Water Management in Agricultural Production, the Economy, and Venezuelan Society

Article *in* Frontiers in Sustainable Food Systems · February 2021

DOI: 10.3389/fsufs.2020.624066

1 author:

Maria Alejandra Moreno Pizani
Instituto de Pesquisas em Educação Continuada em Economia e Gestão de Empresas

frontiers in Sustainable Food Systems

REVIEW
published: 11 February 2021
doi: 10.3389/fsufs.2020.624066

Water Management in Agricultural Production, the Economy, and Venezuelan Society

*Maria Alejandra Moreno-Pizani**

Instituto de Pesquisas e Educação Continuada em Economia e Gestão de Empresas (PECEGE), Piracicaba, Brazil

Edited by:
Maria S. Tapia, Academia de Ciencias Físicas, Matemáticas y Naturales de Venezuela, Venezuela

Reviewed by:
Eduardo Buroz, Academia de Ciencias Físicas, Matemáticas y Naturales de Venezuela, Venezuela
Oscar Simón Rodríguez Parisca, Central University of Venezuela, Venezuela

***Correspondence:**
Maria Alejandra Moreno-Pizani
morenom76@gmail.com

Specialty section:
This article was submitted to Agro-Food Safety, a section of the journal Frontiers in Sustainable Food Systems

Received: *30 October 2020*
Accepted: *31 December 2020*
Published: *11 February 2021*

Citation:
Moreno-Pizani MA (2021) Water Management in Agricultural Production, the Economy, and Venezuelan Society. Front. Sustain. Food Syst. 4:624066. doi: 10.3389/fsufs.2020.624066

The availability of water resources has a direct impact on the economy of a country and the development of the main production processes, from agriculture, irrigation, and food production, to energy generation and water supply. The regional economic and social development is influenced by an adequate management of water resources because it stimulates the economy by expanding and ability to provide water for multiple uses, directly impacting on the generation of employment the improving the quality of life of the population. Venezuela has abundant surface water resources in the large basins. The northern part of Venezuela, where the highest percentage of the population and the main economic activities are based, face a severe water scarcity. Irrigation systems under public sector administration are characterized by large budgetary restrictions, with works for rehabilitation, operation, and maintenance generally carried out with inefficient results, due to lack of adequate technical supervision. There is a gap of official information that allows highlight the crisis that the agricultural sector has faced in the last decade. Another, very important aspect is Venezuela's severe energy crisis which began to present a deficit of electric power generation that has been alarmingly evident since 2009, which has worsened for more than a decade, causing the lack of electricity supply in large regions of the country for periods of time exceeding 100 h, contributing to aggravate the country's economic crisis. Due to the situation described, Venezuelan food systems have been seriously affected mainly by the advanced deterioration of irrigation infrastructure and the water availability on production processes. This paper explores and analyses the influence of water management on production Venezuelan economics and society, focus in three pillars representing the qualitative and quantitative relationships of water management and its impact on the system considering the aspects related to the sustainability of Venezuelan agri-food systems, analyzing the fundamental aspects for food production, main indicators related to the national economy, addressing the challenges to ensure food security.

Keywords: food security, irrigation, development, sustainability, economy

INTRODUCTION

To ensure the food of the world's population, agricultural production has accelerated, leading to water resource shortages in some regions, with environmental deterioration (FAO, 2020; Ibrahiem and Hanafy, 2020; Yang et al., 2020). In order to meet the increase in demand for food and bioenergy it is necessary to intensify existing farmland, increasing crop yields and, without a doubt, the most viable solution is through investments in irrigation technology (Beringer et al., 2011; Taheripour et al., 2016; Ledvina et al., 2018; Vågsholm et al., 2020).

Venezuela has a continental territory of 916,445 km^2, divided into 23 states, a Capital District, 235 islands and 71 islands and cays located in the Caribbean Sea that together are part of the called Federal Units of which, according to the Ministry of the Environment and Renewable Natural Resources MARNR, the total area of forests at that time was 529.060 km^2, of which 70.7% is located in the Guiana region. The rest of the area is covered by a wide range of plant formations of which the most abundant is the open savannah with 118.852 km^2 (Ministerio del Ambiente y de los Recursos Naturales Renovables (MARNR), 1982). The potentially arable lands are located north of the Orinoco river plus the Delta Amacuro state and total 10,986,195 hectares, of which only 2,031,836 hectares are of high quality (classes I and II), which represents 18.8% of the potentially arable lands Medium quality land (class III) constitutes 33.7% and low-quality land (class IV) 47.5%, both percentages refer to potentially arable land (Ministerio del Ambiente y de los Recursos Naturales Renovables (MARNR), 1995). Under tropical climate the temperature spectrum ranges from 0 to 40°C, with the coldest months being January and February with stable temperatures between 15 and 35°C, and maximum temperatures occur in March and September. The dry period (January to April) is characterized by drought and the wet period (May to November) with annual rainfall ranging from 1000 to 1500 mm in the central region of the country.

Since 2000, droughts have severely affected Venezuela's water, agricultural and hydroelectric sectors. During the period 1960–2005, the basins provided to the large Venezuelan reservoirs were exposed to recurrent droughts with varying degrees of intensity and persistence. This situation suggests that the sectors most vulnerable to these events (especially agriculture and hydroelectric), probably did not develop adequate policies to adapt to the climate variability of the environment where they carry out their activities. In any case, this hypothesis should be evaluated to the extent that new rainfall information is available in the watersheds (Paredes Trejo et al., 2016; Paredes-Trejo et al., 2020; Quiroz-Ruiz et al., 2016).

The behavior of a country's hydraulic infrastructure depends fundamentally on the quantity and quality of hydro-climate data available for the planning, project, and operation of each work, especially reservoir data. If hydrological data does not exist, or it is incomplete or deficient, the processes of maintenance and development of new reservoir works are postponed until the minimum essential database is available which results in a delay in the development of the country (Suárez Villar and Suárez Barrera, 2016).

In the case of Venezuela, on one hand, the progressive deterioration and dismantling of the national hydrological network, and on the other, to the climate changes that are taking place on a global scale, which manifest themselves in rivers by variations of the two hydrological extremes in opposite ways: higher flows of the rising during rainy periods and lower flows during the drought, maintaining the average annual flows without significant changes (Suárez Villar and Suárez Barrera, 2016).

In Venezuela, there are plenty not used irrigated and that could be used to meet the current and future agricultural production needs (Nuñez et al., 2009). Access to production data has been limited by government agencies, where the Confederation of Agricultural Producers Associations of Venezuela (FEDEAGRO) has records supplied by the Ministry of Agriculture and Land (MAT) in the period 1997–2017. By 2015 at least 12 items: maize, rice, sorghum, cane, sunflower, orange, coffee, potato, onion, paprika tomato, and sesame showed significant declines reaching in many cases historical minimums in the period evaluated (2015–2018) (Tapia et al., 2017). While FAO's Aquastat platform presents production data for only 2008 (FAO, 2015b), a situation that complicates any process of analysis and strategic planning at normal times and especially in crisis situations such as the current coronavirus pandemic (COVID-19).

One of the most human consumed foods is cereals, being the source of foods that account for more than half of the calories that humanity uses (Team, 2020; Yang et al., 2020). It is cereal production that poses the greatest challenge of sustainability of production in a responsible way that guarantees the protection of water resources (Upadhyay et al., 2020; Yang et al., 2020). In Venezuela, the most historically produced item has been cereals for both human consumption and balanced animal food processing, with this item having been drastically plummeting its production in recent years.

This paper explores and analyses the influence of water management on production (energy and agriculture), Venezuelan economics and society. The discussion of this paper will follow three pillars representing the qualitative and quantitative relationships of water management and its impact on the system.

The following diagram focuses on water management in production, economics, and social aspects, considering its interrelationship between the quantity and quality of this vital resource (**Figure 1**).

WATER MANAGEMENT IN ENERGY PRODUCTION AND AGRICULTURE

Hydropower–the Third-Largest Hydroelectric Plant in the World–Nationwide Blackout

Water management is based on the activities of planning, development, distribution, and management of the optimal and appropriate use of water resources (Su et al., 2020). The extent of irrigation land expansion is quantified based on water availability

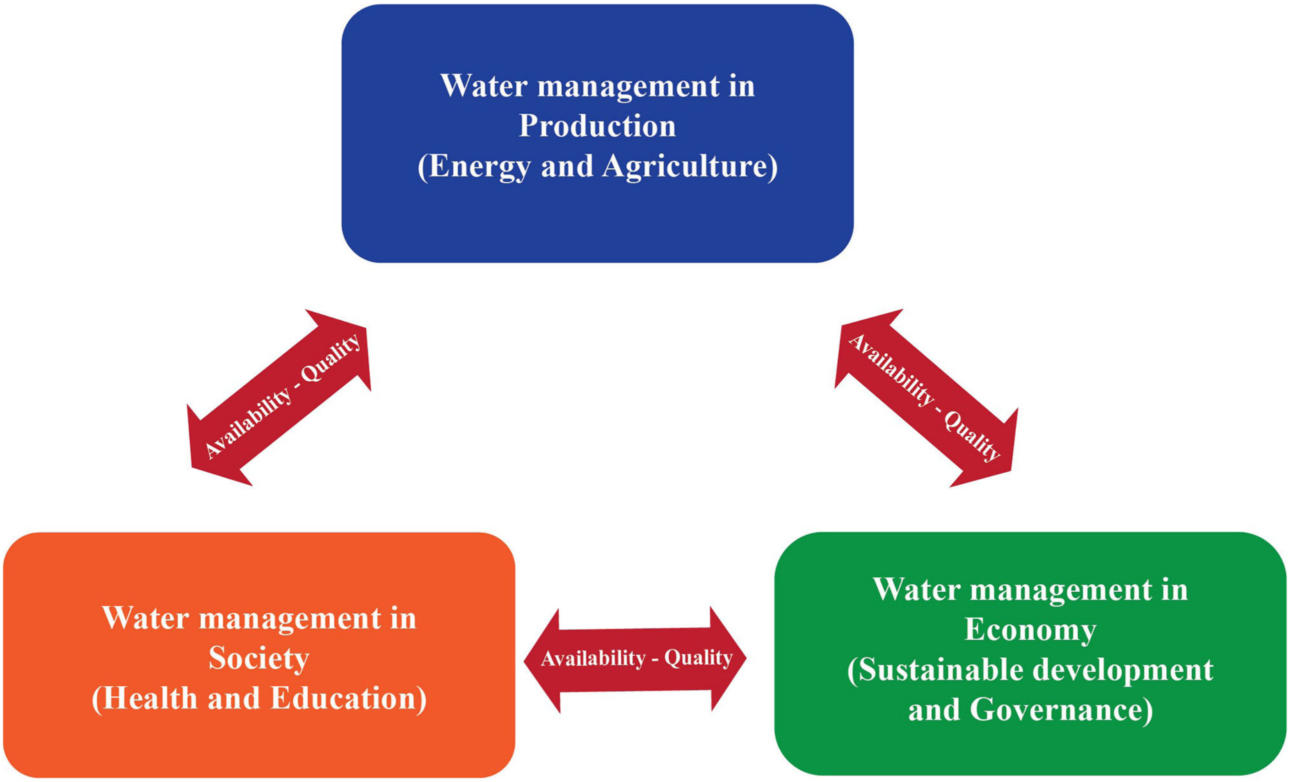

FIGURE 1 | The link of the three water management pillars.

and annual costs of irrigation infrastructure, considering that improvements in irrigation infrastructure include increased water storage, improved transport efficiency and improved irrigation efficiency. To know the conditions of irrigation infrastructure allows an exploration of water availability in land use, energy production, and economic activity (Ledvina et al., 2018). In Venezuela there is only one multi-purpose hydroelectric generation and irrigation system.

It should be noted that despite Venezuela's largely located and developed hydroelectric potential in Lower Caroní, it is a source subject to natural threats such as droughts and that this has consequences, Venezuela also exhibits great potential from hidropower, however today its development is minimal (Posso and Zambrano, 2014), with the exception includes the set of dams in the Lower Caroni: Macagua I, Macagua II, Caruachi, Tocoma (under construction), and El Guri a large-scale hydroelectric plant, whose operational problems and lack of maintenance has recently affected the country's energy balance.

The national electricity system (SEN) had a total installed generation capacity of ∼34,383 MW, for the year 2019, broken down as follows: Thermoelectric infrastructure: 17,985 MW (52.4%); Hydroelectric infrastructure: 16,228 MW (47.3%); 125 MW Eolic infrastructures (0.4%). The current operating capacity of the SEN is estimated at 14,933 MW (44%), broken down as follows: Thermoelectric 3,229 MW (9.4%); Hydroelectric 11,704 MW (34.2%). The discrimination of the available generation power capacity shows out of service: 82% of the thermoelectric, 28% of the hydroelectric plant, 100% of the Eolic infrastructure. The great difference between installed generation capacity and available capacity because of obsolescence, inadequate and inefficient technology, lack of maintenance, unfinished projects, and inadequate management has been worsening in recent years. The thermoelectric plants are practically inoperative, since the most important that Venezuela had was Tacoa and it is completely paralyzed, followed by the Planta Centro, which has been in ruins for years, without a gas supply that allows the precarious existing thermoelectric park to operate. The abandonment of thermoelectric infrastructure promoted the installation of thermoelectric plants of different technologies, including distributed generation units powered by internal combustion engines without adequate infrastructure or fuel supply or alternative supply mechanisms (AVIEM, 2019).

The current crisis in hydroelectric generation is caused by disinvestment caused by non-compliance with maintenance programs and projects aimed at modernizing and updating the generating units and the infrastructure associated with the lower Caroní plants, as well as in the plants located in the South-Western region of the country. The situation of unavailability of 38% of the installed capacity at the Simón Bolívar Power Plant in El Guri is of special attention, which has units 2, 9, and 10 of Power House 1 and units 14, 16, 18 out of service and 20 from Power House 2, for a total of 3,769 MW. The Antonio José de Sucre plant (Macagua) shows an unavailability of 25% of the installed capacity, standing out units out of service since

2012 for maintenance reasons. In the southwestern region of the country, 759 MW (65%) of the installed capacity in the region is unavailable. The total work stoppage of the José Antonio Páez Power Plant (240 MW) and the 52% out of service (269 MW) of the Fabricio Ojeda Power Plant (La Vueltosa) stand out. That 65% of capacity out of service places the electricity supply in the Southwestern region of the country in a very critical condition, because there is not enough thermoelectric generation capacity and capacity limitations to import energy from the national interconnected system (AVIEM, 2019).

The Guri Dam is located in South America and ranks third within the world's largest hydroelectric plants. It is responsible for supplying about 73% of Venezuela's electricity. In the last 40 years, there have been two major drought events recorded in Venezuela: the first from 2001 to 2004 and the second from 2009 to 2010, which caused a drastic decrease of 28% of its reservoir storage capacity in 2003. During the 2010 event, energy rationing policies were implemented to close the electricity gap, where reservoir storage experienced rapid recovery since the last drought in late 2010 (Adamo et al., 2020).

The construction and distribution of dams in Venezuela were carried out to ensure the demand for multiple uses such as: human and industrial supply, irrigation, fish farming, power generation, recreation, and sport. Stored water directly impacts economic and social development through the generation of opportunities and alternatives, providing facilities for new projects.

In Venezuela, the first dam built was Caujarao Dam, located in Falcón state (construction period: 1863–1866), located in the Coro River, which flows over the sedimentary plain of what was the ancient reservoir. By the time, the commission of engineers of the Ministry of Development that received the work, the report highlights that its dimensions are greater than the Croton Dam, the first aqueduct of New York City, built in 1842 (Suárez Villar and Suárez Barrera, 2016).

The construction of hydraulic works, which had so successfully begun in Venezuela in 1863 with the Caujarao Reservoir, is interrupted because of the political turbulence experienced by the country between the last years of the 19th century and the early 20th century. However, as an exception, during this period Ricardo Zuloaga built and put into service in 1897 the El Encantado Hydroelectric Plant, located on the Guaire River downstream of Petare, for the supply of energy to the capital of the country, thus starting hydroelectric generation in Venezuela, which at that time was a global technological innovation (Suárez Villar and Suárez Barrera, 2016).

They are 105 reservoirs in Venezuela that store about 157 km^3 of water. Its hydroelectric potential is one of the most important in Latin America, with 92% of its potential located on the right bank of Orinoco River (Guayana Region). 60% of its electricity is generated from hydroelectric plants (Nuñez et al., 2009; Suárez Villar and Suárez Barrera, 2016). Of these large dams, about half are directly or indirectly associated with an irrigation system, regardless of those that are being carried out to construction. Dams and their reservoirs have contributed significantly to human development in different ways, ranging from storage and deviating for energy generation, agricultural activities such as irrigation, flood control, and other human activities such as transporting fishing, tourism, and recreation (Hogeboom et al., 2018).

Comparing the highest hydro energy production records in history found in **Table 1**, The Guri Dam, the highest in Venezuela with 162 m height, with a capacity of 135,000,000 m^3 (ICOLD, 2020) is located in third place, surpassed only by Itaipu (Brazil–Paraguay) and Three Gorges Dam (China) (ITAIPU, 2020).

The relationship between production vs. flood zone: GWH ratios produced by the reservoir area worldwide are presented in **Table 2**, where the Guri Dam ranks sixth with an estimated 13 GWH per Km^2.

Installed capacity and a comparison between the world's leading hydro energy generating plants are presented in **Table 3**, where the Guri Dam is placed in the third position of this ranking.

On the global stage, water demand is steadily increasing and reaching 2–3% annually in the coming decades. Large climatic fluctuations influence the uneven distribution of finite water resources. With their current storage, dams clearly make a significant contribution to the efficient management of finite water resources. Therefore, know the current state of the reservations and evaluate the need to build many other dams to ensure the proper use of this resource. The lack of electricity, as well as other reliable energy sources, is a key factor in guaranteeing the availability and supply of water for cities throughout the country (Rendon et al., 2020).

Venezuelan dams are embankment, followed by the type of rockfill dams, and gravity, distributed according to **Figure 2**. There are five concrete dams in Venezuela, gravity type: Caujarao (masonry), San Juan, Macagua I, Guri, and Taguacita; two arch dams: Santo Domingo and Ocumarito; five rockfill dams: La Pereza, Turimiquire, Canoabo, Macagua II, and Caruachi; one hydraulic filling dam: Petaquire. All other dams are earth dams (Suárez Villar and Suárez Barrera, 2016).

The evolution of dam construction in Venezuela had a maximum of 31 in the 1970s, from which it began to decline, the most recent being under construction, without being completed three large dams: Yacambú (to provide water one of the most productive regions called the Quibor Valley in Lara state with potential 26,000 ha for vegetable cultivation); Tocoma (intended hydroelectricity) and Cuira (to alleviate drinking water deficiency in the Capital District), which have not been completed.

The northern region of Venezuela, where the highest percentage of the population and major economic activities are based, is the lowest in water resources (FAO, 2015b). The highest concentration of dams built is in the central west of Venezuela, the relative location of the main dams is shown in **Figure 3**.

Impact of Incidents on Venezuelan Dams

An "incident" can be defined as an unwanted or unscheduled event that will deteriorate or decrease the operational efficiency of the company, from understanding the meaning of these concepts, control processes can be initiated for all causes and origins of accident incidents (de Carvalho, 2011). An incident does not necessarily mean the failure of the work, although in some extreme cases this happened (Suárez Villar and Suárez Barrera, 2016).

TABLE 1 | Hydropower production: comparison among the highest operating records in history.

Power plant	Country	Production record (mi de MWh)	Record year	Average of the best 4 years (mi de MWh)
Itaipu	Brasil-Paraguay	98,63	2013	94,27
Three Gorges Dam	China	98,11	2012	84,21
Guri Dam	Venezuela	53,41	2008	51,10
Tucurui	Brasil	41,43	2009	39,52

Source: ICOLD (2020); ITAIPU (2020).

TABLE 2 | Production vs. flooded area–generation capacity relations produced by reservoir area in the world.

Power plant	Country	Generation capacity/Area reservoir (GWh/Km^2)
Grand Coulee Dam	EUA	83
Three Gorges Dam	China	78
Itaipu	Brasil-Paraguay	73
Sayano-Shushenskaya Dam	Russia	41
Tucurui Dam	Brazil	14
Guri Dam	Venezuela	13

Source: ICOLD (2020); ITAIPU (2020).

TABLE 3 | Installed capacity: comparison between the set of generating units of the main plants of the world.

Location	Installed capacity	
Three Gorges Dam (China)	22.400 MW	160%
Itaipu (Brazil–Paraguay)	14.000 MW	100%
Guri Dam (Venezuela)	10.000 MW	74%
Tucuruí (Brasil)	8.370 MW	60%
Grand Coulee (Estados Unidos)	6.809 MW	49%
Sayano Shushenskaya (Russia)	6.400 MW	46%
Krasnoyarsk (Russia)	6.000 MW	43%
Robert-Bourassa (Canada)	5.616 MW	40%

Source: ICOLD (2020); ITAIPU (2020).

Of the existing dams in the country, 32 have suffered failures or incidents, in multiple cases, most of which were successfully re-addressed (Suárez Villar and Suárez Barrera, 2016). In the last six decades in the country, a total of seven dam faults have occurred. A list of these failures and incidents, classified by category is presented in **Table 4**. The failure of the Guapo dam, has been the most destructive, among the damage and losses caused by the collapse of the dam in the sub-region of Barlovento affecting 7,375 people, 5,236 affected and 300 casualties, with 790 homes destroyed, 1,500 affected, one hospital and 100 flooded outpatients, 30 schools with minor damage to serious damage, destruction of 2.5 km of the national road to the east and three bridges, affectation of 9 km of drinking water conduction, the dam supplied 70% of drinking water for the Barlovento sub-region, collapse of nine towers of the 230 kw line and 60% of the Barlovento plantings were left under the waters, losses of 11 billion in crops (Suárez Villar and Suárez Barrera, 2016; Méndez et al., 2018). This is the only case in the country where the loss of human life has been recorded because of the failure of a dam.

Globally, the most common cause associated with the failure of large land dams is their overflow, due to insufficient capacity of relievers, caused by a deficient project that is specifically due to the underestimation of the river flood, which in turn responds, in the case of Venezuela, to the progressive deterioration and dismantling of the national hydrological network (Suárez Villar and Suárez Barrera, 2016; Méndez et al., 2018).

In a park of about 100 dams in Venezuela, the failure of three of them represents a percentage of 3% of the total of these structures in operation. According to statistics from the International Commission of Large Dams (ICOLD), the global average of failures in large dams is about 1%, as the percentage of dam failures far exceeds the global average.

Incidents in Venezuelan dams have generally been treated correctly and rarely have preventive interventions and safety assessments of a dam to anticipate the occurrence of disruption events. From the point of view of dam safety management, the detailed collection and study of each of these incidents justifies the need for a national safety assessment program in order to alert in advance of the possible occurrence of a similar event (Suárez Barrera and Vethencourt, 1997; Suárez Villar and Suárez Barrera, 2016). Venezuelan reservoirs requiring priority actions are: Clavellinos Reservoir (Sucre State), by abandoning the construction of the new take-off work; Turimiquire Reservoir (Sucre State), due to the basset of leaks in the downstream slope; Manuelote Reservoir (Zulia State), due to the subdimension of the spillway; Agua Viva Reservoir (Trujillo State), due to problems of sedimentation and obstruction of the tunnel; Caparo Reservoir (Táchira State), due to damage to gates and control systems; Pao La Balsa Reservoir (Cojedes State), for significant damage to the spillway; Macarao Reservoir (D.F Caracas), because of the high levels of sediment that interfere with the

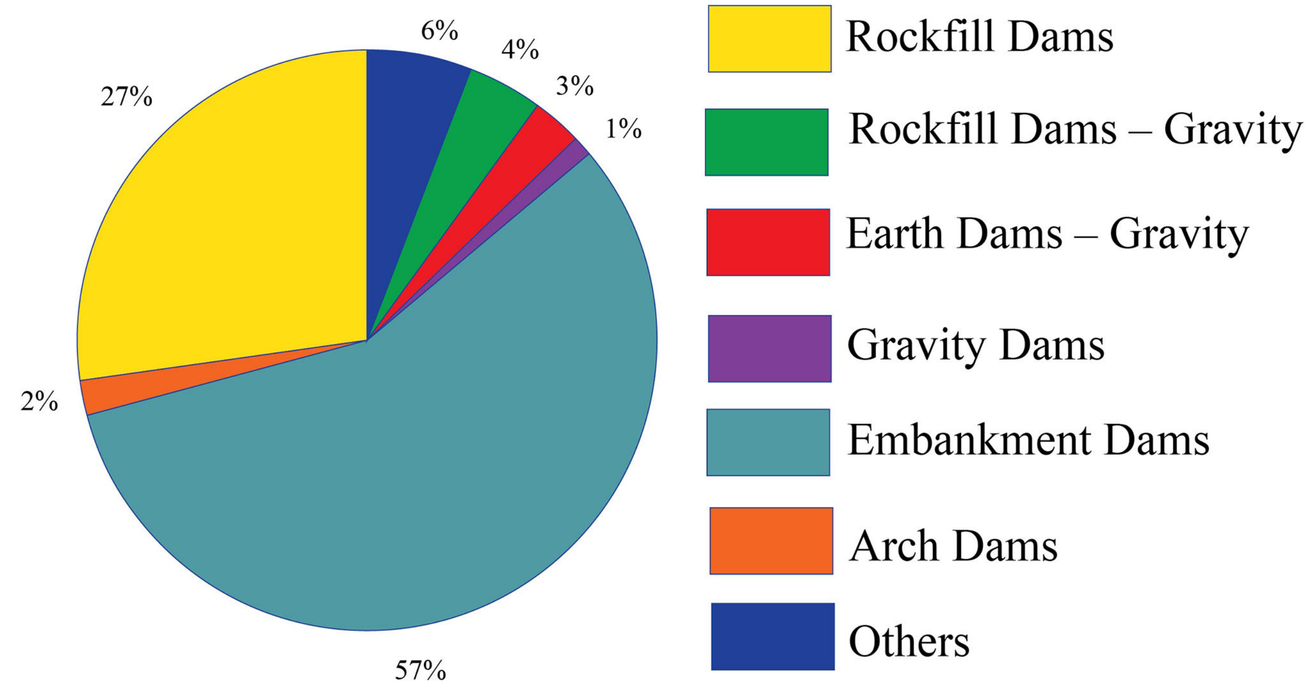

FIGURE 2 | Distribution of the main type of dams in Venezuela. Source: Adapted of FAO (2015a).

management of the gates of the intake tower (Suárez Villar and Suárez Barrera, 2016).

In addition, flow and water supply rates for the population have been reduced by ∼60%, compared to water supplied in 1999, resulting in constant blackouts across the country, highlighting those that occurred in March lasting more than 90 h, causing electricity rationing in Venezuela, a situation that directly impacts the production and development of the economy in the country (Rendon et al., 2020). By March 16, 2019, 9 days after the first mega blackout, the electricity generation capacity had not been recovered from the Bajo Caroní, for that date there was a deficit of 67%. On March 25, 2019, one of Guri's transformers caught fire and a mega blackout occurred again in almost the entire country. In one fell swoop, a quarter of the average effective generation of Bajo Caroní was lost, due to a lack of backup equipment, and lack of maintenance and recycling of other equipment from the San Gerónimo and Yaracuy substations, which were only enough to apply palliative. This situation justifies a national inventory of dams and irrigation systems to determine the current conditions of all this infrastructure and potentials by sustainably supporting an energy and agricultural sector boost, by creating a Water Resource Management system linked to a georeferenced dynamic access database.

WATER MANAGEMENT IN THE AGRICULTURAL PRODUCTION

Venezuela is a resource-rich country, and despite this it suffers from the most severe food shortages historically recorded, (Tapia et al., 2017) due to inefficient public policies, evidenced through public policies based on subsidies and other public policies that have been distorted over time. Hugo Chávez's government created the Mercal Mission, in 2003 to distribute food wholesale and retail to provide and build fixed sales centers (warehouses, small supply and supermarkets) and mobiles, with food with large discounts, subsidized, and another public polices without intermediaries. The Ministry of The People's Power for Food (MPPAL) was established in 2004, with competence in food security with a complex system of administrative bodies. In 2008 the Decree-Law on Agri-food Security and Sovereignty was enacted, to support expropriations and declare the entire production chain as "public utility," allowing the occupation of farms, companies, and any private productive unit without the process or without any prior notification. The Fair Costs and Prices Act was enacted in 2011, with the aim of its reforms intensifying, in including another kind of food, applying to different associations in the agriculture chain and agribusiness (any producer, wholesalers, factory, retailer), making it difficult for marketplaces to operate appropriately (Purcell, 2017; Tapia et al., 2017). The Venezuelan Chamber of the Food Industry (CAVIDEA) has identified than 200 laws, decrees or resolutions that affect final prices. The legal frameworks that manage these price controls and the organizations that manage this work, however, do not implement these controls.

Venezuela has abundant surface water resources in the large basins that make up its hydrography: Orinoco and Cuyuní rivers (Atlantic slope), Negro river (Amazon slope), Maracaibo Lake and Caribbean Sea (Caribbean slope) and the endorheic basin of Lake Valencia. Mean annual precipitation for the

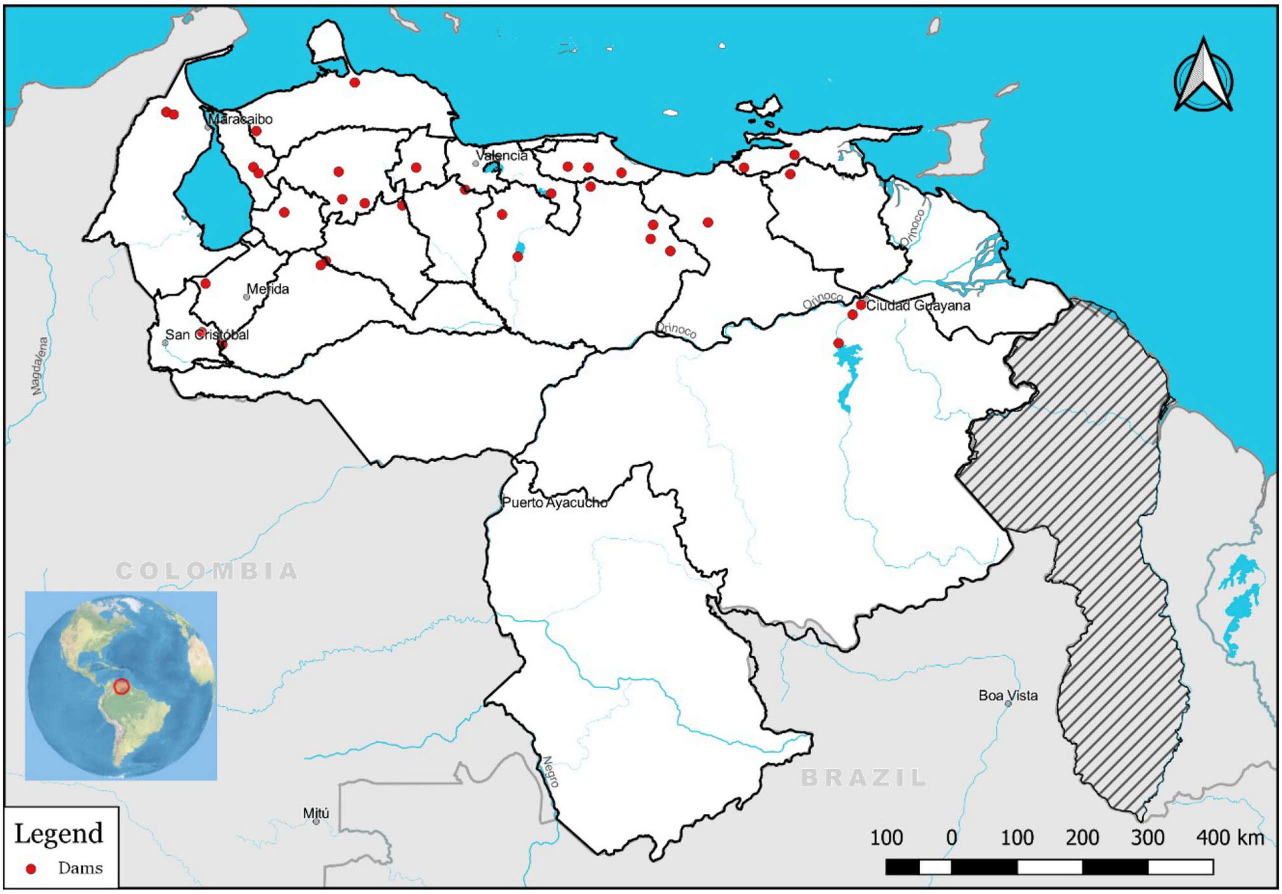

FIGURE 3 | Distribution the meaning Dams in Venezuela.

whole Venezuela is 2,044 mm, which represents 1,864 Km^3 $year^{-1}$. Renewable internal water resources are estimated at 722 km^3.$year^{-1}$, with 85% of the total generated on the right bank of the Orinoco River. The rest of the territory, while those basins that drain into the Caribbean Sea or Lake Maracaibo, contribute the remaining 15% (FAO, 2015b).

The regions that present the most relevant aquifer formations are located on the West Coast of Lake Maracaibo, Mesa de Guanipa and the western part of the Apure River. The recharge of aquifers comes mainly from direct infiltration and recharges from surface water channels, in a minor degree from the Cordillera leaks. Renewable underground water resources are estimated at 227 km^3.$year^{-1}$ (FAO, 2015b).

There are 105 reservoirs in Venezuela, which store about 157 km^3, with 15 of these being in the project or construction phase. Its hydroelectric potential is one of the most important in Latin America, with 92% of that potential located on the right bank of the Orinoco River (Guayana Region). Of these large dams, about half are directly or indirectly associated with an irrigation system, without considering those currently under construction (FAO, 2015b). In Venezuela there are 36 large and medium-sized irrigation systems with a net irrigable area of 302,062 ha of which only 137,002 ha are under irrigation. While there are 1,173 small irrigation systems with a net irrigable area of 147,443 ha of which 111,924 ha are under irrigation. Venezuela is considered to have great potential to increase the area under irrigation. In general, the availability of soils (2,676,000 ha) is vastly superior to the surface with availability of quality water resources. Some recent

TABLE 4 | Failure Dams in Venezuela.

Dam	Type of failure	Date of failure
Siburúa	Slope slippage	1964
Las Tinas	Dispersive clays	1965
Aracay	Dispersive clays	August 21, 1986
El Cristo	Underestimated crescents overflow	April 9, 1999
El Guapo	Underestimated crescents overflow	December 16, 1999
Tocuyo de la Costa (Játira)	Underestimated crescents–overflow	December 17, 1999
Manuelote	Seepage–Underestimated crescents–overflow	December 5, 2010

Source: Suárez Villar and Suárez Barrera (2016).

studies have revealed that Venezuela has1.7 million hectares of potential irrigation area, of which 35% would be irrigated from groundwater and 65% from surface water. There are agrological, edaphotechnical and groundwater studies carried out by the Ministry of Public Works (MOP) since 1970 with valuable information very useful for the strategic planning of irrigation systems and associated structures. The government's response to severe food shortages in 2016, was promoted as the way to "socialist food sovereignty" among many kinds of urban farms and different way of agro-industrial micro-ecology. While the Maduro government speaks of a so-called "economic war," the evolution of Venezuelan agriculture is stagnant, abandoned and trapped within a process of super inflation, scarcity, and with an accelerated increase in "malnutrition and hunger". This is a position and characteristics of a revolutionary government that works in a very well-structured way through the interest of peasantry and the working class, establishing itself as a farce at best and as a self-destructive process in the worst case (Purcell, 2017).

The country had high levels of commodity scarcity, at the beginning of 2017, shortage and fall in agricultural production, which averaged 27% between 1999 and 2014, official figures (other figures 50%). In January 2016, the name was changed to the scarcity index (which measures product shortages) for "appreciation of the existence of overstocking" (87%), which expresses of a real shortage of about 90%, and has not been published since 2014 (24%). The National Superintendency for the Defense of Socio-Economic Rights (SUNDDE) sought to genuine the situation by modifying the price of pasteurized milk (1,973%), chicken (1,000%), and pre-cooked maize flour (900%) (Purcell, 2017; Tapia et al., 2017).

Rising prices in this uncontrolled way leads to the highest inflation levels in the world, confirming that the government's price control policy has been inefficient in Venezuela. Food inflation of 315% in 2016 and more than 700% by 2017 is estimated and the production and marketing of agricultural products has been distorted in Venezuela due to the obstacles of foreign exchange control that prevents supply companies from accessing the market, as well as government-implemented subsidies (Tapia et al., 2017).

Venezuela, the planting of the main maize harvest began at the end of May after the timely start of seasonal rains. Production prospects are unfavorable, as the planting level is likely to continue to follow the downward trend since the 2014 economic crisis and yields are expected to be constrained by severe shortages of agricultural and fuel inputs (FAO, 2020).

Historically, the most produced crops have been the cereal group for both human consumption and balanced animal feed processing. In Venezuela, the production of current maize, is divided into three parts, the first is in the central states constituted by Aragua, Carabobo and some parts of Guárico, the second is in the eastern states such as Monagas and Bolívar, following the western states, where it is produced in Yaracuy, Portuguesa, Barinas and Cojedes. Maize production in Venezuela is of great importance as Venezuelan is a natural consumer of maize flour from a sociocultural point of view. So, if we go to the statistics of the Ministry of People's Power for Productive Agriculture and Land (MinPPAPT) we have to date (December 2016) there have been 1,273,663 metric tons of cereals harvested between white and yellow maize.

The decrease in the harvested area for annual crops is mainly due to reduced financing and increased costs of agricultural inputs, dismissing agricultural producers. It occurs equal in cane, with averages in the middle of the historical in kg per hectare. The reduction of the area planted with coffee has been reduced to 1/3 area and with low yield characteristics, vegetables with many complications by transport and inputs, let's not mention citrus trees destroyed by the yellow dragon disease. In recent agricultural history agriculture was eliminated as the main sector of disaggregation of GDP (Tapia et al., 2017).

In terms of numbers of people in crisis or worse, according to the WFP's Emergency Food Security Assessment for 2019 Venezuela ranked 4th after Yemen, the Democratic Republic of the Congo and Afghanistan with 9.3 million people (32 percent of the total population) in phase three of the Integrated Food Security Phase Classification (IPC) categorized as a crisis of severity of acute food insecurity (FSIN, 2020)

Availability and access to production data in Venezuela has been restricted in recent years, despite sufficient irrigable land that is not being used and that can meet current and future agricultural production needs (Nuñez et al., 2009), sustainable food production and reduced import dependence can only be guaranteed through knowledge and investment (Tapia et al., 2017). Between 2008 and 2014, the reduction in production of the main agricultural areas was accentuated. There were only positive tons per hectare per capita production of banana: 3.3%. The other products considered in the analysis had negative PCPs: beef (−3.2%); rice (−1.3%); maize (−8.4%); oil palm (−0.9%); cassava (−0.9%); sugar cane (−9.0%); cocoa (−2.3%); poultry (−0.9%); eggs (−0.6%) pigs (−1.6%), (Gutiérrez, 2015). Statistics indicate that agri-food imports per capita (MAAPC) increased during the oil bonanza. Lower oil prices and macroeconomic policies led to currency shortages and declining local food production could not be offset by imports. Imports are projected to have been reduced by 66.5% (from 2012 to 2016). MAAPC imports had a year-on-year reduction in 2016 compared to 2015 of −24.5%, and a decrease of 44.2% between 2012 and 2016 (Tapia et al., 2017).

The 12 main items to which FEDEAGRO tracks, whose contribution to the Value of Plant Agricultural Production exceeds 70%, 11 of them in 2015 showed significant declines in many cases historical minimums in the period evaluated (2015–2008): sorghum −80.5%, sunflower −80%, maize −58.5%, rice −37.3%, cane −31.3%, orange 31%, potato −74.3%, coffee −71.2%, onion −52.5%, tomato −18.7%, peppers −40.9%, and garlic 103.3%. In most cases the drop in production due to the lack of agricultural inputs (agrochemicals, fertilizers, and seeds), problems of gain access to currency to attend domestic demand (Tapia et al., 2017) and while FAO's Aquastat platform presents production data regarding the year 2008 (FAO, 2015b).

One of the biggest impacts recorded during this crisis has been the decrease in production volume are in sugar cane of 4 million tons, significant reduction of bovine herd and production of coffee, rice, maize, and potato, overproduction of vegetables, tubers, root, and fruits (Tapia et al., 2017; FAO, 2020).

WATER MANAGEMENT IN ENERGY PRODUCTION IMPACT ON QUALITY OF LIFE, ECONOMIC ACTIVITIES

Despite being one of the 15 territories with the highest renewable freshwater resources, nearly eight out of 10 Venezuelans do not have access to safe water and basic sanitation, about 82% of the population has no continuous water service (Bausson, 2018; Rendon et al., 2020). Drinking water in Venezuela has become a luxury, and just as with price controls set in order, a bottle of water is about $3, a significant portion of the minimum salary of about $8 per month. Water crisis in Venezuela also impacts sanitary wastewater, wastewater control and availability to water for irrigation. Partly as a result, production in agriculture, even for major crops such as rice, maize, and coffee, has fallen to about 60% in the last 20 years. This autumn in agriculture production is associated with the national average weight loss of 12 kg in 2017 (Rendon et al., 2020).

The operation of drinking water treatment systems has been negatively impacted due to the constant electrical failures, which has caused around 1 million Venezuelans to have had to resort to sources of water exposed to contamination, or without being treated, which puts people at risk of waterborne viruses, threatening the lives of children and the most vulnerable (Rendon et al., 2020). At the end of the last century, 96% of households have access to drinking water service at least basic in 1998, ∼87 percent of the population had a continuous and regular supply of clean drinking water. The scale of the water crisis indicates that this percentage of access to drinking water hastily declined in the years after Maduro took power, falling to 18% in 2018. (World Bank, 2015; Beyrer and Page, 2019; Page et al., 2019; World Health Organization, 2020).

Venezuela's water crisis has impacted the infant mortality rate. In 2017, the mortality rate for children under the age of five reached an alarming 31 deaths per 1,000 live births, well above the values recorded in 1990 and much higher than in countries such as Bangladesh and Cambodia. According to the UNICEF report, if the infant mortality rate remained where it was in 2010, 12,000 would have died in 2017. Implementation of projects and actions that promote the improvement and access of the population to sanitation and hygiene systems can contribute to the prevention of child mortality in Venezuela (World Bank, 2015; Tapia et al., 2017; Beyrer and Page, 2019; World Health Organization, 2020).

Influence of Water Management on the Economic Crisis

The last official census conducted in 2011 recorded 27,227,930 inhabitants (INE–Instituto Nacional de Estadística, 2011). In 2013, the total population amounted to 30,405,000 inhabitants, of which 6% were rural populations. The average population density is 33 inhabitants/km^2, ranging from 5 inhabitants/km^2 in rural or less populated areas to 1,381 inhabitants/km^2 in urban areas. In 2007, 94 per cent of the urban population had access to drinking water supply, while in the rural areas 75 percent (FAO, 2015b).

Some aspects of the national context concerning the severe crisis of inaccessibility to basic foods due to uncontrolled and high levels of inflation. The Central Bank of Venezuela reported high inflation rates of 180.9%, by the end of 2015. The International Monetary Fund projected figures of 720.5% in 2017 and 2068.5% in 2018 (Tapia et al., 2017). Venezuela's hyperinflation is severe, started in November of 2016 and has yet to end. It has lasted for 36 months and counting. At the peak of Venezuela's inflation, which occurred in January 2019, it took 14.8 days for prices to double. This puts its rate at the upper-end of the mid-range of hyperinflation severity (Forbes, 2019).

At present, the world's highest inflation rate is Venezuela's, where the annual inflation rate at the end of October of 2020, was 2,265 percent per year. Venezuela and Lebanon are members of the rogues' gallery of hyperinflation episodes, of which there have only been 62 in recorded history. The International Monetary Fund's (IMF) year-end forecasts for October 2020 for Venezuela was 6,500% (National Review, 2020).

The hyperinflation in Venezuela destroyed the prosperity of the middle and upper classes, where the government's supporters gained, and the opponents of the government lost (Pittaluga et al., 2020).

In addition, the fall in oil prices internationally has produced strict controls in the Venezuelan economy, a reduction in the inputs needed for agricultural production and the processing of industrialized food, taxing the import of food, resulting in greater shortages of basic food. In an attempt to combat shortages, the Venezuelan government implemented restrictive policies such as regulating commodity prices, biometric fingerprint registration for food purchases, a failed attempt to regulate and control prices. Food purchase authorization was also implemented through the submission of terminal digit identity documents (one day/week/person), and through the control of so-called local supply and production committees (CLAPs) composed of government organizations and members of the government party that sell regulated staple foods without periodicity, without proper health checks, lacking transparency in the processes and distribution criteria. As a result, the population has had to develop innovative strategies to find regulated scarce staple foods, and with this came the practice of informal food reselling called "bachaqueo" based speculation processes and with consequent price increases of up to 1,500% (Tapia et al., 2017). The so-called "Bachaqueo" has spread and consolidated in time through Venezuela's growing subsidized goods market and unfortunately these networks operate within the armed forces and other state institutions without any control (Van Roekel and De Theije, 2020).

Poverty increased from 48 to 82% in 2016, and was worse in women who, as heads of households, had to wait long lines to get insufficient amounts of food and medicine. According to the Latin American Study of Nutrition and Health, 93.9% of Venezuelans do not cover the recommendations of caloric requirements, with women's caloric intake being 1,749.1 Kcal/day and 2,059 Kcal/men's day. Caloric intake decreased significantly at the age of women (Tapia et al., 2017; Van Roekel and De Theije, 2020).

The crisis has created a situation in which food availability, access and consumption in Venezuela have a closer effect on girls and women, where 6.3% of children under the age of five are severely malnourished, while ∼30% of children under the age of five and 23.9% of women under the age of 15–49 are anemic (FSIN, 2020). This has serious consequences not only for the country, but also on the health and prosperity of future generations of Venezuelans (Tapia et al., 2017).

There is a direct link between the difficulties that the Venezuelan population has in constantly accessing the service of drinking water and sanitation and the presence of diseases. Due to the absence of clean and treated water, the presence of diseases has raised cases of infant mortality from diarrhea (six times greater than a 15-year period). The increase in cases of Hepatitis A (with a rate of 150 times higher only in the city of Caracas), and the increase in cases of dengue and other diseases that had already been eradicated such as malaria (Claborn, 2020). It is likely that, because of this extraordinary increase in infant mortality figures, the government stopped publishing public health data, which had historically been unreliable anyway. In regions where the collapse of the water system is evident, preventable childhood diseases such as diphtheria have reappeared (Rendon et al., 2020).

For many decades, Venezuela was a leader in vector control and public health policy in Latin America, even more so after becoming the first WHO-certified country to eliminate malaria in most of its territory in 1961, over the past 10 years, leading for decades in the implementation of public health policies and vector control. Venezuela has faced a serious economic crisis, precipitated by politics and declining oil revenues. The severe economic crisis, the decline in oil revenues, coupled with political instability has affected public health services. The crisis of success in the quantity and quality of drinking water has negatively influenced a 359% increase in malaria cases in 2010–2015, followed by a 71% increase in 2017 (411,586 cases). Neighboring countries, such as Brazil, have kindly reported malaria cases imported from Venezuela, from 1,538 in 2014 with a growing trend to 3,129 by 2017. In Venezuela, the increase in active transmission of Chagas disease in children (<10 years) has been highlighted. In the period 1990–2016, more than four times the incidence of dengue was shown to increase, and an epidemic peak of chikungunya of 6,975 cases per 100,000 people and the incidence of Zika virus is 2,057 cases per 100,000 people. In 2017 there were 406 malaria deaths, Venezuela's malaria epidemic has crossed international borders, with refugees and migrants often arriving in Brazil and other parts of Latin America, which has led to an increase in Malaria cases in other countries in the region (Page et al., 2019).

Venezuela had the highest rate of malaria growth in the world, and in 2015, TB rates were the highest in the country in 40 years. Between 2017 and 2018, most patients who were infected with HIV discontinued therapy due to a lack of medication. Venezuela's economic crisis has shattered the health system and led to an increase in morbidity and mortality. Accelerated expansion in the country and region of infectious diseases associated with declining basic public health services are at risk of health (Page et al., 2019).

HIV testing among neonatal exposures has decreased by 50% since 2014, and with the scarcity of antiretrovirals (ART) treatments have been discontinued. Drug resistance tests have not been available since 2016, and of the 79,467 HIV patients registered for antiretroviral processing, the Pan American Health Organization (PAHO) estimates that 69,308 (87%) they are not receiving it, and the likelihood that some patients have emigrated to other countries looking for treatment. Between 2014 and 2017, TB cases increased by almost 68% (6,063 cases compared to 10,185); the 2017 TB incidence rate (32.4 per 100,000) was the highest registered in Venezuela in 40 years (Page et al., 2019).

With decaying health infrastructure, a massive departure of trained medical personnel (a full medical professor earns US$10 per month) and the decline of all public health programs, the country is experiencing an increase and expansion of vector-borne diseases. In March 2018, it is estimated that around 40,000 Venezuelans lived in Brazil, and at least 600,000 people have sought refuge in Colombia. Official data are likely to be underestimated given the existence of informal border crossings (Grillet et al., 2019).

Since 2007, reports had a 20-week interruption in publication, regaining periodicity until November 2014, when publication was stopped by the government; the reports have not been published since 8 June 2018, the Venezuelan Centre for Disease Classification–a part of the Division of Epidemiology and Vital Statistics of the Ministry of Health that was in charge of providing PAHO and WHO with updated indicators of morbidity and mortality–was eliminated by the government after 63 years of uninterrupted activity (Grillet et al., 2019).

Considering that the 2019–20 coronavirus pandemic (COVID-19) began in December 2019, in Wuhan, and spread around the world in the first months of 2020, cases began to appear in Colombia in early March, while Venezuela reported its first two cases in mid-March (Chang, 2020). As of 28 April 2020, only 329 confirmed cases had been reported through government sources; however, this number could be underestimated due to lack of tests and tests for the despising of COVID-19 (Paniz-Mondolfi et al., 2020). All this coupled with the precarious availability of water, as hospitals have closed due to shortages of different types: 80 percent do not have access to water, 53 percent do not have adequately equipped rooms, and 60 percent do not have beds (Rendon et al., 2020).

Access to water must be facilitated to ensure proper use for health and hygiene, in small houses there are storage restrictions where family members prioritize the use of water for drinking and cooking to the detriment of hygiene (Ray, 2020). The pandemic situation itself requires a water availability in quantity and quality sufficient to carry out all hygienization activities, spaces, food, rumbles, equipment. Oonly with hand washing for 20 s up to 8–10 times per day (uses per person per day we are talking about at least 8–10 liters of water per person per day more than in normal conditions (Staddon et al., 2020). Members of these households cannot make soap under running water every time they eat, come home with groceries, clean their children's feces, or feed their animals. They must store water in plastic or metal containers and most of the time make large journeys to a water source that is sometimes not drinkable. This situation technically makes it difficult to meet the Sustainable Development Goals for access to basic soap and water supplies (Ray, 2020).

Water Management and Impact on Education

The complexity of the studies, as well as the construction, use and monitoring of irrigation works, requires the participation of specialized personnel in a wide range of disciplines of both engineering and basic, natural, and social sciences. And since the 1930s Venezuela had few specialist professionals in the area, this figure was well below the requirements of a country that was beginning to live a modernization process (Arnal, 2017).

Venezuela's highly skilled brain loss and human capital have been motivated by increased violence and insecurity and policies by the socialist regime, the main reason for academically prepared professionals and skills in high-demand occupations to leave the country in search of better living and working conditions (Garcia Zea, 2020).

Official policies have tended to discourage technological innovation and the training and maintenance of human resources. The largest mass outing of highly qualified researchers, oil industry experts, teachers, and technical staff has been evident in all areas and especially in the water resource management area. The added government policies, the increase in criminality and vandalism that Venezuelan educational institutions and universities have whipped, if as the gradual loss of freedoms and personal deactivations of potential freedoms for and developed, has called for the mass exodus of the country in search of better working conditions and that allows the potential and medium-life development (Garcia Zea, 2020). Official figures from the National Observatory on Science, Technology and Innovation indicate that the percentage of researchers accredited in the PEII Innovation and Research Stimulus Program engaged in agricultural research has fallen from 23% in 2012 to 11% in 2015, with 520 agricultural researchers being lost in 4 years. According to the PEII, in 2015, 61% of the accredited were women and the number of projects fell from 286 in 2014 to just 62 in 2015 (Tapia et al., 2017).

On the other hand, considering that agricultural communities have a single educational infrastructure that has developed over more than a century. This network allowed new technologies and practices to quickly reach the hands of farmers and ranchers to make immediate practical use of them (Rendon et al., 2020).

However, in Venezuela, educational facilities of all levels in both rural and urban regions (from primary institutions to universities) have closed in part because there is no access to water service for drinking or sanitation. The decay of the educational infrastructure, with strong rations of electricity and drinking water supply has negatively impacted the quality of life of Venezuelan professionals dedicated to education (Garcia Zea, 2020). By 2018, 28 percent of students did not attend school due to water shortages, 22 percent due to lack of food at home, and 13 percent due to food shortages at school (Rendon et al., 2020).

INSIGHTS AND CONCLUSIONS

Venezuela has abundant water resources distributed in seven hydrographic systems and 16 hydrographic regions. The problems of water availability are found in the northern region of the Orinoco where the highest concentration of economic activities has been developed and where the highest concentration of the population is located. The country there is only one multipurpose hydroelectric generation and irrigation system, with more than 100 reservoirs built and associated for different purposes: hydroelectric power generation, irrigation, drinking water supply, industrial use, flood control, and recreation.

Challenges in the use of water resources include: Development of plans and projects that can generate reliable information and each on Venezuelan reservoir systems and associated irrigation works; submit projects to international funding agencies as a reinvestment of the required studies; Development and implementation of an integrated water resource management plan; implementation of measures to solve eutrophication problems, loaded–colmatation (sedimentation of reservoirs by sediments derived from erosion and contamination); decrease in water flow and conflicts of use, as well as raising awareness of users for sustainable water management; improve the efficiency of water use in the agricultural, urban and industrial sectors.

It is necessary to promote the development of extension programs that make it possible to disseminate the importance of the value of water and its relationship with food security in the different scenarios of climate change and crisis situations. In addition to promoting the transfer of technologies from manual systems to digital systems to integrate related networks by rethinking the organizational, planning and maintenance processes and the control of irrigation systems and planning the integrated management of water resources. As a result of the proposed studies determine the progress of the rehabilitation of irrigation systems and construction of new ones. And in this way carry out the training of farmers for the administration of irrigation systems, the management of efficient water and the selection of drought-resistant varieties. The planning of the Venezuelan State for Phase I (2015–2019), to increase the irrigation area by 279,404 ha waiting to hit 37 crops, with the expectation that it will make the sanitation of an area of 409,000 ha cured impact at least the main eight crops in the country produced (Tapia et al., 2017).

Considering the above, it is necessary to carry out the monitoring and control evaluation through a system that allows the monitoring, monitoring and control of reservoir and dam works in Venezuela, as well as the irrigation systems associated with them, which will allow the sustainable agricultural and economic development of the country.

In the past, projects were developed under the Organic Law of Science and Technological Innovation (LOCTI), irrigation technologies for farmers of different productive plants in Venezuela, the need for technical support to farmers was detected, both in the installation, management, and maintenance of irrigation systems (Moreno and Farías, 2013). Subsequently, it was proposed to develop a geographic information system for irrigation management (SIGMAR), to carry out the evaluation and monitoring of irrigation systems in Venezuela, adapt to the particularities of each system or set of these, to interpret the results obtained in relation to irrigation statistics at the national level. And establish a procedure to determine the irrigation needs of crops and schedule the distribution of irrigation water. However, the difficulties in the implementation of the Organic Law of Science and Technological Innovation (LOCTI) of the Central University of Venezuela (León, 2014), make the implementation of this last project unfeasible.

There is interest of agricultural workers in innovating for higher yields and profitability, and confidence in research, demonstrated by the active participation of producer associations in discussions of laws such as LOCTI, and by the linkage of the scientific sector with agriculture. One obstacle is the low triangulation between the public, private and science and technology sectors. Considering that 64% of the electricity is generated hydro energy and the hydroelectric potential for 1998 was 83,433 MW (Tapia et al., 2017). Among the challenges: solving power failure problems and developing infrastructure needed to leverage energy resources.

At the educational level, technical assistance and education are required to reduce post-waste losses and at all points in the production chain, and this is only achieved by attracting to the country professionals trained in the different areas of knowledge who migrated in search of a better quality of life based on fundamental rights of food, health, safety, education, and quality of life.

The crisis in public health in Venezuela can have an aggravating by the return of several diseases that were previously controlled by regional efforts. This could represent a threat that could impact in national and global scale, which is why the authorities need to take action to prevent the worsening of these epidemic situation and anticipate an outcoming overflow of them from Venezuelan borders.

Only by ensuring the implementation of public policies that promote the development of agriculture under irrigation and the strengthening of agri-food systems, which promotes and rescues the healthy living and consumption patterns that Venezuelans deserve. It is necessary to promote food autonomy by promoting a positive trade balance against major international trading.

In this way it is necessary to adopt conservation measures as well as research and inventory of natural resources (availability and quality), among others, which together had to take Venezuelan agriculture to new levels both scientifically and technologically (Arnal, 2017).

The Venezuelan crisis is a call for attention for all and contains important lessons for both developed and developing countries. This crisis stems from a perverse combination of corruption, authoritarianism and political misrepresentation that beats the country for the past 20 years. In this way it is necessary to restore the fundamentals of an open society and a prosperous economy based on the rule of law, with public policies technically led by qualified professionals, with transparency, based on prudent fiscal and monetary policy, focused on the development of essential public goods such as education, health, housing, transport and infrastructure promoting the development of the three pillars of water management in production, economy and society in a sustainable way.

It is necessary to incorporate and attract the national and international private sector to make investments to boost Venezuela's production apparatus, to build confidence to stimulate national food production that guarantees the food security of Venezuelans.

Permission to Reuse and Copyright

AUTHOR CONTRIBUTIONS

MM-P conceptualization, data curation, investigation, design, search, and collated references, and wrote the paper.

ACKNOWLEDGMENTS

I especially thank the referees and the editor, for the helpful suggestions that aided the improved this paper.

REFERENCES

Adamo, N., Al-Ansari, N., Hussain Ali, S., Laue, J., and Knutsson, S. (2020). Dams safety: review of satellite remote sensing applications to dams and reservoirs. *J. Earth Sci. Geotech. Eng.* 11, 347–438. doi: 10.47260/jesge/1119

Arnal, Y. T. (2017). El riego agrícola en Venezuela: En archivos de la dirección de obras hidráulicas del ministerio de obras públicas (1936–1960). *Rev. Geogr.* Venez. 58, 184–197. Available online at: http://www.saber.ula.ve/handle/123456789/43816

AVIEM (2019). *Sistema Eléctrico Nacional–Plan País*. Alpharetta, GA: Asoc. Venez. Ing. Eléctrica, Mecánica y Prof. Afines. Available online at: http://aviem.org/wp-content/uploads/2020/07/Numero-06-AVIEM-3.pdf (accessed November 28, 2020).

Bausson, N. (2018). *From Programa Venezolano de Educación Acción en Derechos Humanos (Provea)*. Available online at: https://www.derechos.org.ve/actualidad/entrevista-provea-jose-norberto-bausson-el-82-de-la-poblacion-no-tiene (accessed December 2, 2020).

Beringer, T., Lucht, W., and Schaphoff, S. (2011). Bioenergy production potential of global biomass plantations under environmental and agricultural constraints. *GCB Bioenergy* 3, 299–312. doi: 10.1111/j.1757-1707.2010.01088.x

Beyrer, C., and Page, K. (2019). Preventable losses: infant mortality increases in Venezuela. *Lancet Glob. Health* 7, e286–e287. doi: 10.1016/S2214-109X(19)30013-0

Chang, A. (2020). *Networks in a World Unknown: Public WhatsApp Groups in the Venezuelan Refugee Crisis*. Available online at: http://arxiv.org/abs/2005.05883 (accessed December 2, 2020).

Claborn, D. M. (2020). A narrative review of the role of economic crisis on health and healthcare infrastructure in three disparate national environments. *Int. J. Environ. Res. Public Health* 17:1252. doi: 10.3390/ijerph17041252

de Carvalho, D. (2011). *Barragens. Uma Introdução para Graduandos*. Available online at: https://www.feagri.unicamp.br/portal/en/ (accessed November 28, 2020).

FAO (2015a). *Aquastat–FAO's Global Information System on Water and Agriculture. Geo-referenced Database Dams*. Available online at: http://www.fao.org/aquastat/en/databases/dams (accessed October 28, 2020).

FAO (2015b). *Aquastat Perfil de País–Venezuela (República Bolivariana de)*. Available online at: http://www.fao.org/3/ca0441es/CA0441ES.pdf (accessed July 20, 2020).

FAO (2020). *Perspectivas de cosechas y situación alimentaria #2, julio 2020*. Rome: FAO.

Forbes (2019). *Venezuela's Hyperinflation Drags On For A Near Record-—36 Months*. Available online at: https://www.forbes.com/sites/stevehanke/2019/11/13/venezuelas-hyperinflation-drags-on-for-a-near-record36-months/?sh=43480ef26b7b (accessed December 28, 2020).

FSIN (2020). *Global Report on Food Crises: Acute Food Insecurity, and Malnutrition Forecasts for 2020*. Available online at: https://www.wfp.org/publications/2020-global-report-food-crises (accessed July 5, 2020).

Garcia Zea, D. (2020). Brain drain in Venezuela: the scope of the human capital crisis. *Hum. Resour. Dev. Int.* 23, 188–195. doi: 10.1080/13678868.2019.1708156

Grillet, M. E., Hernández-Villena, J. V., Llewellyn, M. S., Paniz-Mondolfi, A. E., Tami, A., Vincenti-Gonzalez, M. F., et al. (2019). Venezuela's humanitarian crisis, resurgence of vector-borne diseases, and implications for spillover in the region. *Lancet Infect. Dis.* 19, e149–e161. doi: 10.1016/S1473-3099(18)30757-6

Gutiérrez, A. (2015). El sistema alimentario venezolano (SAV): evolución reciente, balance y perspectivas. *Agroalimentaria* 21, 19–60. Available online at: https://www.redalyc.org/pdf/1992/199241170002.pdf

Hogeboom, R. J., Knook, L., and Hoekstra, A. Y. (2018). The blue water footprint of the world's artificial reservoirs for hydroelectricity, irrigation, residential and industrial water supply, flood protection, fishing, and recreation. *Adv. Water Resour.* 113, 285–294. doi: 10.1016/j.advwatres.2018.01.028

Ibrahiem, D. M., and Hanafy, S. A. (2020). Dynamic linkages amongst ecological footprints, fossil fuel energy consumption, and globalization: an empirical analysis. *Manag. Environ. Qual. Int. J.* 31, 1549–1568. doi: 10.1108/MEQ-02-2020-0029

ICOLD, C. (2020). *Dams World Register General Synthesis*. Available online at: https://www.icold-cigb.org/GB/world_register/general_synthesis.asp (accessed May 26, 2020).

INE–Instituto Nacional de Estadística (2011). *Censo Poblacional 2011*. Available online at: http://www.redatam.ine.gob.ve/Censo2011/index.html (accessed March 16, 2020).

ITAIPU (2020). *COMPARISONS. The Grandiose Numbers of Itaipu Give Rise to Impressive Comparisons*. Available online at: https://www.itaipu.gov.br/en/energy/comparisons (accessed May 15, 2020).

Ledvina, K., Winchester, N., Strzepek, K., and Reilly, J. (2018). New data for representing irrigated agriculture in economy-wide models. *J. Glob. Econ. Anal.* 3, 122–155. doi: 10.21642/JGEA.030103AF

León, J. B. (2014). Dificultades para la implementación de la Ley Orgánica de Ciencia Tecnología e Innovación (LOCTI) en la Universidad Central de Venezuela. *Rev. la Fac. Ing. U.C.V.* 29, 7–12.

Méndez, W., Córdova, J., Suárez, C., Pacheco, H., and Landaeta, L. (2018). Anuário do Instituto de Geociências–UFRJ Colapso de la Presa El Guamito (Venezuela) ante las Lluvias Extraordinarias de Diciembre de 1999: Condicionantes Hidrogeomorfológicos en la Cuenca del Río Guapo. *Anu. Inst. Geociênc. UFRJ* 41, 319–332. doi: 10.11137/2018_3_319_332

Ministerio del Ambiente y de los Recursos Naturales Renovables (MARNR) (1982). *Sistemas Ambientales Venezolanos. Proyecto VEN/79/001. Mapa de la Vegetación Actual de Venezuela. Serie: II, sección: 1, documento número: 4, código: II-1-4* (Caracas), pp.231.

Ministerio del Ambiente y de los Recursos Naturales Renovables (MARNR) (1995). "Balance Ambiental de Venezuela 1994–95," in *Recursos Suelos y Tierras, Caracas, Venezuela* (Caracas), 33–38.

Moreno, M. A., and Farías, A. J. (2013). "Influence of different operating conditions on irrigation uniformity with microperforated tapes," in *European Geosciences Union General Assembly* (Viena).

National Review (2020). *Hanke's Inflation Dashboard: Measurements vs. Forecasts*. Available online at: https://www.nationalreview.com/2020/11/hankes-inflation-dashboard-measurements-vs-forecasts/ (accessed December 28, 2020)

Nuñez, N. G., Lahoud, F., and Trezza, R. (2009). La historia del riego en venezuela–una version crítica. San Francisco, CA: Academia, 73–85.

Page, K. R., Doocy, S., Reyna Ganteaume, F., Castro, J. S., Spiegel, P., and Beyrer, C. (2019). Venezuela's public health crisis: a regional emergency. *Lancet* 393, 1254–1260. doi: 10.1016/S0140-6736(19)30344-7

Paniz-Mondolfi, A. E., Sordillo, E. M., Márquez-Colmenarez, M. C., Delgado-Noguera, L. A., and Rodriguez-Morales, A. J. (2020). The arrival of SARS-CoV-2 in Venezuela. *Lancet* 395, e85–e86. doi: 10.1016/S0140-6736(20)31053-9

Paredes Trejo, F. J., Alves Barbosa, H., Peñaloza-Murillo, M. A., Moreno, M. A., and Farías, A. (2016). Intercomparison of improved satellite rainfall estimation with CHIRPS gridded product and rain gauge data over Venezuela. *Atmósfera* 29, 323–342. doi: 10.20937/ATM.2016.29.04.04

Paredes-Trejo, F. J., Barbosa-Alves, H., Moreno-Pizani, M. A., and Farías-Ramírez, A. (2020). "Cambio climático: 'altera el régimen de precipitaciones y caudales en Venezuela?," in *Ríos en Riesgo de Venezuela Vol. 3*, ed. D. Rodríguez-Olarte (Barquisimeto: Universidad Centroccidental Lisandro Alvarado), 137–147.

Pittaluga, G. B., Seghezza, E., and Morelli, P. (2020). The political economy of hyperinflation in Venezuela. *Public Choice* 20, 1–14. doi: 10.1007/s11127-019-00766-5

Posso, F., and Zambrano, J. (2014). Estimation of electrolytic hydrogen production potential in Venezuela from renewable energies. *Int. J. Hydrog. Energy* 39, 11846–11853. doi: 10.1016/j.ijhydene.2014.06.033

Purcell, T. F. (2017). The political economy of rentier capitalism and the limits to agrarian transformation in Venezuela. *J. Agrar. Chang.* 17, 296–312. doi: 10.1111/joac.12204

Quiroz-Ruiz, I., Paredes-Trejo, F. P. T., and Guevara-Pérez, E. (2016). Incidencia de las sequías sobre las cuencas aportantes a los grandes embalses en Venezuela. *Ágora Heterodoxias* 2, 65–89.

Ray, I. (2020). Viewpoint–handwashing and COVID-19: simple, right there...? *World Dev.* 135:105086. doi: 10.1016/j.worlddev.2020.105086

Rendon, M., Schneider, M., and Kohan, A. (2020). *Unraveling the Water Crisis in Venezuela*. Available online at: https://www.csis.org/analysis/unraveling-water-crisis-venezuela (accessed September 21, 2020).

Staddon, C., Everard, M., Mytton, J., Octavianti, T., Powell, W., Quinn, N., et al. (2020). Water insecurity compounds the global coronavirus crisis. *Water Int.* 45, 416–422. doi: 10.1080/02508060.2020.1769345

Su, Y., Gao, W., Guan, D., and Zuo, T. (2020). Achieving urban water security: a review of water management approach from technology perspective. *Water Resour. Manag.* 34, 4163–4179. doi: 10.1007/s11269-020-02663-9

Suárez Barrera, D., and Vethencourt, J. L. (1997). *Incidentes en las presas en Venezuela. Problemas, soluciones y lecciones*. (Undergraduate thesis). Universidad Católica Andrés Bello, Caracas, Venezuela. Available online at: http://biblioteca2.ucab.edu.ve/anexos/biblioteca/marc/texto/AAM3752.pdf (accessed July 20, 2020).

Suárez Villar, L. M., and Suárez Barrera, D. (2016). *Lecciones Aprendidas de los Incidentes y Fallas en las Presas de Venezuela*. Caracas. Available online at: https://www.proyectoshidraulicos.com/publicaciones.html (accessed May 15, 2020).

Taheripour, F., Hertel, T. W., Narayanan, B., Sahin, S., Markandya, A., and Mitra, B. K. (2016). Economic and land use impacts of improving water use efficiency in irrigation in South Asia. *J. Environ. Prot. (Irvine, Calif)* 07, 1571–1591. doi: 10.4236/jep.2016.711130

Tapia, M. S., Puche, M., Pieters, A., Marrero, J. F., Clavijo, S., Gutiérrez, S., et al. (2017). "Seguridad alimentaria y nutricional en Venezuela," in *Secuestro agroalimentario de un país: visión y compromiso*, eds. M. Clegg, E. Bianchi, J. McNeil, L. H. Estrella, and K. Vammen (México: La Red Interamericana de Academias de Ciencias (IANAS); Red Mundial de Academias de Ciencias (IAP); El Ministerio Federal de Educación e Investigación Bundesministerium für Bildung und Forschung (BMBF); Academia Nacional de Ciencias de Alemania-Leopoldina) Available online at: http://www.ianas.org (accessed September 30, 2020).

Team, F. P. M. and A. (FPMA) (2020). *Food Price Monitoring and Analysis (FPMA). Rome*. Available online at: http://www.fao.org/giews/food-prices/tool/public/index.html#/home (accessed October 14, 2020).

Upadhyay, M. K., Majumdar, A., Suresh Kumar, J., and Srivastava, S. (2020). Arsenic in rice agro-ecosystem: solutions for safe and sustainable rice production. *Front. Sustain. Food Syst.* 4:53. doi: 10.3389/fsufs.2020.00053

Vågsholm, I., Arzoomand, N. S., and Boqvist, S. (2020). Food security, safety, and sustainability—Getting the trade-offs right. *Front. Sustain. Food Syst.* 4, 1–14. doi: 10.3389/fsufs.2020.00016

Van Roekel, E., and De Theije, M. (2020). Hunger in the land of plenty: the complex humanitarian crisis in Venezuela. *Anthropol. Today* 36, 8–12. doi: 10.1111/1467-8322.12561

World Bank (2015). *Health, import, and inflation indicators for Venezuela, 2000–2015*. Washington, DC.

World Health Organization (2020). *UNICEF/WHO/The World Bank Group joint child malnutrition estimates: levels and trends in child malnutrition: key findings of the 2020 edition*. New York, NY: United Nations Children's Fund, World Health Organization, and World Bank Group.

Yang, S., Wang, H., Tong, J., Ma, J., Zhang, F., and Wu, S. (2020). Technical efficiency of China's agriculture and output elasticity of factors based on water resources utilization. *Water* 12, 1–23. doi: 10.3390/w12102691

Conflict of Interest: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be constructed as a potential conflict of interest.