THE ISSUE OF WATER IN SLUM DEVELOPMENT IN HAITI: THE CASE STUDY OF CANAAN

LA QUESTION DE L'EAU DANS LE DÉVELOPPEMENT DES BIDONVILLES EN HAÏTI: L'ÉTUDE DE CAS DU CANAAN

EL PROBLEMA DEL AGUA EN EL DESARROLLO DE LOS BARRIOS MARGINALES DE HAITÍ: UN ESTUDIO DE CASO DE CANAÁN

Yolette Jérôme[1, 2], Evens Emmanuel[3], Paul Bodson[4], Paul-Martel Roy[4]

Abstract

In 1992, the United Nations listed Haiti among the countries that will face water scarcity by 2025. Haitian cities, in which water demand is already high, are increasingly exposed to population growth that significantly affects water and sanitation facilities, when they exist. These settlements suffer from the negative effects of increasing water demand on a daily basis. The most critical case is that of the metropolitan area of Port-au-Prince (MAPP). The consequences of the earthquake of January 12th, 2010 included the displacement of the population, the dislocation of the general drinking water supply system, the setting up of several make shift camps in the MAPP and the creation of new slum districts, the largest of which is Canaan, where more than 200 000 inhabitants now live. In a context of low coverage of safe drinking water and basic sanitation, it seems entirely appropriate to take a fresh look at water issues in slum development. The aim of this study is to analyze the supply of, and the demand for, water at Canaan. A field survey of water suppliers and vendors and other household surveys were conducted between February and April 2016. 240 water points, totaling an available volume of 2840 m^3, were covered by the first survey. Regarding demand, a questionnaire was administered to 439 households spread over the six (6) localities composing Canaan. In 2007, only 0.23% from the population studied was living in Canaan. 31.44% of households moved into the area in 2010, just after the earthquake. The share of water in the budget of 90% of these households is higher than 5%. The selling price and frequency of supply remain the main variables responsible for spatial discrimination regarding the supply of the water market in Canaan. Future studies should use larger sample sizes to study the mechanisms capable of ensuring democratic water management in this area.
Keywords: Human settlements, water, population growth, slums, Canaan, Haiti.

Résumé

En 1992, les Nations Unies ont listé Haïti parmi les pays qui feront face en 2025 à une importante pénurie d'eau. Les villes haïtiennes, dont la demande en eau est déjà élevée, se trouvent de plus en plus exposées à une croissance démographique qui affecte considérablement les infrastructures d'eau et d'assainissement, quand elles existent. Ces établissements humains subissent au quotidien les effets négatifs de la demande croissante en eau. Le cas qui apparaît le plus critique, est celui de l'Aire métropolitaine de Port-au-Prince (AMPP). Le tremblement de terre du 12 janvier 2010 a eu, entre autres, pour conséquences un déplacement de la population, la désarticulation des réseaux et services d'eau potable et d'assainissement, la création dans l'AMPP de plusieurs camps de fortune et de nouveaux bidonvilles, dont le plus important est Canaan, dans lequel vivent aujourd'hui plus de 200 000 habitants. Dans un contexte de faible couverture en eau potable et en assainissement de base, il apparaît opportun de jeter un nouveau regard sur la problématique de l'eau dans les bidonvilles en formation. L'objectif de cette étude est d'analyser l'offre et la demande en eau au niveau de Canaan. Une enquête de terrain auprès de fournisseurs ou vendeurs d'eau et une autre auprès des ménages ont été menées entre février et avril 2016. 240 points d'eau, totalisant un volume disponible de 2840 m^3, ont été couverts par la première enquête. En ce qui concerne la demande, un questionnaire a été administré auprès de 439 ménages répartis entre les six (6) localités constituant Canaan. En 2007, seulement 0,23% de la population étudiée vivait à Canaan. 31,44% des ménages se sont installés dans la zone en 2010, juste après le séisme. Le poids de l'eau dans le budget de 90% de ces ménages est supérieur à 5%. Le prix de vente et la fréquence d'approvisionnement demeurent les principales variables établissant une discrimination spaciale au niveau de l'offre sur le marché de l'eau à Canaan. *À l'avenir, il faudra étudier*, sur un échantillon beaucoup plus important, les mécanismes permettant l'implémentationd'une gestion démocratique de l'eau dans cette zone.
Mots clés: Établissements humains, eau potable, croissance démographique, bidonvilles, Canaan, Haïti.

1 Université Quisqueya, Centre de Recherche et d'Appui aux Politiques Urbaines, 218 avenue Jean Paul II, Haut de Turgeau, Port-au-Prince, Haïti.
2 Centre de Techniques de Planification et d'Économie Appliquée, Angle Rue Joseph Janvier et Boulevard Harry Truman, Port-au-Prince, Haïti.
3 Corresponding author. Tel : (509) 3718 4833; E-mail address : evens.emmanuel@gmail.com
4 Université du Québec à Montréal, École des Sciences de la Gestion, Case postale 6194, succursale Centre-Ville, Montréal (Québec), H3C 4R4

Recibido: 29/08/2016
Aceptado: 07/05/2017

Resumen

En 1992, las Naciones Unidas pusieron en una lista a Haití entre los países que harán frente en 2025 a una escasez de agua importante. Las ciudades haitianas, cuya demanda en agua es ya elevada, se encuentran cada vez más expuestas a un crecimiento demográfico que afecta considerablemente las infraestructuras de agua y de saneamiento, cuando existen. Estos establecimientos humanos sufren a diario los efectos negativos de la demanda creciente en agua. El caso que aparece el más crítico, es el del Área metropolitana de Puerto Príncipe (AMPP). El terremoto del 12 de enero de 2010 tuvo, entre otras cosas, como consecuencias un desplazamiento de la población, la desarticulación de las redes y los servicios de agua potable y de saneamiento, la creación en la AMPP de varios campos improvisados y de nuevos barrios de chabolas, de los que uno de los más importantes es Canaán, en los que viven hoy más de 200,000 habitantes. En un contexto de cobertura débil en agua potable y en saneamiento de base, resulta oportuno echar una nueva mirada sobre la problemática del agua en los barrios precarios en formación. El objetivo de este estudio es analizar la oferta y la demanda en agua al nivel de Canaán. Una encuesta de terreno cerca de proveedores o vendedores de agua y otra cerca de los hogares han sido realizadas entre febrero y abril de 2016. 240 puntos de agua, totalizando un volumen disponible de 2840 m^3, han sido cubiertos por la primera encuesta. En cuanto a la demanda, un cuestionario ha sido administrado a cerca de 439 hogares repartidos entre las seis (6) localidades que constituyen Canaán. En 2007, solamente el 0,23 % de la población estudiada vivía en Canaán. El 31.44 % de los hogares se instalaron en la zona en 2010, justo después del seísmo. El peso del agua en el presupuesto del 90 % de estos hogares es superior al 5 %.El precio de venta y la frecuencia de abastecimiento permanecen las principales variables que establecen una discriminación espacial al nivel de la oferta sobre el mercado del agua en Canaán. En el futuro, habrá que estudiar, sobre una muestra mucho más importante, los mecanismos que permitirán la implementación de una gestión democrática del agua en esta zona.
Palabras clave: Asentamientos humanos, el agua, el crecimiento de la población, barrios marginales, Canaan, Haití.

INTRODUCTION

One of the main challenges facing countries today is to find ways to ensure that people and the environment have adequate freshwater resources to maintain and support their existence (UNEP, 2010).Uncontrolled population growth is outstripping the availability of renewable water resources. This imbalanced relationship seems to be leading humanity towards an inevitable shortage of fresh water. Indeed, near the end of the 20th century, hydrologists introduced a new indicator of economic development based on the renewable water resources/population (W/P) ratio. We have now almost reached the level of water scarcity predicted in 1992 according to the annual supply of water of a region per capita. The term water stress is applicable when W/P is below 1,700 cubic meters per person per year.

The issue of sufficiency evaluated on the basis of water availability and the satisfaction of human and environmental needs, and how it lessened during the last decade of the 20th century, has led to considering water scarcity as one of the main factors holding back development in the less advanced countries (Emmanuel and Lindskog, 2002). Falkenmark and Widstrand (1992) considered that per capita water availability below 1700 m^3/year poses development problems; a supply of less than 1000 m^3/year entails a situation of relative shortage, while one less than 500 m^3/year entails absolute shortage.

The Republic of Haiti has a water/population ratio (W/P) between 1200 and 1400 m^3 per person (St-Hilaire et al, 2013). With a potential of renewable water resources estimated at between 12 and 14 billion cubic meters per year, Haiti is already facing severe water stress. The MAPP hardly manages to meet the drinking water needs of its population. BRGM-GERSAR-LGL S.A. (1989) reported an annual availability of 23.7 million m^3 of water to supply the MAPP. On the basis of the minimum quantity of water considered necessary to live a healthy life (Falkenmark and Widstrand, 1992), namely 100 liters per capita per day, i.e. 36.5 m^3 a year, available water resources (BRGM-GERSAR-LGL SA, 1989) and the estimation of the population, i.e. 2,712,958 inhabitants in 2015, (Bodson et al, 2016), the MAPP supplies only 8.74 m^3 per inhabitant, a figure that will fall to 7.61 m^3 by 2025.The phenomenon of uncontrolled urbanization that affects every urban area of Haiti, and more particularly the MAPP, is aggravating an already difficult situation, namely that of the qualitative and quantitative supply of water to the population. The increase of the latter means that the same resources must be divided between more people, thus the quantity of water per capita decreases (Hassan, 2008).

Viewed from the urban angle, Canaan is a human settlement in development and one of the immediate consequences of the earthquake of January 12th, 2010. Deprived of basic urban infrastructures such as water supply, sanitation and electricity, Canaan is a particular epidemiological environment in which there is no collective collection of solid waste, drainage or sewage, and where water consumption of uncertain quality may promote the propagation of diseases and health risk factors for the population and the environment. As a new precarious district of the MAPP resulting from actions of post-earthquake relocation of the inhabitants in camps, Canaan provides the opportunity to approach water management in slums in the context of renovation and urban integration. It also favors the development of, and experimentation with, new models of integrated water management centered on, among other things, the effective

participation of the users/citizens. The aim of this study is to analyze the supply and demand for water in Canaan.

Methodology of the study

Within the framework of this study, adequate water supply and sanitation are considered as common goods and to a certain extent as environmental goods, since they are fundamental indicators of the level of implementation of public health standards.

Field of study

Canaan is situated in the north of the metropolitan region of Port-au-Prince, more specifically in the "habitation Corail-Cesseless" in the municipality of Croix-des Bouquets (Figure 1). Its approximate borders are formed by NR 1 in the south, the Titanyen mine-quarry in the west, and the districts of Jerusalem and Village-Modern in the east. Its access routes are NR 1 and 3. In 1971, the Haitian government declared it a public utility with the aim of developing an area attractive for tourism. This zone was composed of vast tracts of dry land covered only by wild vegetation (Noël, 2012). The presidential order of March 22nd, 2010, concerning the expropriation of several properties for public purposes, was the pretext for the illegal occupation of Canaan. Land held in the framework of this order will be used to reorganize the MAPP and partially to relocate the victims of January 12th, 2010 (Zidor, 2012). The geographical coordinates of Canaan are 18° 38′ 46″ N, 72° 16′ 23″ W. An estimated population of 200,000 lives on a territory covering about 50 square kilometers (UN-Habitat, 2015). Since 2010, earthquake victims that have fled the chaos in the adjacent neighborhoods of Port-au-Prince, migrants from rural zones of Haiti and people profiting from the resulting chaotic situation have invested more than US$10 million in the development of the "new city" (UN-Habitat, 2015).

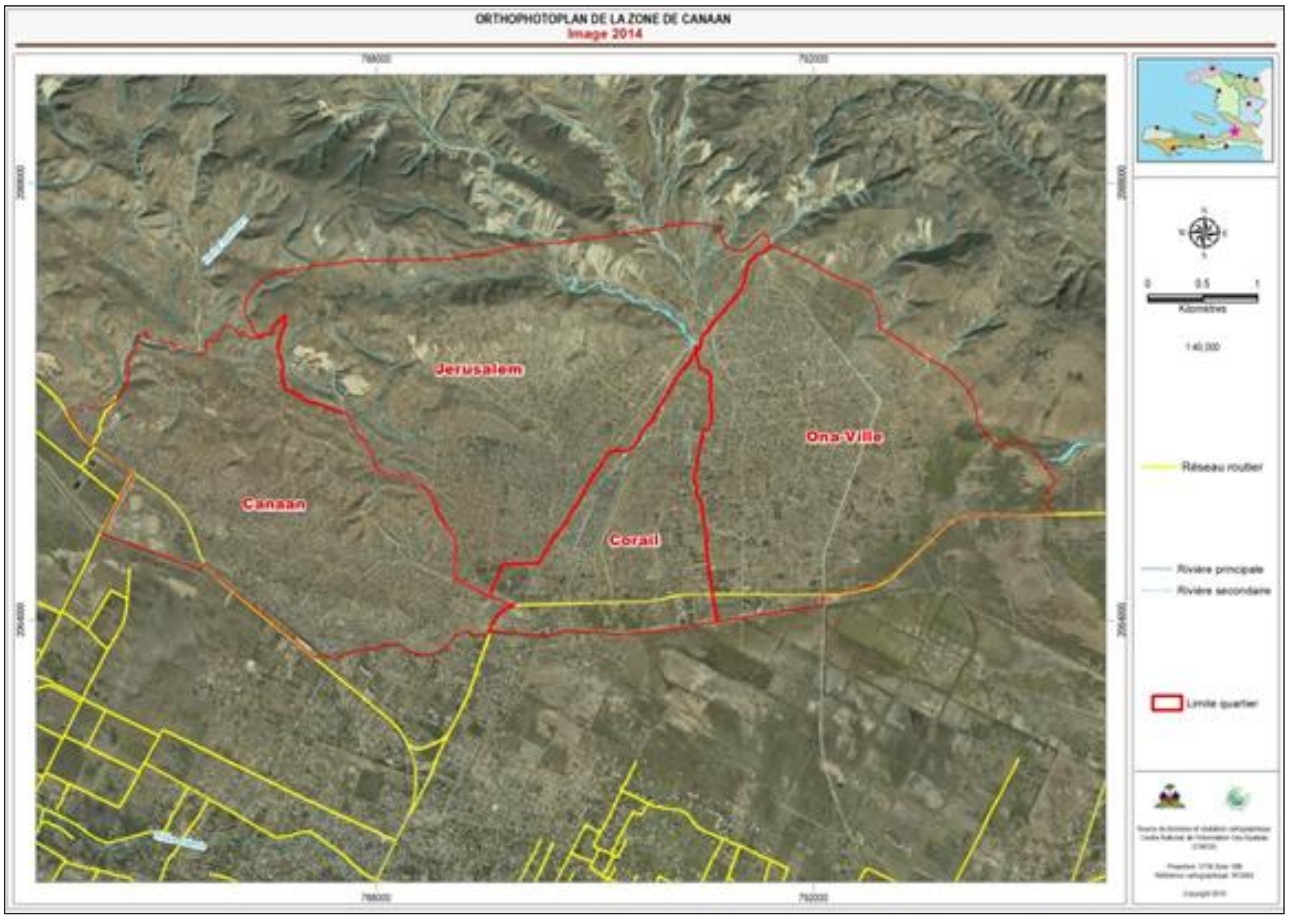

Figure 1. The field study site–the orthophotoplan of Canaan

The national and communal public authorities that should have taken over failed to take on their responsibilities following the departure of the post-earthquake emergency response organizations from Canaan. This explains why the new inhabitants, in collaboration with numerous private initiatives, organized themselves according to the urgency and the means available.

The first occupant to acquire a plot of land not previously owned is responsible for staking out its boundaries. Without the involvement of public authorities, this process is potentially highly

contentious and the reason why groups and networks of people quickly took control of the methods used to define and distribute plots, perform transactions (after the first settlement), stake out public spaces, and progressively organize services for the population. These different networks of people who exercise or try to exercise control over the distribution of the territory are themselves in competition and often do not have a global vision of the social and urban issues at stake in Canaan.

According to preliminary observations, the largest annual influx occurred in 2010 in the months following the earthquake. It remained considerable until 2013 and continued in 2014 and 2015, but at a slightly less sustained pace. Data for 2016 are too partial to be taken into account. This observation, it should be emphasized, refers exclusively to the survey data which concern the study area (Canaan1, 2, 3, 4, 5, Jerusalem and Bellevue; the two last localities are identified in this study as Canaan B) and must be taken into account in the context of the expansion of the territory commonly referred to as Canaan.

Field survey of suppliers and water vendors

The objectives of this field study were, firstly, to collect the geo-spatial coordinates of water points in operation and, secondly, to analyze the supply of water in the study area. The survey covered a total of 240 water points. The geographical references of these points allowed producing the map of the water supply to Canaan (Figure 2).

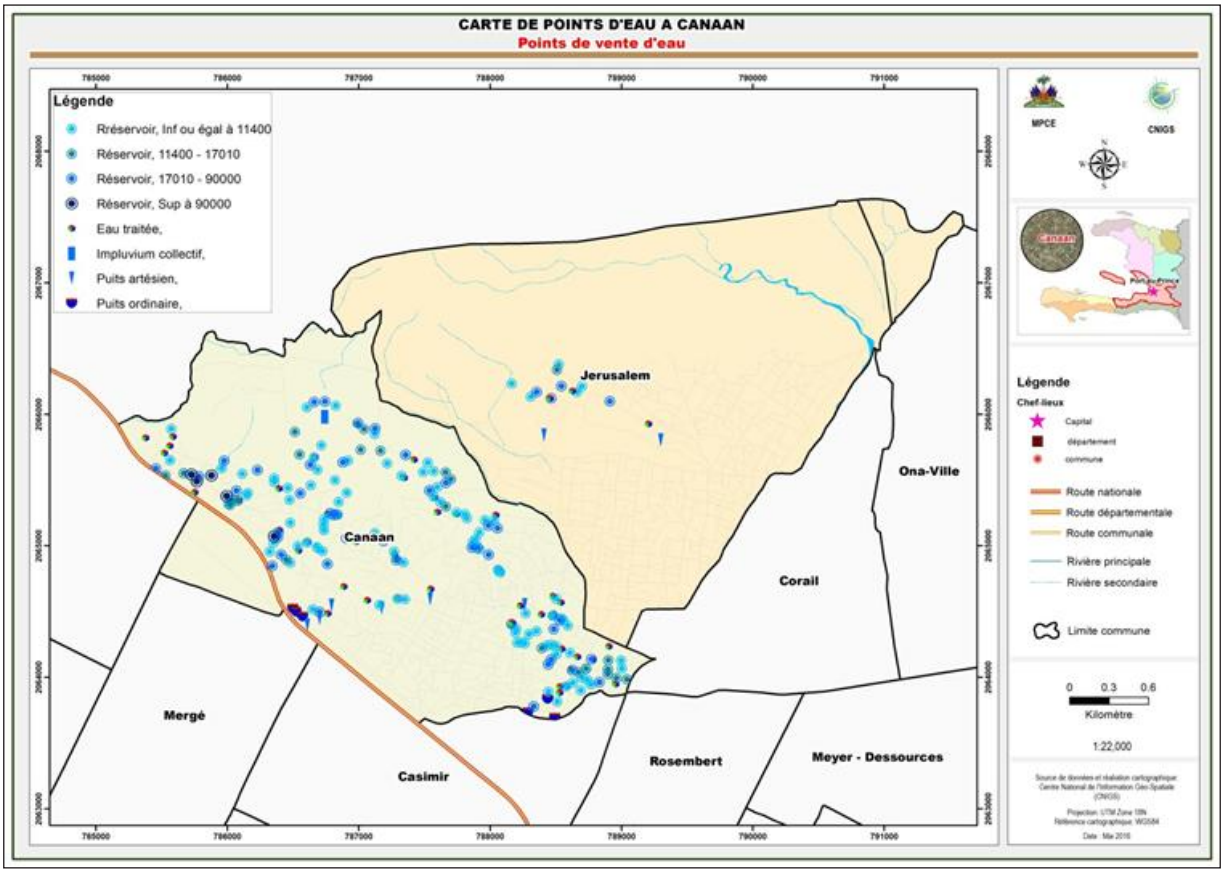

Figure 2. Map of water supply (water storage and/or distribution) in Canaan

Of the 240 water points, only 179, i.e. 74.58%, were selected for the statistical analysis of the water supply. The remaining points (61 water points or 25.42%) were not analyzed because we unable to obtain adequate information during the survey.

From a global standpoint, instead of taking the different localities into account, the subsamples used in the analysis are representative. The survey technique implemented was non-probabilistic with the itineraries method being applied within each locality and a survey step equal to 1 unit (i.e. the water point). Although the method is theoretically non-probabilistic, the representativeness of the sample made it possible to draw inferences on the basis of the results obtained. The treatments and analysis were carried out with the SPSS statistical software. Microsoft Excel was used to generate the tables and graphs.

Field survey of the population

The aim was to study the willingness and ability of this population to contribute financially and socially to the operation and maintenance of the drinking water supply system and adequate sanitation.

- **Basis of the survey -** The Haitian Institute of Statistics and Information (IHSI) has a computer file with 11,958 Sections of Enumeration (SOE) which constitutes the basis of the survey. The latest version is that of the general census of the population in 2003. This basis is old so some SOEs were updated (Gilles et al, 2015) to take into account the significant demographic changes occurring in the SOEs after the earthquake of January 12th, 2010. Within the framework of this study, the basis of the survey was not used for reasons linked to the historicity of the slums of Canaan.
- **Units of observation and analysis -** The observation unit of the survey on the willingness and capacity to pay for the drinking water supply and the quality of sanitation services was the head of household while the unit of analysis for which the data were collected was the household. However, certain conclusions concerned the head of household.
- **Sample size -** The size of the sample was determined on the basis of Simple Systematic Sampling (SSS) as the sampling technique and on global calculation based on the assumption of uniform land use in Canaan. The size of the sub-samples belonging to the blocks was determined after a visit to the area. This size was theoretically 452 households for a 95% confidence level, 5% error margin and 85% response rate. However, for reasons related to the practical implementation of this work, 439 households distributed between the six (6) localities were interviewed.
- **Sample selection -**The probability sampling method was chosen in the framework of this work, because the aim was to reach conclusions on the entire population of Canaan from the sample. Simple systematic sampling was the ideal choice in order to remain in the family of the probabilistic techniques with the best possible coverage. The sampling technique applied was a nonstandard SSS.
- **Selection of households to be surveyed –** Although the updated base of the survey containing the SOE was not chosen in the methodological framework, a series of field visits was performed before carrying out the investigation in view to first determining the number of neighborhoods composing Canaan and, second, to assess the distribution of its population from a theoretical point of view.
- **Data collection method –** The data collection method chosen was the direct interview. Interviews were conducted with the heads of households or any other person in the households able to answer the questions. In each case, a paper questionnaire was used to conduct the interview. Water scarcity is a phenomenon with qualitative and quantitative dimensions. The evaluation of the budgetary weight of water in the household finances required a quantitative approach with the questionnaire being used for data collection. However, a complementary qualitative approach was used in order understand the phenomenon and examine the behavior of the population towards the water. The questionnaire included categorized questions and subjective questions. Visual observations on the ground and interviews with certain people by opportunity, allowed obtaining information and complementary explanations for the quantified data.
- **Limits of the sampling method -** The lack of statistical information on the population of Canaan was decisive in the choice of the sampling technique used. It was not possible to stratify the sample composition. The choice of simple systematic sampling proved the most appropriate as regards the collection of units. The number of households per district was not known, and it was difficult to accurately calculate the number of steps to consider. Efforts were therefore made to achieve coverage of the area in spite of these difficulties and maintain the most scientific approach possible regarding the sample collection.
- **Process of validation, data processing, and analytical models-** The first step of supervising the questionnaires administered during the first two days of the investigation allowed correcting certain inconsistencies and avoid them afterwards. Manual recovery was undertaken thereafter, and during acquisition the statistical software used indicated certain inconsistencies by way of error messages. The validation process and the treatment were carried out on SPSS; Microsoft Excel was used to build the tables and graphs. Data analysis was both descriptive and explanatory. SPSS allowed the production of explanatory analysis tools throughout the analysis and the interpretation of the survey results. In addition to the univariate analyses, the nonparametric chi-square test was used to verify the existence of dependency relationships between two variables, and analysis of variance and the mean comparison were used to determine how a particular factor affected a response variable. A discriminating analysis was performed if data permitted when focusing on the similarity between localities, while a principal component analysis was performed on several explanatory variables.
- **The dimensions considered -** Demographic and socioeconomic characteristics were addressed in this survey as they could

influence the behavior of households in terms of water and sanitation. For water, two types were studied: (i) treated water for ingestion and water for common use. The behavior of the population was seen in terms of supply and water management at the household level. Three dimensions were chosen: rationing, treatment and water conservation. Regarding the behavior of households towards sanitation, the issue was examined in terms of solid waste management and the place of defecation usually used. Each of the dimensions considered was addressed in the collection tool by specific issues such as categorical, closed and semi-closed questions. The indicators and variables were chosen according to Haitian reality and known practices.

Results and discussion

Demographic and socioeconomic characteristics of the households

The distribution of the sample studied between the 6 localities is shown in Figure 3. 38.5% of the respondents live in Canaan 3. 60% of the heads of households are male. 71% live in a couple (married or common-law), 7% are divorced, 21% are single and 1% are widowed. 98% of the population studied lives in the household. The size of the households varies from 1 to 14 people. The sizes of the statistical series present a high concentration between 3 and 7. This edge contains 70% of households. Canaan households comprise an average of 5 people. Both the median and the mode are almost equal to the average, which is typical of normal distribution. 55% of households have between 4 and 6 people.

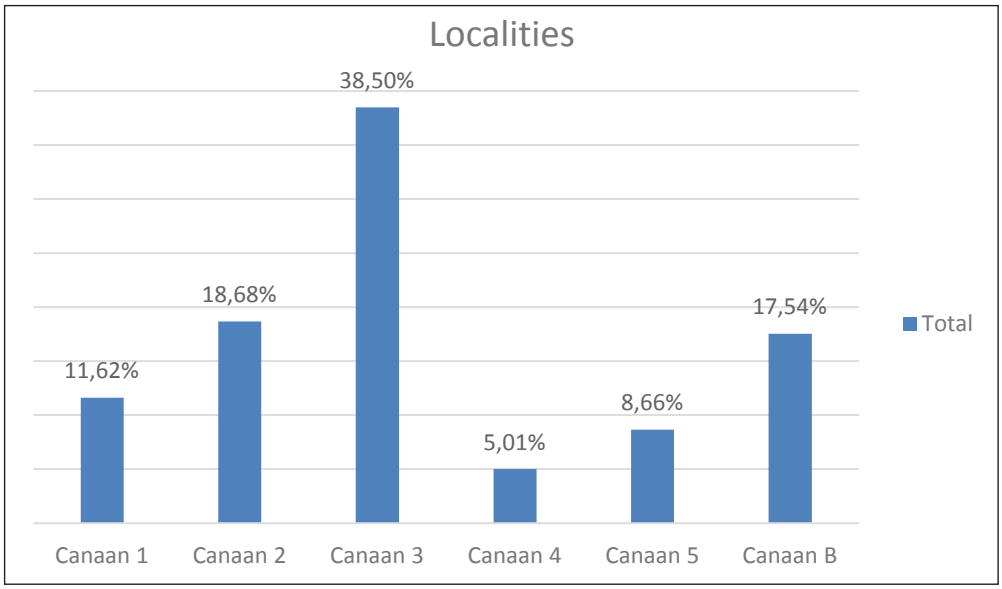

Figure 3. Distribution of the sample units between the localities

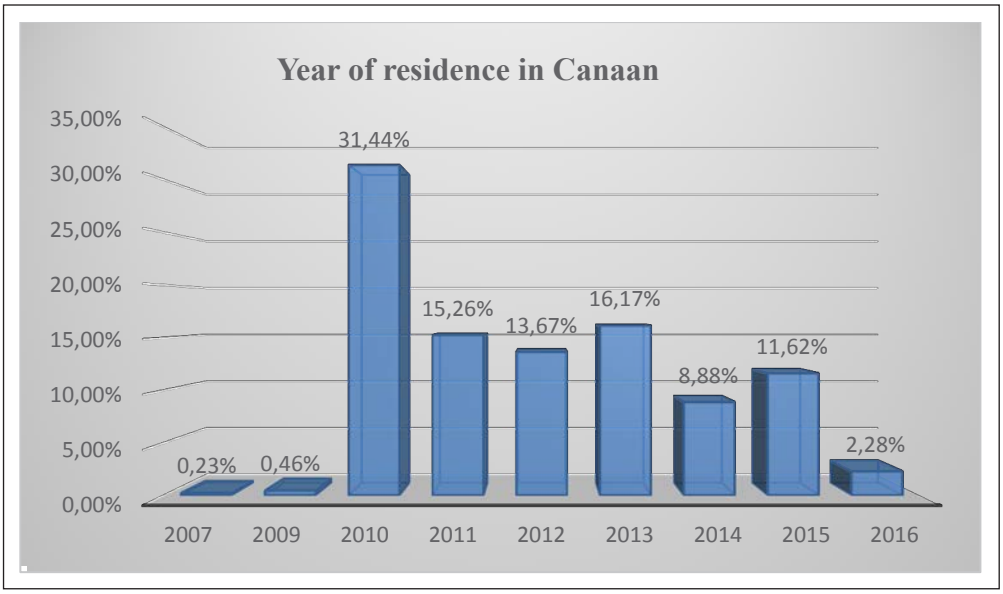

Figure 4. Statistics on the number of times that households were without water

In Canaan, 2.5% of the heads of households attended university, 31% have a high school education, and 21.41% have completed the second cycle of Haitian fundamental education. 28.47% have completed studies for the third cycle of Haitian basic education and 8.8% have never attended school.

The distribution of the households according to years of residence in Canaan is presented in Figure 4. This human settlement did not begin with the earthquake of 2010. The information obtained within the framework of the field survey highlights the existence of this settlement since 2007. Indeed, in 2007, 0.23% of the population studied was living in Canaan. In 2010, just after the earthquake, 31.44% of households moved into the area. New households settled in this area in 2016.

In 2010 and 2011, households preferred to settle in Canaan 1, 2 and 3, without excluding Canaan 4, 5 and Canaan B. After 2011, this difference in location decreased to the point that the Chi square calculated between the arrivals of households per year and their location in the 6 zones mentioned is statistically insignificant at the 0.05 threshold. Thus, the whole territory of the 6 zones progressively densified.

82% of the heads of household declared themselves to be the owners of their house. These people fled to Canaan after the earthquake and built their house there. 4.56% benefited from humanitarian aid which was used as a donation to build the house they occupy without any payment of dues. 3.64% rent their dwellings. Regarding energy, 35% of households have no power source, 27% are supplied by the public supplier, “Electricity of Haiti”, 13% use solar energy, 1% is supplied by batteries and 24% by other non-defined energy sources. According to the information provided by the 439 heads of household, 73% of them reported having private latrines in their home, 13% do not have a private toilet thus they use the latrine of a neighbor, 2% use public latrines, and 4 outdoors or in the surrounding environment.

On the economic level, three classes were defined to identify the heads of household: (i) Active persons. This class includes the persons of working age who have an activity generating income. 84% of the heads of household are in this class. (ii) Active unemployed persons. This class is composed of people of working age but who have no employment and who represent 12% of the heads of household. (iii) The retired, who represent 4% of the interviewees. The salary or monthly income of the heads of family ranges from less than 1,000 to more than 10,000 gourdes. Table 1 shows the distribution of the heads of family according to their monthly income. 33.7% of household heads receive between 5,000 and 10,000 gourdes per month. 7.8% of this population have less than 1,000 gourdes per month and 28% have more than 10000 gourdes a month. 60.9% spend at least 300 gourdes per person/day on consumption. Although subject to overvaluation, the expenditure per person on daily consumption in the household ranges from 40 gourdes to 100 gourdes. These results indicate that about 42% of households have members living on less than US$1 per day for consumer spending. The statistical series of average consumer spending per day lead to the assumption that approximately 50% of the households live in a situation of extreme poverty, with an average amount per person of 62.50 gourdes to spend on daily consumption. Only 10% of these households exceed the threshold of 2 US$ a person a day.

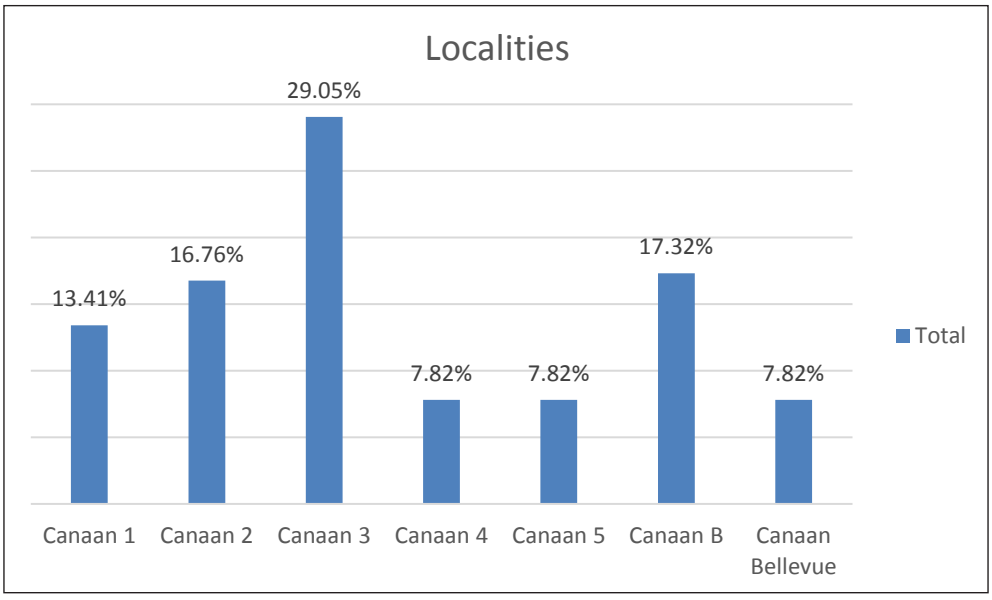

Figure 5. Distribution of water points by locality

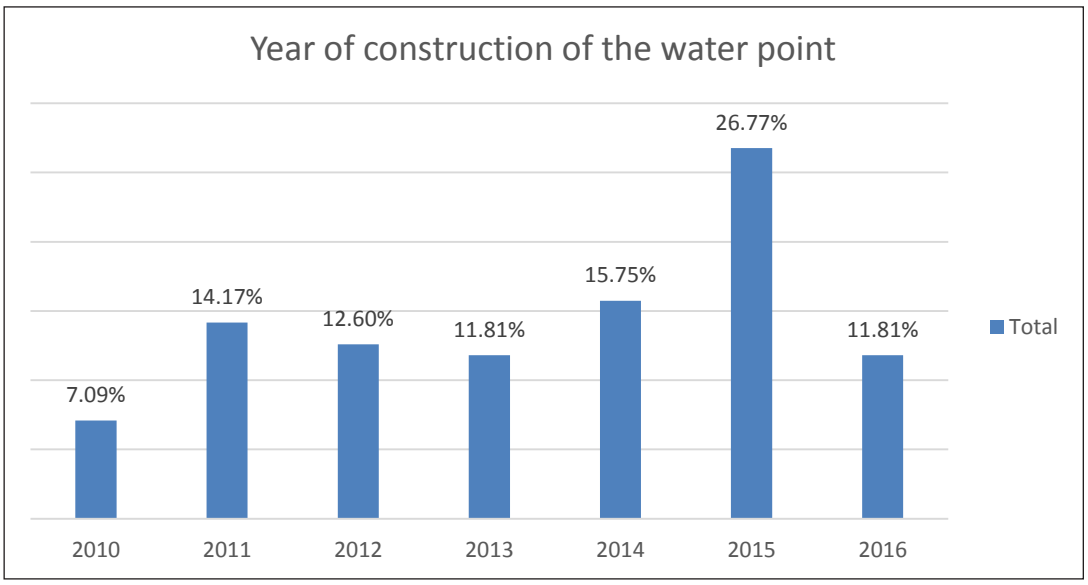

Figure 6. Distribution of water points according to their year of construction

Table 1. Distribution of heads of household by monthly income/salary

Amount in Gourdes (1 $US = 64 gourdes July 30th, 2016)	Effective	Percentage (%)
Less than 1000 gourdes	26	7.8
1000 to 2500 gourdes	50	14.9
2500 to 5000 gourdes	52	15.5
5000 to 10000 gourdes	113	33.7
More than 10000 gourdes	94	28.1
TOTAL	335	100

Analysis of water supply for human consumption in Canaan

Figure 6 provides information on the year of construction of 179 water points used for the statistical analysis. 93% of these structures were built by families, and thus become private water supply facilities. Only 7% have a collective, associative or public status. The latter have been built by NGOs or charitable institutions, or by a public institution or a group of people in the locality. Access to 95% of these water points must be paid for, whereas only 5% are free.

72% of these water points (storage tanks) are reinforced concrete structures. Wells not equipped with a pump represent 2.23% of these infrastructures; wells with hand pumps constitute 3.91% of the sample, and the collective catchment of rainwater less than 1% of the points observed. 39 water points of the179 selected provide water treated by reverse osmosis, which is theoretically intended only for drinking.

The storage tanks have a total capacity of 2,870 m^3. The minimal capacity is 1.5 m^3, and the maximum capacity is 228 m^3. The average storage capacity of these reservoirs is 17 m^33. 127 of them supply untreated water and have a storage capacity ranging from 5,292 m^3 to 228 m^3. Their average capacity is 20,453 m^3. Furthermore, 40 water points of the 167 storage tanks provide water treated by reverse osmosis, which is theoretically only intended for drinking. This water is sold by volume in units of 3.78 liters or 19 liters. The storage capacity of these facilities ranges from 1.5 m^3 to 30,240 m^3. Their total capacity is 242,324 m^3. The 167 storage tanks are supplied by water tanker trucks that fill up at boreholes in the Cul-de-sac Plain. The shortest storage tank refilling (untreated water, treated water) period is 5 although refilling can take as long as 90 days. The average storage tank refilling period is at least 20 days before the next supply by water tanker truck.

Regarding the 5% threshold set, we attempted to verify for the treated water, whether the locality significantly influences the storage capacity, the duration of failure or no water supply, the frequency of supply, and the sale price by liter at the supplier. As shown in Table 2, only the frequency of supply is significantly (p=0013) lower than 0.05. Consequently, the analysis of variance concludes that the fact of being in Canaan 1, Canaan 2, Canaan 3, does not significantly influence the storage capacity, the duration of shortage, or the sale price per liter at the source of supply of the treated water. On the contrary, the locality very significantly affects the frequency of storage tank refilling. By considering the same “locality” factor and the same dependent variables, the analysis of variance for the storage tanks of untreated water showed that only the storage capacity is not significantly influenced by the locality. All other variables are affected by the locality factor (Table 3).

Table 2. Treated water storage tank with: locality as factor (ANOVA in 1 factor)

		Sum of squares	ddl	Average of squares	F	Significance
Storage capacity	Inter-cluster	119900579.600	6	19983429.933	.998	.443
	Intra-cluster	660458972.000	33	20013908.242		
	Total	780359551.600	39			
Stop of service due to breakdown or No water supply	Inter-cluster	483.250	4	120.813	2.075	.147
	Intra-cluster	698.750	12	58.229		
	Total	1182.000	16			
Frequency of supply	Inter-cluster	707.101	6	117.850	3.213	.013
	Intra-cluster	1210.274	33	36.675		
	Total	1917.375	39			
Sale price per litre	Inter-cluster	.029	6	.005	.746	.617
	Intra-cluster	.212	33	.006		
	Total	.240	39			

Table 3. Untreated water storage tank: locality as factor (ANOVA in 1 factor)

		Sum of squares	ddl	Average of squares	F	Significance
Storage capacity	Inter-cluster	8586532747.188	6	1431088791.198	1.949	.078
	Intra-cluster	88114473569.351	120	734287279.745		
	Total	96701006316.540	126			
Stop of service due to breakdown or No water supply	Inter-cluster	30277.432	5	6055.486	3.946	.005
	Intra-cluster	67526.988	44	1534.704		
	Total	97804.420	49			
Frequency of supply	Inter-cluster	2220.911	6	370.152	3.378	.004
	Intra-cluster	13040.557	119	109.585		
	Total	15261.468	125			
Sale price per litre	Inter-cluster	.060	6	.010	5.763	.000
	Intra-cluster	.207	120	.002		
	Total	.267	126			

At Canaan, the water market is segmented into two major compartments. The first includes the providers (the tanker trucks coming from the Cul-de-sac plain) and the owners of the storage facilities. The second consists of the owners of the storage tanks who reside in the area and the households of their respective localities. For each of the compartments, neither the buyers nor the sellers can significantly influence the price of the water. All they can do is to reach agreement on the indicator (the cost of water), by basing it on the price of water in the slums and the distance traveled by the tanker trucks to deliver water.

On the structural level, the market for untreated water is situated between oligopoly and perfect competition. The structure of the market for treated water is not as perfect as that for the untreated water, regardless of the compartment considered.

Water supply in Haiti is therefore a major concern for its inhabitants and for the leaders (Rosillon et al., 2016). According to PAHO/WHO (2003) the population's drinking water requirements are 20 liters per day per person to meet basic needs, if reasonable accessibility is considered on the basis of the permanent water source being located less

than 200 m from the home. The establishment of the human population in Canaan requires a water supply system. In the absence of an adequate structure, some individuals have built storage tanks with a total capacity of 2,870 m^3, to provide water to the 200,000 people living there. By assuming that the volume available in the storage tanks is consumed on a daily basis, the water allocation per person per day in Canaan is 14.35 liters lower than the 20 liters per day per person calculated.

To estimate the maximum daily intake via drinking water, a normal default assumption is 2 L/day for adults and 0.75 L/day for bottle-fed infants (Fawell and Young, 1999). The 40 points offering treated water, thus drinking water, have a total capacity of 242,324 m^3. The results of the survey on the demographic characteristics of this population lead to the assumption that for a household of average size with 5 persons, 2 of its members will be older than 18. Based on the assumption that each household has two adults and three children, the daily demand for drinking water is 250,000 m^3 greater than the supply.

Analysis of water demand in Canaan

Table 4 shows the statistics for the number of times the households lack water. In Canaan, 5% of the daily budget of about 93% of households is spent on purchasing treated water for drinking, while this figure is less than 5% for households using only untreated water. The average percentage share of water in the daily consumption of the households consuming treated water is 13.5%. Without accurate information on household income, the salary of the head of household was considered to assess the percentage weight of water in the monthly income of the household. For 166 selected households, an average of 16% of the income of the head of household is spent on water. For 25% of households, the percentage weight of water in monthly income exceeds 24 %.

76.89% of people make a distinction between the water they drink and that which they use for laundry or bathing. 77% of heads of households having reached the 3rd cycle of basic education make a distinction between treated and untreated water. This percentage is 100 for those who have obtained their certificate of professional competence. A chi-square test was performed to assess the relationship existing between the level of education of the heads of household and the quality of the water used. The probability associated with the chi-square statistics (X-squared = 22.391, df = 7, p-value = 0.002175) calculated is less than 5%. Thus, these two variables are related to a risk of 5%.

The existence of a relationship between the size of the household and the quantity of drinking water purchased on average per day was studied. The resulting correlation coefficient is 0.15 (t = 3.1835, df = 437, p = 0.001559). This result proves that the relationship between these two variables is positive; on average the higher the size of the household, the greater the quantity of water purchased per day increases. This value is significant as the p-value associated with it is well below 5%.

Table 4. Statistics on the number of times that households were without water

Statistics	**Number of times when households were without water because of lack of money.**	**Number of times households were without water because they did not find it.**
Effective	439	439
Mean	3.21	1.42
Median	2	0
Mode	0	0
Standard deviation	4.082	2.366
Minimum	0	0
Maximum	20	10
Percentiles	25: 0 50: 2 75: 5	25: 0 50: 0 75: 2

The cost of water in Canaan

93% of the water supplied must be paid for. The average price per liter for drinking water is relatively the same throughout the area targeted. Its average price is 1.56 gourde with a standard deviation of 0.53. There are nevertheless differences between the sectors of the study area. The average price per liter is higher in Canaan 1, 2 and 3. It fluctuates between 1.60 and 1.63 gourdes, while it is between 1.37 and 1.45 in Canaan 4.5 and Canaan B.

The differences in average price per liter are much more noticeable with respect to water for domestic purposes other than drinking water. The overall average price per liter (0.46 gourde) is much lower

than in the case of drinking water. On the other hand, average prices per liter are highly contrasted between the sectors of the study area and the statistically significant differences at 0.00 level, clearly separating Canaan1, 2,3 from Canaan 4,5 and Canaan B.

The same contrast between the two groups of sectors thus concerns both types of water. It is in all likelihood based on taking into account the different access and delivery difficulties in the two groups of sectors. Furthermore, in the opinion of those involved in the field, local solidarity was not involved in the same way in the different sectors covered by the survey.

CONCLUSION

Very few water resources are organized in Canaan. In the absence of basic social services, in particular the public supply of drinking water, the population organizes itself to bring in some water by tanker trucks to supply 167 storage reservoirs. Globally, this activity is a source of employment and income for a proportion of the population. The water service is ensured by the market and according to market logic. This market provides water supply services that are subject to competition and an oligopolistic structure. The selling price and the frequency of supply remain the main variables that establish the spatial discrimination of supply in the water market in Canaan. A larger sample will be necessary in the future to study the mechanisms capable of ensuring of the democratic management of water in this area.

ACKNOWLEDGEMENTS

The authors would like to thank Les Éditions Pédagogie Nouvelle S.A. (Haiti) and the European Union (Research Program in the urban field – Grant contract: FED/2015/360-478), for financing this study.

REFERENCES

Bodson P., Benoit E.J., Duval J.C., Thérasmé K. La population de la région métropolitaine de Port-au-Prince 2009-2030. Forces et faiblesses de données statitistiques. Rapport de recherche. Université du Québec à Montréal, Programme de recherche dans le champ de l'urbain PRCU FED/2015/360-478. Port-au-Prince, 2016, 47p.

BRGM-GERSAR-LGL SA. Étude des ressources en eau de Port-au-Prince. Volet ABC besoins en eau. Port-au-Prince, 1989.

Emmanuel E., Lindskog P. Regards sur la situation actuelle des ressources en eau de la République d'Haïti. In: Emmanuel E. et Vermande P. Actes du Colloque International Gestion Intégrée de l'Eau en Haïti. Laboratoire de Qualité de l'Eau et de l'Environnement, Université Quisqueya, Port-au-Prince, 2002, p. 30-52.

Falkenmark M., Widstrand C. Population and water resources: a delicate balance. Population Bulletin, Population Reference Bureau, 1992; 47:1-30.

Fawell J., Young W. Exposure to chemicals through water. Exposure Assessment in the Evaluation of Risk to Human Health, Report of a workshop organized by the Risk Assessment and Toxicology Steering Committee, Institute for Environment and Health, Leicester, 1999, pp.22,23.

Gilles A., Joseph O. St-Fleur S. Étude Formative en assainissement, design technique de système d'assainissement et plan de communication pour la promotion de l'assainissement en Haïti. Rapport final. Port-au-Prince : Laboratoire de Qualité de l'Eau et de l'Environnement – Université Quisqueya, 2015, 126p.

Hassan A.R. Les Nations Unies et le problème de l'eau dans le monde: essai sur ONU-Eau.*Mémoire de maitrise*. UQAM. Montréal : Université du Québec à Montréal. 2008, 123p. Disponible sur : http://www.archipel.uqam.ca/id/eprint/1414 . Consulté le 17 novembre 2015.

OPS/OMS (Organisation Panaméricaine de la Santé / Organisation Mondiale de la Santé). Développement durable et santé environnementale en Haïti. Propositions pour la mobilisation de ressources. Port-au-Prince : OPS/OMS. 2003, 51p. Disponible sur :

http://www.networkhaiti.com/resource/sante/haiti_santeRepSanteEnvi_51.pdf consulté le 9/08/2015.

Rosillon F., Deroy J., Emmanuel E. Face à la détresse humaine et environnementale, gestion intégrée de l'eau et écosanté, leviers de développement pour une Haïti nouvelle. In. : Francis Rosillon : L'eau dans les pays en développement. Retour d'expériences de gestion intégrée et participative avec les acteurs locaux. Paris: Editions Johanet, 2016, pp. 313-366. ISBN : 979-10-91089-24-1.

UNEP (United Nations Environment Programme). The greening of water law: Managing Freshwater Resources for People and the Environment. UNEP - Division of Environmental Law and Conventions (DELC), 2010, ISBN: 978-92-807-3108-8, 143p.

St-Hilaire S.M., Jean-Baptiste W., Emmanuel E. Use of environmental accounting of natural resources to manage risk of water stress in Port-au-Prince (Haiti). Geological Society of America Abstracts with Programs, 2013, 45, 2. Available on:

http://www.geosociety.org/Sections/se/2013mtg/documents/2013_SE-AWP.pdf

UNESCO. Sécurité de l'eau : réponses aux défis locaux, régionaux et mondiaux. Plan stratégique. PHI-VIII (2014-2021). IHP/2012/IHP-VIII/1 Rev. Paris : UNESCO, 2012, 62p.