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Quantification of urban water demand in the Island of Santa Cruz (Galápagos Archipelago)

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ABSTRACT

Tourism exerts a significant pressure on water resources in tropical islands and is the main reason for the increase in water demand. This paper analyzes and quantifies water demand in Santa Cruz, the most populated island of Galápagos Archipelago (Ecuador). The data for this study were collected from a survey of 374 households in the two main settlements, Puerto Ayora and Bellavista. Water supply from different sources was assessed and compared with domestic and tourist water use. The study revealed that the daily average water demand per capita differs 40% between the settlements, mainly resulting from a difference in water tariffs. The tourist sector was also confirmed as the major consumer, accounting for 55% of the total water demand. Lastly, implementation of proper water demand management measures is essential in order to develop consumers' awareness and sustainable tourism.

Keywords: Water demand management; Urban water; Small tropical islands; Galápagos; Tourism

1. Introduction

Tourism is a major source of income and employment in small tropical islands [1] and small island states. Despite the fact that islands have limited water resources, the expansion of tourism over the last 40 years has been overwhelming [2]. The proportional increase in water demand is amplified by the consequent growth of local population providing facilities and services for tourists [3]. Tourists often exert demand mostly without a sustainable balance, causing environmental degradation and pressure on natural resources, particularly in water. As a result of tourism growth, several deficiencies on water supply and sewerage services in many island states have been observed [4,5]. Moreover, overextraction of water supply from coastal groundwater supplies may cause marine intrusion, worsening the quality of the water extracted; as already experienced by Malta [6] and most of Canary Islands [7]. It has been identified that the majority of these small islands have a traditional groundwater supply, affecting somehow their aquifers.

The growing pressure on water resources, caused by local population and tourism growth, climate change, pollution, etc., especially in insular areas, has major social, financial, and environmental impacts. These problems often result in inefficiency to meet a basic human service, as well as in ineffective management within institutions. Therefore, sustainable water management for this type of regions is of vital importance. The sustainable practices vary depending on several factors for every island. The study by Gikas and Tchobanoglous [8] summarizes some of them and emphasizes the importance of it. Apart from conventional sources of water supply, it is relevant to notice the importance of incorporating alternative sources, for these could be valuable for islands, as well as arid and semi-arid regions. Nowadays,

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the integrated water resources management refers to the inclusion of principles that include sustainable development and additional non-conventional water resources. Hence, the measures should be taken to account for the relative water balances [9]. The non-conventional water sources mainly comprise desalinated seawater, reclaimed water from wastewater, brackish water, and excess rainwater catchment.

The Galápagos Archipelago is a province of the state of Ecuador. It consists of 13 major islands, located 1,000 km off the coast of mainland Ecuador, in the Pacific, straddling the equator. The islands are known for their lack of water resources, and yet the population has increased 4 times over the last 3 decades, while the number of visitors have increased 11 times. This has lead to problems in water resources management, since tourist facilities such as hotels, swimming pools, restaurants, and bars have increased the pressure on these resources to satisfy tourists' needs. Furthermore, the trend of growth and development has led to difficulties the local authorities have to maintain and upgrade their water supply infrastructure. This has been stated in [10], a study on the perceptions and uses of water on the four main inhabited islands of the archipelago, but also in [11].

Planning and management in water infrastructures is extremely important, especially in water scarce areas. Many studies have aimed to contribute with this issue, such as [12]. Therefore, the first step for a proper planning is the quantification of water demands. This paper analyzes water demand in Santa Cruz Island, which holds 60% of total population of the islands, and is the hub of the tourism activity. The research looked at different types of sources, as well as the four different categories of consumers. In addition, we compared the domestic demands in the coastal town of Puerto Ayora, largest in size and extension, and highland settlement Bellavista, which has grown considerably in recent years. Both these settlements have different population size, practices, sources of water, tariff structures, and microclimate. Finally, we attempt comparisons with other islands that have tourism as a main economic activity. The results are based on the information gathered from the field survey carried out in 2014, combined with information provided by the Municipality of Santa Cruz and other relevant organizations involved in water resources management in Galápagos.

2. Case study description

Santa Cruz is the most inhabited out of the four inhabited islands. As shown in Fig. 1, it is located in the centre of the archipelago and has two main urban settlements: (i) Puerto Ayora, with approximately 12,000 inhabitants, located in the southern part of the island, and (ii) Bellavista, which is a suburb with approximately 2,500 inhabitants, located 7 km from Puerto Ayora [13]. The difference in population originates from the location of major tourist facilities at Puerto Ayora, as well as public sector offices and research centres, among others. In the highlands, where Bellavista is located, population is more dispersed due to economic activities.

The rapid population growth experienced by Santa Cruz has been overwhelming. From 3,000 inhabitants in 1980 to 12,000 inhabitants in 2010 [13] corresponds to an approximate percentage increase of 400% over the last 3 decades. In comparison, the population increase in several Greek islands

Fig. 1. Map of the Galápagos Archipelago.

over the last decades, also threatened by tourism, was only around 15%–25%, according to [14]. Furthermore, in terms of tourism growth, these islands have witnessed increase from 17,500 visitors in the 1980s to 200,000 in 2013, which is 7% annually on average [15].

The Galápagos Islands have often been denominated as 'dry'. Limited water resources on the islands have been witnessed through several investigations and studies. The limitations originate from the volcanic nature of the archipelago, and also because of climatic variability, which makes the availability of resources scarce during several months of the year and abundant in the rest, and very variable from one year to another [16]. Several cracks on the volcanic rock allow local population to extract brackish water from different crevices located around the island. Nevertheless, the nature of the ground has complicated the construction of wells and has forced authorities to take advantage from this natural cracks.

The studies identified that the islands do not have sufficient infrastructure and water resources to accommodate the growth trends [17,18]. Furthermore, construction of tourist facilities is not monitored efficiently. According to the Ministry of Tourism (MINTUR), as of December 2013, there were 106 unregistered rental premises out of the total 159. According to the Department of Potable Water and Sewage (DPWS), there are only 40 service connections belonging to tourist accommodations. The lack of control and regulation encourages illegal and informal accommodations, such as rooms and house rentals, as well as home hostels. Similar to this, the number of laundries has grown as well [11]. While, in the land cadastre of Santa Cruz, there are no premises categorized as laundries; while according to the DPWS, there are only five service connections registered in this category. During the fieldwork conducted in this study, at least 16 laundries were identified. Hence, there is a lack of existing reliable data to assess the water demand in Santa Cruz Island, and the need for an in-depth study including field surveys is obvious.

The Municipality of Santa Cruz has difficulties to cope with the rapid local and tourist population growth.

The municipal water supply system is intermittent (average supply of 3 h/d), unreliable, and has been identified as old. Water losses are high and need further assessment to define exact figures [19]. Furthermore, the water supplied by the municipal network is brackish, therefore, of non-drinking quality due to high chloride concentration levels (800–1,200 mg/l) and elevated contamination levels of faecal coliforms at the source [20,21]. Therefore, to compensate the lack of drinking water, the local population uses desalinated brackish water provided by a few small local companies, sold in containers of different sizes (500 ml bottles, 1 gallon (4.4 L), 20 L containers, and water in bulk).

Water is also extracted by pumping from various crevices located in Puerto Ayora, some of them on private properties, which makes charging from this source by the landowners practically illegal. In the crevices located in public areas, several privately owned pumps and pipelines have been installed. The water from these different crevices is neither precisely monitored nor quantified, even though SENAGUA (National Water Secretariat) has made an attempt to quantify some of the extractions.

Finally, rainwater harvesting is a common practice but only in Bellavista due to higher precipitation levels. It is a significant water source in this area and far more socially accepted than in Puerto Ayora; around 90% of the population collects it according to [10]. A summary of the different types of sources is shown in Table 1.

3. Research methodology

In order to assess the water demand of Santa Cruz, a quantitative survey was carried out during the fieldwork conducted in the period from November 2013 to January 2014 in Puerto Ayora and Bellavista. The minimum sample size was calculated based on the total number of land properties according to the 2012 cadastre from the municipality of Santa Cruz. With a total of 2,460 properties in Puerto Ayora and 435 properties in Bellavista, the minimum sample size was calculated at 339 surveys, by applying the confidence interval of 95% [22]. Next, the actual sample size per consumption category was determined as shown in Table 2. Four local assistants were hired to carry out the surveys, and fifteen residential blocks were randomly selected and assigned to each of them (ten in Puerto Ayora and five in Bellavista), covering a total of sixty blocks. The surveys were carried out during a period of 6 weeks.

Initially, ten domestic surveys were carried out in order to gauge the feelings amongst local population. The selected households finding the interview too long were passive at the moment of answering the questions. This was mostly a result of several similar interviews conducted in the past resulting in little or no improvement of the situation, afterwards. Moreover, several questions regarding the habits and social/economical status were considered sensitive/offensive. Following the trial surveys, the number of questions was

Table 1
Description of different types of water supply in Santa Cruz

Type of supply	Characteristic of water	Description
Municipal (tap water)	Brackish groundwater (800–1,200 mg chlorides/L)	Pumped from crevices by the municipality
Bottled water	Brackish groundwater desalinated by small-private companies with reverse osmosis	Desalinated from municipal (tap) water or from private crevices
'Private' pumping	Brackish groundwater from private crevices	Private pumps and pipes located in various crevices
Water trucks	Brackish groundwater	Water pumped usually from private crevices sold by the property owners
Rainwater	Freshwater	Barely collected in Puerto Ayora, more a common habit in Bellavista

Table 2
Survey sample size per consumption category in Santa Cruz

Consumption category	Number of properties	Percentage of total (%)	Optimal number of surveys[a]	Actual number of executed surveys
Puerto Ayora:				
Domestic	1,996	69	234	240
Hotels	159	6	19	29
Food and Beverages	49	2	6	30
Laundries	5	0	1	16[b]
Bellavista:				
Domestic	435	15	51	59
Others (excluded)	251	8	–	–
Total	2,895	100	310	374

[a]Calculated according to the procedure at http://www.surveysystem.com/sscalc.htm
[b]Includes not officially registered laundries.

reduced, and some of the questions were reformulated to make them transparent and culturally/socially acceptable.

The final version of the domestic survey contained five main categories of questions: (i) general information about the location and description of the household, (ii) family habits addressing the daily routines of the family members, namely the schedules of work, school, preparation of meals, etc., (iii) water demand, referring to the estimates of actual consumption per type of supplied water (bottled, municipal, and/or from trucks), (iv) environmental awareness and water-saving practices, and (v) sanitation practices, addressing questions related the type of wastewater disposal.

The surveys for other demand categories were less detailed and consisted of four categories of questions: (i) general information, (ii) average capacity of customers, (iii) water demand quantification regarding different type of sources, and (iv) environmental awareness.

4. Results of the survey

The results presented in the following section are based on the percentages of responses. Some of the totals do not add up to a 100% because those questions were attempted by choosing more than one of the offered answers.

4.1. Water demand analysis in Puerto Ayora

4.1.1. Domestic category demand

The survey indicates that 92% of the respondents of Puerto Ayora are connected to the municipal network. However, the service is irregular. The degree of intermittency shows that most of the households are supplied a few hours every day, mainly due to management problems and lack of organization in the schedules of supply.

Additional water refers to bottled desalinated water, rainwater harvesting, and brackish water from trucks. 92% of surveyed population use bottled desalinated water, while only 8% use rainwater or brackish water from trucks. Due to evidence of occasional contamination of bottled water [19], some households reported that they perform additional treatment of this water consisting of filtration, disinfection, or boiling.

Furthermore, in order to mitigate the intermittency, the households use different types of storage devices, mainly tanks, and cisterns of various capacities, depending on the family size and habits; in some cases, they even use both. The survey also considered the type and number of water appliances within a household (toilets, basins, showers, bathtubs, washing machines, etc.).

Results also pointed that the majority of the population does not have a bathtub, garden irrigation system, or a dishwasher. Measured with these indicators, a typical family in Santa Cruz is not as wealthy as it can be found in some other parts of Ecuador. On the other hand, it may be assumed that residences with more water appliances of the same type likely reflect small-scale tourist accommodation, like rental apartments. The type of water used in the appliances differs. Fig. 2 shows the percentages of respondents using brackish groundwater and/or bottled desalinated water for the different household activities.

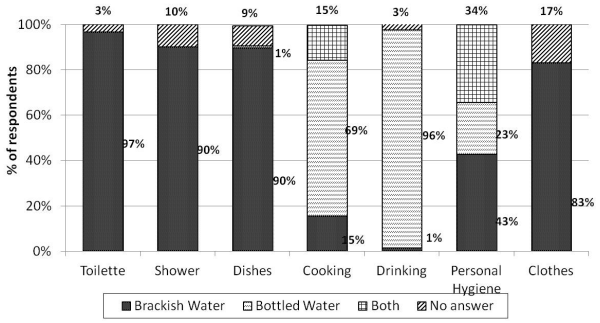

Fig. 2. Survey results for the inhabitants of Puerto Ayora regarding the use of brackish groundwater and bottled desalinated water for household activities.

Fig. 3. Picture of typical elevated tanks in Puerto Ayora.

Equally important for assessment of water demand, water leakage and spillage of water from individual tanks were also covered in the survey (the latter was observed during the fieldwork). According to the municipality of Santa Cruz, the highest water losses take place within premises and result from negligence.

27% of the respondents stated not to close the faucet when the storage tank is filled in their homes, and 70% do not use an automatic device to prevent overflow. The often visible result is shown in the examples in Fig. 3. Although the local population often complain about the lack of service and recognize the importance of saving water, the use of water-saving devices such as water efficient toilets or showers is not widespread, although the interest in having one was confirmed by the survey.

Other important information gathered in the survey concerns sanitation practices. 71% reported to have a septic tank while 20% discharge wastewater directly into crevices or the sea. This confirms the contamination of water sources by the proximity of collapsing septic tanks, as mentioned in several studies [19,20]; 63% of the respondents stated that they have never emptied their septic tank; 12% reported cleaning it every 2 years; and only 16% clean it once per year, suggesting that overflowing septic tanks may also contaminate the water from the crevices.

4.1.2. Tourist category demand (hotels and restaurants)

Several questions were posed about the water consumption of various tourist accommodations and restaurants. 87% of the hotels and 93% of the restaurants reported the municipal supply as their main source of water. The volumes of storage tanks and the frequency of filling per week for municipal water employed by hotels are shown in Fig. 4(a) and by restaurants in Fig. 4(b).

Table 3 shows the average occupancy per type of accommodation (in case of hotels) and the average number of visitors per day in a restaurant. This information is relevant for further calculation of the total water demand.

The survey also addressed questions regarding water treatment by hotels and restaurants. It appears that 43% of hotels and 13% of restaurants have their own purification system for the brackish water (from municipal or truck source). Moreover, there are different types of treatments used in both cases. 61% of hotels use sand filters; 31% use ozonation; and 8% use reverse osmosis (membrane filtration).

The use of water for different activities in hotels and restaurants varies depending on the type of water. Desalinated (bottled or municipal treated by RO) water is used mainly for personal hygiene, drinking, and/or cooking. For the rest of activities, such as toilet flushing, dishwashing, etc., the brackish groundwater suffices (municipal or from trucks). The results for hotels are shown in Fig. 5(a) and for restaurants in Fig. 5(b).

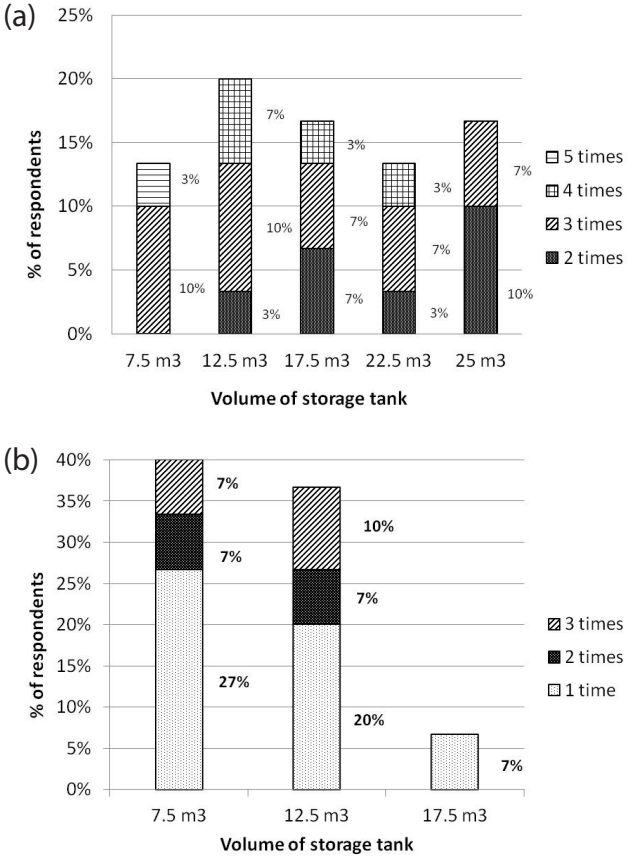

Fig. 4. Survey results regarding the frequency of filling of storage tanks per week in: (a) hotels and (b) restaurants in Puerto Ayora.

Table 3
Average capacity and average visitors for hotels and restaurants

Type of hotel accommodation	Average capacity (guests)	Percentage of restaurants (%)	Average number of visitors per day
Hostel	40	20	<15
2-star hotel	35	20	20–25
3-star hotel	45	3	30–35
4-star hotel	35	23	40–45
		33	>50

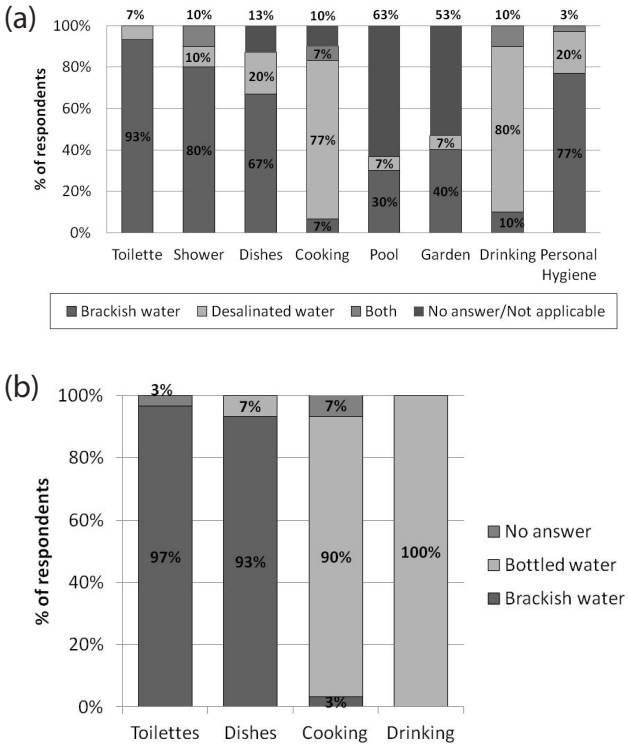

Fig. 5. Survey results regarding the use of brackish groundwater and desalinated water for: (a) hotels and (b) restaurants per type of activity in Puerto Ayora.
*Indicates desalinated bottled water or desalination of municipal water and/or trucks.
**Indicates water sold by water trucks or municipal water.

4.1.3. Water demand in laundries

The type of storage (cistern or elevated tank) and the volume used in laundries was also analyzed. 56% of the laundries have storage tanks between 16 and 20 m^3, 33% between 11 and 15 m^3, and 11% between 5 and 10 m^3. The volume of the storage tank is related to the number of hours the laundry operates and also to the number of available washing machines. 50% of the surveyed laundries operate 12 or more hours per day, and 57% of these premises have four or five washing machines in operation. Over 63% of the laundries used pressure-regulating devices to lower water consumption. Regarding sanitation practices, many laundries dispose their wastewater directly into a crevice or into the sea.

4.2. Water demand analysis in Bellavista

The survey in Bellavista was carried out only for the domestic users, for there are very few hotels, restaurants, and laundries in Bellavista. As in Puerto Ayora, the service in Bellavista is also intermittent, with over 80% of the respondents being connected to the municipal network. About one third of them receive water only once in 3 d, portraying a lower level of service than in Puerto Ayora.

Any shortage of water (since the microclimate is more favourable in Bellavista, approximately 3,100 mm of rainfall annually) is largely compensated with rainwater harvesting (81%). Furthermore, 75% claim to use bottled desalinated water, and 28% use brackish groundwater from trucks. Most of the households perform additional treatment, mostly by filtering or boiling water, depending on the type of water used. Due to the intermittency, the use of individual water storage tanks is common practice. The type and the volume vary according to the family size and consumption habits. Cisterns are more frequently used than elevated tanks, and the typical capacity is 3 m^3 per household.

The results also point the number of water appliances within households in Bellavista. The situation is similar as in Puerto Ayora where the majority of the population do not have a bathtub, garden irrigation system, or a dishwasher.

Fig. 6 shows the type of water used for different activities. As can be observed in Fig. 6(b), rainwater is widely used in Bellavista to compensate water, even for drinking (Fig. 6(a)).

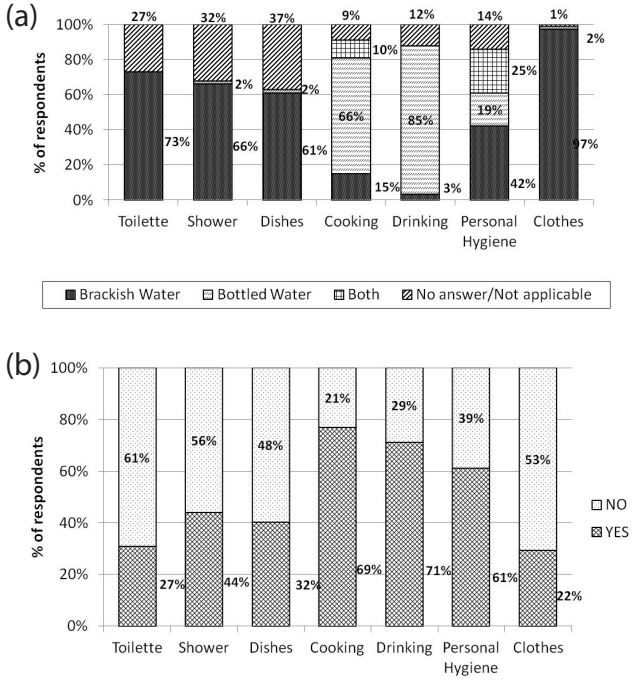

Fig. 6. Survey results for the inhabitants of Bellavista regarding the use of: (a) brackish and bottled water and (b) rainwater for household activities.
*Indicates desalinated bottled water or desalination of municipal water and/or trucks.
**Indicates water sold by water trucks or municipal water.

The use of storage tanks was also examined. The proportion of households in Bellavista that close faucets when the storage tanks are full is greater than in Puerto Ayora (53% compared with 27%). Apart from that, reuse of water or the use of water-saving devices are hardly practiced in Bellavista.

Sanitation practices in this town are similar to Puerto Ayora. Septic tanks are mostly common (88% of the population) and are not cleaned frequently (44% of the households responding to the question have never cleaned their septic tank, and 50% cleaned it once or twice per year).

5. Analyses of results in Puerto Ayora and Bellavista

5.1. The domestic category

Several similarities and differences were found by comparing the two settlements. Firstly, the percentage of connections to the municipal service is higher in Puerto Ayora (91%) than in Bellavista (81%). This may be attributed to the faster growth in the number of households in Bellavista and the consequent inability of the municipality to cope with it, since the average annual increase in number of connections from 2005 to 2013 in Bellavista was approximately 9%, while in Puerto Ayora it was only 2%. Furthermore, the frequency of service is clearly worse in Bellavista. The response by the households however differs from the information provided by the municipality, who claim that water is supplied every day.

Using information collected on the capacity of household storage units, the reported frequency of filling storage tanks, etc. and the number of users per household, an attempt was made to estimate the total water demand from the municipal supply system, as well as the specific demand per capita. The domestic water demand per capita related to the number of inhabitants per premise is shown in Fig. 7(a) for Puerto Ayora and in Fig. 7(b) for Bellavista.

From Fig. 7, it can be seen that larger households have lower demand per capita. This can be explained by the fact that the water consumption for general activities like irrigating the garden, cleaning, and cooking is independent of the number of occupants of a household. Furthermore, the figures for Puerto Ayora show a wider range of demand for the same number of inhabitants, suggesting diverse water use due to different living standards than in Bellavista. The average specific demand and standard deviation for Puerto Ayora is 163 ± 80 lpcpd. In the case of Bellavista, the average and standard deviation is 96 ± 34 lpcpd. The average water demand per capita (from the municipality) differs significantly between the two settlements, probably due to different water tariff structures.

Puerto Ayora has fixed water fees per month for different categories established by the municipality, regardless of the quantity of water consumed (5.11 USD/household for domestic category). On the other hand, Bellavista has a metered system, with a consumption-based tariff structure, where 1.21 USD is charged per cubic meter [23] as shown in Table 4.

As a consequence, the population in Bellavista tends to consume less water than those in Puerto Ayora. However, they supplement their demand with rainwater as shown in Table 4, increasing the total demand per capita. Since Bellavista has

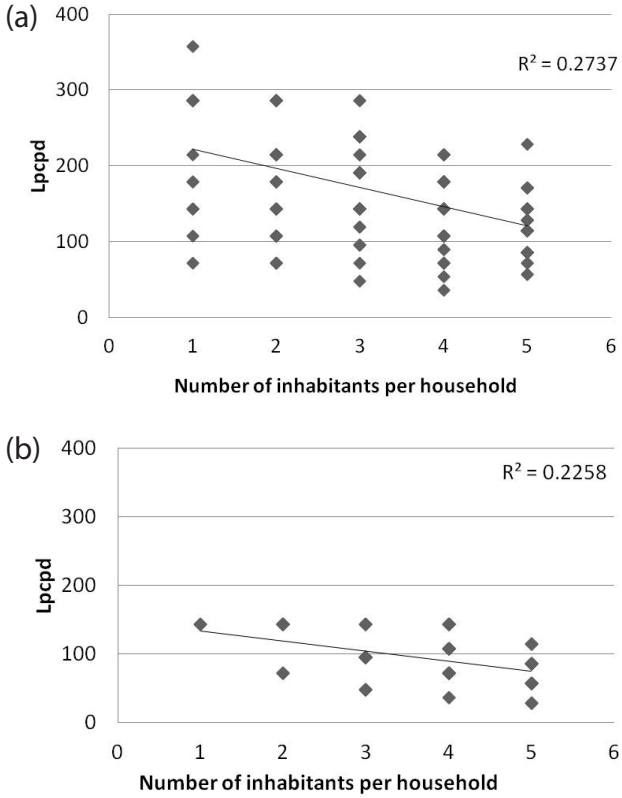

Fig. 7. Water demand per capita and number of inhabitants per household in: (a) Puerto Ayora and (b) Bellavista.

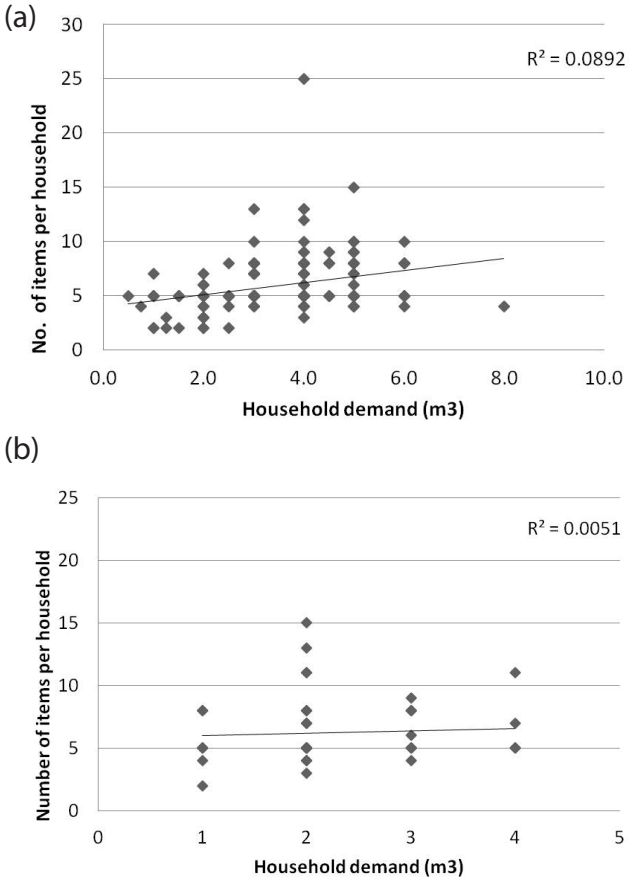

Fig. 8. Demand per household and number of water appliances in: (a) Puerto Ayora and (b) Bellavista.

Table 4
Prices of the water bill per category

Category	Fixed value (USD)
Metered (Bellavista)	1.21/m^3
Domestic	5.24
Commercial	11.24
Hotels	45
Industrial/laundries	45
Small hotels	28.50
Official	6.12

a consumption-based tariff, the customers are more aware of the value of water, unlike in Puerto Ayora, where higher wastage of water is evident with spilling of tanks. The fixed monthly fees in Puerto Ayora seem to be the main reason for such behaviour. According to the municipality, the biggest losses occur at the moment of filling household storage tanks when faucets are not closed after the tanks are filled, resulting in spilling of water. It was observed during the fieldwork that overflow tanks were left unattended for more than half an hour in some cases. The lack of metering and low tariffs in Puerto Ayora appears to encourage the population to wastewater. Nevertheless, some households have shown to use much lower quantities than the others, for the same number of occupants, which in broader terms reflects different styles of living. The high standard deviation suggests that locals use water per household randomly and there is no obvious correlation regarding social stratum or number of occupants, or the neighbourhood.

An analysis was carried out to observe if there was a relation between the number of water appliances in the household (toilets, showers, basins, etc.) and the water demand per household. Figs. 8(a) and (b) depict a low correlation meaning that the demand increases mildly as the number of appliances increases. The connection in Puerto Ayora with a total of 25 water appliances, possibly a tourist accommodation, does not show higher per capita demand, but the reason could also be the limited occupancy of the facility.

A high percentage of responses in Puerto Ayora (32%) identified leaks within their households. Unfortunately, these leaks are rarely fixed, probably due to the fact that the water lost is not charged to the consumer. On the other hand, the leaks within premises in Bellavista are much lower (reported in 15% of responses), meaning that the tariff structure influences the decision to fix them. The majority of leaks were reported to be in old and inefficient toilets, suggesting high losses since toilets account for major water use in a household of nearly 30% of total water consumption [24]. Finally, the less frequent spilling of individual tanks in Bellavista confirms overall higher awareness of the customers, which can be also explained by the difference in water tariff.

Table 5
Water demand per different sources of water in Santa Cruz

Settlement	Municipal supply (m^3/y)	Bottled water (m^3/y)	Water trucks[a] (m^3/y)	Rain water[b] (m^3/y)	Total demand (m^3/y)	Approximate population (no. of inhabitants)	Specific demand (lpcpd)
Puerto Ayora	712,188	7,243	57,518	N/A*	776,949	12,000	177
Bellavista	82,481	2,683	48,307	97,444	230,914	2,500	253
Total	794,669	9,925	105,825	97,444	1,007,863	15,000	190

[a]Water from trucks refers to partial pumping from 'private' crevices.
[b]Rainwater was not considered in Puerto Ayora for it is practiced by less than 10% of surveyed households.

5.2. Total demand quantification for domestic sector

The quantification of domestic water demand was done for all types of sources used. This was possible based on the questions regarding the frequency of service/purchase and volumes of the different sources for every household. The results are shown in Table 5 with total demand per capita calculated for both settlements.

Table 5 indicates relatively high specific demand in view of the reported intermittency and scarce water sources. The public perception in both settlements is clearly that additional water next to that supplied by the municipality is necessary. Nevertheless, rainwater is barely collected in Puerto Ayora. One reason is lower precipitation than in Bellavista, but also that this practice is considered archaic [9]. Oppositely, people in Bellavista collect rainwater regularly and use it for all household activities. Furthermore, in both settlements, the bottled desalinated water is used mainly for drinking and for personal hygiene, while brackish groundwater is used for other domestic activities such as cooking, dishwashing, laundries, toilet flushing, and showers. Moreover, the supply by water trucks has high contribution to the high total demand in Bellavista, which could be explained by lower number of municipal service connections. In summary, the average per capita consumption is considerably higher in Bellavista than in Puerto Ayora. It is however to be noted that all the results are based on the personal assessments of the respondents; this certainly needs to be verified by more accurate measurements. Currently, there is an ongoing study where water metering is implemented in a pilot section in Puerto Ayora, which will help to validate the figures obtained from the survey.

The calculated domestic demand in both settlements is comparable with the domestic demand reported in the literature on other tropical islands dealing with tourism. Nevertheless, Table 6 shows the average for Santa Cruz in Galápagos to be lower than in Greece (Crete, Aegean Islands), Spain (Mallorca), Dominican Republic, or Trinidad and Tobago.

Table 6
Domestic water demand per capita in various tropical Islands

Island	Village	Demand per capita (lpcpd)
Crete (Greece)	Chania	443
	Rethimno	424
	Iraklio	474
	Lasithi	338
Aegean Islands (Greece)	Lesvos	246
	Chios	203
	Samos	270
	Dodecanese	207
	Cyclades	164
	Kalymnos	285
Santa Cruz de Tenerife (Spain)	Tenerife	250
Mallorca (Spain)	–	300
Korčula (Croatia)	–	184
Barbados	–	209
Jamaica	–	160
Dominican Republic	–	421
Trinidad and Tobago	–	324

Note: Adapted from references: [13,21,25–28].

5.3. Analysis of tourist and laundry categories

The total demand was also assessed for tourist facilities in Puerto Ayora: private apartments, hotels, and restaurants as shown in Table 7. The figures have been derived based on the survey questions regarding the volume of storage facilities and the frequency of refilling storage tanks, as well as amount of bottled desalinated water and water supplied by trucks.

Fig. 9(a) shows the daily demand of surveyed hotels; the horizontal axis represents each hotel, given by a serial number. For example, from 1 to 6 are hostels with capacity of 25–45 people, from 7 to 9 are two-star hotels with capacity of 20–25 people, from 10 to 26 are three-star hotels with capacity of 10–50 people, and from 26 to 30 are four-star hotels with capacity of 25–50 people. The water demand varies according to the type of accommodation (hotel rating) and the average capacity. Additionally, the hotels reported whether they have their own purification systems either perform additional treatment for the municipal water as shown in Fig. 9(b).

Majority of the hotels and restaurants are connected to the municipal supply, but some hotels (mainly three stars), and virtually all restaurants are mainly supplied by water trucks. The four-star hotels mostly have their own purification systems (by desalination) and are less dependent on

Table 7
Water demand quantification for hotels and restaurants in Puerto Ayora

Type of accommodation	Average capacity (customers)	Municipal water (m^3/d)	Water trucks (m^3/d)	Bottled water (m^3/d)	Specific demand (lpcpd)
Hostel	40	8.1	0	0	205
2-star hotel	35	4.0	12.3	0.1	470
3-star hotel	45	6.0	29.7	0.3	667
4-star hotel	35	9.6	9.0	0.1	535
Average	38	7.0	11.3	0.1	469
Restaurants	15	0.2	0.9	0.1	126
	25	0.5	1.7	0.1	158
	45	0.4	0.9	0.2	46
	50	0.4	1.8	0.3	79
Average	34	0.4	1.3	0.2	102

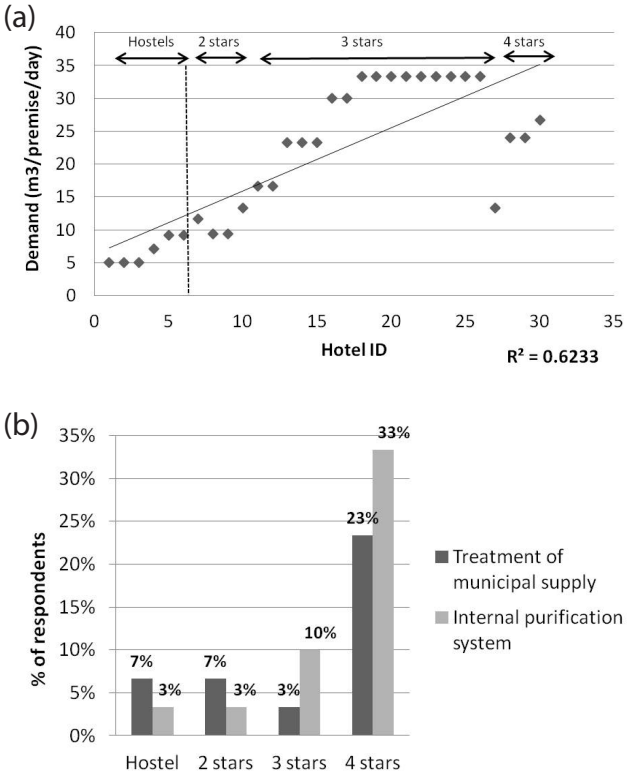

Fig. 9. (a) Demand per surveyed hotel regarding rating and (b) internal purification per surveyed hotels.

the municipal supply, using it less than lower-class tourist accommodations do. Moreover, three-star accommodations use more water because of higher occupancy. In Galápagos, the tendency is towards middle-class tourists; those who cannot afford luxurious accommodations (at average 350 USD/night), which seem to be more careful with water use.

The average water demand per bed, estimated by the survey respondents, was 168 lpcpd, which is far from reality, since the calculated average is 469 lpcpd, i.e., almost 3 times higher. Furthermore, in 10 out of 30 restaurants, the water demand estimate was approximately 0.5 m^3/d. Moreover, 50% of hotels and 36% of restaurants confirmed a variation in the consumption of water depending on the (hot or cold) season of 30% and 40%, respectively.

Table 8
Total water demand quantification considering all categories

Category	Municipal supply (m^3/d)	Bottled water (m^3/d)	Water trucks[a] (m^3/d)	Total demand (m^3/d)
Domestic	1,951.2	19.8	157.6	2,128.6
Hotels	1,107.2	20.6	1,788.8	2,916.6
Restaurants	69.3	7.6	51.1	128.0
Laundries	28.5	0	20.1	48.6
Total	3,156.2	48.0	2,017.6	5,221.8

[a]Water trucks refers to pumping from "private" crevices.

Finally, the total water demand for Puerto Ayora was calculated based on the average consumption derived from the survey, multiplied by the total number of premises per category according to the land cadastre of the municipality.

Table 8 shows the highest demand from the hotels for municipal water and from trucks. Approximately 24% of total demand of municipal water is from unregistered accommodations, which account for 66% of the total in the category of hotels. As in many other tropical islands, the biggest consumers are tourist accommodations, proportionally to the ranking of hotel. The restaurants and laundries do not contribute significantly to the total demand in Santa Cruz, although the total number of registered restaurants and laundry premises in the land cadastre may be higher than reported.

6. Conclusions and recommendations

Even though the answers of the surveys may be overestimated or underestimated, suggesting a possible inaccuracy and a subjective view, this approach is significant for a

preliminary estimation. In the complete absence of data, it is considered a useful methodology.

Water demand quantification for the island of Santa Cruz has been challenging; the available data are scarce and inaccurate. The conducted survey provided a scenario reasonably close to reality, enabling preliminary calculations of water demand for different consumption categories. The highest water demand was observed for the hotels (with an average consumption of 469 lpcpd), which account for 49% of the total water demand on this island. This figure complies with the literature for other tourist accommodations on tropical islands worldwide, who are threatened also by high tourism growth rates.

Regarding the domestic water use, there is an evident difference in per capita averages of consumption of municipal water (163 lpcpd in Puerto Ayora and 80 lpcpd in Bellavista) suggesting that different tariff structures may influence the consumption. In Bellavista, where water is charged per cubic meter, the demand per capita is reduced by nearly 50% than the demand in Puerto Ayora. This suggests that low tariffs influence negatively on higher consumption.

The total domestic per capita demand, including all types of sources, is significantly higher in Bellavista (253 lpcpd). This is caused by a high consumption from rainwater and water purchased from trucks. Based on these findings, it can be concluded that in general there is no real scarcity of the water resources within the island (190 lpcpd in average is consumed per inhabitant in Santa Cruz) but instead there is a deficient management of water supply and demand.

Fixed tariff structures should be abolished in Puerto Ayora and further reviewed in Bellavista. Revised tariffs will help to increase environmental awareness amongst the population and therefore reduce the demand significantly. Also, the municipality will have higher revenues and the financial means to improve the service. In addition, the installation of water meters needs to be considered in Puerto Ayora, in order to help controlling water losses within premises. This would allow more accurate figures of water demand for different categories and consequently a solid base to change policies regarding water demand management. Furthermore, new policies regarding spilling of water when filling tanks must be seriously considered, and penalties may be needed. With a systematic and regular control of this problem, the overall water losses will be lower, and there would be additional volume of water for more hours of service.

Finally, it is necessary to determine the exact number of tourist accommodations in Santa Cruz, in order to make more accurate demand estimates. The MINTUR should monitor systematically the establishment of new tourist facilities and enhance the legalization of the current ones. Also, the promotion of eco-tourism, attracting visitors who understand environmental threats, is needed to control current massive tourism. Unless sustainable measures are developed on time, the Galápagos Islands may lose all their natural attraction and endanger unique species.

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