A holistic and participatory information system for rural water and sanitation sector in Latin America and the Caribbean

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Abstract
The provision of water supply, sanitation and hygiene services has emerged as a top priority of the development agenda in Latin American and the Caribbean. The sector in this region is characterised by decentralisation. Information systems (IS) have supported decision-making, but they have been implemented with poor coordination. In this context, this article introduces a holistic and participatory IS which includes a comprehensive framework for data collection, data analysis and data dissemination that simultaneously fulfils different stakeholders' needs in relation to decision-making at both local and national level. Main results relate to the development on a holistic information system that provides a common monitoring architecture for regional, national and local understanding, collaboration and comparison. The benefits are remarkable in terms of services' sustainability and stakeholders' engagement.

Keywords
Water and sanitation; rural areas; decision-making; information system

INTRODUCTION

Despite the efforts made towards the Millennium Development Goals (MDGs) targets during the last decade, millions of people across the world still lack improved access to water supply or basic sanitation. Specifically, in Latin America and Caribbean countries, even if target related to water access was met, last estimates reported that 16% of the rural population don't have access to improved water resources. Regarding sanitation target to halve, by 2015, the proportion of people without access to basic sanitation was not met and still 34% of the rural population don't have access to it (Joint Monitoring Programme 2015a).

There is little doubt that within the MDG period, monitoring data has played a key role in providing the evidence base for a range of different interventions and actions at different levels, from global to local. Briefly, MDG indicators pursued, on the one hand, to quantify those proportions of population using drinking water directly collected from surface water, employing other unimproved water sources, using "improved" sources other than piped household connections and benefiting from household connections in a dwelling, plot or yard. On the other hand, for sanitation, related indicators gave an understanding of the proportion of population with no sanitation facilities at all, of those reliant on technologies defined by the Joint Monitoring Programme (JMP) as "unimproved," of those sharing sanitation facilities of otherwise acceptable technology, and those using "improved" sanitation facilities (Joint Monitoring Programme 2008). As far as hygiene aspects, no indicators were employed. Nevertheless, there exists a general problem with the access and quality of data. Admittedly, the indicators employed during the MDG period have fallen short of measuring progress in some key areas, and more precise and complete measurements are required to drive the sector forward (Joint Monitoring Programme 2015b). Indeed, a considerable number of people who have been erroneously counted in statistics as "covered / served" do not access to a minimum level of service (Giné-Garriga and Pérez-Foguet 2013).

The agreement of a Sustainable Development Goal (SDG) target of universal and equitable access to water, sanitation and hygiene by 2030 requires a fundamental change in the way the sector is assessed, and multi-sectorial and system-wide approaches to monitoring and evaluation are needed. They represent a shift from a reduction in the percentage of the population without access to improved water and sanitation to aiming to ensure safely managed drinking water and sanitation services for all (Targets 1 and 2 of SDG number 6). In consequence, key monitoring challenges should be adequately addressed, including the monitoring of inequalities and access to services by vulnerable groups, and an adequate definition of safely managed services. Target 6.1 and 6.2 interface, to certain extent, with target 6.3 which seeks halving the proportion of untreated wastewater and increasing recycling and safe reuse.

Information Systems (IS) appear as useful tools for supporting decision-making. In Latin America and Caribbean countries, several IS have been implemented to evaluate Rural Water Supply Services (i.e. “Sistema Nacional de Información del Agua, SINA” in Mexico, “Sistema Único de Información, SUI” in Colombia, “Sistema de Información Sectorial de Agua y Saneamiento, SIAS in Peru, among others). However, these efforts have been carried out with poor coordination. On the other hand, important initiatives took place, as The International Benchmarking Network for Water and Sanitation Utilities (IBNET) promoted by the World Bank to encourage water and sanitation utilities to compile and share a set of core cost and performance indicators, and thus meet the needs of the various stakeholders. Nevertheless, the rural sector, characterised by an increasing decentralization of responsibilities to local administrative units, requires the promotion and implementation of a shared information and reporting system.

This paper aims to describe the development of a holistic and structured Rural Water Supply and Sanitation Information System (SIASAR), which supports decision-making of multiple stakeholders involved in the sector (i.e. governmental bodies, regional and international institutions, NGOs, donors, etc.), and which has been defined, managed and updated in a participatory manner at regional level. This initiative aims to improve resource allocation in the participating countries’ rural water supply and sanitation (RWSS) sector by allowing them to better identify needs and target future investments more effectively (Pena et al. 2014). SIASAR is today in use in eight countries, namely Honduras, Nicaragua, Panama, Dominican Republic, Costa Rica, the Mexican State of Oaxaca, Peru and the Brazilian State of Ceara. This idea emerged from the need for countries to count on systematic and reliable information and aimed at developing an Information and Communication Technology (ICT)-based monitoring and decision-making tool for the rural RWSS sector. The SIASAR tool was developed natively on a highly practical and interactive web platform that draws on the strengths of open source and mobile technology (Pena at al. 2014). The initiative is turning its efforts towards improving the conceptual model and ICT tools on the basis of the lessons learned from its implementation as well as formalizing the institutional and operational arrangements to consolidate and extend its use.

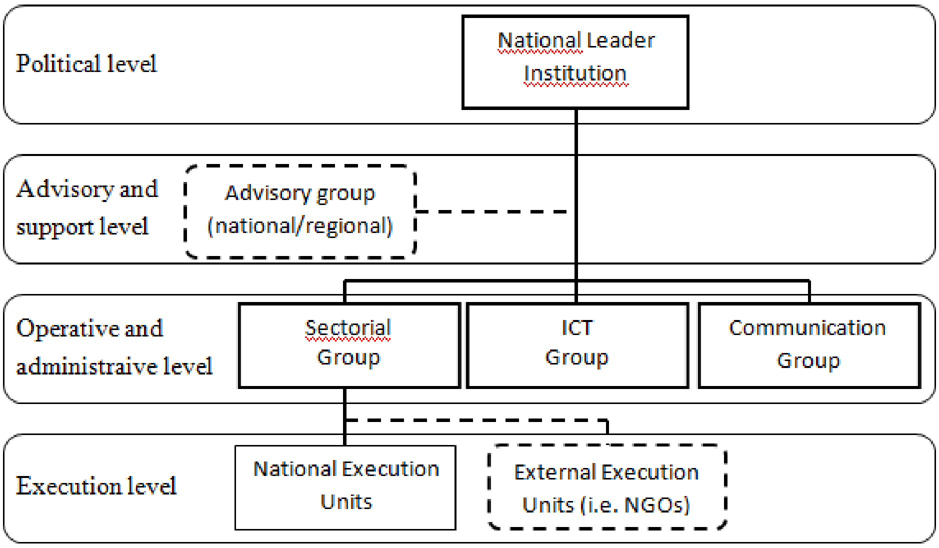
This study focuses on the structure of the SIASAR model, which links field data with a set of indicators and indices, which are exploited to describe different levels of service and to assess sustainability aspects, allowing to direct attention to those areas that require special policy attention.

DEVELOPING SIASAR

This section aims to describe the conceptual framework of SIASAR and the collaborative methodology for its development and implementation. Specifically, it presents the participatory process in place and the core information considered for sector evaluation, as well as a detailed description of how collected data is structured and post-processed under several considerations.

SIASAR initiative is possible thanks to a well-structured organization at different levels that is replicated in every member country (see Figure 1). As reflected in its normative (SIASAR 2016), each nation is committed to appoint a leader institution aiming to ensure the development, implementation, promotion and financing of the IS. At an operative and administrative level, these objectives are supported by the collaboration of three main complementary groups; i) a sectorial one which is responsible to coordinate the execution of conceptual and field aspects, ii) an ICT team that facilitates software development and update, and ensure working permits and data security, and iii) a communication group that collaborates with the creation, design and publication of content and communication materials of SIASAR. The creation of such structure and the commitment to ensure the sustainability of the IS through its institutionalization, actors capacity building and implementation, are minimum requirements to join the initiative. In parallel, these groups are coordinated by one of the SIASAR countries, which assumes an annual leadership, in terms of group organization and economic management, and transfers it after this period. Similarly, national teams count with the support of external advisory groups when mutually agreed.

Figure 1. Basic organizational structure of SIASAR replicated in each member country.



Under this structure, it is remarkable that every step carried out is defined through a participatory process. This progression is facilitated by a constant communication by all SIASAR stakeholders (i.e. every two weeks or monthly videoconferences), where main issues and improvements are discussed, shared and formally approved by all members. Complementarily, several regional meetings and field missions take place every year, allowing participating countries to debate current and future issues and to increase a sense of community. In addition to this, pilot studies are implemented when needed to check in field required aspects. It is clear that this way of working is time-consuming and improvements take place at different rates.

SIASAR initiative is growing year after year since its first steps in 2012, receiving requests from new countries to join it. As mentioned, eight are the countries which have formally adopted this information system, which hinders more dynamic work sessions. This drawback is expected to become more pronounced since three more countries have presented their commitment to be part of this community. However, and against these difficulties, the continuous participation of involved members generate positive aspects in terms of sustainability and stakeholders' empowerment.
Through this participatory process, the monitoring system was defined as a comprehensive set of

indicators assessed by four different survey instruments: i) the community, ii) the water system, iii) the service provider, and iv) the technical assistance provider. In brief, the indicator framework is based on three fundamental pillars: i) data collection and data update procedures, ii) definition of aggregated indices for partial and overall performance monitoring; and iii) definition of planning indicators (UPC 2014).

One of the salient aspects of SIASAR is the definition of six aggregated dimensions to assess water and sanitation services from different and complementary points of view. The aim of this structure is to keep in focus different aspects that characterize an increasing decentralized rural sector, as in practice institutional roles and responsibilities of sectorial issues in many SIASAR countries are assumed by different stakeholders. They have been proposed to measure i) the water service level (NSA); ii) the community sanitation situation and various hygiene issues at the household (NSH); iii) the condition of water system infrastructure (EIA); iv) the service provider performance (PSE); v) the technical assistance provider performance (PAT); and vi) the WaSH situation in public institutions (ECS). Additionally, at an upper level, cited dimensions are aggregated in 2 partial indices: i) Water, Sanitation and Hygiene service Level (NASH), and ii) Water Services Sustainability Index (ISSA). Finally, a last level is represented by an aggregated Water and Sanitation service Performance index (IAS). These last indices must be seen as a means of initiating discussion and stimulating public interest. All presented elements are listed below.

Table 1. General Idex, Partial Indices, Dimensions and Components of SIASAR conceptual model.

Water and Sanitation service Performance index (IAS)	
Water, Sanitation and Hygiene service Level (NASH)	**Water Services Sustainability Index (ISSA)**
Water Service Level (NSA)	**Water System Infrastructure (EIA)**
Accessibility (ACC) Continuity (CON) Seasonality (EST) Quality (CAL)	System Autonomy (AUT) Production Infrastructure (INF) Water Catchment Protection (ZPA) Treatment system (STR)
Sanitation and Hygiene Service Level (NSH)	**Service Provision (PSE)**
Sanitation Service Level (ACC) Personal Hygiene (HPE) Household Hygiene (HHO) Community Hygiene (HCO)	Organizational Management (ORG) Operation & Maintenance Management (GOM) Economic Management (GEF) Environmental Management (GAM)
Schools and Health Centres (ECS)	**Technical Assistance Provision (PAT)**
Water Supply in Schools (EAG) Water Supply in Health Centres (CAG) Sanitation in Schools (SHE) Sanitation in Health Centres (SHS)	Information Systems (SIN) Institutional Capacity (CAP) Community Coverage (COB) Intensity of Assistance (INT)

Each dimension is made up of four components. In turn, each component is fed by a short list of single indicators. The selection of the indicator framework resulted from the involvement of national authorities and key stakeholders. Under a principle of simplicity (as little information as needed, but not less), key information attended the context of each country but, at the same time, it was harmonized to ensure comparability.

In terms of method and technique, index construction relies on a step-by-step procedure (Nardo et al. 2005). Among them, the attention was focused on: i) the selection and combination of key indicators into their corresponding sub-indices, using an equal and dimensionless numeric scale; ii) the determination of weights for each sub-index and their aggregation to yield an overall index; and iii) the dissemination of achieved results.

The first stage involves a revision of survey data and selection of indicators, which are then classified according to the components, dimensions and indices described in the conceptual framework. Collected data, obtained with structured questionnaires, direct observation, and water quality testing, are typically represented on different scales (e.g., percentage of systems with adequate water treatment, distance-to-source in meters, service continuity in hours per day, and so forth), and they therefore have to be normalized prior to their analyses. For each parameter, it was assigned a score between 0 and 1, where 1 represents the best performance and 0 the worst case scenario. Components are then defined by simple and easy-to-use multi-attribute utility functions.

Next, different components of each dimension are aggregated into one single value. Two major issues need to be addressed: i) the choice of weights should reflect the relative importance of each component, and ii) the aggregation function should be consistent with the theoretical framework (Flores Baquero et al. 2016; Giné-Garriga and Pérez-Foguet 2010). For weight assignment, two approaches were compared: i) equal weights, and ii) weights according to expert opinion (Analytical Hierarchical Process, AHP). The AHP method, developed by Saaty (1980), presents several advantages as: i) flexibility, ii) simplicity to use and facility to understand by involved stakeholders, and iii) reliability, as it is commonly used when dealing with participatory tools. In this study, an AHP exercise was conducted to analyse the relative importance of components in each dimension. A total of 21 water and sanitation experts within the involved countries participated and answers were validated, as well as carrying out the subsequent analysis.

Aggregation methods also vary. The aggregation task falls on generating a single value from a set of indicators. Two different methods were tested: i) linear (compensatory), and ii) geometric (partial compensatory). In a linear aggregation, the compensability is constant, while with geometric aggregations compensability is lower for the composite indicators with low values. In terms of policy, if compensability is admitted, a country with low scores on one indicator will need a much higher score on the others to improve its situation when geometric aggregation is used (OEDC 2008). Both techniques were tested on countries' data and results were presented and analysed by SIASAR members.

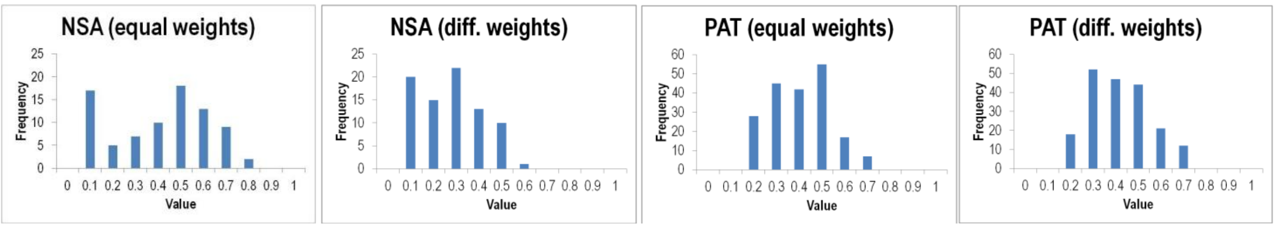
Finally, to promote greater understanding of achieved results among final users and stakeholders, components, dimensions and indices' values are linked to a defined set of categories (A / B / C / D, where A represents the best result and D the worst), in order to foster prioritization and decision-making. Nevertheless, this representation can be done in several ways. Two alternatives were tested: i) equal intervals, and ii) different intervals. According to the methodology employed, results might vary significantly. When different intervals are used, the difficulty to achieve better qualifications increases, as higher service thresholds are established. Results according to these methodologies were presented and subsequent analysis was carried out during described participatory processes.

RESULTS AND DISCUSSION

In this section, results concerning index construction are presented, leading to an agreed methodology acquisition. Next, potentiality of the tool for sectorial assessment at different scales is provided. Finally, suitability and validity of SIASAR to assess and inform about the proposed post-2015 monitoring outcomes is discussed.

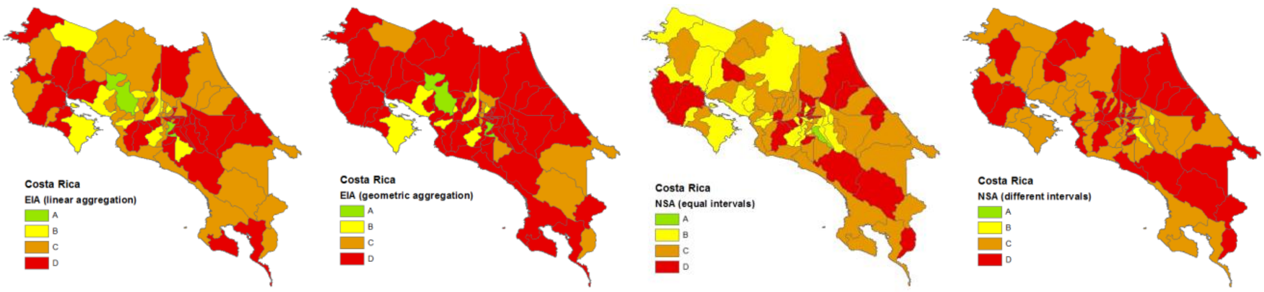
As mentioned in previous section, when dealing with the construction of SIASAR conceptual model, different stages were identified as they may impact on the final values of the indices. Figure 2 presents results concerning the comparison for weigh assignment. Two examples are selected to illustrate the analysis. Expert opinion provided higher differences among NSA components' weights (0.28, 0.14, 0.12 and 0.46), while PAT components obtained similar weights (0.09, 0.32, 0.36 and 0.22).

Figure 2. Histograms corresponding to NSA and PAT dimensions. Both weight assignment methods are compared for each dimension construction.



Based on comparative results, all dimensions are constructed providing equal weights to all components, as slight differences on the results were found out when using different weights (even when higher differences exist). Nevertheless, expert opinion might be used for designing strategies and interventions. Similarly, partial indices are calculated by using an equal weighted grouping of all dimensions and general index (IAS) is created considering both partial indices under the same relative importance.

Figure 3. Visualization as regard the impacts associated to aggregation method (EIA dimension) and classification methodology (NSA dimension). Left: linear aggregation, centre-left: geometric aggregation, centre-right: equal intervals; right: different intervals.



On the other hand, Figure 3 provides visual impacts when different methodologies of aggregation and visualization are employed. According to the analysis carried out, partial compensatory methods (geometric) might favour the appearance of null values, hampering the duty of discrimination among results. In this way, all dimensions are constructed by allowing the compensation of their components (additive aggregation). However, and due to a first compensation, posterior aggregations for partial and general indices fall on geometric ones. As far as visualization methodology, results vary significantly. When different intervals are used, the difficulty to achieve better qualifications increases. Although it might be less simple conceptually, this method favours to establish higher service thresholds. Considering this fact a positive aspect, this is the classification methodology adopted for visualizing results.

SIASAR in use

As a result of the overall process (stakeholders participation, conceptual model definition, etc.), most remarkable aspects fall on i) the existence of a same monitoring architecture, ii) the possibility to compare sectorial situation at different scales, and iii) the development of a regional community where knowledge and good practises transcend beyond borders. At regional level, and as an example, Figure 4 shows results regarding “Water System Infrastructure, EIA” dimension and countries presented. In relative terms, Nicaragua and Dominican Republic posses 36% and 28% of EIA value under 0.4, while Panama and Honduras reach 12% and 18% regarding overall monitored systems. Pointed value represents SIASAR’s “D” classification which expresses a priority attention. At the same time, this first approach might provide interested actors to direct attention to more needed countries. As mentioned, this is supported by an equal set of indicators that assess EIA conditions. On the other hand, and within SIASAR community, countries that count with a more tangible management (i.e. Panama or Honduras) share their experience as to support and guide initiative’s partners. It should be noted that same nature of analysis might be done at general and partial index level, as well as component plane.

Figure 4. Results associated to the evaluation of "Water System Infrastructure" dimension, obtained by the aggregation of its four different components. From left to right: Honduras (y axis: 0 - 1000), Nicaragua: (y axis: 0 - 1000), Panama (y axis: 0 - 100), Dominican Republic (y axis: 0 - 100).

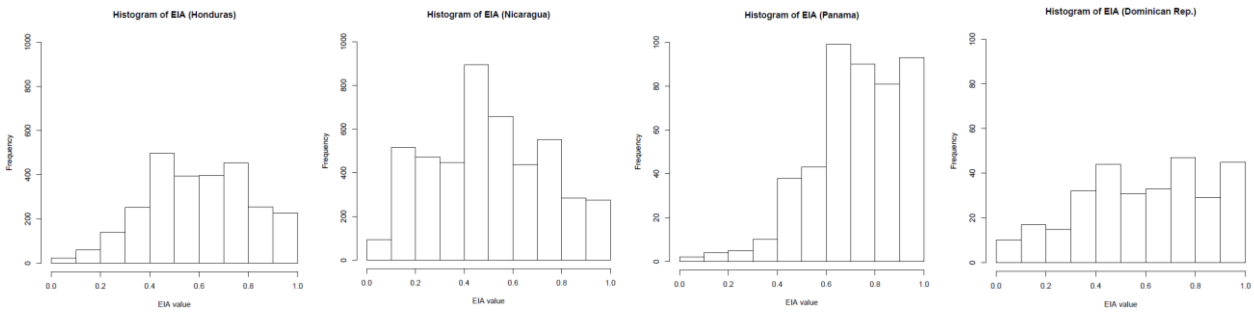
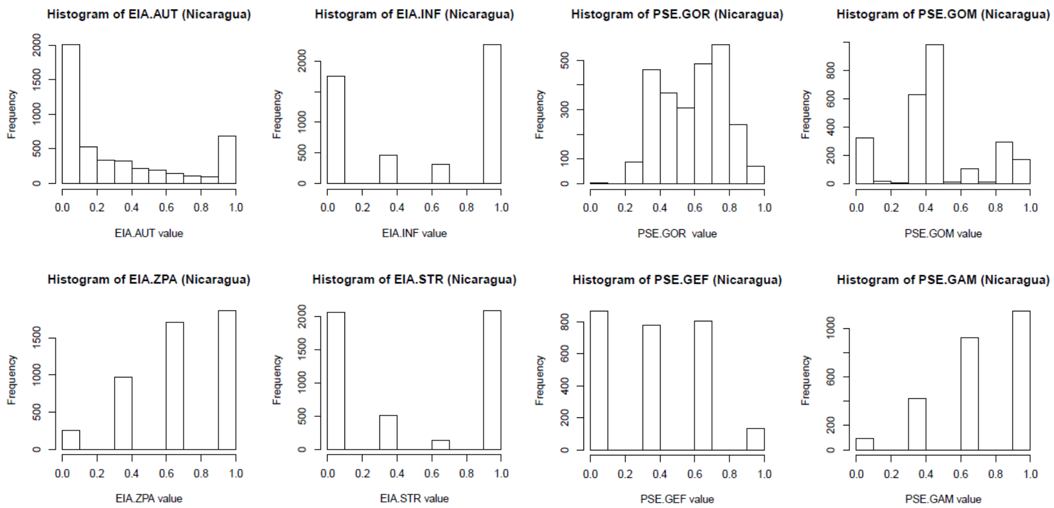


Figure 5. Detailed results represented by the four components of "Water System Infrastructure, EIA" and "Service Provision, PSE" dimensions.



At national level, model structure focus on roles and responsibilities of different stakeholders. As mentioned, water and sanitation sector is characterized by an increasing decentralized administration. In this context, SIASAR provides useful information that allows decision-makers to face the challenging situation to improve levels of service and its sustainability. As an example, Figure 5 presents detailed information regarding “Water System Infrastructure” and “Service Provision, PSE” components. As it can be seen, the model permits to prioritize among the different dimensions as well as the different components. In this case, EIA dimension shows a high frequency of low values in three of its four components (i.e. “Autonomy”, Production Infrastructure” and “Treatment System”). In parallel, PSE dimension provides a vision of where service provider’s performance presents a higher weakness (i.e. “Economic Management”). This first assessment might lead to establish strategies that tackle sectorial needs, as SIASAR’s platform permits to identify listed systems and service providers. According to these results, common in several countries, shared policies were implemented to provide full training to those service providers whose systems are constructed or rehabilitated. It should be noted that results are easily obtained for different administrative scales, allowing decision-makers to better identify needs and target future investments more effectively.

As introduced, the 2030 Agenda requires system-wide approaches to monitor and evaluate the sector. With this in mind, and taking the post-2015 monitoring and reporting architecture as a reference point, we reviewed available indicators of SIASAR and classified them in relation to the key elements identified in targets 1 and 2 of SDG number 6 (Giné-Garriga and Pérez-Foguet 2016) Tables 3 and 4 summarize the list of indicators per each target element.

It can reasonably be inferred from these tables that the proposed post-2015 indicator for drinking-water service will be adequately monitored by SIASAR (Giné-Garriga and Pérez-Foguet 2016). As regards the sanitation and hygiene indicator, various attributes will not be assessed. On the one hand, no information will be available on excreta and/or wastewater treatment, which impedes the adequate evaluation of sanitation services management. On the other hand, accessibility issues are not correctly addressed. Remarkably, this information system will hardly report on the progressive elimination of inequalities in access to different levels of drinking water, sanitation and hygiene services, as it does not specifically address the needs of vulnerable groups (Giné-Garriga and Pérez-Foguet 2016).

Table 3. Summary list of indicators to assess the sanitation-related Target 6.2 (Giné Garriga and Pérez-Foguet 2016).

Keywords, in proposed targets	SIASAR Indicators
access	No data in relation to accessibility issues (easy and safe access when needed)
to ***adequate***	% households with access to improved sanitation (assessed at community level)
and ***equitable***	No data (no focus on vulnerable groups). SIASAR, however, measures to a certain extent intra-household inequalities, i.e. do all household members use the facility?
sanitation	% households with access to improved sanitation (assessed at community level); % households sharing improved sanitation facilities (assessed at community level)
and ***hygiene***	% households with adequate handwashing behaviour (assessed at community level)
for all	% of households where sanitation facilities are used by all household members
end ***open defecation***	% households practicing open defecation (assessed at community level); % of Open Defecation-Free (ODF) community
paying special attention to the ***needs of women and girls***	% schools with access to improved sanitation (assessed at community level); % health centres with access to improved sanitation (assessed at community level)
and ***those in vulnerable situations***	No data (no focus on specific WASH needs found in ‘special cases’ including refugee camps, detention centres, mass gatherings and pilgrimages)

Table 4. Summary list of indicators to assess the water-related Target 6.1 (Giné Garriga and Pérez-Foguet 2016).

Keywords, in proposed targets	**SIASAR Indicators**
universal	% of households with improved water supply; % of schools with improved water supply; % of health centres with improved water supply
and ***equitable***	No data (no focus on vulnerable groups). Basic ethnicity data are collected, although analysing them in relation to WaSH issues is not straightforward.
access	Time to fetch water (assessed at community level, in terms of distance to the source); Service continuity (number of hour per days); % of non-seasonal water sources
to ***safe***	% of water systems with adequate treatment method; % of households with adequate treatment method; Bacteriological water quality; Physicochemical water quality
and ***affordable***	SIASAR collects data on water tariffs and the water payment method. Also, on the number of users that regularly pay the water bill. This information may be exploited, in part, to give an insight into affordability issues
drinking water	No data
for all	No data

CONCLUSIONS

In this paper, we have presented the Rural Water Supply and Sanitation Information System (SIASAR) initiative, which has been implemented in several countries to provide updated and reliable information and facilitate sector decision making. According to presented results, key conclusions are presented as follows:

i) Although a participatory process is time-consuming, the benefits from such a strategy are remarkable in terms of sustainability and stakeholders' engagement. The processes presented have stimulated pedagogic spaces where country members have learnt-by-doing, collaborating in the development of the information system. This fact facilitates a constant improvement of the tool.

ii) The structure of SIASAR conceptual model permits to identify priority elements of the assessment and the technological platform facilitates this analysis at different scales, as to design informed strategies or interventions. Additionally, index construction is presented as easy to understand by different stakeholders and provide heterogeneous results which favour the duty of discrimination. This is achieved by the use of equal weights, both aggregation methods and different interval-based classification methodology.

iii) Clear advantages appear due to the development of a large-scale information system. The use of a same monitoring architecture provides regional understanding, collaboration and comparison.

iv) At national level, SIASAR is presented as an adequate platform to assess dispersed rural water systems, pointing from mere technical aspects to sustainable ones. This is especially important as an increasing decentralization of the sector is taking place.

v) This information system appears as an adequate tool to inform the SDG targets 6.1 and 6.2. However, identified improvements might be done as to completely align the monitoring system with the post-2015 agenda. As SIASAR initiative is in constant improvement and evolution, this last aspect suggests one of the ways forward

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