11. APPENDIX 1: CLIMATE RESOURCES

This appendix provides information on climate resources that are available for the region. These resources include data sources, tools, and available literature for the region. The information provided on regional resources has been adapted from the State of the Jamaican Climate 2015 (CSGM, 2017), which includes comprehensive lists of decision-making services, tools, data, and software specific to the Caribbean Region.

Following this outline is a list of scientific publications relevant to Caribbean climate. These publications cover the topics:

- About Caribbean climate
- Historical changes in rainfall and temperature
- Climate extremes
- Sea level rise
- Hurricanes
- Sea surface temperature and large scale systems
- Modelling and future climate
- Renewable energy
- Impacts of climate change

11.1. CLIMATE RESOURCES

11.1.1. CLIMATE TOOLS FOR DATA ANALYSIS AND DECISION-MAKING

Table 1: Climate tools that can provide users with local, regional, and international climate information and future climate outputs.

CLIMATE SERVICE ITEM	COMMENT	RELEVANCE
KNMI CLIMATE CHANGE ATLAS	The KNMI Climate Change Atlas is a web-based interface that allows users to generate global or regional projections of temperature and rainfall using the most recent IPCC climate projections scenarios. The tool also allows for comparisons from a historical baseline period. https://climexp.knmi.nl/plot_atlas_form.py	The KNMI Climate Change Atlas provides global, regional, and country level observations and projections generated from both global climate models (GCMs) and regional climate models (RCMs).
CLIMATE INTERACTIVE	The Climate Interactive suite of tools and simulations that help people understand the long-term effects of emissions levels, global temperature and sea level rise on climate. Climate Interactive includes such tools as C-ROADS and C-Learn. https://www.climateinteractive.org/	The Climate Interactive suite of tools and simulations are good learning aids at for students, professionals, and non-professionals alike.
IRI CLIMATE MAP ROOM	The Climate Map Room developed by the International Research Institute for Climate and Society provides interactive maps and time series of large-scale atmospheric variables. https://iridl.ldeo.columbia.edu/maproom/	This tool can provide a more detailed look at climate on global and regional scales, and how climate analyses may be applied to addressing climate impacts on health and food security for select regions.
SIMPLE MODEL FOR THE ADVECTION STORMS AND HURRICANES (SMASH)	SMASH is a simple model to allow planners and decision makers the opportunity of examining differing scenarios of tracks and intensity for hurricanes that traverse through the region, and determining the associated rain rates and wind speeds for a given location in a SIDS island. It is the University of the West Indies' contribution to a suite of climate tools developed under the Caribbean Weather Impacts Generator (CARIWIG) Project. http://cariwig.caribbeanclimate.bz/#simulations	SMASH allows planners and decision makers the opportunity of examining differing scenarios of storm tracks and intensities and the associated rain rates and wind speeds for a given location in a Caribbean island.
REGIONAL CLIMATE OBSERVATIONS DATABASE (RECORD)	ReCORD is a climate tool that allows decision makers to analyze climate trends across the Caribbean region. http://173.230.158.211/ReCORD	The tool provides a full suite of carefully selected and packaged projected climate data for rainfall and temperature. This is complemented by the historical frequency of tropical storm passage close to that location, and climatologies of the same climate variables for stations located within the chosen sub-region.

CLIMATE SERVICE ITEM	COMMENT	RELEVANCE
CARIBBEAN WEATHER IMPACTS GENERATOR (CARIWIG)	The CARIWIG data portal is a web service that provides local and regional summaries of climate trends and weather projections based on observed climate data and climate model outputs. http://cariwig.caribbeanclimate.bz/#info	The data portal also sports the following three simulators: i) weather generator that provides synthetic scenarios for variables, such as temperature and rainfall, for select meteorological stations across the Caribbean; ii) tropical storm model that generates weather scenarios using past tropical storms (see the SMASH tool outlined above); iii) threshold detector that allows for the post-processing of synthetic weather outputs.
SIMCLIM 2013	SIMCLIM2013 allows users to generate site-specific climate scenarios using superimposed shapefiles and future climate projections. The software was built for better informed climate change risk assessments for both governmental and non-governmental organizations and students. http://www.climsystems.com/simclim/	SIMCLIM allows users to better assess the impact of projections by pairing projections with geospatial information.

Table 2: Climate tools that allow decision makers and policy makers to make informed decisions on climate-sensitive projects.

CLIMATE SERVICE ITEM	COMMENT	RELEVANCE
CARIBBEAN CLIMATE ONLINE RISK AND ADAPTATION TOOL (CCORAL)	The CCORAL tool is a web-based support system that provides decision makers with tools that assess the degree of climate influence in proposed projects. The tool helps decision makers to consider projects within a climate context. http://ccoral.caribbeanclimate.bz/	Allows decision makers to view project proposals within the climate context; assesses the degree of climate sensitivity and impact.
CARIBBEAN CLIMATE IMPACTS DATABASE	The Caribbean Climate Impacts Database (CCID) provides users with a platform for impacts reporting and also evidence-based information for improved climate risk management. The CCID helps to guide disaster risk planning and implementation. http://rcc.cimh.edu.bb/cid/	The CCID provides evidence-based information for improved climate risk management for various sectors.
REGIONAL CLEARINGHOUSE DATABASE	The Caribbean Community Climate Change Center (CCCCC) is an online platform that provides a variety of climate information. Such information includes local and regional vulnerability and impacts assessments, climate-related project documents, and country profiles. http://clearinghouse.caribbeanclimate.bz/	The database provides a collection of sector-specific vulnerability and impact assessments at the local and regional level. The database also provides regional climate outputs from the PRECIS regional climate model.
C-ROADS WORLD CLIMATE	C-ROADS is a climate change policy simulator that helps people understand the long-term climate impacts of actions that reduce greenhouse gas emissions. https://www.climateinteractive.org/tools/c-roads/	The C-ROADS tool runs real-time policy analysis, easily translates climate mitigation scenarios into emissions, concentrations, temperature and per-capita emissions outcomes. It allows for comparisons between other regions.

11.1.2. SECTOR-SPECIFIC TOOLS, PRODUCTS, AND SERVICES

Table 3: Outline of climate products and services specific to the Agriculture sector.

AGRICULTURE SECTOR		
CLIMATE SERVICE ITEM	**COMMENT**	**RELEVANCE**
Local Climate Products: Seasonal Forecast, Farmers Bulletin, Rainfall Summary, Drought and Evapotranspiration (ET0) Map	Examples include: Jamaica http://www.jamaicaclimate.net/ Dominica http://www.weather.gov.dm/ Trinidad http://www.metoffice.gov.tt/	Hosted by the Meteorological Services in respective Caribbean islands.
The Caribbean Society for Agricultural Meteorology (CariSAM).	Information available via: http://carisam.cimh.edu.bb/ Serves as an interface between Meteorologists, Climatologists, and the Caribbean Agriculture Community.	Hosted by the Caribbean Institute for Meteorology and Hydrology and used throughout the Caribbean
Caribbean Climate Products: Agro-climatic bulletin, drought bulletin, coral reef bulletin, rainfall outlook (including extremes) and temperature outlook, weather forecast	Information available via: http://carisam.cimh.edu.bb/	Hosted by the Caribbean Institute for Meteorology and Hydrology and used throughout the Caribbean. Helps to predict and forecast inhospitable conditions for fisheries, livestock and crops and allows for preemptive remedial actions to be taken
World AgroMeteorological Information Service (WAMIS)- Global website for Agromet	http://www.wamis.org/	Hosted by the World Meteorogical Service, with links to multiple countries
Climate Impacts on Agriculture (Climpag)- A site that seeks bring together various aspects and interactions between weather, climate and agriculture in the general contat of food security	http://www.fao.org/nr/climpag/about_en.asp	Hosted by the FAO with links to multiple countries
FAOSTAT- A global database providing free access to agriculture data for over 245 countrie and terrirtories.	http://www.fao.org/faostat/en/#	Data available for most countries from 1961 to most recent records
The Caribbean Dewetra Platform- Dewetra is an IT system aimed at weather-related risk and forecasting and monitoring. It collects and systematizes all data, automatically or manually and produces value-added products. Forecast models, and in situ observations are integrated with vulnerability and exposure data to produce risk scenarios in real time.	Different modules aimed at forecasting specific hazards such as fires, landslides, stream flow and floods can be easily integrated into the platform. It can produce haard maps, details of land cove-land, land use and vegetation	Used at National level in Italy, Bolivia, Lebanon, Albania and the Caribbean (coordinated in the Caribbean by the CIMH). (http://www.cimafoundation.org/wp-content/uploads/doc/DEWETRA_english.pdf)

AGRICULTURE SECTOR		
CLIMATE SERVICE ITEM	**COMMENT**	**RELEVANCE**
Caribbean Climate Impacts Database (CID)- a comprehensive open source geospatial inventory of impacts occurring from climate events	Provides historical records (both quantitative and qualitative) of severe events from prior to 1900. The site also Includes information of loss and damage to the Caribbean agriculture sector resulting from severe weather systems. Can be used to aid decision making especially with respect to hazard prone areas	Available via: http://rcc.cimh.edu.bb/cid/about.php and used throughout the Caribbean. Also consulted frequently by global users.
Caribbean Climate Outlook Forum (CARICOF)- hosted by CIMH	Incorporates weather data from 18 Caribbean countries to produce region-wide climate seasonal outlooks. Recent outlooks can be found at: https://rcc.cimh.edu.bb/climate-outlooks/	Forecasts are made at both the national level by local meteorological services, and at the regional level by the CIMH. Multiple large scale oscillations are considered in these forecasts, which are made twice per year- during the major Caribbean dry and wet seasons.

Table 4: Outline of climate tools, software, sensors and models specific to the Agriculture and Water sector.

AGRICULTURE SECTOR		
CLIMATE SERVICE ITEM	**COMMENT/DESCRIPTION**	**RELEVANCE**
Modelling System for Agricultural Impacts of Climate Change (MOSAICC)	An integrated package of models for assessing the impacts of climate change on agriculture including the variations in crop yields and their effect on national economies. The Four main components include: 1. Climate (downscaled data); 2. Hydrology (estimate of future water resources), Crops (Yield simulations under climate change); and Economy (economic impacts of future crop yields and water resources projections)	Developed by the Food and Agriculture Organization (FAO) of the United Nations. Links (climate) information and decision making to improve food security
FAO- AquaCrop Model	A Yield to water response model for herbaceous plants (i.e. plants with a known annual cycle). It has capability to predict yield and biomass changes under multiple scenarios of climate change and can also simulate production with saline intrusion considerations	Model is freely available via: www.fao.org/nr/water/infores_databases_aquacrop.html. Model has been parameterized for several crops and is used globally. **(Has been applied successfully to Sweet Potato in Jamaica and relevant to several other crops)**
CROPWAT Model	Used to simulate crop growth and water flow in the rootzone in deficit irrigation studies. It is a powerful tool for extrapolating findings and conclusions from field studies. Very useful for drought impact assessment under climate variability and change	An FAO Model that has global utility
Ex-ACT: Climate Impact Assessment	A software that estimates the likely impacts of agricultural and forestry development projects on greenhouse gas emissions and sequestration in terms of carbon balances	Developed and hosted by the FAO
Decision Support System for Agrotechnology Transfer (DSSAT)	This is a software application programme that comprises crop simulation models for over 42 crops. It allows for various simulations to be made based on soil, weather, crop management (including fertilizer treatments, crop sequencing/rotation, and varietal selection)	Very widely used crop model globally. Highly documented model, which has several crops grown in the Caribbean. More information available at: http://dssat.net/

AGRICULTURE SECTOR

CLIMATE SERVICE ITEM	COMMENT/DESCRIPTION	RELEVANCE
Adapt-N Advanced Nitrogen Recommendation Software	The Adapt-N tool is a user friendly, web-based nitrogen (N) recommendation tool for corn crops. The tool provides precise N fertilizer recommendations that account for the effects of seasonal conditions using high-resolution climate data, a dynamic computer model, and field-specific information on crop and soil management.	The tool is used widely in the USA and can be accessed via- http://adapt-n.cals.cornell.edu/
Tensiometer	An instrument used to determine the matrix water potential (soil moisture tension) in pounds per square inch (PSI). High readings indicate low moisture content (drier soil) and hence the need for irrigation	Used in the Caribbean as a useful means of monitoring soil moisture, allowing for watering only according to the evaporative demand of the crop and therefore improves water conservation
(5TM) Soil Moisture & Temperature Sensor	One in a series of at least 8 different types of Soil Moisture and temperature Sensors. Allows for digital real time monitoring of soil conditions. Other sensors also measure electrial conductivity. More information available at http://www.decagon.com	Can be very useful for mitigating the impacts of heat stress on crops and for reducing impacts of drought. It also allows for monitoring of progress towards maturation through the different phases of crop development. Accumulation of heat units (termed growing degree days) is significantly controlled by temperature.
Spectral Reflectance Sensors (SRS). These are two band radiometers designed to measure Normalized Difference Vegetation Index 9NDVI) or Photochemical Reflectance Index (PRI)	The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not.	Very useful for rapid assessment of vegetation status and for constantly monitoring canopy development under different climate regimes.
Ceptometer (ACCUPARLP-80)- used to measure canopy photosynthetically active radiation (PAR) for non-destructive leaf area index (LAI) measurements	LAI is one of the most commonly used measurement of canopy expansion, which is a key parameter for monitoring crop development. It allows you to measure canopy PAR interception and calculate LAI at any location within a plant or forest canopy. PAR data can be used with other climate data to estimate biomass production without destroying the crop. With the AccuPAR there is no need to wait, it uses radiation measurements and other parameters to accurately calculate leaf area index in real time, in the field	One in a series of three other tools used to measure canopy development (available via www.decagon.com). Can be useful for field work, especially as inputs for crop models
Lysimeter	A measuring device which can be used to measure the amount of actual evapotranspiration which is released by crops. It is a powerful tool since it allows better understanding of soil water balance, including deep drainage.	Very useful for soil water monitoring to maximise crop yields, reduce impacts of drought and improve water conservation.

FISHERIES SECTOR

CLIMATE SERVICE ITEM	COMMENT/DESCRIPTION	RELEVANCE
NOAA Coral Reef Watch Satellite Monitoring	Continuous monitoring of sea surface temperature provide reef monitoring environmental conditions to quickly identify areas at risk for coral bleaching. Bleached corals lead to mortality and eventual death of the whole colony, which in turn cause habitat and spawning ground destruction for most fish species	Used globally and provides input for Caribbean Coral reef watch. The watch provides different alert levels: No stress, Bleaching Watch, Bleaching Warning; Alert Level 1 (Bleaching likely); Alert level 2 (Mortality likely)

LIVESTOCK SUB-SECTOR		
CLIMATE SERVICE ITEM	**COMMENT/DESCRIPTION**	**RELEVANCE**
Digital Infrared Thermometer	Used to measure animal skin temperature which is an effective means to monitoring and predicting heat stress	Heat stress reduces reproductive rate in small ruminants, retards milk production and affects egg production in chickens
WATER SECTOR		
CLIMATE SERVICE ITEM	**COMMENT/DESCRIPTION**	**RELEVANCE**
Water Evaluation and Planning (WEAP) System	Modelling tool for estimating water resources, demand and supply. The WEAP aims to incorporate these issues into a practical yet robust tool for integrated water resources planning. WEAP is developed by the Stockholm Environment Institute's U.S. Center. http://www.weap21.org/	WEAP is a unique approach for conducting integrated resources planning assessments and has several uses: 1) offers transparent structure facilitates engagement of diverse stakeholders in an open process 2) a database maintains water demand and supply information to drive mass balance model on a link-node architecture 3) calculates water demand, supply, runoff, infiltration, crop requirements, flows, and storage, and pollution generation, treatment, discharge and instream water quality under varying hydrologic and policy scenarios 4) evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems 5) dynamic links to other models and software, such as QUAL2K, MODLFOW, MODPATH, PEST, Excel and GAMS
The Hydrologic Modeling System (HEC-HMS) http://www.hec.usace.army.mil/software/hec-hms/	HEC-HMS is physically-based, semi-distributed hydrologic model that simulates the response of a watershed subject to a given hydro-meteorological input. The model has four basic components: the basin models, meteorological models, control simulations and input data. The outputs are represented as discharge hydrographs at junction points of the river system as well as volume of runoff with abstraction or losses from infiltration for each sub-basin.	The HEC HMS is designed to simulate the complete hydrologic processes of dendritic watershed systems. The software includes many hydrologic analysis procedures such as event infiltration, unit hydrographs, and hydrologic routing.
The Geospatial Hydrologic Modeling Extension (HEC-GeoHMS)	Developed as a geospatial hydrology toolkit for engineers and hydrologists with limited GIS experience. HEC-GeoHMS uses ArcGIS and the spatial analyst extension to develop a number of hydrologic modeling inputs. http://www.hec.usace.army.mil/software/hec%2Dgeohms/	HEC-GeoHMS is a GIS-based pre-processor that may be used to simulate watershed features and parameters such as slope, length, parameters for loss or abstraction, which are in turn used as input for HEC-HMS. Along with HEC-GeoHMS, the Arc Hydro Tool and ARC MAP 10.2 are used as pre-processor tools for extraction of catchments or sub-basins from the Digital Elevation Model (DEM) of the watershed.
Simple Model for the Advection of Storms and Hurricanes (SMASH)	SMASH allows users to simulate different scenarios of storm track and intensity by historical hurricanes moving across a Caribbean island along a path determined by the user. SMASH has three basic steps: data collection, execution and data distribution. http://173.230.158.211/SMASH/	SMASH has been used with the HEC-HMS to generate rainfall run-off simulations with the HEC-HMS (please refer to Mandal et al. (2016)).

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NOTES

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