Advancing Drought Risk Management in the Caribbean: A Multi-Sectoral Perspective

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Key Messages

- Drought early warning is one of the evolving climate risk management success stories in the Caribbean.
- In a region deemed generally to have adequate rainfall (though with annual dry seasons), drought was not a hazard traditionally prioritised for risk reduction interventions. This changed with the severe 2009 to 2010 drought event, one of the worst droughts in 40 to 50 years, which resulted in significant impacts across multiple sectors. Since then more focused attention has been paid to this hazard by the Caribbean Disaster Emergency Management Agency (CDEMA) and national disaster management organisations across the region.
- Since the 2009-2010 drought event, significant progress has been made in monitoring, forecasting, and mitigating the impacts of drought in the region, such that by the 2014-2016 drought event - arguably the most severe and widespread drought in the region's history - the Caribbean was better prepared. This event brought even more focus to the need to invest in drought risk management at regional, national and sectoral scales. The important role drought risk management plays in reducing drought risk to multiple sectors and segments of Caribbean society continues to be reinforced over time. Most recently, the COVID-19 pandemic which required the implementation of water intensive COVID-19 health and hygiene protocols to reduce virus spread, resulted in increased demand at a time when water supply was challenged in many Caribbean countries due to the ongoing 2019-2020 drought.
- Since January 2009, the Caribbean Drought and Precipitation Monitoring Network - a regional operational network of national hydrological and meteorological services (NMHSs) coordinated by the Caribbean Institute for Meteorology and Hydrology (CIMH) - has been routinely providing a suite of technical drought early warning (monitoring and forecasting) tools and products geared towards multi-sectoral decision-support, using

primarily the Standardised Precipitation Index (SPI), and more recently adding the Standardised Precipitation and Evapotranspiration Index (SPEI) (for monitoring only). Limited climate data outside rainfall, in particular, and temperature positioned the SPI and SPEI to be the most suitable indicators for monitoring and forecasting. The Caribbean Regional Climate Center (RCC) also developed a drought forecast/alerting system, that issues threat levels using six and twelve month SPI forecasts that are updated every month. The forecasts are highly accurate through the use of a combination of observed rainfall and forecasts.

- One of the main avenues of dissemination of drought early warning information in the Caribbean is the monthly Caribbean Drought Bulletin, which packages drought monitoring and forecast information, especially highlighting the portions of the region where there are any concerns over short and long term drought. Through systematically engaging regional media houses, particularly the Caribbean Media Corporation, the Caribbean Drought Bulletin is one of the most reported climate information products featured in Caribbean media articles. Media houses across the Caribbean routinely update their readership with key messages drawn from monthly updates of the Caribbean Drought Bulletin.
- Strategic partnerships have also been formed with the lead regional technical agencies responsible for promoting the interests of key climate-sensitive sectors. To date, the multi-institutional Consortium of Sectoral Early Warning Information Systems across Climate Timescales (EWISACTs) Coordination Partners have worked together to operationally co-develop and/or enhance sector-specific climate bulletins targeting the agriculture and food security, health and tourism sectors. These climate early warning information tools inform practitioners in these sectors of likely negative impacts, as well as climate opportunities associated with upcoming climate events within the next 3 to 6 months. Drought information is a critical component of these bulletins.
- The downscaling of the regional drought early warning system to the national level is another success. The Caribbean RCC has built the capacity of its network of Caribbean NMHSs in developing their own drought alerting information. Capacity is also being built, but to a limited extent, in the user community in interpretation and application of information.
- National drought planning is important to trigger action and so all players can know their respective roles as the drought evolves. To date, only a few Caribbean countries have Cabinet approved and draft national multi-sectoral drought plans/documents, making the focus on capacity building initiatives for drought risk management at national and sectoral levels critical. However, initiatives in the near future are likely to begin to change this situation. The CIMH/Caribbean RCC continues to work with countries to enhance their national drought risk management frameworks. With agriculture being the sector most severely impacted by droughts, including flash droughts, the agriculture sector is being targeted first.
- The Caribbean is entering a new phase of impacts-based research and product development that goes beyond meteorological forecasting of the drought hazard alone, but extends into forecasting the cascade of potential climate-sensitive outcomes that may occur due to drought. The Caribbean Climate Impacts Database (CID), an open-source geospatial inventory that archives sector-based impacts from various climate phenomena, is triggering research on the relationships between climate and its impacts, including drought impacts. This research is foundational to the Caribbean's thrust towards the provision and mainstreaming of sector-specific impacts-based forecasting information for drought.

1. **Description of the physical and socio-economic characteristics of the Caribbean**

The United Nations recognises 58 Small Island Developing States (SIDS), with 28 of these located in the Caribbean region[1] (UN-OHRLLS 2019). Farrell et al (2010) described Caribbean SIDS as generally having:

- Small land areas with the ratio of the coastal area to the total land area being low;
- Significant amounts of their economic wealth and infrastructure in coastal regions;
- Small climate-sensitive interlocking economies (e.g., agricultural and tourism based) that often lack significant diversity at the national level thereby making them particularly vulnerable to economic and shocks;
- Limited or no natural resources, with Trinidad and Tobago (oil and gas), Jamaica (bauxite) and Guyana (oil, bauxite and precious metals) being exceptions; and
- Expanding populations that are dominated by youth.

Caribbean SIDS are typically categorized as Developing Countries with the exception of Haiti which is included in the group of Least Developed Countries (LDCs). Moreover, the World Bank classifies most Caribbean SIDS as middle-income (lower middle income and higher middle income) or high-income countries, and the UN Human Development Index is generally categorised as high (2019 values range between 0·7 and 0·8) across the region.

Global risk indices have consistently assessed many countries within the region as being at high risk to be affected by climate-related hazards (Verisk Maplecroft 2017; Eckstein et al. 2018). It is important to note that although Caribbean SIDS have a shared colonial history, inter-related economies and common environmental, economic, and social risk factors, these States are not homogeneous. Rather, they have diverse geophysical characteristics (based on location and geography) and socio-economic profiles (related to income and debt levels, access to technology and other knowledge products) that affect their sensitivity to and ability to cope with climate hazards, including drought.

Island states such as Barbados, Antigua and Barbuda, and St. Kitts and Nevis, with less than 1,000 m^3 freshwater resources per capita, are amongst the most water-scarce countries globally (CIMH and FAO 2016; Trotman et al. 2018). Within non-water-scarce countries, local communities and cities may be chronically water scarce, especially under water-stressed conditions. Water scarcity on Caribbean islands is increasing due to a number of factors including the expansion of the tourism industry, population growth (although at slowing rates in several states), urbanization, increasing societal affluence, ineffective water management practices and strategies, and declining water quality due to anthropogenic activities and climatic factors—including changing spatio-temporal climate patterns that will likely lead to increased occurrences of drought.

[1] Antigua and Barbuda, Bahamas, Barbados, Belize, Cuba, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Anguilla, Aruba, British Virgin Islands, Cayman Islands, Curacao, Guadeloupe, Martinique, Montserrat, Puerto Rico, Sint Maarten, Turks and Caicos Islands, and U.S. Virgin Islands.

3. Drought Characteristics and impacts in the Caribbean

3.1 Characteristics of Caribbean drought

Unlike more poleward locations, seasons in the Caribbean are defined by the level of rainfall. In most of the Caribbean, there are two seasons – one wet and one dry per year. In northern, coastal Guianas there are two wet and two dry seasons annually. From The Bahamas and Belize in the west to Trinidad and Tobago in the southeast, the wet season begins around May or June and ends around November or December, producing at least 70 to 80% of the annual total rainfall (Enfield and Alfaro 1999) and peaking in the latter half of the season (Jury et al. 2007; Taylor et al. 2011; Trotman et al. 2018; Van Meerbeeck 2020).

Droughts in the Caribbean are attributed to declines in rainfall, particularly in the wet season (Angeles et al. 2007, Taylor et al. 2012, IPCC 2014), and have, in recent decades, become exacerbated by increasing high evapotranspiration rates associated with increasing temperatures (Herrera et al. 2018; Dai 2013 and 2011). Both temperature and evapotranspiration are projected to further increase in the future. More often than not, the declines in rainfall leading to significant drought impacts are associated with the El Niño phenomenon and with cooler than normal sea surface temperatures in the Tropical North Atlantic Ocean and the Caribbean Sea (Enfield and Alfaro 1999; Giannini et al. 2000; Taylor et al. 2011).

The variable nature of Caribbean rainfall is illustrated by the ranges in variability in the onset, duration, and quantum of rainfall during both seasons. Trotman et al. (2018) outlined the many climate features that significantly influence rainfall variability in the Caribbean, including El Niño Southern Oscillation (ENSO), which is identified as the single-most important factor – particularly when variations are widespread across the basin (Herrera et al. 2018). Herrera and Ault (2017) identified a strong influence of both tropical Pacific and North Atlantic oceans in modulating drought variability in 2013 - 2016.

One of the most important reasons for apathy toward drought in the Caribbean is that its impacts are very seasonal surrounding the annual dry season. At some point, the rains will come again during the climatological wet season. The question is – when? When it comes and relief from impacts are enjoyed, the significant moves toward drought mitigation and risk reduction ceases, often without placing resources toward preparing for the next drought event.

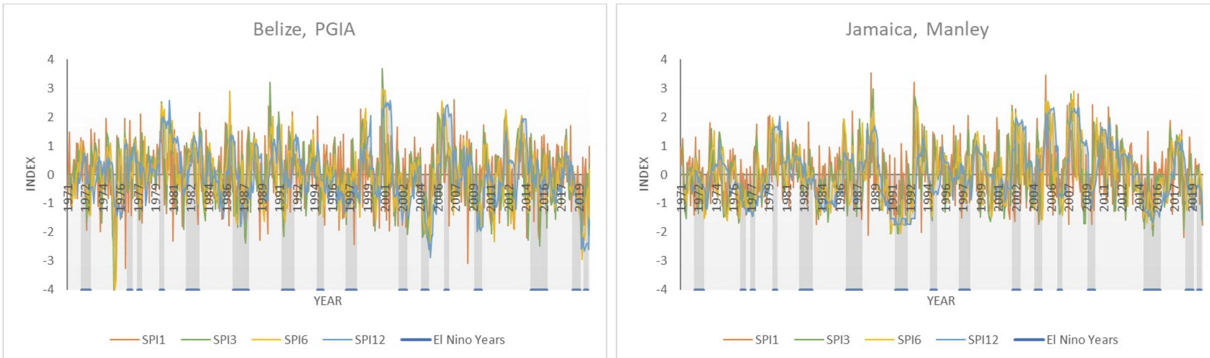
3.2 The History of Drought events in the Caribbean

Since 1950, the Caribbean has experienced several drought events (CIMH and FAO 2016; Herrera and Ault 2018; Van Meerbeeck 2020; CIMH and FAO 2016). The authors identified the following droughts - 1957, 1968, 1976-77, 1986-1987, 1991, 1994, 1997-1998, 2009-2010 and 2014-2016 – as historically noteworthy, and particularly driven by El Niño. More recently, a sub-regional drought was experienced from 2019 into 2020 which impacted the southern part of the eastern Caribbean and part of the west (Belize and Jamaica). That said, the most recent event in that list (2014 to 2016) is estimated as the most severe, with its severity and extent enhanced due to anthropogenic warming (Herrera and Ault 2018). Since 2014 to 2016, drought was intersected by two El Niño events: a weak El Niño from October 2018 to June 2019 and a marginal El Niño from November 2019 to March 2020.

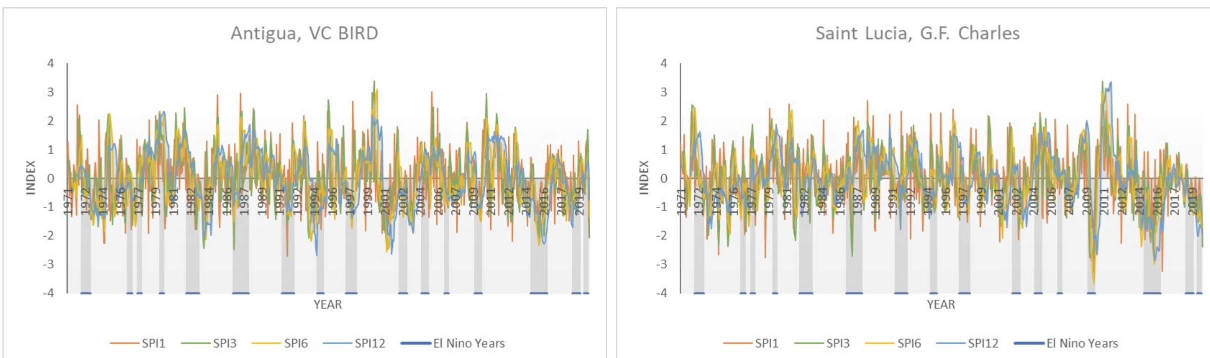
With anywhere from an SPI of -1.3 to less than -2 representing severe to exceptional droughts, Figure 1 below illustrates the impact the El Niño had on Caribbean rainfall. Most El Niño events are associated with at least severe declines in rainfall. Included are the three super droughts of 1982 to 83, 1997 to 98 and 2014 to 2016, which do not necessarily translate into the most intense (SPI value) events across the entire region. However, the super droughts were felt basin wide.

A recent analysis in the Leeward and Windward Islands between 1973 and 2018 compared the occurrence of long-term drought with moderate to strong El Niño events (Van Meerbeeck 2020). In general, pronounced periods of drought and excessive rainfall coincided in the Leeward and Windward Islands, which testifies to the relatively large spatial scale of drought as a hazard. That said, the intensity of dryness or wetness differed between the two sub-regions, with the exception of the most extreme events. This finding suggests a common driver of rainfall extremes at the interannual timescales. As mentioned earlier, El Niño forms the strongest driver for Caribbean-wide drought. According to the US National Oceanic and Atmospheric Administration, moderate to strong El Niño events occurred in 1973, 1982-83, 1986-87, 1991-92, 1994-95, 1997-98, 2002, 2009-10 and 2015-2016. Of those events, only the 1982-83 and 1986-87 were not accompanied by pronounced drought in the Leeward and Windward Islands sub-regions of the Lesser Antilles. Van Meerbeeck (2020) identified three prolonged periods of nearly uninterrupted drought in the Windward Islands coinciding at least partly with moderate to strong El Niños: 1974-1978, 2001-2003 and 2014-2016; in the Leeward Islands, 2001-2003 stands out, but the mid-1970s dryness ended in 1976.

a) b)



c) d)



e) f)

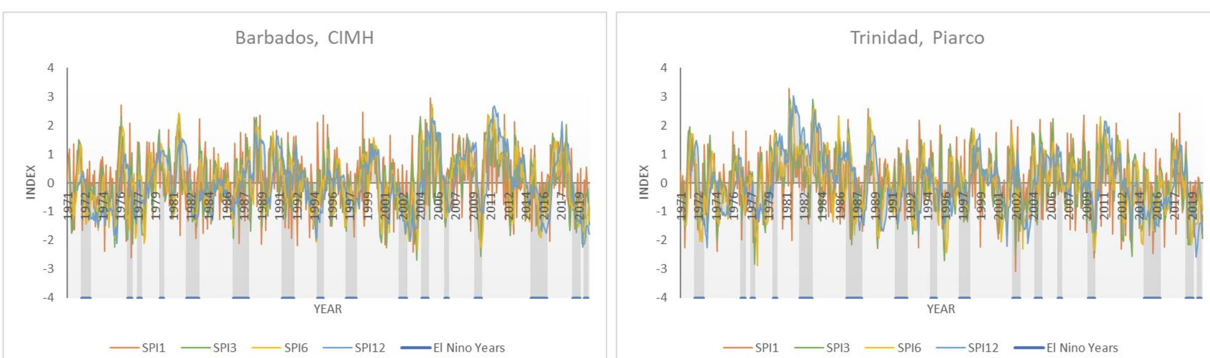


Figure 1 SPI1, 3, 6 and 12 from January 1971 to May 2020 (reference period 1981 to 2010) and the occurrence of El Nino events (grey shaded) +1 years identified, for a) Philip Goldson International Airport, Belize, b) Norman Manley International Airport, Jamaica, c) V. C. Bird International Airport Antigua and Barbuda, d) G. F. L. Charles Airport, Saint Lucia, e) CIMH, Barbados, f) Piarco International Airport, Trinidad and Tobago.

In the Leeward and Windward Islands, long term drought is observed to have been more frequent in the 20-year period (1999-2018) compared to the previous twenty years, but the trend may not be robust as yet. By comparison, no observed trends in short term drought have yet been found (Van Meerbeeck 2020). As reported by Stephenson et al.

(2014), region-wide rainfall has not as yet seen major changes in nature – neither in its average nor its extremes.

3.3 Drought Impacts on the Caribbean's socio-economic sectors: a general overview

Impacts from the 2009-2010 and 2014-2016 Caribbean-wide droughts have been well documented in Farrell et al. (2010) and Trotman et al. (2018), respectively. The authors highlight a range of impacts across multiple sectoral contexts, including reduction in crop yields, losses in livestock, increases in food prices with resulting riots in Haiti, increases in plant pests and diseases, low reservoir levels and reduced stream flows resulting in water shortages and rationing, hotel cancellations in Tobago due to water shortage, significant increases in the number of bushfires and acreage burned, and significant number of landslides on overexposed slopes with the return of the rains. The health sector in Barbados was also impacted, with poor water storage contributing to gastroenteritis in Barbados (Trotman et al. 2018) and *Aedes aegypti* mosquito (the vector responsible for the transmission of dengue, chikungunya, and Zika) proliferation in Dominica (Government of Dominica 2016) and Barbados (Lowe et al. 2018). Energy data provided by St. Vincent Electricity Services Limited illustrates the impact the decline in rainfall during 2014-2016 had on hydropower generation in St. Vincent and the Grenadines, which produced 11,858,670, 16,757,832 and 15,932,020KWh in 2014, 2015 and 2016 respectively, compared to the 9 year (2011 to 2019) average of 20,982,164KWh per year.

The 2019-2020 drought event reminded us that not all droughts in the Caribbean are region-wide, or are associated with strong El Niño signals. Certainly, the El Niño experienced in 2020 was weak, and in 2019 was moderate at best. However, in 2019, significant impacts from drought were felt in Belize and Jamaica in the west, as well as the southern portion of the eastern Caribbean island chain. The onset of the wet season in 2019, though late or slow to develop in these countries, signaled relief from impacts. However, lower than normal rainfall in the wet season in countries like Barbados and Trinidad and Tobago meant that impacts again increased and spilled over to 2020, as the wet season subsided towards the end of 2019. By the end of 2019, Barbados had completed a 24 month period with below normal rainfall, with the country's two main stations at the Barbados Meteorological Services and the Caribbean Institute for Meteorology and Hydrology (CIMH) recording record low rainfall for 2019. This was a significant rainfall deficit that in turn resulted in critical depletion of the island's underground aquifers. Other locations in the west and in the southern islands of the eastern chain experienced similar rainfall deficits as illustrated in Figure 2.

The 2019-2020 drought severely impacted socio-economic activity in the Caribbean. For example, Belize experienced a significant reduction in white and yellow corn yield in the Cayo, Corozal and Orange Walk Districts impacting reducing the availability of corn for export and incoming foreign exchange. The country also reported a rise in unemployment from 7.6% in April to 10.4% in September; with the increase being particularly acute in the Corozal and Orange Walk Districts where agriculture is a major livelihood activity. Female (12.7% and 19.3% respectively) and youth (15.8% and 22.4% respectively) unemployment in these districts was a major concern[2]. Education was also affected with at least one primary school located near the banks of the New River in the Orange Walk District having to close because the stench emanating from the river, (due to a combination of chemicals and dry conditions), became unbearable[3].

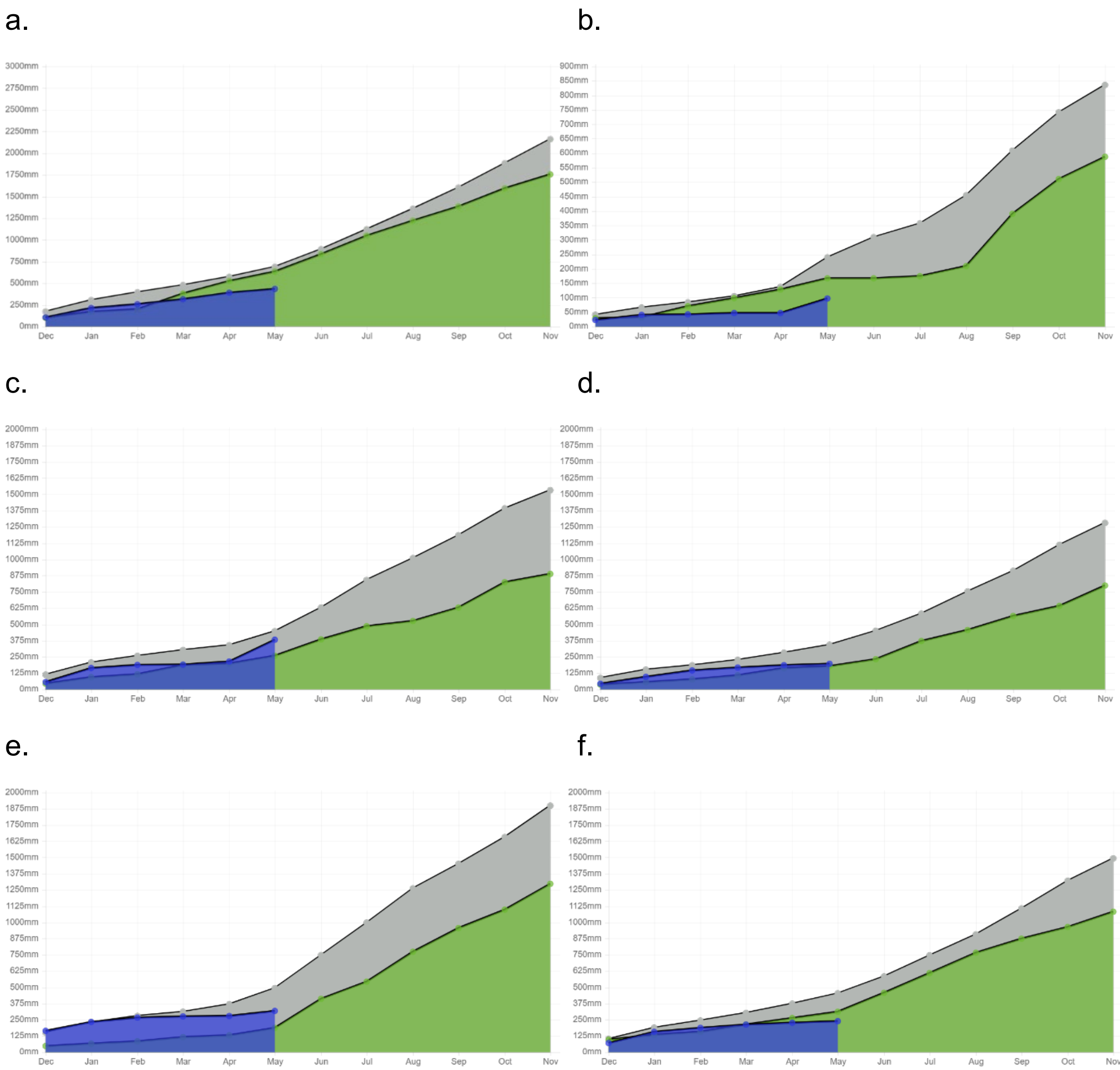


Figure 2 Rainfall accumulation for 2019 (green) and to the end of the climatological dry season (May in blue) 2020 compared to the climatological accumulation (grey) at a)Arnos Vale, St. Vincent and the Grenadines, b) Norman Manley Airport, Jamaica, c) Spanish Lookout Belize, d) CIMH, Barbados, e) Piarco International Airport, Trinidad and Tobago, f) Hewanorra International Airport, Saint Lucia

[2] Belize's 2019 Drought Impact Assessment personal communication from the Ministry of Agriculture
[3] Amandala newspaper, 7 September, 2019

Rainfall deficits have also manifested tangibly in a range of sectoral impacts to date (Table 1).

Table 1 Socioeconomic impacts of the 2019-2020 drought

Sector	Impacts
Agriculture	Jamaica – The hot, dry conditions led to losses in the sector such that the Ministry of Industry, Commerce, Agriculture and Fisheries spent (Jamaican) $15 million to assist affected farmers[4] . Also, Members of Parliament allocated some $19.95 million to assist in providing inputs to farmers island-wide. Firefighters were busy battling bushfires across several parishes due to the high temperatures and dry conditions. Belize – By October 2019, the drought resulted in losses in the agriculture sector output of over Belizean $35 million including $10 million in the sugar industry (Belize's 2019 Drought Impact Assessment). Corn, soybean, vegetables, sugarcane, pastures, honey production and livestock were affected. There was an estimated 30 % decrease in sugar production for the 2020 harvest season, and a delayed start to the season[5]. Cattle were also affected by the drought that resulted in an average weight loss of about 50lbs per head.
Water	St. Vincent and the Grenadines – On 6 April 2020, the Central Water and Sewage Authority (CWSA) announced service interruptions at nights, adding that shutdowns may also have to occur during specified daytime hours[6]. By 29 May, the country was operating at 35% of its capacity over 5 of its major water systems, and therefore continued with water rationing[7]. Barbados – Low levels in aquifers supplying water to pumping stations in the east of the island, with no water to the taps in many parts of the eastern parish of St. John[8]. Saint Lucia - Declared a water related emergency with effect from May 18, 2020, with a number of restrictions on the use of water that for contraveners could result in fines and/or imprisonment[9].

[4] The Observer Newspaper 12 June 2019
[5] Amadala Newspaper 11 January 2020
[6] iWitness News 7 April 2020
[7] Searchlight newspaper 29 May 2020
[8] Barbados Government Information Service
[9] St. Lucia Times, 15 May 2020

Energy	St. Vincent and the Grenadines - Two of the three Hydro-power plants were adversely affected on mainland St. Vincent. The Cumberland Hydro-electric power plant generated significantly lower than average electricity expected for this dry period, the Richmond Hydro-electric power plant was only able to run one of two units, whereas the South rivers Hydroelectric power plant experienced flow reductions but was not severely affected (personal communications, CWSA, May 2020).
Health	Belize - Factory effluent, human waste, and waste from agricultural developments found their way to the New River, and whenever rains are below normal, especially during drought, there is oxygen starvation and this was evidenced by fish dying[10] . The heat, prolonged drought and the temperature of the water, exacerbated the situation, resulting in fish being unhealthy for human consumption, and an unhealthy stench.
Tourism	Belize – September 2019, tourism impacted by high pollution due to low water level in New River around Orange Walk, with fish dying and a pungent smell remaining, affecting tourists[11] .

3.3.1 COVID-19 and drought in the Caribbean

The complex interplay between traditional hazards like drought and new, transboundary threats like the COVID-19 pandemic demonstrate the ways in which a larger prevailing climatic event can exacerbate the impacts of an emerging health crisis. The need to implement water intensive COVID-19 health and hygiene protocols resulted in increased demand at a time when water supply was challenged in many Caribbean countries. For the Caribbean, where travel and tourism contributed 13.9% to regional GDP in 2019 (the highest regional level contribution in the world), the direct link between the spread of COVID-19 and the movement of people has resulted in the widespread closure of tourism activities and significant economic slowdown across the region. The wider knock-on effects to the lives and livelihoods of Caribbean people have been severe, with the COVID-19 pandemic significantly altering the socio-economic profile and purchasing power of many households and businesses within many Caribbean States. The drastic reduction in economic activity resulted in customer defaults on payment to Caribbean water utilities with some utilities warning of the danger of running out of funds to continue their operations (GWP-C 2020). Even in countries where piped water facilities are available, many communities and households were faced with the reality of water rationing and the trucking of water due to drought conditions. In countries most affected by the drought in 2020, the impact was especially felt in vulnerable communities with interrupted or limited access to safe water, hindering the ability of these communities to meaningfully engage in prevention strategies to combat the COVID-19 pandemic,

[10] Amandala Newspaper, 21 August 2019
[11] Amandala Newspaper 9 April 2020

particularly with regards to safe water availability for hygiene purposes. In some cases, the prioritization of the use of water for everyday domestic chores over handwashing became a life-threatening balancing act, prompting the restoration of access to water to households that had previously defaulted on payments due to pandemic-triggered loss of livelihoods.

In St. Vincent and the Grenadines, which in 2020 experienced one of its worst droughts in over fifty (50) years, farmers and fishers had to adapt their routine in an effort to follow national advisories on COVID-19 health protocols[12]. In Grenada, the COVID-19 State of Emergency and its associated restrictions on movement affected farmers who could not visit their farms to care for their crops as these neared maturity (personal communication, Ministry of Agriculture, Grenada). In Belize, where farmers had already suffered millions of dollars in losses in 2019 due to the drought, the COVID-19 pandemic brought economic activity in the Central American region to a halt, severely impeding farmers' ability to export livestock across the border to Guatemala[13].

4. Catalysing drought risk management through early warning information

4.1 The Caribbean Drought and Precipitation Monitoring Network – drought monitoring, forecasting, and alerting

Risk management is the process of identifying, assessing and controlling threats to assets and livelihoods, with climate variability and change posing one of nature's greatest risks. In minimizing climate-related risks, early warning is therefore critical. Through monitoring and forecasting climate status, early warning seeks to identify and assess the threat levels to vulnerable communities and assets, and inform accordingly to provoke action and response to the pending threat. It therefore serves as a critical component toward Target (g) of the Sendai framework which reads "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030" (United Nations 2015).

The World Meteorological Organization (WMO)-designated Regional Climate Centre for the Caribbean (Caribbean RCC) monitors and forecasts drought at the regional scale and has been building the capacity of national meteorological services to do similar at the national scale – thereby forming a critical network of practitioners that make up the Caribbean Drought and Precipitation Monitoring Network (CDPMN). To monitor meteorological drought regionally at different time scales and provide updates on a monthly basis, the CDPMN utilises the Standardised Precipitation Index (SPI) and the Standardised Precipitation Evapotranspiration Index (SPEI). The different temporal aggregations are established to reflect the varied impacts due to duration (WMO and GWP 2016). Whereas time scales of 1, 3, 6, and 12 months were used for monitoring

[12] CARICOM Today,12 June, Droughts, Hurricanes, Pandemic, and Hope: Current realities impacting Caribbean Agriculture, https://today.caricom.org/2020/06/03/droughts-hurricanes-pandemic-and-hope-current-realities-impacting-caribbean-agriculture/.

[13] News 5 Belize, 9 April 2020

from inception (Trotman et al. 2018), recently CIMH added 24-month information, as it was clear that multi-year deficits in rainfall are not unusual and can be related to severe depletions in large river and groundwater resources. The low groundwater reserves at the beginning of 2020 in Barbados can be linked to severe 24 month rainfall deficits between January 2018 and December 2019. The CDPMN, has also recently added products that assess the degree of relative drying (or wetting) trend from month to month.

Trotman et al. (2018) described the approach of the Caribbean RCC to tailoring its climate forecasts such that climate sensitive sectors are able to make more confident decisions outside what tercile forecasts of rainfall - which, internationally, remains the default presentation mode of seasonal rainfall forecasts - can provide. Currently the RCC forecasts SPI6 and SPI12 representing short and long term drought (Figure 3), where alerts are prepared based on the probability of having moderate or severe drought or worse, with increasing probabilities shifting the alerting from no concern to watch to warning or emergency. Climate risk can be estimated as the product of hazard probability and severity, vulnerability and exposure. To provide actionable early warning, the drought alert levels factor in both probability – explicitly, and severity – implicitly. Due to the merging of observed rainfall totals in antecedent months (which is referred to as persistence) and forecast rainfall totals for months to come up, the expected drought probability can be used as a strong predictor for expected drought severity in this alerting system. Indeed, probabilities for expected drought are high when antecedent rainfall deficits were large, and meteorological drought therefore likely intense.

a) b)

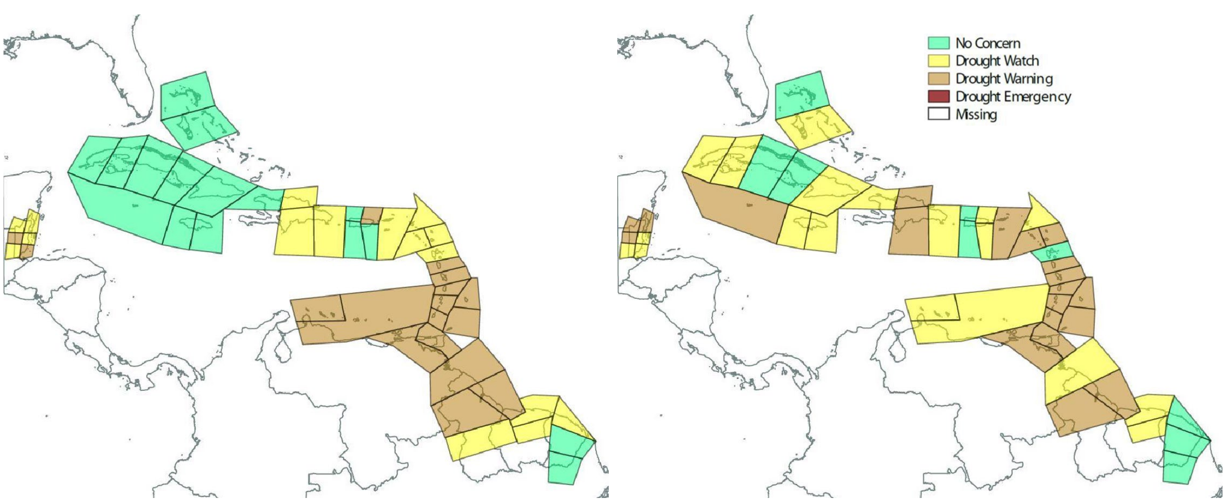
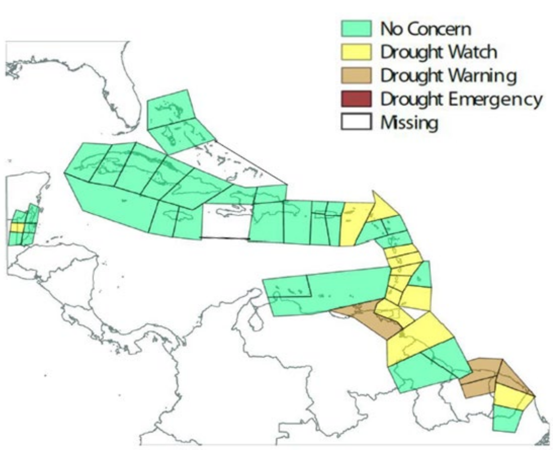


Figure 3 a) Short-term (SPI6) and b) long-term (SPI12) alert levels by the end of May 2020, updated February 2020.

The way the drought alerting system is set up in terms of persistence and forecast periods is further detailed. The approach of using merging persistence with a forecast increases the skill of and confidence in what would otherwise have been solely less confident probabilistic forecasts. As the observed input increases toward the end of the season the skill of the forecast increases as illustrated in the verification information in Figure 4. SPI6 alerts are updated every month for moving 6-month periods, broken up into 2 months of observed rainfall and 4 months of forecasted rainfall. However, the SPI12 is fixed at the end of the two climatological seasons – wet and dry seasons. At the beginning of the wet season in June, the focus is to provide drought alerting information for the end of the season. When this forecast is released in May, rainfall from December of the previous year to April of that year would have already been observed and available as the first 5 months of the 12 month period, with the last 7 months being forecasted. The following month's update would again forecast for the end of November but now with observed May rainfall, and 6 months of forecast. So as the observed input increases toward the end of the season the skill of the forecast increases as illustrated in the verification information in Figure 4.

The NMHSs within the region are trained to deliver similar national drought products. Capacity building is provided bi-annually at the NMHS-focused training sessions of the Caribbean Climate Outlook Forum (CariCOF), as well as at ad hoc national training sessions within initiatives supported by the donor community. Examples of such initiatives include the ongoing Investment Plan for the Caribbean Regional Track of the Pilot Program for Climate Resilience (PPCR), with funding from the Climate Investment Fund through the Inter-American Development Bank; and the concluded Programme for Implementing the Global Framework for Climate Services (GFCS) at Regional and National Scales, funded by the Environment and Climate Change Canada and implemented by the WMO. For example, these two projects provided specific national training for Saint Lucia, St. Vincent and the Grenadines, Grenada, Jamaica, Haiti and Dominica.

a)



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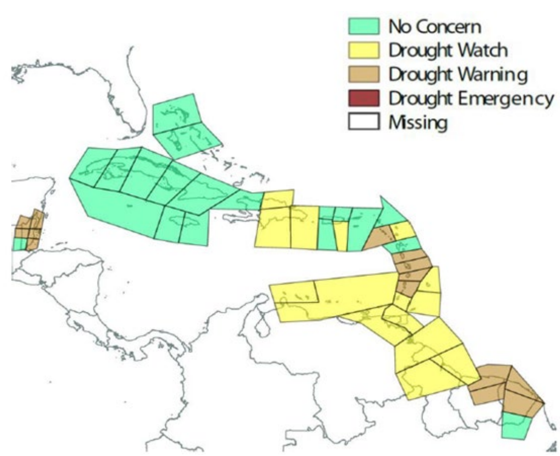

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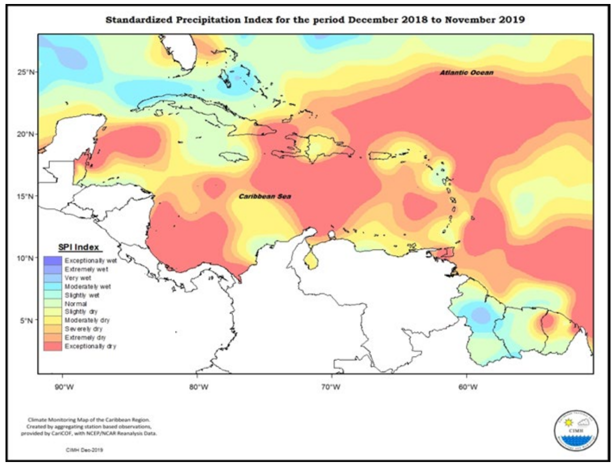

Figure 4 A comparison between a) SPI12 forecast updated May 2019 and b) SPI12 forecast update August 2019 by the end of November 2019 and c) observed SPI12 at the end of November 2019.

4.2 Mainstreaming of the CariCOF drought alerting system

Critical to any early warning system is the means by which the information is made accessible and communicated to users. The Caribbean RCC has employed a multi-pronged approach to the mainstreaming of the CariCOF drought alerting system through several communication channels. One of the main avenues of dissemination of drought early warning information in the Caribbean is the monthly Caribbean Drought Bulletin, which packages drought monitoring and forecast information, especially highlighting the portions of the region where there are any concerns over short and long term drought. Very important to this Bulletin is the “Announcement” sub-section which summarises the information into a few sentences for those who either may be turned off by the presence of graphs and accompanying text or simply want to access the main messages at a glance. The Bulletin also includes recent headline news and other articles that either highlight the impacts of drought or the response to drought (including initiatives to reduce risk from future droughts) in affected parts of the region. The Caribbean Drought Bulletin is disseminated online via the Caribbean RCC website (http://rcc.cimh.edu.bb/climate-bulletins/drought-bulletin/) and emailed to over 500 practitioners within climate sensitive sectors.

Further, the Caribbean RCC in collaboration with sectoral experts routinely prepares climate Bulletins tailored to three of the climate sensitive sectors it currently engages – agriculture, health and tourism. The Caribbean Agro-Climatic, Health Climatic and Tourism Climatic Bulletins which are co-designed, co-produced and co-delivered with regional sector partners (Mahon et al. 2018) include information on drought with messages aligned with sector decision making. Thanks to the funded initiatives like those described earlier, training has been provided to NMHSs to provide sector-specific climate information, including on drought. Importantly, the training is in collaboration with national sectoral agencies to support co-production.

Also important to the communication process is the coverage by media houses from across the region. Through the CariCOF, the CIMH has engaged local and regional media, through training sessions surrounding CariCOF. CIMH maintains a strategic partnership with the Caribbean Media Corporation through the Corporation's recurrent presence at CariCOF. This resulted in the Caribbean Drought Bulletin being followed and covered by a number of media houses from across the region. CariCOF itself is a widely covered event, with close attention paid to how the dry season would evolve at the Dry Season CariCOF.

4.3 Drought alerting at the national level - examples from two Caribbean SIDS

In Jamaica, the Technical Centre for Agricultural and Rural Cooperation (CTA) has partnered with the Rural Agricultural Development Authority (RADA) and the Jamaica Meteorological Service (JMS) to train farmers in adopting climate-smart agricultural practices. In this cause, the JMS has been training small farmers in the parish of St Mary, Portland and St Thomas to use weather advisory services via their mobile phones or internet (for those who can access) to prepare for droughts and possible floods[14]. Some of the information for drought includes their drought tool that provides SPI forecast at the end of a period three months ahead (http://metservice.gov.jm/climate-products). In 2014-2015, Jamaica experienced one of the worst droughts in history, with an island-wide 30% decline in agriculture. Their drought tool (Figure 5 a) was introduced during this time, and an assessment of 600 farmers found that the farmers who had no information lost about 72 per cent of their production compared to farmers who had access to this information who lost only 39 per cent. The JMS drought tool is based on a high resolution forecast system for local drought severity. The high resolution is achieved by the utilization of dozens of station rainfall records and largely addresses and identifies the need for information at the community level. Whereas this tool does not merge persistence to a forecast period, there is however a useful skill and fair confidence in the forecasts of SPI3 values. Achieving useful skill – as demonstrated by the 2014-2015 case – is possible, at least in part, thanks to the larger interannual variability of 3-monthly rainfall totals in Jamaica as compared to the eastern Caribbean, for instance (rcc.cimh.edu.bb/caribbean-climatology). The JMS is also set to release its bushfire forecast tool, as it continues to build on its collaboration with the Jamaica Fire Brigade.

In January 2020 the Barbados Meteorological Services (BMS) released the Barbados Climate Outlook Newsletter, with Barbados experiencing severe drought such that the Barbados Water Authority (BWA) applied restrictions to the use of its water, with penalties for contraveners. Drought was therefore a significant part of this newly released product. The national drought alert map provided by the BMS in this bulletin utilizes the same production tool, method and format as the regional, SPI6-based short term drought alert maps issued by the CariCOF. As compared to the latter, BMS increases the resolution to the parish level using rainfall recorded at all manual rain gauges and weather stations in the country. Besides increased spatial resolution, an additional advantage of BMS's drought alert maps over CariCOF's regional drought alert maps in terms of drought risk management is that the BMS is the national authority in declaring drought and works in

[14] The Gleaner 4 September 2020

close collaboration with national stakeholder agencies such as the Barbados Water Authority.

The Barbados Drought alert map issued in February 2020 is shown in Figure 5 b). It was constructed using observed December 2019 and January 2020 rainfall as the persistence period, and a February to May 2020 forecast period. Note that the drought emergency for St. John corresponds to an expected probability of impactful drought conditions at the end of May 2020 of over 83.3% in that parish four months ahead of time. In practice, such confidence (i.e. high probability) has never been achieved by seasonal rainfall forecasts alone and demonstrates the gains of merging persistence and forecast.

a) b)

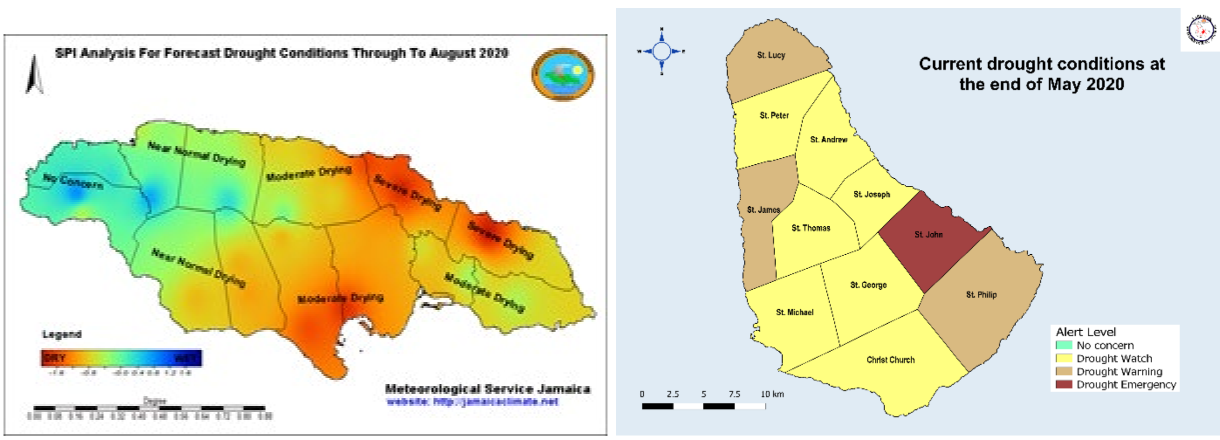

Figure 5 a) Jamaica's Drought Tool, and b) Barbados Drought Alert Map

5. Building drought resilience through integrated research, partnerships and planning

5.1 Scientific advances in drought early warning and drought planning

The meteorology fraternity has recognised that weather and climate impacts, including drought impacts, on the public and various socio-economic sectors, are still large, despite the delivery of high quality weather and climate forecasts by NMHSs and other weather and climate information providers (WMO 2015). To better support risk informed decision-making, providers are moving from forecasting weather and climate to forecasting what the weather and climate will do (WMO 2015; Campbell et al. 2018). For drought, this implies the translation of the risk associated with the drought hazard into sector and location-specific impacts and the development of responses to mitigate those impacts due to significant deficit in rainfall and available water.

To this end, there have recently been increased efforts to forecast drought impacts across the globe (Sutanto et al. 2019; Bachmair et al. 2017; Blauhut et al. 2015). The Caribbean RCC is committed to making investments in scientific advances in drought early warning and drought impacts forecasting, as well as the linking of scientific drought risk information to sector-specific drought planning by a range of sectoral practitioners.

After the impacts of the 2009-2010 event, a number of initiatives provided training in drought monitoring and planning for relevant agencies in Caribbean countries. These exercises resulted in a number of national drought planning documents, including the Terms of Reference for the National Flood and Drought Committee (a sub-committee of its national emergency management system) of Saint Lucia and later during the 2014 to 2016 drought, the St. Kitts and Nevis Drought Management Committee (still to be ratified by its government Cabinet) (Trotman et al. 2018).

The continued upgrade of the content and functionality of the CIMH hosted Caribbean Climate Impacts Database - an inventory of geo-referenced, historical climate-related impacts for 19 Caribbean countries (Mahon et al. 2018) is key to facilitating the development of new impacts-based forecasting information for drought. Moreover, the database has been designed to address the disconnect between drought impacts and response at the national and sectoral levels by the inclusion of national and sectoral response mechanisms and standard operating procedures (SOPs). The CID will continue to be strengthened through the addition of new and/or enhanced sectoral SOPs linked to drought thresholds as these become available.

However, more work is needed to develop a clear understanding of the quantitative relationships between the SPI at various timescales and impacts for a range of climate-sensitive sectors - making the identification of country-specific drought thresholds associated with sectoral impacts a key research activity for the Caribbean. Through an initiative funded by the American People through the United States Agency for International Development (USAID), efforts are commencing to relate the SPI at its varying timescales to impacts on agriculture, particularly for key agricultural commodities. This will not only support agriculture-specific drought impacts forecasting, but also facilitate more empirically based drought planning in the sector.

The Food and Agricultural Organization (FAO) of the United Nations provided support for Caribbean countries to develop Agricultural Development Risk Management (ADRM) plans. Some of these only mentioned drought as a hazard without including planning to build resilience to drought – other plans did not mention drought as a hazard at all. However, in 2016, in collaboration with CDEMA, FAO recognising the deficit in planning for drought in existing Agriculture Disaster Risk Management (ADRM) plans, supported the development of a template as an annex to these plans. These Annexes aim to establish responsibilities and activities in the form of SOPs associated with and triggered by drought risk and severity. The risk levels and associated sectoral responses will be linked to the value of the SPI. More broadly, replicating this process by conducting similar exercises for other climate-sensitive sectors can strengthen drought planning in these sectors as well.

One area that is currently missing from the Caribbean's current drought alerting system that would be particularly game-changing, is tailored information at the sub-seasonal scale, as flash droughts (Pendergrass et al. 2020) are common yield reducers (or even disastrous) in Caribbean agriculture. This implies adjusting drought monitoring from its routine monthly updates to weekly (preferably) or bi-weekly. To this end, the Caribbean RCC has been collaborating with the USRCC in Washington DC that has been providing sub-seasonal[15] (currently 1 and 2 weeks) rainfall since 2019. The aim is to tailor the sub-seasonal rainfall forecasts into alerts, similar to the seasonal forecast, for the agriculture sector.

To achieve the goal of providing actionable drought information, capacity building along the entire service delivery chain for climate information providers is necessary– from information on the drought hazard itself to sector and location-specific impacts and responses to mitigate the impacts is needed to be able to deliver on any climate services and impacts based forecasting mandates for drought. Retraining of the NMHSs to build their procedural capacity to provide impacts-based forecasts would be necessary, and has already begun. Also important would be building capacity in the national disaster management organisations, sectors and communities to be able to respond to the information provided.

To complete the early warning picture, significant investment is required in preparing individuals in the population and sectors, especially climate sensitive sectors, to respond to the risks associated with drought in a timely and efficient manner through water management planning. Effective preparedness actions must be grounded in well articulated water management policy bolstered by an enabling framework including legislation and supporting regulations. Similarly, appropriate governance arrangements with clear delineation of national level leadership within national agencies with responsibility for water supported by the multi-sectoral national emergency management mechanisms inclusive of government, private sector and non-governmental organizations is required. Due to the prolonged duration of drought and the dynamics of the hazard impact, these mechanisms must be informed by science through robust drought monitoring arrangements and a level of flexibility and agility to adjust to the unfolding scenario In Saint Lucia, the Water and Sewage Company (WASCO) is the lead agency for the national Water Management Plan for Drought Conditions. Further, since 2013, the Saint Lucia Cabinet ratified the national Flood and Drought Mitigation Committee that advises the government on issues related to flood and drought, including potential and evolving events. Powers are enshrined within the Water and Sewage Act No. 14 of 2005 to permit mandatory restrictions on water as a mitigation measure, and in addition, activate the National Emergency Response Mechanism should such a need arise (Government of Saint Lucia 2009).

5.2 Building partnerships at regional and national levels to enhance drought resilience

Recognising the many cascading and compounding multi-sectoral impacts from climate-related hazards such as drought, a key strategy pursued by the CIMH since 2015 has been the signing of formal agreements across several key regional institutions responsible for a range of climate-sensitive sectors for collaboration in the development and integration of climate services in sectoral decision-making (Mahon et al. 2018). Fully established in 2017, the Consortium of Sectoral Early Warning Information Systems

[15] http://www.cpc.ncep.noaa.gov/products/international/usrcc/carib_lrf.shtml

across Climate Timescales (EWISACTs) Coordination Partners (Figure 6) is a group of now seven regional sector agencies and a regional climate service provider (the CIMH) committed to the co-design, co-development and co-delivery of user-specific and actionable climate information products and services (Mahon et al. 2018).

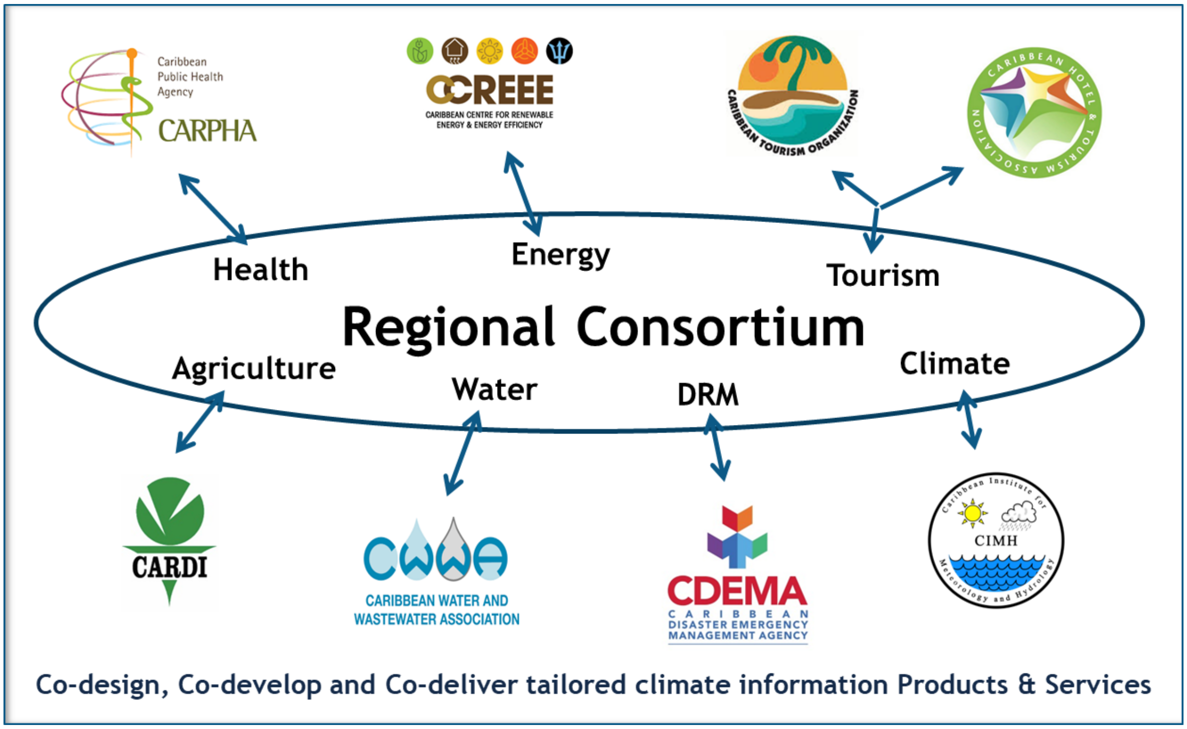

Figure 6 The Consortium of Sectoral Early Warning Information Systems across Climate Timescales (EWISACTs) Coordination Partners. Source: Mahon et al. (2018)

Consortium partners are further supported by a range of ‘Observer’ agencies with diverse but complementary interests in building regional resilience to the effects of climate variability and change. Observer agencies include technical organisations (e.g. the Caribbean Community Climate Change Centre (5Cs), and the Climate Studies Group at the University of the West Indies, Mona Campus); sector organisations (e.g. the Pan-American Health Organization (PAHO), the Agricultural Alliance of the Caribbean (AACARI); and geo-political coordination organisations (e.g. the CARICOM Secretariat, and the Organization of Eastern Caribbean States (OECS) Commission).

Being able to deliver sector specific, impacts-based information is one of the key roles of the Sectoral EWISACTs Consortium. To date, the partnership has resulted in the co-production of three sector-specific climate information Bulletins (mentioned in subsection 4.2) that have facilitated the mainstreaming of drought early warning information into sectoral operations. More recently, Consortium members have co-developed a Regional Roadmap and Plan of Action which articulates the collective goal, outcomes, and outputs that guide the implementation of a long-term coordinated, multi-sectoral climate services portfolio for the period 2020-2030 (CIMH et al. 2020).

The Regional Roadmap and Plan of Action provides the framework for supporting the development of the next generation of tailored, sector-specific climate information for drought and other climate hazards at regional and national scales.

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