# Water as a mirror of environmental health:A symbiotic baseline study in Costa Rica's Osa Peninsula.

Milena Argentina Castro[1], Valentina Rodríguez[2], Luis César Rivera Montero[3], Daniel Ulloa[4], Manuel Salas[5], and Oscar Andrey Herrera[6]

[1]Centro de Investigaciones en Matemática Pura y Aplicada, Universidad de Costa Rica
[2]Escuela de Tecnologías en Salud, Universidad de Costa Rica
[3]Instituto de Investigaciones en Salud, Universidad de Costa Rica
[4]Escuela de Ingeniería Química, Universidad de Costa Rica
[5]Escuela de Ingeniería Mecánica, Universidad de Costa Rica
[6]Centro de Investigación en Ciencia e Ingeniería de Materiales, Universidad de Costa Rica

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### Abstract

To understand an integral environmental health dynamic a symbiotic observation of water and its socio-environmental interactions should be knitted. Assuming circularity of water can provide related knowledge. A robust scientific evidence baseline is essential to allow health impact evaluation, in order to inform collective decisions on infrastructure development. Mixed methods are used to elaborate an analytical process to combine different heterogeneous data sources. Three analytical levels were defined: Population health, socioeconomic status infrastructure and natural resources specifically river basin. In 2017, water quality perception was surveyed in Drake, Osa Peninsula, Southern of Costa Rica. Then in 2018, a socioeconomic and general health census strategy was undertaken. A water microbiology survey was applied to assess river basin quality. Interaction between population health economics and river basin was observed on aqueducts. This technology play an essential role enabling communities for health improvement and address reduction of socio-economic inequalities by means of community-specific tools for social learning. Since water filtering was identified missing in overall water systems, a water bio-sand filter was designed and tested as a novel conservation technology to cultivate drinkable water at a very low cost. Drake's inhabitants perceived the need for technologies to treat drinkable water. Conservation culture should be considered for the design of new aqueduct communal systems. An integral ecosystem health assessment index (IEHAI) is proposed as a baseline specification model to improved water resources research.

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[1] Escuela de Tecnologías en Salud, Salud Ambiental, Universidad de Costa Rica,
[2] Instituto de Investigaciones en Salud, Universidad de Costa Rica,
[3] Escuela de Ingeniería Química, Universidad de Costa Rica,
[4] Escuela de Ingeniería Mecánica, Universidad de Costa Rica,
[5] Escuela de Física, Universidad de Costa Rica,
[6] Escuela de Estadística, Universidad de Costa Rica,
[7] Centro de Investigación en Ciencia e Ingeniería de Materiales, Universidad de Costa Rica
[8] Centro de Investigaciones en Matemática Pura y Aplicada, Universidad de Costa Rica
[9] Centro de Investigación en Ciencias Atómicas, Nucleares y Moleculares,
Investigación Universidad de Costa Rica, Sede Rodrigo Facio
2060 San Pedro, San José, Costa Rica

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**Keywords:** Symbiotic approach · Natural resources · River basins · Population dynamics · Integral Index · Resource management · Social inequalities

## 1 Introduction

Environmental health is a compositional concept integrating observations related with air, radiation, water, soil, residuals, sanitation, noise, traffic accidents, food safety, infrastructure, ocupational conditions, chemical emergencies and polluted areas (Posada de la Paz et al., 2004). These indicators were proposed by the rare disease research center (Centro de Investigación sobre el Síndrome del Aceite Tóxico y Enfermedades Raras -CISATER) in Spain, and the World Health Organization (2019); establishing a frontier between a person and all physical, chemical and biological factors external to a population.

In order to achieve a systemic perspective, this article proposes the observation of the interaction between water complexity and population dynamics as the main focus for environmental health appraisal. This parameter can be knitted with water quality assessment of river basins, aqueducts and socioeconomic variables that include population health into the equation. This systemic approach, then represents the symbiosis embedded when, a population implement different technologies from water resources to fulfill basic needs of nutrition and sanitation. Therefore, a metaphor that can contribute to the interpretation of this approach is represented in Figure 1, where river basins constitute the arteries of the Earth; like blood is extracted and analyzed for population epidemiology diagnosis, this study portrays water as the Earth's blood. Meaning population dynamics are part of a global symbiosis relating land use, river basins health, economical growth and epidemiological evolution of a community. At a closer view, consumption of potable water is known to be an indicator of population health and quality of life, emerging as a critical factor for life expectancy in Costa Rica (Rosero, 1991).

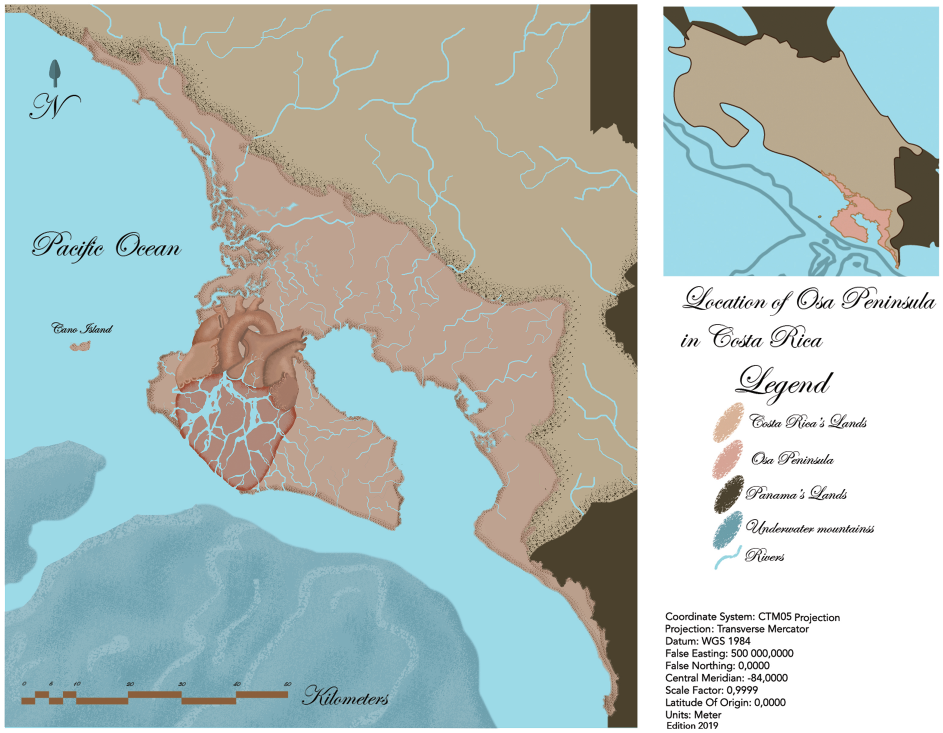



Figure 1: Representation of water arteries behaving as flowing routes interchanging life to Earth.(Original drawing: Montserrat Montero Martínez; Graphic design: Gabriela Aguilar Castrillo & Victoria Torres Zarate).

### 1.1 Social learning and environmental health

Health impact assessment becomes crucial to develop a critical appraisal of the ecosystem, to allow the contrast of decision making for the community benefits and social learning. Therefore, a baseline study should be collected to enable a spatio-temporal contrast for health technologies and infrastructure development. Health promotion practices emerges from planning adequate proposals, strategies and community policies, ensuring health equity(Harris and O'Mullane, 2017).

Nonetheless, allowing social learning in communities implies the generation of integrated and adaptive management strategies, flowing over a complex biological environment (Pahl et al., 2007). Behavioral understanding of the ecosystem is also critical (Berejikian, 1992), to address technological strategies synchronized with ethical community conventions (Groenfeldt and Schmidt, 2013).

Social learning was experimented in London, UK, when in 1854 public health action was observed as needed after a cholera epidemic emerged when its population increased to about 2.4 million people in the previous fifty years. This issue introduced spatial analysis in epidemiological studies and it also marked access to drinkable water and sanitation as main variables for environmental health. Addressing causal relations between water and epidemiological outcomes is a challenge for empirical observation and its appropriate analysis (Brody et al., 2000). In this sense, setting up accurate maps and identifying quality sources of information allows critical analysis of socio-behavioral interactions.

Interaction between river basins and population dynamics emerges at the origin of civilization (Hole, 1966), where water has generated a history of how humanity have learned about social organization and knitted a dialogue with nature, see Figure 1. Water has motivated social learning counterweighting war results as motivation for evolution (Delli, 2000). This interaction locates water resources at the center of a collective action problem (Ostrom, 2015), where access to drinkable water is a human right and the lack of this liquid can represent a public health threat for the globe.

Biodiversity together with water, become important factors interrelating inside a complex biosystem were climate change is tangled. This phenomenon defined by the Intergovernmental Panel of Climate Change (IPCC, 2004), underlines a tragedy of the commons regarding water as a resource (Hourdequin, 2010), often polarized between institutional economics and social dilemmas, up to a global scale (Faysse and Mustapha, 2017). Scaling biodiversity allows monitoring of ecosystem multifunctionality (Lefcheck et al., 2015); therefore its importance for the analysis of environmental health.

Health hazards increase when changes in climate patterns are significant in land use, challenging food safety for example or other daily life activities (Asociación Mundial para el Agua, 2013). The IPCC (2004) describes climate change as having a direct impact on water shortage, given specific changes of the natural patterns of the water cycles, affecting regions including Central America, as part of a global symbiosis phenomenon. At the same time, some approaches to water quality relate chronic low dose exposure to contaminants with possible important effects on brain functioning, however this interactions have yet to be analyzed from proper research design allowing the observation of ecological interactions (Bondy and Campbell, 2018). In order to reduce this impact one of the methods used for water potabilization, is filtration; it is known that this process can help eliminate viruses, parasites and bacteria, provide better flavor, reduce the risk of gastrointestinal diseases, among other benefits (Brady et al., 2008).

Access to safe water has a direct impact on health, while water resources management drives social development, education and various productive activities. In total, by 2017, 90% of the world's population had access to safe drinking water, which means that considering population growth, nowadays more than 785 million people can be affected by water supply problems. In rural areas, only 84% had access to quality water (World Health Organization et al., 2015). In the American Continent, water resources are abundant and embedded in socio-political textures that frames its management into a variety of water quality situations across the region (The Inter-American Network of Academies of Sciences, 2019).

Likewise, the design of technologies for the adequate and sustainable supply of water are essential for human life (Bower, 2014).

### 1.2 A symbiotic methodology proposal

Consequently to a systemic approach, there is a challenge for data collection to obtain a complete spatial characterization, denoting a complex field work to undertake; and meaning a comprehensive methodology encounters heterogeneous information sources and discontinuities (Schutz et al., 2008), depending on the region. Considering this issue, there is the need to knit primary and secondary data analysis and constitute a validated methodology, that can also be scaled globally. Mixed methods combining qualitative and quantitative sources of information should also be incorporated in a pragmatic and accurate manner, to empower social learning and consensus for infrastructural community projects.

In order to observe these ecosystemic interactions mentioned above, between population and water resources management, Drake district was selected to assess its ecosystem health through the application of a comprehensive analytical model. Drake is located at the heart of the Osa Peninsula, right at the south pacific of Costa Rica. According to the research centre for marine and limnology studies of the Universidad de Costa Rica (Centro de Investigación Marina y Limnología -CIMAR, 2019), Costa Rica's territory is 92% water, and is related to this submarine topology that emerges in islands like Caño Island and Cocos Island, as can be seen in Figure 2, providing Costa Rica with a vast marine resource. Drake is part of the Osa canton in the Puntarenas province, bordered to the east by the Pacific Ocean, to the south by the Corcovado National Park (Puerto Jiménez area) and to the north by the Térraba-Sierpe wetland (Román et al., 2013), as can be seen in Figure 3.

The area where Drake's infrastructure is built up is regulated as a forestal reserve named Reserva Forestal Golfo Dulce. This legislation responds to the need of protecting the areas around the Corcovado National Park as a contingency zone to promote its conservation. This important characteristic of Drake, rises the question around the design of a territory regulation plan, taking into account the conservation needs of the area. In Costa Rica, this is one of the most important areas related with water resources as its precipitation levels are relatively high compared to the rest of the country.

In the case of Costa Rica, different entities and institutions supply the vast majority of its population with the resource, however in 2016 8.2% received untreated water (Mora and Portuguez, 2018). Coastal regions such as Drake Bay are part of these affected rural areas and it is reason enough to show the great relevance of characterization of its water supply systems, health of river basins and its populational socio-economic context.

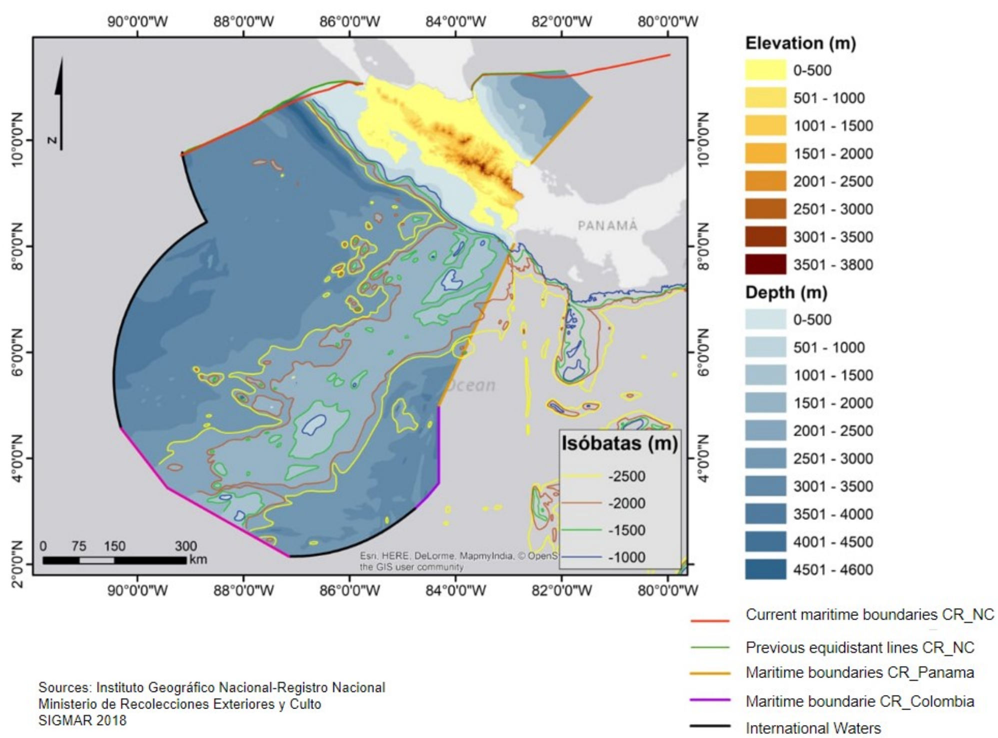



Figure 2: Source: Ministerio de Relaciones Exteriores y Culto de Costa Rica, Instituto Geográfico Nacional-Registro Nacional, The General Bathymetric Chart of the Oceans, GEBCO 2014. Created by Catalina Benavides in 2018, as coordinator of the Geographic Marine-Coastal and Limnology Information System (SIGMAR) of the Centre for research in Marine and Limnology Sciences (Centro de Investigación en Ciencias del Mar y Limnología), CIMAR-UCR.

State models can drive different relations of land use (Mongbo, Roch and Floquet, Anne and Choden, Sonam and Moreno, Mary Luz, 2011) and ecosystem functions can be explained when climate and land use observations are considered (Peters et al., 2019). An initial approximation of these models is the validation of indices that correlate these variables like land use with the quality of surface water bodies (Chacón et al., 2018). Therefore, modeling scenarios should consider essential biodiversity variables to bridge scientific evidences to adequate formulation of public policy (Nature.com, 2019). An Integral Ecosystem Health Assessment Index (IEHAI) is specified in this article as a starting point for the monitoring of different key variables clustered in three dimensions: Population health, Socioeconomic status and infrastructure and the state of the river basin as a natural resource. This index can be also used to allow health impact assessment and identification of appropriate technologies.

## 2 Materials and methods

Drake's community was observed from 2017 to 2018 and characterized as a basal comparator for environmental health. Therefore, empirical evidence can be synthesized to be inserted into more complex models, and allow evaluation of health technologies to be implemented as a policy for the community. In this case, aqueduct assessment represents the health technology of interest. Aqueducts are complex technologies that integrate parts related with the consumption source, filtering and disinfection processes. This analysis incorporates evidence related with bio-sand water filters for potable water cultivation in the locality of Caletas.

This paper also describes the challenges that water technologies can encounter in Drakes environmental context. Likely, a model specification of the ecosystem in this community aims to evaluate bio-sand water filters as a health technology strategy for health policy making.

### 2.1 Study site

Drake district was segregated from Sierpe and constituted as a district in august $3^{rd}$, 2012, by law $N^o$ 36-2012 from the Governance Ministry (Ministerio de Gobernación y Policía). Drake is located at the north of the Osa Peninsula, at the canton of Osa and the extension of its territory is about 393,3$km^2$, see Figure 3. This region is about 300$km$ away from the Great Metropolitan Area. Within the Osa Peninsula, represents the north-west area of the Corcovado National Park and Caño Island, therefore Drake's lifestyle takes place along the coast and the high biodiversity of the mountains that covers the overall soil.

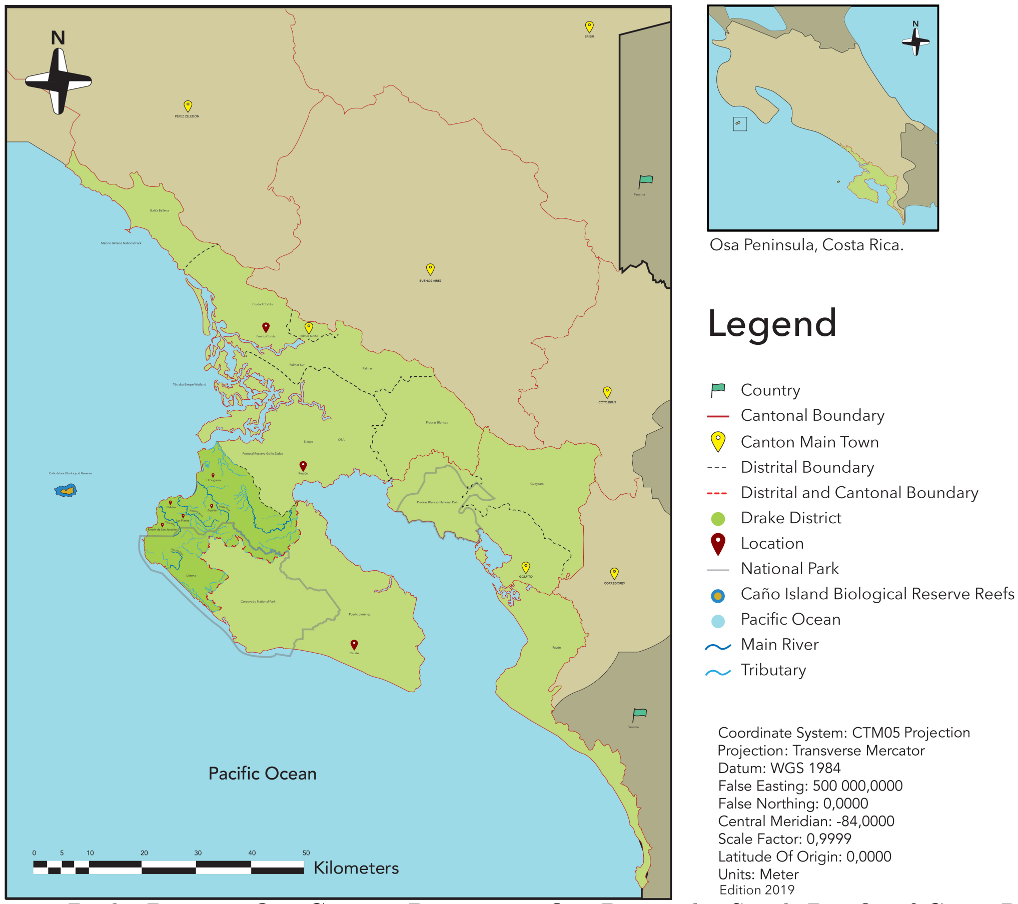



Figure 3: Drake District, Osa Canton, Puntarenas.Osa Peninsula, South Pacific of Costa Rica. Drake 2018. Drake District is the located in the South Pacific coast of Costa Rica, Central America, and shares part of its land with Puerto Jimenez to conform the Corcovado National Park, featuring its biodiversity and water resources. The image shows the study area of this research - Drake district - and its geographical context, where the different conservation areas and forest reserves make it part of a great natural biodiversity where the water resource becomes an important research focus. (Graphic design: Gabriela Aguilar Castrillo & Victoria Torres Zarate).

## 2.2 Study design

The methodological structure implemented in 2017 and 2018 period, is based on three aspects of the community of Drake: population, aqueduct technological differences and river basins. For population variables, questionnaires were used as a data collection technique, it also was aiming to collect socio-economic variables to assess infrastructural development of the aqueduct and cultural dynamics related to health and epidemiology conceptual dimensions. Second aspect of this study is the aqueduct, related to the interaction between this cultural dynamic of Drake's population and how it has been built a bridge from water resources to each house. Third aspect was the characterization of river basins. Water sampling for physicochemical parameters were planned properly and variables related to the environmental characterization were collected, especially water flow estimation. In order to implement a water-improvement technology a prototype of bio-sand filter was also developed and tested in the study area as a first social learning effort. In an approach to an integral analytical model to evaluate the health of the ecosystem, we propose an index that takes into account the variables collected from the different edges involved: socioeconomic, health and environmental characteristics.

Following sections will describe in detail these three research aspects of the methodology: *population, aqueducts, river basin and ecosystem evaluation index.*

**Population** The instrument applied in 2017, involved variables related to population' perception of water resources: socio-demographic characteristics, type of drinking water collection system, characteristics regarding the grime of the water in summer and winter, land use (cultivation area or nearby livestock activities), drinking water availability, use of filtration methods and concerns about the state of the water. A sample of 52 questionnaires were collected using a previous segmentation of the site as follows: Caletas (10), Rincón (7), Agujitas (20) and finally Los Planes (15), a global positioning system was used in order to build a sample framework (CTM05 was used as system of geographical coordinates, equipment model GPSMAP 64s).

By July 2018, a extensive sampling strategy was followed to have an accurate count of families. The same communities analyzed in 2017 were taken into account; the town of El Progreso was included in this census strategy. Each survey was collected home by home, covering each locality in a systematic way counting houses. For this study, only Costa Rican residents of private homes over 18 years old were considered for interview.

A six section questionnaire was designed: dwelling characteristics, environmental characteristics, health issues, morbidity estimations, education, reproductive health perceptions and socio-economic conditions. These variables were selected based on the need to obtain sociodemographic data with a community health perspective, taking into account that the last national census of 2011 does not include Drake as a district, but makes it part of Sierpe district, so the specific information of this population does not currently exist.

Based on the connection between environment, population and health, the variables from the 2018 census that were taken into account to describe the socioenvironmental dynamics were: employment, average income, number of inhabitants per locality, aqueduct features, disease epidemiology and water resource management related variables. This variables are: separation of waters (ordinary and special waste water), existence of septic tanks, use of water storage tanks, perception of the amount of water they receive (sufficiency). This overlap of information between socioeconomic and environmental information, allows to establish an initial inference on the dynamics of development of the zone.

**Aqueducts** The first diagnostic test was carried out in 2017 with a microbiological focus. Sampling strategy consisted in taking multiple samples for each aqueduct mode present in Drake district. Four communities were included in the observation and there were three sample sites for each aqueduct type. Previous observational work identified three main points for analysis: a water sample in the catchment site, another sample of stored water if there was any in the selected house and water samples at nodes of the distribution network. A sample size of 14 sources was defined and were selected according population density of the main localities, Agujitas, Caletas, Los Planes and Rincón: 5 samples were taken in **Agujitas** area. One from each catchment area (2 in total), one in the storage tank and two in the distribution network. In the community of **Caletas**, 4 samples were taken from 2 sources (streams) and from two distribution networks. In the community of **Los Planes** 3 samples were taken, from two well sources and one from a distribution network node. In **Rincón** 2 samples were taken, one from their protected source and another from one end node of the distribution network. The selection of the houses was made mainly by convenience, given the low population density, in order to facilitate sample collection due to the logistical difficulties of the area.

As for the second water sampling exercise in july 2018, both a microbiological and a physicochemical diagnosis of the resource were taken into account. A total of 21 sampling points were recorded, as shown in Figure 4. Samples were taken at the drinking water points (distribution) of the population, with the intention of evaluating the different sources of water used by each community, not specifically considering a certain number of points for each town.

**River basins** These sampling points were selected in such a way to consider one point before and one point after the identified population centres, in order to evaluate the impact they produce on water quality. In total, 6 points were selected and coded from A1 to A6, according to the chronological order of sampling. The geographical distribution of the water sampling points is shown in Figure 4. The sampling points of the surface hydro bodies correspond to two rivers in the study area with drainage to the sea, Drake and Claro rivers.

The samples that were taken correspond to simple and punctual samples mainly in Drake River and Claro River. At these points, basic control parameters such as dissolved solids, conductivity, pH, temperature and dissolved oxygen, biochemical oxygen demand, phosphates, ammoniacal nitrogen and hardness were measured.

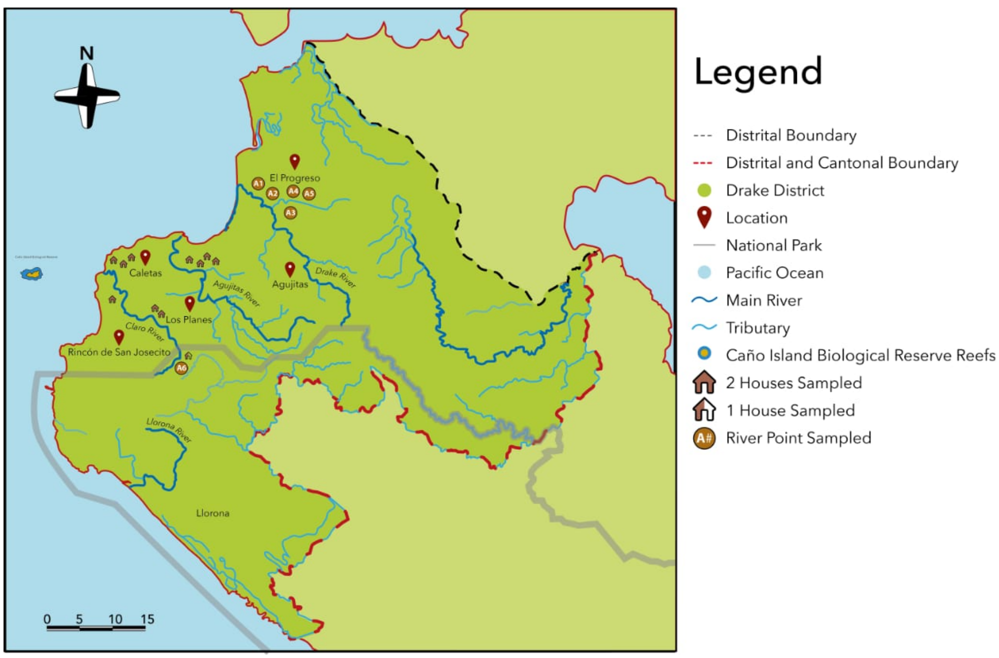



Figure 4: Water Sampling points, July 2018. Water resource sampling was carried out in Claro and Drake rivers and in homes in Agujitas, Caletas and Los Planes. The samples collected were determined by basic physicochemical parameters in all cases (households and river basins), presence of thermo-tolerant coliforms in households (21 samples) through tests carried out with portable equipment in the field (*in situ* methodology), and analysis of nutrients and BOD of rivers basins (6 samples) in the laboratory. (Graphic design: Gabriela Aguilar Castrillo, Victoria Torres Zarate & Nahomy Godinez Carranza).

In order to obtain a methodology for flow estimation three different places were selected on July 2018. Claro river, Drake river and a tributary river, see Figure 4. In order to select the stream or river section to perform the measurement, some conditions were considered: a) A measurement can not be performed close to the river mouth, because the flow may be affected by the tide. A distance of two hundred meters from the shoreline is recommended. b) River height must be no taller than the sampler's waist. This is in order to ensure a simple depth measurement and safety of the staff. c) The water flow in the superficial layer must not be turbulent. The water flow can not be too high, given that it could jeopardize the sampler's safety and the quality of the measurement (the method is more accurate with small flows). d) The river section must be as straight as possible, bends are not eligible. e) The section where the bottle will be released must be the one with the highest water volume and flow (Davie, 2008).

**Integral Ecosystem Health Assessment Index** Establishing a baseline of which is environmentally healthy in Drake enables evaluations of basins to have a comparative parameter on its health and also offer a metric for ecosystem monitoring and understanding. For this, knitting a systemic approach to assess water resources can be obtained by implementing a spatio-temporal perspective of the community.

For the development of the Integral Ecosystem Health Assessment Index (IEHAI), 3 macrocategories were taken into account: socioeconomic, human health condition and water characteristics as a mirror of environmental health. For each macrocategory there are one or more dimensions that were taken into account unsatisfied basic needs (NBI), land use, population epidemiology, microbiological water status), these are composed by parameters that are fed from a set of census variables in case of socioeconomic and human health macrocategories and technical data in case of water characteristics such as *Escherichia coli* counts. This index is summarized in the Table 1.

To accomplished categorization of these variables into a score, several literature was taken into consideration for each one. The NBI calculation method described by the Economic Commission for Latin America (ECLAC) -the Spanish acronym is CEPAL- was used as the basis for this study (Mancero and Feres, 2001). In which four dimensions are taken into account: Housing, sanitary conditions, education and subsistence capacity. More than 3 people per room and materials such as zinc or earth floor generate a NBI. Regarding sanitary conditions, a hollow latrine and insufficient water resources were a reason for NBI. For education, any child between the ages of 6 and 18 who is not enrolled in the education system generates an NBI. In addition, in households with 3 or more members that depend on a single employed person generates an NBI or if the per capita income is less than 100000 monthly. Census variables can be seen in Table 2. Each parameter that is not met is defined as an NBI. For the categorization in score, the percentage of households that have one or more NBI was calculated. The highest possible score (4 points) was taken as a percentage equal to or less than the ten best cantons in Costa

Rica and as a poor (0 points) percentage greater than or equal to the ten most neglected cantons (Gutiérrez Saxe, 2004).

| Macrocategory | Dimension | Parameter | Variable | Values | Categorization | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1=Poor | 2=Low | 3=Sufficient | 4=Good |
| Socioeconomic | Unsatisfied basic needs (NBI) | Dwelling | People per room<br>Materials | Population percentage with one or more NBI | >30% | 25-30% | 21-25% | <20% |
| | | Access to health services | Water supply<br>Waste disposal system | | | | | |
| | | Education | Attendance at schools | | | | | |
| | | Economic capacity | Per capita income | | | | | |
| | Land use | Forestal use | Percentage of forest cover | 0-100 | <33% | 33-49% | 0-64% | >65% |
| Human health | Infectious diseases | Diarrhoea prevalence | Episodes per person per year | 0-5 | >0,79 | 0,40-0,79 | 0,14-0,39 | <0,13 |
| | Chronic diseases | Metabolic disease prevalence | Prevalence | 0-100 | >35% | 26-35% | 16-25% | <15% |
| Water | Microbiological | E. coli count | MPN/100 ml | <1,2-10000 MPN/100 mL | >5000 | 1000-5000 | 20-1000 | <20 |

Table 1: Integral Ecosystem Health Assessment Index

| Basic need | Parameters | Census variable |
|---|---|---|
| Housing access | House quality | Materials used in construction (Wood and tin roof structure as minimum) |
| | Overcrowding | More than 3 people per room |
| Health services access | Water supply | Perception of stability in service (Sufficient) |
| | Wastewater discharge system | Type of system used (septic tank as minimum) |
| Education access | School-age children in the formal system | 100% coverage |
| Economic capacity | Per capita income | Less than a minimum salary for each three people |

Table 2: Unsatisfied basic needs. Modified from Mancero and Feres, 2001, CEPAL.

In the case of land use, technical method for calculation is described below in its corresponding section. Categorization was made using the National Forestal Indian Policy of 1988 as basis. This instrument promotes a minimum of 33% of forestry coverage, nevertheless in mountainous area should be not less than 66%. For human health assessment a model disease was taken as representative of infectious and chronic diseases. Acute diarrhoea and metabolic syndrome were chosen. For acute diarrhoea, episodes per year per person was used as variable. Categorization was established using the mean episodes/person/year of high income countries or less as top score (4 points) and South Asia's or more as bottom score (0 points) (Troeger et al., 2018). In the case of metabolic syndrome, ATP III/AHA/NHLBI criteria was used. In order to establish prevalence requirements were checked by the authors according to survey's answers. For categorization, data from different countries were considered (Saklayen, 2018) (Aguilar et al., 2015). China or any lower prevalence (<15%) was used as reference for top score (4 points), and United States or higher prevalence (>35%) for Hispanics as bottom score (0 points). Finally, for microbiological data the Surface Water Bodies Quality Evaluation was used as basis (Poder Ejecutivo and Gobierno de Costa Rica, 2007) where category one was used as top score with counts less than 20 MPN/100 mL, and category five was used as bottom score with counts greater than 5000 MPN/100 mL. Final interpretation was categorized into five categories according to score as shown in Table 3.

| Category | Score |
|---|---|
| Excelent | 18-20 |
| Good | 15-17 |
| Regular | 13-14 |
| Deficient | 10-12 |
| Poor | <10 |

Table 3: Interpretation for IEHAI

After index development it was implemented for Drake District using data collected as described above.

## 2.3 Technical methods

**Land usage estimation** Spatial databases of the sampling period (2017-2018) will be generated using spectral bands obtained from the Landsat 8 remote sensing system of the United States Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA). They were analysed using the SCP plugin for the QGIS 3.8.3 platform in order to estimate vegetation density using the vegetation index of standard difference (NVDI).

**Physicochemical analysis** Basic control parameters (dissolved solids, conductivity, pH, temperature and dissolved oxygen) were measured *in situ* (Hanna instrument HI 9829). Biochemical oxygen demand (BOD) (5210 D), phosphates (4500P E), ammoniacal nitrogen (4500 $NH_3$ B and 4500 $NH_3$ C) and hardness (2340 C) were determined by laboratory measurement based on the Standard Methods for the Examination of Water and Wastewater (APHA, 2017). Samples transportation met requirements of the method. This analysis were performed at the Environmental Engineering Laboratory (Laboratorio de Ingeniería Ambiental, Universidad de Costa Rica).

**Flow estimation** The method used for our characterization is called the float method, which is an instantaneous method. It requires minimum experience and it does not requires expensive or complex equipment, also stream characteristics allowed it (Dobriyal et al., 2017).

The equipment necessary to perform the float method is composed by the following items: Measuring tape, a floating device, a stopwatch and a GPS device. In the case of the depth measurement tape, it is recommended to use a weight attached to it, in order to ensure a straight measurement.

The method requires different measurements in order to calculate the flow, as shown in Figure 5 and Figure 6. Basically, the method works with two variables, cross sectional area and velocity.

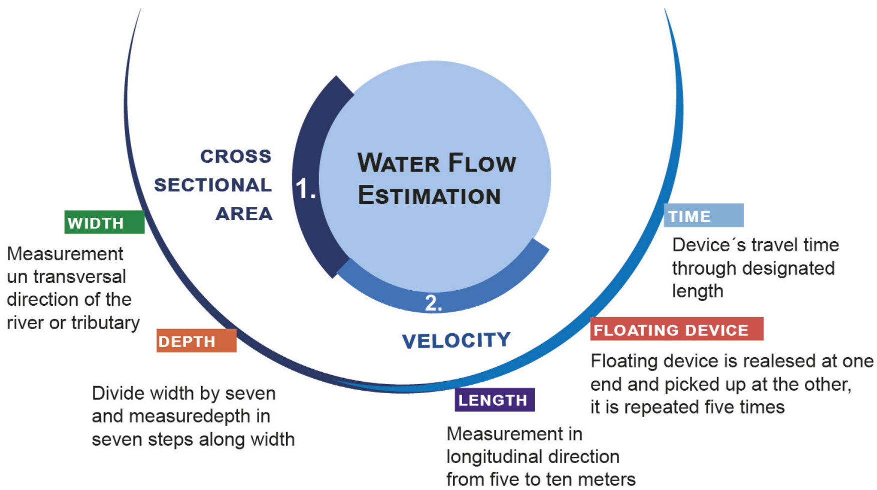



Figure 5: Flow measurement method. Description of a methodological process to measure flow carried out in the Drake District, Osa Peninsula, Costa Rica in 2018. The method includes two processes: calculation of the cross-section area of the river and calculation of the velocity. The first includes the measurement of river width and depth and the second requires the measurement of time, a floating object and a length of between 7 to 10 meters in the same area. (Graphic design: Gabriela Aguilar Castrillo & Victoria Torres Zarate).

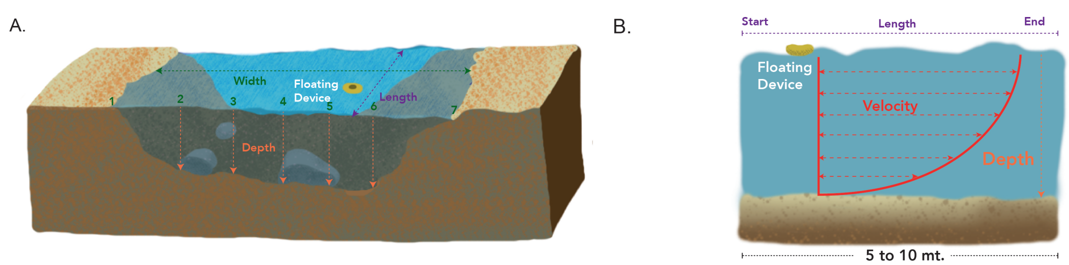



Figure 6: A.Graphic description of the flow measurement. First, the width of the river must be measured and registered. Then, that dimension must be divided by seven. This will provide a horizontal distance, or step size, across the river where a depth measurement must be performed. In this way five depths or steps will be registered, plus two measurements of the river's bank. Lastly, a length measurement is recorded, preferably halfway between the width measurement. Cross sectional area is obtained by multiplying the average depth measurement by the width. B.Description of the water velocity at the flow's sampling site. Water velocity does not behave in an uniform way from the surface of the water to the river bed.

The time taken by the floating device to travel the defined length must be recorded. It must be released at least five times. The different time records must be averaged, and the result multiplied by the length, thus obtaining the velocity (Dobriyal et al., 2017). The multiplication of these two dimensions, cross sectional area ($A_{cs}$) and velocity ($V$), gives the estimated water flow ($Q$). As a final procedure, the location must be pinpoint by the GPS device.

$$Q = A_{cs} \cdot V \tag{1}$$

$$m^3/s = (m/s) \cdot (m^2) \tag{2}$$

**Microbiological analysis:** The basis and sustenance for the adequate collection and analysis of microbiological samples in 2017 were supported by methods dictated by the Standard Methods (9060 A)(9221 E)(9221 F) (APHA, 2017). Samples were delivered for analysis at the water and food laboratory (Laboratorio de Aguas y Alimentos of the Facultad de Microbiología, Universidad de Costa Rica).

The methodology applied *in situ* in july 2018, was realized using the equipment Potaflex WAG-WE10050 of the commercial house WagtechWTD. The sample was taken according to the specifications of the Standard Methods (9060 A) (APHA, 2017). The analysis procedure is described below: First, samples were collected daily in sterile bags without thiosulfate and mantained in refrigeration temperatures until their preparation and setup. Assembly of the equipment and culture media preparation was carried out according to the manufacturer's instructions. Once the equipment has been assembled and sterilized using an ethanol flame, a volume of 100 mL of each sample was filtered through a membrane (provided by the manufacturer). This filter was aseptically placed on a sterile Petri dish with the culture medium (Membrane Lauryl Sulfate Broth, provided) for incubation at 44 °C for 24 hours. Once incubated, the presence of typical colonies of thermotolerant coliforms, which are yellow, was sought.

**Water filter prototype development:** Bio-sand filter (BSF) was constructed and implemented in the rural community of Caletas, as shown in Figure 7.

The materials used were 4 inches and $\frac{1}{2}$ inch PVC pipes, 4 inches PVC joints, PVC $\frac{1}{2}$ inch 90 degrees elbows, a $\frac{1}{2}$ inch PVC globe valve, PVC male and female adapters, gravel and commercial construction sand. The filter is composed of three layers of water, sand and gravel inside a PVC pipe as shown in Figure 7. The vertical dimensions of sand and water were taken from the 2012 edition of the CAWST bio-sand filter with some modifications (Centre for Affordable Water and

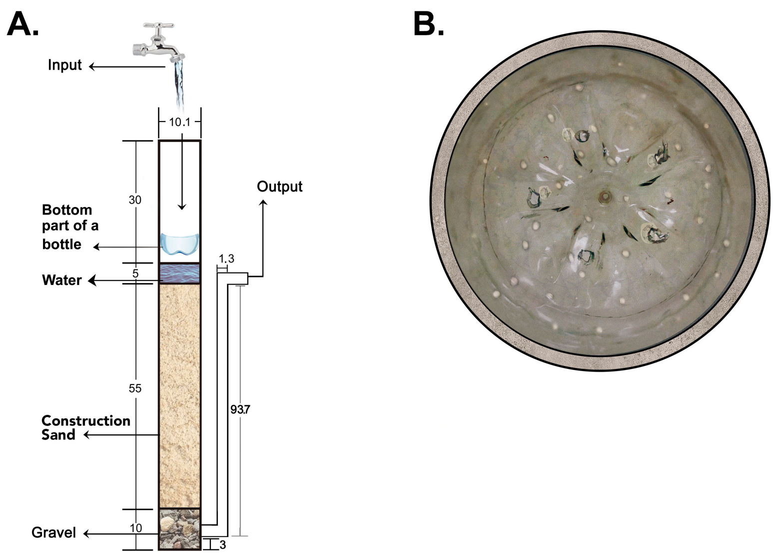



Figure 7: A.Schematic of implemented BSF (Vertical section). Dimensions in cm. The layers in ascending order: stone, gravel, sand, water - this layer allows the formation of the microbial community and decreases oxygen concentration - and finally air.B Horizontal section. The water from the tube enters the filter through the holes at the bottom of a bottle, so the water pressure is not strong.

Sanitation Technology (CAWST), 2012). The diameter of the gravel is approximately $1.27cm$ and the maximum diameter of the sand is less than $3mm$.

Once constructed and put into operation for one month, an incoming and outgoing sample were taken for both physico-chemical and microbiological analysis in the rainy and dry seasons (September 2017 and February 2018) and were performed at the Health Research Institute of the Universidad de Costa Rica (INISA).

## 2.4 Statistical analysis

Descriptive analysis was developed to characterize the relation between population and river basin, in this case this interaction is represented by the aqueduct systems installed by the population. R statistical free software was used for figures and data analysis. Packages like ggplot (Wickham, 2016) were used to provide each statistical graph. The aim of the statistical analysis is centered in the description of the collection of multiple variables allowing systemic perspectives, from a baseline risk line collected in 2018.

## 3 Results

After the proposition of a critical and comprehensive perspective for environmental health embedded in a symbiotic approach, a baseline is synthesized to allow a longitudinal observation, towards the installation of a monitoring strategy of water security. Figure 8 represents the multidimensional elements that specify a route for the analysis, mixing different pieces of empirical evidence. There are three levels of evidences, given the incorporation of three compositional dimensions as: 1) Inhabitants of the community; 2) Institutions involved in the predominant economical dynamic and infrastructural development; and 3) Water bodies flowing through different adjacent land activities. A timeline can be drawn to locate each of the interventions applied in Drake's community, in order to follow an exploration process that helps identification of strategies to ensure growth in social learning qualities, like water quality and its community management decisional framework. Allowing monitoring of water security qualities, need to start from a baseline study drawing a map of the evidence, and the analytical threshold to contrast optimal technology beyond standard development. A natural model is drafted to expose abstract relations between these three dimensions specified in this analysis.

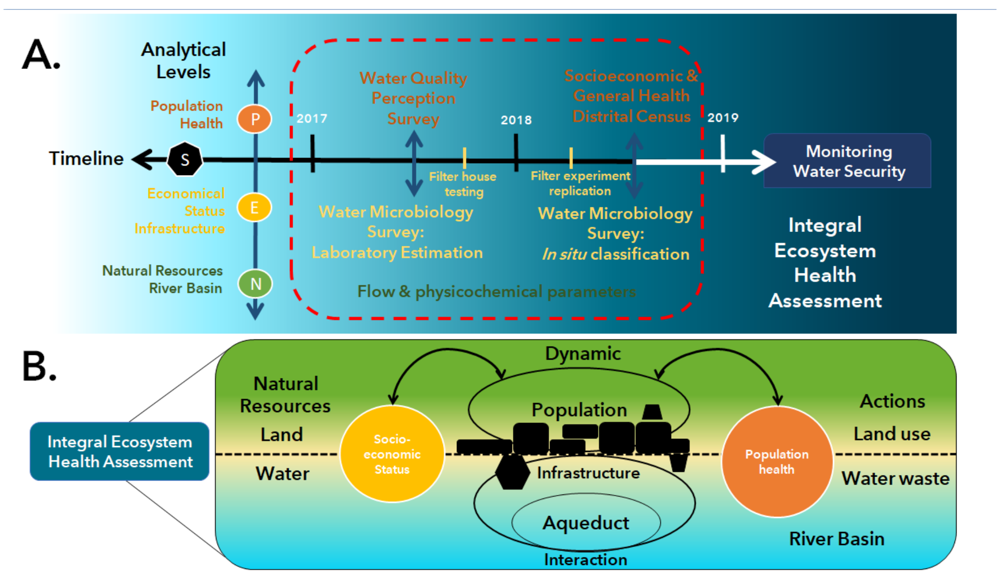



Figure 8: Symbiotic Approach Diagram: An Integral Ecosystem Health Assessment is built from two components of the analysis that are represented in a dual perspective. S = observation starts before 2017. a) Time-linear perspective showing empirical evidences integrated with a mixed method strategy, where there are three hierarchical levels to correspond the analysis: P = Population health, E = Economical status infrastructure and N = Natural resources; and b) Space-relational perspective of a natural model describing the dynamical interaction between natural resources management, land use and wastewater infrastructural systems.

### 3.1 Population health

This dimensional level describe results from the Water Quality Perception Survey and the General Health module inserted in the districtal census strategy. Estimating a general synthesis for population health based on household door interviews. Water quality perception provides a picture of the collective view and provide a derivation of the requirements to reach a water security plan in Drake districtal community. In the other hand, for general health, estimation of chronic diseases prevalences were obtained to start registering for a disease mapping.

Principal population localities in Drake are Agujitas, which is the main population center, see Figure 9, to the west is Caletas town and following over the coast there is a small locality Rincón de Agujitas, on the way to San Pedrillo; and Los Planes is at the southwest. Northeast are the localities of El Progreso, Los Ángeles, Estero Guerra, Alto Laguna and Rincón. Although they belong to the same district, they have important economic differences between localities and within populational level. Until 2018 roads still had no paviment, restricting land access only for a particular type of vehicle capable of crossing rivers and overcome very difficult road conditions. Elevated density of biodiversity is the main natural resource of the region.

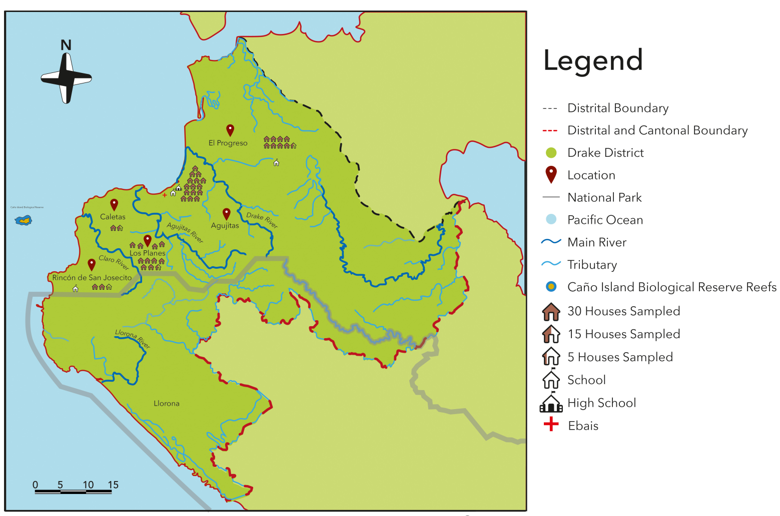



Figure 9: Drake population distribution per localty. On July 2018 census, Drake's total sampled population was 610 people. The communities analyzed taken into account were Agujitas, Progreso, Caletas, Rincón y Los Planes.

**Water Quality Perception Survey.** The following dashboard provides a visualization of the socio-economic characteristics of Drakes population:

Water quality perception and aqueduct characterization in Drake, Osa Peninsula

Regarding water availability, in July 2018, 84% of Drake's households considered they receive sufficient liquid. Taking into account cultural aspects, concerns about water quality are an important issue to be considered for the analysis of resource management. Based on studies of the 2017 survey, there were cases in Drake where the population has been concerned about this issue. These cases are classified in four important areas: infrastructure in terms of treatment systems, potability, health hazards (mostly in rainy season where three quarter of the population received water with small residues of soil or small pieces of branches) and socioeconomic aspects (decrease in water during summer season, a time of high income due to tourism). An interesting result is that houses with individualized systems (wells, springs, streams) have a better perception of water potability than those individuals who are supplied by a pipeline like the ASADA of Agujitas.

**General Health Evaluation.** Chronic diseases prevalences were estimated from 2018 census methodology application. In Figure 10 prevalence estimation for five cardiovascular risk factors: 1) Obesity; 2) Hypertension; 3) Tryglicerides; 4) Metabolic Syndrome criteria; and 5) Type 2 Diabetes Mellitus. It should be noted that the smallest communities whose primary economic activity is tourism, such as Rincón, is the one with highest prevalence of chronic diseases, excluding dyslipidemias.

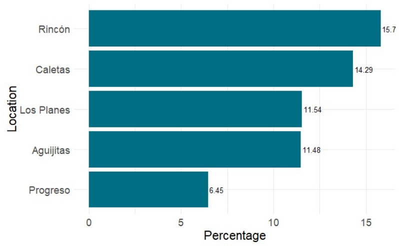
Diabetes prevalence is also in line with national levels, although some communities have lower values such as El Progreso and Agujitas. It is relevant to say that Puntarenas province, where the area under study is located, has a higher incidence rate according to national records.

There are no official records about prevalence of metabolic syndrome. Drake's average prevalence is 7%, nevertheless this data may be under-recorded due to the measurement error.

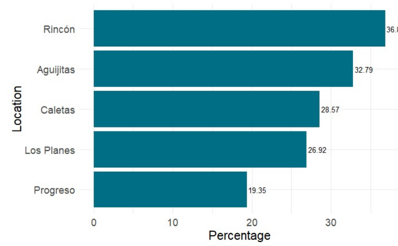
Costarican adults have an average obesity prevalence around 30%, Drake's population have an estimate of 12% prevalence.

Diarrhoea episodes per year were calculated for Drake's district by locality as seen in Figure 11. According to Troeger *et al*, Drake's episodes are below Central American mean. Nevertheless in communities like Caletas, more than 50% of people had suffered from an acute episode in the year of measurement.

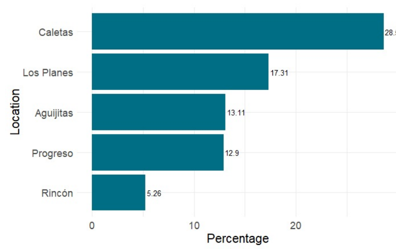
With a high rate of diarrhoea disease, a key factor to study is access to basic hygiene services such as drinking water and subsequent study of the basins that supply the population.



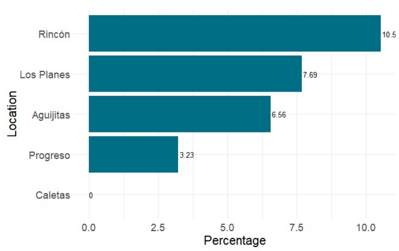

(a) Obesity prevalence



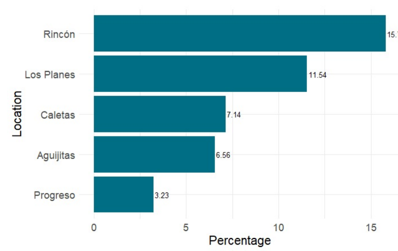

(b) Hypertension prevalence




(c) Tryglicerides prevalence




(d) Metabolic Syndrome prevalence




(e) Type 2 Diabetes Mellitus prevalence

Figure 10: Drake's chronic diseases prevalence. a) Obesity; b) Hypertension; c) Tryglideride dyslipidemia; d) Metabolic syndrome (Calculated based on 2018 survey's answers using ATP III criteria); and e) Type 2 Diabetes Mellitus.

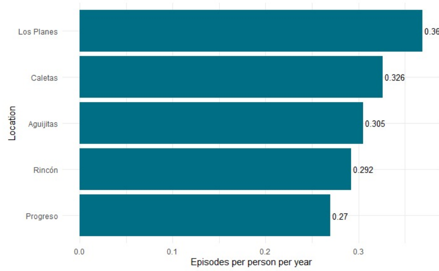



Figure 11: Drake's diarrhoea episodes per person per year, for interanual period 2017-2018. Based on 2018 survey. District mean is 0.31 episodes/year/person.

### 3.2 Socio-economic Status and Infrastructure

There are 9 primary schools, 1 secondary education center and 1 healthcare center for primary attention (Equipo Básico para la Asistencia Integral en Salud), better known by their acronym, EBAIS (Basic Equipment for Integral Health Assistance).

Costa Rica's healthcare infrastructure is composed by different institutions, such as EBAIS, clinics, hospitals and specialized hospitals. Costa Rica's healthcare system works with three levels of attention, depending on the size and the type of service provided by the institution. All EBAIS are in the first level of attention (Caja Costarricense del Seguro Social (CCSS), 2010).

Figure 12 shows the number of houses in the district by locality. These data together with the total population gives a ratio of 2.73 inhabitants per household, however, there is overcrowding in 12% of the households surveyed, reaching 15% in Caletas.

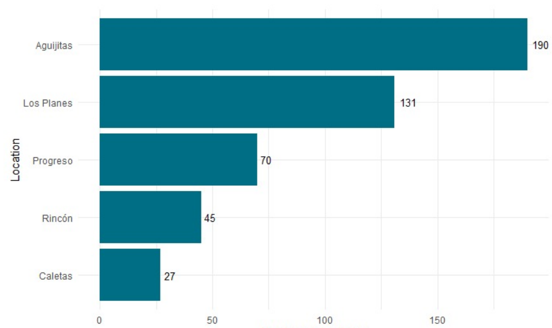



Figure 12: Drake dwellings distribution per localty. On July 2018 census, Drake's total dwellings were 473.

In terms of educational level, as shown on figure 13, 20.53% of the population have primary incomplete, 18.30% have secondary incomplete and only 5.42% have college education.

A 22.5% of Drake's population works for tourism activities and a 17.24% does not work at all, see Figure 14. According to socioeconomic activities, a 44% have a monthly income between \$174.74 (CRC101 000) and \$519.03 (CRC300 000 colones), a 23% have an income

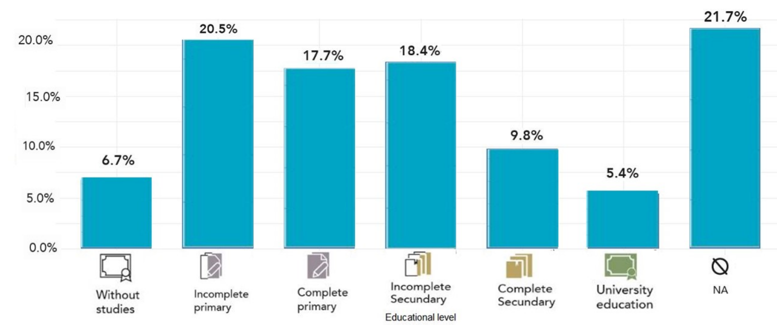



Figure 13: Educational level in Drake's population. With a 39%, the majority of the population have incomplete educational levels, and a 9.37% don't have any educational level. The data related to education allows to obtain a first approach to the different unsatisfied basic needs in Drake, where student desertion may be due to the need to generate income to contribute to households.

between \$519.03 (CRC300 000) and \$865.05 (CRC500 000) and just a 14% of Drake's populations generate income higher than \$865 (CRC500 000).

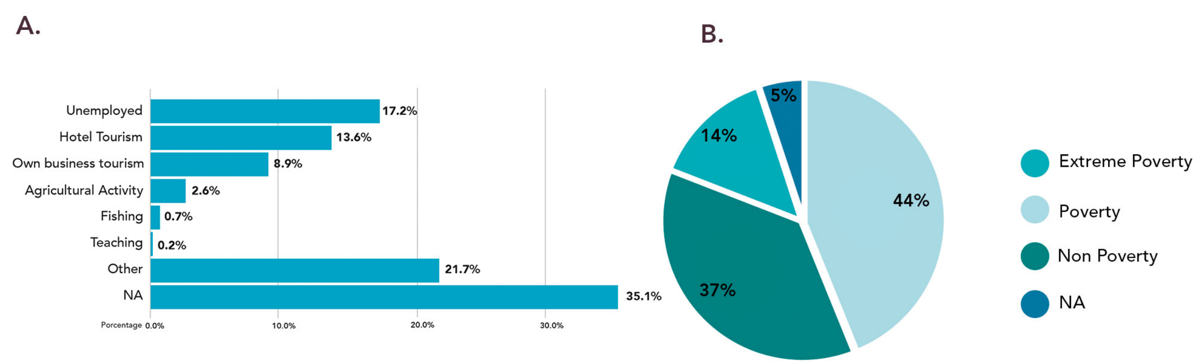



Figure 14: A.Socioeconomic activities of Drake's population. According to Drake's location and its high conservation and biodiversity most developed activity is tourism, followed by other types of work not mentioned by the population. B.Monthly Income of the Population of Drake district. According to National Household Survey, a monthly income lower than \$173.01 (CRC100 000),is catalogued as extreme poverty. Between this and \$520.76 (CRC300 000), population is in a condition of poverty. Population with a monthly income higher have a non poverty condition.

### 3.3 Aqueduct Infrastructure

One of the most relevant features of this region is the high variability of aqueduct systems, where the only location with a centralized system is Agujitas, as shown in Figure 15. The other locations have different systems, such as wells, protected aqueducts, unprotected aqueducts or rain collection systems in order of relevance.

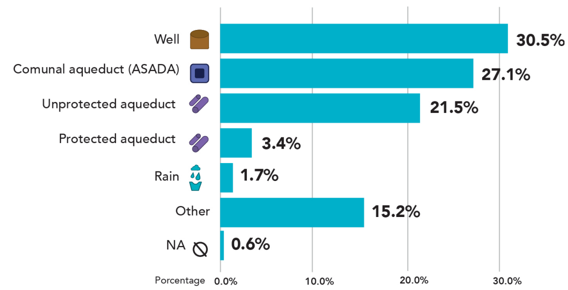



Figure 15: Origin of the water resource in Drake district. In both studies -2017 sampling and 2018 census-, the distribution of water consumption systems in Drake district has similar values regarding to the consume from ASADA and wells systems, which 27% comes from ASADA and 31% of households consume water from a well. There are other types of water consumption systems, such as streams and springs.The large number of supply systems in the different communities in the area, rule out generalization of the Drake area.

The use of a filter provides a sense of security and is more frequent in places with a large influence of tourists, such as Agujitas and Rincón, as well as in educational centers. In this study, a 42% of households use a filtration method to make their water drinkable.

Regarding water disposal and treatment of household wastewater, Figure 16 shows that vast majority of dwellings have a septic tank to collect their wastes.

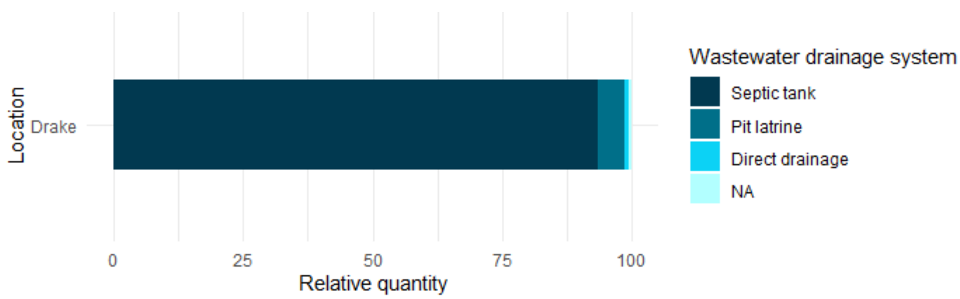



Figure 16: Wastewater drainage systems. 93% of households said that they have a septic tank, 0.6% have a direct outlet of sewage water and 6% use a hole or well for this type of water.

**Water microbiology survey: Households.** As can be seen in Table 4, all samples were positive for total coliforms, which may be in breach of the national regulation N 32327-S (Poder Ejecutivo and Gobierno de Costa Rica, 2005) depending of bacterial genus involved. The second most frequently breached parameter is turbidity, the value of which should not exceed 5 nephelometric turbidity units (NTU). There is a particular case in which a commercial filter is used, in samples 18-SF (without filter) and 18-CF (with filter), there is a significant reduction in turbidity, which decreases to about 70% its value, however, both samples are positive for thermotolerant coliforms, which makes visible the fact that the use of commercial filters do not ensure the safety of the water consumed, on the contrary could give a false sense of safety.

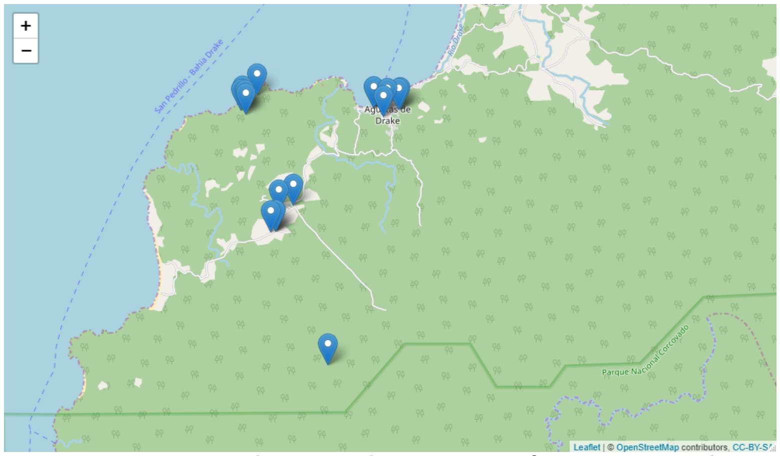


Figure 17: House aqueduct samples. Dynamic figure, see attachment.

It can be seen in Table 4 that almost half of samples met values that exceed 5 NTU. It has been seen a correlation between dissolved particles and countings of microbiological indicators such as *E. coli* and total coliforms (Hipsey et al., 2006). Also, turbidity has been used as an indicator of malfunctioning filters -when they are used, it can be seen in Table 4 that usage of filter importantly reduces turbidity- and correlates with the appearance of others potencial pathogens as *Giardia, Cryptosporidium* (LeChevallier and Norton, 1992). Due to this, a need to adopt a measure to improve the quality of water in communities arose, in a way that is respectful of their culture and vision and that adjusts to socio-economic realities.

**Filter experimental community testing.** The implementation of a BioSand Filter (BSF) was presented as a possible alternative. It is based on a domestic water treatment technology, mostly used in developing countries(Collin, 2009). Filter operates based on 4 mechanisms, adsorption and mechanical trapping, predation and death. In the first stage of the filter (above), a community of microorganisms is developed, this allows predation and competition for nutrients. As it descends into the sand column, the oxygen availability decreases, which entails even more stress and leads to the death of the microorganisms. In addition to this, along the entire column there is adsorption into the sand particles as well as mechanical trapping by pore size. The results of the analyses carried out on the filter samples by reference method (APHA, 2017) are shown against the national standard for potable water (Poder Ejecutivo and Gobierno de Costa Rica, 2005) in Table 5.

During rainy season non-filtered water values out of norm for the source water were: thermotolerant coliforms (TTCs), *E. coli*, turbidity and color. which are very likely to be present in

| Sample | Total coliforms | pH | Temperature (°C) | Conductivity ($\mu S$/cm) | TDS (ppm) | Salinity (Sal) | DO (%) | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| CTT05 | Positive | 6.47 | 26.67 | 0 | 0 | 0 | 85.2 | 5.31 |
| CTT06 | Positive | 8.24 | 30.37 | 188 | 97 | 0.09 | 106.3 | 1.89 |
| CTT07 | Positive | 7.55 | 27.88 | 150 | 75 | 0.07 | 64.7 | 1.73 |
| CTT08 | * | 7.81 | 28.70 | 111 | 55 | 0.05 | 78.08 | 2.08 |
| CTT09 | * | 6.85 | 27.07 | 72 | 36 | 0.03 | 82.8 | 0.91 |
| CTT10 | Positive | 6.45 | 26.92 | 43 | 21 | 0.02 | 97.9 | 2.56 |
| CTT11 | * | ** | ** | ** | ** | ** | ** | ** |
| CTT12 | * | ** | ** | ** | ** | ** | ** | ** |
| CTT13 | * | ** | ** | ** | ** | ** | ** | ** |
| CTT14 | Positive | 7.54 | 27.33 | 328 | 164 | 0.16 | 111.7 | 3.68 |
| CTT15 | Positive | 7.40 | 25.80 | 134 | 67 | 0 | 106.7 | 8.67 |
| CTT16 | Positive | 7.37 | 25.32 | 113 | 57 | 0.05 | 111.0 | 9.99 |
| CTT17 | Positive | 7.50 | 25.18 | 78 | 39 | 0.04 | 101.9 | 4.39 |
| CTT18-SF | Positive | 7.47 | 26.69 | 116 | 58 | 0.05 | 101.9 | 5.15 |
| CTT18-CF | Positive | 7.55 | 26.66 | 134 | 65 | 0.06 | 106.9 | 1.64 |
| CTT19 | * | ** | ** | ** | ** | ** | ** | ** |
| CTT20 | Positive | 7.46 | 27.39 | 143 | 72 | 0.07 | 107.7 | 6.34 |
| CTT21 | Positive | 7.30 | 25.68 | 134 | 67 | 0.06 | 108.1 | 9.99 |
| CTT22 | * | 7.25 | 26.72 | 105 | 53 | 0.05 | 88.5 | 5.80 |
| CTT23 | Positive | 7.51 | 27.73 | 234 | 117 | 0.11 | 100.8 | 5.43 |
| CTT24 | Positive | 7.64 | 27.83 | 73 | 37 | 0.03 | 85.0 | 4.65 |

*Incubation failure **Lost Sample

Table 4: 2018 Physicochemical and microbiological results of household samples.

source water during rainy season due to sediment drag from the topsoil caused by heavy rain, as seen in the visits to zone. During sunny season turbidity and color values fulfilled the law according to the expected lack of topsoil sediment drag, while TTCs and *E. coli* had similar values, this may indicate that a potential source of fecal contamination is constant on both seasons around catchment area, more studies are needed in order to establish its origin -human or animal-.

Regarding the operation of the filter, the samples taken showed that TTCs augmented. There are various possible explanations for this, one is that environmental microorganisms that make up the biofilm are also considered within the group of total coliforms, it has been reported the coliform group can grow inside the filter if the nutrients are adequate (Martensson and Jabur, 2006), for which this count could increase by drag-out and turbulence created in the filter's feeding zone. *E. coli* decreased in both seasons supports the idea of biofilm carryover of other coliform organisms.

Conductivity and suspended solids indicators turbidity and color results showed a reduction after the BSF in the September's 2017 sample, as was expected due to trapping and adhesion of

| Parameters | Accepted values* | September 2017 | | February 2018 | |
|---|---|---|---|---|---|
| | | Source water | After BSF | Source water | After BSF |
| Termotolerant coliforms (CFU/100 mL) | No detectable | 350 | 540 | 350 | 540 |
| *E. coli* (CFU/100 mL) | No detectable | 240 | 79 | 350 | 49 |
| pH | 6.5-8.0 | 7.32 | 7.13 | 7.60 | 7.43 |
| Conductivity(uS/cm) | <400 | 127.4 | 120.5 | 159.4 | 151.7 |
| Turbidity (NTU) | <5 | 7.09 | 5.67 | 0.97 | 2.75 |
| Color (Pt-Co U) | <15 | 30 | 20 | 0 | 5 |
| Temperature (°C) | <30 | 26.4 | 26.4 | 20.07 | 27 |

* (N°32327-S, 2005)

Table 5: Water quality results of samples taken in Sep 2017 and Feb 2018, before and after BSF.

suspended particles in the sand column, widely report(Hoslett et al., 2018) (Collin, 2009) (Centre for Affordable Water and Sanitation Technology (CAWST), 2012). A different phenomenon occurred in February 2018 where both parameters increased, probably caused by dragging of sediments inside the BSF and the low initial value. As expected flavor, odor and temperature did not change because of the BSF in either season. Application of the filter prototype matches with others build and characterized in literature. In this research only parameters seen in Table 5 were measured, nevertheless other may be measured such as heavy metals in order to determine broader specifications for its funcionality (Hoslett et al., 2018). Due to the quality observed in water catchments and distributions, a closer study of basins is necessary, and also allows for the addition of all spatial information on human activity circumscribed to the environmental axis.

### 3.4 River Basin Health Assessment

To approximate the environmental dimension aimed by this analysis, the river basin is taken as the main natural resource. The flow of the water provides a perspective in movement and therefore generating relevant information about the natural state of the community.

**River Flow Estimation.** When establishing a baseline, flow measurement as a characteristic of basins is relevant since it allows longitudinally comparing changes due to direct anthropogenic factors, which would potentially generate other changes in physicochemical parameters as well as monitoring in search of climate change effects that would jeopardize the area, its biodiversity and its inhabitants. For this reason, the estimation of the flow in these bodies of water was carried out in order to obtain the best methodology. Results are shown in Table 6. However, it is considered that this measurement could imply a greater integration with the community to generate more and better data throughout the annual seasons, in a clear use of social learning with other methodologies *in situ*.

| River Name | Estimated Water Flow ($m^3$/s) |
|---|---|
| Drake River, Tributary | 1.26 |
| Drake River | 6.22 |
| Claro River | 1.75 |

Table 6: Water flow estimation results, July 2018

**Obtaining physicochemical parameters.** The physical-chemical results of the river samples from 2018, are shown in Table 1. One of the parameters analyzed, due to its importance as an indicator of water contamination, was the BOD, biochemichal oxygen demand, which showed values between $0mg/l$ and less than $5mg/l$, which, according to the analysis report of the Laboratorio de Ingeniería Ambiental de la Universidad de Costa Rica (Environmental Engineering Laboratory of the Universidad de Costa Rica), denotes good water quality with little or no contamination of organic matter as established by the Regulation for the Evaluation and Classification of the Quality of Surface Water Bodies of the Republic of Costa Rica (Poder Ejecutivo and Gobierno de Costa Rica, 2007).

Two different basins were selected for sampling, one drained by Drake river and other by Claro river. In the case of Claro river, one sample was analyzed (A6), which do not have nearby towns. Drake river basin had more testing sites: a tributary surrounding a town (samples A3, A4 and A5), and a last site downstream (sample A1 and A2). 4

According to the data in the Table 7, obtained in the analysis of the samples in the Laboratory of Environmental Engineering of the Universidad de Costa Rica, the results are in a normal range, excepting the value of turbidity of sample A1 with a value greater than the permissible for this parameter ($<$ 5NTU).

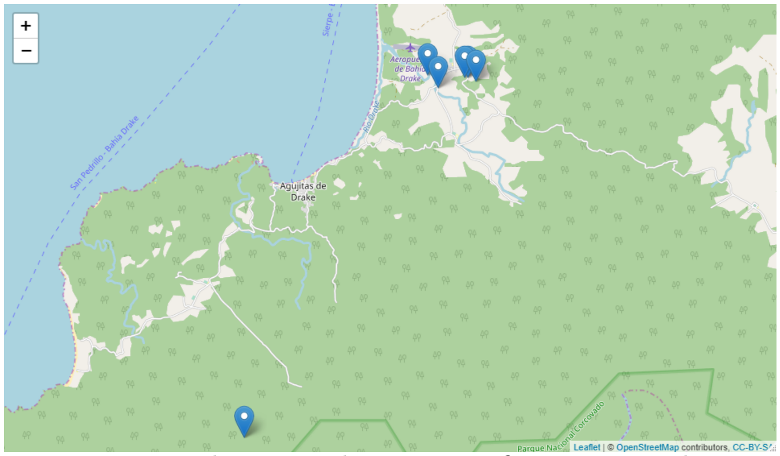



Figure 18: River basin samples. Dynamic figure, see attachment.

| Sample | River | pH | Temperature (°C) | Conductivity ($\mu S$/cm) | TDS (ppm) | Salinity (Sal) | DO (%) | Turbidity (NTU) | Fosfate (mg/L) | Nitrate (mg/L) | Hardness (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | Drake River | 7.57 | 26.73 | 137 | 69 | 0.06 | 74.8 | 8.33 | 0.12 | 4.3 | 100 |
| A2 | Drake River | 7.40 | 26.24 | 133 | 66 | 0.06 | 84.0 | 2.76 | 0.46 | 3.7 | 90 |
| A3 | Drake River | 7.15 | 27.32 | 245 | 122 | 0.11 | 67.8 | 0.67 | 1.54 | 4.2 | 97 |
| A4 | Drake River | 7.24 | 28.93 | 160 | 80 | 0.07 | 105.5 | 1.68 | 0.86 | 4.2 | 75 |
| A5 | Drake River | 6.72 | 30.07 | 119 | 59 | 0.05 | 87.0 | 1.17 | 1.24 | 3.8 | 44 |
| A6 | Claro River | 7.23 | 24.05 | 105 | 25 | 0.03 | 98.1 | 2.78 | 0.87 | 3.9 | 80 |

Table 7: Physico-chemical results of basins samples.

The physicochemical values of two samples of Drake River (A1 and A5) see figure 9 and the samples in houses in Agujitas area (samples 15, 16, 18), as can be seen in the figure 4, increased regarding turbidity, TDS and DO. This may provide relevant information about the state of the pipes that distribute the vital liquid to the community. Those are two of the most densely populated communities.

### 3.5 Assessing Integral Ecosystem Health

An index can be built integrating land use observations and estimating unsatisfied needs indicators.

**Land usage.** As seen in Figure 19 the vast majority of Drake District area is forested (71%), which is in line with the conservation policy. In addition to this, there is also a deforested area with low vegetative growth. According to observations in the zone and reported in the surveys, farming activities are not common in the zone, which suggests that these zones may remain unproductive or with a low productive activity that leaves no signal in the satellite spectrum.

Regarding the percentage of land dedicated to human constructions, the airport stands out with a very characteristic footprint in its NVDI that is no longer presented in the map (there is no use of asphalt in the zone). Buildings dedicated to housing and commerce are concentrated in the area of El Progreso and Los Planes, near the entrance to Corcovado National Park. Satellite images quality was not the one desired due to atmospheric conditions of the area. However, it allowed to generate the analysis.

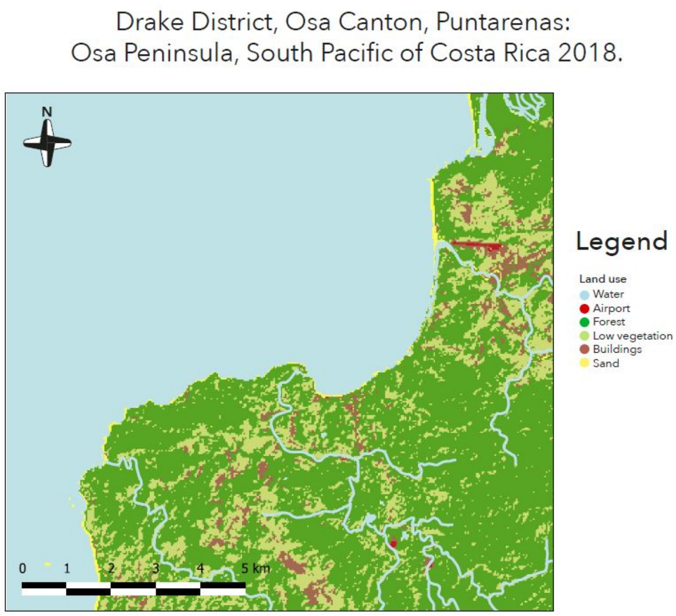



Figure 19: Land Use in Drake district, Osa Canton, 2018

It can be seen that inhabited areas are in very high spatial interaction with water bodies, including the sea, although settlement areas decrease upstream. In 2017, all samples analyzed by fecal coliforms presented a result greater than 1600 MPN/100 ml. In addition, although the vast majority use a sewage disposal system such as the septic tank, proper construction is not a proven fact that leachate could have an effect on the aquifers and rivers of the area, however more studies are needed to prove this specific interaction, such as measuring the ratio of fecal enterococci and fecal coliforms to evaluate the origin of short-term human pollution, as recommended by WHO and applied by other authors in tropical contexts (Ashbolt et al., 2001), (Geldreich, EE and Kenner, BA, 1969), (Rivera et al., 2010). This is highlighted by having high rates of acute diarrhoeal diseases, whose greatest mitigation action is access to safe drinking water and improved wastewater disposal systems.

**Baseline index proposition.** The variables for the proposed index were calculated with the data obtained during the 2018 census and pilot tests carried out in that interanual period. In Table 8 are presented all results needed for index calculation, its sum and interpretation.

| Parameter | Value | Score |
|---|---|---|
| NBI | 45% presents NBIs | 1 of 4 |
| Land use | 71% forestry coverage | 4 of 4 |
| Infectious diseases | 0,37 episodes per person per year | 3 of 4 |
| Chronic diseases | 7% | 4 of 4 |
| Microbiological counts | 1600 MPN/100 mL* | 2 of 4 |
| Total Score | | 13 of 20 |
| Interpretation | | Regular |

*River samples taken in 2017.

Table 8: Drake's district Integral Ecosystem Health Assessment Index, 2018.

As we can see above, even though Drake district is based in a ecotourism economy, with high biodiversity and some other remarkable and unique features, if populational data is not taken into formula, there is an incomplete picture of ecosystem health, in the same way that if just human-related analysis gives a partial view. This is a first approach in pursuit of decipher which parameters can describe easily a integral concept of one health. Human, environmental and their interaction.

## 4 Discussion

Description of the previous situation in the Osa Península, provides references of places with a high quality in their environmental resources like water coming from local river basins.

Interactions defined by the antropogenic processes are essential for the equilibrium of the environment as demonstrated so far by rural spaces like Drake. However, times are showing that population growth represents a tension on the natural resources, requiring for a better administration in every direction, as environmental health are the base of the population health. As in the introduction the event in London was referenced, the same question has to be asked for every single space of the world where there are people developing their own lives and social dynamics; so, question is, for how long are these resources going to be cultivated by the social dynamic?

Here is when the economic question comes across and marks a pattern in the objects that are consumed by the population. Establishing a relation between resources interchange and the specific social dynamic of the community. In Drake, this has been marked by the touristic production. Where some can be very critical of the benefits, balances still has to be found in terms of food sustainability and education access.

Therefore, How to build and adequate aqueduct for the majority of the population in Drake district? can be a good place to start discussing about the essentials of a society.

Integrating three different study dimensions were introduced in this article, where the environmental health is derived from water quality assessments and is also contrasted with economical factors and population health characteristics.

Economical modelling and demographic estimations, are also essential for decision making and long term effects for community development and social learning. Then it becomes vital to collect data in order to allow observational methodologies for complex analysis and elaborate better political policies related with health. This means political decisions can be evaluated and monitored to be contrasted, especially in the short future to identify changes needed to improve health quality in the community. Epidemiological studies should embrace knowledge of variables with amplifying scopes as microbiome studies.

Indicating water resources for its management from a Symbiotic perspective can provide better policy making processes.

Ecosystemic approach is gaining prominence in Latin American countries in this context, thus representing a potential for the ways of understanding and searching for solutions in public health and, consequently, requiring a critical analysis of its limitations.(Angelakis and Zheng, 2009). Water quality improvement technologies are essential for developing a better life-quality both for the inhabitants and for communities. Therefore, research about alternative technologies applicable to this particular type of population with characteristics such as those described above is absolutely vital for the development of countries.

A symbiotic approach of environmental health concept not only enhance the understanding and characterization of population dynamics with regard to water resource, but also the research and analysis of political and economic phenomena of its management. Therefore, this methodology allows the proposition of novel, efficient, effective and sustainable technologies that ensures the use of this resource and the functioning of aquatics ecosystems.

# 5 Conclusion

In such a globalized world and such an economic acceleration, complex analyses of the different symbiotic dynamics, between human beings and their ecosystem, are necessary for a better understanding of the phenomena resulting from that symbiosis and for the sustainable strategies approach that favour the balanced use of this dynamic result, taking into account the evaluation of the health of the environment and people. In this specific case, distinguishing the different lifestyles of an urban center with a rural coastal one, the visions of development are totally different, so it is not possible to pretend an approach in Drake, thinking that the needs are the same as those of an urban center.

Since water is involved in each of the stages of environmental health, depending on the development of human activities and the dependence of each inhabitant of the earth to be able to live and develop his life, water becomes an indicator that can determine the quality of life and environmental health of an ecosystem given this interaction. The importance of analyzing water resource and the population context facilitates the understanding of the dynamics of a community in its relationship with the environment and with the rest of the country. Maintaining a close relation with the community makes it possible to support the response to its own needs and communication with public and private organizations and institutions that collaborate and facilitate access to the population's own interests.

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