Drought and Precipitation Monitoring for Enhanced Integrated Water Resources Management in the Caribbean

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Climate change is expected to have some serious implications for water resources in the Caribbean. One of the greatest concerns is an expected increase in climate variability and in extreme weather causing floods, droughts and storms. As the climate becomes more variable, it is anticipated that even small shifts in climate normals will have potentially large ramifications for communities. Given the potential consequences of future climate events, incorporating climate risk management into decision-making is imperative. One way to deal with the impacts of climate variability and change and the uncertainty surrounding these is to establish monitoring systems and early warning systems for extreme events like floods and drought in vulnerable communities to monitor trends. Such important information enables governments and communities to plan for and respond effectively to the challenges of climate-related events. The Caribbean Water Initiative (CARIWIN), jointly implemented by McGill University and the Caribbean Institute for Meteorology and Hydrology (CIMH) has the goal to increase the capacity of Caribbean countries to deliver equitable and sustainable Integrated Water Resources Management. An innovative component of the project is the Caribbean Drought and Precipitation Monitoring Network (CDPMN). A number of precipitation indices are being investigated to monitor drought and wet episodes in the Caribbean. Combined with the Precipitation Outlook currently produced by CIMH, drought and precipitation projections can be made for up to at least three months. The CDPMN will also afford an opportunity for a participatory process, between CIMH, national and local governments and pilot communities, to propose new Community Water Strategies which consider the extremes of drought and flood for water resource management in Jamaica, Grenada and Guyana. A key element to ensuring the success of the CDPMN will be based on sound monitoring stations, proven institutional capacity, effective data management and smooth information flow (centralized management).

Keywords: Climate variability, climate change, drought; flood; extreme precipitation; monitor; network; indices; early warning system.

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Introduction

Water resource management is central to sustainable growth and poverty reduction. The hydrologic extremes of drought and floods, coupled with pollution, affect Caribbean prosperity. At the local, national and regional levels in the Caribbean, water availability and variability contribute significantly to the risks people face every day in caring for their families and ensuring their livelihoods. The global trend in mitigating these risks is to adopt integrated water resources management (IWRM). The Food and Agriculture Organization of the United Nations defines IWRM as a process that promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (FAO 2005).

The Caribbean Water Initiative (CARIWIN) has the goal to increase the capacity of Caribbean countries to deliver equitable and sustainable IWRM and sets out to achieve this by improving the capacity of the Caribbean Institute for Meteorology and Hydrology (CIMH) to meet water management needs of their member states in a multi-stakeholder environment, in collaboration with regional and national networks, selected national governments and community water users. The mission of CIMH is to build national capacities in meteorology and hydrology. By integrating the IWRM approach into CIMH training and capacity development initiatives, the project will have a significant multiplier effect throughout the Caribbean. CARIWIN is jointly implemented by the Brace Centre for Water Resources Management of McGill University, the CIMH, and the partner countries of Grenada, Guyana and Jamaica. Launched in February of 2007, this six-year project is funded by the Canadian International Development Agency.

In this first year of the CARIWIN project, three short courses on IWRM were co-developed and co-delivered by CIMH and McGill to technicians, water managers, and senior administrators from each of the three partner governments. Dynamic roundtable discussions at these events revealed a collective need for information products that can facilitate the incorporation of climate risk management into decision-making. As a solution, CARIWIN proposes the Caribbean Drought and Precipitation Monitoring Network (CDPMN). The development of this regional network to be hosted at CIMH will centralize data and indices for the monitoring of drought and wet episodes in the Caribbean. It will also build toward the expected project outcome for CARIWIN of CIMH emerging as a strengthened regional training institution and information centre of excellence in equitable and sustainable IWRM.

Overview of the impacts of droughts and floods in the Caribbean

The Caribbean has many examples of the destructive impacts of extremes of rainfall. These events can be attributed to a number of features including the El Niño Southern Oscillation (ENSO) and sea surface temperature anomalies in the tropical north Atlantic (Taylor et al. 2002; Stephenson et al. 2007; Giannini et al. 2000; Enfield and Alfaro 1999; Laing 2004) and the North Atlantic Oscillation (Charlery et al. 2006).

In 1998, Guyana experienced water rationing, cessation of logging and river transport in some places and the loss of livestock due to drought caused by El Niño (National Drought Mitigation Center 1998). Rice farmers were forced to leave 35 % of their rice fields uncultivated and affected more than 1500 Amerindian families in Southern Guyana, reliant on agriculture

(USAID 1998). Jamaica experienced below normal rainfall from December 1996 into 1998. The greatest damage occurred in the agricultural sector[1]. Losses in the sugar sector prompted the Jamaican government to offer the sector a US$100 million assistance package late in 1997[2]. Later, during the 1999-2000 drought, where rainfall was less than 25 % of the average in some places, Jamaican authorities reported crop losses of approximately US$6 million between October 1999 and March 2000 (Jamaican Information Service 2007). One of the islands making up Grenada, Carriacou, experiences less rainfall than the main island. Carriacou also accounts for 30% of the nation's livestock production, and experienced losses of 20 and 40% due to drought in 1984 and 1992 respectively (UNFCCC 2000). On the other extreme, flooding has caused major damage to property and life in the Caribbean. Flooding in Guyana from late December 2004 to February 2005 severely affected 37% of the population, was blamed for the deaths of 34 people and caused about US$ 465.1 million in total damage. Of this, approximately US$ 250 million was lost in the housing sector and US$ 55 million in damage to the agricultural sector, which in 2004 accounted for 35.4 per cent of Guyana's gross domestic product (ECLAC 2005). A similar, but smaller-scale, event the following year resulted in losses to the agriculture sector of US$ 22.5 million in the major affected regions (ECLAC 2006). In 2001, flooding associated with Hurricane Michelle, which resulted in some stations exceeding their average monthly total average on October 29 alone, damaged almost 2000 hectares in crop farmland and approximately US$ 8 million in losses in crops and livestock (ECLAC 2001). The frequencies and intensities of these features are expected be altered by the anthropogenic climate changes.

Climate Change and potential impacts

With limited peer reviewed information for the Caribbean, the IPCC in its Fourth Assessment Report (Mimura et al. 2007) projects that there is a 90% chance that temperatures will rise across the Caribbean. Average of 21 models suggest the increase in the annual temperature could be in the range of 2 to 2.5^{o}C (Christensen et al. 2007). There have already been significant warming trends since the 1950s (Peterson et al. 2002) in the Caribbean, with increases in both minimum and maximum temperatures (in particular the former) and the number of warm days and warm nights. There is however, greater uncertainty in the rainfall projections in the region, particularly in the Lesser Antilles. None-the-less, it is 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 % with the greatest change during the months of June to August (Christensen et al. 2007). Patterns since the 1950s (Peterson et al. 2002) suggest some increase in heavy rains, even though maximum dry spell lengths are decreasing. The effect of anthropogenic climate change on tropical cyclone activity, particularly in the north Atlantic, is without consensus, even though many believe that with the increase in sea temperatures, there is the likelihood of increased hurricane activity. Flooding also accompanies tropical cyclones, and with these systems possibly surviving longer in the Atlantic basin (Webster 2005) flooding may well be more widespread from a single system.

[1] http://www.odpem.org.jm/pdf/DROUGHT%20ALERT.pdf
[2] http://www.nationsencyclopedia.com/economies/Americas/Jamaica-AGRICULTURE.html

Basic Approach of CDPMN

The concept was born out of the need to mitigate and respond to the creeping phenomenon, drought, as well as to cope with the other extreme; flooding. Unless the precipitation situation is closely monitored, one often does not realize that one is in- or approaching – a drought situation, until it is upon the country. However, many of the indices and indicators used to recognize drought occurrence are also used to determine different severities of above normal precipitation.

Drought and the general precipitation status of countries will be monitored using a number of indices (e.g. Standardized Precipitation Index, SPI; The Palmer Drought Severity Index, PDSI; and the Crop Moisture Index, CMI), that by their values express different severities of drought and above average water, and indicators (e.g. water levels, state of vegetation and ecosystems). However, the final drought and precipitation status of the region/country will be determined, by consensus, by a network of persons from different sectors, institutions and communities embracing the diversity in definitions and impacts of drought.

As an addition to this/these final drought and precipitation status product(s), short term and seasonal precipitation forecasts will be used to provide a projection of future drought in the short and medium terms.

Drought and Precipitation Indices

A number of drought/precipitation indices are currently under investigation at CIMH, with the view to them being used together to monitor drought and periods with above normal precipitation.

The Standardized Precipitation Index (McKee et al. 1993) is one such index under investigation. It uses only precipitation information where, using historical data, precipitation is placed in severity classes such that the index value represents a standard deviation from the mean. Using data from the IRI (International Research Institute for Climate and Society) the status of too low or high precipitations over the time periods can be monitored. Examples of these are shown in Figures 1a, 1b and 1c for 1-month, 3-month and 6-month periods.

CIMH is also investigating the application of the PDSI and its derivative, the CMI. These shorter term indices (estimated on a 1-month and 1 week basis respectively) have often been used to identify and classify drought in the agriculture sector. Unlike the SPI, both these indices utilize precipitation, evaporation and soil water capacity data. Figures 2a and 2b show examples of how the PDSI can be used in assessing agricultural drought risk during different times of the year in Barbados. The maps show at worst, on average, mild drought in April and incipient drought in October in some parts of the country. These average maps differs from those in 1998 (an El Niño year), when conditions were drier than normal (Figure 3a), also showing the large variability in conditions intra-annually (Figure 3a and 3b).

Drought and flood coping strategies and early warning examples

Examples of how Canada is coping with drought and floods mainly focus on government (local and federal) initiatives targeted at warning vulnerable or affected stakeholders and communities.

The government of Canada's Department of Agriculture and Agri-Food has a Drought Watch website (http://www.agr.gc.ca/pfra/drought/index_e.htm) in place that provides timely information on the impacts of climate variability specifically on water supply and agriculture.

Recognizing that monitoring the impacts of climate on water supplies, and soil degradation, and consequent impacts on crop production is imperative to preparing for the onset of drought, the website provides map information on indices such as regional precipitation and temperature, and the probability of receiving precipitation for a given region based on historical data (from 1971-2000).

Users of the website are primarily growers and water managers. Some of the tools offered free of charge also include regional agroclimatic data compilations; information on managing drought for agriculture; and crop conditions across the country.

As a precursor to this initiative, the US Drought Monitoring Network was set up in 1999 to provide short-term and long-term indices of on-coming droughts (Svoboda et al. 2002). Their forecasts are based on several indices; the key ones include the PDSI, the CMI, soil moisture percentiles, streamflow percentiles, percentage of normal precipitation, topsoil moisture, and a vegetation health index (Heim 2002). A blend of these indices is used to forecast drought. This service is also web-based and free of charge, and is used widely by growers as a tool for managing water and crops.

Since 2002, the North American Drought Monitor (NA-DM) was set up based on the existing US- Drought Monitor and is collaboration between drought experts in Canada, Mexico and the United States. It too uses a blend of drought indices. The Canadian specific Drought Watch efforts are feeding directly into the NA-DM to help monitor drought over the entire continent.

To better cope with flooding events in Canada, a number of flood warning systems have been set up and/or supported by Environment Canada based on a network of provincial and local stream monitoring stations to predict the magnitude and timing of flood passages. Information on factors affecting flooding such as snow conditions, temperatures, precipitation patterns, surface water levels and streamflow conditions are monitored by the forecast centre. Hydrologic and meteorological data are collected for a given watershed. The data collected is interpreted by government hydrologists to estimate the amount of runoff that will occur and predict water levels. This enables the forecaster to determine where flooding may occur and transmit the information to local agencies, government officials and the media.

A regional specific example for flood control and warning is in the Province of Québec, where a provincial government agency (CEHQ; a branch of the Québec Ministry of the Environment) has the mandate to assure the general proper management of surface water in order to protect the safety of the Québec population. It does this through monitoring their network of 250 hydrometric stations located across the province (a few of these stations belong to Environment Canada) and thereby they compile the data (hydrographs, historical minimum and maximum flows, averages, trends, etc.) and are able to provide flood forecasting and mitigation information to municipalities. The CEHQ also actively manages the water regime of over 800 public dams to prevent flooding, and supply sufficient water to downstream users. Most of the hydrometric stations (149) are able to transmit the data via telemetry (using phone lines or satellite) and thus communicate the data every 15 minutes 14 hours a day to the head office.

These existing drought and flood warning systems have greatly helped to secure the fate, land, and assets of thousands of people, by better preparing for the onset of such events, or by evacuating areas if the event is extremely severe. Farming systems can be better prepared as well, and water can be managed appropriately based on the information collected and the indices compiled. The value of hydro meteorological monitoring stations for implementing such warning systems, and for taking appropriate decisions cannot be overstated.

Decision-making: mainstreaming drought and flood information

One of the greatest future climate concerns is an expected increase in climate variability and in extreme weather causing floods, drought and storm events. As the climate becomes more variable, it is anticipated that even small shifts in climate normals will have potentially large ramifications for communities.

In order to cope with the uncertainty, data and facts are needed by water managers to base their decisions on, and base line data is required to determine if there is a threat. The CDPM network will gather data and monitor trends, as well as convene researchers with stakeholders to determine what the existing needs and scientific knowledge gaps are that need to be addressed in order to better plan for such events, and in order to help reduce the damage caused by extremes in susceptible regions. Forecasting, predicting, strengthening infrastructure, etc. are part of the existing needs, and as such, data collection, monitoring and dissemination will play a crucial part in the network.

Researchers and data from monitoring stations can provide valuable information for decision makers to manage water appropriately. Given the potential consequences of future climate events, incorporating information on potential climatic extreme events into risk management and decision-making is sensible. One way to deal with the impacts of climate and the uncertainty surrounding these is to establish monitoring systems and early warning systems for extreme events (floods and drought) in vulnerable communities to monitor trends in these areas (such as water level, temperature, precipitation, crop and soil indices). This information can then be used by decision makers in a systematic manner to take into consideration sustainable water management during high or low flows, etc.

Mainstreaming drought and flood information is about integrating the consideration of climate indices or factors (e.g. on extremes) into routine decision making processes. For example, taking into account the occurrences of drought and/or flood can be considered as yet another layer of managing risk when deciding on water management, cropping system changes, or new infrastructure to put in place, or new policies to implement. Mainstreaming is about incorporating existing information into risk management and decision making as a prudent way of moving forward, and to increase the resilience of a community to extreme events.

Managing the impacts posed by climate is one more layer to take into account when managing risks. Successful adaptation measures to extremes enable governments and communities to plan for and respond effectively to the challenges of climate-related events. This is all part of an integrated water resources management (IWRM) plan.

Given the complexity, uncertainty and increasing vulnerability of both natural and human systems, water managers around the world agree that the only way forward is through an inclusive and integrated approach to water resources management (UNESCO 2006). The drought and flood information made available by the CDPMN will be accessible to stakeholders and will constitute a valuable IWRM tool in the decision-making process. The CDPMN will be web-based and therefore improve timeliness of, and broaden access to, drought and flood information for decision-making. CARIWIN will develop a network of stakeholders; incorporate drought and precipitation monitoring into training during the project; and use partner countries to validate model outputs. These actions will encourage the mainstreaming of drought and flood information and increase stakeholder involvement, both essential for sound decision-making in water management. In addition, CARIWIN is expanding the data collection infrastructure in the three partner countries by adding rain gauges and stream level recorders at each of the three pilot sites. These additions will serve the CDPMN as case studies for use during training sessions and also as inputs in the development of models for the three partner countries. National workshops facilitated by CIMH will afford an opportunity for engagement of stakeholders.

Community involvement and response to drought and flood

At the local government and community level, CARIWIN will work with selected, rural communities in each country, in concert with their local government interlocutors to strengthen existing community water users groups and to test new community governance models which address IWRM principles. The CDPMN will afford an opportunity for a participatory process, between CIMH, national and local governments and pilot communities, to propose new Community Water Strategies which consider the extremes of drought and flood for water resource management in Grenada, Guyana and Jamaica.

> The socio–economic dimension, with its focus on human concerns, is a crucial component of the [IWRM] approach, taking full account of:
>
> - stakeholders having input in the planning and management of the resource, ensuring especially that the interests of women and the poor are fully represented;
> - the multiple uses of water and the range of people’s needs;
> - integrating water plans and strategies into the national planning process and water concerns into all government policies and priorities, as well as considering the water resource implications of these actions. (UNESCO 2006)

The CDPMN will build on the outlined best practices for IWRM by fostering community involvement in the response to flood and drought events. The pilot communities for the three countries are Great River, Grenada; St Cuthbert’s Amerindian mission, Guyana; and Mile Gully/ Warwick Castle, Jamaica.

Technology and information dissemination strategies

A key element to ensuring the success of the CDPMN will be based on sound monitoring stations (up to date infrastructure), proven institutional capacity (trained staff), effective data management (software, hardware) and smooth information flow (centralized management). In the 3 CARIWIN countries, existing monitoring technology for precipitation varies from the dated manual rain gages at most locations to more sophisticated logger based tipping bucket rain gages. While there is recognized need for improved monitoring, several constraints come into play to ensure continuous data collection and information dissemination.

CARIWIN's role through capacity building initiatives and training courses aim to address this need. One hydrological and rainfall monitoring station will be installed in each CARIWIN partner country, and the pilot community will be trained on the maintenance and data collection routines at the station. Data collection could be in the form of written logs by the community, onsite downloads or wireless/satellite transmission depending on the monitoring station.

An identified agency in each country will be responsible for standardization of datasets, analysis and the transmission of standardized datasheets to a central server at CIMH, host of the CDPMN. A trained staff at CIMH will be responsible for computation of precipitation indices, creating drought forecasts, etc. The CIMH will also be responsible for relaying information (e-mail) back to the countries at regular intervals (weekly or bi-weekly). In the future, web-based hosting for the network will also be set-up, so that information can be accessed from any location.

The networking of researchers and stakeholders (decision makers) will be conducted through workshops held on topic-relevant subjects that are deemed of interest to data users. As a first step, the CDPMN will be introduced to all 3 CARIWIN partner countries; starting in Grenada, a workshop on Water Information System needs will be hosted through the project. The workshop proposes to bring together stakeholders from various Grenadian water agencies (e.g. the Grenada Ministry of Agriculture, NAWASA, Met Office, and the National Disaster Management Agency). In addition, representatives from the CARIWIN pilot community in Grenada - the Great River watershed will be invited to participate. Other participants include the Grenada Network of Rural Women Producers. A presentation will be given on the CDPM network and its expected outcomes. Similar kick off events will be planned for Jamaica and Guyana to present the network and to act as forum for discussion and exchange of ideas.

In terms of a communication strategy, the CDPMN Network will have its own website housed at CIMH, and it will disseminate information via a monthly email newsletter. It will set up discussion groups on the internet, and it will convene key experts and stakeholders through regular workshops on relevant topics to be held in appropriate countries.

Outcomes and benefits expected from CDPMN

The network will assist to better manage water resources, and aid with planning and preparing for adaptation to drought and heavy precipitation / flooding events, which are a real threat.

The network has four main outcomes:

1. Monitor the current status
    - Through the hydrometric stations and sensor data, monitor hydrological indicators (i.e. water levels), climate indicators (i.e. precipitation), and other indicators (i.e. soil moisture) to determine trends of these
2. Undertake projections
    - Compile regional outlooks for seasonal forecast of precipitation probabilities and ranges for next three months
    - Couple the projections to drought monitoring indices (SPI, PDSI, CMI, etc.) and flood warning indices
3. Implement early warning systems
    - Through the CIMH website, update relevant information and post warnings. Network with key agencies, governments, media, etc. in partner countries to disseminate the information
4. Build adaptation and response strategies to drought and flooding events
    - Create a network of researchers working with stakeholders including all levels of government (from the national government level right down to the municipal local level) gaining knowledge on the potential future occurrences of extremes, and examining the impacts that these will have on the community, while providing input on how to cope with and respond to these events.

In addition to collecting data, monitoring trends, implementing early warning systems, and networking, the CPDMN will define knowledge gaps and uncover the needs to address extreme events and coping mechanisms. The network will be therefore be valuable for decision makers to be able to target their efforts on the most vulnerable regions and communities.

Through the CDPMN, researchers and decision makers will gain access to a community of professionals working on drought and flooding/excess precipitation issues. They will partake in workshops and training sessions on impacts of extremes and how to adapt. They will be invited to share experiences and be involved in identifying and shaping the research priorities related to water resources and climate change, and help to identify any knowledge gaps in this area.

The network will keep members abreast of any new activities and developments in this field, and which will house a databank of past and present research on water and climate change issues. Finally, they will be part of a Caribbean climate change network that is comprehensive and interdisciplinary in nature.

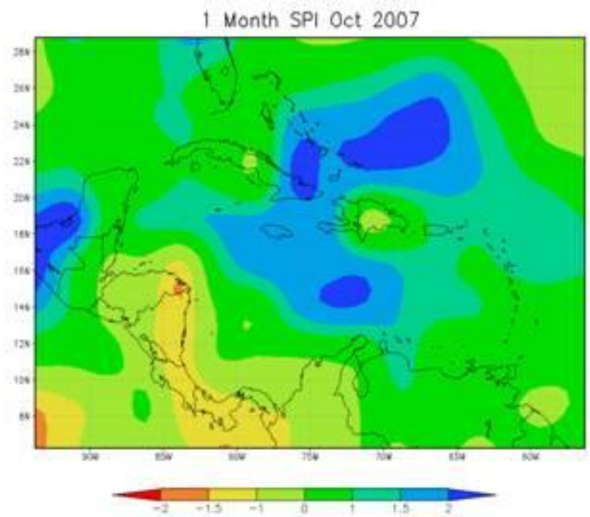

Figure 1a. 1-month SPI for the Caribbean for October 2007

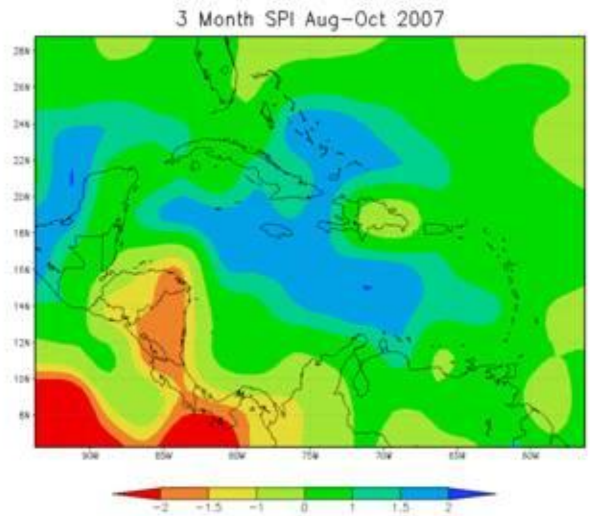

Figure 1b. 3-month SPI for the Caribbean for October 2007

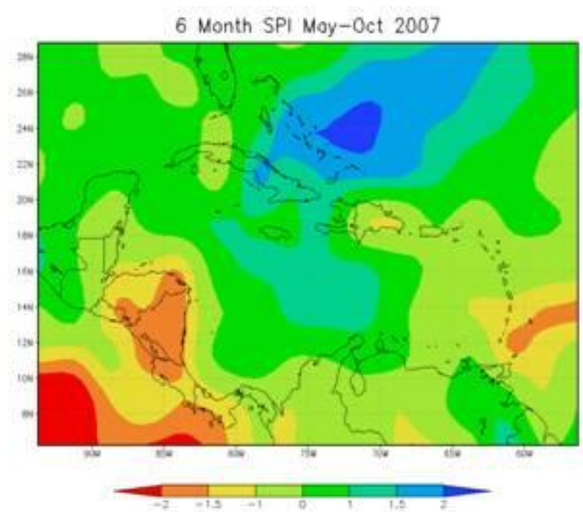

Figure 1c. 6-month SPI for the Caribbean for October 2007

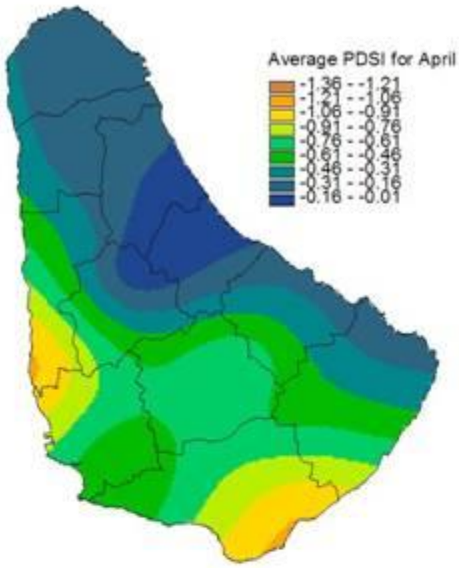

Figure 2a. Mean PDSI values for April for Barbados

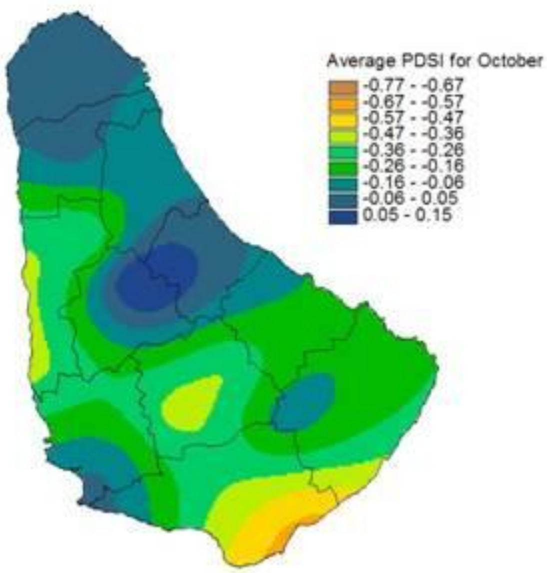

Figure 2b. Mean PDSI values for October for Barbados

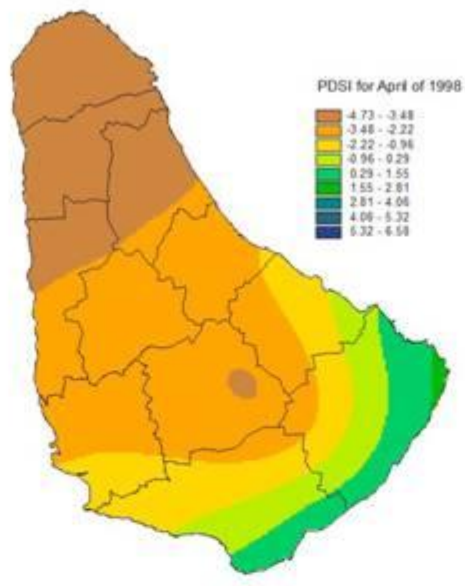

Figure 3a. PDSI values for April 1998 (an El Niño year) for Barbados

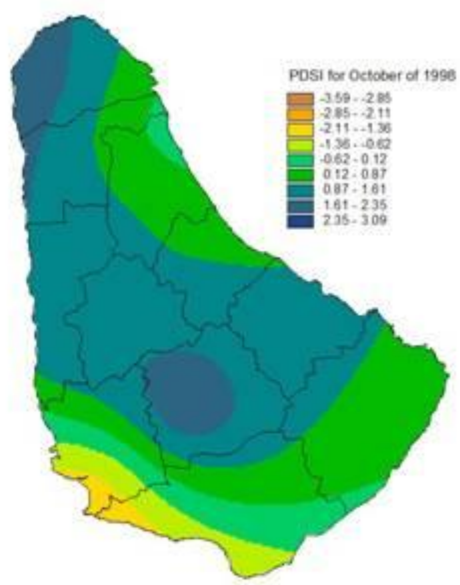

Figure 3b. PDSI values for October 1998 (an El Niño year) for Barbados

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