Territorial analysis: Resilience to climate change at a glance

MONTSERRAT

KEY MESSAGES

Climate change risks

Increased hot season | Major hurricanes | Sea level rise | Warmer oceans | Increasing flash floods | Droughts

Temperatures will continue to rise. Further intensification of the hot season, high to extremely high heat impact potential by 2030, along with more frequent and more intense heat waves. The number of extreme heat events will increase roughly 15-fold by the 2020's and become a nearly year-long occurrence by the 2040s.

Major hurricanes: The frequency of category 4 and 5 hurricanes is expected to increase by 25%–30%. Storms are likely to become 2% to 11% stronger in terms of maximum wind speeds and possibly more frequent.

Continued sea level rise of 11 to 25cm. Rising sea levels combined with stronger winds during the strongest storms substantially increase the potential impact of storm surge and coastal inundation.

Warmer oceans along with steadily rising sea levels, even if global warming is halted in the foreseeable future.Trends in sea surface conditions include a projected rise of 0.77°C to 2.5°C by the end of the 21st century.

Rainfall: Changes in precipitation are more difficult to project; a slight decrease in total rainfall is anticipated, while single rain events will become more intense. Rainfall rates inside hurricanes could increase by up to 30%, increasing flash flood potential.

Droughts will become more prevalent. However, the trend may only become a major issue from the 2050s onwards.

Summary of key socio-economic indicators for Montserrat

Total Area (square km)	*102*
Population	*5,373*
Percent Urbanization	*9.1*
GDP per capita	*US$34,000*
Debt as a percent of GDP	*N/A*
Unemployment Rate	*5.6*
Services as a percentage of GDP	*90*
Services as a percentage of workforce	*90*
Agriculture as a percentage of GDP	*1.9*
Agriculture as percentage of workforce	*1*
Percent Agriculture Land	*30*
Percent Forests	*25*
Human Development Index	*N/A*

Map of Montserrat

Figure 1: www.lonelyplanet.com

This technical assistance operation is financed by the French Development Agency (AFD) and implemented by Expertise France, within the framework of the Adapt'Action facility. This facility, which began in May 2017, supports African countries, LDCs and SIDs in implementing their commitments under the Paris climate agreement, through financing studies and activities on capacity-building and technical assistance, especially in the adaptation sector.

OVERVIEW

Montserrat is a British Overseas Territory in the **Leeward Islands of the Lesser Antilles**, in the Caribbean. The island of Montserrat is approximately 48 km southwest of Antigua. It comprises 104 sq. km and is gradually increasing in aread owing to the buildup of volcanic deposits on the southeast coast. The island is 16 km long and 11 km wide, with rock cliffs rising 15 to 30 m above the sea and a number of smooth bottomed sandy beaches scattered among coves on the western side of the island. Montserrat has two islets, Little Redonda and Virgin, as well as Statue Rock.

The island's topography is characterised predominantly by steep hills of volcanic nature. As part of the Leeward Islands, Montserrat is well exposed to trade winds, which keeps temperatures moderate at around 27°C near sea level. Based on data from surrounding countries in the Leeward Islands, the heat season (May to October) is characterized by around 36 hot days (when day-time high temperatures are above 32°C) and 33 hot nights (with night-time lows above 26°C) on average, as well as, by several heat waves. During the cool season (December to March), heat levels are comfortable and around 31 cool nights (with lows below 22°C) occur on average. Based on just 6 years of record, the wet season appears to span July to November, largely coinciding with the Atlantic Hurricane Season. The mean annual rainfall total in low-lying areas in the northern portion of the island is in the vicinity of 1000 mm, with significantly higher values probable at higher elevations. Based on data from surrounding countries in the Leeward Islands, extreme rainfall has the potential to trigger flash floods once every 3 years in the period April to May and nearly once per year between August and November. By contrast, in smaller, relatively flat islands within the OECS region, spells of seven consecutive dry days occur throughout the year, peaking in frequency during January to May, potentially limiting rainfed crop growth to the wet season. Finally, impactful drought occurs roughly every 4-5 years during the dry season, and roughly every 10-12 years during the wet season, potentially impacting on freshwater availability.

After a major eruption of the Soufrière Hills volcano in 1997 devasted the southern part of the country – including the former capital of Plymouth,which was buried in over 12 m of ashes – became an exclusion zone. Monserrat currently has a population of slightly over 5000 inhabitants.

Topographic map of Montserrat showing the "exclusion zone" due to volcanic activity. The roads and settlements in the exclusion zone have mostly been destroyed and approximately 45% of forest were lost due to volcanic activity.

CLIMATE TRENDS AND PROJECTIONS

OECS, with CIMH, undertook an extensive analysis of the current trends and future projections of climate for the region was based on data from various meteorological services across the region, as well as future projections from regional circulation models (RCMs) developed by the Climate Studies Group of the University of the West Indies. In terms of priorities of relevance for the Leeward Islands, these climate trends and projections (across a range of emissions scenarios: a low (Representative Concentration Pathway 2.6 – RCP2.6), mid-range (RCP4.5) and high (RCP8.5)), (see details page 8) point to the following risks.

PROJECTED HEAT TRENDS

Figure 2 shows that the increase in frequency of hot days and nights in the Leeward Islands is further accelerated into the 2020s, when frequency is eight-fold, to end up close to a 100% of all days in the year in most years during the 2040s. However, given the recent observed increase rate appears to be somewhat slower for hot days and hot nights, one might expect a delay in reaching a near 100% frequency.

For **cool days and nights**, one can see that, from a 1961-1990 model baseline of 10% frequency, a decrease of over 75% was already noted by 1981-2010. This compares to observed decrease rate of over 60% for cool days and over 40% for cool nights.

Cool days and nights become virtually absent from the projected future as early as the 2020s.

Finally, looking at the number of days spent in **heat waves** of at least six consecutive days (the so-called warm spell duration index or WSDI), a remarkable increase is noted across all three scenarios, as well as, in the observations.

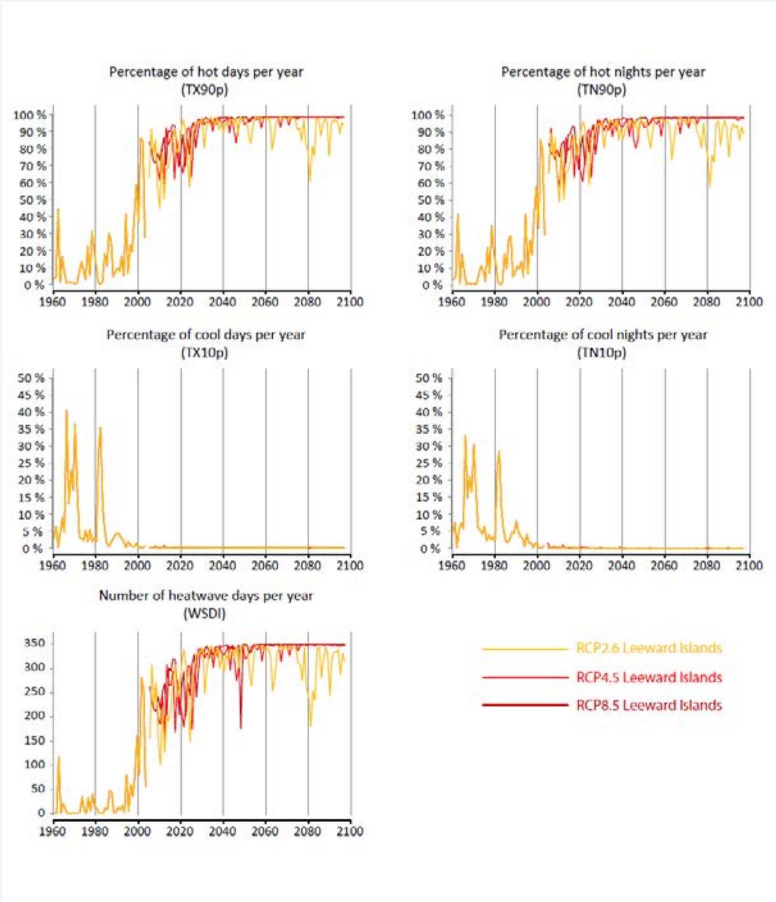


Figure 2

In the Leeward islands: Simulated annual trends in the percentage of hot days (TX90p, top left), hot nights (TN90p, top right), cool days (TX10p, middle left) and cool nights (TN10p, middle right) per year, as well as, trends in the annual number of heatwave days during long heat waves of at least six consecutive days (WSDI, bottom) from three downscaled projections.

Whereas the simulated baseline period only recorded 18 such heatwave days per year on average, the numbers had already increased fivefold by 1981-2010 to further increase roughly 15-fold by the 2020s and becoming a nearly yearlong occurrence by the 2040s.

It should be stressed that the strong simulated trends in the heat-related indices after around 1980 only corresponds well qualitatively with the strong observed trend. However, even with the downscaled projections overestimating the actual trends, hot days and hot nights will likely occur during most days of each year by mid-century, while cool days will likely disappear much sooner. Unfortunately, this committed future change seems to be mostly unavoidable, because the conclusion is valid no matter what RCP scenario is considered.

EXTREME RAINFALL

Projected Changes in Extreme rainfall

As can be seen from Figure 3, there are **no clear signals in projected trends of extreme rainfall.** Clearly, the year-to-year variability exceeds by far the long-term trend in both the proportion of annual rainfall totals from extremely wet days R95pTOT) and the number of days with heavy rainfall (R10mm). While the former appears to increase over time in all three scenarios, the R10mm decreases in both RCP4.5 and RCP8.5. However, if both trends do manifest, this means extreme rainfall will become less frequent, but even more intense. This means that the potential for flash flooding and related hazards may increase throughout the 21st Century, though changes may be hardly detectable by the 2020s and 2040s. An indication of such increasing flash flood potential towards 2100 comes from the fact that the RCP8.5 systematically projects fewer years with at least 5 days with heavy rainfall than RCP4.5 during the second half of the Century. The same is apparent when comparing RCP4.5 to RCP2.6. Indeed, the period 2050 to 2089 contains 19 years with at least 5 days with heavy rainfall in RCP2.6, versus 16 in RCP4.5 and only 10 in RCP8.5.

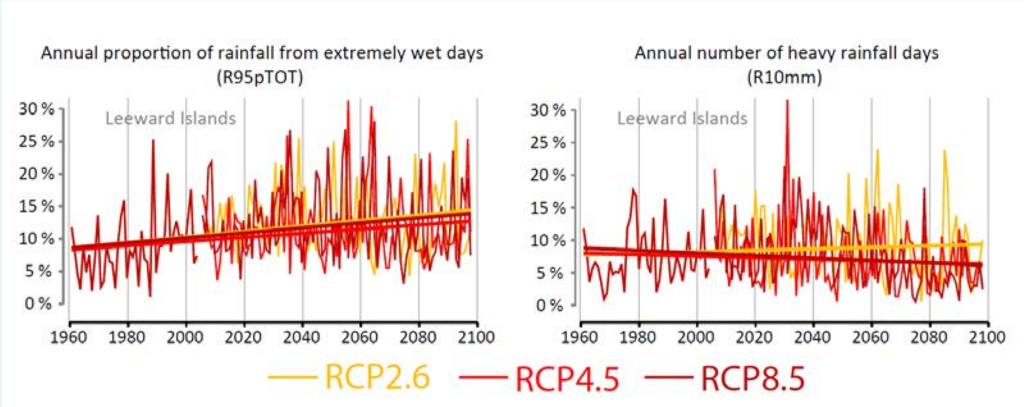


Figure 3

For the Leeward Islands: Simulated annual trends in the percentage of the rainfall total from extremely wet days (i.e. days with rainfall above the 95th percentile only (Rp95TOT, left), the number of days with heavy rainfall (i.e. with at least 10 mm of rainfall – R10mm, right). Also plotted are the simulated trends in the duration (in days) of the longest dry spell (CDD, bottom). The results are shown for the RCP2.6, RCP4.5 and RCP8.5 downscaled projections.

Notes: The absence of significant simulated trends in Rp95TOT and R10mm indicates that flash flood potential may not significantly change in future. Also plotted are the simulated trends in the duration (in days) of the longest dry spell (CDD, bottom). The results are shown for the RCP2.6, RCP4.5 and RCP8.5 downscaled projections. Data source: projections provided by the Climate Studies Group Mona of the University of the West Indies – Mona Campus, Jamaica

DROUGHT

Drought has been and will remain an integral part of climate in the OECS region. This hazard, while physically dependent on both rainfall and evapotranspiration rates, is of lesser concern in the wetter islands with complex topography than in drier, low topography areas of the OECS region. However, where water consumption is intense due to high population density or high consumption by the islands' industries, the sensitivity of the environment and society to drought is significant.

Rainfall-Based Drought Indices

Meteorological drought can be defined as a deficit of rainfall over a period of several weeks to years.

When drier than normal conditions are significant and extend long enough to reduce the amount of available soil moisture, this can lead to crop wilting. Such droughts are called agricultural drought. If drought extends long enough to affect streams, rivers and water reservoirs above and below ground, one can refer to such droughts as hydrological drought. With reduced freshwater availability during prolonged hydrological drought, other socio-economic sectors start being affected, e.g. firefighting, household water provision, construction, tourism, etc. Such drought may be referred to as socio-economic drought.

Typically, reduced soil moisture and reduced flow in streams and small rivers takes anywhere between a number of weeks and about 6 months of rainfall deficits – i.e. **short-term drough**t – to manifest. After 6 months of significant meteorological drought, stream flow in larger rivers and water levels in large reservoirs becomes affected. Finally, after about 9 to 12 months of rainfall deficits – i.e. **long-term drought** –, water levels in the largest surface reservoirs and in aquifers tend to lower and stream flow in the largest rivers tends to decrease.

Hence, a proxy for the different types of droughts should account for the different timescales involved. Furthermore, it should be scalable to the national context of water management. Its calculation should be possible given the climate record available within the territory. One such proxy, recommended by the WMO is the Standardized Precipitation Index (SPI, McKee et al., 1993). The SPI is calculated as a normalized precipitation anomaly over 1 month to 48 months. Given that most droughts in the OECS are seasonal in nature, the most relevant indices are SPIs calculated over three-month (SPI-3), six-month (SPI-6) and twelve-month (SPI-12) periods. However, it is possible for rainfall deficits to exceed 12 months as was the case during the 2014 to 2016 Caribbean drought.

HEAT - AN UNDERESTIMATED HAZARD

Air temperature does not vary much between seasons and years in Montserrat. The heat – being moderated by a prevalent easterly breeze – has **historically** not been regarded as a major hazard but, at best, a discomfort at times. However, with rising temperatures year-round, a more pronounced heat season with more frequent and intense heatwaves are becoming a **new norm**. Heat discomfort and heat stress has started affecting society and the environment. Important impacts (supported by research findings from around the world, including tropical regions and, where references are given, Caribbean countries):

Human health: increased heat-related **mortality and morbidity** (suspected, but not measured in the territory– note that heatwaves are the deadliest weather-related hazard), in particular in persons with lower fitness; increased apathy and aggression; accelerated proliferation of vector borne diseases such as Dengue, etc. (e.g. Lowe et al., 2018).

Education: children's **learning ability** significantly decreases with increased heat exposure.

Energy: increased cooling demand and reduced efficiency in energy production.

National productivity: loss of hundreds of **man hours**.

Environment: exacerbation of **drought**; facilitation of **wildfires**; stress on **animal populations.**

Food security: crop failure due to wilting; severe heat stress related mortality and **morbidity in livestock** (e.g. Lallo et al., 2018).

Finally, because freshwater availability from soils and surface reservoirs can be reduced due to enhanced evapotranspiration rates relative to rainfall, a similar index called the Standardized Precipitation Evapotranspiration Index (SPEI, Vicente-Serrano et al., 2010) can be very useful in monitoring drought. The index is constructed in the same way as the SPI and can therefore be calculated over any relevant time period (e.g. SPEI-3, SPEI-6 and SPEI-12). However, it offers the advantage of calculating a balance between rainfall (i.e. local water input onto the surface) and evapotranspiration (i.e. local water output from the surface).

Projected Changes in Drought

Projected trends in drought are shown in Figure 4 for RCP4.5 and RCP8.5) from 2020 to 2090. Aside from a marked increase in heat exposure, the future projections also indicate that drought will become more prevalent. However, the trend may only clearly manifest from the 2050s onwards.

An SPI value of around 0 is expected on average if rainfall totals are not changing from the 1961-1990 model climatology. However, in the RCP4.5 projection the SPI-6 shifts from close to 0 in the 2020s and 2030s to -0.6 and the SPI-12 from 0 to -1.4 – the latter value falling in the very dry category – in the 2070s and 2080s. Over the same periods in RCP8.5, the SPI-6 shifts from near 0 to -0.8 – moderately dry – and the SPI-12 from near 0 to -1.8, or **extremely dry on averag**e in the 2070s and 2080s. Those significant trends stand out even with the large interannual variability in both the SPI-6 and SPI-12.

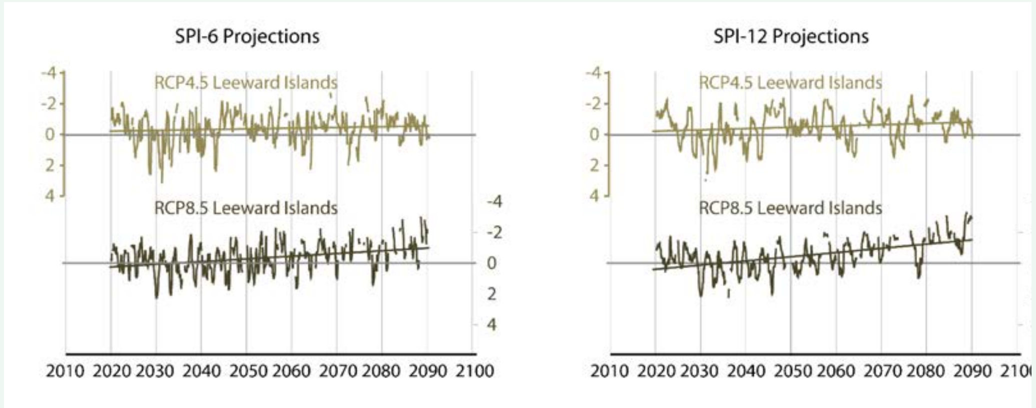


Figure 4

For the Leeward Islands: Simulated trends in the standardized precipitation index over six months (SPI-6, left) and twelve months (SPI-12, right) per year from the RCP4.5 and RCP8.5 downscaled projections.

Data source: projections provided by the Climate Studies Group Mona of the University of the West Indies – Mona Campus, Jamaica

EXTREME WET SPELLS - A PROXY FOR FLASH FLOOD POTENTIAL

Flash floods occur when the rainfall accumulation rate exceeds the rate of soil infiltration and surface drainage. There are rainfall thresholds beyond which the occurrence of wet spells correlates well with the occurrence of flash flood across much of the Caribbean. Caribbean-wide, such **extreme wet spells** are defined as a three-day period during which the rainfall totals are among the top 1% (i.e. exceed the 99th percentile) of all three-day rainfall totals in the historical record at a weather station (CSGM and CIMH, 2020).

While the flood record is incomplete and the number of recorded floods too low for robust statistical analysis, the use of extreme wet spell occurrence as a proxy for flash flood potential is validated regionally by similar findings in countries with a much larger sample of floods.

FUTURE CLIMATE PROJECTIONS - THE USE OF SCENARIOS AND CLIMATE MODELS

The most widely used tools to assess and simulate future or projected climates are **Global Climate Models** (GCMs, in academic circles referred to as General Circulation Models or Earth System Models). Such models can simulate to a great level of detail and reasonable accuracy how climate would behave around the world provided a scenario of socio-economic evolution or external physical factors would affect the energy balance of the earth's climate system. Three commonly used scenarios are the **RCP2.6** (a scenario based on a low carbon emissions future), **RCP4.5** (medium level of emissions) and **RCP8.5** (high emissions), elaborated by the Intergovernmental Panel on Climate Change (IPCC).

The major advantage of GCMs for the purpose of assessing how climate may change through time in future, is that they provide a **full spatio-temporal coverage** of earth's atmosphere. However, for the purposes of small island states in the OECS region, the spatial resolution is **far too coarse** to allow rigorous sub-regional analysis of future heat, drought and climate extremes. Island sub-regions such as the OECS are better served by **Regional Climate Models** (RCMs), which offer finer spatial resolutions. Among the CMIP-5 generation of projections run by a multitude of different GCMs and used in the IPCC's Fifth Assessment Report and many studies thereafter is the HadGEM2 GCM. To enable sub-regional analysis of trends in extremes, downscaled simulations can be performed using the **PRECIS regional climate** model.

Climate change may put pressures on our societies and environments by shifting them closer to or beyond the thresholds of their coping ranges. Therefore, climate projections are conceived to help provide the **scientific evidence base** for societies to adapt to climate change in future and hence build climate resilience for future generations. Such projections provide necessary insight to support **long term planning** for infrastructure, societal activities and the protection of environmental resources. In this climate profile, a special emphasis will be placed on two-time horizons: a **short-term horizon**, namely the 2020s (relevant within the current political context), and a **mid-term horizon**, namely the 2040s, relevant for infrastructure planning and many other societal and environmental systems.

Little Bay, Montserrat, the island's maritime port of entry, the location of the UK project for the new capital city.

Montserrat's lush mountain vegetation
Photo: P. Coblentz – Digital Vision

SOCIOECONOMIC CHARACTERISTICS

Population

The population declined by approximately 50.6% from 1990 to 2015, leaving only 5,241 inhabitants in 2015 (PAHO, 2017). This was due to the volcanic eruption of the Soufrière Hills in 1995 which destroyed the capital, and forced the population to evacuate to the northern side of the island. A significant portion of the population emigrated to Antigua and other parts of the Caribbean. In the most recent intercensal count (2018), the population was at 4,649, and of that 2,289 were males and 2,360 were females (Montserrat Statistics Department, 2018). Estimated life expectancy has risen moderately, with current estimates at 74.4 years overall (75.64 for males and 72.57 for females).

Main Economic Drivers

The loss of the capital, Plymouth, and other major urban and agricultural areas in Montserrat's south was a key factor that affected the territory's economy. The volcanic crisis had a particularly dramatic impact on the private sector. Not only did large local investors leave the island, but assets were destroyed and local markets which supported small and medium enterprises became fragmented. Many businesses fell into debt and key subsectors that had been targeted for development before the crisis, such as tourism, information technology, and export oriented light manufacturing, were decimated.

The economy is currently dominated by Government of Montserrat (administrative, health care and educational services), which employs 40% of the total workforce. The country is still heavily reliant on support from DFID, which provides 70% of the Governments current income (capital included).

Tourism

In 2018, the ECCB recorded total visitors to Montserrat at 18,338, with the majority of them (10,232) defined as stay-over visitors: USA (2,411); UK (2,871); Canada (657); Caribbean (3,850); and other countries (443) (ECCB, 2018).

Table 1

Population and Gender by Districts 2011 (Government of Montserrat, 2012)

District	Male	Female	Total
Look Out	352	318	670
Brades/Shinnlands	246	203	449
St. Peters	226	210	436
Davy Hill North	150	157	307
Olveston	151	141	292
Woodlands	143	134	277
Judy Piece	141	112	253
Baker Hill	105	131	236
St. Johns	129	107	236
Davy Hill South	114	114	228
St. Johns North	101	102	203
Salem West	92	92	184
Geralds	93	87	180
Friths	82	87	169
Salem East	93	68	161
Barzeys	72	75	147
Drummonds	86	59	145
Cudjoe Head	70	67	137
Nixons	61	70	131
Old Towne	27	32	59
Happy Hill	8	8	16
Isles Bay	4	2	6
Total	**2546**	**2376**	**4922**

Table 2

GDP by industry, in constant 2006 basic prices (EC$M) (Adapted from Government of Montserrat, 2018)

Industry	1994	2016	Growth Rate (%)
Production	53	16	-70
Wholesale/Retail	43	8	-83
Hotels & Restaurants	15	3	-79
Transport	30	15	-48
Finance	30	18	-39
Real Estate	53	19	-65
Public Sector	55	70	28
Other	6	3	-49
Total	**285**	**153**	**-46**

Table 3

Employed population by sector and Gender 2011 (Adapted from Caribbean Development Bank, 2015)

Sector	Male	Female	Total
Construction	300	8	308
Hotel and Restaurant	28	77	105
Utilities	59	19	78
Mining and Quarrying	24	4	28
Manufacturing	52	39	91
Education	19	52	98
Public Sector	41	27	68
Private Sector	35	37	72

Energy

Currently, the energy sector is 100% imported fossil fuel based, with the majority being diesel at 57%. The biggest consumer by sector is residential at 47%, followed by commercial at 40% (EU, 2018). However, since 2013, the government has begun exploring the possibilities for geothermal energy with the initial results showing significant amounts of geothermal potential (Government of Montserrat, 2016).

Transport

Montserrat's Gerald Airport provides regular inter-island services to and from V.C. Bird International airport in Antigua, a connecting hub to other destinations.

Land use

Two-thirds of the Island is an exclusion zone, since the eruption in 1995. Figure 1 shows a map of the land use in Montserrat for the remaining third of the island.

Agriculture

The agricultural sector was the main contributor to the GDP. However, it was greatly affected by the volcanic eruptions as it caused the destruction of 90% of the then cultivated land and 75% of land suitable for livestock. Although some of this land has been reclaimed for agricultural purposes, there are still continuing negative effects, such as the increase in soil acidity caused by volcanic ash which has decreased the amount of nutrients available to support the growth of crops (Government of Montserrat, 2018). Currently the main crops grown are cabbages, carrots, cucumbers, tomatoes, onions, and peppers.

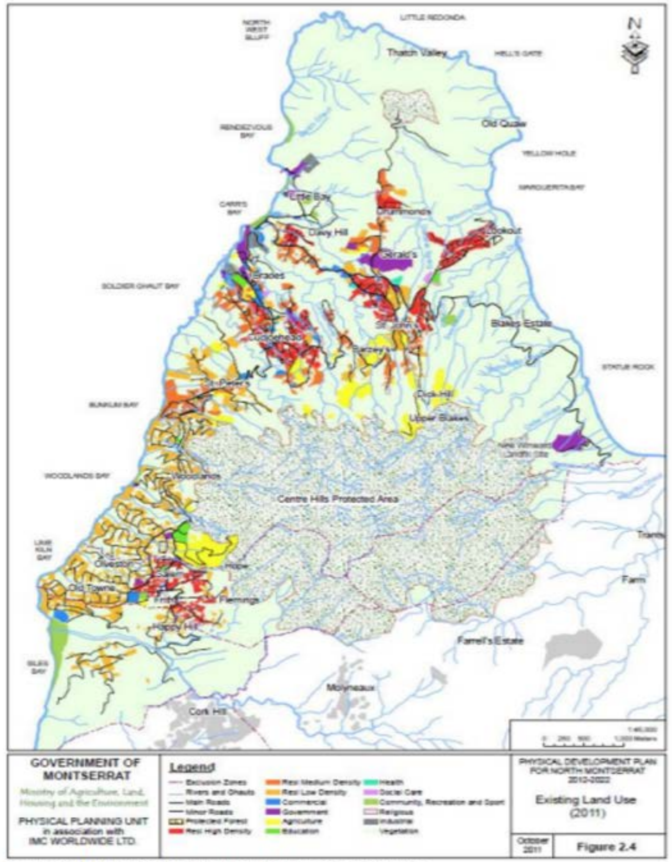
Health

Montserrat provides primary and community care services in the form of four clinics. The one hospital, Glendon hospital, provides casualty, medical, surgical, obstetric and pediatric services although each service remains vulnerable given that the majority of clinical services are medically single-handedly managed (Mott MacDonald, 2017). In 2011 there were 6 physicians, 45 nurses, and 1 dentist in Montserrat (PAHO, 2017).

Figure 5

Land Use in Montserrat in 2011

(Government of Montserrat, 2018)



Source: GoM, Ministry of Agriculture, Land, Housing and the Environment.

VULNERABILITY OF SECTORS AND TERRITORIES TO CLIMATE RISKS

WATER RESOURCES

The trend indicating a decrease in the extents of water-related ecosystems is observable in all OECS member states (except Grenada) that report information on SDG 6 achievements. In terms of water stress, the island is not under critical water stress, although the current situation can change drastically with the impacts of climate change mainly affecting water resources. There is still a lack of information concerning the impacts of climate change on water resources in OECS member states, as well as on the identification of possible conflicts of use that may occur in the future if climate change further affects water resource systems resulting in increased scarcity. Some islands currently rely heavily on desalinization or unsustainable abstraction of groundwater resources, especially to serve the tourism industry. Changes in temperature, rainfall and extreme events will inevitably lead to reductions in water availability and quality, as a result both of damage to service infrastructure and reduced water quality through siltation of streams and rivers via landslides and destructive floods.

AGRICULTURE AND FOOD SECURITY

Agriculture is a critical sector in the economies and livelihoods of many of the countries in the Eastern Caribbean, although the region still relies heavily on food imports to meet local needs, at a significant cost. The sector comprises primarily rain-fed, small-scale subsistence farms growing multiple crops such as yams, sweet potatoes, and various vegetables such as peppers. There are also some large commercial farms focused on export crops such as banana and plantain, coconut, citrus, mango, and avocado. Speciality crops such as nutmeg, cinnamon, ginger and cloves are also important export earners for some islands such as Grenada. Other important grown crops are tropical fruit, coconut, cocoa, vegetables, herbs, tree crops and cut flowers.

Livestock production, likewise, is a basic source of food security for local populations in the Caribbean. Cattle, pigs, chickens, and goats are widely produced across the region, as are dairy foods. The sector is integral to rural livelihoods, providing food, materials, income and mechanical power for pulling carts and ploughing fields. Most of the livestock production follows a similar dynamic to that of agriculture, with small-scale subsistence and commercial producers catering primarily to a domestic market. However, recent efforts to diversify the agricultural industry in response to climate change and global markets have supported livestock exports. Fisheries will be severely impacted by climate variability and change, as the associated impacts of rising seas and extreme weather events alter the productivity of aquatic habitats and the distribution and productivity of marine fish species. These changes are threat multipliers to existing stressors on the sector, including overfishing, loss of habitat, pollution, coral bleaching, and the proliferation of invasive species.

TOURISM

Tourism is essential to the economy of the Eastern Caribbean, contributing substantially to territorial GDP and serving as a source of employment across the region. Tourism relies on critical, government-owned infrastructure such as airports and seaports serving travel between islands, as well as on coastal communication systems, utilities and roads. Tourism also depends on a range of privately-owned infrastructure, including hotels and other beach infrastructure as well as boats for ocean activities and vehicles for land transportation. All this infrastructure is vulnerable both to rising sea levels and damage from floods and storm surge, and more directly to the impacts of hurricanes and other extreme events.

COASTAL RESOURCES

Coastal zones in the Eastern Caribbean are all highly vulnerable to changes brought about by climate-change forces such as rising sea levels, warming ocean temperatures, increasing ocean acidity, and the impact of storms. Rapid coastal erosion and increased salinization of coastal areas, as well as impacts on coral bleaching, have immediate impacts. Vulnerability is also increased through inappropriate land-use-planning and badly designed coastal works such as structures built right on the coast, too close to the beach, hard longitudinal coastal defences on upper beaches (seawalls, revetments), hard cross-shore coastal structures (jetties, groynes), and reclamation of wetlands and mangroves. Built infrastructure, including roads, settlements, hotels and coastal defences, as well as sand mining and other resource extraction and coastal activities have jeopardized the coast and contributed to the destruction of important living resource systems, such as coral reefs, mangroves and seagrass beds (see also the food security section on fisheries).

The major future impacts of sea level rise facing the OECS region include coastal erosion, reduction of land space - including urban space - near coastlines, and saline intrusion into soils and aquifers. Forecasts of coastal erosion impacts on tourism activity within CARICOM member countries point to 30% of coastal tourism infrastructure being affected by a 1m shoreline retreat (SLR) and 60% by a 100 m shoreline retreat.

TRANSPORT SECTOR AND BUILT ENVIRONMENT

Sea level rise, shifting temperatures and precipitation patterns are climatic changes to baseline conditions that affect transport and housing - and the people living within them. These changes can lead to more frequent or more severe droughts, floods, tropical storms and storm surge, and should be considered in road and housing design, siting, materials selection, construction, use, and maintenance. Roads and housing, especially permanent structures, need to be designed to reduce exposure and sensitivity to climate variability and change. Improperly or poorly constructed housing presents one of the greatest risks associated with climate hazards, leaving inhabitants highly vulnerable. Relocation of settlements may become necessary due to gradual impacts such as sea level rise; however, many questions remain on the relocation issue. In many cases managing for greater uncertainty and risk associated with potential extreme conditions rather than past historical trends should be applied. This type of focus on risk analysis and management is commonly applied by the financial and insurance industries and can also be used in assessing proposed development activities.

HEALTH

Extreme weather, coupled with higher temperatures and changes in rainfall, will impact the region's population both directly and indirectly. Heat stress, for example, induces dehydration and has been linked to chronic kidney disease in agricultural and construction workers, and has the potential to increase respiratory and cardiovascular disease risks. Storms and hurricanes can cause death and lead to flooding with significant other effects on crop production, water quality and water-borne illnesses. Additionally, the increased morbidity and mortality of water borne illnesses, as well as mental health effects of extreme events, along with impacts on cardiovascular and respiratory conditions are all subject to climate stress. Moreover, the region's aging population is vulnerable to increased heat stress. Disease outbreaks closely associated with the climatic conditions of the Eastern Caribbean include those transmitted by certain mosquito species. Temperature is an important determinant of biting rate and mosquito development. Precipitation provides habitats for the aquatic stages of the mosquito life cycle and strongly influences vector distribution. Changes in climate are already altering the spatial and temporal dynamics of dengue ecology, potentially increasing vector ranges, lengthening the duration of vector activity, and increasing the mosquito's infectious period. Other climate-related public health issues include harmful sargassum algal blooms and Sahara dust which could have serious implications for human health.

IMPACTS OF RAPID ONSET EXTREME EVENTS

Most of the Eastern Caribbean is made up of small island developing states. When an extreme event happens, it is therefore likely to overwhelm an entire country or territory because of its small size and have an outsize impact on national GDP. Emergency services are likely to be overwhelmed, while critical infrastructure serving the entire country may be significantly damaged or destroyed.

The devastation is likely to be debilitating without outside support to address the immediate needs of the population. Figures 6 and 7 below shows the Number of People Affected by Key Natural Hazards (Source: World Bank Climate Change Portal) and the Frequency distribution of natural hazards.

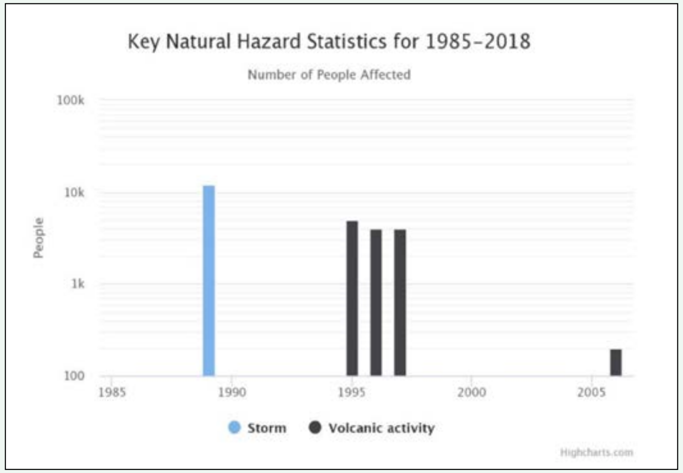


Figure 6

Number of People Affected by Key Natural Hazards in Montserrat

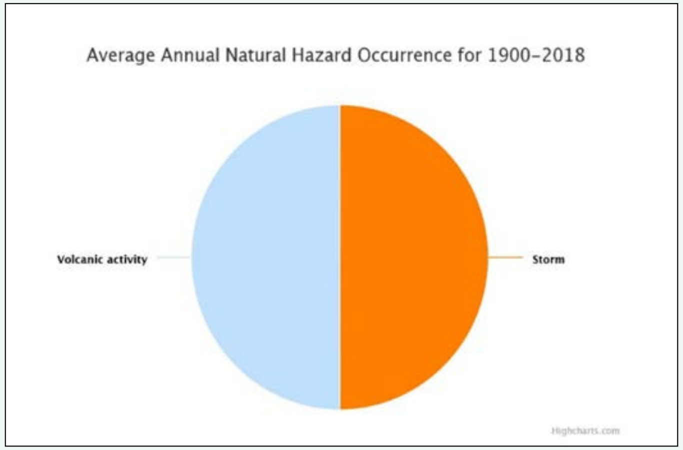


Figure 7

Frequency distribution of natural hazards in Monserrat

Gaps in research and information

Although significant progress has been made to capture the available historical records of climate and hazards, there are still large variations in the needs and quality of research, information, and data.

Research gaps

- Analyses allowing a robust description of the climatology, variability, extremes and trends at any location is possible if long, good quality data records of (sub-)daily weather observations are available. This was not the case for Montserrat, hence leading the analysis to resort to proxies from weather stations in surrounding countries in the Leeward Islands.
- Some knowledge has been gathered since the 1990s on drivers of drought, excessive rainfall and tropical cyclones in the Caribbean as a whole. However, little information is available on the drivers of heat, extreme rainfall, sea level rise at the OECS regional level, let alone the Montserrat territorial level.
- Knowledge on the impacts of and risk associated with hurricanes, sea level rise and rising ocean temperatures engendering coral reef bleaching in the Caribbean is relatively well established. In addition, recent efforts have led to some advancement in mapping flash flood/flooding and drought as hazards and risk factors to socio-economic sectors in the Caribbean and, by extension, Montserrat. However, not much is known or measured with respect to heat impacts on Monserrat's society and environment.

Data and information gaps

- A thorough knowledge of the climatology and trends, as well as, the drivers of hazard-triggering extremes within a country depends first and foremost on the availability of long, good quality data records of (sub-)daily weather observations. With only four monthly rainfall records not exceeding 6 years of data, research into climate-related hazard impact potential is challenging at this time and will remain so until a sufficiently long daily record becomes available.
- With the monthly rainfall records spanning no more than 6 years in length, robust climatological analysis of climate-related hazards is impossible at this time.
- Much more so than weather observations, socio-economic and environmental impact data with respect to climate-related hazards beyond tropical cyclones and sea level rise are scant in the Caribbean, let alone Montserrat. This is particularly the case for heat impacts. Apart from sea level rise, heat is the one hazard that has already intensified and of which we are most confident it will continue to intensify. Therefore, in future, heat impacts on public health, agriculture, water, education, energy and labour need to be observed, archived and data sets made available for research, so as to determine the different dimensions of risk from excessive heat exposure.

CLIMATE CHANGE POLICY PRIORITIES IN TERMS OF ADAPTATION

Montserrat is an internally self-governing Overseas Territory of the United Kingdom. As a British Overseas Territory, Montserrat does not produce National Communications or a Nationally Determined Contributions.

A draft **Climate Change Policy** was produced on the basis of national consultations conducted from 2008 to 2011 funded by the United Kingdom Department for International Development (DFID) and managed by the Caribbean Community Climate Change Centre (CCCCC) under the three-year regional Enhancing Capacity for Adaptation to Climate Change in the Caribbean UK Overseas Territories (ECACC) Project.

This Climate Change Policy is complementary to and supportive of the **Montserrat Sustainable Development Plan** (SDP) which was approved in 2008. It is in particular consistent with its Strategic Goal 3: Environmental Management and Disaster Mitigation Developing measures to adapt to climate change with a view to minimizing the impact of climate change related natural disasters through increased coping capacity at all levels within the country.

Relevant Programmes / Projects

SELECTED PROGRAMME / PROJECT	VALUE (USD)	DONOR	YEAR	IMPLEMENTING AGENCY
Climate Change Adaptation in the Fisheries of Anguilla and Montserrat	£367,110	UK Government from the Darwin Plus: Overseas Territories Environment and Climate Fund under the Darwin Initiative	April 2017 - March 2020	Caribbean Natural Resources Institute (CANARI) with, Fisheries & Ocean Resources Unit - Montserrat & the Centre for Resource Management & Environmental Studies of the University of the West Indies
Regional CLME+: Catalysing Implementation of the Strategic Action Programme for the Sustainable Management of shared Living Marine Resources in the Caribbean and North Brazil Shelf Large Marine Ecosystems . A Regional intervention for Antigua and Barbuda, Dominica, Grenada, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines.	US$ 146.653.695	GEF - UNDP Governments Other Agencies CSO & Academia	March 2015 - February 2020	United Nations Office for Project Services (UNOPS)

KEY RESOURCES

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Climate Risk Profile prepared by: **Artelia and the Caribbean Institute for Meteorology and Hydrology (CIMH)**

Dr. Cedric J. VAN MEERBEECK, Climate Hazards Specialist - CCASAP Project, Climatologist - CIMH, cmeerbeeck@cimh.edu.bb
Fernanda ZERMOGLIO, Team Leader - CCASAP Project, fernandazermoglio@gmail.com
Annie BONNIN RONCEREL, Deputy Team Leader - CCASAP Project, aroncerel@gmail.com

CONTACT: **OECS Climate and Disaster Resilience Unit** cdrunit@oecs.int