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Socio-hydrological analysis of the province of Havana, Cuba

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Abstract

The main objective of this paper is to analyze the relationship that currently exists between the available water resources and the needs of man, understood as a social being, in the province of Havana. A very peculiar relationship due to the characteristics of both components, which currently presents a conflicting socio-hydrological sign in terms of water supply. A very unfavorable scenario of water resources due to Havana's own hydrological conditions, and a capital city of more than 2.2 million inhabitants in an area of just 728 km^2, with a demand for water well above its hydrological possibilities and with a rate of socioeconomic development of great intensity. The methodology used combines, on the one hand, the quantitative variables of the water resource, and on the other, the qualitative socioeconomic characteristics of the capital's population, where in the first case to be able to establish the supply-demand balance of water, and in the second case, the socio-hydrological conflict that generates the scarcity of the resource in the face of a growing demand and that has become hydro-dependent on the water resources of the provinces of Artemisa and Mayabeque. The work concludes with the reaffirmation that the socio-hydrological conflict created for many years is endemic, and that only the intelligence of the capital inhabitants and Cubans in general can make it possible to coexist with the natural limitations of the water resource.

Keywords: water supply, hydrological conditions, water resources, socio-hydrological

Introduction

Water is the most used natural resource and at the same time essential for life. The dependence of man as a social being in relation to water is total, however, there are some aspects of this relationship that are still little known or studied by man himself. Due to the multiple problems that have arisen in recent years in the relationship between the water resource and man, or what is the same, the water-society relationship, the term "socio-hydrological" is being used to describe this relationship in some way widely used among scientists and managers of water resources. Generally, the various ways in which socio-hydrological problems or conflicts manifest themselves have as their context the demand for water for direct or domestic human consumption, agricultural and agro industrial activity in general, as well as in industry and environmental protection but, in addition, and it is the most common, the product of the combination of two or more of these contexts.

Socio-hydrological systems such as agriculture, domestic consumption, industrial and environmental, exhibit unique patterns and paradoxical behavior due to feedback and multi-scale inconsistencies. In these systems, seemingly common-sense solutions that have been proposed and implemented around the world are found to have incidental impacts or even the opposite unintended effect.[1] The issue of providing the demand for water in large cities and/or cities is today a conflictive context that is treated as a topic of broad debate and discussion in regional or world forums. In a scenario of supply for domestic use, the demand for water is not only for direct domestic use such as cooking, washing, drinking, among others, but also for watering garden plants, washing cars, etc. Added to these uses are others of a more collective nature such as community work, street cleaning, urban agriculture, which means that the demand is generally high in terms of per capita consumption coefficients. Among the large cities that face difficulties and limitations in meeting demand are Madrid, Mexico City, Sao Paulo and Havana, just to mention a few.

Since 2009 to the present, the UN has sent successive messages to civil society warning the following: " The population of the planet tripled during the 20th century, while the use of water grew 6 times, in the next 50 years the world population will grow between 40 and 50%, it is obvious that rampant consumption of water cannot continue, more than 3000 million people (almost 50% of the world population) will suffer from water scarcity in 2025 ".[2] There are three problems worldwide related to access to drinking water. The first, the natural and unequal distribution of water resources aggravated by the continuous and accelerated population growth, the second, the permanent threat of climate change that makes possible a lot of uncertainty for an adequate management of water resources in the face of intense droughts and events extremes, and the third, the absence of political will in many countries to meet the demand for drinking water of the vast majority.[3] The city is the most important phenomenon affecting the territory in the last 200 years. Urbanization, industrialization and population growth have modified the natural characteristics of the water cycle, making its operation more complex. This fact has led to important alterations in the hydrographic basins and in the ecosystems related to the urban territory.[4]

For Cuba, and more specifically for the city of Havana (hereinafter only Havana) coinciding with the province of the same name according to the last administrative political division of the country, but also as the capital of the Cuban nation, the background on hydraulics, hydrology and the water supply are long-standing and full of problems of all kinds that last to this day, making the socio-hydrological conflict on this provincial scale very special. Keep in mind that since the end of the 19th century there were already supply concerns from which the idea of the construction of the Albear aqueduct arose, an aqueduct that takes its name from the engineer Francisco de Albear, designer and builder of the work that until today is maintained and that provides a considerable contribution to the inhabitants of the capital.[5] The Provincial Direction of Physical Planning (DPPF),[6] in the "Special Plan for territorial and urban planning of the Vento underground basin (2017 - 2018)" raises the main problems to be solved in the said basin, among which are mentioned: - the overexploitation of the water resources of the basin and the slow period of their renewal, - long periods of drought that endanger the use of this source of supply, - growing population increase on it. On the other hand, and under the assumption of exploiting surface water, Ramirez (2019) estimates this contribution of surface water (without treatment) as a result of the eleven hydrographic basins at a maximum of 340 million m^3 (calculated in all basins up to the mouth) that really usable would be 35% of this total, or 119 million m^3. Havana has a population of 2.2 million inhabitants, of which 98.9% is supplied by the aqueduct networks and that there is an organizational structure subordinated the Provincial Delegation of Hydraulic Resources, which water integral cycle services, complying with the legal bases related to the use of water resources (Lasa Garcia, 2008). Due to the high level of deterioration and its obsolescence due to the years of exploitation, estimated losses of 58% are caused, these results in the reduction of service hours and the work pressures of the (network distribution Lasa Garcia, 2008).

Materials and methods

The very scarce water resources of Havana were pointed out by Gonzalez Piedra and Hanne Domínguez, 2019, in the article "Spatial distribution of Water Resources in Cuba" where they point out that for Havana some 323. 10^6 m^3 are calculated as Usable Water Resources, the lowest in all of Cuba, and at the same time due to the need to satisfy the great demand for water that this great city has, these resources are also considered as Available. For Bui Garcia, 2019, the city and province of Havana, Cuba, is a clear example of this problem, its potential and usable water resources are very scarce, which makes it hydro-dependent on its neighboring provinces of Artemisa and Mayabeque, being necessary an optimal use of these resources at present and in the future. Currently, 597 million m^3 per year are exploited, of which 545 million (year 2018) are for the population through aqueducts and where there are losses of almost 60% through the distribution network, only 303 million reaching the population, less than 50% of their real needs. Most of the volumes are extracted from the Vento underground basin with just over 152 million m^3 (37.5% of the total) for nine of the fifteen municipalities of the province. In the master's thesis "Evaluation of the water resources of the Almendares river basin for the years 2050, 2070 and 2099",[7] a value of approximately 174 million m^3 per year is set for the Vento basin system, very similar to the previous one by Bui Garcia in 2019. According to Lasa Garcia, 2008, the water supply to the capital of the country is carried out through 68 sources; of which 67 are underground and only one is surface. For the latter, there is a purification plant with a capacity of 600 l/s that provides a daily volume of water of 51,840 m^3 from the coordinated operation of three reservoirs: La Coca, La Zarza and Bacuranao of the 67 underground sources, 55 are for drinking water, while 12 are for brackish water that serve the eastern coastal area of the city, so human consumption in this part of the province is guaranteed by tank cars.

Physicogeographic and socioeconomic aspects of the province (city) of Havana

The most outstanding feature of this province is its high degree of anthropization and its intense urbanization. The province of Havana is located on the north coast of the western region of the largest island of the Republic of Cuba, its geographical position situates it between 22°58' and 23°10' north latitude and 82°30' and 82°06' west longitude, it limits to the south and west with the province of Artemisa and to the south and east with the province of Mayabeque, while to the north it limits with the Strait of Florida in the Atlantic Ocean (Figure 1). It is the smallest province in the country, occupying the fourteenth place in extension with 728.26 km^2 representing 0.7% of the total area of the country.

Figure 1 Scheme of geographic location of the study area, city and province of Havana.

Source: Extracted from (Bui, 2019)[5]

The predominant relief in the study area is plain and gentle hills, forming part of three units of the geomorphologic set of west-east development and with the following latitudinal succession: - Alturas de La Habana-Matanzas, a large anticline axis that forms the northern coast, - Almendares-San Juan syncline, stretched between both rivers, - Bejucal-Madruga-Limonar anticline, a series of modest heights in the center-south of the province. Four identified terrace levels characterize Havana: the first near the level of Calle Línea, the second at Calle 17, the third at Calle 23, and the fourth towards the Castillo del Príncipe. To the south of the coastal strip is the northern flank of the Havana-Matanzas anticline, which extends from El Morro to the summit hill in Matanzas, for approximately 100 km. Its maximum height does not exceed 50 m above mean sea level and its width is 12 km from north to south. The Almendares-San Juan syncline is located to the south of the city and has the shape of a plinth plain with heights between 50 masl and 100 masl. The lithological substratum that composes it is made up of Miocene limestone with typical shapes of karst processes (karst funnels and sinkholes). These karstic forms house the most important aquifer for the capital and, therefore, growth in this sector has been limited, today occupying wooded areas and large parks.[8] The land component, for its part, describes the existence of a high percentage of urbanized land in the northern portion of the country's capital, while in some coastal sectors there are manifestations of bare karst. Due to the strong interrelation of the soil component and the relief, we can determine that in the physical-geographical unit Alturas de La Habana - Matanzas the soils are reddish-brown fersialitic and carbonated humic, of great agricultural value and historically exploited. On the territories that make up the Almendares - San Juan syncline, deep soils are developed, mainly ferralitic red clayey, with typical shapes of karst processes (karst funnels and sinkholes).[5]

The current vegetation of the territory is predominantly cultural. The original vegetation has been largely cleared and at best confined to small grassy meadows with isolated shrubs, shrubs essentially in the extreme southeast of the province. While to the south and west it has been practically replaced by crops for the city market (sugar cane, fruit trees and other various crops).[8] The climatic regime in the context of the city as in the rest of the island is a seasonally humid tropical climate. It has a dry and cool winter season from November to April, although with notable nuances due to the influence of the sea, raining one day every month. The accumulated average for this season is between 300 mm and 400 mm, of a frontal nature (cold front entry). The rainy and warm period extends from May to October and it is recorded between 800 mm and 1200 mm. The maximum precipitation has been recorded in the month of June due to connective-type precipitation, generally in the afternoon, with an increase in intensity from the coast towards the interior. Another maximum in rainfall is in the month of September due to the passage of tropical cyclones. The average air temperature in Havana is approximately 24.5 °C with little annual variation.

The maximum temperatures in the territory have been recorded between the months of August and September, where the absolute maximum can reach 34 °C. In winter the average temperatures oscillate around 21 °C. The minimum temperature recorded is 2.0 ºC in the town of Santiago de las Vegas in the municipality of Boyeros; although during the 2010-2011 winter season values below 1.4ºC were recorded. In addition, there is a great oceanic influence on the climate because the Gulf Stream passes off the coast of western Cuba.[5] Within the physical-geographical characteristics of Havana, it is important to highlight its fluvial system and its drainage network due to the importance with the topic that this research deals with. The province of Havana has a very typical fluvial system and drainage network (hydrographic) in relation to the rest of the provinces. It is the only one that has a single fluvial drainage slope (north) and where Las Alturas de La Habana-Matanzas, the great anticline axis that forms the northern coast, constitutes the main dividing line of these fluvial systems that drain to the north. While the Almendares - San Juan Syncline gives rise to the Almendares River basin.

The hydrographic features of Havana are shown in Figure 2, while the distribution of the hydrographic basins is shown in Figure 3. As can be seen to the west of the Almendares river basin there are four small basins: Baracoa, Santa Ana, Jaimanitas and Arroyo Bañabuey with areas smaller than 60 km^2; and to the east there are seven basins: Luyanó, Martín Pérez, Cojímar, Bacuranao, Tarará, Itabo and Guanabo, all between 12.8 km^2 and 119 km^2. Considering that the surface and underground runoff network does not have schematic limits that fully coincide with the limits of the province of Havana, its water characteristics cannot be seen independently, without the surrounding territories, constituting a great system.[5] Table 1 shows the morphometric parameters of greatest interest for the basins of the province of Havana. It can be noted that except for Almendares, the rest of the basins, both those of the west and those of the east, have a certain similarity. The average slope of the basins oscillates between 19.8 m/km and 85.7 m/km, while that of the rivers oscillates between 2.9 m/km and 5.3 m/km. Similarly, the drainage density ranges from 0.78 km/km^2 to 1.9 km/km^2. The longest rivers are Almendares with 49.8 km, followed by Guanabo and Cojímar with 22.1 km.

Table 1 Morphometric parameters of the hydrographic basins of the province of Havana

Basin	Area (km^2)	Average altitude (masl)	average slope of the basin(m/km)	River length (km)	Average slope of the river (m/km)	Drainage density (km/km^2)
Santa Ana	56.9	52.2	19.8	13.7	5.2	0.78
Jaimanitas	28.2	37.8	44.1	11.8	5.1	1,3
Buenabuey Stream	30.3	40.3	44.9	11.7	2.9	1,3
Almendares	402	114	47.3	49.8	3.3	0.85
Luyano	28.5	44	68.8	10.4	5.28	1.7
Martin Perez	12.8	30	53.3	6.4	5.2	1.7
Cojimar	58.8	56	63.7	22.1	3.7	1.9
Bacuranao	62.2	49.1	72	21.7	4.2	1.9
Tarara	14.7	31.5	65.2	9.1	3.9	1.9
Itabo	35.6	37	65.4	17	3	1.9
Guanabo	119	62.8	85.7	22.1	3.9	1.7

Source: National Institute of Hydraulic Resources (INRH), 2014.

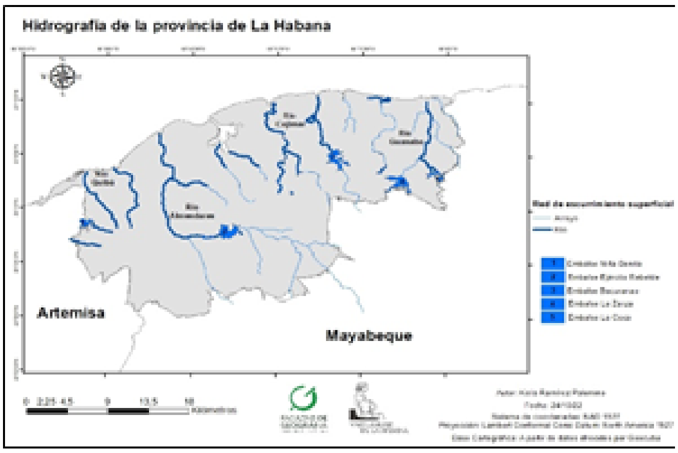

Figure 2 Hydrographic features of Havana.

Source: Prepared by the authors based on information from INRH 2014.

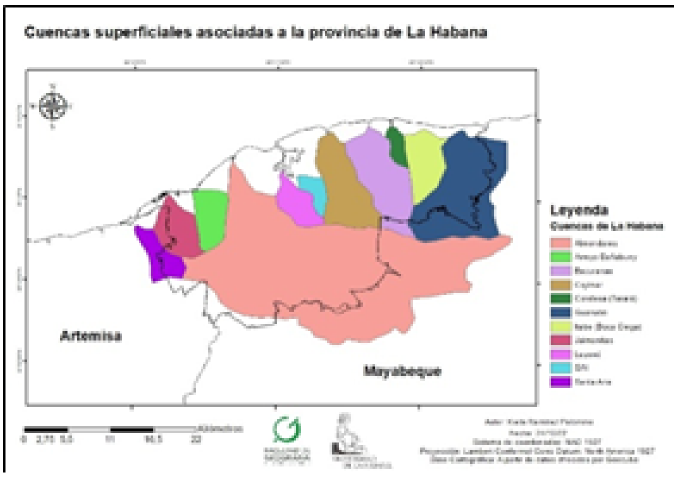

Figure 3 Hydrographic basins of Havana.

Among the most outstanding socioeconomic features of Havana, it should be mentioned that it has the main maritime port of the country, an economic-cultural center of international importance, as well as that by itself it constitutes the main tourist pole of the country. It has 15 municipalities: Playa, Plaza de la Revolución, Centro Habana, Habana Vieja, Regla, Habana del Este, Guanabacoa, San Miguel del Padrón, Diez de Octubre, Cerro, Marianao, La Lisa, Boyeros, Arroyo Naranjo and El Cotorro. Due to its economic and strategic importance, it hosts the headquarters of the national instances of the State and the Government, Ministries, diplomatic headquarters, foreign firms, main hospitals and research centers, as well as cultural, sports and commercial institutions. It is the most populated in the country with 2,129,561 inhabitants according to ONEI, 2021; of the 1,014,788 are men and 1,114,773 women; and a population density of 2,924 inhab/km^2. The largest municipality is Habana del Este with 141.49 km ^{2} and Arroyo Naranjo, which has the largest number of inhabitants with 206,123 people. The region with the average number of inhabitants in relation to the surface unit of the territory is the municipality of Centro Habana with 38,921 inhabitants/km^2. (ONEI, 2021). The average annual growth rate of the population in Havana suffered a considerable decrease, this can be related to a decrease in the migratory balance rate and the decrease in the natural growth rate of the population. Havana has a large population of internal migrants from all the provinces of the country and mostly from the eastern provinces. The migratory balance is positive since the number of immigrants is greater than emigrants, varying from 6.3 to 7 per 1,000 inhabitants in the years 2017, 2018, 2019 and 2021; with a decrease in 2020 of 3.8 per 1000 inhabitants.

Havana can be considered the heart of the Cuban economy since it contributes 42% of industrial production,[9] the main companies that we can find in the province are the José Marti Steel Company, known popularly known as Antillana de Acero, the Ñico Lopez Refinery, the Varona Metal-Mechanics and the Molecular Immunology Center. The services sector also has a notable predominance in the province, with Havana being one of the main tourist destinations in the country, in addition to concentrating most of the retail trade in the country. Havana has an agricultural area of 30.7 thousand hectares (approximately 300 km^2), of which 19.4 thousand hectares (approximately 190 km^2) are cultivated and 42.1 thousand hectares approximately 420 km^2 as non-agricultural surface. The municipalities with the largest agricultural area and equitably the largest number of cultivated hectares are Guanabacoa, Boyeros and La Habana del Este.[10] Despite its official name (Almendares-Vento), this important basin is closely related to neighboring Ariguanabo; since Vento is represented by a unique hydrogeological structure, which despite being divided into two sub-basins (Ariguanabo and Vento), both have a close hydraulic interrelationship through a common discharge area that is the Vento springs; even when the Ariguanabo sub-basin presents a second discharge, of less importance, by the river of the same name or San Antonio, which is born from the Ariguanabo lagoon.

Results and discussion

If for the geographical area of 728 km^2 that the city and province of Havana has, 323 10^6 m^3 have been calculated as Usable Water Resources and as Available Water Resources at the same time (because it is obliged to exploit all its usable resources), Water Stress is 100% because this indicator is calculated as the product of dividing the Available resources by the Exploitable ones in order to know the potential reserves that have not yet been exploited. In addition to the above, remember that the population of Havana is approximately 2,121,871 inhabitants, so it would reach about 152 m^3 per inhabitant per year, incomparable with the national average of 2,090 m^3, thirteen times lower. Previously, in Bui 2019, it was learned that today 405 10^6 m^3 are exploited· of which only 36% are extracted within the limits of the Havana territory, the rest, 64% comes from the neighboring provinces of Artemisa with 13% and Mayabeque with 51%, this assessment leads to the reaffirmation of Havana's hydro-dependence with respect to its neighboring provinces of Artemisa and Mayabeque, especially the latter. These evaluations and previous comparisons lead to unforeseen socio-hydrological scenarios in time and space, since the resulting affectations in the social sphere not only affect Havana but also the communities of the territories of Artemisa and Mayabeque. In terms of the water resource in its connection with society, the current and future demand of Havana must not decrease, on the contrary, it must increase due to population growth and all that this implies in the services provided by this precious resource, and on the other hand, the socio-hydrological conflicts of the neighboring provinces must also increase because they cannot escape from this vicious circle between these three provinces.

From Lasa Garcia, 2008, is extracted the obvious socio-hydrological conflict that is created by having losses in the distribution network that exceed 50% of the total delivered in clear contradiction with the volume limitations of available water resources. This is an aspect of great relevance at this time in the city and province of Havana due to the great efforts made by the provincial and municipal government in the effort to carry out a real empowerment of the people at the municipal level. Decision-making is essential to reduce water losses through the distribution network as much as possible and for a greater volume to reach the population, thereby avoiding the lack of precious liquid sometimes three and more times a week in critical places, due to the present socio-hydrological context. The Vento underground basin is and will be key in the supply of water to a large part of Havana, according to Bui 2019, some 152,10^6 m^3 are extracted annually by plan, equivalent to 37.5% of the annual average delivered. Understood as a systemic unit, that is, as a whole, regardless of whether or not it is entirely within the Havana territory, which is true because a part is within Mayabeque (Cuatro Caminos), this underground basin requires protection not only by part of the authorities and institutions relevant to water resources but by civil society. In fact, it is a basin that is very vulnerable to contamination due to the amount of population and industries that concur in it, this implies a qualitative socio-hydrological context different from the previous ones, in this case, in addition to the quantitative vulnerability already seen before, the qualitative. According to official data, Vento is one of the underground basins with the greatest danger of contamination in the entire country.[11–15]

Conclusion

The resulting analysis of the socio-hydrological conflicts in Havana makes it clear that moments of water scarcity in the province and city seem to be something endemic. Since its foundation more than 500 years ago, it was already envisioned that the supply of water to any settlement that promised development would be the beginning of a conflict between demand and supply that would last to this day, not only in Havana but in many other cities of the country. Some two hundred years ago from our present time it was thought that the work of Don Francisco de Albear would be the solution for Havana, the country's capital, it was not like that and at present no solution of those foreseen has been enough. The issue is as complex as it is serious, and a sustainable socio-hydrological and technical solution to this age-old problem is now essential. Everything seems to indicate that within the limits of the province and city of Havana, the potential, exploitable and therefore supposedly available water resources are and will be the same since the first calculations were made. It is not a matter of mathematics, it is a matter of the geographical nature of the province or city, its climate and hydrology are not in correspondence with the lifestyles and the current and future needs of the society that lives and develops on this geography, which leads to the exploitation of sources of other provinces, that is, outside the administrative political limit making it hydro dependent. This supposed exploitation of the neighboring provinces already brings and will bring socio-hydrological problems and/or conflicts within them that may not now be seen in the magnitude that should be seen. Havana society with its fifteen municipalities has to become aware that our beautiful city of Havana is not perfect; it has defects that are its limitations and insufficiencies, among these the water resource, which should not be renounced forever, putting human intelligence at the service of the Havana, solutions that are sustainable in time and space will appear.

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None.

Conflicts of interest

The author declares there is no conflict of interest.

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