APPLYING A SUSTAINABILITY INDEX TO THE JAPARATUBA RIVER WATHERSHED IN SERGIPE STATE[1]

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Introduction

The environmental threats and the progressive degradation of natural resources are considered impediments to sustainable development (KÖNIG *et al.*, 2011). It is necessary changing this scenery in order to conserve the quality and quantity of natural resources, mainly of water resources, which are essential to the survival of life on Earth.

The water resource sustainability requires fulfilling the needs of several water uses such as domestic use, irrigation, industrial use, recreation and energy generation, since the economic development of the country depends on it. In order to fulfill these needs, it is necessary protecting the environment and improving people's social condition (KUMAMBALA & ERVINE, 2008). Detecting human impacts on river systems is challenging, because this process involves biological and chemical diversity, as well as hydrological and geophysical components that must be assessed (GERGEL *et al.* 2002).

It is necessary assessing sustainability in order to make decisions consistent with the reality of each place, according to the existing issues. Santana *et al.* (2012) have shown that the sustainability assessment process should be part of the environmental management plan, as well as of processes involving environmental diagnosis, planning

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and management. Thus, the decision-making process tends to be carried out in a coherent way, since information plays a key role in it.

The Agenda 21, which recommends the use of sustainability indicators, reports that despite the considerable amount of data, it is necessary gathering more and different types of data at local, state, national and international levels in order to indicate the state and trends of socioeconomic, pollution, natural resource and ecosystem variables (UNITED NATIONS, 1992). The methods used to collect, interpret and display these data should be easy and effective so that the interested parties can participate in the process (FRASER *et al.*, 2006).

Sustainability indicators based on local data provide a practical method to monitor the progress towards sustainable development. In addition, they can go far beyond simply measuring the progress; they can stimulate a process to improve the understanding of environmental and social issues, facilitate community empowerment and guide the development of policies and projects (REED *et al.*, 2006).

Sustainability requires adopting an integrated, holistic and systemic approach. In addition, it generally requires institutional transformation and is based on improving the collective capacity to positively respond to sustainability challenges (BLACKSTOCK *et al.*, 2007). The sustainability indicators may contribute to the sustainable management of environmental resources; when indicators are analyzed in an integrated way, they can guide the formulation of policies and provide valuable information (UNESCO, 2008).

It is necessary understanding the quantitative and qualitative indicators determining the ideal sustainability level in order to assess the state of a watershed (CATANO *et al.*, 2009). The indicators may perform a number of functions such as simplifying, clarifying and making the aggregate information available to public managers. They may help incorporating physical and social sciences into the decision-making process. They may also provide a diagnosis for economic, social and environmental alternatives and help measuring the progress towards the sustainable development goals (UNITED NATIONS, 2007).

According to Chaves & Alipaz (2007), several (social, economic and environmental) aspects affect the sustainability of a watershed. However, they are not often treated as a dynamic and integrated process. A quantitative, dynamic and integrated indicator - the Watershed Sustainability Index (WSI) - can be used to integrate hydrological, social, environmental and political issues, as well as the existing pressures and political responses.

The watershed sustainability index is mainly useful to assess the watershed evolution in order to visualize rapid changes resulting from population growth or industrial development, as well as to compare the evolution of several watersheds in a single region. The WSI is a simple and adaptable instrument used to assess the current sustainability state of a watershed and it is essential to support the decision-making process concerning the integrated water resource management. This instrument identifies the bottlenecks and limitations found in the studied area and represents a window of opportunity to improve the current watershed situation. The WSI is an index of great potential for environmental management purposes, since it incorporates social, economic and environmental factors to the sustainability analysis (CORTÉS *et al.*, 2012).

The aforementioned methodology has already been applied to watersheds in several countries, according to studies conducted by UNESCO (2008), Chaves (2009), Catano *et al.* (2009) and Cortés *et al.* (2012).

The aim of the present study was to assess the sustainability of the Japaratuba River watershed, Sergipe State, Northeastern Brazil, using a proposal of adaptations to be applied to the Watershed Sustainability Index (WSI).

Sustainability Indicators focused on watersheds

According to Santos (2004), all planning aimed at defining policies and choosing alternatives requires knowing the components forming the space. In order to do so, it is essential gathering well-formulated and interpretable data able to represent the reality, since they are the basis of knowledge - whenever data are interpreted, they turn into information.

Since the 1970s, after the emergence of the environmental agenda and of the concept of sustainable development, the efforts to develop instruments able to measure the progress towards sustainability have been deepened. In order to do so, the Agenda 21, which was an initiative proposed in chapter 40 of the Rio de Janeiro Conference Declaration, recommends the implementation of sustainable development indicators (GUIMARÃES & FEICHAS, 2009).

Accordingly, the sustainable development aspects are complex and require different forms of analysis based on the adequate number of indicators and variables that are the most consistent and reliable to portray a given context. There is the evident need of creating or adapting sustainability indicators in order to help overcoming the challenges posed by the sustainable development viability (MARTINS & CÂNDIDO, 2012).

The sustainability indicators are different from the other indicators because they require an integrated world view, which needs to relate the economy, the environment and the society of a given community (SILVA *et al.*, 2009).

According to Siche *et al.* (2007), index and indicator have the same meaning in a superficial analysis, but the difference lies on the fact that an index is the final aggregated value of a calculation procedure, whereas indicators are used as the variables composing such calculation. According to Santos (2004), the indexes result from the combination of a set of parameters associated with each other by means of a pre-established relation, which gives rise to a single value. This value may be achieved through statistics, analytical formulation or mathematical calculation.

The sustainability indicators become sources of significant information used to monitor the processes driving the dynamics of social, economic, environmental and institutional systems, among others. These indicators are relevant tools to enable the sustainable development. Therefore, they are a useful tool in the process of simplifying information about complex phenomena, as well as in the identification of priority demands (BARROS & SILVA, 2012).

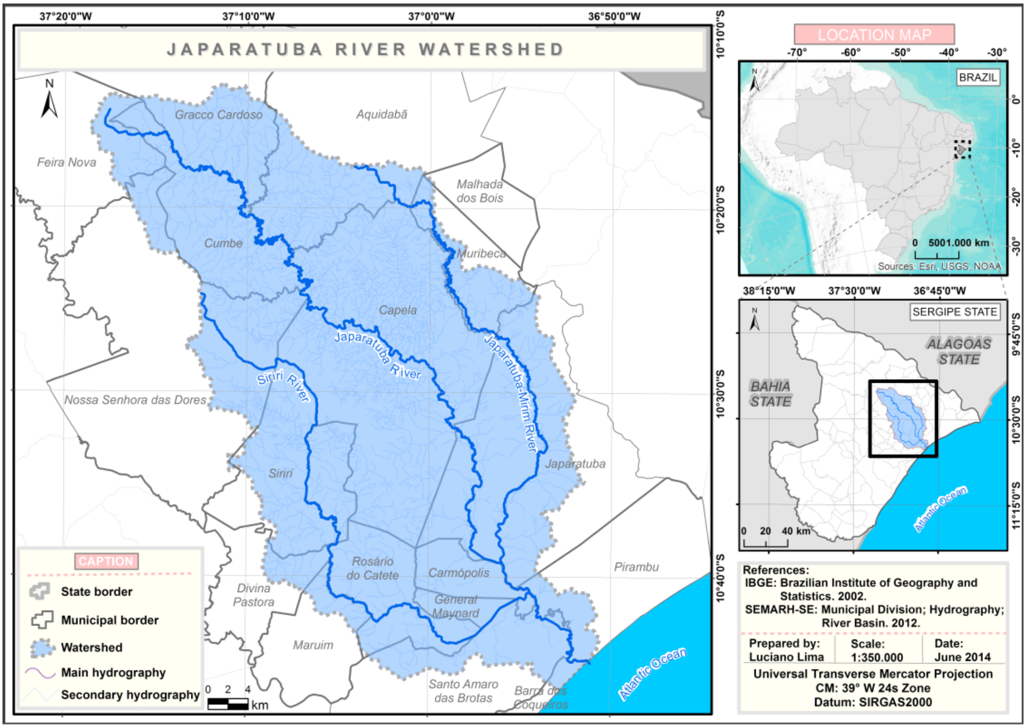
However, there are challenges that need to be overcome in the construction of sustainability indexes and indicators in order to simultaneously aggregate essential aspects to promote changes in society and to support public policy decisions, namely: multidimensionality, comparability, participation, communication and relation between variables (GUIMARÃES & FEICHAS, 2009).

The Japaratuba River watershed

The goal of the watershed analysis is to feature the active physical and biological processes in this planning unit. The planning framework linked to the watershed analysis uses this information to manage the environmental impacts, as well as to identify desired conditions and develop management guidelines to achieve these conditions. This analysis has several advantages over the environmental analyses when it comes to the development of management scenarios compatible with environmental and economic goals (MONTGOMERY *et al.*, 1995).

The Japaratuba River watershed is located in the Brazilian Northeastern region, Sergipe State (Figure 1) and its area has 1,687.67 km² (EMBRAPA, 2012). Eighteen (18) counties are partially or totally inserted in the watershed region, whose total population comprises 119,689 inhabitants, among them 79,012 live in urban areas and 40,677 live in rural areas (SERGIPE, 2010).

Figure 1 - Location of the Japaratuba River watershed, Sergipe State, Brazil



Source: IBGE (2002); SEMARH (2012).

According to the Köppen's climate classification, the predominant climate in the Japaratuba River watershed region is *As* (tropical climate with dry summer). The rainy season happens between April and August; the highest rainfall concentration happens in May, June and July. The Northwestern border of the watershed is affected by the Drought Polygon, which covers approximately 13% of the total watershed area. The rainfall in the watershed presents mean annual value 1,270 mm, with approximately 900 mm/year in its extreme Northwestern portion and 1,500 mm/year at its mouth (EMBRAPA, 2012). The mean annual temperature is 25°C. The relative humidity is approximately 74% (ARAGÃO & ALMEIDA, 2009).

The soil use in the watershed region is predominantly divided in the folowing categories: pasture 98,858 ha (59.96%), agricultural crops 38,737 ha (23.49%), forest areas 18,352 ha (11.13%) and riparian forests 4,377 ha (2.65%) in the watershed area and 103.2 ha in the original Atlantic Forest (SERGIPE, 2010).

This watershed is strategically important to Sergipe State, since it houses the country's largest oilfield, the Carmópolis field, whose area has more than 150 km^2 and 1,200 wells. The oilfield discharges the wastewater resulting from the oil exploration process in the lower portion of the Japaratuba River and it leads to significant changes in the river biota. Such changes result from the presence of metals in the water and sediment (EMBRAPA, 2012).

The implementation of mining and oil exploration industries in the Japaratuba River watershed has led to physical, economic and social changes. The use of the Japaratuba River watershed has changed it from the subsoil to the surface and it has also shaped the terrain through the flatening of hills and slopes in order to suit the industries' exploratory needs (ARAÚJO, 2012).

The Sustainability Index of the Japaratuba River watershed: adaptations to the WSI

The methodology used in the current study was proposed by Chaves & Alipaz (2007) and makes a temporal analysis based on a five-year horizon. It uses the model known as HELP, which was proposed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and comprises four dimensions, namely: hydrological (H - hydrology), environmental (E - environment), social (L - life) and political (P - policy). In addition, Chaves & Alipaz (2007) also have structured indicators in a cause-and-effect matrix: Pressure-State-Response (PSR) of the Organization for Economic Cooperation and Development (OECD, 2003).

Table 1: Structure of the indicators composing the Watershed Sustainability Index (WSI), according to Pressure, State and Response.

	Pressure	State	Response
Indicators	Parameters		
Hydrologycal	Water availability variation per capita in the watershed in 2005-2010	Water availability per capita in the watershed (2010)	Water use efficiency evolution (2005-2010).
	Water Quality Index (WQI)* variation in the watershed in 2005-2010	Annual water quality average in the watershed (2010)	Sewage treatment evolution (2005-2010).
Environmental	Anthropogenic Pressure Index (API) in the watershed during the studied period (2005-2010)	% of watershed area holding natural vegetation (2010)	Evolution of conservation areas in the watershed (Protected Areas and Good Management Practices - GMPs) 2005-2010.
Life	Human-Income Development Index ** variation per capita in the watershed (2005-2010).	Human Development Index in the watershed (2010)	HDI evolution in the watershed (2005-2010).
Political	Human-Education Development Index variation in the watershed (2005-2010)	Institutional and legal capacity for the Integrated Water Resource Management in the watershed.	Evolution in the expenditures on Integrated Water Resource Management in the watershed (2005-2010).

Source: Adapted from Chaves & Alipaz (2007) and translated by the authors of the current study.
* The original methodology by Chaves & Alipaz (2007) used a Biochemical Oxygen Demand, whereas the present study used the Water Quality Index - WQI.
** The original methodology by Chaves & Alipaz (2007) used the GDP variation per capita, whereas the present study has made the option for adapting the methodology by Chaves (2009), who used HDI-Income.

Thus, each HELP dimension has its indicators, which may vary from 0 to 1, in scales 0, 0.25, 0.50, 0.75 and 1, wherein 0 means the worst indicator situation and 1 indicates the best situation (CHAVES & ALIPAZ, 2007).

According to OECD (2003), the Pressure indicators deal with environmental pressures resulting from direct or indirect anthropic activities. In addition, they are related to production and consumption patterns, which reflect the natural resource use intensity, as well as with the trends and changes taking place over a given period. State indicators reveal environmental conditions related to the quality and quantity of natural resources, fact that provides an overview of the current environmental situation. The Response parameter refers both to the individual and to governmental and collective actions designed to mitigate and prevent negative effects, which are mostly of anthropic nature, as well as to stop or reverse the already existing environmental damages in order to preserve and conserve natural resources. Table 2 shows the score information concerning the Pressure, State and Response indicators, according to indicators, their levels and parameters.

Table 2: Pressure, State and Response indicators' scores according to indicator, parameter and level.

PRESSURE			
Indicator	**Parameter**	**Level**	**Score**
Hydrological	Δ1- Water availability variation per capita in the period (m^3/inhab/year).	Δ1< -20%	0.00
		-20% ≤ Δ1 < -10%	0.25
		-10% ≤ Δ1< 0%	0.50
		0 ≤ Δ1< +10%	0.75
		Δ1 ≥ +10%	1.00
	Δ2- WQI variation in the watershed in the period (mean)	Δ2 < -10%	0.00
		-10% ≤ Δ2 < 0%	0.25
		0 ≤ Δ2 < 10%	0.50
		20% ≥ Δ2 > 10%	0.75
		Δ2 >20%	1.00
Environmental	Watershed API in the period.	EPI >20%	0.00
		20% ≥ EPI > 10%	0.25
		10% ≤ EPI <5%	0.50
		5% ≤ EPI <0%	0.75
		EPI	1.00
Life	HDI-Income variation per capita in the watershed, in the period.	Δ < -20%	0.00
		-20% ≤ Δ < -10%	0.25
		-10% ≤ Δ< 0%	0.50
		0 ≤ Δ< +10%	0.75
		Δ ≥ +10%	1.00
Political	HDI-Education variation in the period.	Δ < -20%	0.00
		-10% ≤ Δ < -20%	0.25
		-20% ≤ Δ < 0%	0.50
		0 ≤ Δ < +10%	0.75
		Δ ≥ +10%	1.00
STATE			
Indicator	**Parameter**	**Level**	**Score**
Hydrological	Water availability per capita in the watershed (Wa) in m^3 / inhab / year.	Wa < 1700	0.00
		1700 ≤ Wa < 3400	0.25
		3400 ≤ Wa < 5100	0.50
		5100 ≤ Wa < 6800	0.75
		Wa ≥ 6800	1.00
	Current Water Quality Index (WQI).	0 ≤ IQA < 20	0.00
		20 ≤ IQA < 37	0.25
		37 ≤ IQA < 52	0.50
		52 ≤ IQA < 80	0.75
		80 ≤ IQA ≤ 100	1.00
Environmental	Percentage (%) of natural vegetation remaining in the watershed (Av).	Av < 5	0.00
		5 ≤ Av < 10	0.25
		10 ≤ Av < 25	0.50
		25 ≤ Av < 40	0.75
		Av ≥	1.00
Life	Watershed HDI	IDH<0.5	0.00

		0.5 ≤ IDH < 0.6 0.6 ≤ IDH < 0.75 0.75 ≤ IDH < 0.9 IDH ≥ 0.9	0.25 0.50 0.75 1.00
Political	Legal and institutional capacity for the Integrated Water Resource Management (IWRM) in the watershed.	Very poor Poor Intermediate Good Excellent	0.00 0.25 0.50 0.75 1.00
	RESPONSE		
Indicator	**Parameter**	**Level**	**Score**
Hydrological	Water use efficiency evolution in the watershed, in the period.	Very poor Poor Intermediate Good Excellent	0.00 0.25 0.50 0.75 1.00
	Sewage treatment and disposal evolution in the watershed, in the period.	Very poor Poor Intermediate Good Excellent	0.00 0.25 0.50 0.75 1.00
Environmental	Evolution in the watershed protected areas (Reserves and Good Management Practices), in the period.	Δ < -10% -10% ≤ Δ < 0% 0% ≤ Δ < 10% 10% ≤ Δ< 20% Δ ≥ 20%	0.00 0.25 0.50 0.75 1.00
Life	Watershed HDI variation in the period.	Δ < -10% -10% ≤ Δ < 0% 0% ≤ Δ < 10% 10 ≤ Δ < 20% Δ ≥ 20%	0.00 0.25 0.50 0.75 1.00
Political	Evolution in the expenditures on Integrated Water Resource Management in the watershed, in the period.	Δ < -10% -10% ≤ Δ < 0% 0% ≤ Δ < 10% 10 ≤ Δ < 20% Δ ≥ 20%	0.00 0.25 0.50 0.75 1.00

Sourse: Adapted from Chaves (2009).

The value of each dimension is described through arithmetic mean, as well as through the global WSI. Below, Equation 1 (CHAVES & ALIPAZ, 2007):

$$\mathbf{WSI = (H + E + L + P) / 4} \qquad [1]$$

After identifying the levels and selecting the score for each indicator, the WSI was calculated through the global mean, which is the mean of the columns P, L, S and lines H, E, L, P (Table 1).

The WSI result according to Equation 1 is classified as low, intermediate and high, respectively: WSI <0.5; 0.5 ≤ WSI <0.8 and WSI ≥ 0.8 (CHAVES, 2009). Thus, it was possible interpreting that the higher the index value, the better the sustainability in the assessed watershed.

Details of the methodology by Chaves & Alipaz (2007) can be seen in a Technical Document released by the Unesco International Hydrological Program for Latin America and the Caribbean.

The current study has performed some methodological adaptations according to the methodology by Chaves & Alipaz (2007). For example, Chaves & Alipaz (2007) used the Biochemical Oxygen Demand (BOD) for Pressure and State qualitative hydrological analyses in the Hydrological Dimension, whereas the current study used the Water Quality Index (WQI) instead of BOD. It is noteworthy that Isaias (2008) also used the WQI in his WSI study.

The WQI was chosen to represent this subindicator in the Pressure and State parameters due to its comprehensiveness and contribution to determine the water quality in the studied area. The WQI developed by the National Sanitation Foundation in the United States (FRANCO & HERNANDEZ, 2012) is also used by the National Water Agency (ANA - Agência Nacional de Águas) in Brazil. The WQI stands out for bringing together several parameters in a single value.

It was hard to find available WQI data about the Japaratuba River watershed within the time frame defined in the present study (2005-2010). Thus, it was made the option for using the data available in previous studies concerning 2009 and 2010. The ***Pressure*** parameter was defined through the WQI variation in the watershed in 2009-2010 (MARQUES, 2011). The ***State*** parameter was defined through the current WQI in the watershed, using the mean WQI values found in 2010 by Marques (2011).

The hydrological quantitative ***Response*** parameter was defined through the water use efficiency variation in the watershed during the studied period (2005-2010), using the National Sanitation Information System database (BRASIL, 2005; 2010). This qualitative indicator was proposed by Chaves & Alipaz (2007) and is categorized as very poor, poor, intermediate, good or excellent. However, it was quantified according to the Water Loss Index classification for water supply systems, which is available in Tsutiya (2006), wherein:

- $P < 25\%$: the water supply system is categorized as "good" and its WSI score is 1.0;
- $25 \leq P < 40\%$: the system is categorized as "intermediate" and its WSI score is 0.5;
- $P \geq 40\%$: the system is categorized as "poor" and its minimum WSI score is 0.0.

With respect to the ***Response*** indicator, which refers to the water quality in the warweshed and was given by the sewage treatment evolution in the studied period, the Municipal Sewage Collection and Treatment Index annually provided by the National Information System on Sanitation (SNIS - Sistema Nacional de Informações sobre Saneamento) was used in the current study. Thus, the sewage treatment evolution value in the watershed during the studied period was defined through the variation in the mean index of the counties inserted in the watershed region.

The assessment of the ***Response*** parameter in the environmental dimension was based on the variation in protected areas, according to the Brazilian legislation and to good management practices in the watershed during the studied period. Thus, the final value of this indicator was given by the mean variation between the protected areas (Equation 3) and the good management practices (Equation 3).

$$\Delta PA\% = \frac{\Delta LR\%\ \Delta PPA\%\ \Delta CU\%\ \Delta QUI\%}{4} \quad [2]$$

Wherein
Δ PA %: Variation rate in the protected areas
Δ LR%: Variation in the Legal Reserve areas in the watershed
Δ PPA%: Variation in the Permanent Protection Areas in the watershed
Δ CU%: Variation in the Conservation Unit areas in the watershed
Δ QUI%: Variation in the Quilombola Territories in the watershed

$$\Delta BPM\% = \frac{\Delta BPM\ LR\% + \Delta BPM\ PPA\% + \Delta BPM\ CU\% + \Delta BPM\ QUI\%}{4} \quad [3]$$

Wherein:

Δ BPM LR%: Variation rate concerning the compliance with the Brazilian environmental legislation for Legal Reserve, in the watershed.

Δ BPM PPA%: Variation rate concerning the compliance with the Brazilian environmental legislation for Permanent Protection Areas, in the watershed.

Δ BPM CU%: Variation rate concerning the compliance with the Brazilian environmental legislation for Conservation Units, in the watershed.

Δ BPM QUI%: Variation rate concerning the compliance with the Brazilian environmental legislation for Quilombola Territories, in the watershed.

With respect to the Social (Life) Dimension, the methodology by Chaves & Alipaz (2007) used the GDP variation per capita; however, the current study has made the option for adaptating the methodology by Chaves (2009), who used the HDI-Income, which was herein obtained through the 2013 Atlas of Human Development in Brazil (PNUD, 2014).

As for the Political Dimension, the ***State*** indicator assessed the institutional capacity in the watershed through the Integrated Water Resource Management. Overall, this indicator analyzes the capacity of institutional and legal systems within the watershed and determines whether such capacity is very poor, poor, intermediate, good or excellent (CHAVES, 2009). The current study has used the mean between Legal (LC) and Institutional Capacity (IC) in the watershed, adapted from the Technical Document released by the Unesco International Hydrological Program for Latin America and the Caribbean (UNESCO, 2008), to analyze this dimension.

Validating the Watershed Sustainability Index (WSI)

The current study has sought in the literature for methodologies able to validate its results, mainly methodologies focused on sustainability indexes. However, the tittles of several studies about sustainability indexes use the term "validation", but these studies do not describe in their methodological procedures how this stage was developed.

Several health studies use the Content Validation method to validate their research; Lacerda et al. (2009) have emphasized that this method investigates whether each instrument (indicator) measures what it is suposed to measure in terms of capacity and amplitude to represent the assessed practices, as well as the measure value and consistency.

According to Alexandre & Coluci (2011), *the assessment by a committee of experts* is a stage of the Content Validation method, and it comprises the instrument (indicator) assessment by a group of experts, through questionnaires.

The present study made an adaptation using the *assessment by an expert committee.* The members of the Japaratuba River Watershed Committee and of the State Water Resource Council, the EMBRAPA and Water Resource Superintendency technicians, as well as the civil society, were taken into consideration in the current case.

Thus, the validation of the Sustainability Index found in the Japaratuba River watershed consisted in presenting how the index was built, as well as the information gathered, to the validation workshop participants and, finally, discussing all these issues.

Cortés *et al.* (2012) have carried out a validation workshop with interested parties after data collection and systematization, as well as after the analysis of the Sustainability Index for the Elqui River watershed, in Chile. They took into consideration the subjectivity of some indicators such as Political State.

The Japaratuba River Watershed Committee was established by Decree n. 24650 from August 30th, 2007 in order to promote, within the water resource management scope, the technical and economic-financial feasibility of a program for the investment in and consolidation of urban and regional structuring policies aimed at the sustainable development of the aforementioned watershed.

Results of the Sustainability Index analysis conducted in the Japaratuba River watershed

The levels and scores of each indicator in the Pressure-State-Response matrix were: hydrological, 0.33; environmental, 0.66; life: 0.83; and political, 0.83 (Table 3). It is worth emphasizing that the final WSI value was found through the arithmetic mean between the Pressure-State-Response of each HELP dimension; Next, Equation 1 was applied and it resulted in the Sustainability Index value 0.66 for the Japaratuba River watershed.

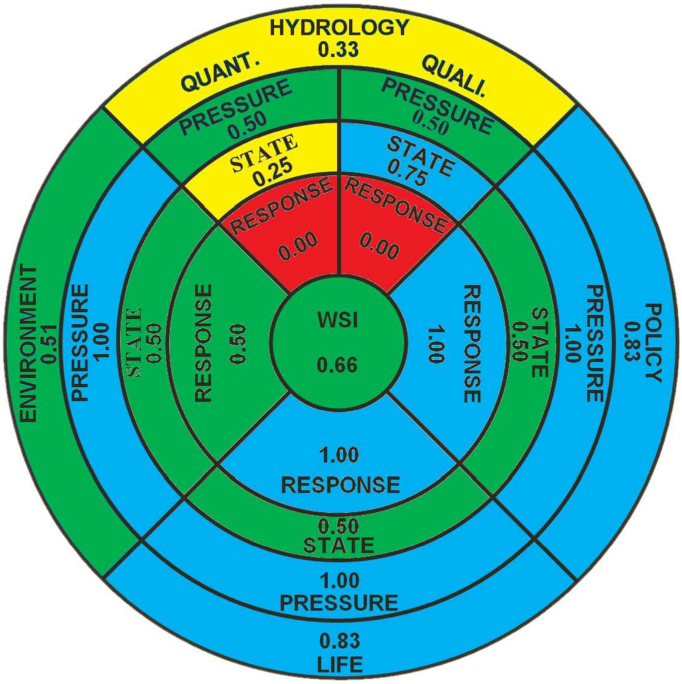
Table 3: WSI composition matrix of Pressure, State and Response indicators in Japaratuba River watershed.

INDICATORS		PRESSURE		STATE		RESPONSE		*SUBTOTAL*	
		Level	Score	Level	Score	Level	Score		
Hydrological	Quant.	- 0.07%	0.50	2.643	0.25	Very poor	0.00	0.25	0.33
	Qualit.	8.11%	0.50	63.25	0.75	Very poor	0.00	0.41	
Environmental		-3.6%	1.00	11.03	0.50	5.85%	0.50	0.66	
Life		17%	1.00	0.613	0.50	37%	1.00	0.83	
Political		67%	1.00	Intermediate	0.50	97%	1.00	0.83	
TOTAL								0,66	

Source**:** Prepared by the authors.

According to Chaves (2009), the Sustainability Index in the Japaratuba River watershed, whose final value was 0.66, has shown intermediate sustainability level. The graph (Figure 2) below was prepared in order to help better visualizing the results. It relates the Score (S) of each indicator to the colors: $0.00 \leq P < 0.25$ is represented in red; $0.25 \leq P < 0.50$, in yellow; $0.50 \leq P < 0.75$, in green; and $0.75 \leq P < 1.00$, in blue.

Figure 2 - Graph representing the Japaratuba River Watershed Sustainability Index (WSI).



Source: Prepared by the authors.

The most critical indicators belonged to the hydrological dimension, namely: the State subindicator, which is related to low water availability per capita; the Response subindicator, which is related to high loss rates in the region; and the water quality--Response subindicator, which is related to the lack of sewage collection and treatment in the counties located in the region of the herein studied watershed.

According to Figure 2, the Life and Political dimensions have shown the best results (0.83). The life dimension result was related to the HDI and its variations. As it was already discussed, this is a ten-year index, which may have leveraged its score, when it was assessed for its variation between 2000 and 2010, because the time interval was longer than it should have been (2005-2010).

On the other hand, the Environmental indicator has presented an intermediate score. It does not mean that the environmental impacts have significantly decreased, but rather that the environmental policies have evolved in the studied period (2005-2010), fact that was also assessed and contributed to the final score.

According to Chaves & Alipaz (2007), the final WSI in São Francisco Verdadeiro River watershed (Brazil) was 0.65, which corresponded to an intermediate sustainability level. Other studies based on the methodology by Chaves & Alipaz (2007), which supported the present research, have shown the following results: according to Contés *et al.* (2012), the Elqui River watershed (Chile) has shown WSI 0.61; according to Chaves (2009), the Pipiripau Stream watershed (Brazil) has shown WSI 0.60 and the Antaquera River watershed (Bolivia) has shown WSI 0.47; according to Cantano *et al.* (2009), the Reventazón River watershed (Costa Rica) has shown WSI 0.74.; and according to Unesco (2008), International Hydrological Project, the Panama Canal watershed (Panama) has shown WSI 0.65.

Validating the study results

The meeting held for the validation of the Japaratuba River watershed sustainability index was attended by 21 people, including members of the Japaratuba River Watershed Committee, as well as technicians from the Water Resource Superintendency, Embrapa and Sergipe State Sanitation Company (DESO), and it was approximately three hours long.

After presenting the results of the research entitled "Assessing the Japaratuba River Watershed Sustainability", when the importance of using the methodology and information gathered to advise the water resource management both in the herein studied watershed and in other watersheds in the State was presented, the meeting has opened space for discussion and the participants have largely contributed to the research.

It is possible stating that the participation level achieved in the validation workshop in the current research was "participation through consultation", according to Verdejo (2006). The researchers took into account the participants' opinion and integrated it to the research focus, although the group of participants did not have the power to decide on previous research stages such as in the methodological choice.

In practice, it means that, according to the discussion, the water resource experts have reanalyzed the research and modified some parameters according to the most relevant suggestions (agreed in the group) such as the weights assigned to the existing protected areas and the analyzed period comprising the financial investments in the watershed.

After the discussion was concluded, the members of the Japaratuba River Watershed Committee have validated the results, recorded all validation steps in an extraordinary-nature Minute, and highlighted the importance of exchanging information among universities, managers and the organized society in order to contribute to an efficient water management, as well as to contribute to the participants' interest, as members of the Watershed Committee, in using the methodology to monitor sustainability.

Synthesis of strategies concerning the weaknesses found in the Japaratuba River watershed

The information gathered and analyzed in the present study allowed synthesizing strategies for the most critical indicators identified in it.

The low water availability per capita was identified as fragility in the quantitative hydrological dimension. Thus, as a strategy, it was suggested monitoring the water users, mainly the industrial and agricultural ones; as well as implementing the charge on water use in order to reduce the consumption of water resources. As for the high water-distribution Loss Index, it was suggested making financial investments in order to implement continuous actions aimed at reducing and controlling these losses. With regard to the fragility of the qualitative hydrological dimension, the low sewage collection and treatment level stood out, fact that made it evident the need of universalizing basic sanitation in the entire watershed area.

The low rate of areas holding native vegetation and the lack of Good Management Practices in protected areas belonging to the watershed were identified as fragilities in the environmental dimension. Therefore, it was suggested increasing the native vegetation areas through forest recovery and continuous monitoring programs, as well as developing a State Forestry Policy able to assure the implementation of instruments, such as the consolidation of Legal Reserve areas, for the preservation of springs and riparian forests in the watershed region. In other words, actions able to assure the effective management of Conservation Units.

The low Human Development Index in the watershed was identified as fragility in the life (social) dimension. The herein suggested strategy comprises making greater investments in education through trainings and economic development incentives focused on the microentrepreneur; as well as assuring basic sanitation to improve people's health.

The political dimension has shown two fragilities, namely: the legal capacity to perform the Integrated Water Resource Management in the watershed and the little financial investment in the Integrated Water Resource Management in the watershed. Thus, the following strategies were suggested: implementing management instruments such as framing water bodies and charging the use of water resources; performing stronger supervision and monitoring of water use grantings; and increasing the financial investments in IWRM in the watershed (implementing sanitation works, water quality monitoring programs, and projects for the recovery and preservation of springs).

It is assumed that the decision making is the stage closing a cycle within the planning process. Such stage consists of selecting the best alternatives by taking into consideration the technical, legal, managerial and financial assessment of these alternatives, as well as categorizing them on a hierarchycal basis (SANTOS *et al*., 2016).

Considerations on the WSI application to the Japaratuba River watershed

The global WSI in the Japaratuba River watershed was 0.66 and it was categorized as intermediate sustainability level. This watershed requires priority attention in the hydrological dimension, mainly when it comes to sewage collection and treatment, as well as to water supply. The resolution of these two critical points may, in fact, solve other issues associated with the population's health and with the quality-of-life improvement in the watershed.

The protected areas can assure better water availability in the watershed, given the relevance of the fundamental interaction between vegetation and hydrological cycle.

Thus, it is possible concluding that the methodology studied in the current study is effective because it integrates four important dimensions, namely: environmental, hydrological, life and political. In addition, it enables the joint and the individual analysis of each dimension, fact that allows looking at the most critical issues in the watershed under a different perspective in order to act in a corrective and/or preventive way and solve its main negative points.

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APPLYING A SUSTAINABILITY INDEX TO THE JAPARATUBA RIVER WATHERSHED IN SERGIPE STATE

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Resumo: Os índices de sustentabilidade são importantes ferramentas no processo de gestão dos recursos hídricos. Este trabalho objetivou calcular um índice de sustentabilidade para a bacia hidrográfica do rio Japaratuba, no Estado de Sergipe, Brasil. A bacia hidrográfica do rio Japaratuba tem área igual a 1.687,67 km^2. O Índice de Sustentabilidade de Bacias Hidrográficas (WSI) considerou as dimensões hidrológica, ambiental, social e política, organizando-as por meio da estrutura Pressão-Estado--Resposta. O WSI calculado para a bacia em estudo foi 0,66, o que indica que a bacia está em um nível intermediário em relação à sustentabilidade. Destaca-se que os indicadores que receberam menor pontuação foram: Hidrológico quantitativo, relacionado à baixa disponibilidade hídrica *per capita*, e Hidrológico qualitativo, que está relacionado à coleta e tratamento de esgotos nos municípios da bacia.

Palavras-chave: Índice. Gestão dos recursos hídricos. Qualidade ambiental.

Abstract: Sustainability indexes are important tools in water resource management. The aim of the current study is to calculate the sustainability index of the Japaratuba River watershed, Sergipe State, Brazil. The Japaratuba River watershed comprises a 1.687,67 km^2 area. The watershed sustainability index (WSI) has taken into consideration hydrographic, environmental, life, and political dimensions, according to the pressure--state-response methodology. The WSI value was 0.66. Such value indicates that the watershed shows intermediate sustainability level. The indexes showing the lowest scores were the quantitative hydrological index, which is related to water availability per capita, and the qualitative hydrological index, which is related to the wastewater treatment in the cities belonging to the watershed region.

Keywords: Index. Water resource management. Environmental quality.

Resumen: Los índices de sostenibilidad son herramientas importantes en la gestión de los recursos de agua. Este estudio tuvo como objetivo calcular un índice de sostenibilidad de la cuenca del río Japaratuba en el Estado de Sergipe, Brasil. La cuenca tiene un área de Japaratuba igual a 1.687,67 km^2. El índice de sostenibilidad del Cuenca Hidrográfica (WSI) considera la Presión-Estado- Respuesta hidrológica, ambiental, social y política a través de la organización de ellos la estructura. El WSI calculado para la cuenca en estudio fue de 0,66, lo que indica que la cuenca está en un nivel intermedio en relación con la sostenibilidad. Es de destacar que los indicadores que recibieron las puntuaciones más bajas fueron cuantitativa Hidrológico, relacionado con la baja disponibilidad de agua por habitante y Hidrológico cualitativa, que está relacionada con la recogida y el tratamiento de las aguas residuales en los municipios de la cuenca.

Palabras clave: Índice. Gestión de recursos hídricos. La calidad del medio ambiente.