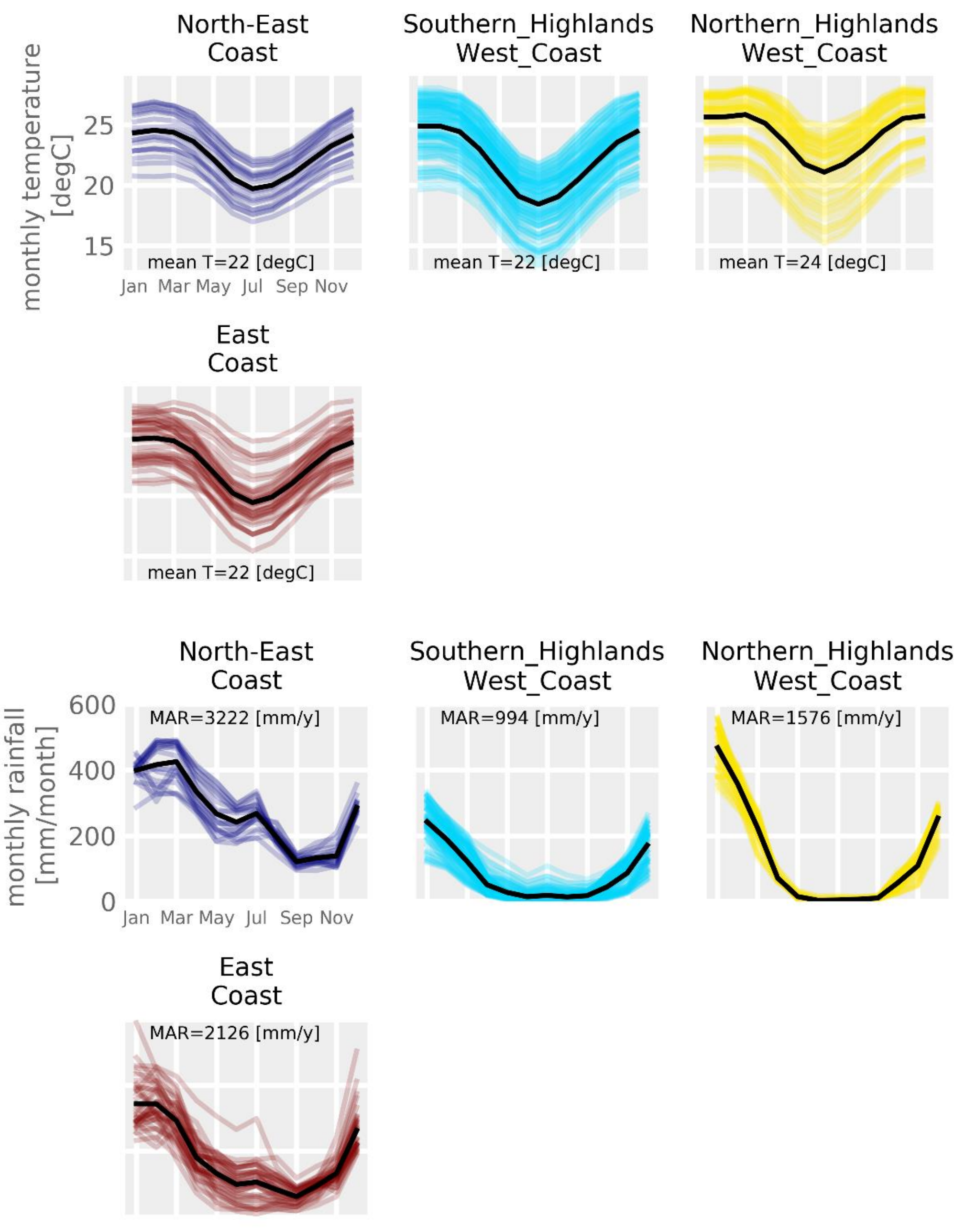


Figure 2-2: Rainfall regions of Madagascar based on similarity of standardised rainfall climatology, and their rainfall and temperature climatologies

Table 2-1: Main rainfall regions of Madagascar

NORTH-EAST COAST	The daily mean temperature is 22° C and the mean annual total rainfall reaches 3220 mm/year. The region has low interannual variability, but rainfall does vary for locations within this region. Rainfall occurs all year round but peaks in January to February with average monthly totals just over 400 mm/month and is at a minimum during September – November with around 150 mm/month. Temperatures display a small but clear seasonal cycle of roughly 5° C with warmest temperatures from November – April and coolest temperature during winter (June – August). The local temperatures within the region are strongly influenced by topography
EAST COAST	The daily mean temperature is 22° C and the mean annual rainfall reaches 2130 mm/year. Rainfall over the region shows relatively low interannual variability but some spatial differences in magnitude. Rainfall occurs all year round but peaks in January to February with average monthly totals just over 350 mm/month and is at a minimum from June – November with around 150 mm/month. Temperatures display a small but clear seasonal cycle of roughly 5° C with warmest temperatures from November – April and coolest temperature during winter (June – August). The local temperatures within the region are strongly influenced by topography
NORTHERN HIGHLANDS / WEST COAST	The daily mean temperature is 24° C and the mean annual rainfall reaches 1580 mm/year. Rainfall over the region shows relatively low interannual variability, with the exception of along the west coast which has lower rainfall values and higher interannual variability. A clear seasonal cycle is evident with rainfall occurring from November to March, peaking in January (500 mm/month) and a dry season from May to September. Temperatures displays a small but clear seasonal cycle of roughly 4° C with warmest temperatures from November – April and coolest temperature during winter (June – August). Little spatial differences are found in temperature.
SOUTHERN HIGHLANDS / WEST COAST	The daily mean temperature is 22° C and the mean annual rainfall reaches 990 mm/year. rainfall over the region decreases from east to west with the west coast being dry with high interannual variability. A clear seasonal cycle is evident with rainfall occurring from November to March, peaking in January (250 mm/month) with little rainfall between May to September. Temperatures display a small but clear seasonal cycle of roughly 5° C with warmest temperatures from November – April and coolest temperature during winter (June – August). The local temperatures within the region are strongly influenced by topography

2.1 Observed historical climate variations and climate change trends

The majority of Madagascar experiences **relatively low to moderate rainfall variability** on an inter-annual basis, with the exception of the western coast which has high variability. On **decadal time scales** Madagascar also experiences **significant variability** with some periods being relatively drier or wetter than others. This variability can be seen in the supporting evidence plots provided in the supplementary Appendix **(Figures A-1 to A-4).**

Long term trends across all regions show strong **increasing temperatures** over the period 1979 – 2015. Long term trend in total annual rainfall and the frequency of rain days and extreme rain days are generally negative but are only strong and statistically **significant** for the East Coast region. The exception is the dry Southern Highlands / West Coast region which shows an upward trend in total annual rainfall and extreme rainfall frequency. Long term trends and variability in the Madagascar region are summarized in **Table 2-2** below and illustrated further in the supplementary Appendix **(Figures A-1 to A-4).**

Table 2-2: Summary of trends in rainfall and temperature attributes in Madagascar (1979 - 2015)

REGION	MEAN T [DEG C/DECADE]	TOTAL RAINFALL [MM/DECADE]	EXTREME RAINY DAYS [DAYS/DECADE]	RAINY DAYS [DAYS/DECADE]
North-East Coast	+0.26	downward	downward	-4.2
East Coast	+0.22	-120.8	-1.7	-4.4
Northern Highlands / West Coast	+0.23	downward	downward	downward
Southern Highlands / West Coast	+0.20	upward	upward	downward

2.2 Projected (future) climate change trends, including temperature, precipitation and seasonality

Projected changes in main attributes of climate for the Madagascar region are summarized in Table 2-3, below, and described in Sections 2.2.1 and 2.2.1. Additional analysis and visualisation of projections be found in Figures A-5 to A-8 in the supplementary Appendix.

2.2.1 Projected changes in precipitation from present to 2100

Rainfall projections across the Madagascar region show a pattern of **potential decreased rainfall** emerging from about the 2060s. The drying pattern appears to be consistent across half the CMIP5 models with the rest projecting the rainfall to remain within the normal historical range. Relative magnitudes of potential decreased rainfall equate to around 24% from the baseline normal for the East Coast and Northern Highlands West Coast regions, 30% for the Southern Highlands West Coast and 40% for the North-East Coast. **The decrease in rainfall** seems to be strongly associated with **decrease in the rainfall events**, however **high intensity rainfall events** (days > 95^{th} percentile) **are projected to increase**. It must be noted that these results are derived from GCM projections which may not accurately represent changes in extreme rainfall dynamics. They are, however, consistent with the increased convective rainfall intensity (e.g. thunderstorm-related rainfall) expected in a warmer climate.

2.2.2 Projected changes in temperature from present to 2100

Air temperature is projected to be between 0.5 and 1°C warmer in all the Madagascar regions by the 2050s. By 2100 the range of projected temperatures is greater with the temperatures projected to increases by between 1.5°C to 2.5°C.

Table 2-3: Summary of projected climate changes across regions of Madagascar for key climate variables by 2050

REGION	AVERAGE TEMPERATURE [°C]	TOTAL ANNUAL RAINFALL [MM/YEAR]	EXTREME RAINY DAYS [DAYS/YEAR]	RAINY DAYS [DAYS/YEAR]
North-East Coast	**Increasing,** +0.5°C to +1°C by 2050s but changes evident in next decades	**Normal to decreasing,** ranging from a small increase to a decrease of up to 30% by 2100.Change could become evident after 2060s.	**Normal to increasing** ranging from no change to an increase by 2050, becoming less consistent by 2100.	**Normal to decreasing,** ranging from no change to up to 15% decrease by 2100. Change could become evident after 2040s.
East Coast		**Normal to decreasing,** ranging from no change to a decrease of up to 25% by 2100.Change could become evident after 2060s.	**Normal**, no change by 2050, becoming less consistent by 2100	
Northern Highlands / West Coast		No consistent signal in the models.	**Normal to increasing,** ranging from no change to up to 50% increase by 2100.Change could become evident after 2030s.	
Southern Highlands / West Coast		**Normal to decreasing,** ranging from a small increase to a decrease of up to 25% by 2100.Change could become evident after 2060s		

2.3 Expected climate vulnerabilities

NOTE: Determining vulnerability of different sectors to climate variations or change is extremely challenging as there are many factors involved in vulnerability and different approaches can yield different results. The vulnerabilities presented here are based on UNFCCC reporting documents such as national communications or national adaptation plans of action where available, and other literature where UNFCCC documents are not available.

On the hot and humid island of Madagascar the large proportion of the people living below the poverty line means that the majority of the population have very limited capacity to adapt to increase in extreme temperatures and rainfall events, as well as to the slower knock-on effects that climate change may have on the economy through impacts on agricultural production, fisheries and tourism. Given Madagascar's extensive coastline, where just under half of the country's population is located, a large portion of the human settlements and associated developments are vulnerable to sea-level rise and associated stresses. The large proportion of the urban population living in slums further exacerbates this vulnerability, as well as vulnerability to extreme weather events. The island experiences regular tropical storms and the occasional tropical cyclone, whose future trajectory of change is as of yet unknown yet whose increasing intensity and frequency could have devastating consequences.

Table 2-4: Broad scale sectoral vulnerabilities and potential climate change impacts in Madagascar

SECTOR	POTENTIAL IMPACTS OF CLIMATE CHANGE
Agriculture	Crop loss and reduced yields owing to increased temperatures and changing rainfall patterns Increased need for irrigation, especially for rice Increased prevalence of pests and diseases, such as cassava mosaic disease Increased sedimentation and soil erosion during extreme events Increased damage to agriculture owing to increased intensity of cyclones.
Fisheries	Loss of habitat and breeding grounds, including mangroves and coral reefs Reduced productivity due to increased sedimentation of rivers and coral reefs Changed fish migratory patterns Loss of life and property during extreme events
Water resources	Reduced availability of water in some areas owing to decreasing rainfall, especially in the south Reduced swamp and wetland areas during the dry season Water infrastructure damage owing to increased cyclone intensity Decreased water quality, in the north owing to flooding and in the south owing to increased drought frequency
Built infrastructure and human settlements	Damage to and destruction of infrastructure owing to increased cyclone intensity and sea level rise Increased coastal erosion due to sea level rise Destruction of social infrastructure (e.g., school, health centres) owing to increased cyclone intensity
Human health	Increased prevalence of vector-borne diseases, especially malaria at elevations greater than 1500 m Increased risk of water-borne disease, especially following cyclone induced flooding Increased mortality rate caused by fish consumption that have accumulated dinoflagellate algae, which flourish in warm water Increased potential for malnutrition and stunting, especially from drought in the south

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3. CLIMATE CHANGE MITIGATION, GREENHOUSE GAS EMISSIONS AND ENERGY USE

The major carriers of Madagascar's energy mix, and the energy demands of major economic sectors, are summarised in Section 3.1, below. The major sources of GHG emissions, described by fuel source and sector, are described in Section 3.2. The latter section also includes summarised statistics on Madagascar's agriculture sector, historical land use change and vegetation cover.

3.1 National energy production and consumption

National energy production in Madagascar is almost entirely generated from the use of biofuels for domestic energy needs (~98%, ~3 MTOE), in addition to which hydro-electricity contributes the remaining ~2% of total national energy production. Biofuels also account for the majority (~52%) of national energy consumption, followed by imported oil (~27%) and coal (~13%). The major consumers of national energy include the residential (~35%), transport (~11%) and industrial (~11%) sectors. A large proportion of Madagascar's energy consumption is categorised as non-specified (~42%), which may include sectors such as tourism, maritime and aviation transport, and various small-scale agricultural and domestic applications. The total annual GHG emissions of the abovementioned sectors and fuel carriers are described further in Section 3.2.

Unless stated otherwise, all energy figures are derived from UN Stats (2014) [10]; World Energy Council (2016); [11]; and the World Resources Institute (2013) [12]. Agriculture & forestry-related emissions are also reported from Food and Agriculture Organisation (2014-2017) [14] and Global Forest Watch. (2015-2017) [15].

The tables and figures below describe Madagascar's energy sector, including total national energy production, primary energy supply, and national energy consumption by fuel carrier and sector.

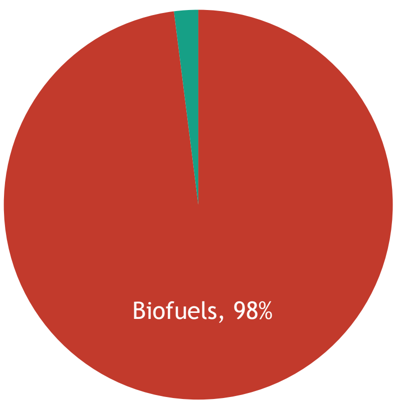

Figure 3-1: Distribution of Madagascar's national energy production between major energy carriers (2014-2016)

Table 3-1: National energy and electricity production in Madagascar (2014-2016)

NATIONAL ENERGY PRODUCTION		
Source	**Total (MTOE) [1]**	**% of total energy production**
Hydro[10]	0.1	4.7
Biofuels[11]	3.0	95.4
Total national energy production	3.1	100.0

1 Energy is expressed in 'Megatonnes of Oil Equivalent', where 1 Tonne Oil Equivalent = 11,630 KiloWatt hours (KWh)

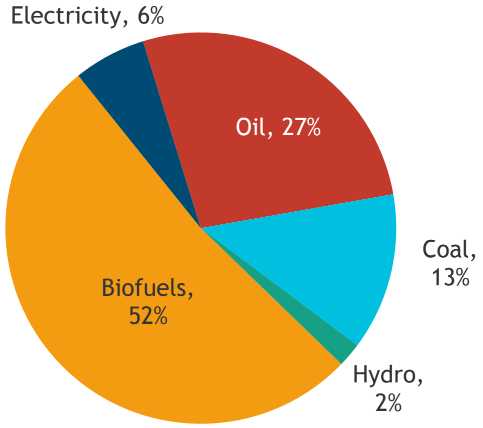

Figure 3-2: Distribution of Madagascar's national energy consumption by major energy carriers

Table 3-2: Madagascar's national energy consumption by energy source

CONSUMPTION BY ENERGY SOURCE	
Source	**Total (MTOE)**
Coal[11]	0.24
Oil[11]	0.51
Hydro[12]	0.04
Biofuels[11]	2.06
Electricity[11]	0.11
Total national energy consumption by source	2.96

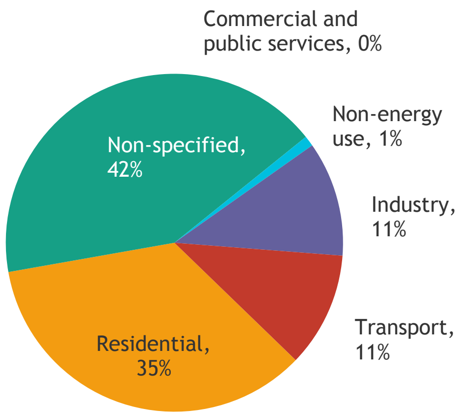

Figure 3-3: Distribution of Madagascar's national energy consumption by sector (2014-2016)

Table 3-3: Madagascar's national energy consumption by sector (2014-2016)

CONSUMPTION BY SECTOR[11]	
Source	**Total (MTOE)**
Industry	0.3
Transport	0.3
Residential	1.0
Commercial and public services	0.0
Non-specified	1.2
Non-energy use	0.0
Total national energy consumption by sector	2.9

Table 3-4: Madagascar's national total primary energy supply (estimated for 2014-2016)

TOTAL PRIMARY ENERGY SUPPLY[11]	
Source	**Total (MTOE)**
Coal	0.2
Oil	0.7
Biofuels	3.0
Electricity	0.1
Total primary energy supply	4.0

3.2 National greenhouse gas emissions by source and sector

The sectors that account for the largest proportion of national GHG emissions are land use change and forestry (~24 MT CO2e) and agriculture (~22 MT CO2e). Data from CAIT (2013) shows that “other fuel combustion” is the only source of GHG emissions from the energy sector, however, this is probably due to emissions in the energy sector not being recorded well, meaning that all emissions in the energy sector are grouped together under this category, i.e. the other sectors within the energy sector do emit GHGs.

Section 3.2.1, below, describes GHG emissions from all sectors of national energy consumption, which therefore includes emissions from fuel combustion as well as industrial and manufacturing processes, and household-level energy consumption. The figures are compiled by the World Resources Institute’s Climate Access Indicator Tools (CAIT). Section 3.2.2 provides additional details on Madagascar’s Land Use and Land Use Change sector, including detailed summaries of emissions from the agriculture sector and historical land use changes.

3.2.1 GHG emissions from primary energy consumption, by source and sector

Table 3-5: Madagascar’s national greenhouse gas emissions from primary energy consumption (estimated for 2014-2016)

NATIONAL GHG EMISSIONS FROM FUEL COMBUSTION BY FUEL SOURCE AND SECTOR[13]		
Source / Sector		**Total emissions (MT CO_2e)**
Energy	Other fuel combustion	5.7
	Fugitive emissions	0.1
	Energy sub-total	5.7
Industrial processes		0.1
Agriculture		21.6
Waste		0.6
Land use change and forestry (LUCF)		24.2
Total emissions (including LUCF)		47.6

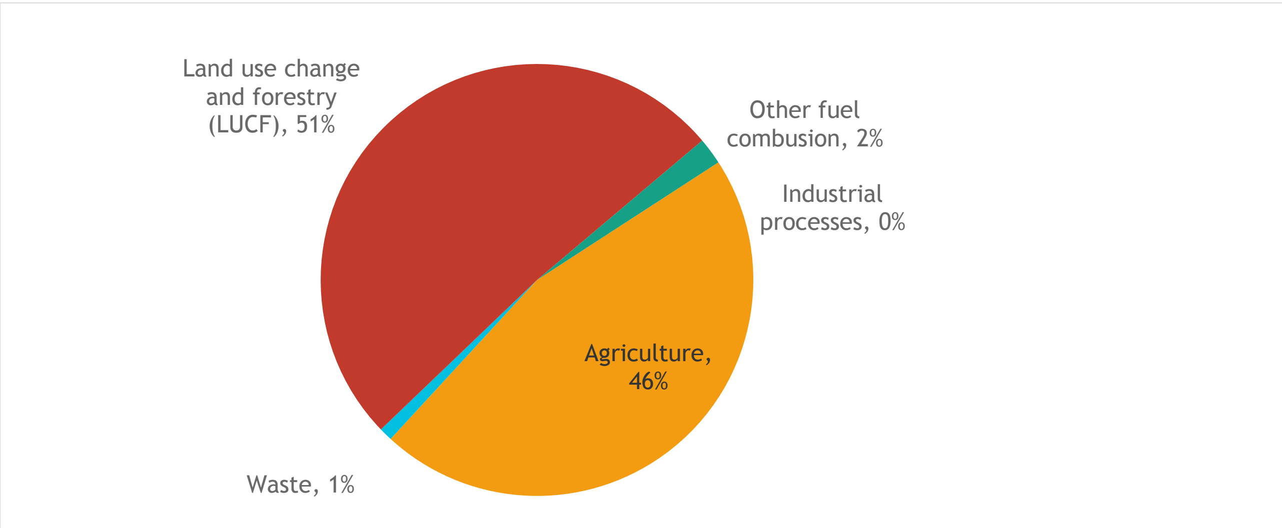

Figure 3-4: Distribution of Madagascar’s GHG emissions by major sectors

3.2.2 GHG emissions from agricultural practices

Table 3-7, below, summarises GHG emissions from Madagascar's agriculture sector (derived from Food and Agriculture Organisation statistics). Although there are multiple agricultural practices that contribute to GHG emissions, in the case of Madagascar, the sectors of livestock production (particularly enteric fermentation and manure left on pastures) and rice cultivation are significant sources of agricultural GHG emissions, contributing ~12.6 MT CO2e and ~5.6 MT CO2e, respectively. In terms of land use change, emissions from land use change in forest areas is the largest single contributor to GHG emissions (~14 MT CO2e).

Table 3-6: National annual greenhouse gas emissions from agricultural practices, forestry and other land use in Madagascar (estimated for 2014-2017)

VARIABLE		ANNUAL EMISSIONS (MT CO_2E)
Annual GHG emission from agricultural practices [14]	Burning - crop residues	0.1
	Burning - savanna	1.7
	Crop residues	0.4
	Cultivation of organic soils	0.7
	Enteric fermentation	7.4
	Manure management	0.5
	Manure applied to soils	0.3
	Manure left on pasture	5.2
	Rice cultivation	5.6
	Synthetic fertilizers	0.1
	Sub-total (Agricultural practices)	22.0
Annual GHG emission from land use change [14]	Grassland	1.4
	Cropland	1.3
	Forest land	14.7
	Burning biomass	4.3
	Sub-total (Land use change)	21.7
Total emissions		43.6

Table 3-8, below, summarises the recent historical changes in land use in Madagascar through analysis of land use change. Statistics derived from the Global Forest Watch database were used to summarise the total area of wooded vegetation in various categories of canopy cover density (where 10-30% canopy cover can be considered as savanna, 30-50% cover can be considered woodland and 50-100% cover can be considered dense forest), as well as the historical rates of change in each vegetation category. Global Forest Watch reports the total aboveground carbon stock of Madagascar's forest biomass as ~1,610 million tonnes.

Table 3-7: Vegetation cover and land use change in Madagascar (estimated for 2015)

VARIABLE		TOTAL (HECTARES)	TOTAL (% OF LAND AREA)	UNIT
Total tree cover [15]	10-30% canopy cover	15,761,748	26.85	% of total land area
	30-50% canopy cover	4,505,364	7.7	
	50-100% canopy cover	10,241,779	17.4	
	Total	30,508,890	52.0	
Land use change and agricultural expansion	Historical annual rate of deforestation[16]		0.1	% of previous year
			0.5	
			1.0	
	Area of agricultural land[17]	41,785,507	71.2	% of total land area

4. SUMMARISED NATIONAL PRIORITIES FOR CLIMATE CHANGE ADAPTATION AND MITIGATION

Madagascar's main priority actions related to climate change are described in the country's submissions to the UNFCCC through the Intended Nationally Determined Contributions (NDC) document. The document includes detailed descriptions of Madagascar's major commitments and priorities related to GHG mitigations (Table 4-2, below) as well as major priorities related to adaptation, derived from the draft National Adaptation Plan (NAP) (Table 4-3, further below).

In 2030, Madagascar aims to reduce approximately 30 MtCO2 of its emissions of GHG, representing 14% of national emissions, compared to the BAU scenario, with projections based off GHG inventory from year 2000 to 2010. This reduction is additive to the absorptions increase of the LULUCF sector, which estimated at 61 MtCO2 in 2030. Total increase in GHG absorption is expected at 32%, compared to the BAU scenario.

Estimated investment costs for the implementation of Madagascar's NDC priorities are estimated to be ~USD 42.099 billion, of which Madagascar indicates ~4% can be met by domestic resources and the remainder of which will require substantial international support. Of the total estimated investment costs, ~USD 28.713 billion is allocated to adaptation, ~USD 6.37 billion for mitigation, ~USD 1.754 billion for capacity-building, and ~USD 5.262 billion for technology transfer, research and development.

Table 4-1, below, gives details on Madagascar's GHG reduction targets outlined in the country's NDC, with information on target gases and sectors, the use of international markets in achieving targets (e.g. the use of carbon credits), and accounting methods used to quantify GHG emissions (e.g. inclusion of land use and land use change).

Table 4-1: Summary of Madagascar's NDC commitments for reduction of GHG emissions

GHG EMISSIONS REPORTED IN NDC (MT CO2E/YR)	BASE LEVEL	REDUCTION TARGET	TARGET YEAR	SECTORS AND GASES	USE OF INTERNATIONAL MARKETS	LAND-USE INCLUSION / ACCOUNTING METHOD
57.65	BAU	14 percent; 32 percent (increased absorption)	2030	CO_2, CH_4, N_2O; Energy, agriculture, LULUCF, waste	No reduction based on of carbon credits purchased outside of Madagascar	Land-use included; accounting methodology not specified

4.1 National priorities for climate change mitigation

Madagascar's mitigation priorities are detailed for the Energy, AFOLU and Waste sectors. Proposed activities and investments within each sector are further categorised according to 'Technology Type', based on the categories of technologies listed by the Green Climate Fund's (GCF) impact indicators for mitigation projects (key for technology types provided below Table 4-2). In the energy sector, national priorities reflect the need to improve access to energy and electricity and to promote renewable energy. Priorities include improving energy efficiency, expansion of existing renewable energy infrastructure (including solar and hydroelectricity) and disseminating improved cooking stoves. In the AFOLU sector, identified priorities are focused on large/landscape-scale initiatives which include the improvement of rice farming techniques, the implementation of conservation agriculture, reforestation and agroforestry, and the enhanced monitoring of forests and grasslands. In the waste sector priorities include the production of biogas from waste water and the sustainable management of organic household waste.

Table 4-2: Mitigation priorities in Madagascar's NDC

PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE* [2]
Energy	Facilitate access to energy by strengthening existing systems and by promoting renewable and alternative energies	1, 5
	Rehabilitate energy producing network and plant stations	1, 5
	Reinforce renewable energy (hydraulic and solar) from the current level of 35% to 79%	1
	Improve energy efficiency	1, 6
	Rural electrification	1
	Disseminate improved stoves (by 2030: 50% of households adopting improved stoves	3
AFLOU	Large scale dissemination of intensive/improved rice farming techniques (SRI/SRA)	4
	Large scale implementation of conservation agriculture and climate-smart agriculture	4
	Dissemination of arboriculture (from 2018: 5,000 ha per year)	4
	Large scale reforestation for sustainable timber production and indigenous species for conservation	4
	Reduction of forest timber extraction	4
	Promotion of REDD-plus	4
	Large scale adoption of agroforestry	4
	Forest and grassland forests enhanced monitoring	4
Waste	Biogas production from waste water	4
	Sustainable management (compost) of organic household waste (50% of waste treated in urban agglomerations)	4

[2] *GCF Technology Type Key (derived from GCF's Results Framework for mitigation)*

1. Reduced emissions through increased lower emission energy access and power generation.

2. Reduced emissions through increased access to low-emission transport.

3. Reduced emissions from buildings, cities, industries and appliances.

4. Reduced emissions from land use, deforestation, forest degradation, and through sustainable management of forests and conservation and enhancement of forest carbon stocks.

5. Strengthened institutional and regulatory systems for low-emission planning and development.

6. Increased number of small, medium and large low-emission power suppliers.

7. Lower energy intensity of buildings, cities, industries, and appliances.

8. Increased use of low-carbon transport.

9. Improved management of land or forest areas contributing to emissions reductions.

4.3 National priorities for climate change adaptation

Madagascar's adaptation priorities are detailed for various sectors: AFOLU, transport, water, community-based adaptation, institutional, and coastal zones. Proposed activities and investments related to adaptation are further categorised according to 'Technology Type', based on the categories of technologies listed by the Green Climate Fund's (GCF) impact indicators for adaptation projects (key for technology types provided below Table 4-3). General adaptation priorities in all sectors are based on the effective implementation of existing or new policies and strategies. For example, in the water sector, Madagascar's priorities are based on the adoption of actions for integrated water resource management. In the coastal zone, adaptation priorities are focused on reducing the vulnerability of coastal, marine and inshore areas. Multiple adaptation priorities are identified for Madagascar's AFOLU sector, which include inter alia measures to develop and apply Resilient Agriculture Integrated Models, to improve and intensify rice farming, to restore natural habitats, and to implement ecosystem-based adaptation. At an institutional level, Madagascar aims to reduce vulnerability to climate change impacts through actions that will improve monitoring of climate information and improve and implement multi-hazard warning systems.

Table 4-3: Adaptation priorities in Madagascar's NDC

PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE[3]
Transport	Effective application of existing or newly established sectorial policies of flood-resistant terrestrial transport infrastructure standards	3
AFOLU	Development of Resilient Agriculture Integrated Model pilot projects/programmes (combination of watershed management, selected/adapted varieties, locally-produced compost, rehabilitation of hydro agricultural infrastructures, input access facilitation system, conservation agriculture, and agroforestry) or "climate-smart agriculture"	1, 2, 4
	Promotion of intensive/improved rice farming system and rain-fed rice farming technique	1, 2
	Restoration of natural habitats (forests and mangroves: 45,000 ha; lakes, streams, etc.)	4, 5
	Widespread application of Resilient Agriculture Integrated Models in major agricultural centre, cash crop zones, extensive livestock farming areas, priority areas for fisheries, mangroves, as well as drought hotspots	1, 2, 4
	Implementation of ecosystem-based adaptation to cope with sand-hill progression (multiple causes but phenomena aggravated by climate change) by leveraging research findings and best practices	4, 5

[3] *GCF Technology Type Key (derived from GCF's Results Framework for adaptation)*

1. Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions.

2. Increased resilience of health and wellbeing, and food and water security

3. Increased resilience of infrastructure and the built environment to climate change threats

4. Improved resilience of ecosystems and ecosystem services

5. Strengthened institutional and regulatory systems for climate responsive planning and development

6. Increased generation and use of climate information in decision making

7. Strengthened adaptive capacity and reduced exposure to climate risks

8. Strengthened awareness of climate threats and risk reduction processes

PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE4
Water	Formulation and implementation of the National Strategy for Integrated Water Resources Management	2, 4, 5
	Sustainable and integrated water resources management, particularly in sub-arid areas and those vulnerable to drought periods	1, 2, 4
Institutional	Strengthen climate change adaptation mainstreaming in all strategic/framework documents	5
	Multi-hazard early warning systems primarily that mainly consider cyclones, floods, drought and the public health surveillance	1, 6
	Real-time monitoring of climate information	6, 8
	Effective implementation of multi-hazard early warning systems, including cyclones, floods, food security	6, 8
	Strengthen and upgrade casualty multi-hazard early warning systems including the aspects of phytosanitary, agricultural, drought and food security monitoring	6, 8
Coastal Zones	Reinforcement of natural protection and reduction of the vulnerability of coastal, inshore and marine areas affected by coastal erosion and receding shorelines progress (Menabe, Boeny, South-west and East)	1, 8

[4] *GCF Technology Type Key (derived from GCF's Results Framework for adaptation)*

1. Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions.

2. Increased resilience of health and wellbeing, and food and water security

3. Increased resilience of infrastructure and the built environment to climate change threats

4. Improved resilience of ecosystems and ecosystem services

5. Strengthened institutional and regulatory systems for climate responsive planning and development

6. Increased generation and use of climate information in decision making

7. Strengthened adaptive capacity and reduced exposure to climate risks

8. Strengthened awareness of climate threats and risk reduction processes

5. ASSUMPTIONS, GAPS IN INFORMATION AND DATA, DISCLAIMERS

The observed and projected climate trends described in Section 2 'Climate and Weather' are derived from a combination of publicly-available observational data and CMIP5 climate models. Detailed information is included in Section 6. Appendix 1, including '6.1.b. Historical Trends and Variability Analysis' and '6.1.c. Climate Projections Visualisations'.

Unless stated otherwise, all statistics reported in Section 1 ('Geographic and Socio-Economic Context' and Section 3 'Climate change mitigation, greenhouse gas emissions and energy use') are derived from databases of publicly available datasets managed by international or multilateral agencies including inter alia The World Bank Group, the United Nations, World Resources Institute and International Energy Agency.

Unless stated otherwise, all energy and greenhouse gas emission figures are derived from UN Stats (2014); World Energy Council (2016); the World Resources Institute (2013), and the International Energy Agency (2016). Agriculture & forestry-related emissions are also reported from Food and Agriculture Organisation (2014-2017) and Global Forest Watch. (2015-2017). Full .

references are provided as a supplementary appendix.

As a result of the use of standardised methodologies and data sources across the 25 countries included in this AfDB Climate Change Profile, statistics and estimates reported herein may differ from other publicly available datasets or national estimates. Readers are advised to always check for updated publications and newly released national datasets.

This AfDB Climate Change Profile series is intended to provide a brief touch-stone reference for climate change practitioners, project managers and researchers working in African countries. The figures and estimates provided herein are intended to inform the reader of the main climate-related challenges and priorities, however these should be used to inform a process of additional research and in-country consultations. The University of Cape Town, the African Development Bank and its Boards of Directors do not guarantee the accuracy of figures and statements included in this work and accept no responsibility for any consequences of its use

6. APPENDIX 1

1.a Supporting evidence

The climate projections detailed in Chapter 2 (above) are supported by rigorous analysis of observed and model projections data. More details of this analysis and supporting figures can be found below.

1.b Historical trends and variability analysis

The analysis of historical trends and variability of key climate variables is presented below. This analysis uses the WATCH Climate Forcing dataset which has been selected as the most broadly representative of station observations across Madagascar. Long term (1979 to 2015) trends as well as inter-annual variability (decade to decade) has been analysed for total annual rainfall, number of rainfall days, number of extreme rainfall days, and daily mean temperatures for each of the four climate regions across Madagascar. The plots below detail **inter-annual variability** (dotted lines), **decadal variability** (smooth bold solid curves) and **long term trends** (thin straight lines) for each region and statistic. This allows for comparison of different types of variability against the long term trend. It can be seen that for rainfall statistics, inter-annual and decadal variability are typically fairly large compared to long term trends. For example, for total annual rainfall, the North-East Coast region has very high inter-annual (2000mm in some years to 4500mm in other years) and strong decadal variability (2000mm in some decades to 3500mm in other decades). Long term trends are not statistically significant but could be around -135mm over the 30 year period.

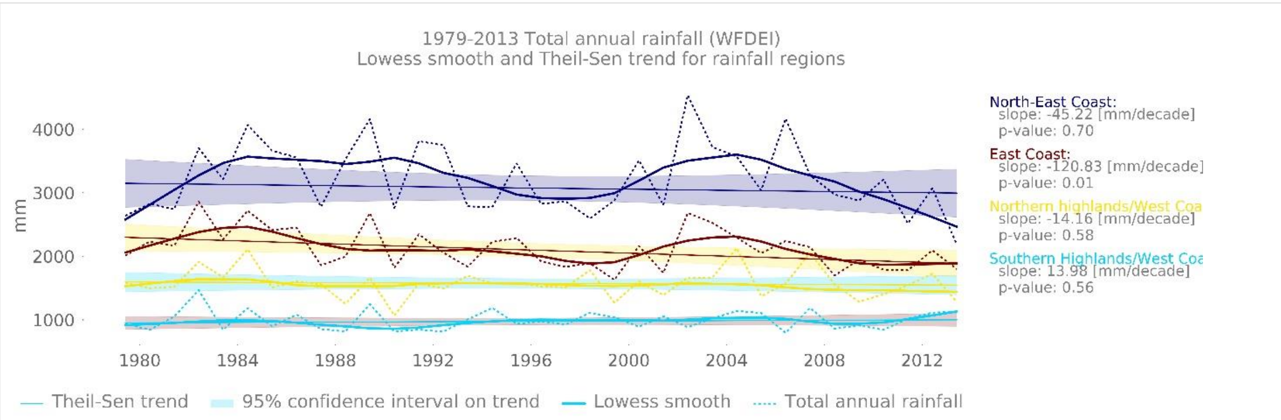

Figure A-1: Long term trends and variability in total annual rainfall for rainfall regions

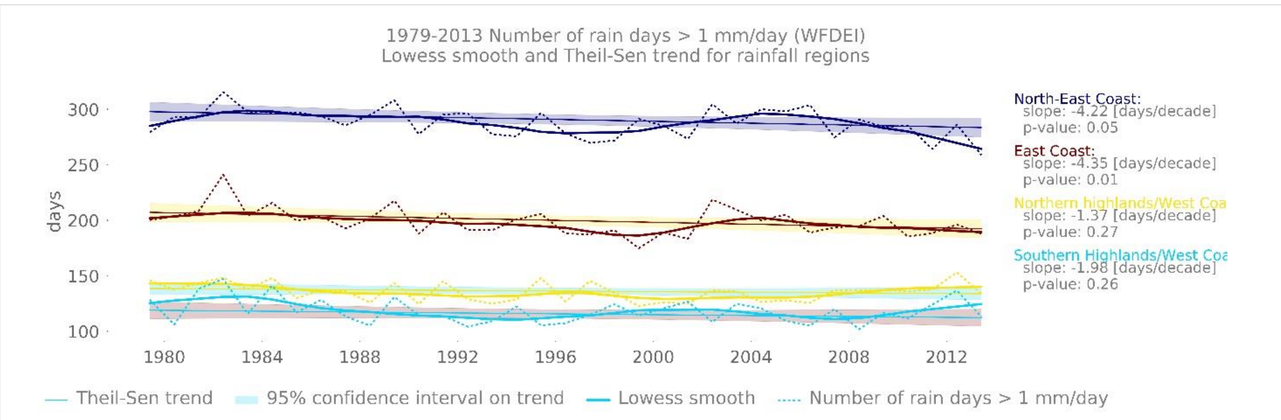

Figure A-2: Long term trends and variability in frequency of rainfall events for rainfall regions

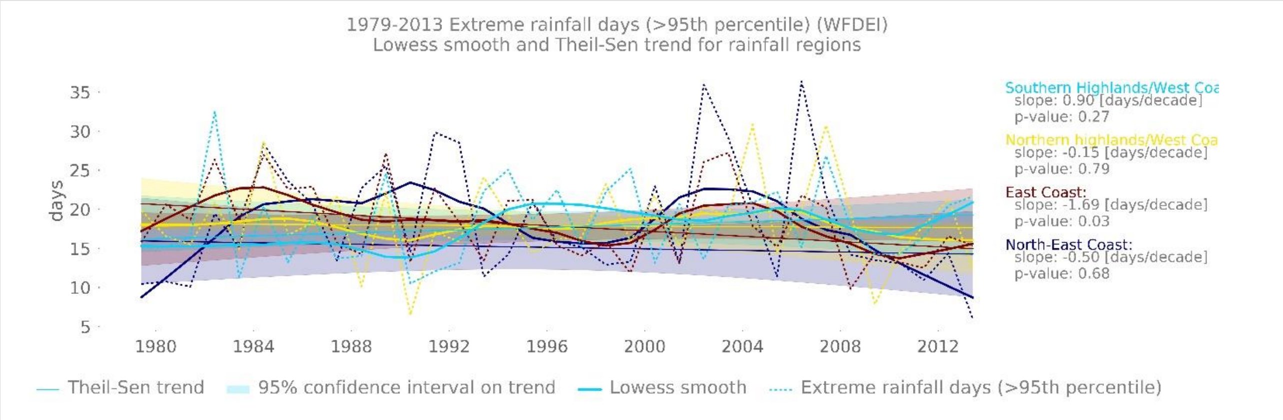

Figure A-3: Long term trends and variability in extreme rainfall events for rainfall regions

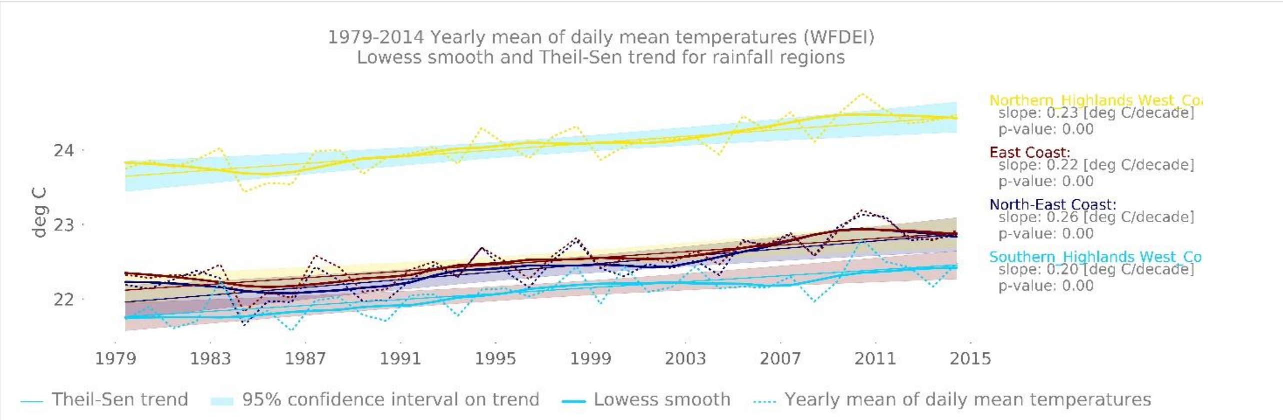

Figure A-4: Long term trends and variability in daily mean air temperatures for rainfall regions

1.c Climate projections visualizations

The plots below (Figures A-5 – A-8) are called plume plots and they are used to represent the different long term projections across the multiple climate models in the CMIP5 model archive used to inform the IPCC AR5 report. The plots show projected variations in different variables averaged over the climate regions. The blue colours indicate variations that would be considered within the range of natural variability, so in other words, not necessarily the result of climate change. The orange colours indicate projection time series where the changes would be considered outside of the range of natural variability and so likely a response to climate change. It is important to note that these are global climate model projections and so likely do not capture local scale features such as topography and land ocean boundary dynamics. They also may not capture small scale features such as severe thunderstorms that can have important societal impacts. Finally, these projections are averages over relatively large spatial areas and it is possible that different messages would be obtained at small spatial scales and if various forms of downscaling are performed.

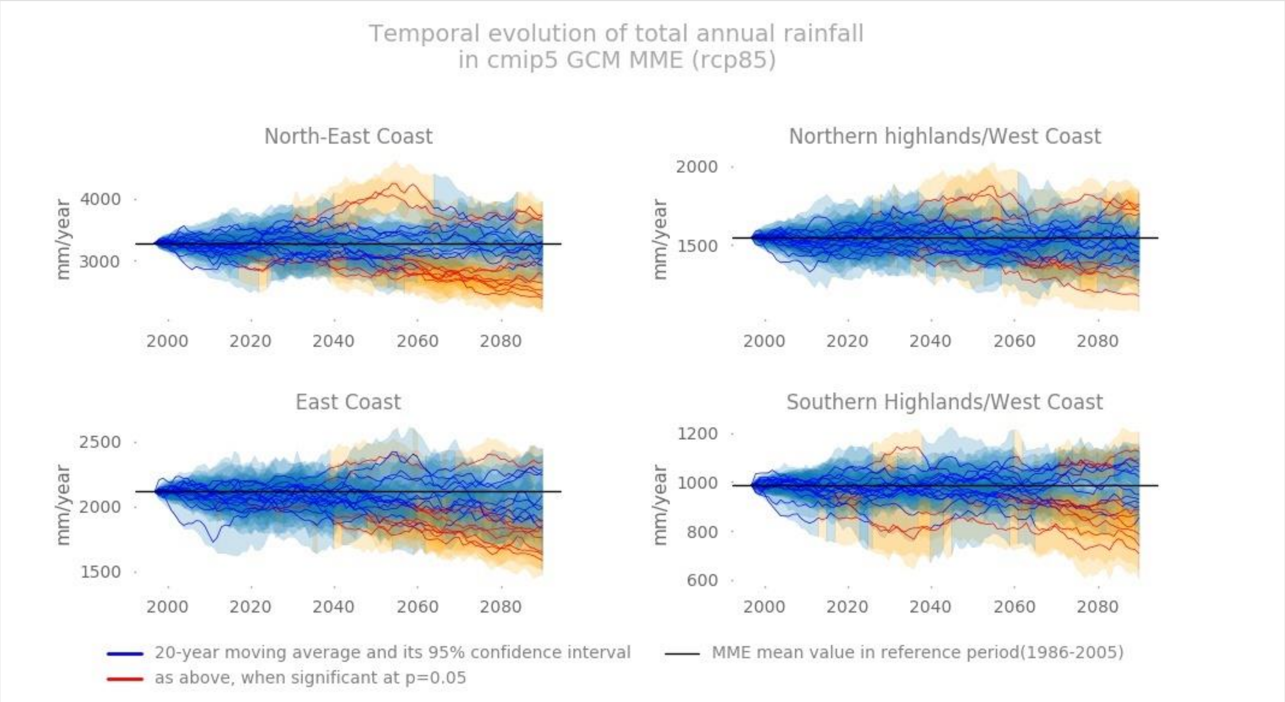

Figure A-5:: Projected changes and emergence of changes in total annual rainfall

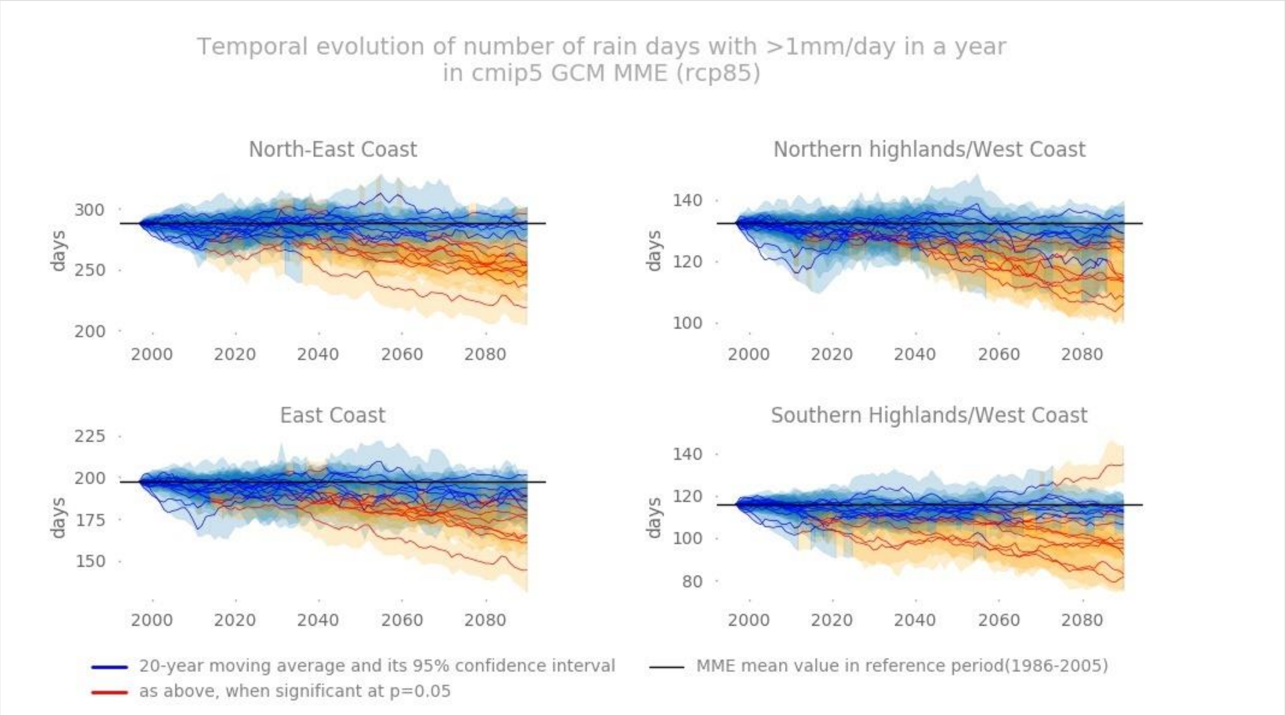

Figure A-6: Projected changes and emergence of changes in number of rain days per year

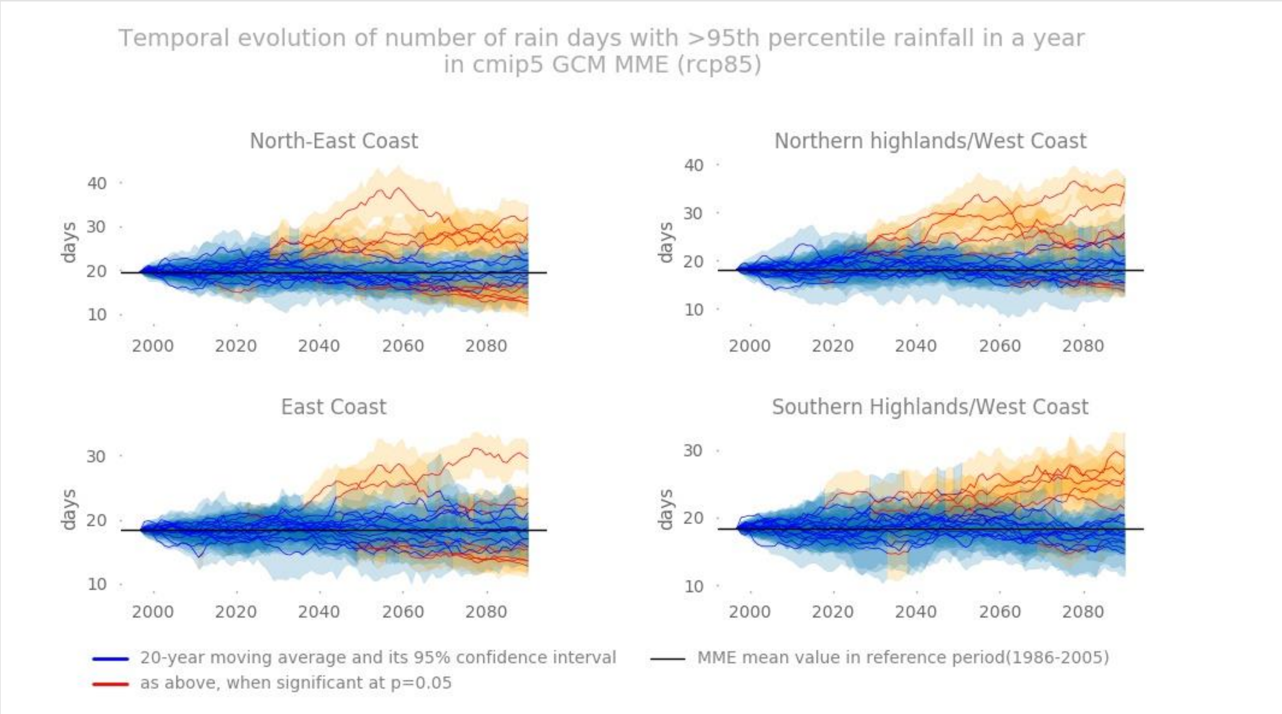

Figure A-7: Projected changes and emergence of changes in number of very heavy rainfall days (greater than 95th percentile) per year

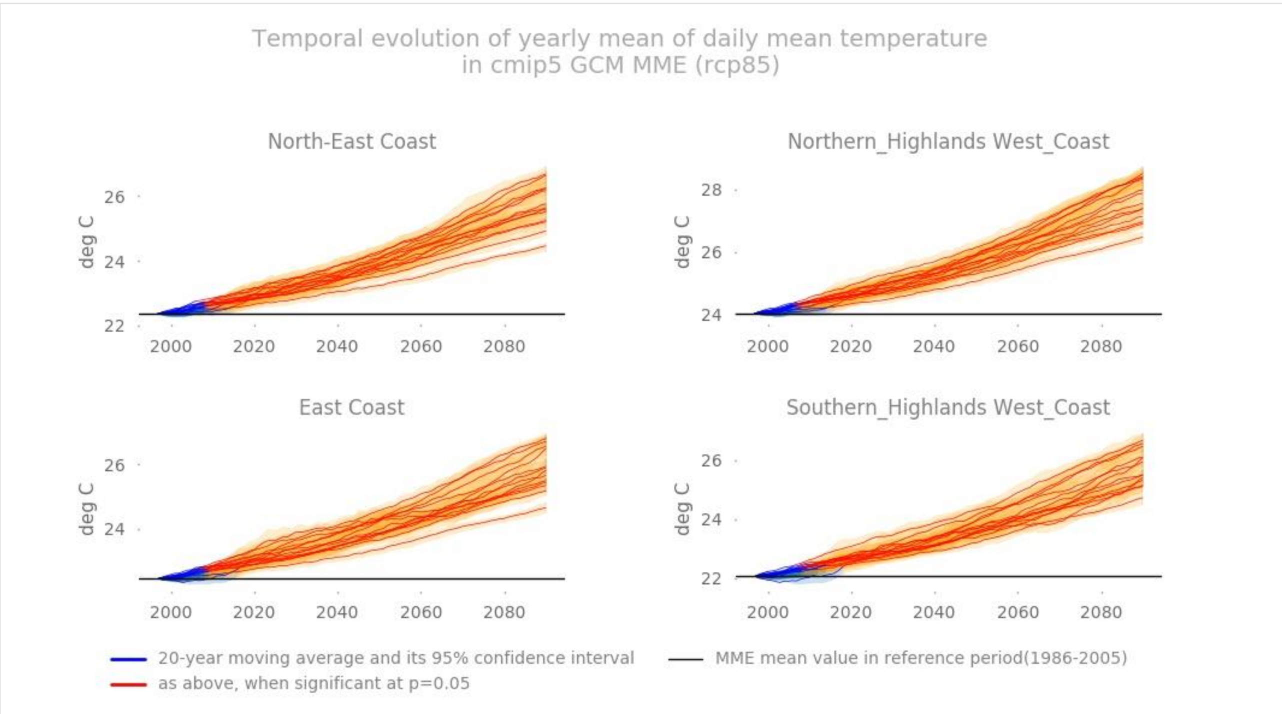

Figure A-8: Projected changes and emergence of changes in annual mean daily mean temperatures

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