CASE STUDIES

Multivariate Analysis and Indices Construction: Data Mining Applied to the Rural Water and Sanitation Sector in Honduras

Camila Vergara Fuentes and Agustí Pérez Foguet

PHOTO: "Local engineering". Honduras. David Requejo-Castro

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6 MULTIVARIATE ANALYSIS AND INDICES CONSTRUCTION: DATA MINING APPLIED TO THE RURAL WATER AND SANITATION SECTOR IN HONDURAS

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1. INTRODUCTION

Access to water, sanitation, and hygiene (WaSH) is essential for human development and well-being. These are not only objectives in and of themselves but are also critical for the achievement of other development objectives. However, too many people have no access to these basic services. This situation has been recognized by the Member States of the United Nations, who signed the Millennium Declaration in 2000, which led to the Millennium Development Goals (MDGs). Subsequently, in September 2015, a historic United Nations summit was held, and world leaders approved the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development. These new Objectives are people-based and should lead, over the next 15 years, to countries intensifying their efforts to end poverty in all its forms, reducing inequality, and fighting against climate change while guaranteeing, at the same time, that no one is left behind. Specifically, Goal 6 calls for guaranteeing, by 2030, the availability of water, its sustainable management, and sanitation for all, with 8 additional proposed goals.

In order to achieve these objectives, it has been necessary to develop a global strategy and to define which factors should be considered, and how this should occur, with the aim of providing some guidance in the application of possible actions. In this context, indicators and indices play a key role, providing information that allows some questions to be answered that are related to what, how, where, and who should act.

In this case study, a current situation regarding the access to water and sanitation will be introduced, showing how monitoring of the sector has evolved in recent years. Secondly, a specific approach to the Honduran reality will be provided. Finally, the necessary information related to its water and sanitation sector situation and work context (database Lempira Department, Honduras) will be provided to execute the proposed activities.

1.1. DISCIPLINES COVERED

The main discipline addressed in this case study is the analysis of real data through statistical techniques, including Principal Component Analysis (PCA) and Multiple Linear Regression (MLR), according to the available information (e.g., data and quantitative assessments). The objective is to improve the knowledge of these techniques and to apply them by using specialized software, analysing the data series, and interpreting the results. Based on these premises, a basic knowledge of statistics is considered indispensable.

No less important, aspects related to cooperation for development are also addressed. In

parallel, teamwork is promoted, as most of the proposed activities are to be carried out in small groups, which ultimately should stimulate a general debate in the classroom.

1.2. Learning outcomes

As a result of this case study, it is expected that students will be able to:

- Understand the problem associated with the lack of access to drinking water and sanitation services, and its consequences for human development, as well as links with poverty;
- Understand how information management can support decision-making processes, such as the allocation of resources in a given study region;
- Apply statistical analysis on real data by using specialized statistical software, in addition to other basic statistical analysis;
- Understand statistical techniques such as PCA and MLR, in order to apply them to data analysis.

1.3. Activities

The proposed work to carry out is based on two activities:

1) A first activity is designed to be done in the classroom and is divided into two blocks. In the first block, students are invited to reflect on the theoretical knowledge presented through the approach of various issues. The second block is a "workshop" in which the students will be guided in the application of basic statistics concepts, the methodology of PCA, the application of MLR, and the corresponding construction of indexes. This will be supported by using the free software R (version 1.0.143);

2) The second activity will be carried out autonomously but in small groups (of approximately 3 people). Basically, students will be encouraged to apply the concepts and methods learned in the first activity. However, a more in-depth analysis will be required for simulating decision-making processes related to the presented case study.

Each activity done with the support of the specific software comprises four parts:

- Part 0: Univariate and multivariate statistical analysis

- Part I: Application of unsupervised techniques
- Part II: Application of supervised techniques
- Part III: Reflection

2. Context

In this section, relevant information is provided to contextualize the case study. The first example highlights the evolution that the water and sanitation sector has experienced, in terms of monitoring. At the same time, latest global estimates are given in order to show the current situation of the sector. Secondly, the specific situation in Honduras is presented, highlighting aspects such as the governance of the sector. Finally, basic aspects of the Rural Water and Sanitation Information System (SIASAR, for the Spanish name *Sistema de Información de Agua y Saneamiento Rural*) are introduced as an initiative that spans 11 countries in Latin America and the Caribbean, and in which Honduras was involved from the beginning. Additionally, real data related to this information system are provided to carry out the proposed activities.

2.1. Brief history of the monitoring of water and sanitation access

Access to water, sanitation, and hygiene (WaSH) is essential for human development and well-being (Carter et al., 1999; Cairncross & Valdmanis, 2006). The improvement of these aspects is also essential for the achievement of other development objectives, such as adequate nutrition, gender equality, education, and poverty eradication (Joint Monitoring Program, 2015a). In this context, monitoring and evaluation are fundamental for decision-making, since governments, civil society, and donors need objective and reliable data on which to base planning, prioritization, and accountability mechanisms.

In 1977, the United Nations Conference on Water was held in Mar del Plata (Argentina), creating the first international initiative to monitor the state and trends associated with access to water and sanitation. As a consequence of this Conference, in which both high and low income countries prominently participated, the International Decade of Water Supply and Sanitation was declared for the 1981–1990 period. The overarching objective was the universal provision of safe water and sanitation. During this period, each country´s government provided their own estimates for monitoring the progress achieved. Despite not achieving the goal of providing water and sanitation for all, important lessons were learned. On the one hand, the reliability of the data used was questioned (Cotton & Bartram, 2008).

In this sense, the need to base estimates on representative samples of the population was highlighted. On the other hand, the need for defining a joint monitoring framework was pointed out, from the perspective of "you cannot manage what you cannot measure" (Creech et al., 2002, cited by Giné-Garriga, 2015).

In response to these needs, the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) combined efforts in 1990 with the Joint Monitoring Program for Water Supply and Sanitation (JMP), whose main objective was and is to monitor national progress towards the universality of access to safe water and sanitation. Since then, the water and sanitation sector has undergone an important transition in the way the access to these services are assessed. Initially, the indicators employed basically quantified the mere access to water or sanitation infrastructure in terms of coverage. Progressively, the monitoring of the sector has been oriented to be carried out in broader terms of "level or quality of service" instead of in terms of "coverage" only. In fact, the term "level of service" has been widely discussed and used to categorize and differentiate between service qualities (Lloyd and Bartram, 1991; Howard and Bartram, 2003; Moriarty et al., 2011; Potter et al., 2011 Giné-Garriga et al., 2011; Giné-Garriga & Pérez-Foguet, 2013a).

In 2000, the Member States of the United Nations signed the Millennium Declaration, which led to the formulation of the Millennium Development Goals[1] (MDGs), which called the international community to halve, by 2015, the proportion of people without sustainable access to drinking water and basic sanitation services. During the first half of this period, and in order to improve the comparison of information between countries, JMP defined a series of criteria to describe the level of progress in water and sanitation service delivery. For access to water, and based on the technology used, it was assumed that some infrastructures were better than others. As a result, a "ladder" with three rungs was proposed to differentiate service levels defined as "not improved", "improved" and "piped on premises" (Joint Monitoring Program, 2008). For access to sanitation, and considering the wide range of existing technologies according to the context, the suitability (concept of "improved") of the infrastructure was defined as long as it was of private use and the excreta was separated hygienically from human contact (Joint Monitoring Program, 2008). As a result, a ladder with four rungs was presented: "open defecation" (lower step), "not improved", "shared", and "improved" (upper step). In this sense, only those people with access to "improved" water and sanitation services were considered to be "covered". During the MDG period, important advances were made. However, in 2015, estimates showed that 663 million people around the world still used unimproved sources of drinking water, and that 2,400 million people used unimproved sanitation facilities. At the same time, it was estimated that 79% of those people

[1] *More information available at: http://www.un.org/es/millenniumgoals/bkgd.shtml*

who did not have access to improved water are in rural areas, where only 51% had access to improved sanitation (Joint Monitoring Program, 2015a).

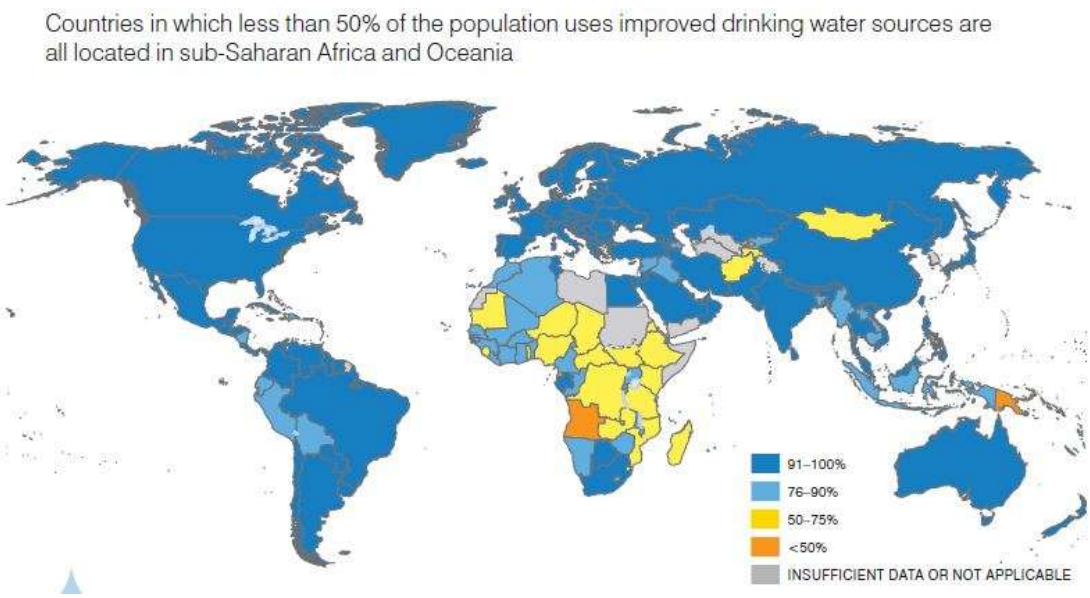

Figure 1 *Proportion of the population using improved drinking water sources in 2015. Source: Joint Monitoring Programme, 2015a.*

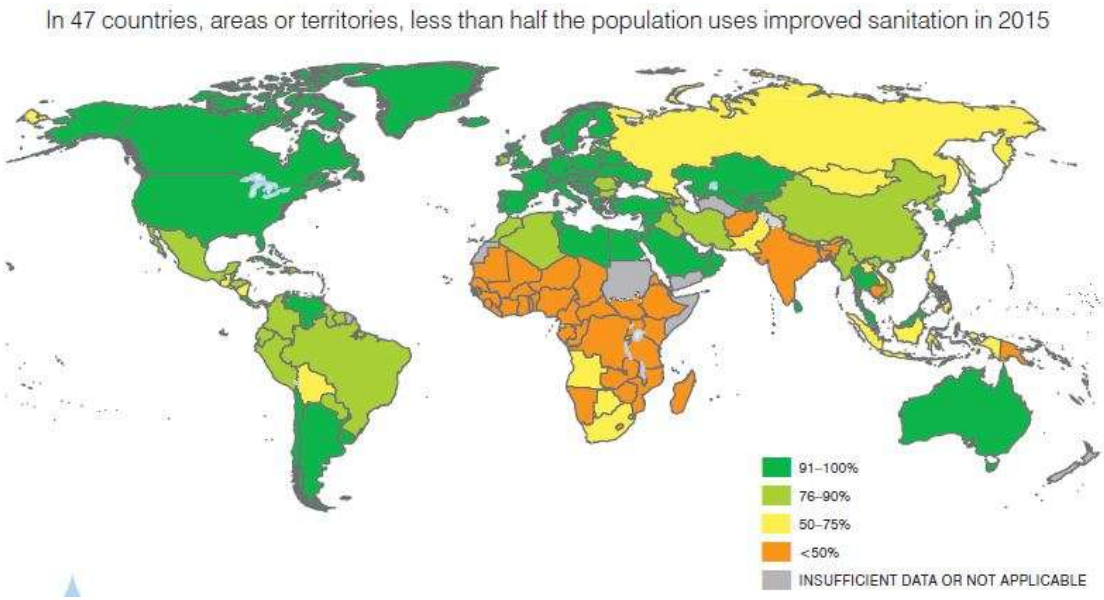

Figure 2 *Proportion of the population using improved sanitation facilities in 2015. Source: Joint Monitoring Programme, 2015a.*

In 2010, the UN General Assembly and the UN Human Rights Council recognized water and sanitation as a human right (United Nations General Assembly, 2010a, 2010b). These human rights, as described in the respective resolutions of the General Assembly, are met

through the progressive realization of universal access to sufficient, safe, physically accessible and affordable services (United Nations General Assembly, 2010a, 2010b).

Target 6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all

TARGET LANGUAGE		NORMATIVE INTERPRETATION
By 2030, achieve	*universal*	Implies all exposures and settings including households, schools, health facilities, workplaces, and public spaces
	and *equitable*	Implies progressive reduction and elimination of inequalities between population subgroups
	access	Implies sufficient water to meet domestic needs is reliably available close to home
	to *safe*	Safe drinking water is free from pathogens and elevated levels of toxic chemicals at all times
	and *affordable*	Payment for services does not present a barrier to access or prevent people meeting other basic human needs
	drinking water	Water used for drinking, cooking, food preparation and personal hygiene
	for all	Suitable for use by men, women, girls and boys of all ages including people living with disabilities

Figure 3 *Normative interpretation as regard the terms employed in target 6.1. Source: Joint Monitoring Programme, 2017.*

Target 6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations

TARGET LANGUAGE		NORMATIVE INTERPRETATION
By 2030, achieve	*access*	Implies facilities close to home that can be easily reached and used when needed
	to *adequate*	Implies a system which hygienically separates excreta from human contact as well as safe reuse/treatment of excreta in situ, or safe transport and treatment off-site
	and *equitable*	Implies progressive reduction and elimination of inequalities between population sub-groups
	sanitation	Sanitation is the provision of facilities and services for safe management and disposal of human urine and faeces
	and *hygiene*	Hygiene is the conditions and practices that help maintain health and prevent spread of disease including handwashing, menstrual hygiene management and food hygiene
	for all	Suitable for use by men, women, girls and boys of all ages including people living with disabilities
	end *open defecation*	Excreta of adults or children are: deposited (directly or after being covered by a layer of earth) in the bush, a field, a beach, or other open area; discharged directly into a drainage channel, river, sea, or other water body; or are wrapped in temporary material and discarded
	paying special attention to the *needs of women and girls*	Implies reducing the burden of water collection and enabling women and girls to manage sanitation and hygiene needs with dignity. Special attention should be given to the needs of women and girls in 'high use' settings such as schools and workplaces, and 'high risk' settings such as health care facilities and detention centres
	and *those in vulnerable situations*	Implies attention to specific WASH needs found in 'special cases' including refugee camps, detention centres, mass gatherings and pilgrimages

Figure 4 *Normative interpretation as regard the terms employed in target 6.2. Source: Joint Monitoring Programme, 2017.*

In 2015, the UN General Assembly adopts the 2030 Agenda for Sustainable Development, a plan of action in favour of people, the planet and prosperity, which also intends to strengthen universal peace and access to justice (United Nations General Assembly, 2015). This agenda establishes 17 Sustainable Development Goals[2] (SDGs) and 169 goals designed to be universally relevant and applicable to all countries. The SDGs require an integrated approach with respect to social, economic, and environmental dimensions. As for the MDGs,

[2] *More information available at: http://www.un.org/sustainabledevelopment/es/objetivos-de-desarrollo-sostenible/*

the SDGs integrate a specific objective for water and sanitation (SDG 6), which includes a series of targets that address all aspects of the water and sanitation cycle, while reflecting the recognition of water and sanitation as a human right. *Figures 3* and *4* capture the normative interpretation of Targets 6.1 and 6.2, which refer to water supply and sanitation, respectively.

In terms of monitoring, and in order to report on progress towards Targets 6.1 and 6.2, it was proposed to expand the water and sanitation ladders mentioned above. Among the main differences proposed, a new threshold (or higher "rung") was established for the level of drinking water service and sanitation (called "safely managed"). Additionally, a specific ladder for hygiene (hand washing) was proposed. Thus, the drinking water ladder distinguishes between "safely managed services", "basic services", "unimproved", and "surface water" (without service). Sanitation, on the other hand, is broken down into "safely managed services", "basic services", "limited services" (shared facilities), "unimproved", and "open defecation". Finally, the hygiene ladder reports separately on "basic facilities", "limited" (with water, but without soap), and "without facilities". The underlying idea behind the improvement of service levels is not only to increase the number of people with access, but also to promote progressive improvements in the quality of services, based on the normative criteria of the human right to water and sanitation (availability, quality, accessibility, acceptability, and affordability). Therefore, the indicators used for monitoring have been designed to match the normative interpretation of this right as closely as possible, while recognizing that routinely measuring some elements is not yet possible. It should be emphasized that countries are not expected to copy–paste the global objectives into their own national plans. In this regard, the 2030 Agenda asks countries to set their own national goals guided by world-level ambitions yet still taking into account national circumstances. Global indicators can be used even if national targets aim to reach a certain level, rather than universal coverage, by 2030. In countries where basic services are not yet universal, national objectives may thus focus more on the lower rungs of the water, sanitation, and hygiene ladders (Joint Monitoring Program, 2017).

2.2. Honduras, Lempira: Context of the case study

The Republic of Honduras is located in the centre-north of Central America. It is bordered to the north and east by the Caribbean Sea, to the southeast by Nicaragua, to the south by the Gulf of Fonseca and El Salvador, and to the west by Guatemala. Honduras is divided into 18 departments, and these into 298 municipalities, according to the 2001 Census, with an estimated 3,731 “aldeas” (villages) and 30,591 “caseríos” (hamlets).

Figure 5 *Political map of Honduras*[3].

Table 1 *General information. Source: http://www.presidencia.gob.hn/index.php/honduras/historia.*

HONDURAS GENERAL INFORMATION	
Official Name	Republic of Honduras
Capital	Tegucigalpa, MDC
Territorial extension	112,492 km^2
Population	8,630,890 inhab. (2015) [INE]
Population density	75 inhab. / km^2
Official language	Spanish
Currency	Lempira

The population is mainly engaged in agricultural activities, trade, manufacturing, finance, and services. The territory is very rugged, with high mountains, high plains and deep valleys, which host an enormous biodiversity. Honduras preserves some of the best archaeological remains of the Mayan culture and good examples of the advanced hydraulic engineering of its settlements.

[3] *Sources: www.wikipedia.org; mapadehonduras.blogspot.com*

Water and sanitation sector: current situation

Honduras belongs to the Latin American and Caribbean group according to the assessments carried out by the JMP. It is one of the 16 countries that achieved its goal of increasing access to piped water in premises by more than 25%, and of reducing open defecation by more than 25%, between 1990 and 2015 (Joint Monitoring Program, 2015). The most recent estimates point out that:

- The population with improved drinking water sources in urban areas increased from 92% to 97%;
- The population with improved drinking water sources in rural areas increased from 60% to 84%;
- The population with improved sanitation facilities in urban areas increased from 70% to 83%;
- The population with improved sanitation facilities in rural areas increased from 33% to 78%.

Despite having achieved the targets proposed by the MDGs, there are still significant disparities between the richest and poorest population, especially in rural areas of the country. In addition, a part of the population still spends more than 30 minutes to fetch water, and Honduras continues to be one of the countries in which water collection in rural areas falls mainly on women.

Governance

The Drinking Water and Sanitation (APS, by its acronym in Spanish) sector of Honduras is undergoing a process of profound change based on its decentralization policies, which establish the orderly transfer of APS services to the Municipalities.

The Ley Marco (Framework Law), approved in 2003, indicates the need to readjust the legal and institutional framework of the APS sector, in order to improve the planning, regulation, control, and provision of the services. Framed in the State's decentralization policy, the objective is to assign a leading role to the Municipal Governments; as this needs a broader participation of the social sectors, it implies establishing mechanisms to encourage the joint participation of the municipal authority and citizens. In this way, the Ley Marco determines in a precise way the different roles of the actors in the sector. It should be noted that national agents exercise their skills at both rural and urban levels.

At the state level, CONASA (National Council for Drinking Water and Sanitation) represents the governing body. It is mainly responsible for the formulation of policies, the definition of objectives and goals, the development of national strategies and plans, and the elaboration of the investment plan. ERSAPS (Regulatory Entity for Drinking Water and Sanitation Services) regulates the provision of APS services and counts with functional, technical, administrative, and budgetary independence. SANAA (National Autonomous Service of Water Systems and Sewers) fulfils mainly two roles related to the rural water and sanitation sector: 1) as the technical secretary of CONASA, it supports the formulation of policies (guiding functions); and 2) it provides technical assistance and support for the execution of rural programs. Finally, although not specifically mentioned in the 2003 Ley Marco, the Honduran Social Investment Fund (FHIS, by its acronym in Spanish) is worth mentioning due to its presence in the sector, its relevance, and its activities; FHIS is the executing agency of the Government of Honduras, mainly through the Unity Coordinator of the Rural Infrastructure Project (PIR, by its acronym in Spanish). Within the general objective of rural poverty reduction through access to basic infrastructure services, the sub-projects of drinking water and sanitation aim to increase coverage in rural areas, promote sustainability of services, and promote hygiene, benefiting the dispersed rural population that is still not served.

At the sub-state level, the Municipal Water and Sanitation Commissions (COMAS, by its acronym in Spanish) have been created to implement the decentralized supervision and control of APS services. It is noteworthy that COMAS are integrated by community members and councillors of the Municipal Mayors. Its functions focus on applying the regulations within the municipality, based on the laws and guidelines formulated by CONASA. On the other hand, the Local Control and Supervision Units (USCL, by its acronym in Spanish) are integrated by community members with the responsibility of monitoring the compliance of the law and its regulations, depending on a so-called “technician for regulation and control” in every municipality. In other words, it is ERSAPS counterpart, but at the municipal level.

In the rural area, more than 5000 Drinking Water and Sanitation Administration Boards (JAAPS, by its acronym in Spanish) apply community management, framed in the Regulation of Administrative Boards issued by ERSAPS. These JAAPS are responsible for the operation, maintenance, and administration of drinking water services, and they have the power to manage their legal status, establish their statutes, and set and collect fees (ERSAPS, 2006).

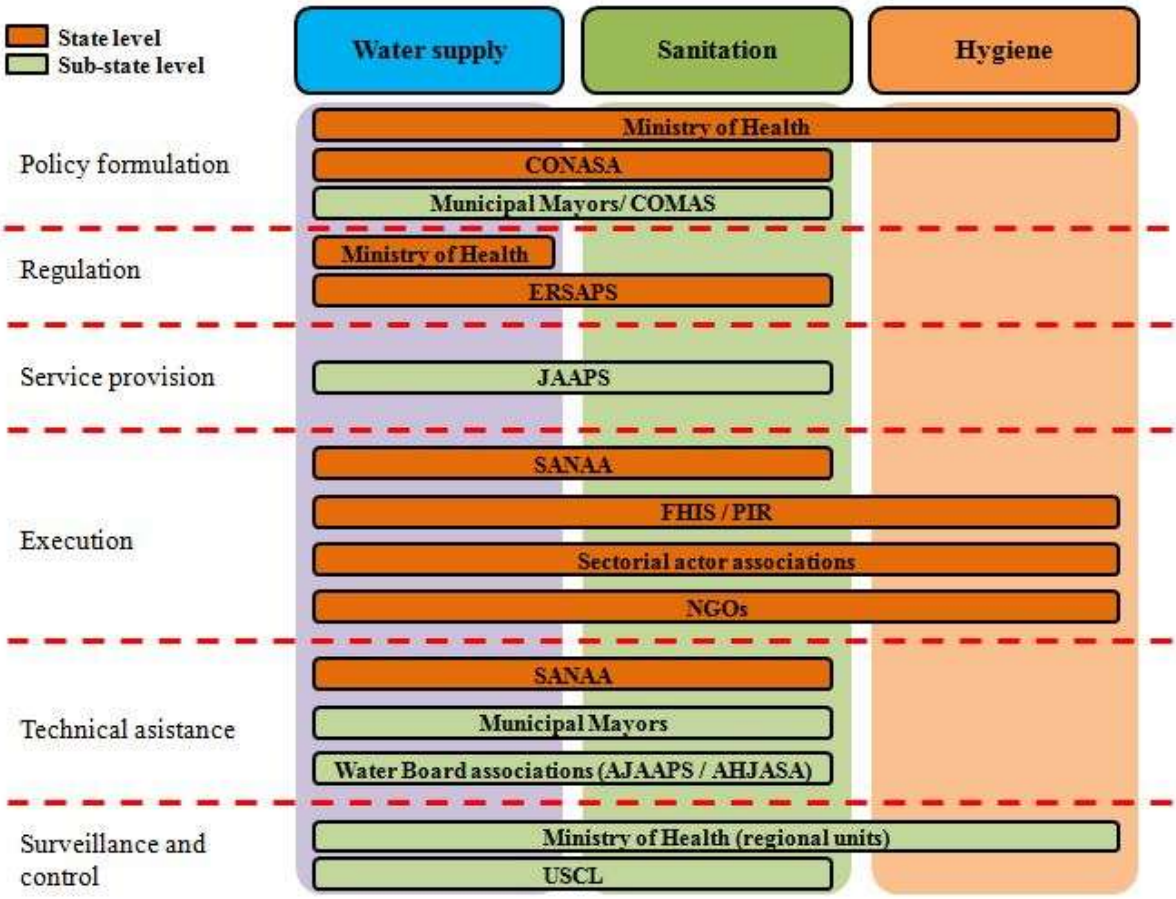

Figure 6 *Representation of main actor presented in Honduran water and sanitation sector, institutional and non-institutional, differentiating areas of action and competences. Source: own elaboration, from CONASA, 2013.*

Figure 6 schematically integrates the main actors presented above. However, the existence of other agents can be appreciated as well, which also have a relevant role in the Honduran APS sector. In this sense, several aspects to be mentioned. First, and despite the multiplicity of actors present in the sector, communication—in terms of information exchange—has been found to be insufficient. This is a key aspect, since several of the existing actors, such as the Ministry of Health, FHIS / PIR, and NGOs, are generators of information. Second, and in terms of the decision-making processes that occur in the sector, two clearly differentiated groups can be distinguished: 1) institutional actors, on whom a large part of the APS service delivery responsibility falls. These are usually characterized by a limited experience in the sector and a deficiency in the performance of their functions. This fact conditions the existence of decision-making processes that impact the current sectorial situation. Only the FHIS (PIR), which has greater financial support, and the Ministry of Health play an active role and integrate well-defined decision-making processes within it. The work of CONASA in the formulation of municipal policies is also significant, although it recognizes the still broad way to go, especially as a leading institution at the national level; and 2) external co-operators, who are characterized not only by the positive work they do in the APS sector, but also by their incorporation of clearly defined decision-making processes. In this sense, the

need to design strategies that make efficient use of the effort that several relevant actors are developing in Honduras is evident.

2.3. RURAL WATER AND SANITATION INFORMATION SYSTEM (SIASAR)

The Rural Water and Sanitation Information System[4] (SIASAR) is a joint initiative, launched in 2011 by the governments of Honduras, Nicaragua, and Panama, whose strategic objective is to have a basic information tool, updated for and with comparisons between the rural water and sanitation services existing in each country. In 2017, 11 countries were already integrated into initiative and had already designated SIASAR as the national reference information system.

The specific objectives of this information system are to: i) support action planning, coordination, and evaluation regarding the different actors in the sector; ii) monitor the coverage, quality, and sustainability of rural APS services; iii) register the performance of technical assistance providers, including their limitations in logistics; and iv) allow the transfer of water and sanitation statistical data, facilitating the exchange with other sectorial databases.

Public investment in the APS sector of Latin America and the Caribbean countries has traditionally been biased towards the construction of new infrastructures, with little attention paid to other factors that affect the sustainability of the provision of APS services (Lockwood et al. al., 2010). Understanding these factors is essential to addressing sustainability gaps and to improving policy development, sectorial planning, priority setting, budget allocation, project design, and technical assistance delivery.

This central idea has led countries to design and agree on a set of monitoring instruments (surveys) to analyze the quality and sustainability of APS services from different perspectives: i) the community; ii) the water system; iii) the service provider; and iv) the technical assistance provider. Additionally, this initiative incorporates combined methodologies and tools to address all aspects related to the collection of information (capture, editing, and validation of data), its processing and analysis, and finally, the use of such information through the web application and generation of reports.

One of the most outstanding aspects of SIASAR is the way in which collected data are organized and analyzed (Pérez-Foguet & Flores-Baquero, 2015). In its so called "conceptual

[4] *More information available at http://siasar.org/es*

model", six aggregate dimensions are defined to evaluate water and sanitation services from different but complementary points of view. The objective of this structure is to maintain the focus of the different aspects that characterize the increasingly decentralized APS sector. The reason is that, in practice, the roles and responsibilities of sectorial issues are assumed by different actors (Giné-Garriga & Pérez-Foguet 2013a, 2013b).

Table 2 *SIASAR conceptual model: components, dimensions, partial indices, and general index. Source: Requejo-Castro et al. (2017).*

WSP (Water and sanitation performance index)	
NASH (Water, sanitation, and hygiene service level)	**ISSA (Water services sustainability index)**
Water service level (NSA) Accessibility Continuity Seasonality Quality	**Water system infrastructure (EIA)** System autonomy Production infrastructure Water catchment area protection Treatment system
Sanitation and hygiene service level (NSS) Sanitation service level Personal hygiene Household hygiene Community hygiene	**Service provision (PSE)** Organization management Operation & maintenance management Economic management Environmental management
Schools and health centres (ECS) Water supply in schools Water supply in health centres Sanitation and hygiene in schools Sanitation and hygiene in health centres	**Technical assistance provision (PAT)** Information systems Institutional capacity Community coverage Assistance intensity

The mentioned dimensions propose to measure: i) the Water Service Level (NSA), ii) the Sanitation and Hygiene Service Level (NSH), iii) the service provision in Schools and Health Centres (ECS), iv) the Water System Infrastructure (EIA), v) the Service Provision (PSE), and vi) the Technical Assistance Provision (PAT). Additionally, these dimensions are grouped into two partial indexes: i) Water, Sanitation and Hygiene Service Level (NASH), and ii) Water Services Sustainability Index (ISSA). These partial indexes seek to maintain the focus on aspects related to the quality and sustainability of services, identified by all member countries. Finally, a final level is represented by the Water and Sanitation

Performance Index (WSP). These latter indices provide a means to initiate discussion and stimulate public interest. These elements are presented in *Table 2*.

Briefly, and as reflected in detail in Requejo-Castro et al. (2017), each dimension comprises four components, and each component is fed by a short list of individual indicators with a total sum of 109. Regarding the methodology used to process the information, first the indicators are classified according to the conceptual model described above. Since the collected data are often represented at different scales (percentage of systems with adequate water treatment, distance to the source in meters, continuity of service in hours per day, etc.), they have to be normalized before the analysis. Thus, a score between 0 and 1 is assigned to each parameter, where 1 represents the best situation and 0, the worst one. Finally, the components are defined by simple and easy-to-use utility functions. The different components of each dimension are then added as a single value. In this sense, it should be mentioned that the final agreement reached by the countries grants the same weight to all components, dimensions, and indices. Additionally, an additive aggregation method is used for the different dimension construction (allows compensation between components) and a geometric aggregation for the definition of partial and general indices. Finally, in order to facilitate prioritization and decision making, obtained results are presented more comprehensible to end users and stakeholders by linking components, dimensions, and indices to a defined set of categories (from A–D, with A being the best result, and D, the worst). These categories are defined according to the following ranges: A [1–0.9], with both limits included, B (0.9–0.7], C (0.7–0.4], and D (0.4–0].

Although the indicators that make up the conceptual model differ to some extent from those proposed to monitor the SDGs, it should be mentioned that the SIASAR initiative admits the need to align with international monitoring systems. In this sense, a thorough review of the questionnaires for data collection is being carried out in order to adapt them to the key monitoring elements of the SDGs (Requejo-Castro et al., 2017).

Considering the above, an example is shown in *Figure 7* of some preliminary results obtained from the information collected in different countries. In this example, the sustainability of APS services in the communities (general index WSP) is only evaluated as such in 8% and 31% of the cases, obtaining a grade of A and B, respectively. It should be noted that reaching a classification of C or a lower implies the need for external help, which is not associated with a sustainable situation. The service providers fared slightly better, with almost 52% of service providers (JAAPS) reaching a grade of A or B in the ISSA partial index. Intriguingly, a high percentage of JAAPS Board of Directors that qualified as A or B were composed of 2 or more women members (of the 7 members required by law): for the A grade, 68% had ≥2 women, and for the B grade, 60% had ≥2 women (a lower yet still significant percentage). A final aspect to be highlighted is the difference between SIASAR and the JMP, in terms of access to water. The first has a more restrictive approach, as it

considers other aspects beyond access. As a result, the JMP estimated in 2014 that 16% of the population in Honduras did not have access to improved drinking water sources. In contrast, the SIASAR estimations focused on access to sustainable services and increased this number to 55% of the rural population.

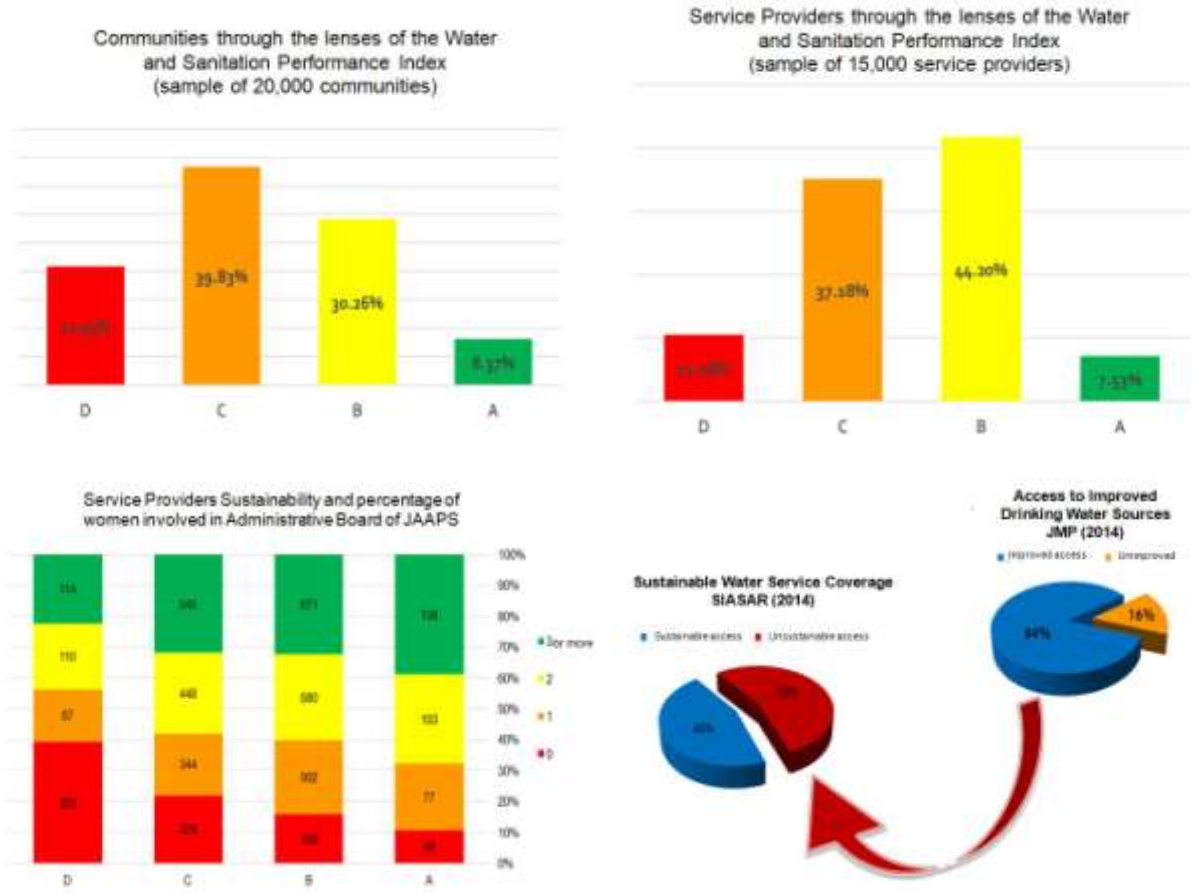

Figure 7 *Preliminary results based on SIASAR information. Sources: World Bank, 2017; SIASAR 2014; JMP 2014.*

At the present, and after 6 years participating in the SIASAR initiative, Honduras has exhaustive information on its 3,869 communities (55% of the total estimated rural communities), 3,123 associated water systems, and 2,585 JAAPS (service providers). These numbers reveal one of the most important challenges facing by SIASAR countries. Undoubtedly, information collection is a crucial stage, and it is associated with the need for important human and logistic resources. The challenged faced with this is not only obtaining the information but also keeping it updated.

In the particular case of Lempira Department, work is being done on as to define the Annual Operational Plan (POA, by its acronym in Spanish) for the year 2017. The objective is to analyze the results of 2016 in order to define the actions to be executed during 2017. Thus,

the definition of strategies for strengthening effectiveness in decision-making processes is based on the information obtained through SIASAR.

As a more specific example, the municipality of Piraera, in Lempira, is immersed in the management of a participatory process among different actors (municipal mayor, civil society, and JAAPS) with the aim to develop a water and sanitation diagnosis and analysis. This context seems auspicious for exploiting SIASAR as a tool to support decision-making and to develop a municipal strategic plan for water and sanitation. This objective, although simplified, will be the central part of this case study.

2.4. STATISTICS AS A TOOL FOR DATA ANALYSIS

In order to monitor the compliance with the SDGs, there has been a need to define indicators that measure progress or setback in the achievement of the proposed goals. Information management is of great importance for decision-making, since it allows undesirable situations and trends to be identified, with the aim of ultimately being able to establish measures against them.

Working with large volumes of data requires the use of statistical tools as to develop objective and affordable analysis and, ultimately, to use the information and results to facilitate and support decision-making processes. Specifically, in this case study, the use of software R is proposed, which is an open-access, integrated development environment (IDE).

The information that will be used as a reference comes from a database of 412 communities belonging to the Department of Lempira (Honduras). As mentioned previously, this information is collected in field through SIASAR questionnaires. From these communities, and with the aim to simplify the proposed activities, we will work with 19 indicators[5] (original variables) related to community characteristics, as well as water and sanitation service levels and service provider performance associated with them.

It is essential to recognize that working with large volumes of data, and especially those obtained through questionnaires or surveys, requires information pre-processing in order to make the content easily accessible and manageable. In particular, incomplete or inconsistent data must be either corrected (by elimination of duplicates, anomalies, and atypical data) or recovered in a more complete form.

[5] *Chosen information is an extract of the database available at http://doi.org/10.5281/zenodo.571351*

In this case study, facilitated data is already pre-processed. This includes the elimination of communities with variables that take NA values ("no answer"), zeros that do not correspond, or errors in the values. For example, answers which specified more than 24 hours of service per day were eliminated. As a result, the number of communities initially selected was reduced from 412 to 386, comprising 22 of the 28 Municipalities of Lempira. This can be considered as a representative sample of the Department of Lempira.

In particular, in this case study, aspects related to basic univariate statistics will be addressed, such as:

- Calculation of typical descriptors in quantitative variables (mean, coefficient of variation, median, quartiles, minimum, and maximums, Fisher's asymmetry coefficient, and Shapiro-Wilk and Pearson Chi-square normality test);

- Construction of simple indicators, based on basic operations between available variables, providing them with interpretative content;

- Transformation and normalization of variables. These techniques will be used to facilitate interpretations and applications of subsequent methods.

Additionally, multivariate statistic concepts will be addressed, such as:

- Calculation of correlation and covariance matrices;

- Principal Component Analysis (PCA), which is a technique used to reduce the dimensionality of a data set. Specifically, a set of observations of possibly correlated variables is converted into a set of observations (new variables) that are not correlated with each other, called principal components[6]. This is achieved by diagonalizing the correlation or the covariance matrix;

- Application of an orthogonal rotation (Varimax) to redistribute variances in a subspace determined by a part of the principal components. Thus, rotated components, called factors by the application of factorial analysis technique, depend strongly on a minimum number of original variables[7];

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[6] *Additional information can be found in Maindonald and Braun (2010) - Chapters from 2 to 4, and 12 -, Kottegoda and Rosso (2009) - Chapters 1, 5 and 6 -, Ross (2014) - Chapters 2, 7 and 8, Ugarte et al. (2015) - Chapters 2 and from 7 to 10.*

[7] *More information related to rotations and their geometric interpretation in Tucker and MacCallum (1997) - Chapters 8 and 9 -, Kottegoda and Rosso (2009) - Chapter 7 -. Additional information regarding index construction, variable selection and weighting methods can be found in Nardo et al. (2005) - Chapter 2 -.*

- Multiple Linear Regression (MLR), used to approximate a dependent variable based on some predictor variables values[8];

- Definition of indexes related to variance (unsupervised techniques) and based on supplied information (supervised techniques).

3. CLASS ACTIVITY

This activity is structured in two large blocks:

Block I. The work in Block I should be carried out in small groups (of 3 or 4 people), to encourage a final sharing. The duration of this activity is estimated to be 1 hour, with 30 minutes of group discussion, and 30 minutes of general discussion. We suggest that the professor acts as a moderator. In order to facilitate the development of this block and the subsequent activities, we recommend that the students receive all information presented in Section 2 of this case study. Ideally, the contextualization of the case study should be facilitated prior to developing the activities, in order to provide adequate time for reading and understanding.

Block II. This is a guided workshop by the teacher. Thus, we recommend that the students work individually. We estimate that Block II should take 2 hours; note that it can be carried out in one or two sessions, at the discretion of the teacher. Specifically, the workshop consists of observing and replicating step-by-step the provided programming code. Once the code has been replicated, with each step understood and each result interpreted, a group discussion should be carried out on the context and data availability, and their implications in planning and decision making.

For workshop implementation, a guide composed of 4 parts is provided, each with a different objective. All necessary material is provided in form of Annexes and under the following nomenclature:

- A.I_Caso_Estudio_G.pdf → R procedure guide.

- A.II_CE_guiado.R → R procedure code.

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[8] *More information regarding regression models can be consulted in Kottegoda and Rosso (2009) - Chapter 6 -, Maindonald and Braun (2010) - Chapters from 5 to 7 -, Ross (2014) - Chapters 9 and 10, Ugarte et al. (2015) - Chapter 12 -.*

- A.V_datos_CS.RData → Initial data by communities.

- A.VI_WSP_CS.RData → Additional data of numerical assessment (for Part II).

BLOCK I

This first activity aims to raise awareness of the importance of access to adequate water and sanitation services. At the same time, it also seeks to highlight the relevance of monitoring water and sanitation progress to support decision-making processes (together with the difficulties involved). In this sense, and after presenting the theoretical content of this case study, we propose to reflect on and then answer the following questions:

1. Which are the direct and indirect impacts for the various aspects of water and sanitation progress? For this, we propose that the students fill out the following table, indicating the direct and indirect impacts associated with the specific aspects; however, students can also add further aspects. Impacts can be identified from distinct perspectives, such as health, development, or environment, among others.

ASPECT (deprivation)	DIRECT IMPACTS	INDIRECT IMPACTS
Water quality (presence of pollutants)		
Availability (service hours per day)		
Affordability (water tariff paid)		
Water accessibility (coverage)		
Sanitation accessibility (coverage)		
Gender equality (women presence in Administrative Boards)		

2. Which positive and negative aspects may exist in the development of global monitoring systems? And in the alignment of other information systems with these global initiatives (e.g. SIASAR)?

3. Considering the specific context of Honduras, it is clear that obtaining information is one of the most important challenges in the sector. What initiatives could be proposed to facilitate this task?

4. The policy of decentralization of APS services in Honduras is transferring responsibility for service provision and management to the municipalities, where it is taken on by civil society groups that are usually inadequately prepared. How could this transition be made more favourable?

BLOCK II

The objective of this block is to introduce the students to basic guidelines that permit an autonomous use of the proposed software. In parallel, it should lead to a discussion about the interpretation of the obtained results, specified to the context of Lempira Department (Honduras).

Part 0

1. Based on available variables, construct simple indicators (minimum 6) that allow community water and sanitation situations to be assessed;

2. Apply a basic descriptive analysis that allows the behaviour of each indicator to be characterized, reflecting on the need to transform and / or normalize them;

3. Apply a descriptive analysis—this time multivariate—that allows possible relationships between indicators to be identified, using graphs and correlation matrices;

4. Save the database with the constructed indicators in order to use it in the subsequent activity.

Part I

1. Carry out PCA. Decide the number of components to work with and identify significant indicators;

2. Construct variance-based indices according to the direction of the principal components. Approximate the total variance by grouping the components.

Part II

1. From the Water and Sanitation Performance (WSP) numerical valuation available (A.VI_WSP_CS.RData), apply MLR successively to identify the most influential indicators on WSP;

2. Construct an index based on the generated linear model.

Part III

Base on your previous work, answer the following questions:

1. Which are the indicators (variables) that have the most influence when applying PCA? And when applying MLR? Are they the same? To answer these questions, use the table of alpha coefficients;

2. Is there any relationship between the constructed indexes (I1, I2, IMV, IWSP)? It is recommended to use the dot charts as support;

3. What would be the impact of a reduction of variables, both on practice and in terms of data collection?

4. Which communities should be worked with first? Which criteria would be more convenient to use: constructed indexes, which try to focus on the "relevant" variables, or only coverage aspects? In order to justify the answer, it is suggested to generate rankings that allow the worst-evaluated communities to be visualized.

3.1. Solution and evaluation criteria

Block I solution

Taking into account that the answer possibilities are open, we have listed some possibilities in the Table below to order to guide the teacher/moderator during the general debate.

1. Which are the direct and indirect impacts for the various aspects of water and sanitation progress? (using the following table).

ASPECT (deprivation)	DIRECT IMPACT	INDIRECT IMPACT
Water quality (presence of pollutants)	- Human health affected (including death) - Ecosystem deterioration (pollution)	- Difficulty to develop capacities (poverty increment); health expenditure increases - Subsistence resource reduction (food security decreases and poverty increases)
Availability (service hours per day)	- Needs cannot be met when required (drinking and cooking, hygiene, washing food and clothes)	- Economic investment, for example, in household deposits for water storage
Affordability (water tariff paid)	- Discrimination against the most unfavourable sectors of the population - Possible generation of social conflicts	- Difficulty in accessing to other services; Increment of the gap between those who have more and those who have less - Increment of the gap with public institutions or actors responsible for service management; Citizen participation decrement
Water accessibility (coverage)	- Water consumption needs cannot be guaranteed, in case the source is far away (drinking and cooking, hygiene, washing food and clothes) - Insecurity increment (especially when women and girls collect water and when distances are wide)	- Difficulty to develop vital and economic activities - Potential increment of aggressions against girls and women
Sanitation accessibility (coverage)	- Human health affectation - Common environment deterioration (habitat)	- Difficulty to develop capacities (poverty increment); Health expenditure increment ; Lack of awareness about hygienic practices - Proliferation of parasitic diseases and infectious pathogens; Loss of eco-tourism value (economic impact)
Gender Equality (women presence in Administrative Boards)	- Discrimination against women in decision-making - Empowerment possibilities decrement	- Promotion of patriarchy and women dependency - Gender inequality continuity

2. Which positive and negative aspects may exist in the development of global monitoring systems? And in the alignment of other information systems with these global initiatives (e.g. SIASAR)?

A first positive aspect that could be highlighted would be using common indicators for the comparison of global data, as having countries “speak the same language" allows those countries or regions that require more attention to be identified. Second, the establishment of international goals has been a precursor of national policies and strategies with the aim of improving the sectorial situation. Third, and related to the first point, the visualization of sector status is relevant, both to encourage the initiative of the countries to improve and to stimulate international cooperation.

Negative aspects could include the difficulty to obtain and update the proposed information for some countries. The definition of "simple" indicators may leave out other relevant aspects that favour the identification of those sectors of the population that are most vulnerable. However, it must be recognized that obtaining more detailed information implies a cost increment, which would even further hinder the information-gathering capacity of some countries.

The alignment of other monitoring systems is relevant for contributing to international goals monitoring. Undoubtedly, the possibility of obtaining information compatible with the proposal at an international level would favour a more accurate and reliable monitoring. Data of this type are the central axis of any information system that would stimulate the positive aspects mentioned above. However, other information systems may have specific interests, which are different than the ones contemplate globally. Such considerations should not represent a problem, nor should it limit other national interests and goals.

3. Considering the specific context of Honduras, it is clear that obtaining information is one of the most important challenges in the sector. What initiatives could be proposed to facilitate this task?

As explained above, there is a multiplicity of actors, some of whom are generators of information. Basically, this is possible thanks to the availability of human and logistical resources, aspects which other actors do not have. At the same time, the existing deficiency in the exchange of information has become relevant. Therefore, the creation of a common information system that integrates a series of agreed indicators of interest could be a first step to be taken. It should be an information system accessible by any user. Thus, the common information could be obtained in the field by the different existing actors. In this sense, the important costs associated with this task could be shared collaboratively and within the possibilities of each actor.

4. The policy of decentralization of APS services in Honduras is transferring responsibility for service provision and management to the municipalities, where it is taken on by civil society groups that are usually inadequately prepared. How could this transition be made more favourable?

One of the first aspects to take into account is the preparation or capacity of the actors present in the municipalities, which is usually quite low. Thus, a first approach might be to training local agents. However, this would not be enough if local public institutions were not also trained. The main objective is to improve the involvement of these institutions in the regulation, supervision, and support of service management. Due to the fact that training is a gradual process, technical assistance by professionals during a certain period of time would be necessary. At the same time, mechanisms of citizen participation and accountability should be established, in order to promote awareness about water and sanitation as well as transparency. Another interesting initiative would be designating/creating spaces for discussion and debate, in which others' experiences can be shared and learnt from.

Block II solution

The numerical solution of the proposed activity, including the discussion of results, can be found in the attached document, under the name "Caso_Estudio_G.pdf". It should be mentioned that this is not the only solution, as students can construct their own indicators or define different criteria from those proposed.

In any case, for both PCA and MLR, 3 of the 7 variables are discarded. This implies a significant reduction in terms of time and costs, if the considered variables do not intervene with data collection. However, and despite the fact that both methods recognize the same 4 variables as relevant (coverage indicators and ratios), the relative importance of these variables is different for each method. Therefore, and depending on information available (data and / or qualitative assessment), the most important aspects or variables to be considered might differ. From a planning perspective, communities in more deficient situations can be identified according to a new index proposal (IMV and IWSP), which incorporates more information to typical coverage assessments. In an extended manner, and over many years, investment decisions in the water and sanitation sector have been made based on the percentage of coverage, leaving out important aspects of the service provider and the quality of the service itself.

Evaluation criteria

In order to provide the students with an objective and transparent evaluation system, we suggest using the provided rubric (see Annex IX), which shows: i) the knowledge that

students are expected to acquire, and ii) the criteria that will be used to evaluate the content of the resolution associated with the proposed activities.

The way to use the rubric depends on the previous knowledge by the students and professors. That is, the rubric must be provided with the information related to the contents to be evaluated. Thus, some guidance should be given to students to allow them to carry out the proposed activities.

Specifically, to evaluate Block I, each group must submit a written document answering the questions raised. These answers will be evaluated based on the proposed rubric. However, the professor is free to choose an alternative evaluation method if she/he considers it more appropriate.

Block II will not be evaluated, as it is a guided workshop with the sole objective of providing the necessary knowledge to develop the autonomous activity that is proposed.

4. HOMEWORK ACTIVITY

In this activity, students are suggested to work in small groups of 3 or 4 (note that maintaining the same working groups as in the previous activity would make it easier to evaluate the overall work). This activity can take about 8 or 10 hours. Basically, it consists of applying the methodology shown in the guided workshop, with the difficulty of incorporating into the analysis a G1 and G2 classification of the communities, forcing a double-blind analysis to be carried out independently.

The proposed activity integrates the generation of code and interpretation of results simultaneously. In this sense, the wording provided in this section will facilitate the development of the activity in an orderly manner, through different suggestions and questions. The necessary material is provided in the form of Annexes and under the following nomenclature:

- A.VII_IND_CS.RData[9] → Initial data, simple indicators constructed during the class activity.
- A.VIII_CLAS_G12_CS.RData → Data of communities graded as G1 or G2.

[9] *It should be mentioned that this database is provided within the Annexes. However, it is recommended the students to create their own database during the guided workshop. In so doing, the character "#" should be eliminated from the code line: save(data_f,file="IND_CS_nombre.RData").*

- A.VI_WSP_CS.RData → Additional data of numerical assessment (for Part II).

This activity requires the students to work autonomously with the proposed statistical software, analysing and interpreting the results obtained for this case study. For this purpose, we recommend to follow the guidelines detailed below in an orderly manner, as well as to answer the proposed questions:

Part 0

1. Load saved data from guided workshop (A.VII_INS_CS.RData), which corresponds to the simple indicators constructed, transformed, and normalized for the 386 communities at hand;

2. Load data associated to the classification G1-G2 (A.VIII_CLAS_G12_CS.RData) of the communities and incorporate this grading as an additional column in previously loaded database (community identifier, 6 simple indicators, and classification G1-G2). How many communities of each class exist? Identify the differences that characterize each group, in terms of indicators. Use dot charts and different colours depending on the class;

3. Apply the summary function constructed in the previous activity for G1 and G2 communities separately. What does the summary show? Is it possible to conclude that G1 communities have a higher value than G2 communities? Draw histograms and box plots for all variables and for each class. Analyze and discuss, taking previous activity as an example;

4. Use point graphs crossing some of the variables. Is there any relationship among these variables? Calculate the covariance matrices by group and discuss the results. How could the covariance matrix be interpreted? Which variables are more related to each other (in each group)? Is it similar to what was observed in the previous activity (guided workshop)?

Part I

1. Apply PCA to G1 class communities. Explain what this method is about. Could it be applied without using the default function of R? How?

2. Construct indices according to selected principal components and an index that approximates the total variance. How many components should be used? Which percentage of the variance explains each selected component? Which is the main

difference between the indices related to each principal component and the total variance index? Which are the most significant indicators (dimensionality reduction)?

3. Repeat the procedures for G2 class communities.

Part II

1. Incorporate WSP numerical valuation into the database at hand.

2. Apply a linear regression to G1 class communities, considering the 7 indicators. Are outliers identified? If yes, eliminate such data. Does the linear regression improve by eliminating these data?

3. Apply successive linear regressions eliminating indicators until the best model is adjusted. Is it obtained a reasonable R^2? Do any of the models correctly represent the WSP index? Reflect on the amount of data available. How many and which indicators are finally significant?

4. Construct a new index from the chosen linear model, in case a valid model is achieved;

5. Repeat the previous procedure for the G2 class communities.

Part III

Answer the following questions based on the results obtained. For this purpose, we recommend to use the graphics and tables constructed during the development of the activity:

1. Which are the indicators (variables) that are the most influential when applying PCA and MLR? Are they the same, or do they coincide? Use alphas coefficients table. Is there any relationship among the indices constructed by class? Use point graphics as support;

2. What additional information about the groups is obtained by applying the methodology separately? Can G1 be differentiated from G2 according to the variables that are the most influential? Is it useful to differentiate communities in G1 and G2 in order to apply investment decision criteria such as those proposed in the guided workshop?

3. In which communities should a hypothetical investment be prioritized, in the case that not all of them can be attended to? Make a proposal (technique) to support this decision. In the proposal, would it be important to consider other factors to support decision-making, such as the existing population in each community?

4.1. Solution and evaluation criteria

Proposed activity solution

The numerical solution of this homework activity can be found in attached Annexes under the name “A.III_Caso_Estudio_A.pdf” (in addition to “A.II_CE_guiado.R”, which corresponds to the solution code). In this occasion, the objective is to guide the teacher in relation to the expected results. It is worth mentioning that the solution corresponds to the numerical values and the graphics obtained when applying the requested methods. However, for this solution, it is useful when the community service levels are classified, which allows the analysis to be focused on those communities with a more deficient situation (in this case, G2). Thus, the analysis is more specific, showing the deficiencies within the group rather than in the entire data set. This directs the focus of proposed investment prioritization, and the associated actions, to those of class G2 (with smaller average of indicator values). In addition, we suggest considering factors such as community population, to invest in those communities in which there is a large population with a low level of service, and the number of women participating in Administrative Boards, to promote gender equality as a catalyst for development within the communities.

Evaluation criteria

In order to evaluate this activity, a report will be requested that stems entirely from the proposed activity. This report should be accompanied by the codes developed (in the form of annexes). Synthesis capacity should be evaluated, based on the simulation of using the report as a guide for the administration of Lempira in its decision-making processes.

We suggest using the rubric (as mentioned previously) for the report evaluation (see Annex IX). Specifically, those technical aspects identified in the rubric will be evaluated. However, and depending on students’ responses, evaluation might also consider reference made to other aspects not included in the rubric. Therefore, the rubric represents a possible instrument to facilitate the evaluation of the proposed activities as a whole. As previously mentioned, the teacher is free to choose an alternative evaluation method if he/she considers it more appropriate.

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ANNEXES

I. Class activity procedure guide < A.I_Case_Study_G.pdf >

II. Class activity R code (comments in Spanish) < A.II_CS_guided.R >

III. Homework activity solution <A.III_Case_Study_A.pdf >

IV. Homework activity R code (comments in Spanish) < A.IV_CS_autonomous.R >

V. Class activity data < A.V_datos_CS.RData >

VI. Activities data < A.VI_WSP_CS.RData >

VII. Homework activity data < A.VII_INS_CS.RData >

VIII. Homework activity data (separated by group) < A.VIII_CLAS_G12_CS.RData >

IX. Evaluation rubric proposal < A.IX_Evaluation_rubric.pdf >

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