STUDY OF CLIMATOLOGICAL STATIONS AND NETWORKS IN HAITI

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1. Introduction

Haiti's agricultural sector contributes 22% to the national GDP (World Bank, 2019). About half of the Haitian population resides in rural areas and depends on small-scale agricultural production as their main source of income. The country has one of the highest levels of food insecurity in the world, with 60% of the population living below the poverty line and over half reported as undernourished (WFP, 2019).

Agriculture is predominantly rainfed and depends on the timing and distribution of rainfall. Weather and climate information enables millions of farmers around the world to make a wide variety of decisions, including what to grow, when to sow, harvest and apply fertilizers. In Haiti, the Ministry of Agriculture (MARNDR) uses data to monitor the development of crops, the Ministry of Public Works to meet the needs of the aviation sector, the Civil Protection Department to predict, monitor and manage meteorological extremes and the Ministry of Health to monitor and manage the spread of malaria and other diseases that are linked to climate variations.

Study justification

The national network of weather stations is fragmented. There is very little information on the location of stations, their equipment, frequency of maintenance, accessibility and ease of access to weather information. This situation limits the access and usefulness of data for all actors working in agricultural development.

Objectives

The objective of this article is to provide an inventory of weather stations and networks in Haiti, to determine the number and location of stations that are in operation and those that give public access to the data, as well as the variables available and the constraints associated with the data. These may include measurement equipment limitations, frequency of maintenance, the accessibility to information, among others. Through this work, we seek to raise the awareness of this information to national and international organizations that may need the available climate in their research and decision-making activities. We also propose recommendations to the agents involved in data collection in order to support the consolidation and sustainable management of a national network of stations in Haiti.

2. Methods

This study is based on archival work and discussions with both current and former public and private entities working in the national weather infrastructure in Haiti. These organizations include Haiti's Hydrometeorological Unit (UHM), the National Center for Geospatial Information (CNIGS), the International Center for Tropical Agriculture, the World Meteorological Organization (WMO/OMM), Meteo-France, and Cuba's Instituto de Meteorología.

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The main points addressed are based on the history of weather data collection, the current situation and the ideal future scenario for moving forward to enhance these services.

3. Results

History of weather data collection

The national weather station network was created by the Ministry of Agriculture in the early 1860s. It was developed gradually and was the subject of numerous negotiations between the ministries of Agriculture, Transport, Interior and Defense. In the 1920s, the responsibility for the network was assigned to the Ministry of Agriculture, Natural Resources and Rural Development (MARNDR). At the time, data were taken manually by a municipal officer on a regular schedule. At first, the weather station network collected the amount of precipitation that fell each day. This information was of particular interest to the most important sectors of the Haitian economy at the time, namely agriculture, livestock and forestry. The equipment required was relatively simple and locally available (Figure 1 (a)). Subsequently, the introduction of the thermometer provided daily temperature measurements including the average, maximum and minimum temperatures for each location.

From 1940-1950, the availability of more advanced equipment made it possible to measure daily humidity, atmospheric pressure, wind force and direction, cloudiness and eventually solar radiation to meet the needs of the agricultural sector and emerging aviation industry (Figure 1(b)).

(a) (b)

Figure 1. (a) An ordinary rain gauge with an outer rim 11.28 cm in diameter and a laboratory cylinder graduated in cubic centimeters and (b) an automatic model is used to measure precipitation.

Initially, weather stations were located in areas of economic importance in the country including Port-au-Prince, Cap-Haitien, Les Cayes, and Jérémie. The network grew from 22 stations in 1920 to 75 stations between 1930 and 1960 (Démétrius, 1985). In the early 1960s, sociopolitical unrest caused a wave of external migration. This reduction in technical capacity at the local level weakened the level of education and led to the abandonment of regular monitoring of weather stations at several locations. Many archives have been lost in the successive waves of sociopolitical and natural disasters observed since 1960. This has resulted in a discontinuity in the collection and transfer of data and a fragmentation of the management of the network of stations listed throughout the territory. By 1970, there were only 27 remaining, according to the Lalonde, Girouard and Letendre (LGL) et Associés (1977) inventory of hydraulic resources.

In the 1980's, with support of the international community, the number of stations increased and new models of "automatic" stations were introduced. Using a series of sensors, these stations report measurements including

temperature, precipitation, humidity, evapotranspiration, wind speed and direction at intervals and do not require people to take data. However, the change to automatic stations led to problems in reading and standardizing data across the whole territory (Project Inventory of Hydraulic Resources, May 1977, LGL). In response to this disparate situation, correction coefficients were determined in the 1980s for the MARNDR's weather station at Damien as well as those located at the airports of Port-au-Prince, Cap-Haïtien, Les Cayes, Jérémie and Jacmel (Démétrius, 1985). The budget allocated to the collection and transmission of data by the national authorities during the years 1960 to 1990 has been considerably reduced since (Hydrometeorological Unit, 2019).

Concerns about global warming and its consequences for island states led international organizations operating in Haiti to fund the maintenance of weather stations and continue to introduce new station models. However, international organizations often work on time-limited projects. Once projects are completed, stations and data monitoring are often overlooked or abandoned due to a lack of funding.

The current situation

More than 150 manual stations are documented (Hydrometeorological Unit, 2019). These stations are supported by various actors including the Ministries of Agriculture (MARNDR), Environment (MDE), Planning (MPCE), Interior and Territorial Communities (MICT), Brothers of Christian Instruction (FIC), nongovernmental organizations (NGOs), regional universities, large planters, amateurs and schools (Figure 2).

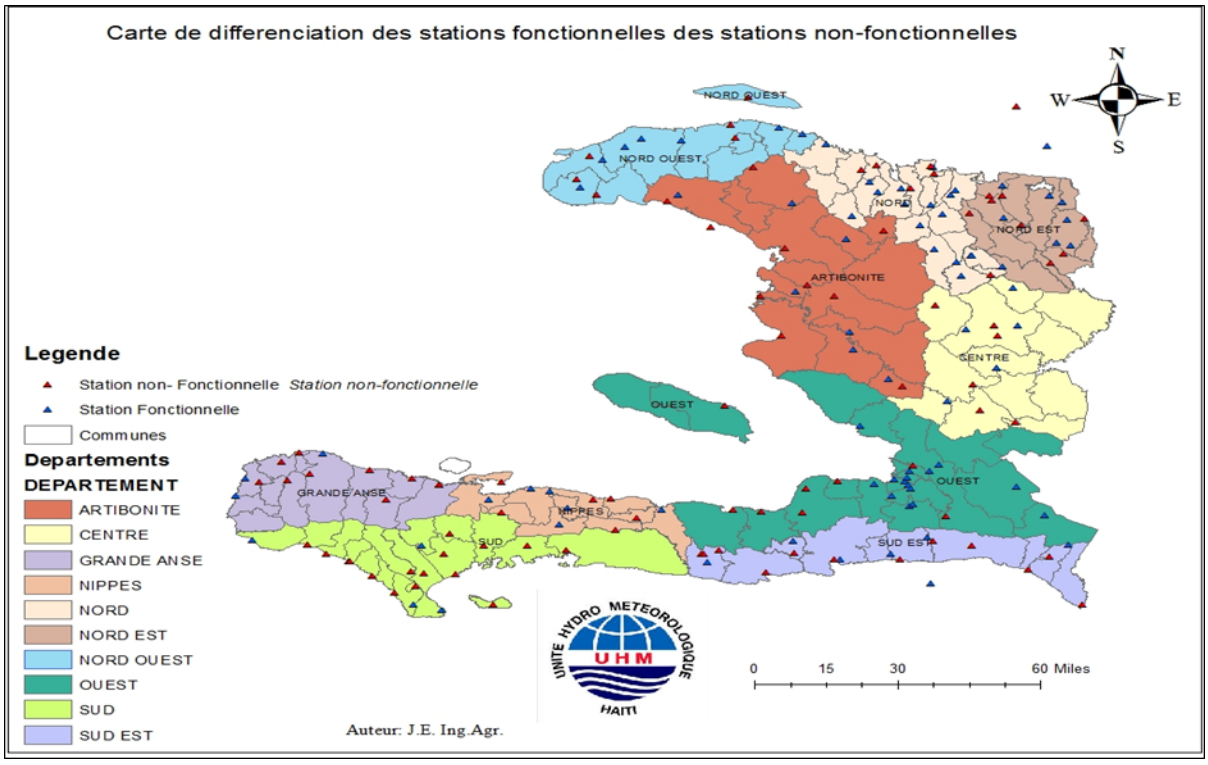

Figure 2. Coverage of manual stations listed on Haitian territory according to UHM, J.E, 2019. Not all of the stations are operable. They are independent of the official network, which includes about 30 automatic stations (Table 1).

Table 1: Distribution of manual and automatic stations (UHM, J.E, 2019)

No.	Department	Number of Stations	Functional	Automatic (functional)	Manual (functional)
1	Artibonite	21	20	6	14
2	Central	15	8	4	4
3	North-East	17	11	4	7
4	North	28	21	5	16
5	Nord-East	65	9	3	6
6	West	33	20	7	13
7	South-East	21	12	2	10
8	Nippes	14	8	2	6
9	South	23	9	4	5
10	Grande Anse	16	6	3	3
	Total	253	124	40	84
% functional			49%		
				32%	68%

According to the various groups that we interviewed, the institutions that have the most recognition in the climate sector are the National Center for Geospatial Information (CNIGS) which has national coverage with 24 automatic stations, and UHM. UHM, reports to the Directorate General of MARNDR who represents the national authority and is responsible for 5 automatic stations. However, only the station at Port-au-Prince airport meets the technological standards for collecting data that is recognized by the World Meteorological Organization (WMO). The archives from the station at Cap-Haitien Airport are relatively complete (1940-1998). This station is recognized by the International Civil Aviation Organization ICAO in aeronautical terms but is not yet on the WMO list as a climatic station. All of the individuals that were interviewed noted that the usefulness of existing meteorological data was limited. Most of the available records are incomplete. Below we present more information on the different networks that we identified. It's important to note that this may not include all stations.

1) MARNDR - UHM

This is the main national climatological network and includes five complete automatic stations (multi-sensors (THIES brand) located in the main airports (Port-au-Prince, Cap Haitian, Jacmel, Les Cayes, Jérémie) (Table 2). This network is managed by UHM, which reports to the Directorate General of the Ministry of Agriculture and the National Office of Civil Aviation (OFNAC). These stations are among the best in the country. The stations established in 1980, were upgraded in 1995 to automatically transfer data every 10 minutes to the UHM server. A SIM card is used to send the data to the server via the general packet radio service (GPRS). UHM pays a relatively low fee ($5 USD per month) for this service to the NATCOM telecommunication company.

Maintenance is scheduled every four months, unless a station breaks down. The batteries for the station are efficient and last for two years. In 2020, the stations are not being maintained due to the Covid-19 pandemic and ongoing civil unrest in Haiti. Some stations have been subject to theft. For example, the battery in the Jérémie station was stolen and the station no longer collects data. Before replacing the battery, the fence needs to be rebuilt to help with security. Even when the Jérémie station was working, the transfer of data from the station was occasionally interrupted because of the low signal strength associated with the NATCOM network in the region.

Over 50% of the demand for the data generated by these stations comes from the aviation sector. Airlines receive hourly real-time data from UHM. UHM also receives data requests from the Ministry of Agriculture, road construction companies, the Ministry of Civil Protection, as well as individuals such as students, teachers, the staff of embassies (primarily Japan and the United States). (Source: B. Leriche, UHM). UHM provides the data free of charge.

Table 2: MARNDR - Hydro Meteorological Unit (UHM)

List of stations and their characteristics (length of archive 1980 - 2019)

NO	STATION Name	Department	Latitude	Longitude	Elevation	Frequency	Variable
1	Port-au-Prince airport	West	18.5775	-72.2938	28m	10min, Per hour, Daily, Monthly	Rain, Temperature, Humidity, Wind (speed and direction), Atmospheric pressure, Solar radiation
2	Cap Haïtien airport	North	19.7334	-72.1956	7m	10min, Per hour, Daily, Monthly	Rain, Temperature, Humidity, Wind (speed and direction), Atmospheric pressure, Solar radiation
3	Jacmel aiport	Southwest	18.2372	-72.5184	46m	10min, Per hour, Daily, Monthly	Rain, Temperature, Humidity, Wind (speed

							and direction), Atmospheric pressure, Solar radiation
4	Les Cayes airport	South	18.2712	-73.7843	63m	10min, Per hour, Daily, Monthly	Rain, Temperature, Humidity, Wind (speed and direction), Atmospheric pressure, Solar radiation
5	Jérémie airport	Grand Anse	18.6627	-74.1701	64m	10min, Per hour, Daily, Monthly	Rain, Temperature, Humidity, Wind (speed and direction), Atmospheric pressure, Solar radiation

Source: Hydro Meteorological Unit (UHM)

2. Centre National de l'Information Géo-Spatiale (CNIGS)

CNIGS has 24 automatic multi-sensor stations (CIMEL brand) but only 18 are operational (Table 3). Because the stations have an expected lifetime of five years, they should soon be replaced. This network is relatively well-known and records include temperature, precipitation, humidity, wind direction, and insolation. These stations were installed in 2013 and there is an archive of data for the network. The Ministry of Planning and External Cooperation (MPCE) is responsible for the network but they struggle to obtain the funds to make it function to serve the community. The support of the international community keeps the network functioning and it is expected that the network will become more important over time.

The stations are designed to save the data automatically on a SIM card using the global system for mobile communications (GSM) standard. CNIGS has a contract with the Digicel to transfer the data to CNIGS. Payment delays have caused disruption in data transfer. Issues related to low signal strength have also caused interruptions in the transfer of data. Maintenance is irregular and takes place only when an issue is reported.

The main user of the data from CNIGS is the Centre National de la Sécurité Alimentaire (CNSA). There are other demands from the UHM and other governmental agencies. Also, private institutions and individuals request the data (source: R. Eugene, CNIGS). The data is available free of charge at UHM.

Table 3: List of CNIGS automatic stations and their characteristics (length of the archive 2013 - 2019)

No.	Name	Department	Latitude	Longitude	Elevation	Frequency	Variable

1	Anse Rouge	Artibonite	19.664005	-73.0219	38m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
2	Arcahaie	Ouest	18.82493	-72.5687	4m	10min, Per hour, Daily, Monthly	Rainfall
3	Belle Anse	Sud-Est	18.28176	-72.1064	805m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
4	Bombardopolis	Nord-Ouest	19.69337	-73.3345	490m	10min, Per hour, Daily, Monthly	Rainfall
5	Corail	Grande-Anse	18.54268	-73.9354	153m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
6	Hinche 1	Centre	18.97453	-73.0073	251m	10min, Per hour, Daily, Monthly	Rainfall
7	Hinche 2	Centre	19.12804	-72.1028	332m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
8	Jean Rabel	Nord-Est	19.88218	-73.1356	89m	10min, Per hour, Daily, Monthly	Rainfall
9	Jérémie	Grande-Anse	18.66399	-74.1708	55m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
10	La Chapelle	Artibonite	18.93731	-72.3544	108m	10min, Per hour, Daily, Monthly	Rainfall

11	Les Anglais	Sud	18.30866	-74.2199	4m	10min, Per hour, Daily, Monthly	Rainfall
12	Les Irois	Grande-Anse	18.40899	-74.4558	11m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
13	Limbe	Nord	19.71135	-72.3914	57m	10min, Per hour, Daily, Monthly	Rainfall
14	Limonade	Nord	19.65165	-72.1426	33m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
15	Marchand	Artibonite	19.23879	-72.4775	28m	10min, Per hour, Daily, Monthly	Rainfall
16	Marigot	Sud-Est	19.13814	-71.9390	487m	10min, Per hour, Daily, Monthly	Rainfall
17	Mole St Nicolas	Nord-Ouest	19.8028	-73.2605	638m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
18	Petit Trou de Nippes	Nippes	18.52377	-73.5061	1m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
19	Petite Rivière de Nippes	Nippes	18.25727	-72.3568	5m	10min, Per hour, Daily, Monthly	Rainfall
20	Pignon	Nord	19.38802	-72.1312	367m	10min, Per hour, Daily, Monthly	Rainfall

21	Port-a-Piment	Sud	18.24204	-74.0875	7m	10min, Per hour, Daily, Monthly	Rainfall
22	Port-salut	Sud	18.07472	-73.8819	153m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
23	Thomazeau	Ouest	18.65674	-72.0983	54m	10min, Per hour, Daily, Monthly	Temperature, rainfall, humidity, wind direction, solar radiation
24	Thomonde	Centre	18.97453	-72.0073	343m	10min, Per hour, Daily, Monthly	Rainfall

Source: CNIGS3.

3. The Freres de l'Instruction Chretienne (FIC)

FIC operates a network of nine manual rain gauges (Figure 1 (a)) located at school sites, including Delmas 33, Pétionville Juvenat1 and Gabriel Dehouvray2, Port-au-Prince, rue du Center, Cap-Haïtien, Jacmel, La Vallée, LesCayes, and Ouanaminthe (Table 4). These data are available free of charge at UHM thanks to a subsidy from the Ministry of Agriculture. The FICs are the most reliable partners of the UHM and send information to the UHM on a regular basis. However, this work has not been subsidized since 2013 and risks ending without a means of support.

Table 4: Brothers of Christian Instruction (FIC). List of stations and their characteristics (length of archive 1940 - 2018)

No.	Name	Department	Latitude	Longitude	Elevation	Frequency	Variable
1	Delmas 33 (FIC)	Ouest	18.55425	-72.303283	120m	Daily, Monthly	Rainfall
2	Pétionville (FIC Juvenat1)	Ouest	18.524066	-72.29985	401m	Daily, Monthly	Rainfall
3	Pétionville (FIC Gabriel Deshayes)	Ouest	18.525732	-72.294567	403m	Daily, Monthly	Rainfall
4	Port-au-Prince,	Ouest	18.546798	-72.343841	15m	Daily, Monthly	Rainfall

	(FIC Rue du Centre)						
5	Cap-Haïtien (FIC Ville)	Nord	19.76	-72.2	6m	Daily, Monthly	Rainfall
6	Ouanaminthe(FIC)	Nord-Est	19.548909	-71.714776	32m	Daily, Monthly	Rainfall
7	Jacmel (FIC ville)	Sud-Est	18.238016	-72.53905	21m	Daily, Monthly	Rainfall
8	La vallée (FIC)	Sud-Est	18.263767	-72.66726	780m	Daily, Monthly	Rainfall
9	Les Cayes (FIC)	Sud	18.192933	-73.746817	21m	Daily, Monthly	Rainfall

Source: FIC

In 2018-2019, the AREA project collaborated with the organization Statistics for Sustainable Development (Stats4SD), UHM and FIC on a quality control project of the following eight stations: Cap-Haïtien, Delmas 33, Jérémie Château, Ouanaminthe, Pétionville Juvenat, Thiotte, and Les Cayes (Figure 3). The most important archives come from the Cap-Haïtien and Les Cayes stations. The Thiotte station (not shown below) has an archive dating from 1998 - 2018.

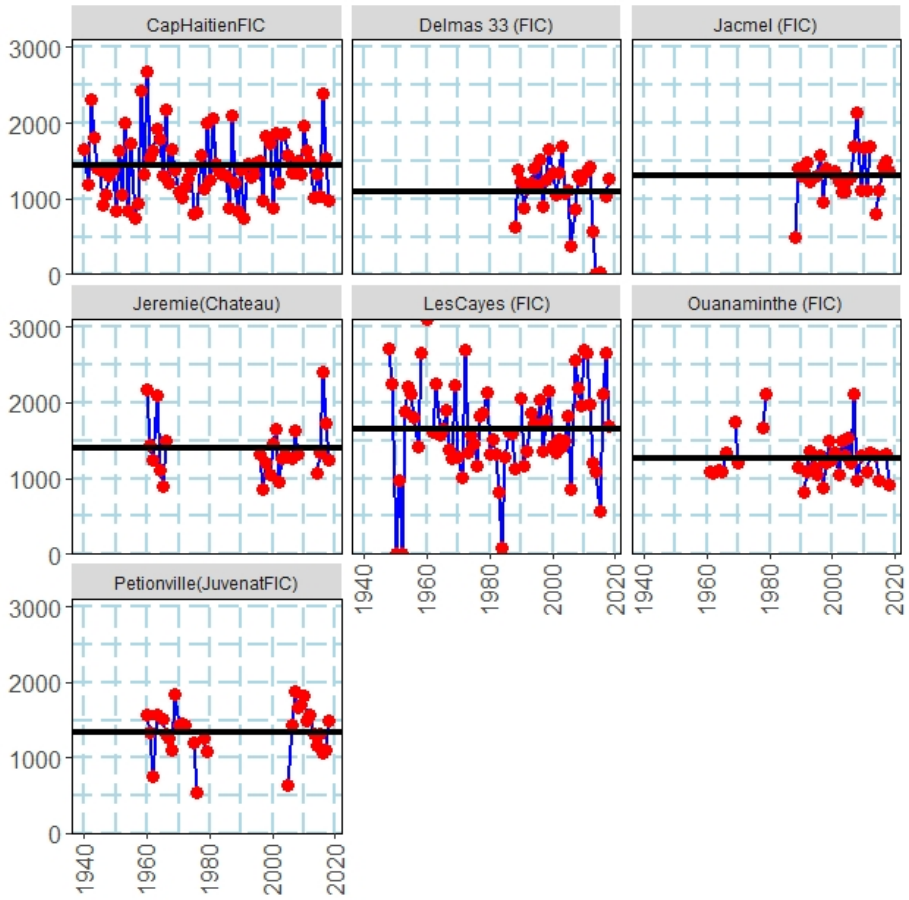

Figure 3. Annual amount of rain (mm) at seven stations from the network of the Brothers of Christian Instruction. The black line represents the mean.

4. Other networks

The following institutions have networks with fewer stations and less archival data. The following information has been obtained about these networks.

The Ministry of the Environment (MDE) is responsible for six multi-sensor stations and is receiving support from Canada and the United Nations. The NGO Protos, located in the North and Central part of the country, has more than 20 stations in Port de Paix, Jean Rabel, Bassin Bleu and Belladere. The NGO Agro Action Allemande / WHH in the North-West has more than 20 stations in Jean Rabel, Mole St Nicolas, Baie de Henne and Bombardopolis. The NGO What If Foundation in the North has three stations in Perches, St. Raphael and l'Acul.

MESONET, a group of meteorology enthusiasts, has six stations, in Delmas, Haut Turgeau, Léogane, Carrefour Feuilles, Boutilliers Grenier and Anse a Veau. The Appui a la Recherche et au Developpement Agricole (AREA) project is piloting a new prototype of stations at the American Caribbean University (AUC) in Les Cayes, the Centre de Recherche et de Developpement Durable (CRDD) at the Wynne farm in Kenscoff, the CRDD in Bas-Boën, the CRDD in Montrouis, the National Association of Agricultural Producers for the Advancement of Agriculture in Haiti (ANAPAAH) at Crois des Bouquets and at the Faculty of Agronomy and Veterinary Medicine (FAMV) in Damien. AREA stations are still in development.

5) Data transmission procedure

Data from manual stations are generally collected using a monthly report sheet, or by telephone (SMS or voice transmission) (Table 5). For automatic stations, transmission is typically by computer; stations are often equipped with a USB key. This often requires the intervention of a technician. More modern stations transmit information automatically over the internet via Wi-Fi, but problems with Wi-Fi networks make this process unreliable, especially in rural areas.

Table 5. Data transmission procedure associated with the main networks.

Mini Networks	Transmission procedure
MARNDR-UHM Airport Stations (Automatic) MARNDR-UHM Field Stations (Manual)	Wi-Fi / SIM phone Manual Sheet / Telephone
FIC (Manual)	Manual Sheet / Email
CNIGS (Automatic)	SIM phone / Direct connection / Email
NGOs (Manual or Automatic)	Manual Sheet / Email SIM phone / Direct connection / Email

6) The maintenance of automatic and manual station networks

The manual rain gauges were regularly monitored and were maintained until the early 1960s. Technicians were responsible for cleaning the sensors and instruments. In most cases the deterioration of the institutions, the lack of motivation and allocated resources caused the stations to be abandoned.

Currently, a new wave of international support on the part of NGOs is directed towards the management of the stations. However, technical and financial autonomy is still lacking due to the lack of governmental support, which limits the sustainability of these initiatives.

7) New directions

As part of the HYDROMET project funded by the World Bank, UHM is working on upgrading 30 automatic stations and identifying manual stations that should be part of the new national system in order to cover as many urban areas, watersheds and agroecological zones as possible.

In 2019, UHM carried out the operational validation of the manual stations with the support of the NGO Famine Early Warning System Network / FEWSNET.

Through the HYDROMET project, the Ministry of Agriculture has been developing the prototype of a platform to make data available to all partners in a standard format. The management and monitoring of data from these stations will be the responsibility of UHM. This centralization would solve the problems of interconnection between the different networks.

8) Recommendations

It is important to reinforce the manual and automatic data collection system in order to capture the diverse microclimates of Haiti. Given that various government sectors use climate information, the national authorities can justify an investment that would ensure the sustainability of the measurement system.

Internal struggles for control of funds allocated by the international community have undermined and weakened the sector for a long time. It would be desirable that a regulatory body or working group facilitate the standardization of practices so that more reliable, consistent and uniform data can be made available to key sectors. An effort to harmonize and standardize equipment, software and data sharing would benefit the further development of a common national network.

It is important to reduce the dependence on use of weather stations that depend on consultants to service them and fix programming issues. Standardizing the data collection equipment where feasible could facilitate the development of local capacity to service and upgrade the stations. Haitian technicians should be trained in the construction, installation and maintenance of modern, cost effective models.

Capacity-building is also necessary to promote the long-term compilation, quality control, analysis and interpretation of data using standardized procedures, to ensure the dissemination of useful and quality information to the various stakeholders.

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