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Drought characteristics and management in the Caribbean



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Drought characteristics and management in the Caribbean

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Foreword

Drought is a normal phenomenon of all climates, with varying characteristics between regions. It materializes in a reduction of precipitation from the long-term average, that extends over a given space scale for a specific period of time and results in impacts. Over the past decades, drought episodes have become more widespread and prolonged in many parts of the world, with increased socio-economic and environmental impacts. Agriculture is particularly vulnerable to drought with severe consequences on food supplies and livelihoods, especially for smallholders and the poor layers of rural societies.

The provision of emergency response to the affected population, in the form of food, feed and creation of jobs, is the most common approach adopted by governments to deal with drought. While important for alleviating starvation and saving lives, this approach is currently known to have several limitations. A paradigm shift to a more pro-active approach, based on the principles of risk reduction, to build greater societal resilience to drought impacts, is the right solution.

This concern is fully embedded into the new FAO Strategic Framework which drives the organization's activities. Increasing the resilience of livelihoods to all disasters, including drought, is one of five Strategic Objectives that constitute FAO's priorities.

Within this Strategic Objective, FAO joined hands with the Robert B. Daugherty Water for Food Institute of the University of Lincoln-Nebraska, for launching a study on drought characterization and management in drought prone regions of the world. Getting a close picture of both drought characteristics and the way it is managed in different regions is essential not only for steering the shift from emergency response to more pro-active policy and long-term planning but also for assessing gaps and elaborating the right support to countries to achieve this shift. The ultimate goal of the studies is to provide background information for designing drought risk management planning guidelines that are tailored for the specific characteristic and needs of each region. The study has been carried out between 2012 and 2015 and concerned several regions and countries. A synthesis report that draws experiences and the lessons learnt from these studies is being produced.

The present report pertains to the characterization and management of drought in the Caribbean, a region commonly hit by climate-related hazards, including drought. We hope that it will contribute to fostering the fundamental shift in the way drought is perceived and managed in the Caribbean and we reiterate FAO's continued support to the countries of the region for the development and implementation of national drought management policies consistent with their development objectives.

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The study is a contribution to FAO Strategic Programme Five which is aimed at increasing the resilience of livelihoods to disasters. It was conducted in partnership with the Robert B. Daugherty Water for Food Institute of the University of Nebraska-Lincoln, USA.

Executive summary

This report reviews information on drought characteristics and management in the Caribbean region, identifies the relevant national and regional agencies and focal points involved in drought management, and brings together information on their work at national and regional level.

Climate-related hazards are the most frequently occurring natural hazards in the Caribbean. The region's vulnerability to climate-related hazards, such as strong winds, storm surge, flooding, and drought, manifests in loss of life, economic and financial losses, and damage to the environment. The Caribbean region faces significant challenges in terms of drought. It has focused mainly on floods and storms, and so currently lacks effective governance, human resource capacity, and finance, and has poor national coordination, policy-making, and planning in place to deal effectively with drought issues.

The Caribbean accounts for seven of the world's top 36 water-stressed countries. Barbados is in the top ten. The Food and Agriculture Organization of the United Nations (FAO) defines countries like Barbados, Antigua and Barbuda, and St. Kitts and Nevis as water-scarce with less than 1000 m³ freshwater resources per capita. The predominant practice of rainfed agricultural production means the region is vulnerable to the very variable and unpredictable rainfall. This review is based on three approaches – a review of published and grey literature on drought, specifically its impact on agriculture; a review of the steps being taken mainly by government agencies to plan for and manage drought; and a questionnaire on drought sent to farmers and those who provide water services to assess their views on drought and drought management.

Climate change is expected to increase mean temperatures with more warm days and warm nights, with significantly more warming at night. Annual rainfall is expected to decline by the end of this century, particularly during the wet season. The combined effect of higher temperatures, associated increase in evaporation, and less rainfall means that the Caribbean is likely to experience more intense and frequent droughts. Recent trends in temperature are consistent with these projections. However, changes in rainfall are less consistent with only weak positive trends in intensity, particularly daily intensity. So the projection of declining rainfall is not yet being experienced.

The alternating wet and dry seasons mean that the region already experiences drought-like events every year, often with low water availability impacting agriculture and water resources, and a significant number of bush fires. But the Caribbean also experiences intense dry seasons particularly in years with El Niño events. The impacts are usually offset by the next wet season, but wet seasons often end early and dry seasons last longer with the result that annual rainfall is less than expected.

Agriculture is the sector most vulnerable to the seasonal nature of drought. Most cropping is rainfed and soil moisture deficits build up quickly in hot dry conditions. Further deficits will subsequently impact water resources, forests and other ecosystem services, and hydro power. A severe drought which brought all these issues into sharp focus was in the 2009-2010 season. Such conditions reveal the society's vulnerable groups and sectors which include not only the farmers (in particular smallholders), but

also the poor, children, rural and indigenous communities, downstream users and the economically important tourism industry.

The drive to reduce risk in agriculture and water resources from natural and other hazards, through policy-making, planning and adaptation, is well supported by a number of frameworks and led by a number of regional institutions and supporting projects at the national and regional levels. Three very relevant frameworks are the Comprehensive Disaster Management Strategic Framework that is guided by the Hyogo Framework for Action (HFA), the CARICOM Regional Framework for Achieving Development Resilient to Climate Change: 2011-2021, and the Jagdeo Initiative that directly speaks to the development and sustainability of agriculture. Agricultural authorities in the region, along with regional organisations, are well guided in the development of products, tools, best practices and advice for the management of drought risk.

Many regional and national programmes have initiated responses to build resilience against the impacts of drought in some of the countries. Policies and plans to adapt to drought have been developed driven by the desire to effectively manage water resources. However, too many of these are still in draft, poorly implemented, or in need of review. In other countries in the region, they are still being developed. Many of the policies and plans elaborate the key elements for drought resilience as outlined during the High Level Meeting on National Drought Policy, which was an international meeting held in 2013 to promote the development of national drought policies. These key elements include:

- Promoting standard approaches to vulnerability and impact assessment,
- Implementing effective drought monitoring and early warning systems,
- Enhancing preparedness and mitigation actions, and
- Implementing emergency response and recovery measures that reinforce national drought management policy goals.

In 2009, the Caribbean Drought and Precipitation Monitoring Network (CDPMN) was established, through a project titled the Caribbean Water Initiative (CARIWIN), with the following expected outcomes:

- Monitoring the status of water via climatological, hydrological, and other indicators,
- Undertaking projections with lead times of up to 3 months,
- Posting warnings and disseminating them to key agencies, governments and media, in partner countries, and
- Developing adaptation and response strategies to drought (and excessive rainfall).

The CDPMN was launched just months prior to the worst drought in decades in 2009 to 2010, which forced CARICOM Heads of Governments to meet to seek solutions to mitigate the impacts of future events. Although it was still under establishment, the CDPMN was able to provide advice for regional governments to reduce the impacts of this event by monitoring rainfall and reviewing its seasonal forecasts. The event also led the Caribbean Disaster Emergency Management Agency (CDEMA) to add drought to its list of disasters. Furthermore, the drafting of Drought Early Warning Information

Systems (DEWIS) for Jamaica and Grenada and the elaboration of terms of reference for a National Drought Monitoring Network that forms part of an existing National Flood and Drought Mitigation plan for St. Lucia were the culmination of a training on drought monitoring and planning funded by the Government of Brazil. Finally, a drought alerting product was launched in 2014 and continues to be improved and modified with the support of stakeholders.

Integrated Water Resources Management (IWRM) has also been widely promoted across the region. This helps to build resilience to drought once the policies, strategies and plans are adopted and implemented. Various Acts and policy instruments have helped to identify lead and collaborating agencies that would develop or implement policies and plans on water resources management. Projects such as Integrating Watershed and Coastal Area Management (IWCAM) in the Small Island Developing States (SIDS) and conventions and programmes, such as the United Nations Convention to Combat Desertification (UNCCD) and the SIDS 2014 preparatory programmes, have assisted several Caribbean countries in thinking through and drafting policy documents. Plans for Agriculture Disaster Risk Management (ADRM) also exist, albeit not widespread, but they have little focus on drought even though most crops are rainfed and are most at risk from limited water availability. Hurricanes and flooding are given greater priority. This would imply that plans for ADRM in the region should be reviewed and strengthened to incorporate drought risks.

Respondents to a questionnaire on drought risk management mechanisms prioritised demand management options over supply enhancement options; e.g. public awareness and education or water rationing, both short-term measures. Lower implementation costs may explain this preference. The most popular long-term measures were monitoring and forecasting, followed by increased water collection and storage, and applying water-saving irrigation techniques. Many of these measures are implemented to some degree throughout the region. However, there are key barriers to policy-making and planning to upscale their implementation. These include:

- Inadequate policy, regulatory, and institutional environment that includes poor national coordination,
- Lack of capacity at every level that hinders the work necessary for planning, reviewing of policies and plans, and implementation,
- Weakly coordinated land management that enhances land degradation,
- The value of water, that questions restrictions on a public good that should be freely accessible,
- Lack of transparent mechanisms to address up-stream/down-stream user conflicts, and
- Lack of finance.

Identifying and then seeking to remove these barriers may hold the key to more effective management of water resources, in turn leading to reduced vulnerability to drought.

Acronyms and abbreviations

ADRM	Agriculture Disaster Risk Management
APUA	Antigua Public Utilities Authority
BADMC	Barbados Agricultural Development and Marketing Corporation
BWA	Barbados Water Authority
CACOF	Central America Climate Outlook Forum
CAMI	Caribbean Agrometeorological Initiative
CARDI	Caribbean Agricultural Research and Development Institute
CariCOF	Caribbean Climate Outlook Forum
CARICOM	Caribbean Community
CARIWIN	Caribbean Water Initiative
CARPHA	Caribbean Public Health Agency
CCA	Climate Change Adaptation
CCCCC	Caribbean Community Climate Change Centre
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CDEMA	Caribbean Disaster Emergency Management Agency
CDERA	Caribbean Disaster Emergency Response Agency
CDM	Comprehensive Disaster Management
CDPMN	Caribbean Drought and Precipitation Monitoring Network
CEHI	Caribbean Environmental Health Institute
CIMH	Caribbean Institute for Meteorology and Hydrology
CMI	Crop Moisture Index
COTED	Council for Trade and Economic Development
CPT	Climate Predictability Tool
CRFM	Caribbean Regional Fisheries Mechanism

CSGM	Climate Studies Group Mona
CWWA	Caribbean Water and Wastewater Association
DEWIS	Drought Early Warning and Information Systems
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EMDAT	Emergency Events Database
ENSO	El Niño Southern Oscillation
FAO	Food and Agricultural Organization of the United Nations
GEF	Global Environment Facility
GEF-IWCAM	Global Environment Facility Integrating Watershed and Coastal Area Management Project
GDP	Gross Domestic Product
GIS	Government Information Service
GWP-C	Global Water Partnership-Caribbean
HFA	Hyogo Framework for Action
HMNDP	High Level Meeting on National Drought Policy
IICA	Inter-American Institute for Cooperation on Agriculture
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society
IWCAM	Integrating Watershed and Coastal Areas Management
IWRM	Integrated Water Resources Management
NaDMA	National Disaster Management Agency, Grenada
NAWASA	National water and sewage authority
NDMC	National Drought Mitigation Center
NDMC	National Drought Management Committee
NDMN	National Drought Monitoring Networks
NDVI	Normalised Difference Vegetation Index

NEMO	National Emergency Management Organisation
NWC	National Water Commission, Jamaica
ODPEM	Office of Disaster Preparedness and Emergency Management, Jamaica
OECS	Organisation of Eastern Caribbean States
PDSI	Palmer Drought Severity index
SDG	Sustainable Development Goals
SIDS	Small Island Developing States
SPEI	Standardised Precipitation and Evapotranspiration Index
SPI	Standardized Precipitation Index
SUPSI-IST	Institute of Earth Sciences, University of Applied Sciences of Southern Switzerland
TMAC	Technical Management Advisory Committee
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
VHI	Vegetative Health Index
WASA	Water and Sewerage Authority
WASCO	Water and Sewerage Company
WMO	World Meteorological Organization
WRMA	Water Resource Management Agency

1. Introduction

The Caribbean region is often described as being one of the two most at risk in the world when it comes to natural disasters. Events related to these hazards challenge sustainable development activities as they force regional governments to reallocate funds from national development to disaster recovery. Most Caribbean States are Small Island Developing States (SIDS) or small economies like Guyana (in South America) and Belize (in Central America). As a result, increasing the region's resilience to natural hazards is critical.

The Caribbean islands vary in population, size, income, and ethnic composition, but they all share a common heritage in agriculture. In the past, the economies of the Caribbean islands were based on cultivation of tobacco and cotton, but were later transformed to sugarcane-based economies. In recent decades in many Caribbean States, the tourism and services sectors have become economic forces while agriculture has declined in relative importance, both in terms of contribution to GDP and the share of the labour force. Some of the problems facing the agriculture sector include losses in preferential markets (e.g., sugar and bananas in Europe); inefficient production, slow traditional farming methods on predominantly small holdings, and serious soil erosion in the mountainous islands; slow technological advances (e.g., supplementary irrigation systems), pests and diseases; and shortage of inputs. Nevertheless, a good proportion of the economically active population is still involved in agriculture. The agricultural employment is especially important for the livelihoods of the poor, with the sector employing 15 to 20% of the workforce in many Caribbean States (Table 1). However, only a few countries can boast of agriculture's GDP contribution being more than 10%, with only two countries over 20%. Weather and climate impacts are added stresses to this vulnerable sector, but there is insufficient information on hazards, like drought, being made available to reduce the risk associated with these events or to take advantage of more suitable conditions.

The most frequently occurring natural hazards in the Caribbean are climate related. The region's vulnerability to climate related hazards is manifested in loss of life, and annual economic and financial losses that result from strong winds, flooding, and drought. Between 1970 and 2000, the Caribbean region suffered direct and indirect losses estimated between US\$700 million and US\$3.3 billion due to natural disasters associated with weather and climate events (Charvériat, 2000). Quoting the then Minister of Agriculture of Guyana at a symposium focused on farmer insurance, the *Kaitaur News* (2010) reported that events like droughts and floods “...can put a tremendous amount of pressure on Guyana's productive capacity, its economic stability, and its budgetary planning systems, and compromise food security both regionally and nationally. Furthermore, they have the frightening power to reverse any gains on poverty reduction which is predominantly concentrated in Guyana's rural areas, where agriculture is the main source of income”. Similar sentiments would apply to the other Caribbean States when it comes to climate-related hazards.

With limited volumes of freshwater and conflicting and competing uses, the World Economic Forum (2013) suggested water supply crises as one of the highest impacting and the most likely risk facing the planet. Drought which originates from an anomalous decline in precipitation enhances the potential for such crises. This is particularly true

TABLE 1
Agriculture's contribution to GDP and employment in the Caribbean

Country	Agriculture (% of GDP)		Agricultural employment (% of total)	
	2000	2012	2000-02	2009-11
Antigua and Barbuda	2	2	2.8	-
Barbados	2	1	4.0	3.3
Belize	17	13	27.5 ¹	-
Cuba	8	5	21.7	19.7
Dominica	14	15	21.0	-
Grenada	6	6	13.8 ¹	-
Guyana	31.4 ¹	-	21.4	-
Haiti	27.9 ¹	-	50.6 ¹	-
Jamaica	5.5 ¹	-	20.1	17.6
Dominican Republic	7	6	15.9	14.5
St. Kitts and Nevis	2	2	0.2	-
St. Lucia	6	4	12.2	-
St. Vincent & Grenadines	8.8 ¹	-	15.4 ¹	-
Suriname	10.67 ¹	-	6.1 ¹	-
Trinidad and Tobago	1.1 ¹	-	6.9 ¹	-

Source: World Development Indicators, World Bank, (2013); Trotman *et al.*, (2009)¹

in water-stressed countries, where the Caribbean can account for seven¹ of the top 36, some of which might be surprising to many, and all with the highest possible water stress scores (WRI, 2013). Also, based on FAO's definition of a water scarce country as having freshwater resources of less than 1000 m³ per capita, the Caribbean island of Barbados finds itself in the top 10 list of countries. Agriculture, which accounts for as much as 70% of global use of freshwater (World Water Assessment Programme, 2012), is a sector that is greatly at risk during drought. The FAO reported that drought ranks as the single most common cause of severe food shortages in developing countries, and is regularly listed as a cause in the majority of food emergencies (FAO, 2003). In a region like the Caribbean, which mostly practices rainfed agriculture, the percentage of freshwater use by agriculture would be lower, but also signifies that the sector is vulnerable to the variable nature of its rainfall.

Effective water resources management is paramount to the efficient use of the resource. The Caribbean region is one where limited human resource capacity, untrained and unskilled work-force, lack of financing, and lack of or poor national coordination, policy-making and planning impact the effective management of water resources. Furthermore, effective water resources management in the Caribbean for hazards like drought has to embrace the reality that each country and watershed is unique, including the decline in rainfall and the demand for water. Water is an integral part of the ecosystem, a natural resource, and a social and economic good, whose quantity and quality determine the nature of its utilisation (UNCED, 1992). Many initiatives in the Caribbean, particularly the Integrating Watershed and Coastal Area Management in

¹ Antigua and Barbuda, Barbados, Dominica, Jamaica, St. Lucia, St. Vincent and the Grenadines, Trinidad and Tobago. <http://www.wri.org/blog/world%E2%80%99s-36-most-water-stressed-countries>.

the Small Island Development States (SIDS) of the Caribbean (GEF-IWCAM) project, have lobbied to establish policies and plans related to Integrated Water Resources Management (IWRM), with some focus on managing drought. The IWCAM Project, with its objective to “...strengthen the commitment and capacity of the participating countries to implement an integrated approach to the management of watersheds and coastal areas”², began in 2005 with funding provided by the Global Environment Facility (GEF). Through its Draft national IWRM roadmaps (e.g., CEHI and IWCAM 2007, 2008, 2010; CEHI 2007 for Grenada, Barbados, Saint Lucia and Union Island St. Vincent and the Grenadines) and local (community) projects, it is made clear that policy and planning in this area need much attention to reduce vulnerability and avoid potential water crises, including during times of drought.

The main objective of this report is to review existing information on drought characteristics and management in the Caribbean region, identify relevant national and regional agencies and focal points involved in drought management, and gather information on their work at the national and regional levels. This analysis was conducted using three approaches:

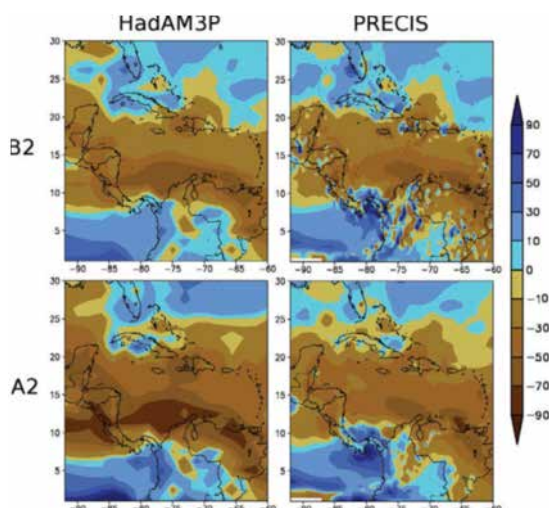
- Review of literature associated with drought and water management in the Caribbean agriculture industry,
- Illustrate work related to drought and water (resources) management, particularly through regional projects, as these reveal strengths and weaknesses of drought management,
- Analyse responses to a questionnaire, completed in 2014, sent to producers/farmers and service providers who respond to drought situations or provide information for decision-making. The survey was conducted by the Caribbean Institute for Meteorology and Hydrology (questionnaire in Annex I). The questions seek to understand perceptions and institutional perspectives on drought impacts and management and the means to build resilience. Service providers include water utility companies, water resources management agencies, agriculture extension services and national meteorological services. Although the number of responses is limited, they do provide important insights into perceptions and management activities related to drought in the region. The number of producers and service providers by category and country are listed in Annex II.

² <http://iwcam.org/>

2. Rainfall – present and future

Rainfall in the Caribbean islands is characterised by a wet season and a dry season each year. The wet season normally begins in May to June and finishes in November to December. At least 70-80% of the rainfall occurs, on average, during this season (Enfield and Alfaro, 1999). In Guyana, in particular the north, the influence of the Inter Tropical Convergence Zone is responsible for two wet and two dry seasons per year. The dry season normally presents a period where relatively low soil water levels can be expected, with associated increased cost of irrigation. The seasons, both wet and dry, express much variability in commencement, duration, and rainfall quantities. Also, it is not unusual to experience significant dry spells during the wet season or very wet spells in the dry season (Trotman, 1994). Cycles of 50 to 60 years (Burton, 1995) suggest phases of high and low rainfall, with significant inter-annual and inter-decadal variability. During the low phases, water shortages will be more frequent, whilst flooding will be more common during the high phases. These extreme climate events impact heavily on sectors, such as agriculture and food security, water resources, disaster management and tourism. Caribbean rainfall variability and extremes (including droughts) are often a result of the El Niño Southern Oscillation (ENSO)³ (in particular Pacific-Atlantic gradients in Sea Surface Temperatures – Enfield and Alfaro, 1999; Giannini *et al.*, 2000; Giannini *et al.*, 2001; Taylor *et al.*, 2002; Stephenson *et al.*, 2008; Taylor *et al.*, 2011); the North Atlantic Oscillation (Charlery *et al.*, 2006) and North Atlantic High Pressure (Gamble *et al.*, 2007); the Caribbean Low-Level Jet (Cook and Vizy, 2010; Taylor *et al.*, 2012); and the Atlantic Multi-decadal Oscillation on a decadal scale (Stephenson *et al.*, 2014). Within these influences there is much variation. Caribbean variability is likely to be much greater because of anthropogenic climate change increasing the threat to the process of sustainable development of Caribbean States due to resource vulnerability.

FIGURE 1
Annual mean changes in precipitation for 2071–99 with respect to 1961–89 (%) as simulated by HadAM3P (left) and PRECIS (right). Top (bottom) shows results for the B2 (A2) emission scenario.



Source: Climate Studies Group Mona, University of the West Indies Mona Campus, Jamaica.

Climate change poses great concerns for the future, particularly extreme rainfall events. The IPCC in its Fourth Assessment Report (Mimura *et al.*, 2007) projects a 90% chance that temperatures will rise across the Caribbean, up to 2 to 2.5°C (Christensen *et al.*, 2007) by the end of the century. This is similar to the warming that Hall *et al.* (2012) suggest, of 2 to 3°C. They also concluded that the mean temperature would be accompanied by an increasing number of warm days and warm nights. With greater uncertainty in the rainfall projections, particularly in the Lesser Antilles, it is

³ The ENSO is often linked to Caribbean droughts. See Figure 2

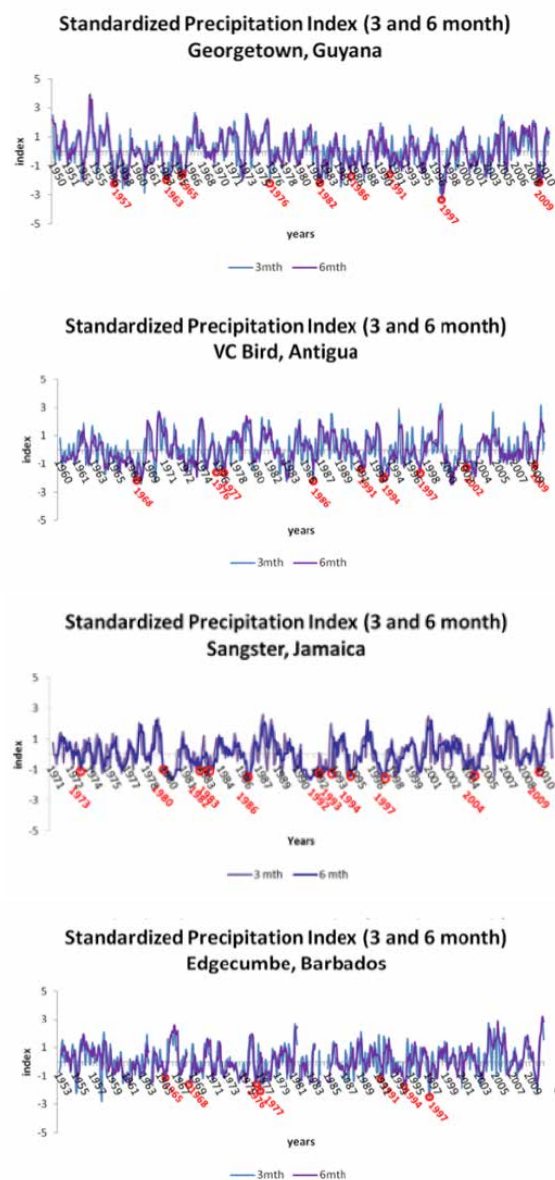
projected that rainfall is likely (66%) to decrease in the Greater Antilles during the months from June to August. Most models predict a decrease in annual precipitation in the region of 5 to 15% (Christensen *et al.*, 2007). Further, many Caribbean-based studies (Taylor *et al.*, 2013; Taylor *et al.*, 2011; Campbell *et al.*, 2011; and Centella *et al.*, 2008) agree with the reduction (Figure 1). The authors indicate that this will occur during the wet season months, south of 21 to 24°N, but that rainfall will increase north of 21 to 24°N latitude. It is therefore anticipated that droughts will become more frequent in the future. Increased drought risk will be exacerbated by increased pumping during drought and increasing salinity in underground water supplies (Cooper and Bowen, 2001). In the future, salt water intrusion into aquifers is also likely due to global sea level rise (Christensen *et al.*, 2007).

Toba (2009) estimated that the total annual impacts of potential climate change on all CARICOM Member States and Associated Members by ca. 2080 will be US\$11.2 billion (referenced to 2007). In addition, the report estimated the total Gross Domestic Product (GDP) in 2007 would be approximately US\$99.3 billion, meaning annual losses would amount to about 11.3% of the total annual GDP of all 20 CARICOM Member and Associate States. Of these annual losses, US\$3.8 million is attributed to drought.

Is the Caribbean experiencing these globally projected climates? Recent work by Stephenson *et al.* (2014) illustrates that, in general, the Caribbean is experiencing increased temperatures, with stronger warming trends at night (as indicated by minimum temperatures) than during the day (as indicated by maximum temperatures). The authors also report that warm days, warm nights, and extreme high temperatures are more frequent, with fewer cool days, cool nights and extreme low temperatures. This suggests that the warming trends projected are already being experienced. The same work reported that the rainfall changes are less consistent with only weak significant positive trends in intensity. So, the projection of declining annual rainfall is not being experienced yet.

FIGURE 2

Three and six month SPI values for stations in the Caribbean. Values less than -0.8 indicate periods of at least moderate meteorological drought, with values less than -1.6 indicating at least extreme drought for the two time intervals. The red highlighted years indicate droughts associated with ENSO. Droughts of these lengths are very significant to crop production in particular, as most annual crops complete their life cycles within these periods



Source: CIMH

However, during the past decades, the Caribbean has experienced several drought events (Figure 2), and particularly so in years with El Nino events. Notable periods were 1957, 1968, 1976-77, 1986-1987, 1991, 1994, 1997-1998, and 2009-2010. The impacts of Caribbean droughts tend to be offset by the next wet season, therefore making them more seasonally-impacting in nature. This is unlike large continents where impacts can be felt for a stretch of many years (though sometimes interspersed by briefly relieving wet spells), as was experienced in the Sahel between 1967 and 1984 during the well-known Sahelian drought (Glantz, 1987). Maybe, this is one of the reasons, along with its slow onset nature, that droughts often go unnoticed, and why less attention is paid to drought as a hazard in the Caribbean compared to more high impact, frequent hazards such as hurricanes and floods. However, the agriculture and water sectors suffer because of these seasonal events. It is particularly so if climatological drivers trigger an early end (early beginning) to a wet (dry) season that produce lower than normal rainfall and/or a late end to a dry season.

In 2009, the latter part of the rainy season was drier than normal and was followed by a drier than normal dry season (Farrell *et al.*, 2011), resulting in the worst drought in 40 to 50 years, with severe impacts across many sectors (see Section 6.2). If the future projections of declining rainfall are realised, and with increasing temperatures, the lower rainfall regime would be exacerbated, enhancing future drought impacts by increasing evapotranspiration and providing an even more conducive environment for bush fires. Such were the conditions in 2009-2010, where higher than average temperatures accompanied severe to exceptionally dry conditions (Table 2).

TABLE 2
Mean daily temperatures, °C, from October 2009 to May 2010 in at three stations in the Caribbean

Month	MBIA, Grenada		ET Joshua St. Vincent and the Grenadines		Piarco, Trinidad and Tobago	
	Mean	2009-2010	Mean	2009-2010	Mean	2009-2010
October	28.0	28.2	27.9	28.6	27.2	28.2
November	27.5	27.9	27.5	28.1	26.8	27.6
December	26.9	27.5	26.9	27.8	26.2	26.8
January	26.5	27.1	26.3	27.4	25.6	26.2
February	26.5	27.2	26.2	27.8	25.6	26.7
March	26.9	27.9	26.6	28.6	26.1	27.9
April	27.7	28.4	27.3	28.2	26.8	28.5
May	28.2	28.2	28.0	28.5	27.4	28.5

Source: CIMH

3. Drought history

Two of the most severe Caribbean droughts in terms of intensity, geographical extent and economic impact on agriculture occurred in 1997-1998 and 2009-2010. Many of the impacts reported by producers and service providers pertain to these two events.

In 1998, Guyana experienced water rationing, cessation of logging and river transport in some places and the loss of livestock due to drought associated with El Niño conditions (National Drought Mitigation Center, 1998). Rice farmers were forced to leave 35% of their rice fields uncultivated and more than 1,500 Amerindian families in Southern Guyana reliant on agriculture were affected by this event (USAID, 1998). In other cases, Jamaica experienced below normal rainfall from December 1996 into 1998 with the greatest damage occurring in the agricultural sector (more than US\$8 million in losses) with a significant portion of the losses due to bushfires (Ministry of Agriculture, Government of Jamaica, 2010). In late 1997, losses in the sugar sector prompted the Jamaican government to offer the sector a US\$100 million assistance package. Also, in 1998, between April and July, Cuba recorded the lowest rainfall since 1941, with significant impacts on agriculture.

As indicated in Section 2, drought occurred also on many seasons other than 1997-98 and 2009-10. Between October 1999 and March 2000, with rainfall less than 25% of the average in some places, Jamaican authorities reported crop losses of approximately US\$6 million (Jamaican Information Service, 2007). One of the islands making up the nation of Grenada – Carriacou – experienced less rainfall than the main island. The island which accounts for 30% of the nation's livestock production experienced losses of 20% and 40% due to drought in 1984 and 1992, respectively (UNFCCC, 2000). It was reported that drought in 1984 in Antigua and Barbuda forced authorities to barge water from neighbouring islands (Cooper and Bowen, 2001), while hundreds of livestock died, and farms stopped work (Environment Division, Ministry of Tourism & Environment, 2000). The Cooper and Bowen report also indicated that, due to a lack of a clear policy during severe drought in Antigua and Barbuda, water from wells and reservoirs used by some farmers was made available for municipal use instead, at a time when their own production was seriously threatened. In Haiti, the poorest Caribbean territory and one that still struggles after a major earthquake in 2010, Thomas Reuters Foundation (2013) reported that a food crisis, enhanced by lack of rainfall and seeds, forced farmers to sell young livestock and charcoal and others to survive on food aid. Also in 2013 in Jamaica, drought was reported to have adversely affected 1,606 hectares of the 4,564 hectares under cultivation in select parishes, with crop yield reductions from 2% to 70% (Fulton, 2013).

However it was the severity of the 2009-2010 drought that led to significant water shortages across the region, which in turn resulted in agricultural and other losses from key economic sectors that affected many livelihoods. The event forced the region to consider, particularly in light of climate change projections, a drier Caribbean by the end of the century as a disaster that has to be planned for and managed more strategically.

3.1 2009-2010 DROUGHT

This drought event occurred at an untimely juncture as many Caribbean states were experiencing either slowly growing economies or economic decline. The drought event threatened to further reduce their rate of economic growth or increase the rate of economic contraction. Further, the event exacerbated conditions in existing water stressed countries (e.g., Antigua and Barbuda, and Barbados) and local communities. This resulted in various interventions by water resources authorities that included use-restrictions aimed at conserving water. It was reported that impacts of this drought were still being felt in Cuba up until April, 2011.⁴

As a result, the drought and its impacts on the water sector were addressed at the July 2010 meeting of the CARICOM Heads of Government and subsequently at a special meeting on water issues held by the CARICOM Council for Trade and Economic Development (COTED) in September 2010. To facilitate the discussion at both meetings, the CARICOM Secretariat commissioned its specialised agencies with responsibility for water issues – The Caribbean Environmental Health Institute (CEHI) and the Caribbean Institute for Meteorology and Hydrology (CIMH) – to prepare a status report on the drought. The report informed the Heads of Government of (i) the current situation regarding the drought, (ii) perceived reasons for the late recognition of the prevailing drought conditions across the Caribbean region, (iii) recommendations for the water sector to mitigate the short and mid-term impacts of the drought, and (iv) policy recommendations for mitigating the severity of future droughts on national economies and sustainable socio-economic development (Farrell *et al.*, 2010).

Some of the impacts of the 2009 to 2010 drought that prompted the two high-level CARICOM meetings, predominantly taken from Farrell *et al.* (2010) except where indicated, are summarized below.

SIGNIFICANT DECLINE IN RAINFALL

Rainfall at Maurice Bishop International Airport in Grenada in 2009 was the lowest in 25 years of recording. Areas in the interior of the island that usually experience above 4,000 mm in the rainy season, with no dry months, experienced 1-2 dry months in 2009. Between March 2009 and February 2010 rainfall was less than 50% of the average, with February 2010 in particular experiencing 0.03% of the monthly average. Impacts on rainfall were mirrored across the majority of the Caribbean to varying degrees, in particular the eastern Caribbean, where rainfall was in the lowest 10% (some as record lows) of recorded totals for February. Cuba reported that this event was the worst ever recorded in the western half of the island, resulting in severe water deficits.

IMPACTS ON AGRICULTURE

In Guyana, the largest food producer in the Caribbean Community (CARICOM), the President allocated US\$1.3 million to bring relief to farmers of Region 2 in February 2010. In some cases, the desperation for water by some rice farmers resulted in them pumping saline water to about 60 hectares of rice lands even though they knew the potentially grave long-term consequences of such actions. In Region 5, it cost the government US\$16,000 per day to operate pumps and conduct other works essential for delivering water (e.g., excavating and re-routing canals).

⁴ Cuba faces its worst drought for fifty years (14th april 2011). BBC news. Available at: <http://www.bbc.com/news/world-latin-america-13079773>

By March 2010, on the island of Dominica, banana production declined by 43% compared to the previous year, resulting in a significant reduction in banana exports and foreign exchange. In St. Vincent and the Grenadines, agricultural production was 20% lower than average and in Antigua and Barbuda; the 2010 onion crop yielded 25% less and 30% of the tomato crop was lost. In Trinidad and Tobago, regular grazing lands were taken over by low quality nutrition species over the drier more saline lands. Mastitis, the inflammation of the mammary gland and udder tissue of mammals, occurred in Trinidad and Tobago cattle, due to the lack of water for sanitising.⁵

SIGNIFICANT INCREASES IN FOOD PRICES

In St. Vincent and the Grenadines, prices of tomatoes were ECD⁶\$2.35 per pound in February 2010. During March 2010, the prices rose to ECD\$6.00 per pound. In Trinidad and Tobago, food prices increased 6.9% in March, 6.3% in February and 2.7% in January 2010. The Central Bank of Trinidad and Tobago specifically mentioned an increase in the price of fruit in March 2010 by 60.8%, up from 40.7% in February, partly related to the severe drought.

INCREASE IN BUSH FIRES

The destructive potential of bush fires to natural habitats, agriculture, and even domestic houses and other buildings was significant. In Dominica, the fire department attended to 160 fires (mainly bush fires) during the 1st quarter of 2010; this was significantly greater than 103 fires for the entire year 2009. In St. Vincent and the Grenadines, seven different farms reported the destruction of at least 0.8 hectares of crops. In Grenada, there was a 150% increase in the amount of bush fires that also had an impact on agricultural production and cultivation with a number of farms being affected. The irony of these situations is that the same scarce commodity at that time (water) had to be used to reduce the risks to the human population and property. As a result of the bush fires that destroyed large areas of citrus farms, it is reported that imports of citrus increased from TT⁷\$38 million in 2008 to more than TT\$50 million by the end of the 2010 drought. Denuded slopes from bush fires provided a catalyst for land slippage and degradation once heavy rains returned, as was the case in Dominica on 24 May, 2010, when three persons were killed.

DECREASED WATER STORAGE AND FLOWS

Several Caribbean countries, including Jamaica, Dominica, and St. Lucia, reported significantly lower than normal flows in many of their streams. In St. Lucia, the only large reservoir was depleted, threatening to run out of water within a short period potentially affecting more than 50% of the population and the majority of the tourism and business community (CEHI and GEF-IWCAM, 2010). In Antigua and Barbuda, the Potswork Reservoir, which is the island's largest surface water impoundment, providing most of the 22% of annual water supply derived from surface water sources on the island, was all dry by March 2010. Grenada shipped 340,000 litres of drinking water to its dependency, Carriacou. In the case of Barbados, water levels in aquifers reached low enough levels to prompt the Barbados Water Authority to implement Stage 1 of its Drought Management Plan (see also section 7.2) in March 2010, urging customers to practice good water use habits and to employ voluntary conservation measures. In Trinidad and Tobago, farmers were asked to pay a fee to the state utility,

⁵ Presentation made on behalf of The Ministry of Agriculture of Trinidad and Tobago at the Caribbean Water Monitor/Drought and Precipitation Monitoring Workshop, Ministry of Agriculture's Research Division, Centeno, Trinidad and Tobago, 12 May, 2010.

⁶ Eastern Caribbean Dollar. 1 USD = 2.688 ECD as of 10 March 2014.

⁷ The Trinidad and Tobago Dollar. 1 USD = 6.275 TT as of 10 March 2014.

Water and Sewerage Authority (WASA), to extract water from rivers, streams and other water courses that were not being used for potable water⁸. This as the Caroni Arena and Navet reservoirs fell to almost half their usual volumes in April 2010 (personal Communication, Ricardo Ramdin, Water Resources Agency). With the impacts of drought being felt into April 2011 in Cuba, many of its reservoirs were reported to be at one-fifth of their capacities by that time, with poor, leaking pipe networks exacerbating the situation.

CONCERNS ABOUT ENERGY OUTPUT

Concerns were also raised over the reduction in output from the energy sector, as drought impacts reduced the potential for hydro-power. In St. Vincent and the Grenadines, hydro power contribution to total electricity production fell in January and February 2010 to 8.2% and 12.0%, respectively. These are compared to January 2008 and 2009 when its contribution was 17.4% and 28.1%, respectively, and in February 2008 and 2009 when it was 21.3% and 28.7%, respectively.

⁸ From Newsday PAY FOR RIVER WATER March 16 2010. <http://www.newsday.co.tt/news/0,117387.html>

4. Vulnerability to drought

The resources of SIDS and small economies like those in the Caribbean are vulnerable to environmental hazards such as climatic extremes and the added threat of these due to climate change, which diminishes the potential for sustainability of their development. As far as the hydro-meteorological hazards are concerned, floods rather than droughts are the extreme that impacts the Caribbean the most. However, as indicated in Table 3, drought impacts are significant enough in the Caribbean to warrant attention and mitigation. These data do not include information from the worst recorded drought in 2009-2010, but suggest that droughts are capable of affecting many hundreds of thousands of people and causing millions of dollars-worth of damage.

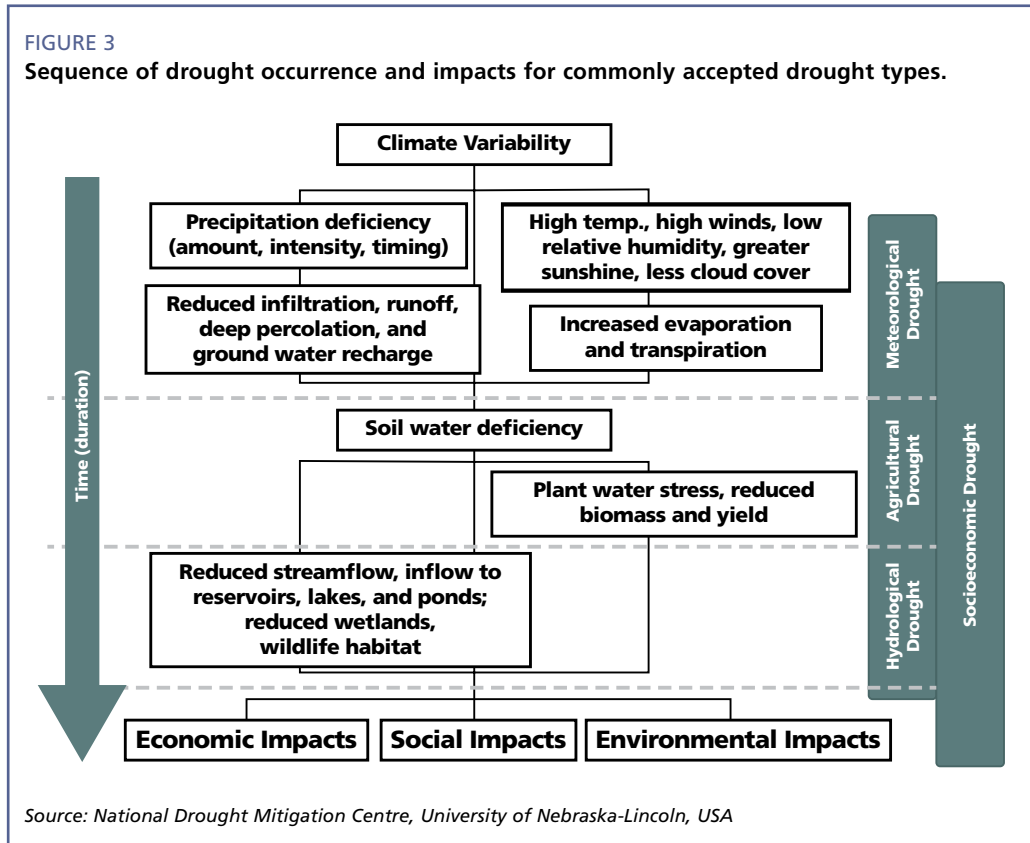
TABLE 3
Impacts of historical drought events in select Caribbean countries^a

Country	Year	No. of people affected	Damage (000 US\$)
Antigua and Barbuda	1983	75,000	
	1998	820,000	
Cuba	2004		3,139
	1997	607,200	29,000
Guyana	1974	1,000,000	
	1977	507,000	
Haiti	1992	450,000	
	1968	100,000	500
Jamaica	2000	-	6,000

Source: EMDAT database <http://www.emdat.be/result-country-profile>

^a Taken from the EMDAT database <http://www.emdat.be/result-country-profile>

Wilhite (2007) suggests that increasing societal vulnerability to recent droughts results from “...*unsustainable resource use and growing pressures on natural resources*”, including limited water supplies. Drought itself stems from a deficiency in rainfall, which over time impacts other important sectors, particularly agriculture and water resources, cascading into other impacts - economic, social and environmental (Figure 3). The impacts are manifested at varying spatial scales targeting the most vulnerable. One of the first impacts is expressed as low soil moisture that can expose plants to water stress. In fact, water stress in plants can be witnessed after only a few consecutive dry days (a dry spell). So, without a supplementary water supply or measures that can conserve water, agriculture is very vulnerable to drought. With more extended dry periods, water sources would be impacted, surface water first as it is exposed to the atmosphere’s drying elements (solar radiation, low atmospheric humidity, wind). Then, with longer duration, groundwater resources would be affected. Even though set in a region of sub-humid to humid climate, with seemingly adequate rainfall when the total rainfall is considered, the dry seasons present challenges to agriculture and water resources, particularly as in most Caribbean countries, the primary sources of fresh water are surface waters (Table 4).



The two most vulnerable sectors to drought are agriculture, which includes forestry and fisheries, and water resources. The steps illustrated in Figure 3 are very applicable in the Caribbean context.

TABLE 4
Water supply sources of Caribbean countries

Countries	Water supply		
	Surface	Ground	Desalination
Antigua			XXX
Barbados		XXX	
Dominica	XXX		
Grenada	XXX		
Guyana	XXX		
Haiti	XXX		
Jamaica		XXX	
Saint Vincent & the Grenadines	XXX		
Saint Lucia			
Trinidad and Tobago	XXX		

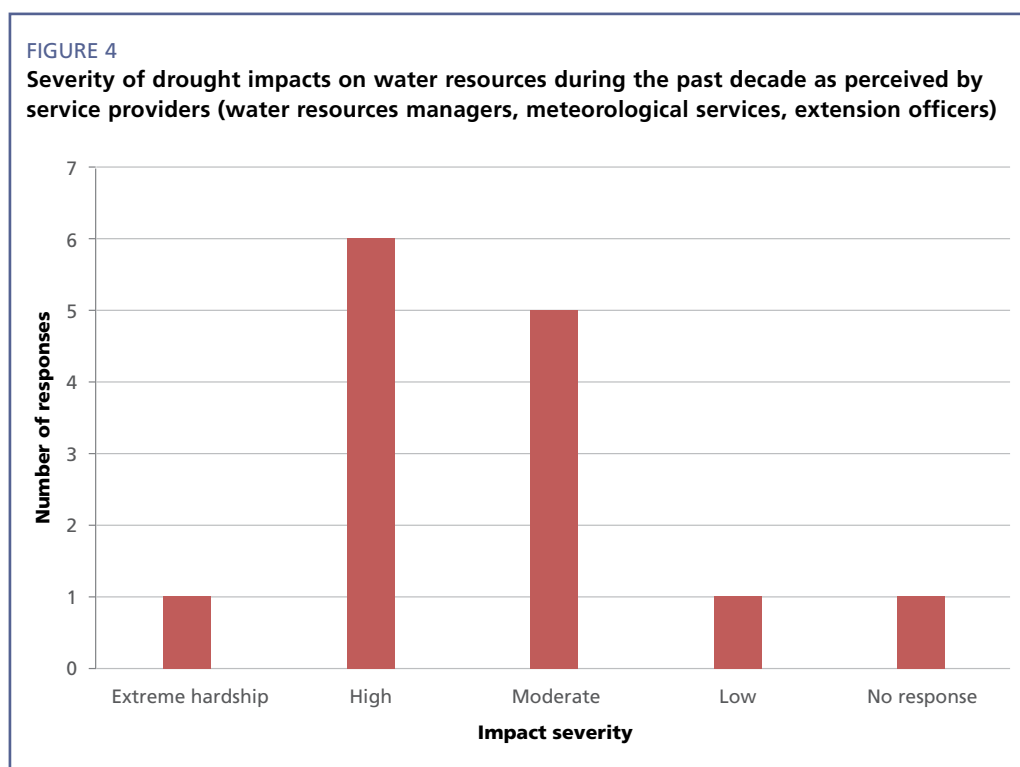
XXX signifies the largest source

N.B. All countries practise rainwater harvesting to varying degrees. In Grenada, the dependencies of Carriacou and Petit Martinique are almost 100% reliant on this source. Also, desalination is the main source in the Grenadines islands of St. Vincent and the Grenadines, but on mainland St. Vincent, nearly 100% is surface water.

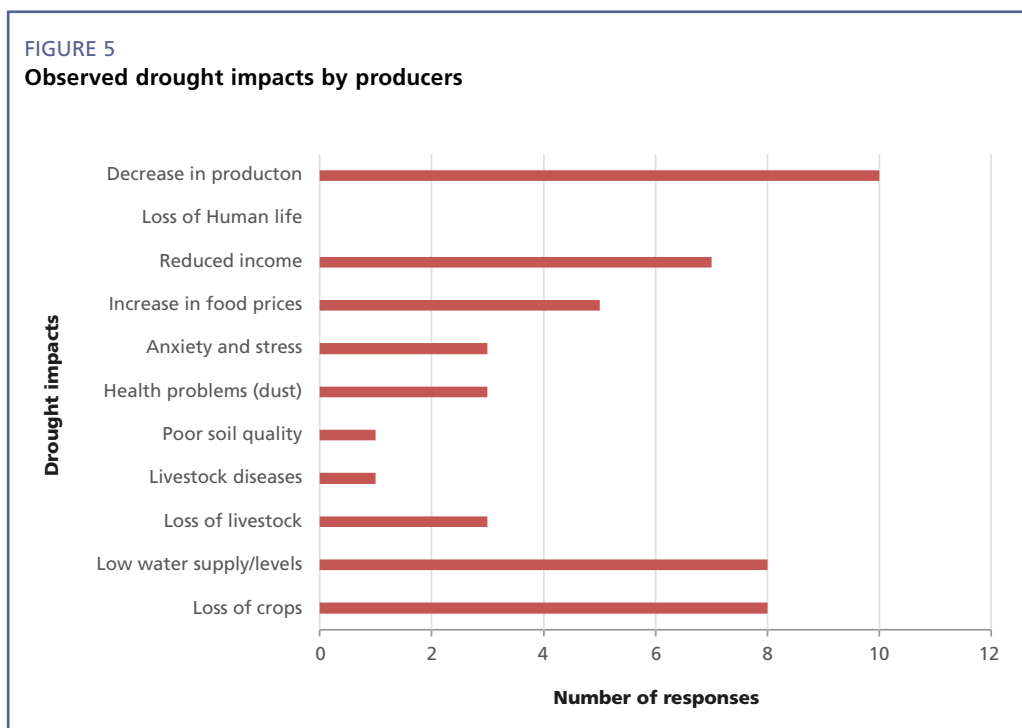
Source: Global Water Partnership, 2014.

4.1 PERCEPTIONS OF DROUGHT IMPACTS

The severity of drought impacts can vary depending on measures put in place prior to, during and after a drought. Thus, policy making, planning and implementation are important. The survey/questionnaire sent to various service providers (i.e., water resources managers and providers, agriculture extension officers and meteorological services throughout the Caribbean) produced varied results, but with the majority of respondents rating drought impacts as moderate to high (Figure 4). Countries that experience high impacts included Antigua and Barbuda, Grenada, Jamaica, whereas Barbados, Dominica, Guyana and Trinidad and Tobago experience moderate impacts (See Annex III, noting that there may have been more than one respondent in each country when comparing the results with Figure 5). Of the options provided for consideration (Annex I), there appears to be less concern about loss of human life, livestock diseases and health problems. However, there was a prevalence of loss of crops and livestock, decreased production, low water levels, rise in food prices and soil quality degradation. To a lesser extent, but seen as concerns by the majority, were reduced income and anxiety and stress.



Responses by producers revealed that the greatest impact was on levels of production, followed by low water supply and loss of crops, and then reduced income. These were quite similar to the impacts highlighted by service providers. Other impacts mentioned were increased food prices, anxiety and stress, health problems from dust, poor soil quality, livestock diseases, livestock losses (probably as a result of fewer livestock producers) (Figure 5). Unlike for the service providers, poor soil quality was seen as less of a concern.



4.2 ECONOMIC AND SOCIAL VULNERABILITY

With droughts being more seasonal in nature in the Caribbean, agriculture is the most likely sector to be impacted by drought with serious economic and social consequences. This is particularly so since the majority of Caribbean Agriculture is rainfed. The agriculture sector responds to the conditions by reduced crop yields, and premature death and low productivity in livestock and poultry. Even a dry spell of 7-10 days can result in a reduction of yield, depending on crop stage, soil texture and depth, plant health and other environmental conditions. All these factors can influence the livelihoods of farmers. With irrigation use becoming more widespread in the Caribbean, a country's fresh-water supply becomes increasingly important, along with volume, accessibility and ultimately management.

Suárez *et al.* (2008) suggested that fluctuations in water regimes due to climate change will be amongst the greatest impacts on Caribbean terrestrial biodiversity. Low rainfall periods can also reduce the extent of forested areas and other forms of natural vegetation, as fires often accompany droughts, not only because of the dry conditions, but also because of associated higher temperatures and stronger winds that accompany the Caribbean dry season (a well-known aspect of the climatology of the region). The fires can also impact wildlife as their natural habitats are affected. Such large losses in vegetation and dry conditions can trigger the development of pests and diseases and viral infections (FAO, 2008), such as mites, corn ear worm on peppers, aphids, pepper midge, and bacterial wilt (as witnessed in Trinidad and Tobago during 2010).

4.2.1 Water resources

Drought also impacts surface water resources. During the dry season, water levels fall drastically, with aged, leaking infrastructure contributing to unequal water distribution problems, including limited or no access to water in some rural areas. The competing uses (municipal supply, irrigation, recreation, wildlife and other ecosystem services)

for water adds to the problem during the dry season, as the municipal service becomes priority. Drought can impact the environment, with significant reductions in water flow impacting terrestrial and marine ecosystems. Countries (like Barbados) or communities with predominantly groundwater resources are impacted after a longer time than surface water, due to lack of evaporative losses, but can suffer from over-pumping during drought, at times being infiltrated by saline water, reducing its quality. Projected sea level rise will augment the vulnerability of those aquifers (Trotman *et al.*, 2009).

4.2.2 Fisheries

The Caribbean Regional Fisheries Mechanism (CRFM) is unaware of any studies in their Member States that addresses the impacts of drought on Caribbean fisheries (personal communication, Dr Susan Singh-Renton, Deputy Executive Director, CRFM, 2014). However, Dr Singh-Renton noted that drought is likely to affect freshwater fish most of all, and rainfall (including drought) may affect the movement of pelagic fish, making them more or less available to coastal fishing operations. Rainfall can also affect the spawning success of some marine species, such as shrimp, and also change salinity levels that may trigger spawning behaviour in some fishes. Dr Singh-Renton also indicated that CRFM is now beginning to consider these relations in its fisheries analyses. For example, CRFM (2013), reports on a workshop held to “...*contribute to strengthening regional and national inter-sectoral cooperation and development of capacity to address climate change impacts and disasters in the fisheries and aquaculture sector*”. The report mentions drought as one of the areas for adaptation. Certainly with respect to freshwater fisheries, aquaculture is one of the fisheries sub-sectors that can be vulnerable to drought. It is also noteworthy that CRFM has established a Working Group to Promote Sustainable Aquaculture Development, which after further discussions with CIMH, will be considering issues related to climate, including drought.

4.2.3 Tourism

Tourism is the most vital economic sector in many Caribbean countries. This industry is water intensive and therefore vulnerable to drought (Environment Division, Antigua, 2000). Both the low quantity and quality of water could heavily impact the tourism sector during drought. Hotels manage to reduce some of this vulnerability through desalination processes and increased water storage, including through rainwater harvesting. However, the desalination process leads to increased production costs for the industry.

4.2.4 Hydropower

Hydropower energy sources are also vulnerable impacts as reported for St. Vincent and the Grenadines during the 2009-2010 drought (Farrell *et al.*, 2011; see also Section 3.1). Most countries in the region expect that hydropower potential will decrease due to climate change, as rainfall is expected to decline as the end of the century approaches.

4.2.5 Coping capacity among communities

Little or no capacity to cope makes some communities and groups more vulnerable to hydro-meteorological hazards like drought. Some of the vulnerable groups include:

- Farmers, particularly small farmers, with more limited resources, are vulnerable as their livelihood is threatened by low rainfall where cropping is rainfed, and by low water levels and increased production costs due to increased irrigation (and therefore energy) use. Livestock grazing areas change in nutritional value, as more low quality, drought tolerant species dominate during extensive droughts, causing the vulnerability of livestock to increase. The potential for livestock diseases also increases, as the capacity to sanitise is lessened.
- The poor are vulnerable as food price increases are often associated with drought, and a large percentage of their income is spent on food. Løvendal *et al.* (2007) suggested that food price increases would impact the urban poor more than the rural poor since rural areas are more likely to have some food, however little, during such crises. Expensive, desalinated water resources are becoming more important in the Caribbean (Table 4), accounting for as much as 70% in Antigua and Barbuda, and this can impact the poor significantly.
- Children are also a vulnerable group as they are at highest risk from inadequate water supplies during drought. They are also at highest risk of malnutrition (CCCCC, 2012). The study by Løvendal *et al.* (2007) reported that increased food prices can have a significant effect on the short-run nutritional status of children, diminishing in the long-run.
- Rural communities are vulnerable since potable water networks are less dense and therefore more heavily impacted during drought. Some communities are provided with potable water outside the recognised supplier (e.g. Dominica through small projects by NGOs, OECS (2012)). Rural areas are prone to water-stress as distribution to remote communities is unequal (e.g. as noted in the Climate Change Risk Profile for Saint Lucia (Simpson *et al.*, 2012). They are also vulnerable due to increased incidences of bushfires associated with the drier, warmer and windier conditions. There are recorded examples of rural indigenous farms being affected by forest fires in Surama, Guyana (Bynoe, 2008).
- Many water conflicts stem from over-abstraction upstream, be it for irrigation which affects the availability of potable water on the island of Antigua, or for hydroelectric power plants damming water on the island of St. Vincent (OECS, 2012). In instances of low water availability, downstream users become very vulnerable, with many facets of the society being impacted. These would include crop and livestock farmers, aquaculture establishments and biodiversity.
- Trotman *et al.* (2009) reported that indigenous populations in the Caribbean largely experienced deteriorating developmental status (such as the Human Development Index, HDI), with low quality of life, over the years, which increased their vulnerability. Their access to potable water is also poor. Indigenous communities exist in Belize, Jamaica, Dominica, Suriname (Trotman *et al.*, 2009) and Guyana (Bynoe 2008). Bynoe (2008) reported impacts on the indigenous community in Surama during dry times, such as decline in cassava yields (also associated with increases in caterpillars), and increased food prices. Also accompanying these were diarrhoea, as sanitation issues became more pronounced during drier times and destruction of farms by forest fires.

5. Government policy on drought

5.1 A COMPREHENSIVE DISASTER MANAGEMENT STRATEGY

In 2001, the Caribbean Disaster Emergency Response Agency (CDERA), now the Caribbean Disaster Emergency Management Agency (CDEMA), spearheaded the adoption of a Comprehensive Disaster Management (CDM) framework with the strategic objective of integrating disaster management considerations into the development planning and decision-making process of its Participating States. The CDM framework incorporates the five principles of the Hyogo Framework for Action (ISDR, 2007), which are:

- Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation,
- Identify, assess, and monitor disaster risks and enhance early warning,
- Use knowledge, innovation, and education to build a culture of safety and resilience at all levels,
- Reduce the underlying risk factors, and
- Strengthen disaster preparedness for effective response at all levels.

In 2007, a revised and “Enhanced Regional Strategy and Programming Framework” to guide CDM programming for 2007-2012 was developed. This Strategy was established within the context of the 2005-2015 CARICOM Regional Framework, with six main priorities:

- Hazard mapping and vulnerability assessment,
- Flood management,
- Community disaster planning,
- Early warning systems,
- Climate change, and
- Knowledge enhancement.

The CDM Strategy and Programme Framework itself has four main Priority Outcomes:

- Outcome 1: Institutional support for CDM programme implementation at national and regional levels is enhanced,
- Outcome 2: An effective mechanism and programme for management of CDM knowledge is established,
- Outcome 3: Disaster Risk Management (DRM) is mainstreamed at national levels and incorporated into key sectors of national economies (including tourism, health, agriculture and nutrition),
- Outcome 4: Community resilience in CDERA (now CDEMA) States to mitigate and respond to the adverse effects of climate change and disasters is enhanced.

5.1.1 2014-2024 CDM Strategy

The Enhanced CDM Strategy was base-lined in 2010 and reviewed in 2012 and its findings were used as the basis for developing the draft 2014-2024 CDM Strategy. The goal of the draft CDM Strategy 2014-2024 is to realise the “*Safer, more resilient and sustainable CDEMA Participating States through Comprehensive Disaster Management*”. The strategic framework embodies seven elements, which will lead to the desired future state of participating States:

- National, regional, and sectoral institutions with adequate/minimum standards of capacity to deliver the CDM programme,
- Knowledge management applied for fact-based decision-making,
- Disaster resilience enhanced within key sectors of the economy,
- Operational readiness at regional, national, sectoral and local levels,
- A clearly established and understood nexus between Climate Change Adaptation (CCA) and Disaster Risk Reduction with programming and governance harmonised,
- Community resilience enhanced for the most vulnerable with gender concerns addressed at all stages and levels,
- Resource allocation to underpin the ability to deliver the strategy.

Since the drought of 2009-2010, CDEMA has included drought as one of the hazards to be managed more strategically. The priorities, intended outcomes and elements of the Strategic Framework are expected to support improved planning and management of future drought events in the Caribbean.

5.2 THE JAGDEO INITIATIVE

The Jagdeo Initiative (JI) identifies and defines critical and binding constraints to reposition and redefine agriculture, and aims to develop and implement targeted and practical interventions at both the regional and national levels to overcome those constraints. The goals of the JI are to make the difference in Caribbean economies through:

- More private and public investment in agriculture,
- Increased employment in the sector,
- Increased intra-regional agricultural trade,
- Increased extra-regional trade and hence foreign exchange,
- Improved food security and nutrition.

Between 2004 and January 2005, national and regional consultations were held by the Inter-American Institute for Cooperation on Agriculture (IICA) to further elaborate the constraints to the sector. Ten key binding constraints (which have since been revised to nine) and interventions were identified, two of which are directly related to the development of agriculture disaster risk management (ADRM) and water resources management:

- Inefficient land and water distribution and management systems,
- Deficient and uncoordinated risk management measures, including praedial larceny (theft of growing crops).

There are Technical Management Advisory Committees (TMACs) for each of these constraints, with Lead country Minister as Chairs, and a Lead Agency responsible for technical perspectives (www.caricom.org). For the Land and Water TMAC, the lead country is Guyana with FAO as Lead Agency. For the Disaster Risk Management and Praedial Larceny TMAC, the lead country is Antigua and Barbuda, with the Lead Agency is CDEMA.

The TMAC for Disaster Risk Management and Praedial Larceny has developed a Strategic Plan 2013-2018 to provide focus, direction, and action in order to address the issue of deficient and uncoordinated agricultural risk management measures, including praedial larceny. Drought risk management is very much a part of the Strategic Plan.

5.3 DEVELOPING RESILIENCE TO CLIMATE CHANGE – A REGIONAL FRAMEWORK

Guided by the Liliendaal Declaration that provides the vision of transformational change in the Caribbean response to the challenges of a changing climate, in July 2009, the Heads of Government of the CARICOM approved a submission by the Caribbean Community Climate Change Centre (CCCCC) entitled ‘Regional Framework for Achieving Development Resilient to Climate Change’ (CCCC, 2012a). The implementation plan was approved by the Heads of Government, in Suriname in March, 2012; it defines the Regional Strategy for coping with Climate Change in key sectors (including agriculture), with the objective of building resilience to a changing climate and creating low carbon economies.

The framework, which provides a roadmap for action by Member States and regional organisations, is guided by five strategic elements and twenty goals designed to significantly increase the resilience of the CARICOM Member States’ social, economic and environmental systems. The strategic elements are as follows:

- Mainstreaming climate change adaptation strategies into the sustainable development agendas of CARICOM states,
- Promoting the implementation of specific adaptation measures to address key vulnerabilities in the region,
- Promoting actions to reduce greenhouse gas emissions through fossil fuel reduction and conservation, and switching to renewable and cleaner energy sources,
- Encouraging action to reduce the vulnerability of natural and human systems in CARICOM countries to the impacts of a changing climate,
- Promoting action to derive social, economic, and environmental benefits through the prudent management of standing forests in CARICOM countries.

5.4 HIGH-LEVEL MEETING ON NATIONAL DROUGHT POLICY

The High Level Meeting on National Drought Policy (HMNDP) took place in Geneva, Switzerland from 11-15 March, 2013. The meeting was sponsored by the World Meteorological Organization, the Secretariat of the United Nations Convention to Combat Desertification (UNCCD) and FAO, in collaboration with a number of UN agencies, international and regional organizations and key national agencies. The goal of the HMNDP was to provide recommendations for useful, science-based actions to address key drought issues being considered by governments and the private sector and the development of national drought policies.

The key elements in a national drought management policy, as issued in the Policy Document⁹ of this meeting, fall under the following areas:

- Promoting standard approaches to vulnerability and impact assessment,
- Implementing effective drought monitoring and early warning systems,
- Enhancing preparedness and mitigation actions,
- Implementing emergency response and recovery measures that reinforce national drought management policy goals.

The Final Declaration¹⁰ of the meeting focused on these key elements and reiterated the need for national drought policies and implementation. Important to driving home the need to develop national drought policies is understanding the cost of inaction, as outlined in the scientific document¹¹ of the meeting.

⁹ Policy Document: National Drought Management Policy – http://www.ais.unwater.org/ais/pluginfile.php/516/course/section/175/PolicyDocument15212_Eng.pdf

¹⁰ Final Declaration of High-level Meeting on national Drought Policy - http://www.hmndp.org/sites/default/files/docs/HMNDP_Final_Declaration.pdf

¹¹ Science Document: Best Practices on National Drought Management Policy http://www.hmndp.org/sites/default/files/docs/ScienceDocument14212_Eng.pdf

6. Drought early warning capabilities

The High-level Meeting on National Drought Policy and the many regional disaster reduction frameworks highlighted the need for early warning and information systems as part of any plan to reduce drought risk. Figure 2 (3 and 6 month SPI) illustrates that drought is a part of the Caribbean climate, and therefore requires strategic responses to mitigate its effects. Certainly, the Caribbean countries have for many years discussed and even recommended early warning systems (e.g. Moore and Associates, 2002) as options for improving decision-making to mitigate impacts of and respond appropriately to drought. Yet, such systems have not moved beyond the recommendation, or are weakly developed.

Chen *et al.* (2005) noted that monitoring agricultural drought was seen as a case of comparing monthly and annual rainfall totals to their respective averages and monitoring biological indicators in the field. In recent years, the Caribbean Institute for Meteorology and Hydrology (CIMH), with the assistance of a subset of the National Meteorological and Hydrological Services in the Caribbean, engaged in a comprehensive effort to establish a more structured, proactive and coordinated approach to monitoring and predicting drought. This effort is supported by monitoring impacts on the ground, including water resources (rivers water levels and discharges, reservoir levels, evaporation, rainfall, water quality), agriculture and forests, terrestrial and coastal and marine ecosystems, as these impacts demonstrate the true ‘severity’ of any drought event. Water resources are normally monitored in the Caribbean countries, but to varying degrees and with varying technology from country to country and watershed to watershed. However, a more strategic approach to monitoring and drought early warning in general is needed. CIMH and its collaborators continue to build on this effort.

6.1 DROUGHT AND PRECIPITATION MONITORING NETWORK

With concerns over drought, it was thought necessary to develop a system that can monitor and forecast such events and thereby allow for the mitigation of their impacts and provide some means for adaptation in the future. Strengthening drought early warning was one of the recommendations to CARICOM after the drought of 2009-2010. The Caribbean Drought and Precipitation Monitoring Network (CDPMN) was launched in January 2009 under the Caribbean Water Initiative (CARIWIN, www.mcgill.ca/cariwin) project. The goal of CARIWIN was to increase the capacity of Caribbean countries to deliver equitable and sustainable Integrated Water resources Management (IWRM). The Network, viewed as essential to Caribbean IWRM, intended for drought and general precipitation status to be monitored on two scales:

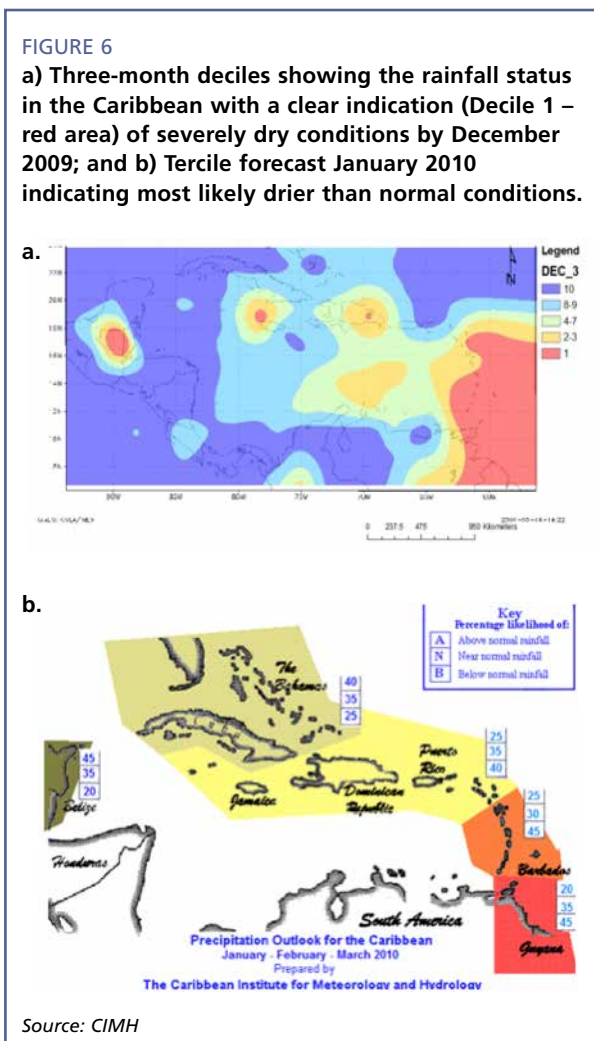
- Regional, encompassing the entire Caribbean basin,
- National using a wide range of indices and indicators.

Indices such as the Standardised Precipitation Index – SPI (McKee, 1993) and Deciles (Gibbs and Maher, 1967) would be indicators of normal or abnormal rainfall, thus

being able to detect Meteorological Drought when subnormal. Other indices provide information on normal or abnormal soil moisture (Palmer Drought Severity index, PDSI, developed by Palmer in 1965; and Crop Moisture Index, CMI, developed by Palmer in 1968) or status of vegetation (Normalised Difference Vegetation Index, NDVI; and Vegetative Health Index, VHI). Others can provide information on stream and river flow, lake and reservoir levels and ground water quantities. The final drought and precipitation status of the region/country should be determined, by consensus, by a network of persons from different sectors, institutions, communities and backgrounds embracing the diversity in definitions and impacts of drought utilising the spectrum of indices and indicators.

The CDPMN has four main expected outcomes:

- Monitor the status of water via climatological, hydrological, and other indicators,
- Undertake projections with lead times of up to 3 months,
- Post warnings on CIMH website and disseminate to key agencies, governments and media, in partner countries,
- By creating a network of researchers working with stakeholders, including all levels of government (from the local/community level to national), develop adaptation and response strategies to drought (and excessive rainfall).



Interestingly enough, the CDPMN, was launched just months before the severe to exceptional conditions of 2009-2010, with the intention of being fully operational by the end of 2010. However with the conditions becoming extremely worrying, particularly in the eastern Caribbean (Figure 6), and forecasts of continued below normal rainfall being the most likely scenario in the follow up months, the information and advisories were forced to flow from the CDPMN to Caribbean governments from January 2010, well before the recommended operational date.

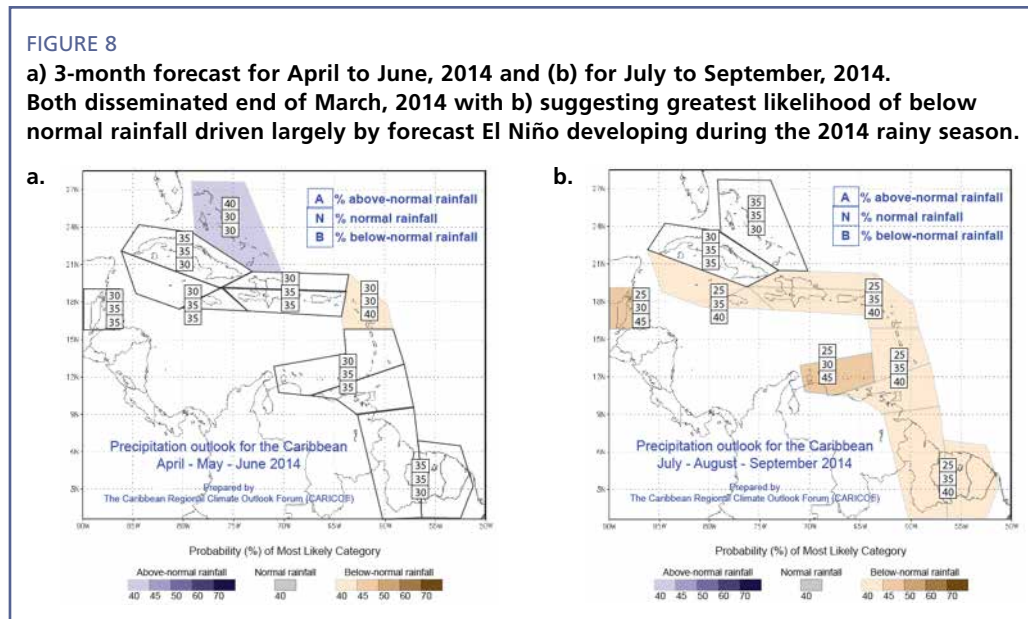
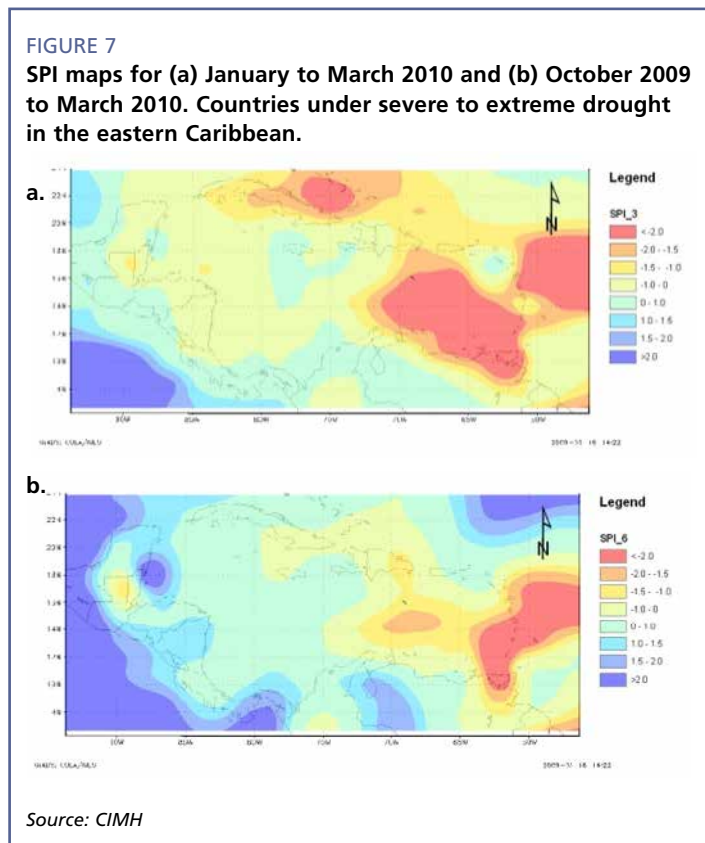
6.2 BASIN MONITORING

The Caribbean basin monitoring was the first area of focus. The Caribbean basin is predominantly sea surface, so the only indices/indicators of drought that would merit use on the regional scale with such a large proportion of sea surface would be related to rainfall as water flows, water levels and soil moisture would have limited application. SPI and Decile maps are currently produced. The first regional maps were produced on 7 April 2009, which provided the precipitation status as at end of March on four time scales (1, 3, 6 and 12

month), reflecting the reality that different types of drought manifest themselves after different periods of exposure (e.g., agricultural drought is expressed much sooner than hydrological drought). Examples of the 3 and 6-month SPI are shown in Figure 7. An example of deciles is shown in Figure 6a.

6.3 DROUGHT FORECASTING AND OUTLOOKS

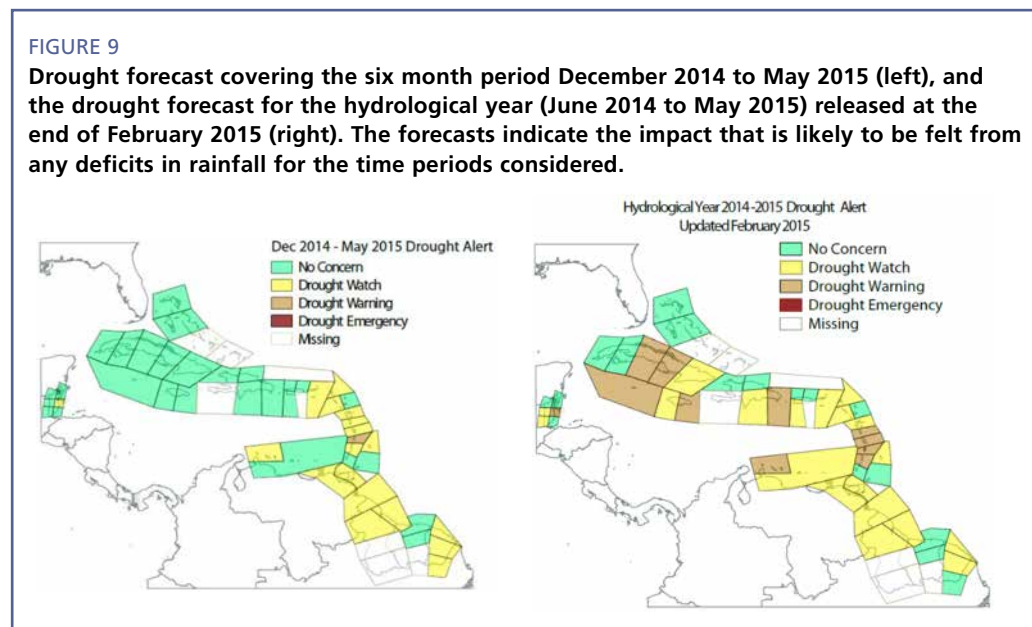
CIMH has produced seasonal forecasts for over a decade. However, since February 2012, this has become a consensus process, along with meteorologists and climatologists from about 20 national meteorological services across the Caribbean, as a product of the Caribbean Climate Outlook Forum (CariCOF). Precipitation forecasts from the Guianas in the south across the island chain to Belize in the west (Figure 8) are prepared, along with user-friendly newsletters, every month¹². Two 3-month forecasts are prepared that provide information for the following 6 months, using output from the statistical climate prediction software package called Climate Predictability Tool (CPT) that is driven by Caribbean data, as well as output from WMO Global Producing Centres of



¹² <http://rcc.cimh.edu.bb/long-range-forecasts/caricof-climate-outlooks/>

Long-range Forecasts (GPC)¹³. The tercile information is in the form of probabilities of normal, above normal and below normal rainfall. It has to be made clear, however, that there is greater uncertainty the longer the lead time of the forecast. Apart from contributing to the regional precipitation outlooks, national meteorological services also provide national outlooks, increasing the potential for better decision-making at the national scale. Drought is often accompanied and exacerbated by high temperatures. The CariCOF newsletter also provides outlooks on temperatures.

Using seasonal forecasts, the CDPMN also issues a table with the most likely projected index range of the Standardised Precipitation Index for select Caribbean stations¹⁴, and therefore gives an idea of possible severity of drought. However, when it comes to providing early warning information for drought, the most exciting development was the launch of a drought alerting system¹⁵ at the CariCOF in May 2014 in Jamaica, in collaboration with the Central American Climate Outlook Forum and the International Research Institute for Climate and Society, Columbia University. Forecasts for the 6-month time scale and the hydrological year from June (the start of the rainy season in much of the Caribbean) to May (the approximate end to the dry season), with examples shown in Figure 9, are currently produced. The information facilitating the creation of these maps considers actual rainfall in the months preceding and forecasted rainfall for the succeeding months. This information supports a decision-support alerting system (Table 5) that indicates levels of alert, as well as recommended actions associated with each level. CariCOF continues to seek stakeholder involvement in refining the alerting system and making it more relevant. In another recent development, all drought information is now compiled and disseminated via the monthly Caribbean Drought Bulletin¹⁶.



¹³ Global Producing Centres are WMO-certified centres that assist WMO Members by providing operational long-range forecasts on the global scale as input for regional and national climate services. http://www.wmo.int/pages/themes/climate/global_producing_centres.php

¹⁴ <http://rcc.cimh.edu.bb/long-range-forecasts/spi-outlook/>

¹⁵ <http://rcc.cimh.edu.bb/long-range-forecasts/caricof-climate-outlooks/>

¹⁶ <http://rcc.cimh.edu.bb/>

6.4 NATIONAL MONITORING

In recent times, greater emphasis has been placed on establishing national monitoring networks. This is the scale of greater importance, but the one that proved more difficult to establish even though workshops on drought monitoring and forecasting and their benefits were held in Jamaica, Guyana, and Grenada under CARIWIN; in Barbados, and Trinidad and Tobago under another collaboration between CIMH and The Institute of Earth Sciences, University of Applied Sciences of Southern Switzerland (SUPSI-IST).

Compared to the Caribbean basin scale, indices and indicators utilising data other than precipitation can be engaged more meaningfully at national level. Possible applicable data sets are, for example, soil moisture, soil available water capacity, evapotranspiration, vegetation indicators, streamflow and reservoir levels. Analysis of these data along with rainfall would facilitate a more comprehensive assessment of the status of drought (and possible prognosis) for the range of water resources. National scale maps illustrating the status of these resources would be an asset for monitoring the degree of exposure and potential impacts, and thereby solicit the necessary reaction from the relevant authorities. A project entitled Building Capacity to Manage Water Resources and Climate Risk in the Caribbean, funded by the United States Agency for International Development (USAID), is developing a Climate Impacts Database to assist research efforts in supporting the necessary responses to varying degrees of drought, as observed and forecast severity would be better related to potential impacts.

TABLE 5
Drought Alerting Levels and recommended actions

Alert Level	Meaning	Action Level
No concern	No drought concern	Monitor resources
		Updates and ratify management plans
		Public awareness campaigns
		Upgrade infrastructure
Drought watch	Drought possible	Keep updated
		Protect resources and conserve water
		Implement management plans
		Response training
		Monitor and repair infrastructure
Drought warning	Drought evolving	Protect resources
		Conserve and recycle water
		Implement management plans
		Release public service announcements
		Last minute infrastructural repairs and upgrades
		Report impacts
Drought emergency	Drought of immediate concern	Release public service announcements
		Implement management response plans
		Enforce water restrictions and recycling
		Enforce resource protection
		Repair infrastructure
		Report impacts

In 2012, through an agreement between the Government of Brazil and CARICOM, in collaboration with CDEMA, FAO and CIMH, steps towards establishing formal national monitoring networks began in three pilot countries (Jamaica, Grenada, and St. Lucia). The activities carried out included:

- Training by CIMH in collaboration with the National Drought Mitigation Centre (Lincoln, Nebraska, USA) on the use of indices, indicators and tools for monitoring;
- Preparation, enhancement and sharing of tools to assist in national monitoring, such as (i) *the Caribbean Water Monitor* that allows countries to graph and map rainfall status, (ii) *the Caribbean Rainfall Impact Reporter* that allows persons on the ground in each country to participate in monitoring and upload observed impacts to a portal, and (iii) software that calculate indices such as the *SPI* and the *Standardised Precipitation and Evapotranspiration Index (SPEI)*;
- Providing measuring stations that would enable monitoring of the three most common types of drought (meteorological – rain-gauges; agricultural – soil moisture probes; hydrological – water level sensors);
- Developing National Drought Early Warning and Information Systems (DEWIS) Implementation Plans. DEWIS Draft Plans for Grenada and Jamaica follow in the framework discussed later in Section 7.3¹⁷.

Although much work is being done in the region on monitoring rainfall and water resources and forecasting climate events like drought, responses to the questionnaire shows that most Caribbean producers (7 out of 10 respondents) are unaware of such work and the resulting products. However, the service providers (12 out of 15 respondents) were much more aware of these products. This suggests that public awareness and education systems need to be more effective, particularly at the community level. This would mean expanding the network of stakeholders to include communities and not just sectoral ministries and agencies. It may also suggest the level at which this information may more clearly fit initially in the decision-making process.

¹⁷ St. Lucia added its plans to an existing flood plan of its National Emergency Management Organisation, which is modified as the Terms of Reference for the NEMO Flood and Drought Mitigation Committee) and was approved in July 2013.

7. National drought policy-making and planning

It is accepted to have policies and plans to establish national drought plans or plans for water resources management that include drought. These can be seen in the numerous reports on the United Nations Convention to Combat Desertification (UNCCD) Action Plans, the SIDS 2014 Preparatory Progress Reports for the Caribbean, IWRM Roadmaps and other publications referenced in this document. Priorities are often discussed in these reports, outlining needs for water resources management and drought planning (e.g., GWP-C, 2013), with little follow up in establishing or approving plans for drought management. However, there are not many policy documents or action plans that are being approved and implemented in the region at Cabinet level. In a review of water resources policy development in the OECS (2012), only two (St Lucia and Grenada) of the six Member States' draft policies reached Government adoption, two other drafted policies that were not yet adopted (Dominica and Antigua and Barbuda); and the final two (St. Kitts and Nevis, and St. Vincent and the Grenadines) had not embarked on policy development. For successive governments and administrations to pursue or continue implementation as a priority, approval is paramount, even if only to have necessary resources made available.

Draft and ratified Policies on Integrated Water Resources Management (IWRM) in the OECS (OECS 2012) highlighted and recommended integrated drought mitigation and management planning as important aspects in any IWRM plans to be developed. However, such plans are not widespread in the Caribbean, and many of its States are left with water management policies and Acts, but no plans for implementation, or where plans do exist implementation is lacking. Lack of planning was evident in countries. For example, in Trinidad and Tobago, the Water and Sewerage Authority was publicly criticised in the media for the lack of planning, which forced WASA to prohibit water abstraction from some water courses and request payment from farmers for abstraction during the 2009 to 2010 drought (Newsday, 2010). Furthermore, there are existing plans that outline emergency response actions during low water levels, suggesting the reactive nature of water management.

In many of the countries, water resources management is under the responsibility of the national (government-owned) water utilities, supported by statute. Therefore, many of the response plans concentrate on the municipal supplies or are sector, agency, or company based, but not very many pursue a holistic, national well-coordinated response to water management (e.g., see ECLAC 2008 for Antigua and Barbuda, Dominica and Grenada), particularly with respect to drought. The GEF IWCAM project in its Final Conference acknowledged that “... *sectoral approach to the management of watershed and coastal resources which prevails in Caribbean countries is unsustainable*” (GEF-IWCAM 2012). Sectoral approaches lead to fragmented and uncoordinated development and management of water that increases competition for this finite resource. These concerns support the need for a more holistic, integrated approach to water resources management.

What the Caribbean does better is to restrict abstractions (with some exceptional cases) during drought and low water levels. These are often through legal instruments

(Acts) that allow for enforcement. Most countries issue abstraction licences, thereby regulating the process, and can thereby limit the rate of abstraction during those times of emergency or threat. This is done in Trinidad (WRA) for example, where fees for abstraction to farmers is \$TT 0.10/m³ (1US\$ approximately 6 TT\$), that is after paying the typical administration fee of \$TT150 and \$TT120/month. There are similar fee structures in other countries of the region.

There is a plan in St. Lucia that was approved in 2009 and brought into action during the 2009 to 2010 drought (Government of St. Lucia, 2009). It is used here as an example of the decision-making process, and also indicates the authorities and agencies involved, their responsibilities and roles, and the varying stages for action as drought develops.

7.1 DROUGHT PLANNING IN ST. LUCIA

The Water and Sewerage Act No. 14 of 2005 established the Water Resources Management Agency (WRMA), which was formalised and became functional towards the end of 2008¹⁸. The primary objective of WRMA is the sustainable management of the country's water resources. The mandate of WRMA is "*...to enable the sustainability of economic growth, human development and the environment by promoting and facilitating the efficient and effective use and management of water resources in Saint Lucia*". The specific functions of WRMA are to

- Consider applications for abstraction licenses and permits for use of water in control areas and permits for waste discharge
- Promote the sustainability of water resources
- Undertake water resources assessment and planning including surveying, monitoring, research and development
- Develop watershed management plans and facilitating regulation accordingly
- Undertake the preparation of water master plans and allocation schemes
- Advise the Minister in relation to water control areas and waste control areas
- Advise the Minister in relation to water related emergencies.

The St. Lucia plan is limited to the coordination of the Water and Sewerage Service responses to actual or potential major events. It acknowledges that disasters such as drought need to include prevention, preparedness, and mitigation, prior to the hazard, and response, recovery and rehabilitation afterwards. There is a Drought Task Force chaired by the Water and Sewerage Commission, with membership that includes:

- Managing Director - Water and Sewerage Company (WASCO)
- Water Bottling Companies
- Executive Directors of St. Lucia Hotel and Tourism Association, Manufacturing Association, Chamber of Commerce, Caribbean Environmental Health Institute (CEHI)
- Director - Saint Lucia Meteorological Services
- Chief Medical Officer

¹⁸ http://www.malff.com/index.php?Itemid=57&id=50&option=com_content&view=article

- Chiefs of Agricultural Services, Forestry Division, Environmental Health Department, Water Resources Management Unit
- Commissioner of Police
- Chief Fire Officer
- Fire Service - Divisional Officer [South]
- Representatives of Ministry of Commerce, Ministry of Tourism, Ministry of Physical Development, Ministry of Public Utilities
- Director - National Emergency Management Organisation (NEMO)

WASCO is responsible for provision of water supply services and should take action to manage water during drought and cooperate with NEMO. To support WASCO's water management as part of preparedness, prevention, and mitigation in normal conditions, activities should include:

- Monitoring of water resources and rainfall by the Saint Lucia Meteorological Services and the Hydrological Department of the Ministry of Agriculture (now the Water Resources Management Agency, WRMA)
- Regulating water abstractions by the Ministry of Agriculture (WRMA)
- Developing emergency and conservation plans, led by WASCO
- WASCO and water bottling companies developing additional storage and treatment facilities, evaluate distribution system
- WASCO providing general advice and information on water conservation techniques to the public.

The following is planned in response to a threatening drought event:

- On issuing of a drought watch, the Managing Director of WASCO will convene the Drought Task Force to coordinate activities, and as necessary during the drought
- Monitoring will be intensified, making sure the necessary human capacity is in place to support the Drought task Force, and addressing water use conflicts
- WASCO will disseminate information to the public on the drought event via the media

As the situation worsens, a Drought Warning is issued, and there is greater urgency that includes:

- More frequent Drought Task Force meetings
- WASCO requests voluntary conservation of the public, and provide the necessary awareness and educational information
- Responding to local and individual appeals for assistance
- Distributing health information

When the situation reaches the stage where low water levels threaten population centres, the Minister of Public utilities will declare a Water Emergency. This will activate the National Emergency Response Mechanism, and trigger the following responses:

- Drought Task Force provides a Situation Analysis for NEMO, that will determine if the Plan and the National Emergency Operations Centre (NEOC) will be activated
- If NEOC is activated, it takes over coordination of response, requests additional resources and ensures adequate support to WASCO functions, and Standing Operation Procedures come into effect
- Mandatory restrictions on water use, which may include banning some outdoor water uses, capita quotas, cut-backs to non-residential users, and irrigation
- Enforcement of laws.

If water levels become critically low, the Managing Director of WASCO can request of the Prime Minister to Declare a Water Deficiency Disaster. At this point:

- NEMO implements emergency operations plan
- There can be emergency releases from reservoirs above low flow
- Bottled water and sanitation supplies will be provided to users, with priorities to emergency services, including the fire service and hospitals.

Supported by funds from the Government of Brazil in cooperation with the Caribbean Community (through the Caribbean Disaster Emergency Management Agency (CDEMA) and in collaboration with the FAO, the Caribbean Institute for Meteorology and Hydrology (CIMH) set out to assist three Caribbean nations (Jamaica, Grenada and St. Lucia) in developing DEWIS plans. During the project, St. Lucia thought it necessary to boost its preparation and mitigation planning for drought. There already exists a flood mitigation plan under NEMO. The decision made by national agencies was to add drought (and the Terms of Reference) to the mitigation plan and establish the Terms of Reference of the NEMO Flood and Drought Mitigation Committee, which was approved in 2013. The committee, chaired by the Director of the Saint Lucia Meteorological Services with the Director of the Water Resources Management Agency (WRMA), has over 20 other national agencies with interest in drought management and risk reduction as its members:

7.2 OTHER POLICIES, ACTS, AND PLANS RELEVANT TO DROUGHT

In Jamaica, another Caribbean country where policies and plans are fairly well established with regard to water resources that includes drought, the Water Resources Act established (i) the Water Resources Authority (WRA), (ii) the Water Resources Advisory Committee, and (iii) the National Water Resources Master Plan¹⁹. As indicated in the Jamaica Water Sector Policy Paper (Ministry of Water, 1999), the WRA “assesses the likelihood of extreme hydro-meteorological events, such as floods and droughts. It contributes to preparing for, managing and mitigating the effect of such events using flood warning, flood plain mapping and drought plans”. It was also responsible for the development of the Water Resources Master Plan that guides water resources development on a national level. It contains an inventory of Jamaica's surface water and groundwater resources in relation to supplying the present as well as future demand for water by all users. One of the expectations of the WRA is to provide timely information on drought, facilitated through its monitoring of national water resources

¹⁹ http://www.wra.gov.jm/dynaweb.dti?dynasection=general&dynapage=doc_library

and collaboration with the national Meteorological Service that monitors and informs on climate. Certainly, through its developed National Irrigation Development Master Plan (See more in Section 8) that defines the irrigable areas and the irrigation water demand, the relief for many farmers in drier times is better planned. It should also be noted that through 1965 Act, the National Water Commission was established that focussed particularly on overseeing contracts and rates for water and sewerage works in Jamaica. This Act was revised in 2004, where the emphasis is on quality water supply and sewerage service. The main responsibilities of the NWC include production of water collection, water treatment and disposal of urban sewage. Provision for rural water is shared between the NWC and the Parish Councils. During drought and the dry season, the NWC can restrict the access to potable water as deemed necessary, as illustrated in the most recent dry season of 2014 where the Mona Treatment Plan that serves much of the corporate capital, was shut down nightly (National Water Commission, 2014).

In Guyana, there is a Water Resources Act that, according to its title “...provide for the ownership, management, control, protection and conservation of water resources, the provision of safe water, sewerage services and advisory services, the regulation thereof and for matters incidental thereto and connected therewith”. It authorises the Minister responsible for Agriculture, under the advice of the responsible department, to issue a Drought Order for a period of up to 3 months to:

- Authorise persons to abstract water from any water course, but subject to conditions and restrictions, and the circumstances of the persons, and also to carry out emergency works.
- Authorise the department to modify existing licenses governing the use of water resources, and prohibit abstraction from sources that may seriously affect water supplies in the area.

The Act provides for the establishment of the National Water Council, The Guyana Water Inc.²⁰ The Act also governs abstraction and licences for abstraction and offences for those that contravene the Drought Order. It also provides information for the public during events.

In Barbados, the Barbados Water Authority (BWA) Act came into operation in October 1980 (Barbados Water Authority Act, 1980). Some of the relevant functions of the BWA include:

- To manage, allocate and monitor water resources
- To keep under constant review the quality, reliability and availability of water supply and sewerage services, and the rates to be charged for the services
- To control and regulate the production, treatment, storage, transmission, distribution and use of water for public purposes
- To disseminate information and advice with respect to management, collection, production, transmission, treatment, storage supply, and distribution of water and where applicable, sewage.

²⁰ The mission statement of Guyana Water Inc. is “To deliver safe, adequate and affordable water and to ensure safe sewerage systems for improved public health and sustainable economic development.”

- To provide facilities for training and educating its employees and for research

A drought and emergency Plan for Barbados was approved by the Planning and Priorities Committee in 1997. It identifies parameters that would be used to monitor, forecast and predict the impact of drought. Such parameters include - rainfall measurements, groundwater measurements, and salinity and weather data from the Meteorological Office as well as reservoir levels (Moore and Associates 2002). The Barbados Water Authority has responsibility for this and issues information to the public as to the various stages of exposure to drought:

- Stage 1 - Voluntary Stage; no use of hoses to water lawns, ornamental plants or cars, use water more efficiently.
- Stage 2 – Mandatory Stage; there will be prohibitions on use of water and the start of night-time shut offs in selected distribution systems.
- Stage 3 – Extreme Stage; even more austere measures, with extended shut-offs in the distribution system, even at times during the day.

In Antigua and Barbuda, an Act passed in 1973 established the Antigua Public Utilities Authority (APUA) to provide an adequate supply of water for use of the public in general.²¹ It does this through the management of water sources such as ponds, dams, reservoirs, wells and the ocean, and managing the distribution infrastructure which includes constructing and expanding water mains and repairing broken pipes.²² APUA was reported to have a long-term water development plan with emphasis on desalinization of seawater to eliminate the risk of drought and inadequate surface storage and groundwater facilities²³, but through the questionnaire it was indicated that the existing plan could be developed further. It was further reported that the lack of policy guidance to provide adequate water had resulted in the APUA focusing all its resources on supplying water to the general public and neglecting its management role (ESAL 2008). However, a policy for Integrated Water Resources Management for Antigua was drafted in 2011 and endorsed by a high level committee of Permanent Secretaries, with a vision to “*Ensuring the sustainable management and protection of the water resources and watersheds of Antigua and Barbuda for the equitable, economic, social and environmental benefit of our people and natural resources*” (Government of Antigua and Barbuda, 2011). One of the ten policy elements in the draft focussed on promoting water management as a means of climate adaptation against drought. The policy also seek to establish a relevant, robust legislative framework to govern water management, particularly acknowledging lack of national coordination and a history of sectoral and agency planning that acts against the grain of efficient water management. Currently there is no irrigation and agricultural water development policy in Antigua and Barbuda. Ad hoc programmes and projects are generally used to satisfy the individual farmer's demand for small-scale irrigation infrastructure, such as small dams. But it was reported through the questionnaire that the knowledge and production of alternative crops that can better withstand drought conditions is part of the drought management strategy for agriculture. Also, the draft policy has acknowledged the need for a strategy that would include irrigation, particularly in rural areas.

In Grenada, in 1990, the National Water and Sewerage Authority (NAWASA) Act was passed, with “full power over all waters whether surface or underground in the State of

²¹ Laws of Antigua. Public Utilities.

²² <http://www.apua.ag/business/water-division/>

²³ http://www.fao.org/nr/water/aquastat/countries_regions/ATG/index.stm

Grenada, and shall collate and publish information from which assessment can be made of the actual and prospective water resources in the State” (CEHI and GEF-IWCAM 2007). The Act governs:

- Measures for the protection and conservation of catchment areas in collaboration with the Ministry of Agriculture
- Water and sewerage works
- Financial provisions
- Rates and charges for the varying sectors of metred and un-metred domestic users, metred and un-metred commercial and industrial users, ships and private trucks and tanks.
- Acquisition of property and wells and boreholes

7.3 DROUGHT EARLY WARNING INFORMATION SYSTEMS (DEWIS) PLANS

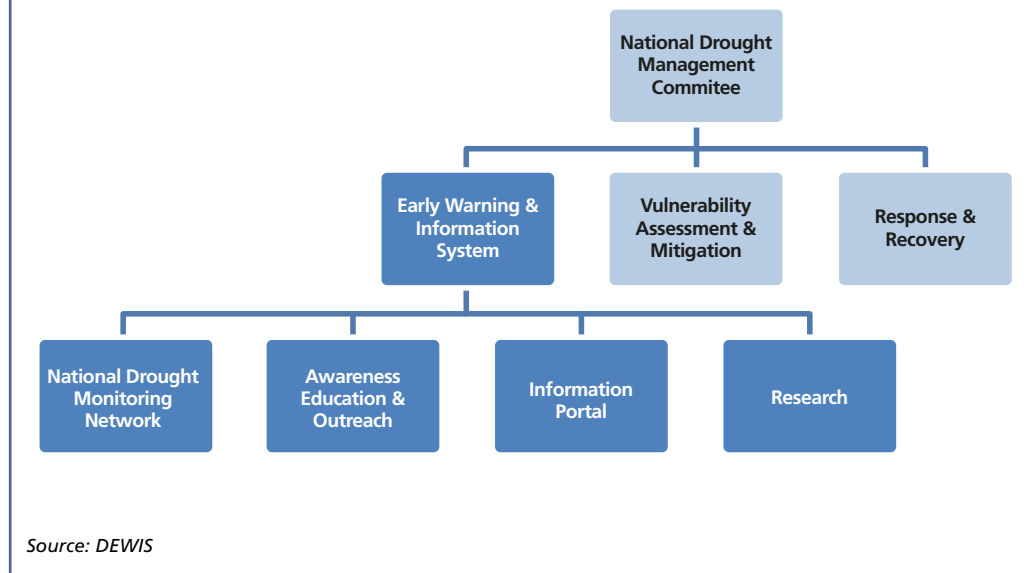
Two of the main challenges suggested by the Water Resources Agency of Trinidad and Tobago (personal communication, Ricardo Ramdin, WRA 2010) during the 2009 to 2010 drought were: (i) predicting the end of the drought, and (ii) public education. Establishing national Drought Early Warning and Information Systems (DEWIS) plans are expected to respond to such challenges. DEWIS plans were supported by the aforementioned Brazil-funded project (Section 6.4), where a framework was proposed and followed by Jamaica and Grenada. Set in the context of National Disaster Management, and particularly for drought as outlined in the Final Declaration of the High-level Meeting on National Drought Policy (Section 5.4), the framework recommends the establishment of a National Drought Management Committee (NDMC) that would have an overall management role of the system. The NDMC would be a High Level Committee of Ministers and/or Permanent Secretaries or their selected representatives, along with the Director of the country’s agency responsible for disaster management. Subcommittees directly responsible for key elements of drought policy will report to the NDMC. The recommended key elements of drought policies are:

- Early warning systems
- Information dissemination and communication
- Vulnerability and impact assessment
- Preparedness and mitigation
- Response
- Recovery

Drought Early Warning and Information Systems (DEWIS) committees that focus on the first two of the key elements, would oversee networks and working groups on:

- National drought monitoring and forecasting
- Public awareness, education, and outreach
- Establishing and maintaining a drought information portal
- Research.

FIGURE 10
Schematic of recommended National Drought Management framework, focusing on Drought Early Warning and Information Systems



At the time of development of the framework, there was an existing Drought Management Plan in Jamaica. A National Drought Management Committee is led by Ministry of Water, Land, Environment and Climate Change and chaired by the Minister. The droughts of 1996 to 1998 and 2004 prompted the mobilisation of that committee to consider responses to the impacts of these drought episodes. However, although still in effect, the current plan is seen as obsolete and is being revised by the relevant national and private sector agencies, institutions, and other stakeholders to make it more relevant. The framework in Figure 10 intentionally mimics this to some extent, particularly as it is led by high-ranking officials in the governance structure that coordinates its activity, and involves multiple agencies and other players in the varying phases of the disaster cycle. Unfortunately the project focused on DEWISs, with the intention that regional (or national) agencies with the capacities in the other areas would build on the Plan by developing the other key elements. It was necessary to frame the DEWIS Plan in the context of holistic, comprehensive national drought management, but acknowledging those gaps.

In Jamaica, the Draft Plans provide objectives, agencies to be involved, scope of work, terms of reference, and the reporting process for each network/working group. As Jamaica revises its existing Drought Management Plan, it is recommended that the Draft DEWIS Plan be incorporated. A similar DEWIS plan was drafted for Grenada, except that they will return after approaching Cabinet to expand on plans for supportive research, as they need to engage the St. George's University and the University of the West Indies in discussions. This is unlike Jamaica that was already engaging the University of the West Indies, Mona, particularly the Climate Studies Group and the Disaster Risk Reduction Centre.

The questionnaire also sought to establish the roles of national agencies that provide information, water supplies, and other services to farmers. Service providers indicated their role in drought risk reduction, specifically their role in assisting with the implementation of the drought management plan/policy in their respective countries. Annex V shows the role of the responding service providers, drought management

strategies included in the management plan/policy, and an indication of the effectiveness of the drought management plan/policy. The majority of service providers who responded are involved in providing information to assist in early warning. This dominance in responses might have been due to the efforts of CIMH in encouraging countries to consider national drought polices and plans. CIMH intends to spread the awareness of this framework across CARICOM States. CIMH is willing to assist any of its Member States in developing Drought Early Warning plans around this framework to safeguard against the impacts of future droughts. However, the impetus for this to make a significant difference is in the hands of the countries themselves.

8. Measures to build resilience to drought

A study was commissioned by the FAO to review the status of development and implementation of disaster risk management (DRM) plans for hurricanes, floods and drought for the agriculture sector throughout the Caribbean. The results of the study by Roberts (2013) revealed three types of countries with varying degrees of Agricultural Disaster Risk Management Plans (ADRM):

- Countries with draft ADRM plans, namely Belize, the Dominican Republic, Grenada, Jamaica, Saint Lucia and Saint Vincent and the Grenadines
- Countries in the process of developing plans, namely the British Virgin Islands
- Countries with no plans, the other 12 of 19 countries that participated in the exercise.

The study indicates that varying frameworks, such as the CDM and Hyogo Framework for Action (HFA) provided pathways for development of the draft plans. The study also suggests that one of the main reasons for such poor disaster planning in Caribbean agriculture is that Ministries of Agriculture place a low priority on the development of ADRM plans, despite the devastating impacts of natural hazards on the subsector, and further suggests that this should be of great concern to “... *Caribbean agriculture, food and nutrition security and sustainable livelihoods*”.

The study also indicated that the greatest obstacle to the development of ADRM Plans in 64% of the countries was the lack of technical capacity, including in developing the plan itself. In building such capacity in the future, there should be priority placed on three levels:

- Level 1: hazard and vulnerability assessment, disaster preparedness, development of Early Warning Systems
- Level 2: impact mitigation, response, and recovery
- Level 3: climate change adaptation, rehabilitation and insurance systems.

The lack of capacity was followed by lack of financial assistance (11%) as an obstacle.

Hurricanes appeared to be the major issue developed in the draft plans, followed by floods. Of the six countries that had draft ADRM Plans, only Jamaica and St. Lucia addressed drought risks. The Dominican Republic mentioned drought as a hazard, however it was not addressed in the plan.

Of the two ADRM plans that included drought, Jamaica has an established institutional framework and implementation mechanism, with some established roles and responsibilities and horizontal and vertical coordinating protocol with the Office for Disaster Preparedness and Emergency Management (ODPEM – the agency

responsible for national disaster management) and parish-based operating entities. For the St. Lucia plan, the strategic approach to strengthen capacities for DRR within the agriculture subsector was based on the five priority areas of the HFA. The community centred, partnership-based participatory approach was lauded as a potential model to be followed across the Caribbean.

The development of the Jamaica ADRM plan revolves around three strategic objectives (Ministry of Agriculture and Fisheries, Government of Jamaica 2010):

- Strengthening of the capacity of RADA and other relevant institutions to fulfil the requirements of ADRM by 2015
- Instituting mechanisms and capacities to build resilience to natural hazards (in particular hurricanes, flood, droughts, crop and livestock diseases and infestations) in the agricultural sector
- Incorporating disaster risk reduction and risk management approaches into disaster preparedness, mitigation, response, recovery and rehabilitation programs for the agricultural sector.

The Rural Agriculture Development Authority (RADA) has responsibility for the disasters at all stages of the disaster management cycle, as well as implementation of ADRM strategies in the Sector, and is the lead agency for the implementation of the Plan. One of the major recommendations is the establishment of parish- and national-level ADRM committees. The plan identifies community level planning with a bottom-up approach to risk reduction as critical. As far as its approach to drought management in the sector is concerned, the plan takes into account the existing Drought Management Plan (Section 7.3). Its proposals also include:

- Drought prediction and mapping activities
- Integrating drought vulnerability into agricultural land use planning
- Educating farmers and youths on cost effective drought management measures.

Since the report by Roberts (2013), Guyana released its ADRM plan. In the plan, drought is identified as a hazard with high-risk impact on lives and agriculture livelihoods (Ministry of Agriculture, Guyana 2013), behind floods. The Strategic Framework is structured around four Result Areas:

- Strengthening institutional and technical capacities within the agriculture sector
- Risk identification, information system and early warning
- Building resilience for sustainable livelihoods in the agriculture sector
- Preparedness, response and rehabilitation.

The objectives will be achieved through the following inter-related, mutually supportive outcomes:

- Institutional mechanism that fosters optimal coordination and implementation of DRM programmes within the agriculture sector are developed and promoted
- Innovative and culturally appropriate risk transfer instruments are designed and

adopted to improve the recovery potential of farmers and fisher-people, with an emphasis on the most vulnerable

- Risks are systematically assessed, and institutional capacities for hazard monitoring and dissemination of early warning information that stimulates proactive mitigation, preparedness and response among all end users, especially at the community level are improved
- DRR and CCA policies and programmes designed to strengthen resilience to significant hazards particularly among vulnerable groups are improved
- Education, training, and public awareness are promoted as tools to advance a culture of prevention and safety
- Resources for disaster preparedness and response at all levels, especially in high risk communities/regions are properly planned and coordinated
- DRR and CCA principles and best practices are systematically incorporated into the design and implementation of recovery and rehabilitation policies and programmes in affected communities.

Outcome 1 recommends the development of a National Drought Management Plan for Guyana to be led by the National Drainage and Irrigation Authority to be completed and approved by 2016. Under Outcome 4, breeds of livestock and crops varieties are to be developed and/or tested that would be suitable under drought conditions.

Even though it is clear that drought (and dry spells) is a hazard that has only been given recent attention as a potential disaster hazard, it is surprising that it has not been given greater consideration in the agriculture context. As predominantly rainfed in their nature, agriculture outputs are often heavily impacted by limited rainfall, as would occur in drought (or significant dry spells). Agriculture is probably the most vulnerable economic sector to drought. This would imply there is a need for greater planning for a hazard for which Caribbean agriculture is vulnerable.

In Cuba, however, according to Rivera (2013), in recognition of the vulnerability to drought, and unlike many of its Caribbean counterparts, great emphasis had been placed on establishing systems and programmes of action to more effectively manage drought and reduce the risks from such events. Building the response to drought began back in the 1960s. This was enhanced in the 1990s with institutional arrangements that involved administrators at the provincial and municipal levels, with the National Defence Council providing strategic guidance for response and recovery across the country in an integrated manner. In 1977 Cuba established a monitoring, surveillance and communication system for early detection of invasive and emerging pests and diseases during and in the wake of hazards such as drought (FAO 2008). Creating natural or artificial reservoirs (dams or wells) is used to increase storage for water for animals and for irrigation (FAO 2008). Beehive feeding with sugar is also performed to save bees from starvation in adverse weather. A multi-institutional network, operated by the Centre for Disaster for Training in the Reduction of Animal and Plant Health Disasters was introduced in 2005. Its members include institutions, researchers, professors, specialists, and high-ranking officials of relevant ministries. It provides a forum for real-time interconnection between the various professionals, stimulating multi-sector and interdisciplinary cooperation and communication.

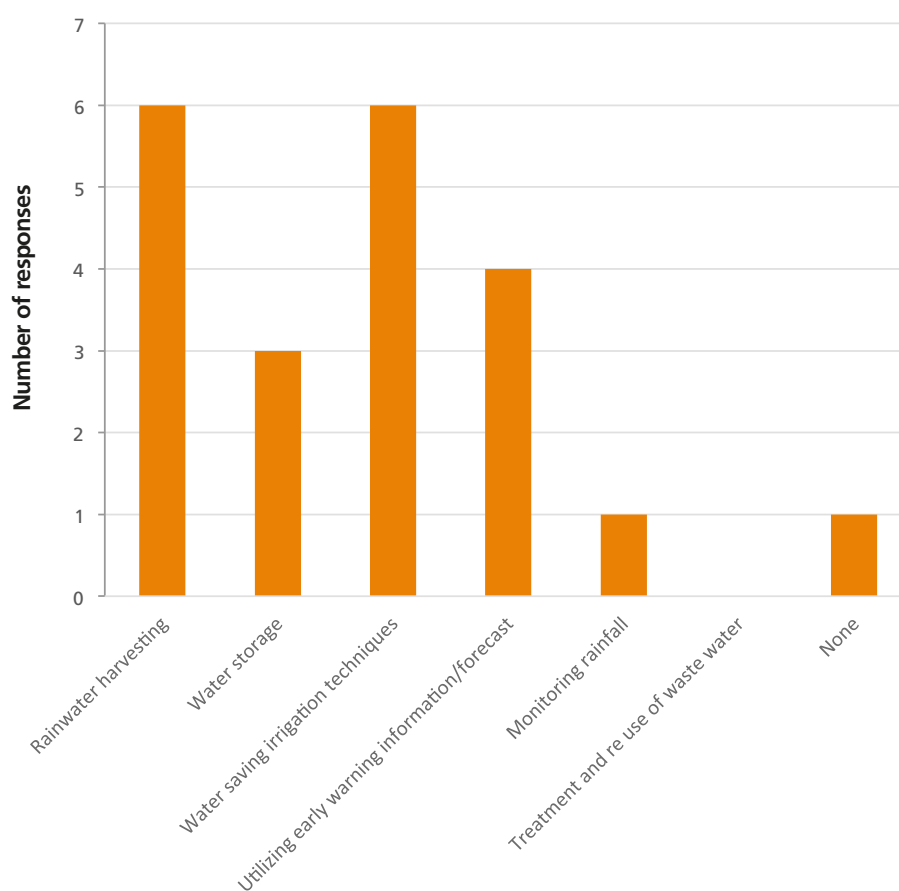
8.1 REDUCING AGRICULTURAL DROUGHT RISK

Farmers are very aware of the potential impacts of drought and dry spells. Where possible, they employ their own mitigation measures to reduce their risks. Those measures mentioned by respondents in the questionnaire are shown in Figure 11. Being able to provide irrigation water to crops efficiently and rainwater harvesting (as storage for dryer times) were the two most popular methods; the latter suggesting that supply enhancement is primary for producers (Annex IV). It is also noted that generally water storage, rainwater or otherwise, was recommended. Other measures mentioned by respondents include utilising early warning information (as from the CariCOF Precipitation Outlooks) and monitoring rainfall.

Responses to the questionnaire suggest that there are number of services provided to support farmers during and after a drought event (Figure 12). From the small pool of respondents, the most popular was tools and technologies to inform decision-making (for example the provision of climate and weather information). This was followed by supplying fresh seeds after drought, social support services (for example relaxing the policy of debt collection for water supply services) and emergency water supply (using trucks). Other support measures mentioned were advice on water conservation and early warning and tax relief.

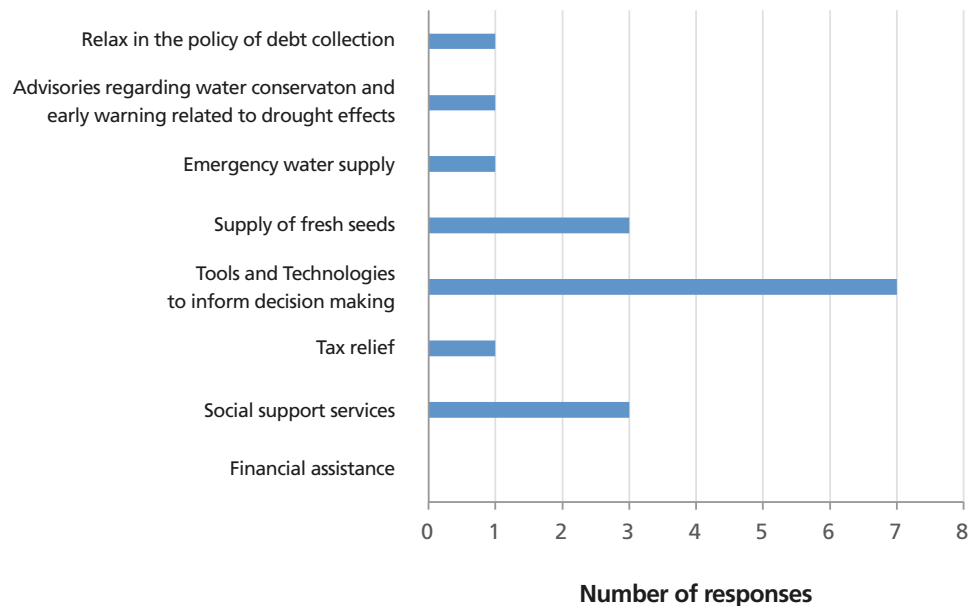
FIGURE 11

Best practices employed to build resilience to drought as reported by a small survey of producers in the Caribbean



Source: CIMH own elaboration, 2014

FIGURE 12

Support services provided to farmers during drought as reported by producers and service providers in a survey

Source: CIMH own elaboration, 2014

Providing sufficient water to cover the deficit due to a drought event would be an obvious first thought by farmers. However, though increasing over the past two decades, most Caribbean agriculture is still not supplemented with irrigation (Table 6), though water use by agriculture represents a large, and in many cases the majority, of water withdrawals. Most of the cultivated land in Trinidad and Tobago is under irrigation (84%) and represents the highest percentage in the region. Trinidad is followed by Suriname (76%), then Guyana 30%, Cuba 20%, the Dominican Republic (18%) and Haiti 10%. The remaining States irrigate less than 10% of arable land. So, apart from Trinidad and Tobago and Suriname, cropping in Caribbean States is predominantly rainfed. This seems to accord with global statistics, as according to the World Water Assessment Programme (2012) irrigation accounts for more than 40% of the world's production, but on less than 20% of the cultivated land.

Fulton (2013) reports that Jamaican farmers are encouraged to use efficient and economical irrigation systems such as gravity drip systems, small portable pumps, and tanks for water storage. The author also stated that sourcing funds for irrigation schemes, as outlined in National Irrigation Development Master Plan of National Irrigation Commission (NIC), is a priority.

The NIC is an agency within the Ministry of Agriculture that was established in 1986 with objectives "To manage, operate, maintain and expand such existing and future irrigation schemes and systems as may now or hereafter be established by the Government of Jamaica or by any Department or agency" and "To fix and collect the rates or charges to be paid for the use of such water". The Master Plan itself was commissioned in 1996 with the objective to "...promote a sustainable approach to Irrigated Agricultural Development, through policy revision, irrigation development strategies, prioritize irrigation projects to the year 2015, increase farmer participation in irrigation and make the NIC self-sustainable". The components of the Master Plan are:

TABLE 6
Annual renewable water resources, withdrawals for agriculture, irrigated area for selected States

Country	Annual renewable water resources (m ³ /capita 2011)	Water withdrawal (% total)	Irrigated area (% of cultivated area)
Antigua & Barbuda	589.89	-	20.45
Barbados	283.89	32.84	34.88
Belize	50588.09	20	6.88
Cuba	3380.62	74.65	61.72
Grenada	-	-	32.35
Guyana	304723.08	97.56	8.52
Haiti	1296.74	77.50	64.22
Jamaica	3474.60	34.21	41.46
Dominican Republic	-	-	-
St. Kitts and Nevis	-	-	-
St. Lucia	-	-	-
Suriname	169276.02	92.54	0.52
Trinidad and Tobago	-	-	-

Source: World Development Indicators, World Bank, 2011

- The state of agricultural production with irrigation development
- Identification and evaluation of projects and their rank in order of priority
- Generic environmental assessment on the irrigation sector
- Recommendation on irrigation policies and strategies to successfully implement the Plan
- The proposed implementation strategy
- Proposal for institutional strengthening within the agricultural sector

The Government of Barbados put an incentive scheme in place, which provides a rebate of 18% of the cost of new irrigation equipment for non-sugar agriculture utilising drip irrigation (Moore and Associates 2002). Subsequently the Barbados Agricultural Development and Marketing Corporation (BADMC)²⁴, which provides irrigation water to a number of agriculture schemes under national Land Lease and Land for the Landless projects, offers a 40% rebate on irrigation systems; subsidised water from the irrigation scheme; free technical advice to farmers; and ensures that farmers use water conservation measures (UNEP 2010; The Ministry of the Environment, Water Resources and Drainage Government of Barbados 2010). This is extremely important for countries like Barbados, deemed as water scarce, with less than 1000m³ per capita, as like at least two other Caribbean countries – Antigua and Barbuda, and St. Kitts and Nevis (Table 6). Enhancing irrigation efficiency is also important due to the high cost of energy to pump water. Irrigation timing is also an important aspect of efficient

²⁴ The mission of BADMC is to develop agriculture through innovative technological applications, technical and marketing research, and to create opportunities for investment that engenders enterprise, food security and prosperity in the agricultural sector. http://www.agriculture.gov.bb/agri/index.php?option=com_content&view=article&id=62%3Abarbados-agricultural-development-and-marketing-corporation-badmc&Itemid=77

water use, as some stages of the plant development cycle are more sensitive to water stress than others.

Water storage, also identified by farmers as amongst the most important measures, is becoming more widespread. Even domestically, rainwater harvesting is a policy in many islands, with water collected from roofs and stored in cisterns or tanks (for example in Antigua and Barbuda, Barbados, and the Grenada island dependency of Carriacou). As indicated by the Ministry of Environment of Antigua and Barbuda (2000), a 2000 ft² roof can capture 10,000 gallons of water, which can meet the needs of a household for up to three months. Some of this water is used to irrigate lawns and support backyard production. In Barbados originally, dwellings with 3,000 ft² or more of floor area must have rainwater storage corresponding to at least 2.0 gallons per ft² of floor area. This was subsequently changed to 1500 ft². For the commercial sector, the requirement is that they must provide at least 4 gallons per ft² of floor area once the building has a floor area of 1,000 ft² or more (Barbados Water Authority, 1997; Moore and Associates 2002). Other large farms and farmers groups establish ponds with much larger storage. In St. Lucia, The Veterinary and Livestock Services Division has made it mandatory that all livestock structures approved for construction should include an acceptable rain water harvesting system (Valmont 2011). On a much larger scale, in Guyana, there is a system of drainage and irrigation canals that feed shallow reservoirs, known as “*conservancies*,” designed to provide irrigation water. However, these storage facilities are often silted due to lack of frequent cleaning and dredging (US Army Corps of Engineers 1998), and this was seen as a concern to be rectified in the future in Antigua and Barbuda, as well (Global Water Partnership (GWP) Caribbean, 2013).

Service providers were also asked what short and long term drought risk management options they currently employ in their countries. The Table in Annex IV shows their responses. For the shorter-term measures, the option most frequently employed is public awareness and education. This was followed by water rationing. In most cases, these options are very effective, public awareness being one of the most effective mitigating mechanisms that can be implemented. When the public is educated about droughts, their impacts, and the measures taken to build resilience, then the implementation of other demand management measures will be less problematic. Other popular options include diverting water from specific areas, reviewing operations of reservoirs, decreasing transport and distribution losses, and restricting municipal uses. Demand management options are favoured over supply enhancement options. This may be due to lower implementation costs.

Also from Annex IV, the most popular long-term measure is monitoring and forecasting. Most, if not all, of the water agencies in the Caribbean perform some level (though inadequate at times) of water resources and rainfall monitoring (often in collaboration with National Meteorological and Hydrological Services). This was followed by increased water collection and storage, and employing water-saving irrigation techniques. Other popular measures include assessing vulnerability and advising water users, incentives to invest in water saving technologies, and treatment and reuse of wastewater.

Outside the questionnaire, the literature revealed many measures adopted in the Caribbean that would greater ensure adequate water in the field and thereby enhance resilience. These measures are indicated below:

- Drilling of wells for new sources of water (Cooper and Bowen, 2001)
- Constructing mini-dams to safeguard water supplies (GWP Caribbean, 2013)
- Cleaning badly silted storage facilities such reservoirs and ponds
- Growing seedlings in trays before transplanting (Fulton, 2013) to ensure lower (more controlled) water loss during the early stages (as compared to the open field)
- Planting crops at the start of rainy season/onset of rains. This implies the importance of seasonal rainfall forecast information that indicates the likelihood of commencement of the rainy season.
- Use of drought tolerant crops, often mentioned as one of the adaptation measures in agriculture against climate variability, particularly once forecasted (Ministry of Agriculture and Fisheries, Government of Jamaica 2010; Environment Division, Ministry of Public Works, Antigua and Barbuda, 2005), and a projected declining rainfall regime by the end of the present century. Fulton (2013) mentioned a few of these drought tolerant crops in use in Jamaica - cassava, pineapple, sweet potato, gungo peas, and ginger.
- Measures to modify crop microclimate (Skeete, n.d.) also often suggested to reduce risk due to climate variability and change, include mulching that reduces crop evapotranspiration (also reported by the Environment Division, Ministry of Public Works, Antigua and Barbuda 2005), and use of row covers and green houses to better control water loss and application (also reported by Fulton 2013). Skeete (n.d.) also provided some examples of types of mulch: dry grass and fallen leaves, fence clippings, shredded plant waste, coconut fibre, green waste, wood chips, newspaper, farm manure, fabric mulch, and plastic mulch. Mulching with Guinea Grass was also reported as a good practice used in Jamaica (Spence 2008).
- At a Workshop on Drought Management organised by the FAO in St. Johns Antigua and Barbuda in 2013, farmers (personal communication from farmers during the meeting) discussed using flat beds if they know of a pending drought and using raised beds for periods of forecasted heavy rains
- In the livestock industry in St. Lucia, farmers found the need to build forage banks (Valmont 2011)
- Trucking water is a common response in times of drought when domestic taps, in particular, run dry
- Use of firebreaks to reduce fire spread, and therefore the impact from drought-related fires in agricultural fields and communities (Ministry of Agriculture and Fisheries, Government of Jamaica 2010; Spence, 2008)
- Recharging aquifers, which necessitates significant collaboration amongst institutions (Ministry of Agriculture and Fisheries, Government of Jamaica, 2010; Spence, 2008)

There are yet other measures that are policy and institutionally driven and geared towards reducing the vulnerability of farmers, but not directly linked to watershed or field activities. Agriculture insurance, provides a mechanism to transfer a variety of risks faced by crop, livestock, forestry, or aquaculture production. As small island nations and economies exposed to regular weather and climate threats, agriculture is seen as high-risk, making re-insurance expensive and therefore premiums very high (Carballo and dos Reis, 2013). It was reported (Carballo and dos Reis, 2013) that only two insurance companies exist in the Caribbean: i) Windward Island Crop Insurance

(WINCROP) for banana growers and, ii) the Aseguradora Agropecuaria Dominicana SA (AGRODOSA) that provides multi-peril coverage to 7% of the cultivated area in the Dominican Republic.

The Caribbean Catastrophe Risk Insurance Facility (CCRIF) is exploring agriculture insurance²⁵. Agriculture insurance was widely discussed during a symposium²⁶ in June 2010 in Antigua and Barbuda, with Weather Index Insurance being suggested as an approach that is most suited for drought, but more challenging for sudden-risk events like hurricanes. The symposium concluded with one main resolution, of the need to establish a regional programme for disaster risk management. It was also suggested that a combination of mitigation, risk transfer (insurance), and coping is needed to deal with agriculture risk management in the Caribbean.

Desalination water has made it more possible for agriculture risk reduction as it lessens the concern of some for farmers by reducing the demand for regular agriculture sources for municipal use (Cooper and Bowen, 2001). Antigua provides most of its water from this source.

²⁵ <http://www.ccrif.org/node/86>

²⁶ Caribbean Agriculture Insurance Symposium on Disaster Risk Management in St. Johns Antigua, http://www.caricom.org/jsp/pressreleases/pres281_10.jsp?null&prnf=1

9. Issues

Any comprehensive water management plan would include the elements, defined earlier, of early warning, mitigation, preparedness, prevention, response, recovery and rehabilitation. However, managing water sustainably in any country context needs sound governance and an environment for enforcement, along with comprehensive, sound strategic planning that can only be supported by adequate human and financial capacity, and national coordination that encourages the participation of public and private sector stakeholders at all levels. For any development or ratification of policies and plans, or for the many resilience measures adopted or recommended by farmers, foresters, watershed managers, agriculture extension officers or others to work as effectively and efficiently as they should, there are some key barriers symptomatic of much of the Caribbean that have to be removed.

In developing a framework to diagnose barriers to climate change, Moser and Ekstrom (2010) suggested that barriers are "...obstacles that can be overcome with concerted effort creative management, change of thinking prioritisation, and related shifts in resources, land uses, institutions...". The authors went further to posit that such barriers can be overcome by sufficient political will, social support, resources and effort. Many programmes and projects have identified key barriers in the Caribbean, many of which have weak enabling environments and governance, which involve legislation and institutional frameworks, lack of finance, and poor national coordination. Moser (2009) describes governance as the "skilful and strategic navigation of competing interests, the ability to overcome institutional obstacles and inertia, employ needed strengths and overcome impeding capacity limits in the context of a dynamic environment of competing goals, needs, opportunities, necessary trade-offs, and the interests of a wide range of stakeholders". How these competing interests are balanced in the future, along with strengthening of institutions and building necessary capacity will determine how effective policies and plans, drafted or to be drafted, ratified or pending ratification, will be in managing Caribbean water resources.

In seeking to establish model water policies in the Organisation of Eastern Caribbean States (OECS), OECS (2012) outlined a number of barriers that would hinder resilience building in the water sector, and by extension, reduce resilience to drought impacts. These identified barriers, which are also supported by other authors, are described in the following sections.

INADEQUATE POLICY, REGULATORY, AND INSTITUTIONAL ENVIRONMENT

A weak enabling environment is seen as a critical barrier. ECLAC (2008) reported that, for three OECS countries, i) there were no specific IWRM policy, strategy and plans and ii) institutional frameworks of the water sector were inadequate with respect to planning, management and regulatory functions of water resources. Inadequate institutional and regulatory capacity was also seen as a barrier. These inadequacies prevent good governance of water resources and also prevent water utilities from operating in a financially viable environment. In many countries, water utilities, whose primary interest is an adequate municipal supply, oversee water management. The utilities are not equipped to preside over overall management of the resource. Further, such inadequacies continue to support fragmented management of the resource, as agencies and even private sector interests seek to entertain their own brands of

management based on their varying interests. CARICOM (2010) posits the need for more cross-ministerial and cross-departmental partnerships and planning. Such partnerships require improved national coordination and planning approaches should lead to national coordination of efforts toward IWRM and national drought planning. If there is a lack of coordination, risks can increase and events can be compounded to status of disaster. This lack of national coordination is seen as a major stumbling block to effective IWRM, including management during drought events.

LACK OF CAPACITY AT EVERY LEVEL

Policy and plan development is often compromised by lack of capacity (see also Roberts 2012 and ECLAC 2008). This was further supported by Francis (2013) who, reporting on Antigua and Barbuda, identified inadequate institutional and regulatory capacity as a barrier. One result of this is that where policies do exist, they are often not comprehensive enough, or are not evaluated and updated often enough. In fact, lack of capacity impacts on every facet of management of the water resource.

WEAKLY COORDINATED LAND MANAGEMENT

Water quality is of prime importance during drought, as sources of low quality limit water availability - even more during drought. It also increases the treatment cost of production. Weakly coordinated land management supports land degradation and pollution that reduces quality. This is often facilitated by weak regulation, particularly of private lands. Such management becomes politically sensitive, adding to the reluctance of strengthening land management policies.

THE VALUE OF WATER

Given the fundamental role water plays in human health and sanitation, it is generally considered a basic human right that must be made available at the lowest possible cost, or at times via free access. Abscission is therefore basically seen as a right and should not be restricted. However during drought, restrictions may become necessary as allocation to urgent and necessary activity, particularly domestic and municipal use, is prioritised. This also brings into focus private sector interests as privatisation of water supply drives expectations of increases in water prices by the public. There is already private sector involvement in the water sector since water bottlers supply water. Also, other interests like hotels provide their own desalinated water that, with further discussions, can find its excess being added to the national grids. These would strengthen the need for well-defined policies.

LACK OF TRANSPARENT MECHANISMS TO ADDRESS UPSTREAM/DOWNSTREAM USER CONFLICTS

Many water conflicts in the Caribbean stem from over abstraction upstream, such as for irrigation that impacts on the availability of potable water on the island of Antigua, and damming for hydroelectric power plants on the island of St. Vincent. In instances of low water availability, downstream users become very vulnerable, impacting many facets of the society. Part of the problem stems from the lack of transparent mechanisms to address upstream/downstream user conflicts. Maintaining an overall weak regulatory environment and the fragmentation of operation of the various agencies that have shared responsibility for water resources management, sustains this problem.

LACK OF FINANCE

This is another a barrier to policy-making (OECS 2012) and planning (Roberts 2012), and implementation as the gap in internal capacity cannot be filled externally without adequate financing. Further, lack of finance has also hindered actual management

activity, as the necessary equipment and tools are lacking, as well as maintenance. In Guyana, for example, the drainage and irrigation systems that feed the conservancies (mainly for irrigation) had deteriorated because of lack of maintenance and could no longer sufficiently provide water needs (US Army Corps of Engineers 1998). In other Caribbean countries, lack of maintenance and replacement of pipelines have caused great losses due to leakage. These enhance the impacts during drought. Further, un-metred users increases the difficulty to assess water use, and by extension its regulation.

To remove these barriers needs policy-makers with the will to carry out those suggestions of Moser and Ekstrom (2010), described earlier. One of the barriers is associated with changing policies and decisions that are without definite or strong guidance from Cabinet-ratified policies and plans that are still in draft form, that are weak and/or need reviewing to serve present situations. Policies and plans should promote the active participation and partnership of communities, governmental and non-governmental organisations, the private sector and development partners in the conceptualisation, design, and implementation. Finally, it may be worthwhile to study the diagnostic framework for barrier identification to climate change adaptation by Moser and Ekstrom that recommends key components, which recognise the roles of actors involved from the community to national levels, the larger context in which they act that includes the enabling governance environment, and the system on which they act that is exposed to climate change, and finally overcoming the barrier by mapping the source of the barrier relative to the actor's influence over it.

10. Regional agencies, institutions and projects

The Caribbean has a number of regional organisations with key roles in drought management, driven by frameworks for Disaster Risk Management (particularly in agriculture) and Climate Change Adaptation. The specific Caribbean frameworks that include those mentioned in Section 5 are: i) the Comprehensive Disaster Management, ii) The CARICOM Regional Framework for Achieving Development Resilient to Climate Change: 2011-2021 (CCCCC 2012), and iii) the Disaster Risk Management and Praedial Larceny and Technical Management Advisory Committees of the Jagdeo Initiative. The regional agencies with key roles are listed in Annex VII.

11. Conclusions

Hurricanes and floods are the natural climate-related hazards that command attention in the Caribbean, mainly due to the frequency of their threats and the magnitude of their damage over a relatively short time frame. However, drought is a slow-onset event whose impacts accumulate over months and even years, with a lesser regularity that for many years made it go unnoticed in the Caribbean. These combined with a lifespan that is curtailed by the start of the next rainy season, means it is usually of lower priority.

However, severe recent droughts have shown the significant impacts such events can have on agriculture, water resources, and ecosystem services. The most recent event in 2009-2010 was severe enough that the regional disaster agenda under the regional lead agency, CDEMA, included a focus on policy-making and planning to mitigate the impacts of drought. This was particularly so in two key socio-economic sectors – agriculture and water resources.

Policy-making and planning is hindered by weak governance, poor national coordination, lack of capacity, weak coordinated land management, lack of finance, and user conflicts. However, these can be overcome by strong political will that encourages participation in policy and planning processes by all actors in the social strata from community groups, who determine how resilient systems can be, to the political directorate that provides the enabling environment for sustainable development of water supplies and its efficient use. A careful study of how these actors interact with the water resources systems can offer key insights into building resilience in the widely varying Caribbean communities and particularly in agricultural systems that would enhance regional food security.

12. References

- Barbados Water Authority.** 1997. Draft policy framework for water resources development and management.
- Burton, S.** 1995. *Long-term fluctuations in rainfall over Barbados. Technical Note No. 30.* Caribbean Meteorological Institute.
- Bynoe, P.** 2008. Climate change adaptation with a gender perspective in the Caribbean: A case study of Surama, Guyana. *In Proc. 3rd Caribbean conference on comprehensive disaster management a catalyst for change. The Hilton Barbados, December 8 12, 2008.* (available at http://www.cdemavl.org/bitstream/123456789/149/27/palette_bynoe.pdf).
- Campbell, J.D., Taylor, M.A., Stephenson, T.S., Watson, R.A. & Whyte, F.S.** 2011. Future climate of the Caribbean from a regional climate model. *International Journal of Climatology*, 31: 1866-1878, doi:10.1002/joc.2200.
- Carballo, D.A. & dos Reis, L.** 2013. **The agricultural insurance market in the Caribbean.** World Bank notes series “enbrevé”, No. 183. Washington (available at <https://openknowledge.worldbank.org/bitstream/handle/10986/17030/762050BRI0Box30nBreve01830Eng0Print.pdf?sequence=1>).
- Caribbean Community Climate Change Centre (CCCCC).** 2012a. *Caribbean regional strategic program for climate resilience (SPCR).* Prepared for the Pilot Program for Climate Resilience. Belmopan, Belize (available at http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/Caribbean_Regional_Track_SPCR_CIF_Endorsed_Final.pdf).
- Caribbean Community Climate Change Centre (CCCCC).** 2012b. *Delivering transformational change 2011-21: implementing the CariCom regional framework for achieving development resilient to climate change. Executive Summary. Technical Report.* Belmopan (available at www.caribbeanclimate.bz).
- Caribbean Environmental Health Institute (CEHI).** 2007. *Roadmap toward integrated water resources management planning for Union Island, St. Vincent and the Grenadines.* In partnership with the United Nations Environment Programme Collaborating Centre for Water and Environment and the GEF-funded Integrating Watershed and Coastal Areas Management Project.
- Caribbean Environmental Health Institute (CEHI) and GEF-funded Integrating Watershed and Coastal Areas Management Project.** 2007. *Integrating watershed and coastal areas management (IWCAM). Roadmap toward integrated water resources management planning for Grenada.* In partnership with the United Nations Environment Programme Collaborating Centre for Water and Environment. Government of Grenada (available at http://www.pacificwater.org/userfiles/file/IWRM/Toolboxes/planning%20process/IWRM%20Road%20Map_Grenada_April%2007.pdf).

- Caribbean Environmental Health Institute (CEHI) and GEF-funded Integrating Watershed and Coastal Areas Management (IWCAM) Project.** 2008. *Roadmap towards integrated water resources management planning for Barbados* (draft). In partnership with the United Nations Environment Programme Collaborating Centre for Water and Environment. Government of Barbados.
- Caribbean Environmental Health Institute (CEHI) and GEF-funded Integrating Watershed and Coastal Areas Management (IWCAM) Project .** 2010. *Roadmap towards the preparation of an integrated water resources management (IWRM) plan for Saint Lucia*. Government of Saint Lucia.
- Centella, A., Bezanilla, A. & Leslie, K.** 2008. *A study of the uncertainty in future Caribbean climate using the PRECIS regional climate model*. Technical Report. Community Caribbean Climate Change Centre, Belmopan.
- Charlery, J., Nurse, L. & Whitehall, K.** 2006. Exploring the relationship between the North Atlantic oscillation and rainfall patterns in Barbados. *International Journal of Climatology*, 26: 819-827.
- Choy, D.** 2010. Pay for river water. *Newsday*. 14 January (available at <http://www.newsday.co.tt/news/0,117387.html>).
- Christensen, J.H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R.K., Kwon, W.T., Laprise, R., Magaña Rueda, V., Mearns, L., Menéndez, C.G., Räisänen, J., Rinke, A., Sarr, A. & Whetton, P.** 2007. Regional climate projections. In Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. & Miller, H.L., eds. *Climate change 2007: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change*. Cambridge University Press, Cambridge, New York, USA.
- Cook, K.H. & Vizi, E.K.** 2010. Hydrodynamics of the Caribbean low-level jet and its relationship to precipitation. Special U.S. CLIVAR Drought Collection. *American Meteorological Society*, pp. 1477-1494.
- Cooper, B. & Bowen, V.** 2001. *Integrating management of watersheds and coastal areas in small island developing states of the Caribbean*. National report for Antigua and Barbuda. Environment Division, Ministry of Tourism and Environment. Antigua and Barbuda.
- Caribbean Regional Fisheries Mechanism (CRFM).** 2013. *Formulation of a strategy, action plan and programme proposal on disaster risk management, climate change adaptation in fisheries and aquaculture in the CARICOM and wider Caribbean region*. Regional Workshop Report. CRFM Technical & Advisory Document, pp. 8-28.
- Enfield, D.B. & Alfaro, E.J.** 1999. The dependence of Caribbean rainfall on the interaction of the tropical Atlantic and Pacific oceans. *Journal of Climate*, 12: 2093-2103.
- Environment Division, Ministry of Public Works.** 2005. UNCCD draft national action plan for Antigua and Barbuda.

- Environment Division, Ministry of Tourism & Environment.** 2000. *Antigua and Barbuda national report on the implementation of the Convention to Combat Desertification.*
- Environmental Solutions Antigua Limited (ESAL).** 2008. *Water quality guidelines for Antigua & Barbuda.* (available at http://gefantigua.org/wp-content/uploads/2010/11/Water-Quality-Guidelines-for-AB-Final_0.pdf).
- FAO.** 2008. *Assistance to improve local agriculture emergency preparedness in Caribbean countries highly prone to hurricane related disaster.* TCP/RLA/3101.
- FAO.** 2003. *The state of food insecurity in the world: monitoring progress towards the world food summit and millennium development goals.* Rome.
- Farrell, D., Trotman, A. & Cox, C.** 2010. Drought early warning system and risk reduction: a case study of the Caribbean drought of 2009–2010. *Global assessment report on disaster risk reduction.* United Nations International Strategy for Disaster Reduction (ISDR), Geneva.
- Fulton, L.** 2013. *Drought conditions and management strategies in Jamaica.* Presented at the UN Water Initiative on Capacity Development to Support National Drought Management Policy.
- Gamble, D.W., Parnell, D.B. & Curtis, S.** 2007. Spatial variability of the Caribbean mid-summer drought and the relation to North Atlantic high circulation. *International Journal of Climatology*, (28)3: 343–350. DOI:10.1002/joc.1600.
- GEF-IWCAM.** 2012. *Finding a balance between meeting needs and addressing policy issues in integrated watershed and coastal areas management.* GEF IWCAM Final Project Conference Summary 16–18 November 2011. Oranjestad, Aruba (available at <http://iwlearn.net/iw-projects/1254/newsletters/gef-iwcam-final-project-conference-summary>)
- Giannini, A., Kushnir, Y. & Cane, M.A.** 2000. Interannual variability of Caribbean rainfall, ENSO and the Atlantic Ocean. *Journal of Climate* 13, 297–310.
- Giannini, A., Chang, J.C.H., Cane, M.A., Kushnir, Y., & Seager, R.** 2001. The ENSO teleconnection to the tropical Atlantic ocean: contributions of the remote and local SSTs to rainfall variability in the tropical Americas. *Journal of Climate* 14: 4530–4544.
- Gibbs, W.J., & Maher, J.V.** 1967. Rainfall deciles as drought indicators. *Bureau of Meteorology Bulletin No. 48*, Commonwealth of Australia, Melbourne.
- Glantz, M.** 1987. *Drought and hunger in Africa.* Cambridge University Press. 457 pp.
- Global Water Partnership.** 2014. *Integrated water resources management in the Caribbean: The challenges facing small island developing states.* Technical focus paper.
- Global Water Partnership-Caribbean.** 2013. *Priorities on water resources and issues on WRM monitoring and reporting. National stakeholder consultations on water: supporting the post-2015 development agenda* (available at <https://sustainabledevelopment.un.org/content/documents/1815nationalstakeholder.pdf>).

- Government of Antigua and Barbuda.** 2011. A national integrated water resource management (IWRM) policy for Antigua and Barbuda.
- Government of St. Lucia.** 2009. Water management plan for drought conditions (available at <http://archive.stlucia.gov.lc/nemp/index.htm>).
- Hall, T.C., Sealy, A.M., Stephenson, T.S., Kusunoki, S., Taylor, M.A., Chen, A.A. & Kitoh, A.** 2012. Future climate of the Caribbean from a super-high-resolution atmospheric general circulation model. *Theoretical and Applied Climatology*, 113(1): 271-287, doi:10.1007/s00704-012-0779-7.
- International Strategy for Disaster Reduction (ISDR).** 2007. *The Hyogo framework for action 2005-2015*, extract from the final report of the United Nations World Conference on Disaster Reduction (A/CONF.206/6). Geneva (available at http://www.unisdr.org/files/1037_hyogoframeworkforactionenglish.pdf).
- Jamaican Information Service.** 2007. Ministry of Finance and Planning.
- L.R.O 1/2012. Water Resources Act.** 2002. Laws of Guyana, Chapter 30:01 (available at <http://faolex.fao.org/docs/pdf/guy43370.pdf>. Accessed 24-01-2014.
- Løvendal, C.R., Jakobsen, K.T., Jacque, A.** 2007. *Food prices and food security in Trinidad and Tobago*. ESA Working Paper No. 07-27, Economics Division, FAO, Rome.
- McKee, T.B., Doesken, N.J. & Kleist, J.** 1993. The relationship of drought frequency and duration to time scales. Preprints, *8th Conference on Applied Climatology*, pp. 179-184. January 17-22, Anaheim, California.
- Mimura, N., L. Nurse, R.F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet and Sem, G.** 2007. Small islands. In M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson, eds. *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change*. Cambridge University Press, Cambridge, UK, pp. 687-716.
- Ministry of Agriculture, Guyana.** 2013. Disaster risk management plan for the agriculture sector 2013-2018. Georgetown.
- Ministry of Agriculture and Fisheries, Government of Jamaica.** 2010. Agriculture disaster risk management plan.
- Ministry of the Environment, Water Resources and Drainage.** 2010. *Barbados national assessment report of progress made in addressing vulnerabilities of SIDS through implementation of the Mauritius strategy for further implementation (MSI) of the Barbados programme of action*. Government of Barbados (available at <http://www.sids2014.org/content/documents/18Barbados-MSI-NAR2010.pdf>).
- Moore & Associates.** 2002. *Barbados national action programme to combat desertification and land degradation, and to mitigate against the effects of desertification, land degradation and drought*. Working Draft. Ministry of Physical Development and Environment, Barbados.

- Moser, S. & Ekstrom, J. 2010. A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences of the United States of America*, 107(51): 1-6.
- Moser, S. 2009. *Governance and the art of overcoming barriers to adaptation*. IHDP Update, (3): 31-36.
- National Drought Mitigation Center. 1998. *Reported drought-related effects of El Niño for March 1998*. Retrieved May 1st, 2008 from <http://www.drought.unl.edu/risk/world/nino398.pdf>.
- National Irrigation Commission Limited. n.d. *The national irrigation development master plan* (NIDP). Jamaica (available at <http://www.nicjamaica.com/NIDP/NIC%20nidp%20Master%20Plan.pdf>). Accessed December 2013.
- Jamaican National Water Commission. 1965. *National Water Commission Act*. (available at <http://moj.gov.jm/sites/default/files/laws/National%20Water%20Commission%20Act.pdf>).
- Organization of Eastern Caribbean States (OECS). 2012. Water sector model policy and model water act for countries within the organization of Eastern Caribbean States. Reducing the risks to human and natural assets resulting from climate change. Synthesis Report prepared by the Caribbean Environmental Health Institute.
- Palmer, W.C. 1965. *Meteorological drought*. Research Paper No. 45. U.S. Department of Commerce Weather Bureau, Washington, D.C.
- Palmer, W.C. 1968. Keeping track of crop moisture conditions, nationwide: The new crop moisture index. *Weatherwise* 21: 156-161.
- Roberts, D. 2013. Status of disaster risk management. Plans for floods, hurricanes and drought in the agriculture sector: a Caribbean perspective. FAO Subregional Office in Barbados.
- Simpson, M.C., Clarke, J.F., Scott, D.J., New, M., Karmalkar, A., Day, O.J., Taylor, M., Gossling, S., Wilson, M., Chadee, D., Stager, H., Waithe, R., Stewart, A., Georges, J., Hutchinson, N., Fields, N., Sim, R., Ruddy, M., Matthews, L., Charles, S., & Agosta G'meiner, A. 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA). Dominican Republic, DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.
- S.I. 1980. N. 153. Barbados water authority act. 8th October 1980 (available at [http://www.oas.org/usde/environmentlaw/waterlaw/documents/Barbados-Water_Authority_Act_\(1980\).pdf](http://www.oas.org/usde/environmentlaw/waterlaw/documents/Barbados-Water_Authority_Act_(1980).pdf)).
- Skeete, S. n.d. The drought survival kit: A 5 point approach for coping with harsh, droughty conditions. Ministry of Agriculture, Food, Fisheries & Water Resources (available at: http://www.agriculture.gov.bb/agri/images/stories/food/Food_crop_research/documents/drought_survival_kitreducedcov.pdf).
- Spence, B. 2008. Assistance to improve local agricultural emergency preparedness in Caribbean countries highly prone to hurricane related disasters. *Good practices for hazard risk management in agriculture*. Summary report for FAO TCP/RLA/3101. Jamaica.

- Stephenson, T.S., Chen, A.A. & Taylor, M.A. 2008. Toward the development of prediction models for the primary Caribbean dry season. *Theoretical and Applied Climatology* 92: 87-101.
- Stephenson, T.S., Vincent, L.A., Allen, T., Van Meerbeeck, C.J., McLean, N., Peterson, T.C., Taylor, M.A., Aaron-Morrison, A.P., Auguste, T., Bernard, D., Boekhoudt, J.R., Blenman, R.C., Braithwaite, G.C., Brown, G., Butler, M., Cumberbatch, C.J., Etienne-Leblanc, S., Lake, D.E., Martin, D.E., McDonald, J.L., Zaruela, M.O., Porter, A.O., Ramirez, M.S., Tamar, G.A., Roberts, B.A., Mitro, S.S., Shaw, A., Spence, J.M., Winter, A. & Trotman, A.R. 2014. Changes in extreme temperature and precipitation in the Caribbean region, 1961-2010. *International Journal of Climatology*, 34(9): 2957–2971, DOI: 10.1002/joc.3889.
- Suárez, A. G., Garraway, E., Vilamajó, D., Mujica, L., Gerhartz, J., Capote, R. T. & Blake, N. 2008. *Climate change impacts on terrestrial biodiversity in the insular Caribbean*. Report of Working Group III, Climate. Caribbean Natural Resources Institute (CANARI).
- Svoboda, M., LeComte, D., Hayes, M., Heim, R., Gleason, K., Angel, J., Rippey, B., Tinker, R., Palecki, M., Stooksbury, D., Miskus & D., Stephens, S. 2002. The drought monitor. *Bulletin of the American Meteorology Society*, 83: 1181-1190.
- Taylor, M.A, Centella, A., Charlery, J., Bezanilla, A., Campbell, J., Borrajero, I., Stephenson, T., & Riad Nurmohamed, R. 2013: The precis Caribbean story: lessons and legacies. *Bulletin of the American Meteorological Society*, 94: 1065-1073. doi: <http://dx.doi.org/10.1175/BAMS-D-11-00235.1>.
- Taylor, M.A., Enfield, D.B. & Chen, A.A. 2002. Influence of tropical Atlantic versus the tropical Pacific on Caribbean rainfall. *Journal of Geophysical Research* 107 (C9), doi:10.1029/2001/JC001097.
- Taylor, M.A., Stephenson, T.S., Owino, A., Chen, A.A. & Campbell, J.D. 2011. Tropical gradient influences on Caribbean rainfall. *J. Geophys. Res.*, 116, D00Q08, doi:10.1029/2010JD015580.
- Taylor, M.A., Whyte, F.S., Stephenson, T.S. & Campbell, J.D. 2012. Why dry? Investigating the future evolution of the Caribbean low level jet to explain projected Caribbean drying. *International Journal of Climatology* DOI:10.1002/joc.3461.
- Thomas Reuters Foundation. 2013. *Drought, poor harvest to worsen Haiti food crisis*. World Food Programme (WFP) (available at <http://www.trust.org/item/20130618050112-zpqnd>. Accessed 01-02-2014.
- Toba, N. 2009. *Potential economic impacts of climate change in the Caribbean community*. LCR Sustainable Development Working Paper No. 32 World Bank, pp 35-47.
- Trotman, A. 1994. *Agroclimatic study of Barbados, 1970 to 1990: Rainfall*. Technical Note No. 28. Caribbean Meteorological Institute.
- Trotman, A.R., Gordon, R.M., Hutchinson, S.D., Singh, R. & McRae-Smith, D. 2009. Policy responses to GEC Impacts on food availability and affordability in the Caribbean Community. *Environmental Science & Policy* 01/2009; DOI:10.1016/j.envsci.2009.02.001.

- UNCED.** 1992: *Report of the United Nations Conference on Environment and Development*, Chapter 18. A/CONF.151/26 (Vol. II).
- UNFCCC.** 2000. *Grenada's initial communication to the UNFCCC*, October 2000, pp. 100. Accessed on: <http://unfccc.int/resource/docs/natc/grnnc1.pdf>.
- United Nations Environment Programme (UNEP).** 2010. *National environmental summary: Barbados* (available at <http://www.pnuma.org/publicaciones/FINAL%20Barbados%20NES%20Nov%202010-%20edited.pdf>).
- US Army Corps of Engineers.** 1998. *Water resources assessment of Guyana*. United States Southern Command (available at <http://uog.edu.gy/faculties/fot/repository/sites/default/files/Water%20resources,%20Guyana.pdf>).
- United States Agency for International Development, USAID.** 1998. *El Niño southern oscillation - ENSO 1997/98 and risk management in the Latin American and Caribbean region*. Office of U.S. Foreign Disaster Assistance.
- Valmont, V.V.** 2011. *Impact assessment report: disaster risk mitigation - livestock*. Report for FAO project TCP/STL/3202 (disaster risk mitigation in agriculture.) Ministry of Agriculture, Lands, Forestry and Fisheries, St. Lucia.
- Water resources act** (Act 36 of 1995). 6th November 1995. Jamaica (available at http://www.nepa.gov.jm/symposia_03/laws/Other_Laws/Water_resources_Act_1995.pdf).
- World Bank.** 2009. Implementation completion and results report (Tf-51853) on a global environment facility grant in the Amount of US\$ 5.0 million to the Caribbean community/Caribbean community climate change centre for a Caribbean mainstreaming adaptation to climate change project. Sustainable Development Sector Unit Caribbean Country Unit Latin America and the Caribbean Region (available at http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2009/10/21/000333038_200910210222304/Rendered/PDF/ICR11630P0733810disclosed0101191091.pdf).
- World Bank.** 2011. *World Development Indicators 2011*. Washington DC.
- World Bank.** 2013. *World Development Indicators 2013*. Washington DC.
- World Economic Forum.** 2013. *Global Economic Report 2013*.
- WWAP** (World Water Assessment Programme). 2012. *The United Nations World Water Development Report 4, Volume 1. Managing water under uncertainty and risk*. Paris, UNESCO (available at <http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/WWDR4%20Volume%201-Managing%20Water%20under%20Uncertainty%20and%20Risk.pdf>).

Annex I. Drought questionnaire used in the study

The questionnaire was divided into two sections, Section A is tailored to persons involved in production and Section B to those involved in support services.

Name:	Organization/Company:
Country:	Telephone:
Email:	Date:

SECTION A- PRODUCTION

1. What role do you play in the agriculture sector?
- a. Crop production b. Livestock rearing c. Fisheries and agriculture
 d. Forestry } e. Other _____

2. What do you consider to be a drought?
- _____
- _____

3. During the past decade, how have droughts impacted your company/business?

- a. No impact
- b. Low impact
- c. Moderate Impact
- d. High impact
- e. Extreme Hardship

If option (a) is selected, please skip to question 5.

4. How have you been impacted by drought in the past?

- | | |
|--|---|
| Loss of crops <input type="radio"/> | Low water supply/levels <input type="radio"/> |
| Loss of Livestock <input type="radio"/> | Livestock diseases <input type="radio"/> |
| Poor soil quality <input type="radio"/> | Health problems (dust) <input type="radio"/> |
| Anxiety and stress <input type="radio"/> | Increase in food prices <input type="radio"/> |
| Reduced income <input type="radio"/> | Loss of human life <input type="radio"/> |
| Decrease in production <input type="radio"/> | _____ % less production/revenue |
| Other _____ | |

- 5a. What support did you receive during the drought?
 None Financial assistance Social support services
 Tax relief Tools and technologies to inform decision making
 Emergency water supply Supply of fresh seeds
 Other _____
- 5b. What departments/agencies/organizations provided support services during the drought?

6. What practices have you adopted to build your resilience to drought?
 Rain water harvesting Treatment and reuse of wastewater
 Water storage Water saving irrigation techniques
 Monitoring rainfall Utilizing Early warning information/forecasts
 None
 Other _____
- 7a. How effective have these practices been in building your resilience?
 Not effective Effective Very effective
- 7b. If not effective, what can be done to make these efforts more effective?

- 8a. Are you aware of the Caribbean drought and precipitation monitoring network (CDPMN)?
 Yes No
- 8b. If yes, do you use the information provided? Yes No
- 8c. If yes, how do you use the information to build your resilience to drought?

- 9a. Are you aware of the Caribbean rainfall forecast prepared by the Caribbean Climate Outlook Forum?
 Yes No
- 9b. If yes, do you use the information provided? Yes No
- 9c. If yes, how do you use the information to build your resilience to drought?

10a. Are you aware of a drought management policy/plan in your country?

Yes No

10b. If yes, how effective is the policy/plan?

Not effective Effective Very effective

10c. If not effective, what can be done to make the policy/plan more effective?

10d. What drought management strategies are included in the policy/plan?

11. What drought management strategies do you think should be developed for the Caribbean?

Thank you for your assistance!

SECTION B- SUPPORT SERVICES

1. What role do you play in the agriculture sector?
 - a. Extension officer
 - b. Researcher
 - c. Water resource management
 - d. Water provider
 - e. Other: _____

2. What do you consider to be a drought?

3. During the past decade, how have droughts impact your water resources?
 - a. No impact
 - b. Low impact
 - c. Moderate Impact
 - d. High impact
 - e. Extreme Hardship

4. What impacts have you observed during droughts in the past?

Loss of crops <input type="radio"/>	Low water supply/level <input type="radio"/>
Loss of Livestock <input type="radio"/>	Decrease in production <input type="radio"/>
Poor soil quality <input type="radio"/>	Health problems <input type="radio"/>
Anxiety and stress <input type="radio"/>	Loss of human life <input type="radio"/>
Reduced income <input type="radio"/>	Increase in food prices <input type="radio"/>
Other _____	

- 5a. Does your organization/department provide support to the agriculture sector during a drought?

Yes No

- 5b. If yes, what support is provided?

Financial assistance Social support services Tax relief

Tools and technologies to inform decision making Supply of fresh seeds

Emergency water supply None

Other _____

- 6a. Have any other ministries/departments/organization/agencies assisted with the provision of support services during a drought? Yes No

- 6b. If yes, please name the ministries/departments/organization/agencies.

- 6c. What support is provided?
 Financial assistance Social support services Tax relief
 Tools and technologies to inform decision making Supply of fresh seeds
 Emergency water supply Other _____
- 6d. How effective have these support services been in alleviating the impacts caused by drought?
 Not effective Effective Very effective
 If not effective, what can be done to make these efforts more effective?

7. What practices do you recommend to your stakeholders (farmers, water users) to build their resilience to drought?
 Rain water harvesting Treatment and reuse of wastewater
 Water storage Water saving irrigation techniques Monitoring rainfall
 Utilizing Early warning information/forecasts None
 Other _____
8. What short term measures have you employed to address water shortages?
- Supply enhancement**
- | | |
|--|-----------------------|
| Mixing fresh and low quality waters | <input type="radio"/> |
| Exploiting high cost waters | <input type="radio"/> |
| Over-drafting aquifers | <input type="radio"/> |
| Diverting water from specific areas | <input type="radio"/> |
| Decreasing transport and distribution losses | <input type="radio"/> |
| Adjust legal and institutional framework | <input type="radio"/> |
| Other _____ | |
- Demand management**
- | | |
|---|-----------------------|
| Restricting agricultural uses | <input type="radio"/> |
| Restricting municipal uses (lawn irrigation, car washing) | <input type="radio"/> |
| Review operations of reservoirs | <input type="radio"/> |
| Water metering and pricing | <input type="radio"/> |
| Water rationing | <input type="radio"/> |
| Public awareness and education | <input type="radio"/> |
| Provide permits to exploit additional resources | <input type="radio"/> |
| Provide drilling equipment | <input type="radio"/> |
| Incentives to invest in water saving technologies | <input type="radio"/> |
| Adjust legal and institutional framework | <input type="radio"/> |
| Other _____ | |

9a. How effective have these measures been in alleviating the impacts caused by drought?
 Not effective Effective Very effective

9b. If not effective, what can be done to make these measures more effective?

10. What long term measures do you intend to put into place?

Supply enhancement

- Increase water collection and storage opportunities
- Desalination of brackish and saline waters
- Treatment and reuse of wastewater
- Water transfers
- Artificial precipitation
- Locate potential new resources (standby supplies)
- Aqueducts and canals
- Groundwater recharge
- Monitoring and forecasting
- Adjust legal and institutional framework
- Other _____

Demand management

- Adopting supplementary and deficit-irrigation
- Water saving irrigation techniques (drip, sprinkler)
- Incentives to invest in water saving technologies
- Water recycling
- Dual distribution networks for drinking water supply
- Inventory private wells and negotiate their public use
- Assess vulnerability and advise water uses
- Elaborate alert procedures
- Carry over storage
- Conjunctive use
- Adjust legal and institutional framework
- Other _____

11a. Are you aware of the Caribbean Drought and Precipitation monitoring network (CDPMN)?

Yes No

11b. If yes, do you use the information provided? Yes No

11c. If yes, how do you use the information to build your resilience to drought?

- 12a. Are you aware of the Caribbean precipitation forecast prepared by the CariCOF?
Yes No
- 12b. If yes, do you use the information provided? Yes No
- 12c. If yes, how do you use the information to build your resilience to drought?

- 13a. Is there a drought risk management policy/ plan that is executed in your country when a drought occurs? Yes No
- 13b. If yes, what role does your organization/ department play in executing this plan?

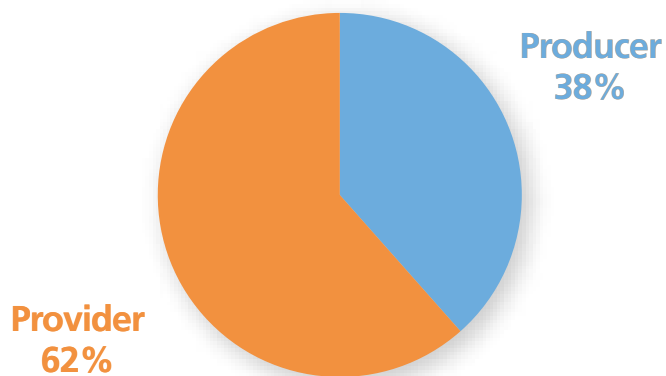
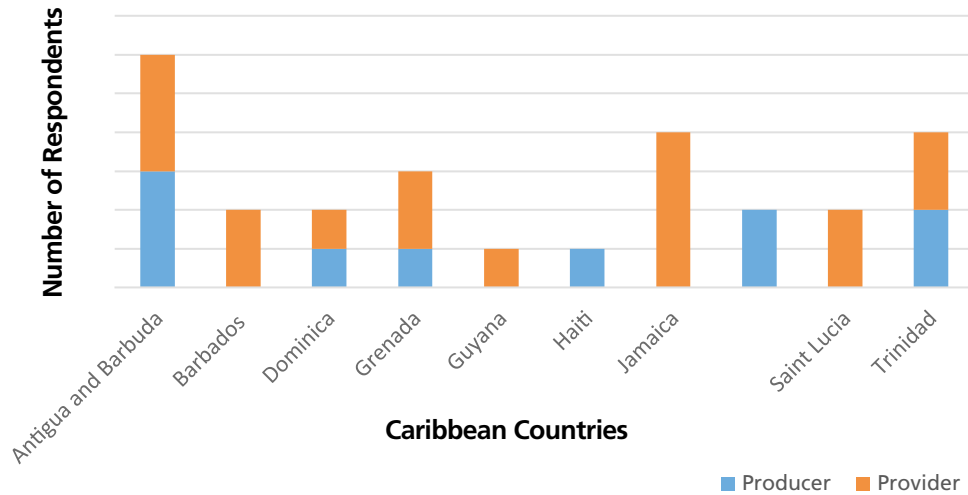
- 13c. How effective is the policy/plan?
Not effective Effective Very effective
- 13d. If not effective, what can be done to make the policy/plan more effective?

- 13e. What drought management strategies are included in policy/plan?

14. What drought management strategies do you think should be developed for the Caribbean?

Thank you for your assistance!

Annex II Categories of survey respondents



Respondents by organisation, country and category (service provider/producer).

	Name	Organisation/Company	Country
Service Providers	Farzana Leon	Water Resource Management Agency, Government of Saint Lucia	Saint Lucia
	David Lewis	Forestry Department	Saint Lucia
	Jacqueline Spence	Meteorological Services	Jamaica
	Trevor Thompson	Ministry of Agriculture, Land Use Division	Grenada
	Donessa David	HYDROMETEOROLOGICAL SERVICE	Guyana
	Kenneth Kerr	Trinidad and Tobago Meteorological Services	Trinidad and Tobago
	Basil Fernandez/ Herbert Thomas	Water Resources Authority	Jamaica
	Lenworth Fulton	Rural Agricultural Development Authority	Jamaica
	Benedict Peters	National Disaster Management Agency	Grenada
	Owolabi Elabanjo	Ministry of Agriculture, Extension Division	Antigua and Barbuda
	Roberta Williams	Gilbert Agricultural & Rural Development Center	Antigua and Barbuda
	Dianna Henry	Ministry of Agriculture	Dominica
	Keithley Meade	Antigua and Barbuda Meteorological service	Antigua and Barbuda
	Edmund Brathwaite	BADMC	Barbados
	Alex Ifill	Barbados Water Authority (BWA)	Barbados
David Samm	WASA	Trinidad	
Producers	Audrey Walters-Butler	Women In Agriculture for Rural Development (WARD)	SVG
	Evans Gooding	North East Farmers Organization	Grenada
	Julius Ross	Ministry of Agriculture	Antigua & Barbuda
	Devica Sookoo	ASTT	Trinidad
	Talot Bertrand	PROMODEV	Haiti
	Ipha	ECTAD/CaFAN	SVG
	Pamella Thomas	TFPC- CaFAN	Antigua and Barbuda
	Ramgopaul Roop	Rocrops Agrotec	Trinidad
	Dianna Henry	Nature Isle Pineapple Producers Ltd (NIPPA) Farmer	Dominica
	Dale Destin	Antigua and Barbuda Meteorological service	Antigua

Annex III Drought impacts and their severity based on survey respondents, by country

Respondents by organisation, country and category (service provider/producer)

Country	Impacts	Severity of impact
Antigua and Barbuda	Loss of crops, loss of livestock, low water supply/level, decrease in production, poor soil quality, reduced income, increase in food prices	High
Barbados	Loss of crops, low water supply/levels, poor soil quality, anxiety and stress, increase in food prices, decrease in production	Moderate
Dominica	Loss of crops, low water supply/level, decrease in production, poor soil quality, reduced income, increase in food prices	Moderate
Grenada	Loss of crops, loss of livestock, low water supply/levels, decrease in production, poor soil quality, anxiety and stress, reduced income, increase in food prices	High
Guyana	Loss of crops, low water supply/levels, decrease in production, reduced income, increase in food prices	Moderate
Haiti		
Jamaica	Loss of crops, low water supply/levels, decrease in production, health problems, anxiety and stress, increase in food prices	High
St. Vincent and the Grenadines		
Saint Lucia	Low water supply levels	High
Trinidad	Low water supply/levels, anxiety and stress, reduced income, increase in food prices	Moderate

Annex IV Drought risk management options to address water shortages implemented by countries as reported in the survey

Short term measures	Antigua	B'dos	Dominica	Grenada	Guyana	Haiti	Jamaica	SVG	SLU	T & T
Supply Enhancement	Mixing fresh and low quality waters									
	Exploiting high cost waters				X		X			
	Over-drafting aquifers									
	Diverting water from specific areas				X	X	X			X
	Decreasing transport & distrib losses	X	X				X			X
	Adjust legal and institutional framework				X					
	Mixing fresh and low quality waters									
	Exploration of alt. sources of water								X	
Demand Management	Restricting agricultural uses				X					X
	Restricting municipal uses	X			X		X			X
	Review operations of reservoirs		X		X	X				X
	Water metering and pricing	X	X		X					
	Water rationing	X	X		X		X		X	X
	Public awareness and education	X	X		X	X	X		X	X
	Provide permits to exploit additional resources									
	Provide drilling equipment									
	Incentives to invest in water saving technologies	X	X					X		
	Adjust legal and institutional framework				X					

Long term measures	Antigua	B'dos	Dominica	Grenada	Guyana	Haiti	Jamaica	SVG	SLU	T & T
Supply Enhancement										
Increased water collection and storage	X	X		X	X		X		X	
Desalination of brackish and saline waters		X		X						
Treatment and reuse of wastewater	X	X					X		X	
Water transfers		X			X		X			
Artificial precipitation										
Locate potential new resources (standby supplies)	X			X						
Aqueducts and canals										
Groundwater recharge	X	X					X			
Monitoring and forecasting	X	X		X	X		X		X	X
Adjust legal and institutional framework				X					X	
Incentives toward rainwater harvesting									X	
Demand Management										
Adopting supplementary and deficit-irrigation	X	X		X						
Water saving irrigation techniques (drip, sprinkler)	X	X	X	X	X		X			
Incentives to invest in water saving technologies	X	X		X			X			
Water recycling	X	X					X		X	
Dual distribution networks for drinking water supply										
Inventory private wells and negotiate their public use									X	
Assess vulnerability and advise water uses	X			X		X	X			X
Elaborate alert procedures	X			X						X
Carry over storage										
Conjunctive use										
Adjust legal and institutional framework				X			X			

Annex V Service providers and their roles in drought management as reported in the survey

Service providers and their roles in drought management

Country	Role of Provider	Drought management strategies	Effectiveness
Antigua and Barbuda	Antigua Public Utilities Authority (APUA) has proposed an unofficial plan that could use further development	Cheaper alternative water supply, e.g brackish water desalination. Also, the knowledge and production of alternative crops that can better withstand drought conditions.	Not effective Further input on a broader scale and making use of the tools that exist
Grenada	The role of the Ministry of Agriculture, Land Use Division is the provision of information, field assessment, data collection, analysis and distribution	Committees to be setup to look at early warning information systems drought monitoring, awareness and information, research	Effective But it is focused on response measures, not based on a plan. Knee-jerk reaction. It needs greater support from technical and senior ministry staff so that it can be taken to policy makers for adoption by cabinet.
Jamaica	Provide current drought conditions and precipitation forecast (Met. Services) Provision of regular status updates on water resources availability especially surface water resources.	Monitoring and research Early warning system Mostly trucking which is why it is being revised to include: proactive forecasts, artificial recharge, expanded monitoring of rainfall and water resources, emergency measures, priority areas for irrigation, crops with low water demand for irrigable lands and variation in licences to abstract and use water during drought periods	Effective Plan being revised to include new forecast techniques, increased public education/awareness, make more proactive rather than the reactive mode that is now in place and more integrated.
Saint Lucia	Prior to drought: Early warning through drought monitoring precipitation index and hydrological monitoring Recommendation to Minister declaring a water emergency (Water Resource Management Agency, Government of Saint Lucia)	Monitoring for early warning Advising the public on conservation	Effective
Trinidad and Tobago	Meteorological department responsible for monitoring and determining when a drought has occurred, department triggers the early warning system	Water conservation program, including redistribution	Effective

Annex VI Agency and roles in the draft drought early warning and information systems plans for Grenada

Committee/Working Group/ Network	Objective	Agencies Involved
Drought Early Warning and Information Systems (DEWIS) Committee	Coordinating and Policy Role - to contribute to efforts to mitigate the effects of droughts in Grenada through provision of early warning, and public education and awareness information.	Ministry of Agriculture (Lead Agency); Meteorological Services; National Water and Sewerage Authority; NaDMA; Farmers' representatives, Fire Department (of the Royal Grenada Police Force), Media Representative, Government Information Systems, Grenada Chamber of Commerce
Drought Monitoring Network	To manage climatological and hydrological data, and from this produce the necessary climate and water monitoring information and forecasts for Early Warning advice	NAWASA, Ministry of Agriculture, Inter-American Institute for Cooperation in Agriculture (IICA), Farmers Groups, Meteorological Service, NaDMA, Inter Agency Group of Development Organisations.(IAGDO), Ministry of Environment.
Awareness, Education and Outreach (AEO) Working Group	To develop and implement a Drought Education and Awareness Plan throughout the Tri-Island State	NaDMA, Meteorological Service, NAWASA, Ministry of Agriculture, Farmers' Representatives, Media Workers Association of Grenada (MWAG), Government Information System (GIS), Ministry of Education; Chief Education Officer, Friends of the Earth Grenada (FOEG).
Web Information Portal Working Group	To house and disseminate information related to drought including such on Early Warning, Education and Outreach	Meteorological Service, Ministry of Agriculture, NaDMA, NAWASA, Ministry of Agriculture – NWIS, NAWASA- GIS, NaDMA – GPRS.

Annex VII Regional agencies, institutions and projects concerned with drought

THE CARIBBEAN DISASTER EMERGENCY MANAGEMENT AGENCY (CDEMA)

This agency coordinates regional disaster management. Formerly the Caribbean Disaster Emergency Response Agency (CDERA), CDEMA leads the region in continued development and transformation of Comprehensive Disaster Management, fully embracing its principles and practice. CDEMA's functions are: i) mobilising and coordinating disaster relief, ii) mitigating or eliminating, as far as practicable, the immediate consequences of disasters in Participating States; iii) providing immediate and coordinated response by means of emergency disaster relief to any affected Participating State; iv) securing, coordinating and providing to interested inter-governmental and non-governmental organisations reliable and comprehensive information on disasters affecting any Participating State, and v) encouraging the adoption of disaster loss reduction and mitigation policies and practices at the national and regional level, cooperative arrangements and mechanisms to facilitate the development of a culture of disaster loss reduction; and coordinating the establishment, enhancement and maintenance of adequate emergency disaster response capabilities among the Participating States.

THE CARIBBEAN COMMUNITY CLIMATE CHANGE CENTRE (CCCCC)

This centre coordinates the Caribbean region's response to climate change, working on effective solutions and projects to combat the environmental impacts of climate change and global warming. It provides climate change-related policy advice and guidelines to the Caribbean Community (CARICOM) Member States. CCCCC also serves as an archive and clearing house facility for regional climate change data and documentation. CCCCC is responsible for the development and implementation of the CARICOM Regional Framework for Achieving Development Resilient to Climate Change: 2011-2021. CCCCC is recognised by the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Environment Programme (UNEP), and other international agencies as the focal point for climate change issues in the Caribbean. With rainfall projected to decline significantly by the end of the century, adaptation to drought impacts, including in the agriculture and water sectors, is paramount to CCCCC Member States.

CARIBBEAN INSTITUTE FOR METEOROLOGY AND HYDROLOGY (CIMH)

This is the technical arm of the Caribbean Meteorological Organisation, with a mandate to "assist in improving and developing the meteorological and hydrological services as well as providing the awareness of the benefits of meteorology and hydrology for the economic well-being of the CIMH member states". This is achieved through training,

research, investigations, and the provision of related specialized services and advice. It is also the Lead Agency for the Caribbean Drought and Precipitation Monitoring Network (CDPMN) and the Caribbean Climate Outlook Forum (CariCOF), a significant part of the regional climate early warning mechanism. CIMH is also a Regional Climate Centre (in demonstration phase) of the World Meteorological Organization (WMO).

CARIBBEAN AGRICULTURAL RESEARCH AND DEVELOPMENT INSTITUTE

The Institute has a major role in support of the attainment of regional food security and the overall development of Caribbean people, through pursuing the research and development needs of agriculture and food security of the region. Its priority areas are: i) knowledge generation, diffusion & application, focusing particularly on the development of commodities that ensure food and nutrition security, ii) risk management that focuses on the threats, challenges, and opportunities for managing invasive species and climate change, and iii) soil and water management with emphasis on soil rejuvenation, soil conservation, water harvesting, and use and soil water enhancement.

UNIVERSITY OF THE WEST INDIES (UWI)

This is vital to regional research and capacity building. It is important to mention the Climate Studies Group Mona (CSGM), Mona Campus, Jamaica. The CSGM is currently engaged in research on drivers of Caribbean climate that would be instrumental in improving drought forecasting in the region. The Mona campus also houses the Disaster Risk Reduction Centre that through its research, complements the work of agencies like CDEMA. UWI also works in a number of areas related to water, including policy, irrigation and engineering across its three main campuses.

CARIBBEAN ENVIRONMENTAL HEALTH INSTITUTE (CEHI)

This institute began as a Technical Institute of the Caribbean Community (CARICOM). It was established in 1979 by Governments of the Caribbean to address environmental concerns and further the sustainable development of the region. The Institute's environmental health mandate focuses on the impacts of human activity on the environment and the consequent effects on human health and the socio-economic development of CARICOM States. CEHI is dedicated to finding cost effective solutions to environmental problems. The relevant area of environmental management of importance here in which CEHI was actively involved was water resources management, sustainable land management and integrated watershed and coastal areas management. It has collaborated with other agencies in the region in areas such as rainwater harvesting and water policy. In January 2013, CEHI operationally joined four other regional health institutes to form the Caribbean Public Health Agency (CARPHA)²⁷, which was legally established in 2011. The functions of what was CEHI continue under CARPHA with much of its work continuing on the campus in St. Lucia.

²⁷ www.carpha.org

CARIBBEAN WATER AND WASTEWATER ASSOCIATION (CWWA)²⁸

This is a regional non-governmental organization (NGO) established by an Act of Parliament in Trinidad & Tobago in 1991. The CWWA is a grouping of water, wastewater, and solid waste professionals in the public and private sectors. CWWA's mission statement is to advance the science and practice of water supply, wastewater, and solid waste management and promote the efficient management of utilities for the sustainable development of Caribbean people. Its two main objectives are to: i) promote education and training to ensure an adequacy of trained manpower and well-informed members of the public, and ii) encourage study, research, and development and the publication of results to provide appropriate and dynamic technological advances in the Caribbean.

CARIBBEAN NATURAL RESOURCES INSTITUTE (CANARI)

This is a non-profit organisation registered in Saint Lucia, St. Croix, and Trinidad and Tobago, with its main office in Port of Spain, Trinidad. CANARI's geographic focus is the islands of the Caribbean but its research findings are often relevant and disseminated to the wider region.²⁹ Its mission is geared toward *"Promoting and facilitating equitable participation and effective collaboration in the management of natural resources critical to development in the Caribbean islands, so that people will have a better quality of life and natural resources will be conserved, through action learning and research, capacity building, communication and fostering partnerships"*. It achieves its mission through applied and action research on, and analysis, monitoring and evaluation of, innovative policies, institutions and approaches to participation and governance; sharing and dissemination of lessons learned, including capacity building; and fostering partnerships, particularly those that build on regional assets and talents and contribute to closer regional cooperation.

THE CARIBBEAN REGIONAL FISHERIES MECHANISM (CRFM)

This was officially inaugurated on 27 March 2003, in Belize City, Belize, where it is headquartered, following the signing of the Agreement Establishing the CRFM on February 4, 2002³⁰. It is an inter-governmental organisation with its mission being to "...promote and facilitate the responsible utilization of the region's fisheries and other aquatic resources for the economic and social benefits of the current and future population of the region". Certainly, the formulated Strategy, Action Plan and Programme Proposal on Disaster Risk Management, Climate Change Adaptation in Fisheries and Aquaculture in the CARICOM and Wider Caribbean Region (CRFM 2013), and the established working group on sustainable aquaculture would pave the way for adapting Caribbean fisheries to climate-related hazards like drought.

OTHER ORGANISATIONS

There are other institutions that play significant roles in supporting national governments of the Caribbean (and regional institutions) in establishing policies and plans and supporting effective water resources management for natural hazards like drought, with offices operating in the Caribbean. These include:

²⁸ www.cwwa.net

²⁹ <http://www.canari.org>

³⁰ <http://www.caricom-fisheries.com/AboutCRFM/tabid/56/Default.aspx>

- Global Water Partnership with a Caribbean (GWP-C) branch based in Trinidad and Tobago
- Inter-American Institute for Cooperation in Agriculture IICA
- Food and Agriculture Organization of the United Nations (FAO).

During the past ten years, a number of regional projects have contributed, or sought to improve water management, and have paved the way for policy and planning that would also improve management during drought and enhance resilience to this climate-driven phenomenon. Some of the relevant projects and programmes were already highlighted in this text: i) CariCOF and CARICOM/Brazil Cooperation on Drought that focus on early warning; and ii) Status of Disaster Risk Management in the Agriculture Sector. Regional projects and programmes that play significant roles are elaborated at this point.

INTEGRATING WATERSHED AND COASTAL AREA MANAGEMENT (IWCAM) IN THE SMALL ISLAND DEVELOPMENT STATES (SIDS)

The IWCAM Project, with its objective to “...strengthen the commitment and capacity of the participating countries to implement an integrated approach to the management of watersheds and coastal areas”³¹, began in 2005 with funding approved by the Global Environment Facility (GEF). The now completed project was implemented by the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP). Executing agencies were the Secretariat of the Cartagena Convention (UNEP-CAR/RCU) and the Caribbean Environmental Health Institute (CEHI). The thirteen participating Caribbean SIDS were Antigua & Barbuda, The Bahamas, Barbados, Cuba, Grenada, Dominica, Dominican Republic, Haiti, Jamaica, Saint Kitts and Nevis, Saint Lucia, Saint Vincent & the Grenadines, and Trinidad & Tobago. The main issues of concern were:

- Diminishing freshwater supplies
- Degraded freshwater and coastal water quality
- Inappropriate land use
- Hygiene and sanitation

The long-term goal was to enhance the capacity of the countries to plan and manage their aquatic resources and ecosystems on a sustainable basis, focussing particularly on improvements in integrated freshwater basin-coastal area management on each island of the regional groupings of Caribbean SIDS.

Some of the major contributions were: i) through nine demonstration projects implemented in eight different countries, providing experience, lessons learnt and illustrating benefits of IWRM approach. Each of the demonstration projects fell under one of the following thematic areas:

- Water Resource Conservation and Management (Saint Lucia and Saint Kitts & Nevis)

³¹ <http://iwcam.org>

- Wastewater Treatment and Management (Antigua & Barbuda; The Bahamas-Exuma and the Dominican Republic)
- Land-use Planning, Zoning and Alternative Practices (The Bahamas-Andros and Trinidad & Tobago)
- Targeted Model IWCAM (Cuba and Jamaica).

ii) developed a toolkit for formulating legislation in support of IWCAM, iii) building capacity in many relevant areas, and iv) and collaborating with former CEHI on drafting Roadmaps towards Integrated Water Resources Management Planning in project countries, some of which are referenced in this document.

THE CARIBBEAN WATER INITIATIVE (CARIWIN)³²

This further promoted the expansion of the IWRM philosophy. CARIWIN was funded by the Canadian International Development Agency (CIDA), and was led by the Brace Centre for Water Resources Management at McGill University and the CIMH, in partnership with the relevant government agencies from Grenada, Guyana, and Jamaica. The project aimed to improve existing capacity in the three countries by involving local community organizations, water user associations and regional and national networks. The project also strengthened CIMH to continue to build the IWRM capacity in the region. The legacy of CARIWIN is explored in its five areas of focus: (i) decision-support tools, (ii) professional development, (iii) partnerships, (iv) research, and (v) dissemination of knowledge. Several training workshops and courses were held each year on the principles of IWRM; hydro-meteorological data processing and management; use of field instrumentation; and water policy. Through the project, five Master of Science degrees and one Doctoral degree were conferred. Three notable IWRM tools developed during the project were:

- National Water Information System, a centralised database for water-related information and a powerful decision-support tool. One such was developed for Grenada under the project
- The Caribbean Drought and Precipitation Monitoring Network, principally the regional early warning mechanism for drought
- A Community Water Strategy (CWS) framework to guide the development and implementation of Community Water Strategies (CWS), based on IWRM principles. In addition, CWS background documents were produced for Grenada, Guyana, and Jamaica, each examining water resources management at the national level and establishing the context for the CWS in the pilot watershed. The information is summarised from country policy documents, strategies, and on-going programmes and projects.

REGIONAL FRAMEWORK FOR ACHIEVING DEVELOPMENT RESILIENT TO CLIMATE CHANGE (CCCCC, 2012)

This developed under the guidance of the Caribbean Community Climate Change Centre, which identified a number of projects and programmes from which this framework would build. Projects over the past ten years, some of which are continuing, include the Adaptation to Climate Change in the Caribbean (ACCC) project (2001-

³² www.mcgill.ca/cariwin

2004), the Mainstreaming Adaptation to Climate Change (MACC) project (2003-2009), and the pilot projects being undertaken under the Special Pilot Adaptation to Climate Change (SPACC), and the Pilot Program for Climate Resilience (PPCR).

The ACCC project was designed to sustain activities initiated under CPACC and to address issues of adaptation and capacity building not undertaken by CPACC, thus further build capacity for climate change adaptation in the Caribbean region. ACCC also facilitated the transformation of the Regional Project Implementation Unit (RPIU) originally established through CPACC into a legal regional entity for climate change (the CCCCC) - a major development.³³ It also paved the way for the Third Caribbean project – MACC.

MACC was implemented by the World Bank with funding from the Global Environment Facility (GEF). The executing agency is the CARICOM Secretariat located in Georgetown, Guyana (which was eventually taken over by its founded CARICOM organisation (CCCCC)). In-kind participants include the Government of Canada and the Government of the United States of America through the National Oceanic and Atmospheric Administration (NOAA). The objective was to facilitate the creation of an enabling environment for climate change adaptation in CARICOM small island and coastal developing states (World Bank, 2009). One of the major contributions from MACC was the development of the Regional Strategy for Climate Change, which was adopted by the Heads of Government of CARICOM States on July 5, 2009. The other major outcomes of MACC included: i) the mainstreaming of adaptation to climate change into national and sectoral (including agriculture and water resources) planning and policies through the use of climate models developed and customized through the project; ii) a strong public education and outreach (PEO) program and a comprehensive communications strategy including all stakeholders in the Caribbean mass media- 7 national PEO Strategies were developed; and iii) the creation of an environment conducive to the implementation of measures for adaptation to climate change.

The objective of SPACC was to support efforts by Dominica, Saint Lucia and St. Vincent and the Grenadines to implement specific (integrated) pilot adaptation measures addressing the impacts of climate change on the natural resource base of the region, focused on biodiversity and land degradation along coastal and near-coastal areas³⁴. Some of the relevant outcomes of the project include: i) assessment of Hydro-Meteorological Sensors to support National Park Management, Data Collection and Management Strategy, and feasibility reports for irrigation in Dominica; ii) environmental Management Plan (EMP) for the Construction of Rainwater Harvesting and Waste Water Recycling Facility at the Coconut Bay Beach Resort and Spa in Vieux Fort, Saint Lucia; and iii) implementation of adaptation measures to address the absence of fresh water and coastal vulnerabilities and Environmental Impact Assessment of the Installation of a Photovoltaic Solar Powered Salt Water Reverse Osmosis Plant at Paget Farm Bequia, St. Vincent and the Grenadines.

Another project, currently being executed by CCCCC is the Pilot Program for Climate Resilience (PPCR)³⁵. The PPCR is executed globally through a number of

³³ <http://www.caribbeanclimate.bz/closed-projects/2001-2004-adaptation-to-climate-change-in-the-caribbean-project-acc.html>

³⁴ <http://www.caribbeanclimate.bz/closed-projects/2007-2011-special-program-on-adaptation-to-climate-change-spacc.html>

³⁵ <http://www.caribbeanclimate.bz/ongoing-projects/2009-ppcr-caribbean.html>

regional and national programs and is intended to: i) pilot and demonstrate approaches for integration of climate risk and resilience into development policies and planning; ii) support the strengthening of capacities at the national levels to integrate climate resilience into development planning; iii) scale up and leverage climate resilient investment, especially by building on other on-going initiatives; iv) enable learning by doing and lesson sharing at the country, regional and global levels; and v) strengthen cooperation and capacity at the regional level to integrate climate resilience in national and appropriate regional development planning and processes. PPCR execution is done in two phases, with the first and current phase designing a multi-year Strategic Program for Climate Resilience (SPCR) and relevant investment plan. The Caribbean PPCR is designed into a national track with pilots in each of six countries, and a regional track that is supported by a number of regional institutions.

Funded by the John D. and Catherine T. MacArthur Foundation, the Caribbean Natural Resources Institute (CANARI) have implanted a number of projects under the Climate Change and Disaster Risk Reduction Programme. The programme, which has as its objective, “to assess the threats and vulnerabilities to biodiversity from climate change in the insular Caribbean through an examination of current research and the identification of a research and policy agenda for the region” began in 2007. One of the projects under the programme yielded reports of working groups that include climate change impacts on terrestrial biodiversity in the insular Caribbean, which at times highlighted significant future impacts of climate change due to fluctuating water levels. The project on Promoting Participatory Information communication technologies (ICTs) for adding value to traditional knowledge in climate change adaptation, advocacy and policy processes in the Caribbean, aimed at gathering local and traditional knowledge to aid in adaptation to climate change. One major output was the Building of a Participatory 3D Model P3DM of Tobago to get communities involved in "climate-related decision-making" through a training workshop that trained trainers from the Caribbean region to document, share and combine traditional and other forms of knowledge, identify the risks from climate change and extreme climate events, recommend the adaptation policies and actions required and to catalyse dissemination and use of the tool across the Caribbean islands.³⁶

³⁶ <http://www.canari.org/ccddr6.asp>

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Drought characteristics and management in the Caribbean

Drought is a normal phenomenon of all climates, with varying characteristics between regions. It materializes in a reduction of precipitation from the long-term average, that extends over a given space scale for a specific period of time and results in impacts. Over the past decades, drought episodes have become more widespread and prolonged in many parts of the world, with increased socio-economic and environmental impacts. Agriculture is particularly vulnerable to drought with severe consequences on food supplies and livelihoods, especially for smallholders and the poor layers of rural societies.

This report pertains to the characterization and management of drought in the Caribbean, a region commonly hit by climate-related hazards, including drought.

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