Implementation of a Wind-Powered Water Pumping System in Panama (#XXX)

Implementation of a Windmill-Powered Water Pumping System for Community Irrigation in Coclé Province, Panama.

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About GWP

The Global Water Partnership's vision is for a water secure world. Our mission is to advance sustainable development and water resource management at all levels.

GWP was created in 1996 to foster the implementation of integrated water resources management and help countries with sustainable management of water resources in order to achieve a water secure world, i.e. with a reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks.

GWP is a neutral, pluralistic and broad-based network that facilitates processes aimed at building consensus and integrating efforts. It includes government institutions, universities, professional associations, research institutions, non-governmental organizations and the private sector.

The Network has 13 Regional Water Partnerships, 85 Country Water Partnerships, and more than 3,000 Partners located in 182 countries.

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Content

1. Context

In all countries, socioeconomic development is unavoidably linked to its water resources, which in addition are a vital element for natural environments and their conservation. The world gradually faces a growing demand for water while the availability of this resource decreases, which means that decisions regarding its management must be taken under a holistic approach. Based on this scenario, Integrated Water Resource Management (IWRM) is considered the best approach given that it promotes coordinated development and management of water, land and related resources, in order to maximize economic development and social welfare in an equitable manner without compromising the sustainability of ecosystems.

Given the accelerated population growth in developing countries, migration towards cities, jungle and forest degradation due to encroaching agricultural frontiers, and climate change, IWRM has acquired a crucially important dimension in the international, national and local scenario. It is considered the most comprehensive and adequate management model because of its adaptative nature in terms of physical and social determinants and its coordinated and equitable management across sectors for sustainable development.

According to the Intergovernmental Panel on Climate Change (IPCC), Central America is one of the most vulnerable regions. Effects are reflected in more intense, recurrent and prolonged hydrometeorological phenomena located at opposite ends of the same spectrum: floods and drought, and the Central American Dry Corridor (CSC) is one of those most affected. In addition, it is necessary to consider existing gaps in ecosystem protection, poor resilience of infrastructure and low territorial development. Panama is not part of the CSC, but one of its regions shares similar climatic characteristics - the dry arch of Panama.

Those living in the dry arch are experiencing increasing scarcity of water for consumption and productive activities due to the area's low precipitation levels. Studies confirmed the existence of potentially exploitable aquifers that could contribute to solving this issue through reasonable use. To address this situation, GWP Central America in recent years became involved in implementing a water pumping system using renewable energy sources - a wind rope pump to extract well water in Coclé province as part of its Water, Climate and Development Programme (PACyD) and pilot projects. This was achieved through articulation of member and partner institutions. This process, which has generated important achievements in terms of technical aspects and networking and contributed to better understanding of integrated water resource management in these types of interventions, has been documented.

2. Background

Between May and July 2014, Central America suffered the effects of an ENSO phenomenon that caused drought and an irregular rainfall regime that prolonged the *canícula* (dry period in the middle of the rainy season). In Panama, drought persisted during much of 2015. The effects for the 2014-2015 agricultural cycle were devastating and production deficits continued until the first quarter of 2016. It is estimated that 17,000 fewer hectares were cultivated during the 2014-2015 cycle than in the previous cycle, which forced the government to import more than 45,400 metric tons of rice just to cover national demand (Telesur, 2015). It is estimated that the country lost US$ 2,957,225 and US$ 949,050 in maize and bean production, respectively, in 2014 (GWP, 2016).

3. Problem Statement

3.1. Drought in Central America and the Dry Arch

In Central America, drought is cyclical and usually closely related to the El Niño - Southern Oscillation (ENSO) phenomenon. The Central American Commission for Environment and Development (CCAD) reports that some ten ENSO events - lasting between 12 and 36 months - have been recorded over the past 60 years (GWP, 2015). According to the Köppen Climate Classification, Panama's dry arch region is classified as tropical savannah climate. The average annual precipitation rate for the region is 1,054 mm, notably lower than the country's annual national average of 2,928 mm. As in the rest of the Central American region, anomalies in rainfall occur mainly during the rainy season, during the *canícula*, and drought periods of 30 days or more have been observed.

The longest drought periods coincide with the occurrence of the ENSO Phenomenon. The dry arch comprises the lower basin of the Tonosí River and the middle and lower basins of the Guararé River (Los Santos province); the La Villa, Parita and Santa María Rivers (Herrera province); and the Rio Grande and Río Antón Rivers (Coclé province). The population density in the arch region is 45 people/km^2, higher than the national density of 37.6 people/km^2 (Autoridad Nacional del Ambiente, 2010).

This drought in Panama has been the longest in Central America so far this decade. The first signs of drought were detected in 2014 and increased in 2015 with the occurrence of the ENSO phenomenon. Even though this phenomenon was not detected in 2016, authorities maintained drought measures during the first half of 2016. The Panama Canal Authority (ACP) recorded historical lows in the Gatún reservoir, which feeds the locks and supplies both hydroelectric power and drinking water. This is therefore considered the worst drought in 103 years of recorded history, causing an economic impact of around 40 million Balboas in Canal operations alone (Autoridad del Canal de Panamá, 2018).

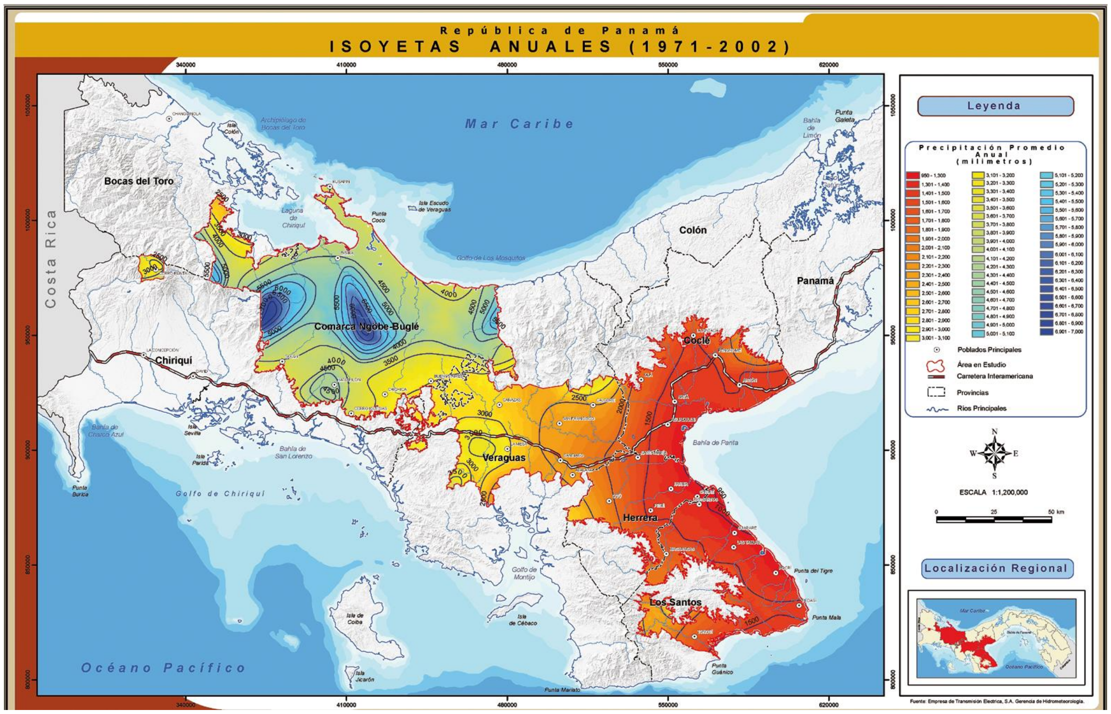

Figure 1: Annual isohyetal lines (source: MiAmbiente **-** Atlas of dry and degraded lands in Panama)

The gravity of the situation led the Central Government to declare a State of Emergency in August 2015, creating the High-Level Water Security Commission, banning the watering of lawns and sports fields, as well as suspending the granting of water concessions for scenic purposes and permits for agricultural purposes (Presidencia, 2015). In Coclé, the National Aqueducts and Sewerage Systems Institute (IDAAN) reported a decrease in production at its plant in Penonomé, going from 3,000 gpm to only 800 gpm, which reduced water levels to 30 cm below the water treatment plant's operating level and required damming and dredging a Zaratí River tributary. Furthermore, 70 per cent of wells in Coclé reported significant decreases in water level (La Estrella de Panamá, 2015).

3.2. Lack of infrastructure and Poor Exploitation Practices

Approximately 266 wells were built in Coclé province to extract groundwater. Of these, IDAAN and the Ministry of Health (MINSA) built approximately 60 to supply water to certain communities; 130 were built for various uses, mainly for private agricultural and/or industrial purposes; and the Ministry of Agricultural Development (MIDA) built six community wells with the private sector. (Autoridad Nacional del Ambiente, 2013).

Despite the importance of aquifers, given surface characteristics in the dry arch, a lag exists at the national level in applying the IWRM approach to groundwater in comparison to surface water. Its exploitation has been disorganized and often empirical with no prior studies or hydrogeological exploration, which compromises the sustainability of the resource and exposes it to risks such as pollution, saline intrusion or water stress due to overexploitation (GWP, 2015).

In Panama, as in other countries of Central America, small and dispersed rural communities usually lack aquifer exploitation systems, mainly due to high operating costs from the use of electricity and because these communities fall below the investment lines of central governments.

4. Decisions and action taken

As part of its WACDEP, GWP Central America set out to contribute to integrated and sustainable economic development and promote water security, climate change adaptation and risk reduction by including pilot projects in its actions. In Panama, GWP partnered with the Centre for Hydraulic and Hydrotechnical Research (CIHH) and the Coclé Regional Centre's Mechanical Engineering programme - both of which belong to Universidad Tecnológica de Panamá (UTP) - to implement a wind-powered pump (windmill) to extract groundwater for a community irrigation system. This measure was taken to respond to decreased flows in surface water sources caused by drought and to contribute to maintaining the agricultural activities of a community in the area. This project was also supported by the Ministry of Environment (MiAmbiente) and IDAAN. The wind rope pump was chosen because it is a low-cost solution that is easy to design and build as well as simple and cheap to maintain. This technology has been successfully implemented in other areas in Panama.

The first step was identifying a suitable site that met certain general requirements, such as: presence of organizations and/or families with financial difficulties; that have trouble accessing water for irrigation; that own the land, which is also easily accessible; and favourable meteorological (wind) and hydrogeological (aquifer) variables. El Jagüito in Llano Grande, Coclé province was selected, a community composed of 17 farming families who have organized to form the Association of El Jagüito Small Producer Families (ASPPFUJA). The community grows various crops such as maize, banana, beans, tubers, certain produce and exotic vegetables, the latter of which are intended for consumption by the Chinese community in the province. A significant portion of production is sold to hotels and restaurants along the coast and the rest is destined for local consumption.

Before installing the wind pump, an anemometer and a wind vane were installed to measure the horizontal component of the wind, followed by two transects for electrical prospecting purposes using geophysical techniques to determine the electrical resistivity of the soil. This allowed identifying the groundwater level and aquifer depth, which in turn helped to determine the best site to drill the well.

The well was designed, drilled and a pumping test performed. The well is 10 inches in diameter and 55 meters deep (175 feet), has a 12-foot sanitary seal, a 6-inch well casing plastic pipe and 115 feet with no casing. A 48-hour pumping test yielded a flow rate of 3 GPM. Physical, chemical and bacteriological tests were performed on water samples, as can be seen in Table 1, showing that the water was apt for irrigation but required prior disinfection (chlorination or boiling) if used for human consumption.

Image 1: Installing the anemometer

Image 2: Drilling the well **Image 3:** Multi-parameter water quality tests

Parameter	Method	Sample SI-035-M1	Uncertainty	DGNT – COPANIT 23-395-99
Temperature (°C)	2550 B	30	± 0,1	N/E
Conductivity (µmho/cm)	2510B	320	± 5	N/E
pH	$4500H^{+}$	6,6	± 0,1	6,5-8,5
Turbidity ($NTU_{FORMAZIN}$)	2130 B	0,56	±0,21	1,0
Phosphates ($mgPO_4{}^{3}$-P/L)	4500-P D	<0,03	N/A	N/E
Nitrates ($mgNO_3$-N/L)	4500 - NO_3B	0,45	N/A	10,00
Nitrites ($mgNO_2$-N/L)	4500 - NO_2B	<0,2	N/A	1,0
Total coliforms (NMP/100mL)	9223 B	8	N/A	10
Suspended solids (mg/L)	2540 D	< 1	N/A	N/E
Total dissolved solids (mg/L)	2540 C	170	N/A	500,00

Total solids (mg/L)	2540 B	192	N/A	N/E
E. Coli (NMP/100mL)	9223 B	2	N/A	N/E
Chlorides (mg CI/L)	4500-CI B	8,0	± 0,10	250,00
Sulphates (mg $SO_3{}^{2-}$/L)	4500-$SO_4{}^2$E	4,46	N/A	250,00
Calcium (mg Ca/L)	3111 B	58,14	N/A	N/E
Magnesium (mg Mg/L)	3111 B	4,34	N/A	N/E
Sodium (mg Na/L)	3111 B	23,89	N/A	200,00
Potassium (mg K/L)	3111 B	2,29	N/A	N/E
Iron (mg Fe/L)	3111 B	<0,10	N/A	0,30
Manganese (mg MN/L)	3111 B	<0,10	N/A	0,1
Bicarbonate (mgcaCO3/L)	2320 B	161	N/A	N/E

Table 1: Water quality analysis results. Source: GWP, 2016

The windpump's parts were designed and built by fourth-year Industrial Mechanics students from UTP's Coclé Regional Centre under faculty supervision. Students' full commitment to this project should be noted, who worked outside school hours to deliver the parts and ensured that the windpump's design adapted to local conditions.

A team of 18 people made up of both beneficiaries and UTP staff worked on installing the windpump, which included unloading the tower and its elements as well as raising and anchoring said elements. The system includes a 4,000-litre storage tank, a probe for measuring purposes as well as the pipes that will carry the water to plots and is connected to an existing irrigation system composed of three five-metre sprinklers that irrigate a four-hectare area of cultivated land. The remaining area is watered by hand.

Image 4: Raising the tower **Image 5:** Irrigation conduction line

GWP Central America together with UTP held a training session attended by UTP personnel and representatives of the beneficiary community. The training consisted in a holistic approach that dealt with environmental and climate change adaptation issues as well as IWRM and its implementation in the project, in order to ensure the sustainability of water resources through good practices and awareness regarding proper water management. The training also addressed technical and maintenance aspects. During this training, participants received printed materials on IWRM concepts and a book on windpump construction and operation prepared by UTP's

Coclé Regional Centre. It is necessary to mention the valuable academic support and guidance provided by UTP throughout the entire process, as it allowed developing a windpump design that adapted to local conditions and having on-site technical assistance from a UTP team that included mechanical engineering students and faculty.


Images 6-7-8: Training session on IWRM and windpump operation

5. Results

Infrastructure built: The entire infrastructure was successfully installed (well, tower, storage tank, pipes). The community now has an efficient, economical extraction system that runs on clean energy. Before the project, the community had a two-inch surface water tap connected to an intake work that carried water to a small pit that was used as a reservoir for basic needs and irrigation. The pit was severely affected by the drought that hit the region.

IWRM and Capacity-Building: IWRM was the cross-cutting axis of the beneficiary training workshop, promoting concepts such as water security, good environmental and agricultural practices, climate change adaptation and experience sharing on water resource conservation. This was favourably received by beneficiaries.

Community members' involvement throughout the technical process was well received and helped them to learn how to properly operate the windpump, which is evident in how they correctly operate and provide maintenance to the windpump

Productivity increased: Producers reported drastic falls in production during periods of drought, e.g. going from 15 boxes of vegetables to just three or four. This led to having to put a hold on supply contracts with local businesses (mostly hotels) and intermediaries. After the installation of the windpump, they have managed to recover their productivity rates.

Having a clean extraction method that runs on renewable energy leads to substantial savings in relation to methods that require investing in fuel. The fact that the system has a tank has improved water management and enabled doubling the area under cultivation, going from 2.5 to

5 hectares. Under favourable conditions, it is estimated that the system produces 30,000 litres of water per month, which supplements the amount of water produced by the existing surface intake system.

Stakeholder articulation: While UTP was the main partner in this project, it is worth noting that GWP Central America in addition managed to coordinate efforts and leverage resources with the central government, through various institutions such as MiAmbiente and IDAAN, and beneficiaries through ASPPFUJA. The latter highlighted that the project strengthened the community's teamwork capabilities, as they used to work in an isolated manner. This was particularly important given that the timeframe had to be extended because of the studies conducted, which were covered thanks to contributions from these institutions, as can be seen in Table 2.

Project Costs		
Category	**Description**	**Total (USD)**
GWP CAM financing	Construction, installation and training	16.998,66
In-kind contributions	Human resources	31.947,58
	Transport	1.389,60
Others	Water sample analysis – LABAICA	737,00
	Pumping tests – IDAAN	2.500,00
	Physical Retrospection Test	5.620,00
	Monitoring of meteorological variables	150,00
	Total	**59.342,84**

Table 2: Windpump installation costs. Source: GWP, 2016

Dissemination and replicability: Project results were widely covered by national media, including Televisora Nacional (TVN), UTP Noticias (radio and television), UTP social networks and forums organized by GWP Panama.

Dissemination has been significant, as many non-governmental organizations have expressed interest in replicating the project with the university. UTP is currently conducting studies and research on the project related to maintenance and modifying elements to improve efficiency and durability. The project has been a platform for UTP student engagement in various disciplines, from the design and manufacturing of mechanical elements to farming methods.

In late November 2018, engineer David Vega, who is part of the team that implemented the project, was awarded the Researcher of the Year *Cuásar* prize in the Social Innovation Project category for his work in the project. Engineer Efraín Conte, who was in charge of designing, mechanical operations and construction of the tower, wrote a book called "Experiences in Construction and Implementation of Wind Rope Pumps in Panama" based on the experience gained through this project.

6. Lessons Learned

- Pumping technologies that run on renewable energy are an option for supplying irrigation to local communities experiencing drought conditions, at a lower cost and with fewer environmental impacts.
- Solid inter-institutional coordination is required. In-kind contributions helped to defray costs related to the studies needed to ensure proper project implementation and to deal with unforeseen situations encountered along the way.
- UTP's participation as an implementer facilitated access to technical support to design the technological solution as well as spot-on, continuous technical assistance to the community. It also facilitated students' engagement, which was fundamental because their commitment and readiness made it possible to build parts as fast as possible, under faculty supervision, and adapted to the local context.
- It is necessary to prepare a system operation manual that includes troubleshooting.
- As this is a system that relies on favourable wind conditions, it could be supplemented with other types of energy such as photovoltaic energy through solar panels when there is no wind.
- Pipe systems can be improved by evenly distributing micro-sprinklers to irrigate plantations, in order to make the most of the planting space available, and thus avoid using more pipes more than necessary, and use water more efficiently.
- Ensuring a source of water for irrigation in the community contributed to increasing people's income during periods of drought by enabling them to increase production levels from three or four boxes to the 15 they usually obtain during non-drought periods.

7. Conclusion

Under the new context of climate change, the impact of droughts is increasingly drastic and recurrent. In areas such as the Central American dry corridor and the arch of Panama, governments must develop adaptation and resilience strategies that involve dispersed rural populations, which are usually the most affected and the ones that lack the infrastructure that allows them to better adapt to new challenges. These strategies must go hand in hand with IWRM as a cross-cutting axis, as well as address other approaches such as the Water-Energy-Food Nexus in order to ensure the sustainability of any policy or intervention.

Several GWP Toolbox tools are used in planning and implementing this technology:

- Investment frameworks (A3.01)
- Community-based water supply and management organizations (B2.03)
- Civil society organizations (B3.03)
- Building partnerships (B4.03)
- Promoting social change (C8)

The wind rope pump system has proven to be a low-cost, efficient, clean-energy alternative technology, as well as ideal for rural environments because it is simple to operate and maintain. The effective articulation achieved between international organizations (GWP CAM), academia (UTP), government (IDAAN and MiAmbiente) and the community is evidence of existing opportunities for multisectoral solutions at different levels for comprehensive drought management. Furthermore, the windpump is an excellent example of solutions that involve the Water-Energy-Food Nexus and constitutes yet another sustainable approach to take into account. However, to achieve this sustainability, it is necessary for initiatives to build the capacity of all involved through training and awareness-raising spaces that promote water security.

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9. Contact Details

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10. Support References

The report on the windpump pilot project can be accessed at:

https://www.gwp.org/globalassets/global/gwp-cam_files/pp-panama.pdf

The book on implementation experiences prepared by UTP can be downloaded from:

https://drive.google.com/open?id=1SPmmEIG_j19Zs9OsG47XGhWnAXhIEyl0