Build up a database to determine the management of drinking water in the Province of Cartago, Costa Rica
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ABSTRACT

In Costa Rica, the majority of people have drinking water in their homes, but because of climate change along with the increase of population and non-existent planning programs, the distribution of this resource could be affected. To ensure sustainability of drinking water, information on demand and supply is required. Unfortunately, the information is outdated and there is no single unified database to which all management related institutions have access. Costa Rica has many public institutions that perform quality control, monitor and provide licenses for water exploitation. Each institution organizes its information according to their own criteria, therefore, making it impossible to compare the data, and difficult to identify the main problems. The authors verified and compared every database available, aiming to consolidate one database to determinate management of water distribution in Cartago. The main results of this research identified distribution of water suppliers throughout the province, the results were: Aqueduct Administration Associations (27.1%), Municipal Aqueducts (60.2%) and National Costa Rica Aqueducts and Sewerage Institute (AyA) Aqueducts (14.1%). One hundred per cent of Municipal and AyA Aqueducts disinfect and provide potable water, but 25% of Aqueduct Administration Rural Associations do not disinfect the water and there is not enough information about the quality of water that they offer.

Key words | disinfection water, drinking water, rural water distribution, water management, water suppliers

INTRODUCTION

The use of drinking water is of great importance for life and is an extremely delicate issue. In Costa Rica, up to 95% of the population in urban areas receive quality drinking water (MinSalud 2013); however, in rural zones, many areas have no drinking water supply (Mora & Araya 2008). Costa Rica occupies the 47th position among 147 countries in improved sanitation facilities (Mora & Portuguez 2008). The main water suppliers in the country have the technology, human and financial resources for adequate water management, contrarily, in rural areas the Aqueduct Administration Rural Associations (ASADAs) did not present these conditions.

There are many databases of potable water distribution in Costa Rica, but the methodologies and index classification are different; all the data is dispersed, it is not consistent, many of the data is inaccessible to the public or is outdated. Because of this, all the information is uncertain, no one uses the information for planning and it is impossible to determine the risks associated with the supply of water.

GENERAL CHARACTERISTICS OF THE STUDY SITE

The Province of Cartago has a population of 490,903 inhabitants, according to the National Costa Rica Institute of Census (INEC). Administratively, it is divided into eight cantons and two municipal district councils, with an extension of 3,125 km².
Eighty-four per cent of the population live in urban areas, whereas the remaining 16% inhabit rural areas. The cantons with the greatest proportion of rural population are Turrialba (43%), Jiménez (47%), Alvarado (45%) and Paraíso (23%) (INEC 2011).

Climatic change impacts

Documents from the Meteorological National Institute and Environmental Ministry predicted for 2080 an increase of annual rainfall in the Caribbean basins (Pacuare regime, Reventazon and Sixaola). Seasonal variations are very marked, and it is predicted that in the rainy season (November–February) the rain will decrease by up to 30%, but on the contrary it will increase by 100% during the dry season (June–August). These changes would relate to lower activity of cold fronts and north winds during the winter, and greater intensity of wind trade during the summer. Costa Rica is one of the hottest points of climatic change in tropical areas (AIACC-LA 2006; Alvarado et al. 2012). The availability of extracted drinking water could change because of the new patterns of rain.

Potable water service suppliers in Costa Rica

National Costa Rica Aqueducts and Sewerage Institute (AyA) and Municipalities are the main water suppliers in Costa Rica (Aya 2016), but there are many private entities like Rural Aqueduct and Sewerage Committees (CAARs), ASADAs and other private organizations that operate aqueducts, wells and/or springs (Reglamento de ASADAs 2000; Espinoza et al. 2003).

The proportion of the population served by each one of these service providers is not clearly defined because each water supplier has its own database and it is not common to share information with others.

AyA is the principal company of water distribution, they have the experience, budget and technical skills in this area. The rural inhabitants are attended by ASADAs (associations for management of aqueducts) and CAARs. These types of organization are a special authority focused on drinking water, there is no technical or professional management but instead the neighborhood community cooperates and organizes itself in order to provide clean and safe drinking water.

Population increase in country

The global increase of population in Costa Rica has decreased in the last two decades, but the absolute number of people that live in the country grew from 2,665,865 in 1985 to 4,890,379 in 2016 (Rosero 2002).

Institutions involved in governance, control and supply of the service

The National Controller Office (CGR) authorizes budgets for all of the public institutions in the country (CGR 2016). Although this entity does not directly intervene in the operation of ASADAs, it has produced reports on the quality and distribution of the water they provide. The Regulatory Authority of Public Services (ARESEP) authorizes maximum rates charged by service providers, which affect AyA, Municipalities and ASADAs (ASESEP 2016).

Besides managing drinking water in the country, AyA owns aqueducts for water administration and distribution. Its relationship with ASADAs is for exertion of control, surveillance, auditing, evaluation, normalization and management direction from the scope of governance, as the system management itself corresponds to ASADAs by delegation of the AyA (Reglamento de ASADAs 2000).

The Ministry of Environment, specifically the Water Department (MINAE), grants operating concessions to private and public entities (MINAE 2016). The National Environmental Technical Secretariat (SETENA) analyses and approves environmental impact studies for projects of potable water supply, sanitary sewerage and residual water treatment systems (SETENA 2016). The Ministry of Health approves the potable water supply projects, applies norms and audits the quality of water provided to the population and, in the case of Cartago, exerts sanitary surveillance over the ASADAs and certain other private aqueducts (MinSalud 2016). The National Service of Underground Waters, Irrigation and Drainage (SENARA) handles irrigation, drainage, flood prevention and preservation of aquifers; however, the only information offered by them are the cubic meters of concession granted (SENARA 2016).
In general, 55% of the population in Costa Rica is supplied by underground waters (Morales-Hidalgo 2010); superficial waters are highly polluted in the Great Metropolitan Area, therefore they cannot be used directly to provide the drinking water supply.

**METHODS**

It is necessary to compile only one database in pursuance of identifying the water distribution and the risk associated according each water supplier. In order to develop this, it was required to:

1. Browse the Internet and documents given in government offices, all available databases related to water supply in the Cartago Province.
2. Identify the principal key/descriptive words used in the compiled database. The list of key/descriptive words used for compilation in the new database were:
   (A) number of subscribers attended by:
      (1) ASADAS
      (2) CAARS
      (3) Municipalities
      (4) AyA
   (B) Name of each water supplier
   (C) Phone number of each water supplier
   (D) Water disinfection methods applied for every water supplier.
   (E) Population attended by each water supplier: The data managed in the various institutions corresponded to the number of subscribers by service provider. In order to identify the proportion of the population supplied, it was necessary to geographically locate each provider and, by employing the population density index per district reported by the INEC, it was possible to estimate the population supplied. The population index of each canton used was indicated in the 2011 Census of the INEC.
   (F) Physical location of each water supplier.
3. Classify the ASADAs: Costa Rica does not have any official criteria to classify ASADAs according to the number of subscribers, but in many papers and technical information the people classified this using the terms: large, medium and small ASADAs but without any references. The authors decided to classify those ASADAs according to their frequency distribution by sorting them out by their number of subscribers. The results of this classification is the following:
   A. Small: ASADAs with 1 to 56 subscribers
   B. Medium: ASADAs with 57 to 216 subscribers
   C. Large: ASADAs with 217 to 1,175 subscribers.
4. Verify the rigorousness and quality of the information. All the information from each database was read, and the duplicated records were deleted. Other records were peculiar because their number of subscribers was the same, resulting in the authors checking all of them by telephone calls, or asking the government authorities. In the case that records could not be verified, they were automatically deleted. The rest of the records of physical addresses for every ASADA were checked by georeferencing on a map.
5. Develop a compiled database with the validated records.

The authors checked and selected the most updated and validated record from each database and compiled it into one database.

**RESULTS AND DISCUSSION**

**List of databases for water resource planning found in Costa Rica**

The authors used the databases listed in Table 1. All the data was obtained between 2014 and 2015. AyA offered some databases for online consultation in their website, but they are incomplete and access to all of the information is impossible.

The MINAE databases have information about waterworks concessions granted to private entities, but it is very difficult to understand and use the information given that some of it is outdated and incomplete.

The offices of SENARA provide some information about flow volumes, yet it has not verified the available amounts of ground waters and the website does not offer any information that is useful for planning.

The National Institute of Statistics and Censuses (INEC) collected the results of the national household survey and
hence contains a certain amount of information about water distribution, but the classification system is different from the other entities.

The Ministry of Health (MinSalud) has a database used for sanitary surveillance. This database was built upon basic information provided mainly by ASADAs and, unfortunately, some information was given by the AyA. Meanwhile, the ARESEP has databases of payment rates and some information about ASADAs, although it is incomplete. All of these databases are inconsistent and cannot be employed directly for research in order to estimate the state of water supply. Each organization uses sub-classifications and methodologies that cannot be compared.

<table>
<thead>
<tr>
<th>Database</th>
<th>Records found in the database</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online. National census 2011, by National statistical and census of Costa Rica (INEC 2011)</td>
<td>Quantity of subscribers from ASADAs-CAARs and AyA</td>
<td>The number of subscribers served by ASADAs and CAARs presented together</td>
</tr>
<tr>
<td>Online. National water concessions (MINAE 2016)</td>
<td>None</td>
<td>The database is incomplete</td>
</tr>
<tr>
<td>Online. Comunal system (System of information about Water Supply community organizations, administered by AyA (SICEO)) by AyA (AyA 2016)</td>
<td>None</td>
<td>The database did not have any statistical information, only offered some technical reports</td>
</tr>
<tr>
<td>Electronic sheet. Working forms of Health Ministries, Region of Cartago. This information was provided by Health Ministries</td>
<td>Number of subscribers, name of each ASADA, disinfection state</td>
<td>This information was the most updated and useful. Some repeated records were found and others were incomplete</td>
</tr>
<tr>
<td>Electronic sheet. Database of exploitation of water, this information was provided by CGR</td>
<td>Name of each well, river, spring, the exploitation flow and location</td>
<td>The information was disorganized; some records were not possible to understand. The information about Cartago was insufficient</td>
</tr>
<tr>
<td>Electronic sheet. Distribution of water by Municipal, Special Audit on Municipal Aqueducts Administration, this information was provided by CGR</td>
<td>Number of subscribers of each municipal aqueduct</td>
<td>The information was clear and useful</td>
</tr>
<tr>
<td>Electronic sheet. Comunal system (SICEO) by AyA. This information was provided by CGR</td>
<td>Number of subscribers, name of each ASADA, disinfection state</td>
<td>This information is compared with the electronic sheet from Health Ministries</td>
</tr>
<tr>
<td>Database of Resource License of MINAE. This information was provided by CGR</td>
<td>List of every resource licence registered by private companies, quantity of water provided, type of water used, date of licence, and quantity of water offered</td>
<td>Although there were many records in this database, the information was mixed and it was not possible to use these records to determine the offer and supply of water</td>
</tr>
<tr>
<td>Online. ‘Servicio Nacional de aguas subterráneas, riego y avenamiento’ SENARA 2016</td>
<td>None</td>
<td>The online site did not offer any kind of information</td>
</tr>
<tr>
<td>Online. ARESEP 2016</td>
<td>None</td>
<td>The online site only offered information about payment rates and quality of water</td>
</tr>
</tbody>
</table>

### ASADAS

The results corresponding to the comparison among the various databases according to the ASADAs water distribution are condensed in Table 2. The databases of AyA and the MinSalud only include the ASADAs in their index classification criteria, but INEC includes the CAAR, because of that the authors decided not to use INEC database. The AyA database was difficult to understand because of duplicated records, and did not have the physical addresses of...
many ASADAs. On the other hand, the ‘Working forms of Health Ministries, Region of Cartago’, has more detailed information about each ASADA, and it has the most updated database, the authors decided to use this last database as a reference. Prior to using the working forms of MinSalud, it was necessary to check the records. The methodology by means of which information is compiled depends solely on the team in charge of that task within the institution. Concerning this research, it was detected that in the Ministry of Health, the most reliable data corresponded to the Governance Unit of Paraíso, as it is in this office where the greatest openness and communication with all audited ASADAs exist.

As can be observed in Table 2, information on the number of subscribers in each canton, as well as the amount and type of water supply, is hardly comparable since data differs in all cases. In regards to INEC, data from the national household survey cannot be overlapped or correlated to data from the other institutions mentioned above as all of these employ different classification systems for operating entities and water management.

According to the findings it is impossible to determine that only one of the other databases has the most reliable and representative information. This creates a serious issue for planning, auditing, response and determination of risks for the water resource in Costa Rica.

Municipal aqueducts

The information of subscribers from aqueducts administered by the municipality was consistent between the different databases; aleatory check of the information shows the accuracy of them, consequently, corroboration was unnecessary. The authors decided to use the database ‘Special Audit on Municipal Aqueducts Administration, instrument by the General Accountability Office of the Republic, 2014’ because all the information was collected directly from the water service receipts emitted. The results of the number of subscribers of Municipal Aqueducts are shown in Table 3.

Aya aqueducts

Regarding the data from AyA aqueducts, it was not possible to corroborate such information with the administering entity, as none of its official databases were available despite repeated searches for them in different offices. It was
necessary to search the records in the national census, the data is shown in Table 4.

**Summary of distribution of water supplies in the Cartago province**

The study included all the water suppliers from Cartago province. Given that the database of the Ministry of Health was the most updated, the authors decided to continue employing the database as a reference for ASADAS, taking account of the other databases occasionally. Nevertheless, the MinSalud Database contained repeated and confusing records, thereby making it necessary to corroborate it with personnel from their respective governance offices. Cases that were not possible to corroborate were consulted directly with the respective personnel of each ASADA. The data with the highest degree of uncertainty corresponded to the canton of Turrialba, which may be justified by its broad extension, the presence of indigenous areas and the low socio-economic development of the zone. The database had records for 113 ASADAs, yet it was impossible to locate by phone or to know the physical address of 24 of them (they were not included in the final database).

In Cartago province, 60.2% of subscribers are attended by municipal aqueducts (Table 3), 23.6% by ASADAs (Table 2) and only 14.1% by AyA (Table 4). The local distribution according to different cantons is shown in Figure 1. In the canton of Alvarado and the Central canton, potable water distribution is managed solely by the local municipality. In the cantons of La Unión and El Guarco, the AyA is the main administrator. In Turrialba, Oreamuno and Jiménez – the most rural and extensive cantons – the task of water distribution corresponds to ASADAS, which are the entities possessing the least financial and technical resources. Significant differences are detected in the number of subscribers in the Province of Cartago; thus ASADAs are found servicing from 26 up to 2,000 subscribers, but municipality aqueducts are servicing from 1,327 up to 33,829 subscribers. The number of subscribers for AyA are still not completely confirmed, resulting in the authors having to use the reference of the national census and not the official data from AyA since it was never submitted.

AyA and municipal aqueducts have potable treatment facilities, but ASADAS do not have any. The consolidated database was verified as detailed in the methodology, it was built up using: (a) the database of MinSalud for determined subscribers from ASADAS, (b) CGR references for Municipal Aqueducts and (c) INEC estimations for AyA aqueducts. Figure 1 shows the distribution of water suppliers in Cartago and their cantons.

Costs for construction, design and data collection for maintenance of every database is very high. For example, in the case of AyA, the investment reached approximately 2 million US dollars (CGR 2016). No information about the cost of designing a database is available in the case of the Ministry of Health, but it is known that this institution has permanent staff hired to operate and maintain up-to-date databases. The INEC, on the other hand, invests considerable resources in the elaboration of a national survey, which gathers general information. However, the general character of this information does not allow for its adequate use in the planning of and response to national issues.

**Consumption of non-disinfected water in the Province of Cartago**

The frequency distribution of the number of subscribers of ASADAs allows the classification of the ASADAs by size. Those that have 476 or more subscribers were classified as large ASADAS, medium between 86 and 475 subscribers, and less than 85 are classified as small. Another form of classification is whether the water is

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**Table 4**: Number of subscribers of AyA Aqueducts in the Province of Cartago, 2014

<table>
<thead>
<tr>
<th>Canton</th>
<th>Number of subscribers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central canton</td>
<td>718</td>
</tr>
<tr>
<td>Jiménez</td>
<td>0</td>
</tr>
<tr>
<td>La Unión</td>
<td>10,485</td>
</tr>
<tr>
<td>Oreamuno</td>
<td>6</td>
</tr>
<tr>
<td>Paraíso</td>
<td>18</td>
</tr>
<tr>
<td>Turrialba</td>
<td>122</td>
</tr>
<tr>
<td>Alvarado</td>
<td>64</td>
</tr>
<tr>
<td>El Guarco</td>
<td>6,618</td>
</tr>
<tr>
<td>Total</td>
<td>17,984</td>
</tr>
</tbody>
</table>

Online. National census 2011, by National statistical and census data of Costa Rica (INEC 2011). In order to estimate the total population the number of subscribers was multiplied by 4.2.
disinfected or not. Forty-four ASADAs applied disinfection to water, while the remaining 45 did not. Of ASADAs that do not apply disinfection, 71% were classified as small. Table 5 shows the distribution of all ASADAs in Cartago.

The population supplied by ASADAs in each canton of the Province of Cartago is shown in Table 6, along with the population supplied with non-disinfected water. Turrialba has the greatest number of subscribers receiving non-disinfected water. Twenty-five per cent of the population in Cartago province attended by ASADAs is not supplied with disinfected water.

All the municipal and AyA aqueducts provide disinfection to water, but 44 ASADAs (about 50%) were found lacking in disinfection systems, representing 25% of the population attended by ASADAS. Eighty-two per cent of small ASADAS and 23% of large ASADAs do not have disinfection. Small ASADAs are characterized by having scarcely trained workers and many operation and maintenance problems, which adds to their low income. The Cantons of Turrialba and Oreamuno show a high percentage of population receiving water with no disinfection from ASADAs, implying a serious risk for these areas.

There exists a risk associated with the topic of non-disinfection in rural settlements in the country, as is clearly

![Figure 1](https://iwaponline.com/washdev/article-pdf/6/4/584/386004/washdev0060584.pdf)
reflected in this study. In the area of Turrialba in particular, 68% of ASADAs do not possess disinfection systems but the majority of these are classified as small and the impact on the total population in the canton is 32%.

**CONCLUSIONS**

It is confirmed with this study that there exists some water resource information in the country, however it is scarcely processed, inaccessible, dispersed and inconsistent. Decision makers in the political and technical field cannot hold information contained in these databases as true, since suppositions and overlapping of information may take place, which does not constitute good practice for the government.

Distribution of water supplier information is dispersed and inconsistent; a big proportion is unavailable to the public and outdated. It was necessary to perform a field investigation in order to acquire the most recent and complete data, and consolidate them into one unique document.

Prior to the building of the new consolidate database, all the information was disorganized and dispersed, the name of each record different from every database and because of that it was impossible to use this information, therefore making it essential to create an updated, unique and reliable database in order to establish risks associated to drinking water distribution in the Province of Cartago.

The main purpose of this research was to build a new consolidated database. The information should be checked and updated to avoid downgrade. Public universities could contribute to strengthening the information with new data from other regions.

To access and analyze data from the hydrological sector is a complex task, one performed with great uncertainty. This information has been collected by local and national institutions at different times with the employment of different methodologies and instruments. Consequently, there is overlapping and contradictions in some cases that lead to low reliability for using this information as a tool for water resource management and planning, especially in the face of climatic change scenarios.

Costa Rica is a country of limited economic resources. The lack of coordination, planning and organization among the various institutions causes squandering of these resources, which could otherwise be spent in maintaining a unique and widespread database, of easy access to any citizen or organization requiring it.

An evaluation of the institutional framework of the drinking water and sanitation sector in the country must be made, aiming towards the establishment of policies, governances allowing for efficient planning and the development of this sensitive and critical sector.

Due to their structure, ASADAs are potable water suppliers that face greater risks. The principal and most evident risk is non-disinfection, only observed in ASADAS, principally the smaller ones. Furthermore, there are many institutions exerting governance, control, audit and regulations over them.

Finally, a tendency to use AyA or municipal services is observed in more urban populations with greater financial incomes, leaving administration on behalf of ASADAs to the more rural and dispersed populations. This situation then becomes critical for the more distant and segregated towns, where ASADAs are organizations with very little preparation and resources that confront great difficulties for providing potable water, additionally aggravated by the many institutions auditing, approving and governing the ASADAs as a consequence of the organizational structure of the country.
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