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World
Climate Services Operational Pathways
Pathways for Transforming Weather, Water, and Climate Services in Jamaica

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Disclaimer

List of Abbreviations and Acronyms

AWS	Automatic Weather Stations
CariCOF	Caribbean Climate Outlook Forum
CCCCC	Caribbean Community Climate Change Center
CCD	Climate Change Division
CIF	Climate Investment Funds
CIMH	Caribbean Institute for Meteorology and Hydrology
CSGM	Climate Studies Group-Mona
DSSAT	Decision Support System for Agrotechnology Transfer
E&L	Evaluation and Learning
GDP	Gross Domestic Product
GoJ	Government of Jamaica
GOS	Global Observing System
IbF	Impact-based Forecasting
ICDIMP	Improving Climate Data and Information Management Project
ICT	Information and Communication Technology
MCH	Meteorological, Climatological and Hydrological Database Management System
MOH	Ministry of Health
MoU	Memorandum of Understanding
MSJ	Meteorological Service of Jamaica
NEPA	National Environment Planning Agency
NGO	Non-governmental Organization
NHC	National Hurricane Center
NIC	National Irrigation Commission
NOAA	National Ocean and Atmosphere Administration
NSDMB	National Spatial Data Management Branch
ODPEM	Office of Disaster Preparedness and Emergency Management
PIU	Project Implementation Unit
PPCR	Pilot Program for Climate Resilience
PPE	Public-Private Engagement
RADA	Rural Agricultural Development Authority
SOFF	Systematic Observations Financing Facility
SST	Sea Surface Temperature
WHYCOS	World Hydrological Cycle Observing System
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization
WRA	Water Resources Authority

Executive Summary

The Climate Investment Funds (CIF) were established with the mandate to serve as a learning laboratory for scaled-up climate finance through a range of investments to address climate change and accelerate climate action. The CIF Evaluation and Learning (E&L) Initiative is helping to fulfill this mandate by various strategic and demand-driven studies covering some of the most important and pressing challenges facing climate finance funders and practitioners, including ensuring sustainability and enhancing project design and implementation to better respond the needs and capacities of beneficiaries.

Drawing on experience from across the CIF portfolio of investments in clean energy, forests and climate resilience in 72 developing countries, the E&L Initiative identifies strategic lessons and enables learning that is relevant, timely and useful to inform climate programs, strategies, and investments, for both the CIF and the wider climate finance sector.

The study *Pathways for Transforming Weather, Water, and Climate Services* was commissioned by CIF's E&L Initiative to distill lessons from CIF's Pilot Program on Climate Resilience (PPCR) support identifying, designing, and implementing hydrometeorological and climate services investments. It seeks to generate learning and strategic insight into the different operational pathways that can be taken by national hydrological and meteorological services to develop, deliver, and strengthen hydrometeorological and climate services.

The outputs from the study comprise of one synthesis report and three country studies for Jamaica, Mozambique, and Nepal. These three countries have been selected for the study due to their different institutional frameworks, hydrometeorological systems, and socio-economic context. They provide diverse in-depth insights in hydrometeorological and climate service development, delivery, and use. In this respect, the PPCR-supported *Improving Climate Data and Information Management Project (ICDIMP)* was selected as a case study project for Jamaica. As of December 2021, the project is still under implementation and, based on the project experience acquired so far, this country study elucidates lessons learned on the process for modernizing hydrometeorological systems and developing climate services to users. Furthermore, it offers insight into challenges and opportunities for climate services development, delivery, and use in the Caribbean countries and small island developing states.

Qualitative methods, including structured interviews and literature review, were used to identify promising pathways to transform weather, water, and climate services in the three case study countries. In Jamaica, the analysis of the data collected revealed seven themes regarding critical pathways to continue to transform weather, water, and climate services in the country. These comprise of integrating hydrometeorological data resources; hydrometeorological and climate service design and delivery; fostering hydrometeorological and climate services impact through user feedback; building appropriate human capacity; strengthening national coordination; promoting international collaboration; and institutional strengthening. The section below summarizes key findings and recommendations.

Key findings and recommendations on pathways to continue to transform weather, water, and climate services in Jamaica:

1. Integrating hydrometeorological data resources

- ***Bolstering data collection in key parameters such as soil moisture, sea level, and sea surface temperature can enhance the capacity of service providers to continue to advance research and development of hydrometeorological and climate services.*** Freely available data products and services can help address this challenge in the short-term. However, future investments in the country should explore financing the installation of stations to collect this data that is critical for climate change adaptation in a small island state such as Jamaica.

- ***Strengthening the data management system of the Meteorological Service of Jamaica (MSJ) can help increase their capacity to process data and to respond to the requests from users more efficiently, enhancing salience and usefulness of the climate information products.*** Future hydrometeorological and climate services investments in Jamaica should explore investing in a robust data management system to continue strengthening the hydrometeorological and climate services offered by MSJ.

2. Hydrometeorological and climate service design and delivery

- ***Expanding and increasing the knowledge within local communities, Ministries, Departments, and Agencies, as well as commercial and private institutions, on the climate information products offered by MSJ would help bolster their uptake and use. Thus, maximizing socioeconomic benefits.*** Implementing participatory climate services development approaches can help increase the uptake of the hydrometeorological and climate services information products produced by MSJ. This should be accompanied by communication strategies to increase awareness on the products available.

3. Fostering hydrometeorological and climate services impact through user feedback

- ***Establishing a structured process to gather feedback on the hydrometeorological and climate information products delivered to users can help service providers better understand user needs and the relevance of the products produced.*** Therefore, formally implementing a feedback mechanism is critical to continue to advance water, weather, and climate services in Jamaica. It provides an opportunity to assess areas of improvement in the design and delivery of hydrometeorological and climate information products.

4. Building appropriate human capacity

- ***Enhancing human capacities is pivotal for the development of innovative and quality hydrometeorological and climate information products. Capacity building activities need to be continuously supported.*** Future investments in climate services should continue to strengthen capacities to develop products, and promote research to inform country-specific solutions.

5. Strengthening national coordination

- ***Expanding collaboration and coordination among PPCR project technical implementing agencies and intermediary users of hydrometeorological and climate information is key to continue advancing the development of hydrometeorological and climate services.*** Fostering these collaborations would help better understand user needs and increase synergies to develop more targeted hydrometeorological and climate information products.

6. Promoting international collaboration

- ***Regional collaboration for a small island developing state such as Jamaica is key as it allows to address a number of technical, financial and human resources limitations.*** In the Caribbean, regional collaboration is strong and it has allowed Jamaica to benefit from a diverse range of hydrometeorological and climate information products including hurricane and seasonal weather forecasts. Continuously promoting cooperation among countries in the region is critical to increase the country's capacities on hydrometeorological and climate services.

7. Institutional strengthening

- ***Strengthening the meteorological policy framework, and ensuring clarity in the mandate of hydrological and meteorological service providers, can help strengthen their capacity to collect, produce, and deliver hydrometeorological and climate services.*** Thus, reinforcing the hydrological and meteorological institutional framework would help the country to continue to advance water, weather, and climate information, products and services.

1. CONTEXT

1.1 Climate risk and vulnerability in Jamaica

Jamaica is highly vulnerable to weather-related disasters and climate hazards. The country is exposed to hurricanes, tropical storms, floods, and droughts. Over half of the population resides within a mile of the shoreline, where more frequent hurricanes and sea level rise threaten settlements and livelihoods. Furthermore, over 70% of productive industries and service sectors, responsible for producing 90% of the country's Gross Domestic Product (GDP), are located in coastal zones, making the country's economy vulnerable to weather and climate risks (USAID, 2017).

Current climate variability presents a challenge for the country's economic growth and development. Between 1999-2017, Jamaica experienced 15 hydrometeorological events which resulted in costs ranging from 0.1 to 6.8% of the GDP (UNICEF, 2020). In addition, weather-related events have large impacts in key economic sectors such as fisheries and agriculture. In 2008, Hurricane Gustav occasioned US$14 million losses to the marine fisheries sector, mainly through the loss of equipment (Oxenford H.& Monnereau I., 2017). Hurricane Ivan, in 2004, damaged key export crops including sugarcane, banana, and coffee, with losses of US$49 million, prompting a number of farmers to abandon the agricultural sector (USAID, 2017).

Climate change is expected to further exacerbate Jamaica's weather and climate risks. Results from global and regional climate models suggest the country will experience higher temperatures and more frequent droughts. In addition, it will endure an increase in precipitation variability and storm intensity, as well as rising sea levels. These changes in weather and climate patterns will affect crop productivity, reduce water availability and quality, impact the frequency and extent of forest fires, increase heat stress and the risk of waterborne and vector-borne diseases (Climate Studies Group Mona, 2017).

1.2 Building resilience with hydrometeorological and climate services

Recognizing the country's vulnerability to hydrometeorological and climate risks, the Government of Jamaica (GoJ) has taken a number of actions to integrate climate resilience into development planning, and to reduce the current and future impacts of hydrometeorological and climate events within the country. This is reflected in national development plans and policies including: The Vision 2030 Jamaica - National Development Plan (Planning Institute of Jamaica, 2009), the Disaster Risk Management Act (Government of Jamaica, 2015), the National Water Sector Policy and Implementation Plan (Government of Jamaica, 2019), the Watershed Policy (Government of Jamaica, 2003), and the Climate Change Policy Framework (Government of Jamaica, 2015).

These policy instruments, that placed climate services as a key component to build climate resilience and to reduce hydrometeorological and climate risks, were complemented and reinforced by the Climate Investment Funds' (CIF) Pilot Program for Climate Resilience (PPCR), which in 2015 provided a US$7 million grant to implement a seven-year project in Jamaica entitled *Improving Climate Data and Information Management Project (ICDIMP)*. The project, which is still under implementation, aims to improve the quality and use of climate data and information for effective planning at local and national levels.

The PPCR Project was designed with respect to three strategic objectives:

- **Upgrading hydrometeorological data collection, processing and forecasting systems,** including strengthening and optimizing physical sea-level, hydrometeorological and agrometeorological monitoring networks; upgrading the weather Doppler radar; and strengthening human capacity on data collection, management and forecasting.

- **Strengthening climate resilient planning and hydrometeorological information services,** including updating downscaled high-resolution climate change scenarios; conducting national vulnerability assessments; preparing health sector vulnerability assessments; carrying out community-based risk profiling; and upgrading the multi-agency climate and natural risk data and information sharing system.

- **Promoting climate change education and awareness,** including implementing climate change information, education, and communication campaigns to adopt practical means of coping with severe weather events, climate variability and change; and conducting attitude and behavioral change initiatives to address climate change adaptation needs and influence behavioral change.

The PPCR project emphasized the benefits of upgrading hydrometeorological systems and strengthening the dissemination of weather forecasts and climate information to reduce the economic losses caused by weather and climate events. Moreover, it highlighted the advantages of improved forecasts to advise decisions related to agriculture, fisheries, energy, tourism, and transportation as articulated in Table 1.

Table 1: Benefits of hydrometeorological services to support economic sectors in Jamaica (adapted from World Bank, 2015).

Sector	Benefits from improved weather forecasts
Agriculture	Farmers require temperature and precipitation information to decide when to irrigate, plant, and to improve harvesting time decisions to ensure productivity, and to reduce agricultural losses from hydrometeorological events and climate risks.
Fisheries	Fishers rely on weather forecasts to determine sailing times, duration of fishing activities, and fishing location to avoid adverse weather conditions that can result in loss of life and/or damage of assets.

Energy	The energy sector requires weather forecasts to inform power plants when to increase or decrease electricity production. Moreover, stream flow forecasts and climate projections support the operational planning of hydroelectric generators.
Tourism	The tourism sector depends on weather information to manage infrastructure such as golf courses and plan tourist activities, including recreational fishing and other outdoor and marine-based activities.
Transportation	The transportation sector depends on weather forecasts to plan travelling routes of trucks, vessels, and airplanes. Weather information ensures the efficiency and security of transportation.

The project beneficiaries are government institutions providing meteorological, hydrological, and climate data and information, as well as users, including vulnerable communities and population, who benefit from more reliable and consistent hydrometeorological and agrometeorological information services. These institutions comprise the Meteorological Service of Jamaica (MSJ) and the Water Resources Authority (WRA), which are responsible for hydrometeorological data collection, processing, management, and operation and maintenance of hydrometeorological equipment. Moreover, beneficiaries include: the Rural Agricultural Development Authority (RADA), the Ministry of Health and Wellness (MOHW), the Office of Disaster Preparedness and Emergency Management (ODPEM), the Climate Change Division (CCD), among other government institutions.

The PPCR project is supervised and implemented by the Planning Institute of Jamaica (PIOJ), a statutory body within the Ministry of Finance and the Public Service. As the executing agency, PIOJ has established a project implementation unit (PIU) responsible for coordinating project activities and provide fiduciary support to the technical implementing agencies of the PPCR project, including procurement, financial management, and project reporting. The technical implementing agencies include: MSJ, WRA, RADA, ODPEM, MOHW, CCD, and the National Spatial Data Management Branch (NSDMB).

The GoJ has established an umbrella Steering Committee to provide advice and oversight to the implementation of the PPCR project. The Steering Committee is responsible for ensuring that the project is effectively and expeditiously implemented, maintaining its development objectives, results framework, and budget. Further, the Steering Committee is responsible for addressing any interagency and strategic level issues and risks that may adversely affect the implementation of the project.

A detailed map of the PPCR project implementation arrangements is found in **Figure 1**.

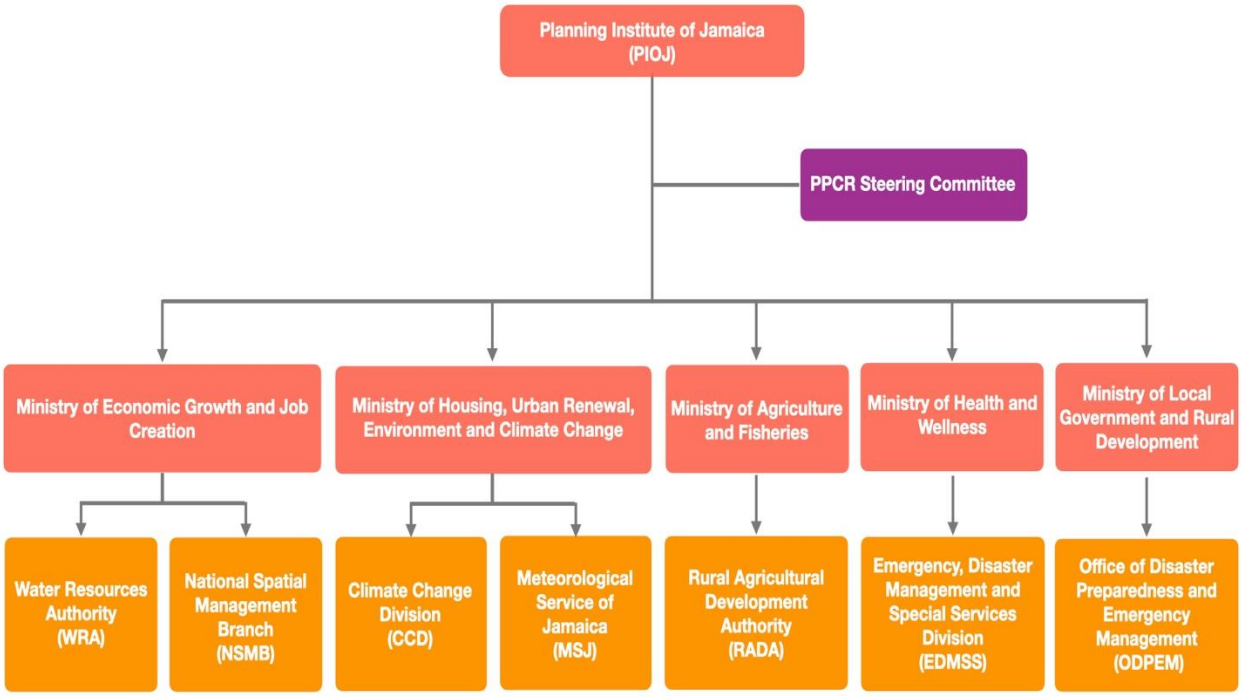

Figure 1: PPCR project implementation structure (adapted from World Bank, 2015).

2. STUDY: PATHWAYS FOR TRANSFORMING WEATHER, WATER, AND CLIMATE SERVICES

The study *Pathways for Transforming Weather, Water, and Climate Services* was commissioned by CIF's E&L Initiative to distill lessons from CIF's Pilot Program on Climate Resilience (PPCR) support in identifying, designing, and implementing hydrometeorological and climate services investments. It seeks to generate learning and strategic insight into the different operational pathways that can be taken by national hydrological and meteorological services to develop, deliver, and strengthen hydrometeorological and climate services.

Furthermore, the study aims to understand the aspects that allow or limit the development, delivery, and use of hydrometeorological and climate services by gathering lessons learned on: the mechanisms that can improve coordination between hydrometeorological and climate service providers and sector institutions to improve the development, delivery, and use of hydrometeorological and climate information; the elements within the climate services value chain that promote or obstruct the delivery and use of hydrometeorological and climate services; and, the extent to which intermediary users and end-users utilize and are aware of hydrometeorological and climate services.

The outputs from the study comprise of one synthesis report and three country studies for Jamaica, Mozambique, and Nepal. These three countries have been selected for the study due to their different institutional frameworks, hydrometeorological systems, and socio-economic context. They provide diverse in-depth insights in hydrometeorological and climate services development, delivery, and use. In this respect, the PPCR-supported *Improving Climate Data and Information Management Project (ICDIMP)* was selected as a case study project for Jamaica. As of December 2021, the project is still under implementation and, based on the project experience acquired so far, this country study elucidates lessons learned on the process for modernizing hydrometeorological systems and developing climate information services to users. Moreover, it offers insight into challenges and opportunities for climate services development, delivery, and use in the Caribbean countries and small island developing states.

The themes explored for generating knowledge and distilling lessons in the three country studies were based on the components of the hydrometeorological and climate services value chain conceptual and analytical framework outlined in Figure 2. It was used to ensure consistency of the learning approach across country studies, and with the intention of producing learning outcomes relevant to the broader hydrometeorological and climate services community. The hydrometeorological and climate services value chain framework consists of the following components: hydrometeorological data collection and management, development and delivery of hydrometeorological and climate information, products and services, and its application to support climate resilient development outcomes.

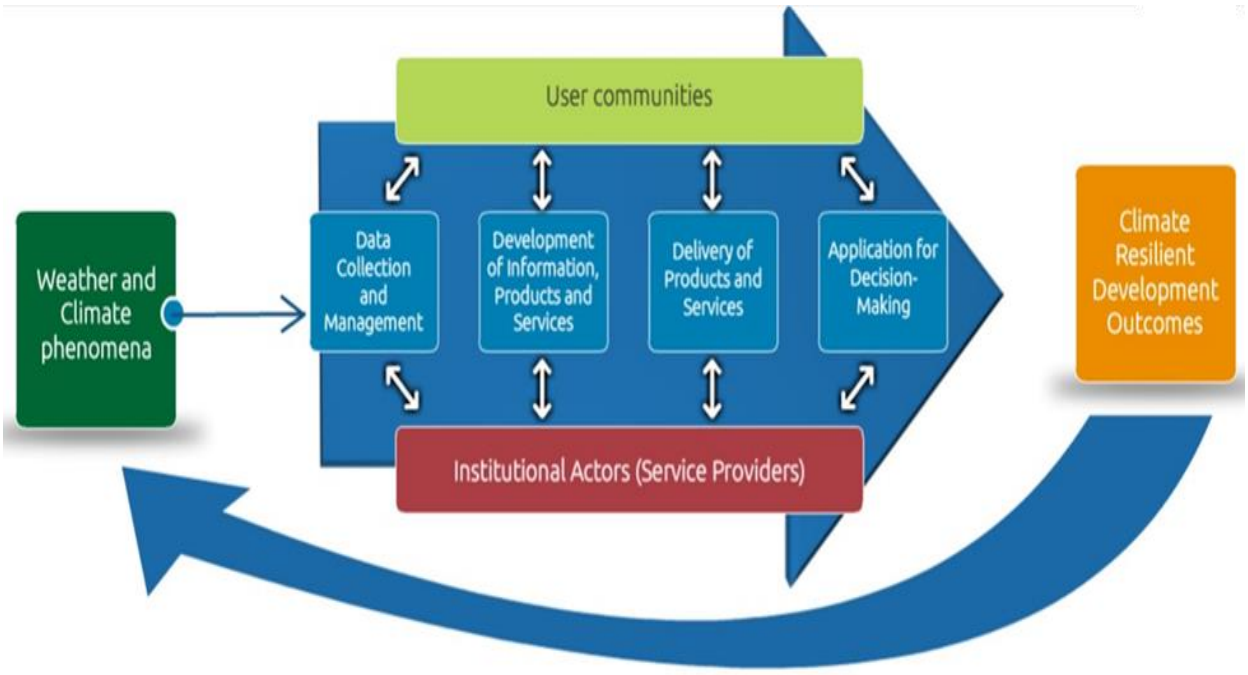

Figure 2: Climate Services Value Chain (Source: World Bank, 2021)

The hydrometeorological and climate services value chain begins with the production of services which is composed of hydrological and meteorological observations, and data processing and management (Figure 2). Data processing generally encompasses the use of models and other tools to visualize and produce real-time hydrometeorological forecasts and climate information. Subsequently, this information is delivered as hydrometeorological and climate services to decision-makers who then take actions that translate into prevented human and economic loss, as well as increased productivity of key economic sectors. A better understanding of weather, water, and climate from more reliable hydrometeorological and climate information can inform long-term planning and investments to mitigate or adapt to climate risks, and help understand the potential impacts of long-term climate.

This hydrometeorological and climate services value chain is operationalized by hydrological and meteorological service providers who are responsible for data collection, management, and processing. They rely on intermediary users to transform and translate the data collected into sector-specific information to produce hydrometeorological and climate information products and services. The intermediary users are different from the final end-users of climate information who frequently do not need hydrometeorological and climate information or data, but a finished useable advisory service or product they can use for their decision-making. The end-users can comprise farmers, fishermen, among other groups, as well as national decision-makers and planners who may need finished hydrometeorological and climate information products (Tall A., 2013).

3. BACKGROUND

3.1 Institutional landscape

As mentioned in section 1.2, the institutions responsible for generating and disseminating meteorological and hydrological information in Jamaica include the Meteorological Service of Jamaica (MSJ) and the Water Resources Authority (WRA), respectively. In addition, the National Environment Planning Agency (NEPA) monitors sea surface temperature. Institutions from the private sector, including agricultural companies, large-scale farmers, and bauxite companies, have established their own stations to collect independently their own hydrometeorological and climate data. In addition, these institutions collaborate with MSJ to gather and report weather data by granting them permission to install Automatic Weather Stations (AWS) in their premises.

Figure 3, represents a detailed map of the institutional landscape of hydrometeorological and climate services in Jamaica.

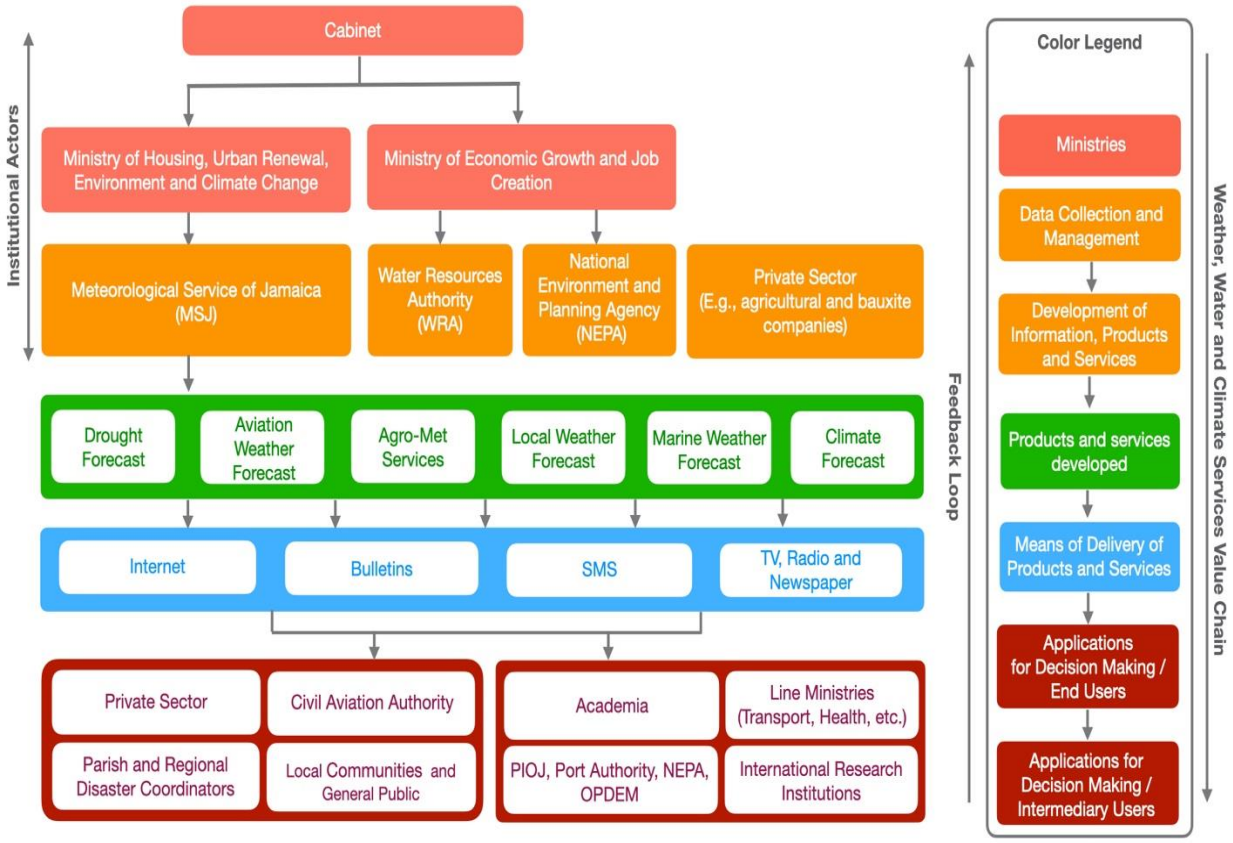

Figure 3: Institutional landscape of hydrometeorological services in Jamaica (Source: Author).

Previous to the PPCR project implementation, the country's hydrometeorological system, and capacity of MSJ and WRA to develop and deliver hydrometeorological and climate information products and services, had deteriorated as a consequence of the following challenges:

- **Inadequate financial resources:** The limited financial resources of MSJ and WRA did not allow them to provide appropriate levels of maintenance to the hydrological and meteorological stations, to replace malfunctioning equipment, and/or to expand the hydrometeorological network.

- **Deteriorated hydrometeorological equipment:** The network of 23 climatological stations only had six stations functioning. The 22-year old Doppler Weather Radar at Cooper's Hill was obsolete and subject to periodic malfunctions.

- **Insufficient capacity:** This limited the capability to collect and process hydrometeorological data, develop products, and deliver information and services necessary to predict and prepare for hydrometeorological and climate events.

The inadequate financial resources, deteriorated hydrometeorological equipment, and insufficient capacity constrained the capacity of the country to predict and prepare for hydrometeorological events and climate hazards; and thus, to increase the country's resilience to climate impacts (World Bank, 2015).

3.2 Existing hydrometeorological and climate services

Hydrological and meteorological services are provided separately by MSJ and WRA, as described below.

- **Meteorological Service of Jamaica:** The MSJ is responsible for the observation and forecasting of weather conditions in Jamaica, and for delivering weather forecasts to the general public. In addition, it produces aviation and marine weather forecasts for transportation purposes. During the hurricane season, which extends from June to November, MSJ is responsible for maintaining a continuous hurricane watch and for adding tropical cyclone warning messages to its roster of severe weather warnings.

- **Water Resources Authority:** The WRA is responsible for managing the country's hydrological network and for collecting hydrological data, including information on streamflow and groundwater levels. The data collected is used to assess the resources available for water supply, as well as for the assessment of floods and droughts. Further, the WRA prepares flood plain maps and collaborates with the Office of Disaster Preparedness and Emergency Management (ODPEM) in the declaration of floodwater control areas, and in identifying potential sites for early warning systems.

The different interventions under PPCR project supported the improvement of hydrometeorological data collection and the development of a number of products to enhance the country's response to extreme weather-related events and increase its resilience to climate change.

4. STUDY APPROACH

Qualitative methods were used to identify promising pathways to continue to transform weather, water, and climate services in Jamaica. This involved collecting and analyzing empirical evidence through key informant interviews with relevant stakeholders of hydrometeorological and climate services in Jamaica. Furthermore, it included the analysis of key documents that consisted of the project appraisal document, project progress reports, project restructuring papers, implementation status and results reports, the project's mid-term evaluation, as well as a literature review on hydrometeorological and climate services.

4.1 Data collection

A list of key informants was developed in conjunction with the World Bank PPCR project team, and a snowball approach was used to add additional stakeholders when appropriate. In total, 32 key informants from 17 organizations (Appendix 1), drawn from a broad spectrum of actors in the hydrometeorological space in Jamaica, were interviewed. These largely included but were not limited to actors involved in the implementation of the PPCR investment program in Jamaica.

Interviews were in-depth (lasting over an hour) with the objective of revealing stakeholders' perception of the hydrometeorological and climate services development and delivery process in the country. Separate sets of questions were developed for different stakeholder groups: (i) climate service providers; (ii) climate service intermediary users; (iii) climate service end-users; and (iv) climate service experts (academia, private sector, international organization representatives). While main interview questions were common to all stakeholder groups to permit comparative analyses, additional questions were tailored to the specific stakeholder group's role in the climate services value chain.

Key informant interviews were carried out virtually due to the COVID-19 pandemic from April to June, 2021. They were recorded and transcribed. The transcriptions were analyzed through a thematic content analysis approach to identify recurrent themes and issues. An interview protocol is included in Appendix 2.

4.2 Data analysis

As indicated in section 2, the hydrometeorological and climate services value chain and its four different components were used as a guiding conceptual and analytical framework to analyze the data collected, as well as to identify opportunities and bottlenecks to continue transforming weather, water, and climate services in Jamaica.

The data collected through interviews was organized into themes that are presented in the Results & Discussion section below.

5. RESULTS & DISCUSSION

The data collected through the interviews revealed eight themes regarding critical pathways to transform weather, water, and climate services in Jamaica. These are: integrating hydrometeorological data resources; hydrometeorological and climate service design and delivery; fostering hydrometeorological and climate services impact through user feedback; building appropriate human capacity; strengthening national coordination; promoting international collaboration; institutional strengthening; and project management. These eight themes are presented and analyzed below.

5.1 Integrating hydrometeorological data resources

Access to high-quality and timely hydrometeorological observations, as well as efficient data management and processing systems, are essential to build salient and reliable hydrometeorological and climate information products and services that can support climate-informed decision-making. Consequently, observational data on key hydrological and meteorological variables and adequate data processing systems, form the basis for the development of water, weather, and climate services.

The PPCR project is enhancing the quality of hydrometeorological observations and the monitoring network in Jamaica, as well as it is bolstering the integration of data resources. Efforts supported by the PPCR project to improve the meteorological observational monitoring network through MSJ up to December 2021, include:

- Procurement, installation, and operationalization of a Doppler weather radar.
- Physical works and instrumentation for 53 Automatic Weather Stations (AWS), including 14 agrometeorological and 39 weather stations.
- Technical assistance to evaluate the surface area observation network, as well as to assess gaps in MSJ forecasting process.
- Recovery and infilling of a rainfall dataset for 1971-2010[1].
- Development of an AWS Real Time Data Platform.
- Installation and operationalization of a real-time sea level tide gauge at the Montego Bay Pier, as well as procurement of two additional sea level tide gauges.
- Procurement and instrumentation of 20 soil moisture probes.

Similarly, efforts supported by the PPCR project to expand and enhance the observational hydrological network through WRA comprise of the following measures:

- Establishment of a hydrological monitoring center and situation room for remote monitoring of hydrological resources.
- Implementation the Water Resources Authority Water Information System which provides access to the Water Resources Database via a browser.

[1] Long-period datasets are necessary for climate modelling and spatial and statistical analyses. In Jamaica, a fire destroyed many paper rainfall records at MSJ in 1992. In addition, equipment constrains affected rainfall data recording from 1971 to 2010.

- Physical works and instrumentation for 57 hydrometeorological stations, comprising of stream and river gauges, as well as rain intensity gauges.

- Modernization of over 40 rain gauges and water level sensors for real-time data transmission.

- Procurement and instrumentation of 12 soil moisture probes.

These efforts, to improve hydrometeorological equipment and infrastructure for data collection and monitoring, have enhanced the capacity of MSJ and WRA to produce more reliable hydrometeorological and climate information products. Nonetheless, there are areas to continue enhancing hydrometeorological data collection and management, increase data coverage and accessibility, and bolster data sharing. These priority areas for future investments are discussed in the section below.

5.1.1 Hydrometeorological data collection

While under the PPCR project data collection has improved due to investments to expand AWS and to modernize stations for real-time data transmission, respondents highlighted there are further areas to continue enhancing the data collection process. Specifically, these areas are related to the data collected by local readers, the timeliness of the retrieval of the data from AWS, and the need to strengthen data collection in other parameters relevant to a small island developing state such as Jamaica.

Jamaica's hydrometeorological observation network comprises of a mix of automatic and manual stations. As a result, MSJ and WRA still rely on local readers to physically collect data from manual stations. In certain locations, the data collected by local readers does not accurately reflect the hydrometeorological conditions. This is because of human errors when recording the observational data from hydrometeorological stations. Errors in the data registered can impact the accuracy of weather forecasting. In addition, it can affect the data that form historical observational datasets necessary to understand climate variability and change.

Another aspect to enhance the data collection process in Jamaica is related to the timeliness of the retrieval of data from certain AWS. As one of the respondents explained, in certain locations where there are automatic stations, they have to wait for a person to physically go to the stations and retrieve the data. This does not always occur in a timely manner. Thus, they cannot access the data when is necessary.

If the data collection process does not occur on a consistent and regular basis, it can affect the development of hydrometeorological and climate information products and services and, ultimately, the timeliness of their delivery. As a consequence, it can impact the relevance and usefulness of the information for users.

Increasing and strengthening data collection in soil moisture, sea level, and sea surface temperature, can reinforce the capacity of hydrometeorological and climate service providers to continue to advance research to better understand the impact of hydrometeorological events, as well as climate hazards in Jamaica. Furthermore, it can enhance their capacity to continue advancing hydrometeorological and climate services.

- **Soil moisture:** Expanding the number of soil moisture probes is critical to continue strengthening flood and drought monitoring and to produce hydrometeorological and climate information products such as drought indices.

- **Seal level:** Increasing tidal gauges is fundamental to strengthen the capacity of service providers to adequately measure and monitor sea level rise, and to determine trends in mean sea level, storm surges, and other coastal hazards.

- **Sea Surface Temperature:** Extending investments to monitor sea surface temperature (SST) is key to continue advancing climate and seasonal forecasting, validate atmospheric models, evaluate coral bleaching, among other weather and climate applications.

One step to continue enhancing the data collection process in Jamaica could be for the stations hosted by MSJ to adopt the WMO Integrated Global Observing System (WIGOS) framework. WIGOS provides a basis to better use existing and emerging observational capabilities from WMO and WMO co-sponsored observing systems (WMO, 2021). Similarly, WRA could adopt the hydrological component of WIGOS, the World Hydrological Cycle Observing System (WHYCOS) to improve hydrological observations.

The use of freely available data products and services, including data repositories, such as the IRI Data Library from the International Research Institute for Climate and Society at Columbia University; satellite products, including data from Sentinel Hub, Landsat, MODIS, etc. could additionally contribute to improving the data collection process of hydrological and meteorological service providers in Jamaica.

5.1.2 Hydrometeorological data gaps

Observational datasets, covering extended periods of time, are fundamental for climate research and weather forecasting. These datasets comprise climatological records over time periods that usually span over several decades. Unfortunately, missing values in climatological records can result in temporarily sparse datasets that are not appropriate for long-term forecasting and climate modelling (Bagueria S. et al, 2019).

A fire in 1992 destroyed a large number of paper rainfall records at MSJ. As a result, monthly rainfall data from 1992 includes many gaps. The PPCR project has afforded to significantly recover and infill data from 1971 to 2019. This effort has contributed to filling those data gaps, and thus enhanced MSJ's weather forecasts. Nevertheless, respondents pointed out that continuous data rescue and statistical infilling are necessary to fill the remaining gaps in rainfall records.

Another area to strengthen historical observational datasets in Jamaica is related to temperature data. Before 2009, the hydrometeorological network of MSJ comprised of rainfall gauges and a limited number of temperature stations. The installation of AWS for temperature data collection started 12 years ago. Thus, long-term records of temperature data are limited. In this regard, one of the respondents noted that there is a limited number of stations that have been operative for 30 years. As a consequence, it is challenging to produce requests for data analysis for long-term periods for certain parameters, being difficult to analyze temperature back beyond 1990.

Continuation of supporting data recovery and infilling is necessary to address observational data gaps, and strengthen the capacity of hydrological and meteorological service providers in Jamaica to increase the accuracy and salience of hydrometeorological and climate forecasts.

5.1.3 Hydrometeorological data management

Upgrading the current data management system of MSJ would further strengthen their capacity to adequately manage the observational data collected. The meteorological agency currently manages data in an Excel spreadsheet. This spreadsheet is used for data summarization of weather parameters such as rainfall and temperature. Improving the data management system would help maximize MSJ's capacity to identify errors in data, and thus enhance data quality control and assessment.

Furthermore, advancing the data management system would allow MSJ to process data and to respond to requests from users in a timely manner. Currently, data processing requires more manual input and thus it can take longer periods of time to produce meteorological and climate products. In certain cases, data processing needs to be done twice to develop the same meteorological product.

A well-functioning data management system would increase the efficacy of data processing and the capacity to develop and deliver hydrometeorological and climate information products in a timely manner. Thus, ameliorating their salience and usefulness, and maximizing the uptake of the products developed by MSJ.

It is critical to continue strengthening MSJ's data management system and upgrade it to one that allows to archive, manage, and process the observational data collected. One step to achieve this could be to use an open-source data management system such as WMO's Meteorological, Climatological and Hydrological Database Management System (MCH). This license-free database allows to store, manage, analyze, and visualize observational data (WMO, 2021).

5.1.4 Hydrometeorological and climate data accessibility

A number of respondents pointed out the importance of continue strengthening the access to hydrometeorological data. Indeed, a fundamental aspect for integrating data resources with other data products or applications is data accessibility.

Hydrometeorological data is freely available in Jamaica. However, the access to this information differs between service providers. While the data collected by the Water Resources Authority (WRA) is available online, the information from the Meteorological Service of Jamaica (MSJ) is only available upon request. The data available online is limited to local weather and climate forecasts, including tailored meteorological products such as aviation, marine, and towns & cities forecasts. An agrometeorological bulletin with information on key weather patterns is shared via email to stakeholders.

Respondents highlighted the importance of enhancing accessibility to MSJ's information and data on key weather variables. Upon the request, it can take several days for MSJ to share the data. This can affect the ability of users to access information in a timely manner, and in consequence, to use the information for the development of climate-related products or to take decisions.

The establishment of a data repository with both hydrological and meteorological datasets could improve data accessibility and enhance the application of climate information. This could also involve exploring the use of existing platforms such as the National Spatial Information Platform to store and publish information. Timely and prompt access to climate data can bolster the development of water, weather, and climate products and services, and foster climate-informed decision making.

5.1.5 Hydrometeorological and climate data sharing

Robust data sharing mechanisms among service providers and intermediary users can help leverage climate data availability and, consequently, foster climate-informed decisions. Data sharing is crucial for an enabling environment for establishing the co-production process of water, weather, and climate services (Bamba M., 2018).

Previous to PPCR project implementation, the collaboration between WRA and MSJ was not formalized. This limited the use of hydrometeorological data and the efficiency of the data collection process. In that regard, data sharing between the two institutions took considerable time and, due to the lack of communication, the location of their hydrometeorological stations would overlap.

The PPCR project supported a Memorandum of Understanding (MoU) between WRA and MSJ to facilitate the sharing of hydrometeorological data from rainfall, intensity, and streamflow stations. Further, the MoU enhanced the coordination between the two institutions to locate hydrometeorological stations and expand the spatial coverage of data collection.

While the MoU addressed data sharing and collaboration challenges between MSJ and WRA, a number of respondents noted the importance of strengthening coordination and data sharing mechanisms between service providers and intermediary users. In this regard, for example, NEPA collects sea surface temperature in more than 40 locations but it is not shared or linked to the data system of MSJ. Enhancing data sharing and collaboration between these two institutions would contribute to a robust data system, including greater data coverage and data collection.

Continuation of promoting formal collaboration and data sharing mechanisms, through MoUs and other policy mechanisms, could foster data sharing among service providers and intermediary users. Further, it could increase the efficiency in data collection, and help the expansion of the monitoring network.

5.2 Hydrometeorological and climate services design and delivery

A general overview of services provided by MSJ and WRA is included in section 3.2. To advance service provision, and to promote Jamaica's readiness for climate events, the PPCR project has fostered work to enhance climate change scenarios modelling, prepare vulnerability assessments, and develop early warning messaging.

The project has been supporting the provision of products to define priorities and actions on climate resilience. These products include:

- **Downscaled Climate Change Scenarios:** The development of downscaled high resolution (10-4 km grids) climate scenarios for 2030, 2050, 2080, and 2100. The objective is that these scenarios will be used in priority sector development plans.

- **State of the Jamaican Climate Report for 2015 and 2019:** The development of the State of the Jamaican Climate Report for 2015 and 2019[2]. The reports assess climate trends and evaluate how key sectors for Jamaica might be influenced and impacted by climate change.

- **Health Sector Vulnerability Assessment:** The development of a Health Sector Vulnerability Assessment to identify the risk of key health facilities and operations to weather-related disasters and climate hazards.

- **Community Disaster Risk Management Plans:** The development of Community Disaster Risk Management Plans through participatory planning approaches. The objective is to scale-up resilience mitigation and adaptation plans in 14 communities.

[2] The State of the Jamaican Climate Report for 2015 was published in 2017 and can be found here: https://sustainabledevelopment.un.org/content/documents/19514The_State_of_the_Jamaican_Climate_2015.pdf. As of December 2021, the State of the Jamaican Climate Report for 2019 is still under preparation. A draft version of the Report can be found here: https://www.pioj.gov.jm/product/the-state-of-the-jamaican-climate-2019-historical-and-future-climate-changes-for-jamaica/

- **Early Warning Messaging:** The development of early warning communication messages for vulnerable communities including low-income groups living in unplanned settlements in hazard-prone locations, persons with disabilities, among others.

These efforts to support the development of hydrometeorological and climate information products have contributed to promoting readiness for weather-related disasters and climate hazards. There are different areas that could continue to be strengthened in future investments to enhance the development and delivery of water, weather, and climate information products and services. These, which are discussed below, include: bolstering awareness and use of climate information, improving communication and credibility, and enhancing the delivery of hydrometeorological and climate information products and services.

5.2.1 Bolstering awareness and use of hydrometeorological and climate information

A number of respondents noted that it is critical to continue bolstering awareness among local communities on the hydrometeorological and climate information products produced and delivered by MSJ and WRA. In this regard, one of the respondents highlighted that raising awareness on the products available is increasing the uptake and use of hydrometeorological and climate information products and services. This is critical for information products to maximize their socioeconomic benefits.

One step to continue increasing awareness on the hydrometeorological and climate information products that are being produced could be through participatory processes. Co-designing and co-developing climate information services can contribute to implementing climate information services that are tailored to users' needs. As potential users invest time and resources in the development of hydrometeorological and climate information products, they gradually come to consider the output product as their own. Moreover, they are likely to make full use of it, invest in its maintenance, and recommend it to others (Paparrizos S. et al., 2021).

Participatory climate services development approaches could be accompanied by an assessment of the means and channels used by local population to access climate information. This could help better understand how to improve hydrometeorological and climate services delivery. Further, this could be complemented by a communication campaign that highlights the products produced by service providers and their benefits.

5.2.2 Improving communication and credibility

Another relevant area identified by respondents that needs to be continuously strengthened, is related to the understandability of the hydrometeorological and climate information delivered, and the formats utilized to present the information. Indeed, information must be interpreted and provided to a broad user community in understandable terms and formats (World Bank, 2018). If the information cannot be understood, then it will not be used.

It is important to continue reinforcing the capacity of service providers to communicate hydrometeorological and climate information in a non-technical manner. Thus, different levels of users can understand the climate information that is being provided.

Various respondents suggested to address this issue by providing weather forecasts and advisories focusing on the impacts of weather events and the actions that should be taken to minimize risks. Impact-based forecasting (IbF) emphasizes on what the weather will do rather than what the weather will be, and by doing so, translates weather hazards into sector-specific impacts. The aim is to target only those at risk, rather than the entire population (Rogers D. et al., 2019).

With regards to IbF, respondents from MSJ noted they were trying to move towards the development of this product. Nonetheless, they noted that producing it would require a change in their processes. To produce IbF, it is necessary to enhance the collaboration with disaster risk management organizations within the country, the research community, among other actors in the hydrometeorological and climate services field. These collaborations are critical to analyze data and translate it into sector-specific information. In addition, access to vulnerability and exposure information, which is usually provided by DRM institutions, is also is key for the development of IbF (UN ESCAP, 2017).

5.2.3 Enhancing the delivery of hydrometeorological and climate information products and services

Several respondents emphasized the importance of enhancing the delivery of hydrometeorological and climate information products in Jamaica. Indeed, ensuring the use of adequate means to deliver hydrometeorological and climate information is fundamental to ensure that information reaches the intended users.

One of the key areas to continuously strengthen the capabilities of service providers with regards to delivery is related to new technologies. The increasing number of digital services and platforms constantly transform how hydrometeorological and climate information is accessed and delivered. The different users of digital services and platforms require that service providers develop and use different formats to engage with them. Including formats for websites, apps, different social media platforms, among others. Thus, enhancing the number of human capacities of service providers to adapt to these new services and platforms is key to respond to the rapidly changing needs of users.

One possible step to address this area for further enhancement is through a periodic and systematic assessment of the channels most utilized by users to access information. This could help prioritize the most relevant means to deliver hydrometeorological and climate information, and help service providers organize their human capacity to develop and deliver these products in an effective manner.

Another area to strengthen service delivery is related to internet connectivity. For instance, many locations in Jamaica still do not have access to the internet. In addition, these areas may have limited access to print media. This affects the capacity of service providers to reach communities that may be located, for example, in hilly areas and/or areas with dense vegetation where connectivity is difficult. In addition, in those locations with internet accessibility, connectivity might be interrupted during weather events, and thus affect the delivery of warnings.

To enhance hydrometeorological and climate service delivery in areas with difficult connectivity, respondents suggested to explore arrangements with mobile service providers to disseminate information via SMS. They also recommended to continue using traditional means of communication including radio and newspapers. This would also help ensure that elderly population, that do not use mobile phones or the internet, can continue to access information. Furthermore, respondents highlighted the importance of considering persons with disabilities when delivering information. Including closed captioning and sign language interpretation could, for example, increase the reach of hydrometeorological information to deaf communities.

5.3 Fostering hydrometeorological and climate services impact through user feedback

Views on the hydrometeorological and climate information products delivered to users are a useful source of information on the quality of the products developed by service providers. It allows to better understand how products are meeting user needs, and how salient and accurate weather forecasts are. Thus, it provides an opportunity to improve the development of climate information (WMO, 2002).

In Jamaica, MSJ and WRA receive informal feedback regarding their products from line Ministries and government institutions. This feedback comes in a variety of formats and instances. For instance, it might occur through an email, a forum, or a committee meeting.

Establishing a structured process to gather feedback on the information products delivered to users is key to continue to advance water, weather, and climate services in Jamaica. It could help service providers better assess areas of improvement in the design and delivery of climate information.

Box 1 below provides an example of how the UK Met Office receives annual feedback on its services.

Box 1: Met Office User Satisfaction Surveys

The UK Met Office carries out annual and ad-hoc surveys to gain insight into the public's requirements and levels of satisfaction with their forecasts and severe weather warning services. These surveys are carried out for the Public Weather Services Customer Group by independent market research companies to ensure they are unbiased and representative of the views of the UK public. They also help the Met Office to identify new requirements and ensure they are providing services that meet public needs. The results are updated annually after a series of surveys are carried out.

National Severe Weather Warning Service Surveys

It is important to ensure that the warnings the Met Office issues reach the people who need them and that they find the warnings useful. Thus, the Met Office carries out surveys following selected severe weather warnings.

- Telephone interviews of 500 people in the affected area.
- Monitors awareness, reach, and usefulness of warnings and forecasts.
- At least six surveys are carried out each year.
- Conducted independently by DJS Research Ltd.

Example is adapted from Weather the Change: How to Improve Hydromet Services in Developing Countries? (World Bank and GFDRR 2019)

5.4 Building appropriate human capacity

Strengthening human capacity is an area where significant investments need to occur for quality hydrometeorological and climate investments (Rogers D. et al., 2019). In Jamaica, continuously strengthening capabilities and increasing the number of staff is critical to advance transforming water, weather, and climate services. Respondents emphasized different areas to further build human capacity. These areas, which are discussed and analyzed below, comprise of data collection, research, and training on the existing services.

5.4.1 Enhancing capacity in hydrometeorological data collection

As indicated in section 5.1.1, MSJ and WRA still rely on local readers to physically collect data from manual stations. While there is a good network of trained local observers, a large number of them are retiring. Consequently, service providers need to train new observers. Numerous respondents noted the majority of these new observers are less committed to the collection of data.

The limited commitment can impact the quality of the information compiled by the new observers. For instance, they might not register the data from stations correctly or go to the field to collect the information from stations in a timely manner.

It is important to continue to raise awareness on the importance of the data collected, and establish a process to continuously achieve this within local communities and observers. This will help advance the ownership and understanding on the benefits of collecting data for their livelihoods.

5.4.2 Advancing capacity for data analysis and research

While the PPCR project has extensively supported capacity development through trainings on operations and maintenance of AWS, on soil moisture probe operations, among other key areas on hydrometeorological and climate services, a large number of respondents discussed the importance of continuous capacity development. Indeed, a well-trained workforce is fundamental to continue to progress the development of hydrometeorological and climate information products.

Specifically, respondents emphasized the importance on continuous training on hydrological and meteorological modelling. The ability to utilize observations and continue to develop forecasting products requires the ability to manipulate and interpret big data (Rogers D. et al., 2019). Thus, enhancing human capacities is pivotal for the development of innovative and quality hydrometeorological climate information products and services.

Future investments in hydrometeorological and climate services should continue to promote knowledge transfer through learning exchanges and practical training, and foster research to develop products that are relevant to the country.

5.4.3 Fostering an informed user community

One area to foster the use of hydrometeorological and climate information products in Jamaica is related to the extent users can understand and apply the hydrometeorological and climate information delivered to them.

Various participants discussed the importance of continuous training for using and applying the information disseminated by service providers. If the information is delivered to users but they cannot understand it and interpret it properly; then, they will not be able to use it and make decisions that result in increased economic productivity and/or reduce climate risks.

Strengthening human capacity in the understanding of climate information is essential to ensure that users benefit from the information and can take informed decisions. Indeed, it is key to start building this capacity at the primary and secondary education levels not only to broaden the understanding of the importance of hydrometeorological and climate information but to maximize the capacity to use and apply the information. Similarly, it is important to continuously train local communities on the application of climate information.

5.5 Strengthening national coordination

Coordination between different institutions is fundamental for the production of sector-specific products, the translation of climate information in order that it is usable to different user groups, and it is necessary for sharing relevant information that feeds into the development of the different products produced by service providers.

Respondents identified several areas where enhancing coordination and collaboration could help strengthening the development and delivery of climate information products in Jamaica. These areas, which are discussed in the sub-sections below, include collaboration between service providers and government organizations, between service providers and the academia, and with respect to hydrometeorological and climate services coordination within the country.

5.5.1 Bridging hydrometeorological and climate service providers and intermediary users

As indicated in section 5.1.5, under the PPCR project, a MoU was signed between the Water Resources Authority (WRA) and the Meteorological Service of Jamaica (MSJ) to foster the collaboration between the two institutions on hydrometeorological data collection and sharing. While the MoU has strengthened the coordination and collaboration between the WRA and MSJ, maximizing collaboration between climate service providers and intermediary users is key to continue transforming water, weather, and climate services in Jamaica.

In this regard, enhancing collaboration among service providers with line ministries and sectoral institutions could foster the development of hydrometeorological and climate information products such as Impact-based Forecasting (IbF), as discussed in Section 5.2.3, and other sector-specific information products. For example, one of the respondents highlighted the importance of closer collaboration between service providers and the Ministry of Health and Wellness for the development of hydrometeorological and climate services for the health sector.

Furthermore, collaboration between service providers and government institutions could help better understand hydrometeorological and climate information needs, as well as facilitate data necessary for the development of products that are relevant for specific sectors.

Implementing formal collaboration mechanisms such as MoU can help strengthen the collaboration and coordination between relevant agencies. To ensure these mechanisms are successfully implemented, it is key they include measures to ensure collaboration is strengthened and coordination is carried out. For instance, by establishing channels, such as monthly meetings, to exchange data and discuss the development of products. In addition, it is key to identify sectors that require specific climate information and that should be prioritized.

5.5.2 Hydrometeorological and climate services coordination

Under the PPCR project, progress has been made in advancing the coordination of hydrometeorological and climate services in Jamaica. The establishment of the interagency Hydromet Working Group allows the technical implementing agencies of the PPCR project to discuss issues related to the hydrometeorological and climate services landscape in the country.

While this working group is currently limited to the technical implementing agencies, it could be institutionalized and expanded to include other government organizations, such as the Ministry of Tourism, that would benefit from hydrometeorological and climate information. Thus, this could be an opportunity to establish a platform for continuous coordination, collaboration and dialogue between service providers and users of hydrometeorological and climate services beyond the PPCR project. It could help better understand user needs and promote collaboration for the development of targeted hydrometeorological and climate products. As a result, enhancing efficiency in product development and creating synergies between users and service providers.

5.5.3 Furthering university collaboration

As demonstrated by the PPCR project, the academic sector can contribute to the development of hydrometeorological and climate information products.

Under the PPCR project, the Climate Studies Group – Mona (CSGM) at the University of the West Indies is responsible for the preparation of the State of the Jamaican Climate Reports. Moreover, CSGM has demonstrated the key role academic institutions can play in research and innovation. Under the PPCR project, it has had the responsibility for the development of downscaled high-resolution climate scenarios for 2030, 2050, 2080, and 2100.

Creating synergies and strengthening the collaboration between service providers and academic institutions can further strengthen research and development, and benefit the capacities of the actors involved.

5.6 Promoting international collaboration

Expanding the production, distribution and use of relevant climate information can best be achieved through international cooperation (GCFS, 2021). This is particularly relevant for a small island development state such as Jamaica, that is highly vulnerable to climate risks but has limited human and financial capabilities. Consequently, strong regional and international collaboration and coordination is occurring in the country.

The Caribbean Institute for Meteorology and Hydrology (CIMH) has a crucial role in the region. It coordinates seasonal outlooks through the Caribbean Climate Outlook Forum (CariCOF). These forums are organized twice per year; one before the beginning of the wet/hurricane season and another one before the dry season begins. Between CariCOFs, CIMH coordinates the monthly update of seasonal forecasts (CIMH, 2021). Furthermore, CIMH coordinates and organizes trainings to enhance the capacities of meteorologists and climatologists within the region. The organization of these events enhance the coordination between the different countries in the region. It allows participants to share experiences on the development and delivery of climate information products.

Similarly, the National Ocean and Atmosphere Administration (NOAA) plays an important role in the dissemination of regional forecasts for extreme weather events. In this regard, NOAA's National Hurricane Center (NHC) provides information on hurricanes.

In relation to hurricanes, Jamaica participates in WMO's Regional Association IV Hurricane Committee that meets annually to discuss the region's hurricane operational plan, as well as train meteorologists, exchange information and review case studies. In addition, the Caribbean Community Climate Change Centre (CCCCC) provides forecasts and analyses of potentially damaging impacts from hydrometeorological hazards (Bazo J. & Kruczkiewicz A., 2021).

Although there are strong mechanisms for regional cooperation that should continue to be strengthened, including regional learning exchanges to promote continuous learning, bilateral cooperation occurs on an *ad hoc* basis with no formal mechanisms to facilitate data sharing and the use of that data. This is an area that could be further explored to benefit service providers in Jamaica.

5.7 Institutional Strengthening

The legal and institutional frameworks that establish national meteorological and hydrological services are an important element for its successful operation. It helps to define its mission and mandate; ensure clarity in the definition of its responsibilities; gain recognition of its contribution to society; and facilitate allocation of adequate resources (WMO, 2017).

Respondents emphasized the need to strengthen the institutional framework for hydrometeorological and climate services in Jamaica, and the need to ensure financial sustainability. These two challenges are discussed below.

5.7.1 Institutional framework for hydrometeorological and climate services

To collect, produce, and deliver climate services effectively, hydrological and meteorological service providers need a coherent mandate and adequate institutional framework in place. In this regard, several respondents highlighted the importance to strengthen the institutional framework of hydrological and meteorological service providers in Jamaica.

The Water Resources Act rules the WRA, entitling it to manage water resources and the extraction use of freshwater resources. Nevertheless, an amendment of the Act has been in process for the past ten years to include the floodwater control which is currently in the Flood Control Act under the National Works Agency (The Gleaner, 2021).

The lack of clarity in the mandate of WRA constraints its capacity to provide hydrological services.

On the other hand, MSJ does not have a fully coherent policy framework to provide meteorological and climatological services. This gap limits the understanding of MSJ's mandate and authority.

Strengthening the policy framework of service providers in Jamaica is critical to continue transforming water, weather, and climate information products and services.

5.7.2 Ensuring financial sustainability

The Government of Jamaica (GoJ) is responsible for the budget allocation of the WRA and MSJ. Nevertheless, as respondents noted, it is necessary to strengthen financial allocation as it is currently limited due to competing priorities, as well as the economic constraints posed by the COVID-19 pandemic.

Financial limitations can impact the capacity of hydrological and meteorological service providers to: continue to invest in hydrometeorological stations; provide adequate maintenance of the observational network; increase the human resource capacities; carry out research necessary to develop products that are relevant to users, among others. Thus, financial challenges consequently can affect the ability of MSJ and WRA to respond to the increasing demands of users.

One possible step to enhance the financial capabilities of service providers could be through public-private engagements (PPE). These arrangements, between service providers and the private sector, could complement and enhance the functions of service providers by developing cost-sharing and revenue-generating activities (World Bank, 2020). PPE could be focused in hydrometeorological data collection and climate services production. In this, for example, the private sector could be responsible for the procurement of hydrological stations while service providers could be responsible to provide regular maintenance to the equipment. This would benefit both parties by allowing service providers to expand its network and reduce the costs of procuring the stations. Nonetheless, a clearly defined legal framework is critical for PPE (Rogers D. & Tsirkunov V., 2013).

In addition, evaluating the socioeconomic benefits that result from strengthening the capacity of service providers could help in building government's understanding of the importance of water, weather, and climate services, and thus expecting a commitment to increase budgetary support (Kootval H. & Soares A., 2020)

5.8 Project Management

The preparation and implementation of hydrometeorological and climate services projects are often complex due to their nature and the equipment involved (WMO, 2017). The following section discusses key insights of the PPCR project implementation to date.

5.8.1 Project coordination

As stated in section 1.2, the PPCR project is supervised and implemented by the Planning Institute of Jamaica (PIOJ). In that regard, several respondents concurred that the participation of PIOJ has been beneficial for the project coordination and implementation. Through the establishment of the project implementation unit (PIU), PIOJ conveyed different responsibilities including coordinating project

activities and providing fiduciary support to the technical implementing agencies of the PPCR project, including procurement, financial management, and project reporting.

The support from the PIOJ benefitted the technical implementing agencies such as WRA and MSJ by relieving them from some of the activities these agencies would have been required to do if they had not had the support of PIOJ. For example, WRA and MSJ can focus more on project implementation as they do not have to be constantly involved in the development and implementation of project procurement processes.

Further, WRA and MSJ did not have the adequate experience or human capacity for project management. Therefore, the role and experience of PIOJ has facilitated the project coordination and implementation, and allowed the technical implementing agencies to focus on the implementation of the project activities.

Similar implementation arrangements could be explored and replicated in future hydrometeorological and climate services projects where the human capacities of the technical implementing agencies are limited, and where organizational arrangements could include a separate agency with capacity and experience of coordinating and implementing cooperation projects.

5.8.2 Project Sustainability

Project sustainability is critical to ensure that the activities implemented under the project are maintained after completion. In that aspect, while investments in hydrological and meteorological stations can strengthen observations, sustaining the equipment and increasing the capacity of service providers after project completion is key to ensure the impact of the project.

In this regard, to ensure project sustainability, the PPCR project has been building sustainability from a human capacity perspective to maintain the hydrometeorological equipment financed under the project. It has invested in the training of service providers to install and maintain the network of stations, and it has supported the development of manuals on the trainings provided. In addition, the project has developed several plans including a continuity plan to manage the surface network during extreme weather events and procured spare parts to fix any issues with the equipment.

Although efforts are being made to ensure the sustainability of the project, it is important to consider how to continue to strengthen the capacity of service providers in the long-term.

6. CONCLUSIONS AND EMERGING RECOMMENDATIONS

Jamaica continues to advance in the production and use of weather, water, and climate services. To date, ICDIMP has contributed to enhancing the country's hydrological and meteorological network of observing stations, strengthening the collaboration between service providers, and supported the development of

climate scenarios and vulnerability assessments to increase the country's capacity to adapt to weather events and climate risks.

The analysis finds that efforts to advance weather, water and climate services in Jamaica have several promising areas for advancement. These areas include:

- **Integrating hydrometeorological data resources**

  Data collection and management is key to produce quality hydrometeorological and climate services products. Specially, data collection of key parameters such as sea level, soil moisture, ground water, and others is necessary to develop products relevant to a small island state such as Jamaica that is vulnerable to storm surges and sea level rise impacts.

- **Improving hydrometeorological and climate services design and delivery**

  User-driven hydrometeorological and climate services design and delivery are key to ensuring the uptake and use of hydrometeorological and climate information products and services, and generating socio-economic benefits.

- **Fostering hydrometeorological and climate services impact with user feedback**

  A structured feedback mechanism can help service providers design more relevant hydrometeorological and climate service products. A formal feedback mechanism can help better understand user needs and capacities. Thus, helping service providers produce user-driven hydrometeorological and climate information products.

- **Building appropriate capacity**

  Continuously strengthening human capacity is necessary to advance the development and research of hydrometeorological and climate information products and services. Building appropriate capacity does not only include enhancing the technical capacity of service providers but also users to better understand hydrometeorological and climate information.

- **Strengthening national coordination**

  Continued collaboration and coordination are necessary to enhance the capacity of service providers, for example, to expand data coverage. In addition, it is critical to develop products related to impact-based forecasting and sector-specific hydrometeorological and climate services.

- **Promoting international collaboration**

International and regional collaboration is key for a small island developing state such as Jamaica as it allows the country to address human, technical and financial limitations.

- **Institutional strengthening**

  A coherent and clear institutional framework is pivotal to avoid duplication of efforts and resources used, and to establish clear mandates and facilitate more effective working relationships between governmental organizations and with private sector partners.

- **Project Management**

  Hydrometeorological investments can also contribute to build project sustainability by enhancing human capacity through training and by developing continuity plans to ensure projects are sustained.

The analysis underscores that there is no one area where additional investment will transform weather, water and climate services. Indeed, while data and analysis underpin the information component of such services, attention must also be paid to connecting with users; understanding and evaluating the impact of the hydrometeorological and climate services produced; building user and service providers capacity and fostering collaboration at the local, national, regional, and international levels. This is best articulated through the value chain depicted in Figure 2 shown in Section 2.

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APPENDICES

Appendix 1 - List of organizations of key informant interviews

Name of agency	Number of people interviewed
END-USERS	
Ministry of Health and Wellness	2
National Environment and Planning Agency	1
INTERMEDIARY USERS	
Ministry of Tourism	1
Ministry of Agriculture and Fisheries	1
Port Authority of Jamaica	1
Climate Change Division - Ministry of Housing, Urban Renewal, Environment and Climate Change	4
Planning Institute of Jamaica	4
Rural Agricultural Development Authority	3
Office of Disaster Preparedness and Emergency Management	2
National Spatial Data Management Branch	1
EXPERT INSTITUTIONS	
University of Technology, Jamaica	1
Climate Studies Group - University of the West Indies, Mona	3
Caribbean Agricultural Research and Development Institute	1
SERVICE PROVIDERS	
Water Resources Authority	2
Meteorological Service of Jamaica	3

Appendix 2 - Interview protocol

Q.0 Role of agency: Describe the role of your agency in the value chain

Q1.1 Weaknesses of VC: Which elements of the hydromet and climate service system are weakest, and which present the greatest challenge

Q1.2 Strengths of VC: Which elements of the hydromet and climate service system are strongest, and which present the greatest challenge

Q2. Importance of user-provider collaboration: Would you consider collaboration between providers and users in data collection and management important to the successful functioning of the hydromet climate services system in your country?

Q5. Types of products/services: Which types of hydromet and climate information, products and services are delivered (do you deliver) to your organization, and how is this done?

Q6.1 Areas of improvement for data collection and management: What would you suggest are the most important areas where improvements in data collection and management?

Q6.2 Areas of improvement for delivery and development of products/services: What would you suggest are the most important areas where improvements in development and delivery of hydromet information, products and services are needed? What improvements would you recommend?

Q7. Collaboration with stakeholders: Which stakeholders – internationally (including other national NHMSs) and/or nationally (such as local communities) – does your agency collaborate with during development of information, products and services? How important are these partners?

Q9. Technology influence: Is technological advancement influencing the operation (positively/negatively) of different phases of the value chain (i.e. data collection and management, and development and delivery of information, products and services in any way? If so, how?

Q10. Utility for decision-making: For the information, products and services that you receive, is content useful for decision-making? Are the information reaching the intended users?

Q12. Feedback: Do you provide feedback to hydromet and climate information providers and do you receive feedback from users (if you play a role in development and delivery that is)? If so, how is feedback provided and what are the key areas from which improvements are regularly highlighted? (please see list below for guidance). If not, why not?

Q14. Institutional landscape: How does the wider institutional landscape in your country affect the ability of your organization to deliver or receive a quality service? e.g. institutional leadership, institutional capacities, budgets relationship with key non-government actors, legal frameworks, etc.)

Q15. Coordination of international actors: How would you describe the coordination of international actors (e.g. WMO, donors, UN agencies, etc.) with respect to hydromet and climate information, products and services in your country? (Excellent; Very good; Good; Poor; Very Poor; Don't Know)