SPATIAL DISTRIBUTION OF RIVER BASIN SUSTAINABILITY INDICATORS IN TRANSITION REGION OF NORTHEASTERN BRAZIL

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Abstract. Sustainability indicators were applied in river basins of a state in Northeastern Brazil, aiming to outline and support effectively sustainable actions of water resources management. Twelve indices and three indicators of Sustainability focused on socioeconomic, hydrological and institutional issues were calculated for six hydrographic regions, quantitatively and qualitatively. Partial scales for all indices related the calculated values to levels of performance (Very High, High, Medium, Low, and Very Low). Posteriorly the indices were grouped in global scales, constructed with levels of water sustainability for all indicators. The results have shown an overall intermediate performance in the assessed river basins, indicating the need to adopt priority measures in the hydrological dimension, especially in relation to groundwater; attention to primary sanitation, with regard to public supply; reduction in water demand and waste; implementation of management tools; consolidation and support to river basin committees. The spatialization of water sustainability indicators enabled a clearer perception and an unmistakable assessment of each river basin surveyed.
Keywords: *water resources, decision-making, indicators, sustainability, river basin*

Introduction

The imbalance between water availability and demand causes its scarcity, which has become one of the most pressing problems in the world (Peterson and Schoengold, 2008). This situation may worsen due to population growth, global climate change and deterioration of water quality (Qu et al., 2013). Demand for water is expected to increase by more than 40% by 2050. By 2025, about 1.8 billion people will live in countries or regions where water is scarce, and two-thirds of the earth may live in a condition where the supply of clean water does not meet its demand (UN, 2015; Ross, 2017).

In Brazil, water demand has grown significantly in the last decades due to the economic development process, the increase of population clusters and the quantification, increasingly grounded, of environmental needs (Carvalho and Curi, 2013). Although Brazil has an abundance of water, it is poorly distributed in relation to the demographic density of the country, with 80% of the water being in the Amazon region and a severe scarcity existing in the Northeastern region (ONU, 2007). However, in addition to misdistribution, Brazil faces more severe issues, such as permanent contamination and waste of the remaining clean water (Bragatto et al., 2012).

According to Oelkers et al. (2011), one of the key solutions to this global water crisis is better management of this valuable natural resource. The literature reports that, as the complexity of issues related to water resources has increased, there have been extensive studies to combine the concept of sustainability with water management matters (Loucks e Gladwell, 1999; Loucks et al., 2000; Starkl and Brunner, 2004; Mays, 2006; Policy Research Initiative, 2007). An integrated view of water is essential because it can add social, economic, environmental and institutional aspects to all management processes (Juwana et al., 2010), contributing to understand the evolution of the water system and its influences, that is, the achievement of a sustainable management of water resources (Sun et al., 2016).

According to the OECD (2003, p. 19), "water is the perfect example of a sustainable development challenge – encompassing environmental, economic and social dimensions." The sustainable management of water resources, therefore, implies not only the indefinite continuation of physically and biologically stable systems, but also concern for the other dimensions of sustainable development, such as the economic efficiency of water use, the equitable distribution of the costs and benefits of water resource developments and participatory approaches to policy-making and decision-taking (Ioris et al., 2008).

Sustainability indicators have become relevant tools for the integrated planning and management of water resources (Hooper, 2010). Very useful in decision-making, they enable the simplification of information on complex phenomena and the identification of primary demands (Barros and Silva, 2012). The adoption of indicators to assess and monitor progress towards sustainable development is highly recommended by scientists (Moldan et al., 2012; Cornescu and Adam, 2014; Bolcárová and Kološta, 2015), policy developers (UN, 2007), financial institutions (OECD, 2014; WWAP, 2003), governments (OSE, 2008), business sector (WBCSD, 2000) and nongovernmental organizations (WWF, 2010), as they are means to assess the level of satisfaction of several criteria, helping to translate abstract concepts into measurable parameters (Lee and Huang, 2007).

In Brazil, several authors have used indicators to analyze and propose suggestions aimed at enabling water management in an integrated and sustainable method in river basins (He et al., 2000; Pompermayer et al., 2007; Chaves and Alipaz, 2007; Ioris et al., 2008, Vieira and Studart, 2009; Magalhães Júnior, 2010; Carvalho et al., 2011; Maynard et al., 2017), fact also occurs in river basins in several countries, according to studies carried out by UNESCO (2008), Ioris et al. (2008), Catano et al. (2009), Cortés et al. (2012), Pellicer-Martínez and Martínez-Paz (2016).

Currently, society is seeking a broader debate on sustainable development in terms of rational use and valuation of natural resources. Therefore, discussing aspects related to water management in river basins by using indices and indicators in order to enable a more integrated and sustainable water management brings relevant contributions to the current scenario.

This article it is proposed to a holistic assessment of river basins through indicators that measure how water management is progressing in the perspective of sustainability in a strategic region of Brazil, located between the semiarid Northeastern region and the Amazon region.

As a background, specifically regarding water resources in Maranhão, the area used to perform this study, Dias (2018) points out that there is a notable gap in literature on water resource management, which presents an unfavorable framework regarding the

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implementation of management instruments. There are no studies that address the issue of water sustainability in the State of Maranhão.

Thus, this study also intends to help fill a specific gap in the Northeastern part of Brazil, where there is little literature related to integrated management of water resources aiming at the sustainability of river basins.

Taking into consideration these arguments and the relevance of this issue in the context of water management and sustainability, this article aims to diagnose, through indicators, the water sustainability of river basins in the State of Maranhão, in Northeastern Brazil, and to substantiate the decision-making process for the integrated management of water resources.

Materials and methods

Characterization of the study area

The study was conducted in the State of Maranhão, which is located in the Northeastern part of Brazil, between the coordinates of 02° to 10° south latitude and 44° to 48° west longitude. Covering an area of 331,935,507 km², Maranhão has approximately 7 million inhabitants, being the fourth most populous state in Northeastern Brazil (IBGE, 2017).

It is located in a transition area between the Amazon (wet) and Northeastern (semiarid) regions, favoring great annual rainfall contrasts. The portion of Legal Amazon in Maranhão covers an area equivalent to 80% of the territorial area of the State, about 264,000 km². The region of transition between the Amazon and Cerrado biomes is characterized by a high diversity of ecosystems and biodiversity. (Silva et al., 2016).

The State of Maranhão is divided into twelve hydrographic regions, of which six were selected for this research: Parnaíba, Tocantins, Gurupi, Munim, Mearim and Itapecuru (*Fig. 1*).

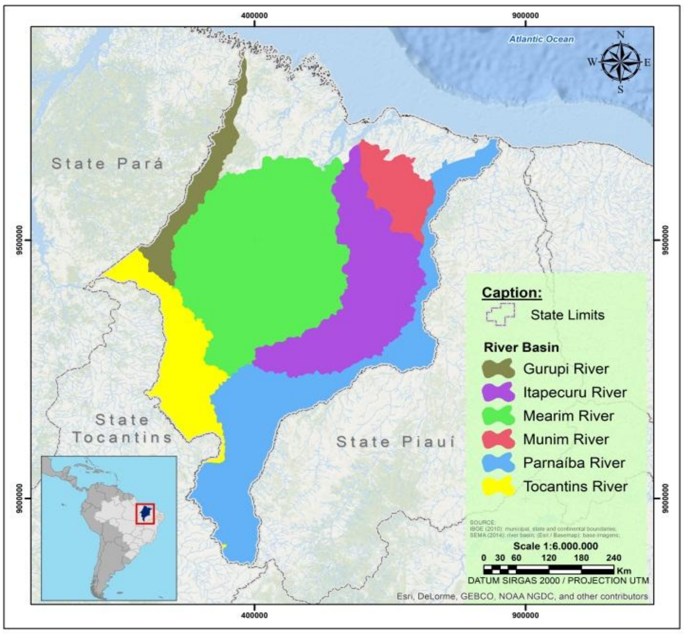

Figure 1. *Geographical location of the river basins researched*

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Frame 1 shows some demographic characteristics of the river basins studied.

Frame 1. *Demographic characteristics of the river basins studied in this research. (Source: IBGE, Censo Demográfico, 2010; NUGEO/UEMA, 2011)*

Basin	Area (km²)	Population	% over the State area	Population density in the basin (inhabitant/km²)	No. of cities in the basin
Tocantins River	30,665.15	498,105	9.24%	16.24	23
Parnaíba River	66,449.09	717,723	20.02%	10.80	39
Gurupi River	15,953.91	178,302	4.81%	11.18	12
Mearim River	99,058.69	1,681,307	29.84%	16.97	83
Munim River	15,918.04	320,001	4.79%	20.10	27
Itapecuru River	53,216.84	1,019,398	16.03%	19.16	57

Selecting indicators and setting indices

The selection process was initially based on an extensive bibliographical research on indices and indicators applied to water resources, aiming at meeting the need to evaluate water sustainability conditions in the basins of Maranhão.

Based on the information required to compose each indice and indicator and the information available in the river basins studied, we have decided to use the methodology elaborated by Vieira (1999) and modified by Campos et al. (2014). Thus, based on these authors, we have chosen to apply the following indicators:

(a) Indicator of Potentiality, Availability and Demand (IPAD), to assess information regarding potentiality and availability of the water from the river basin, as well as the capacity to meet demands; (b) Indicator on Water Resources Management (IWRM), to reflect how entities are implementing it and instruments of the water resources policy; and (c) Water Use Efficiency Indicator (WUEI), to inform the conditions of environmental sanitation in the river basin and the level of efficiency of public utilities in the distribution of the captured water. These sustainability indicators were applied at the river basin level, which is the water resources management unit. Chaves and Alipaz (2007) highlight that this consideration is important, since the assessment of water resource sustainability cannot be limited by jurisdictional boundaries.

The process of choosing indicators also considered whether they meet the four criteria of sustainability: social, economic, environmental and institutional, as described by Pires et al. (2017). In this evaluation, the three indicators IPAD, IWRM and WUEI meet most sustainability criteria. Thus, the chosen indicators can be applied to reliably diagnose the sustainable use and water management in selected river basins. In addition, they are interesting tools that allow us to see some of the multiple aspects of water management and use from specific angles.

The following criteria were taken into consideration to define the indices constituting each indicator: (a) relevance (ability to translate the phenomenon); (b) local adherence (ability to capture the phenomenon produced or that can be transformed at the local level); (c) availability (coverage and timeliness of data); and (d) ability to allow time comparisons (Campos et al., 2014).

Frame 2 shows the indices selected for each indicator.

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Frame 2. *Indicators and their respective indices selected for this research. (Based on Campos et al., 2014)*

Indicator	Indice	Description
IPAD Indicator of Potentiality, Availability and Demand	Activation of Potentialities **(IAP)**	Relation between availability and potentiality
	Use of Potentialities **(IUP)**	Relation between demand and potentiality
	Use of Availabilities **(IUA)**	Relation between demand and availability
IWRM Indicator on Water Resources Management	River Basins Committees **(IRBC)**	Existence and scope of operations
	Grant **(GI)**	Level of implementation of the grant
	Collection **(CI)**	Level of implementation of the collection
WUEI Water Use Efficiency Indicator	Households Supplied by Wells **(IHSW)**	Percentage of households supplied by wells in relation to the total number of households
	Households Supplied by a Water Supply System **(IHSWSS)**	Percentage of households supplied by a water supply system in relation to the total number of households
	Sewer Connections **(ISW)**	Percentage of households with a sewage network or a septic tank in relation to the total number of households
	Sewage Treatment **(IST)**	Percentage of households with sewage treatment in relation to the total number of households
	Solid Waste Treatment **(ISWT)**	Percentage of households with waste collection in relation to the total number of households
	Water Loss in the Network **(IWLN)**	Average percentage of physical losses (leaks) and billed losses (illegal connections)

Data collection and calculation of indices

The information used in this study was obtained by bibliographic research. To determine the IPAD, the values of availabilities, potentialities and surface water demands were obtained from the most recent report prepared by the Geoenvironmental Nucleus of the State University of Maranhão (NUGEO, 2010), entitled “Estimation of demand and water availability of river basins in Maranhão”. The determination of demands by river basin has taken into consideration human supply (urban and rural), industry, irrigation and livestock (*Frame 3*).

Frame 3. *Potentialities, availabilities, and surface water demands, by river basin, in the State of Maranhão. (Source: NUGEO, 2010)*

Basin	Potentialities (h^3/year)	Availabilities (h^3/year)	Demands (h^3/year)
Parnaíba River	3828.41	1475.17	288.38
Munim River	4098.95	269.8	66.44
Itapecuru River	6599.97	1112.55	306.64
Tocantins River	11692.44	2412.15	432.4
Mearim River	13971.85	665.21	290.47
Gurupi River	5970.17	1263.94	27.62

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Information on availability, potentialities and underground water demands were based on data from Brasil (2009) and Santos (2010). In the calculation of the water demands, we have considered human supply (urban and rural), industry, irrigation, livestock, agricultural production and environmental demands (*Frame 4*).

Frame 4. *Potentialities, availabilities, and underground water demands, by river basin, in the State of Maranhão. (Source: Brasil, 2009; Santos, 2010)*

Basin	**Potentialities (h^3/year)**	**Availabilities (h^3/year)**	**Demands (h^3/year)**
Parnaíba River	9030	1107.92	2076.08
Munim River	3120	183.85	220.87
Itapecuru River	1550	219.54	267.68
Tocantins River	500	81.11	150.08
Mearim River	3490	639.16	656.18
Gurupi River	2510	90.85	299.72

The data necessary for the calculations of the indices composing the WUEI were obtained on the platforms of the Brazilian Institute of Geography and Statistics (IBGE, 2010) and the National Information System on Sanitation (Sistema Nacional de Informações Sobre Saneamento - SNIS) for the reference year of 2010.

Data on total households, households supplied by wells, households supplied by a water supply system, households supplied by a sewage network or septic tank, households with sewage treatment, households with waste collection and information on water losses in the supply network were gathered by municipality (see *Appendix*). The final indice, by river basin, was calculated from the average among municipalities that compose the basin.

Currently SNIS has the most comprehensive data on the sanitation sector in Brazil, constituting the largest and most important information tool on water services, collection and treatment of sewage since 1995, as well as solid waste management since 2002 (SNIS, 2015). Thus, the information in this study is very relevant regarding the reliability of its data.

Information on Grant, Collection and Committees required to compose the IWRM was obtained from the Superintendency of Water Resources of the State Department of Environment and Natural Resources of Maranhão (SEMA), the agency responsible for water resources management in Maranhão.

Partial scales

According to *Frame 2,* the indices constituting IPAD are the following: IAP, IUP and IUA. These indices show that regions with IUA > 1 are under situations of exhaustion of availability (Fernandes, 2002).

Vieira (1999) states that due to natural physical limitations, the maximum IUP value would be equal to 0.8. Thus, IUP values > 0.7 would indicate a critical situation of use of water resources in a river basin.

The IAP indice, on the other hand, would represent the level of efficiency of the water resources of a basin, being larger as they are closer to 1 (Fernandes, 2002).

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Thus, the partial scale for all indices relates the calculated values to levels of performance (Very High, High, Medium, Low, and Very Low). For example, a IUA value greater than 1, a IUP value greater than 0.7 and a IAP value closer to 0 were related to “Very Low” performance levels; a IUA and a IUP equal to zero and a IAP closer to 1 are related to “Very High” performance levels.

These indices were calculated by river basin considering superficial and underground waters, which allows us to observe the relations of the demands with availabilities and potentialities. Vieira and Gondim Filho (2006) strongly recommend that these indicators are spatially implemented in terms of surface and ground potentiality.

The indices that make up the IWRM (IRBC, GI, CI) are subjective and determined from the analysis of their application to the hydrographic basin being studied. The partial scales for these indices are qualitative (*Frame 5*).

For the indices that make up the WUEI (IHSW, IHSWSS, ISW, IST, ISWT, IWLN), the partial scales (also from Very High to Very Low) are related to percentages ranging from 0 to 100%. For example, an indice with a value equal to 60% is classified as “Medium”, while another with a value equal to 25% is considered “Low”. These indices were calculated for all the cities that compose the river basins.

Frame 5. *Partial scales for IWRM indices. (Source: Campos et al., 2014)*

LEVEL	DESCRIPTION
Indice of River Basins Committees (IRBC)	
Very High	The committee is well articulated and has a high rate of problem solving in the basin
High	The committee has been operating for a few years and has a mean rate of problem solving in the basin
Medium	The committee has been recently set up and has a low rate of problem solving in the basin
Low	The committee has been proposed by law and is being set up
Very Low	There is no action for creating a committee in the basin
Grant Indice (GI)	
Very High	The grant has been implemented, it is very well supervised and there is a high reduction in water consumption
High	The grant has been implemented and the level of inspection and reduction in water consumption is medium
Medium	The grant has been implemented and the level of inspection and reduction in water consumption is low
Low	The grant has been proposed by law and is being implemented
Very Low	There is no action for deploying a grant in the basin
Collection Indice (CI)	
Very High	The collection has been implemented, a high amount is being collected and there is a high level of development in the basin
High	The collection has been implemented, a significant amount is being collected and there is a good level of development in the basin
Medium	The collection has been recently implemented and involves a deficit
Low	The collection has been proposed by law and is being implemented
Very Low	There is no action for deploying a collection in the basin

Global scales

When the indices are grouped, global scales are constructed with levels of water sustainability for all indicators in order to allow a better understanding of the value obtained for each indicator. The levels of the scales are qualitative, varying according to

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the values obtained when grouping the indices. This grouping can occur by considering the average of the indices (IPAD) and (WUEI), or by joining the management instruments (IWRM) (*Frame 6*).

After obtaining the indicators and respective level of water sustainability for each basin surveyed, the indicators IPAD, IWRM and WUEI were spatially distributed. For the development of maps, we used ArcGIS 10.3 software (ESRI, 2011), a GIS (Geographic Information System) tool that allows the manipulation of geospatial, matrix and vector databases.

Frame 6. *Global scale for the indicators used in this research. (Adapted from Campos et al., 2014)*

LEVEL	**IPAD and WUEI** **Average (%)**	**IWRM** **Joint Indices (J)**
Very High	80 ≤ M	Committee, grant and collection in full operation in the basin, generating a high reduction in demand
High	60 ≤ M < 80	Committee, grant and collection operating for a few years, generating little reduction in demand
Medium	40 ≤ M < 60	Committee, grant and collection (one or more) recently implemented, but with operational problems
Low	20 ≤ M < 40	Committee, grant and collection (one or more) proposed by law, in the process of installation
Very Low	M < 20	There is no action to apply a committee, a grant and a collection in the basin (one or more)

Results

Indicator on water resources management - IWRM

The assessment of the performance indicator for the water resources management system can be observed in *Table 1*.

Table 1. *Classification of the indices composing IWRM*

Basin	Indice of River Basins Committees (IRBC)	Grant indice (GI)	Collection indice (CI)
Parnaíba River	Very Low	Medium	Very Low
Munim River	Medium	Medium	Very Low
Itapecuru River	Very Low	Medium	Very Low
Tocantins River	Very Low	Medium	Very Low
Mearim River	Medium	Medium	Very Low
Gurupi River	Very Low	Medium	Very Low

Water use efficiency indicator – WUEI

Table 2 shows classification of the indices composing WUEI.

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Table 2. *Classification of the indices composing WUEI*

BASIN	Indices					
	IHSW	**IHSWSS**	**ISW**	**IST**	**ISWT**	**IWLN**
Mearim River	11.67	13.08	47.64	16.73	15.22	50.30
	VL	**VL**	**M**	**VL**	**VL**	**M**
Itapecuru River	9.53	14.06	14.67	7.77	6.90	55.72
	VL	**VL**	**VL**	**VL**	**VL**	**M**
Parnaíba River	14.48	73.92	17.01	9.72	8.53	48.69
	VL	**A**	**VL**	**VL**	**VL**	**M**
Tocantins River	11.85	18.45	20.76	10.22	14.64	30.15
	VL	**VL**	**L**	**VL**	**VL**	**L**
Munim River	15.40	9.82	13.50	5.25	4.19	67.59
	VL	**VL**	**VL**	**VL**	**VL**	**A**
Gurupi River	17.94	16.95	28.31	11.50	12.91	26.14
	VL	**VL**	**L**	**VL**	**VL**	**L**

Indices: IHSW - Indice of Households Supplied by Wells; IHSWSS - Indice of Households Supplied by a Water Supply System; ISW - Indice of Sewer Connections; IST - Indice of Sewage Treatment; ISWT - Solid Waste Treatment; IWLN - Indice of Water Loss in the Network. Classification: (VH), Very High; (H), High; (M), Medium; (L), Low; (VL), Very Low

Indicator of potentiality, availability and demand – IPAD

The application of sustainability indices for this indicator has shown the low utilization of existing water resources in all river basins surveyed (*Table 3*).

Table 3. *Classification of the indices composing IPAD*

BASIN	SURFACE			UNDERGROUND		
	IAP	**IUP**	**IUA**	**IAP**	**IUP**	**IUA**
Parnaíba River	0.39	0.08	0.20	0.12	0.23	1.87
	L	**VH**	**H**	**VL**	**H**	**VL**
Munim River	0.07	0.02	0.25	0.06	0.07	1.20
	VL	**VH**	**H**	**VL**	**VH**	**VL**
Itapecuru River	0.17	0.05	0.28	0.14	0.17	1.22
	VL	**VH**	**H**	**VL**	**VH**	**VL**
Tocantins River	0.21	0.04	0.18	0.16	0.30	1.85
	L	**VH**	**VH**	**VL**	**H**	**VL**
Mearim River	0.05	0.02	0.44	0.18	0.19	1.03
	VL	**VH**	**M**	**VL**	**VH**	**VL**
Gurupi River	0.21	0.00	0.02	0.04	0.12	3.30
	L	**VH**	**VH**	**VL**	**VH**	**VL**

Indices: IAP - Indice of Activation of Potentialities; IUP - Indice of Use of Potentialities; IUA - Indice of Use of Availabilities. Classification: (VH), Very High; (H), High; (M), Medium; (L), Low; (VL), Very Low

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Water sustainability

The assessment of the sustainability indicators used in this research is described in *Table 4*.

Table 4. *Classification of water sustainability indicators*

BASIN	IWRM	WUEI	IPAD	
			sur	**und**
Mearim River	M	L	H	L
Itapecuru River	M	L	VH	M
Parnaíba River	M	L	VH	M
Tocantins River	M	VL	VH	L
Munim River	M	L	VH	M
Gurupi River	M	L	VH	VL

Indicators: IWRM - Indicator on Water Resources Management; WUEI - Water Use Efficiency Indicator; IPAD - Indicator of Potentiality, Availability and Demand; sur - surface; und - underground. Classification: (VH), Very High; (H), High; (M), Medium; (L), Low; (VL), Very Low

All basins of the state showed a "Medium" level of sustainability for IWRM (*Fig. 2*).

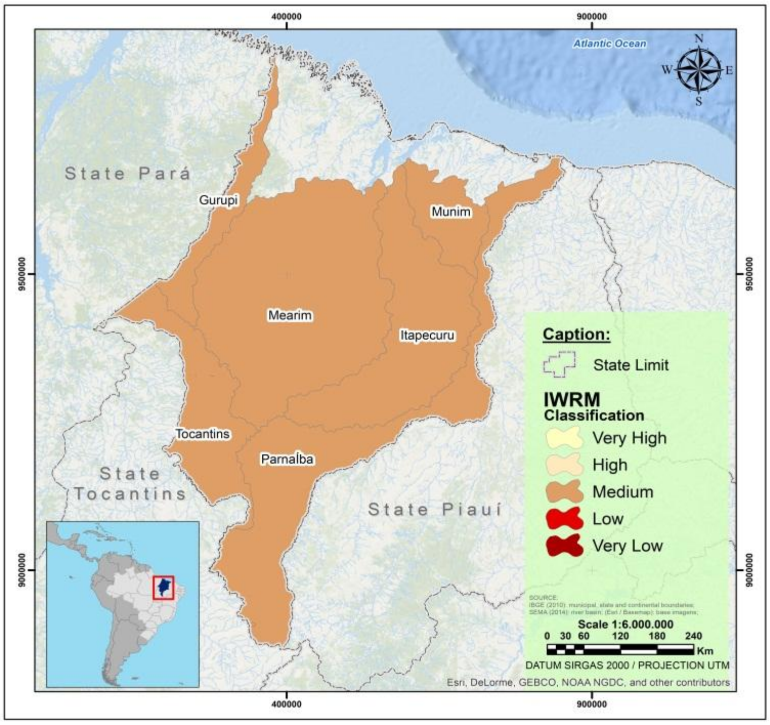

Figure 2. *Spatial distribution of IWRM*

The WUEI showed a sustainability level ranging from "very low" to "low" in the state river basins (*Fig. 3*).

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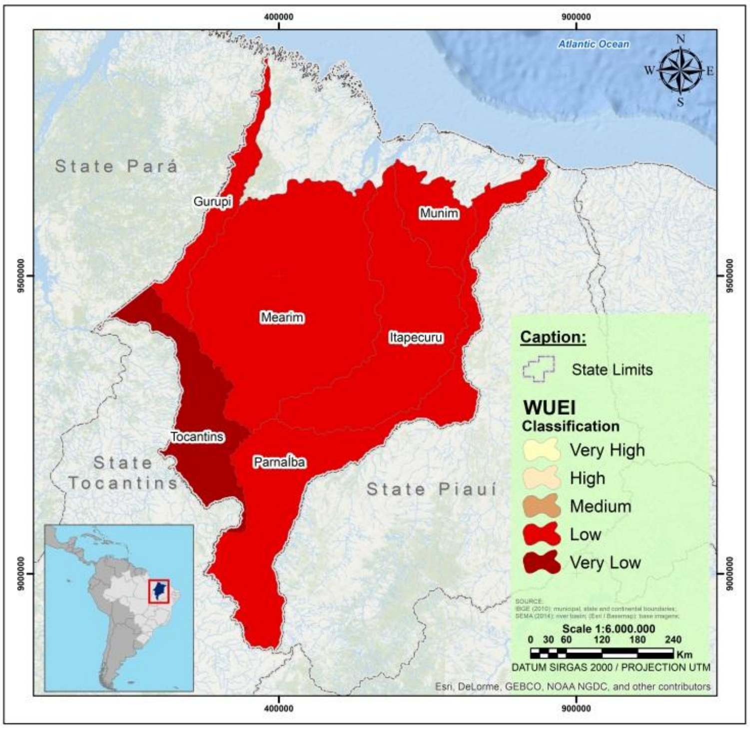

Figure 3. *Spatial distribution of WUEI*

On the global scale, for surface water the IPAD showed a sustainability level ranging from “Very High” to “High” (*Fig. 4*), depicting surplus availabilities in relation to demands and indicating that water resources are not fully available in the basins studied.

Figure 4. *Spatial distribution of IPAD, for surface water*

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The global scale of IPAD for groundwater showed sustainability levels varying from "very low" to "low" and "medium" (*Fig. 5*), due to demands higher than the available water resources, which means that the potential of the basins is not fully activated. Despite these results, the indissociability of surface and underground waters should be noted, as well as the importance of groundwater in maintaining the flow of the Maranhão rivers that have perennial characteristics.

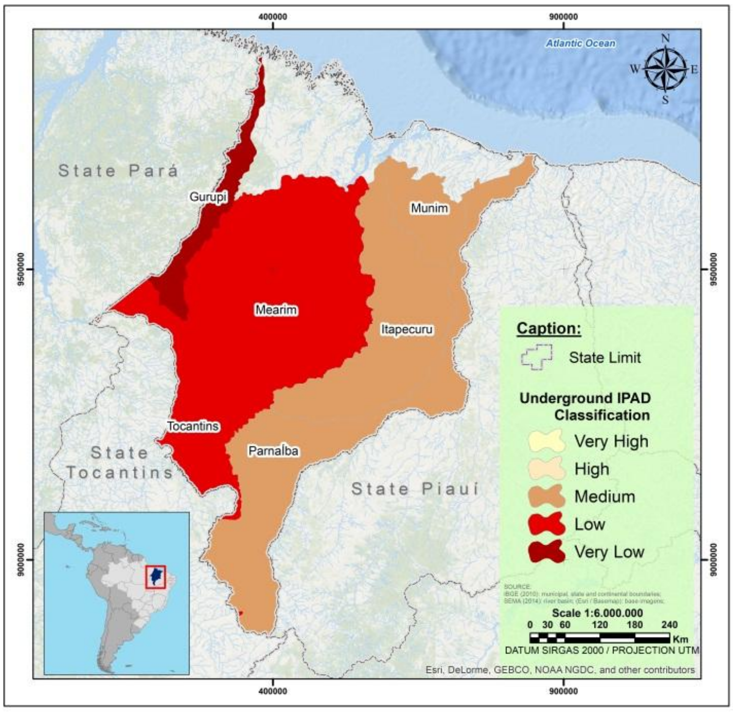

Figure 5. *Spatial distribution of IPAD, for groundwater*

Discussion

About IWRM, the grant indice had a "medium" level in all basins in Maranhão because this instrument is implemented, but it has a low level of inspection and reduction in water consumption. The collection indice has shown a "very low" level in all basins because the collection for the use of water is only established in the state policy of water resources (Brazilian Law no. 8.149/2004). The effective implementation of this instrument would require legal regulation, but there is still no state action in this regard in any of the basins studied in this research. The indice of river basins committees has shown a "very low" level for the Parnaíba, Tocantins, Itapecuru and Gurupi river basins, since none of these has a committee; and a "medium" level for the Mearim and Munim river basins, because they are the only ones that have a recently installed committee, but both have a low rate of problem solving.

Despite the average level of sustainability obtained in the IWRM, the shallow institutionalization of management instruments (grant with problems in implementation undergoing a bureaucratic process, poor inspection, collection for the use of nonexistent water) is clear.

Only two committees have been created so far in the state, which have little or no economic and political sustainability, indicating the existence of issues and fragilities in

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their effective performance and resulting in the low performance of these organizations. The river basin committees which are members of the National System of Water Resources Management play a relevant role in water management. The effective performance of these entities implies in the democratization of water resources management and in sharing the power to decide. This requires effort from the public authorities to share power, and effort from users and civil society to share responsibilities.

The IHSW and IHSWSS indices, which make up the water use efficiency indicator, were “very low”, indicating little coverage of water supply (including by wells).

According to a diagnosis carried out by the National Information System on Sanitation - SNIS, approximately 83% of the Brazilian population is served by a water supply system (Brazil, 2016). Although it appears to be a positive percentage, 17% do not have access to this basic utility, which represents more than 35 million people, mainly concentrated in the Northern and Northeastern regions of the country (Araújo et al., 2016).

Almost all basins studied have shown “very low” ISW and IST levels, except for the Tocantins and Gurupi river basins, whose ISW was “low”. These data show a poor service of collection and sewage treatment. In the calculation of IST, for example, we have observed that in some cities there were no data available on sewage treatment or, when this type of treatment did not occur in the region being studied, the percentage was equal to zero. It should be noted that the National Plan for Basic Sanitation (Plano Nacional de Saneamento Básico - PLANSAB) considers as an appropriate sanitary sewage service not only the presence of a sewage collection and treatment network, but also the use of a septic tank. This fact may have contributed to increasing the level of the ISC indicator, since it also considers the households served by septic tank, the main type of treatment adopted in the cities of Maranhão.

It is important to note that the percentage of cities in Maranhão that has appropriate systems of sewage treatment, with effective removal of organic load, is minimal. Most cities only implement sewage removal in urban regions, with in natura discharge in surface waters, or preliminary treatment, facts that may have contributed to the low level obtained in the IST indicator. According to ANA (2017), the lowest levels of organic load removal from sewage are found especially in the Northern and Northeastern regions of the country. Of the 5,570 cities, 70% remove at most 30% of the organic load generated.

The ISWT indicator also reached a “very low” level in all the basins surveyed, indicating a deficiency in solid waste collection services. The collection of waste in general is not a guarantee that this waste will receive proper treatment, because despite the goal of closing all dumps in Brazil by 2014 as established by the National Policy on Solid Waste, Brazilian Law no. 12.305/2010, Maranhão is now the second State of Brazil with the largest number of dumps, totaling 250 in operation that are responsible for receiving daily almost three thousand tons of waste (ABRELPE, 2017).

The inappropriate disposal of solid waste has become a worldwide issue and can cause damages to the environment, particularly water pollution. This type of pollution can change the characteristics of the aquatic environment through leachate percolation associated to rainwater and springs in the waste disposal sites (Pires et al., 2016).

As for the IWLN indice, which measures the percentage of physical and billed losses, the level shown in the Mearim, Itapecuru and Parnaíba river basins was “medium”. In the Tocantins and Gurupi river basins it was “low” and in the Munim

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river basin it was “high”, above 60%. Elevated levels of loss in water distribution systems have been reported in Northeastern Brazil, including in Maranhão, reaching 60% and 70% (Maranhão, 2014; Araújo et al., 2016).

Except for the basins with low indices, the others are above the national average, which is 37.57% (Brazil, 2016). In addition, all the basins assessed are above the level of water loss considered acceptable by Cambrainha and Fontana (2015), which is 10%.

A survey released by IBNET (International Benchmarking Network for Water and Sanitation Utilities) showed that, in terms of water loss, Brazil ranks 20th in a ranking of 43 countries (Instituto Trata Brasil, 2015). According to the institute, around 6.5 billion cubic meters of treated water were lost in Brazil in 2013, which amounts to a financial loss of 8.015 billion Reais.

The elevated level of loss of water resources observed in this research indicates the fragility and precariousness of the sanitation system and of the companies that operate water supply services in the regions studied. This also results in many problems, not only economic and social, but mainly environmental, since this loss increases the need for exploration of surface and underground sources of water (Morais et al., 2010).

The the low degree of sustainability of WUEI revealed alarming sanitation conditions, such as low coverage of supply by public utilities, poor or non-existent sewage collection and treatment, incipient waste collection and significant losses of water in the distribution network, which reflects the current reality of Maranhão although the data and information refer to 2010.

As for the IPAD, the Indice of Use of Availabilities - IUA for surface waters ranges from 0.02 to 0.028 and 0.44, resulting in “Very High”, “High” and “Medium” levels, respectively. A “Medium” level of sustainability was observed in the Mearim river basin, being the greatest demand considered for irrigation. The “High” level was observed in the Itapecuru river basin, in which the higher demand is mainly used for urban supply. The “Very High” level was seen for the Gurupi river basin, which presents demands for multiple uses, such as urban and rural supply, industry, irrigation and livestock. The assessment of this indicator revealed surplus availabilities in relation to demands, meaning there is no unmet demand.

The indice of use of underground availability evidences demands higher than availability, which results in a “Very Low” level of sustainability in all basins analyzed. Therefore, there is a situation of exhaustion of availability, with repressed demands in all basins, which would imply the need to increase supply by drilling more wells or adopting other measures such as demand rationalization. Currently, the situation is even more critical as demand has been growing mainly for urban supply, industrial use and irrigation.

Specifically, with respect to groundwater, Costa (1994) already observed that its availability was, in general, lower than the total demand in most regions of Northeastern Brazil. Vieira and Gondim Filho (2006), using potentiality, availability and demand indicators in river basins in Northeastern Brazil, classified the groundwater of the Itapecuru, Mearim and Tocantins basins as little sustainable due to the high demands in these regions. Recent articles show that groundwater resources are under increasing pressure in developing regions and in other regions that are more crucial to economic development (Mukherjee et al., 2015; Watto and Mugera, 2015).

The “Very High” IUP levels for surface waters and the “Very High” and “High” IUP levels for underground waters indicates a comfortable situation regarding the use of potentiality of water resources in all basins.

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The IAP indice, on the other hand, showed that water resources are not efficiently available in all basins, especially in relation to groundwater, for which the level obtained in all the basins was "Very Low". As for surface water, the IAP levels ranged from "Very Low" to "Low", meaning that the basins potential is not fully activated.

Relevant information was observed in this research by assessing the IPAD for 2010. On the other hand, it is necessary to calculate such indice with updated data to allow comparisons and to obtain a more current picture on the balance of demand, availability and potentialities of the river basins in the State of Maranhão.

Currently, in the case of surface water, it is already possible to identify conflicts over the use of water in some regions of Maranhão, especially in times of water scarcity. In the Parnaíba river basin, for example, conflicts in the southern region of the State are related to the use of water for irrigation. In the Mearim river basin, in addition to demands for irrigation, there is a growing use of water for intensive and semi-intensive fish farming, associated with illegal abstractions and effluent releases without the authorization from the water resources management authority. In this basin there are also problems with floods, especially in the Pindaré and Grajaú rivers, two important tributaries of the Mearim river. In the Itapecuru river basin, the demand for urban supply stands out because the Italuís system, which supplies a large part of the metropolitan region of São Luís, the state capital, will have its uptake flow doubled by the end of 2018. In addition, deforestation, silting and irregular sand extraction are some of the main environmental problems found in the course of the main river. In recent years, the Tocantins river basin has undergone droughts and significant reductions in the level of the main river and its tributaries, compromising the basin's sustainability, multiple uses of water and also the production of energy, as the basin houses the hydroelectric power plant of Estreito, which has an installed rated capacity of 1,087 MW.

Concerning groundwater, particularly in the metropolitan region of São Luís, there are reports of wells with high levels of salinization. In 2013, there were a total of 462 records of deep wells, distributed by several municipalities of the State (Cunha et al., 2013). Currently, there are more than 11,000 wells drilled (CPRM, 2018), which may indicate a scenario of overexploitation of the aquifers in Maranhão.

Conclusion

This study presents the application of a methodology that uses river basin sustainability indicators, bringing a contribution to the related literature, in particular to water resources management in terms of diagnosis of sustainability and support to planning and decision making. Sustainability indicators were used in the context of river basins, analyzing surface and underground waters when possible, since water resources are part of an integrated whole that has great relevance in the constitution of life and in a balanced ecosystem.

The application of the methodology to the basins of the state of Maranhão, located in Northeastern Brazil, determined sustainability with an overall intermediate performance in the river basins assessed in this research. These basins require priority measures in the hydrological dimension, especially for underground waters; attention to basic sanitation, including with regard to public supply; reduction of demands and waste; in addition to proper sewage collection and treatment. The results also highlighted the need to improve the state water management system, with actions oriented to the

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implementation and consolidation of the water resources policy instruments and promotion and support to river basin committees.

The spatialization of the indicators enables a clearer view of the water sustainability of the basins in Maranhão, so that all concepts regarding the performance of the water management structure, efficient use of available water as well as potentialities, availability and water demands could be unequivocally considered.

The application of this methodology may be a model for the assessment of other river basins, especially with conditions similar to the ones evaluated in this study. This tool, provided it is regularly applied, can provide an appropriate description of the evolution of basin conditions in terms of sustainability, assisting different stakeholders and water managers in the planning, decision-making and implementation of local strategies for sustainable development. Authors such as Corrêa and Teixeira (2006) recommend that sustainability indicators are annually applied to observe their evolution and to evaluate the effectiveness of the actions proposed from the surveys of the previous period.

Carvalho et al. (2011) have shown that the adoption of an average value as a measure to build the sustainability indice may be an area of weakness, which may represent a fragility in this study. Another difficulty found when conducting this research was the scarce availability of data in most of the state river basins, a fact that prevented the inclusion of other basins in this analysis and limited the assessment of more indicators.

However, we may conclude that these results were satisfactory and are applicable in regions with scarce data. Consideration was given to variables that fulfill the main components of sustainability, with social, economic, hydro-environmental and institutional characteristics, despite their incommensurability and the complexity of grouping information from indicators of such diverse nature, in particular in places where data availability is scarce. In addition, the aspects of the indicators used here allowed the joint and separate analysis of each dimension. This allows a unique look at the most critical issues of each basin, so as to act correctively and/or preventively to solve the main negative items.

The bottlenecks and limitations identified in this study represent a window of opportunity to improve the current situation in the basins, but it requires a more efficient coordination between the different institutions involved in water resources management.

In this specific application in river basins in the Northeastern part of Brazil, the results are particularly relevant, since there is a considerable gap in the literature on the integrated management of water resources for this region, and especially in the state of Maranhão, which can support more sustainable management actions.

As for future studies, it is recommended that researches shall be carried out on the potentialities, availabilities as well as superficial and underground water demands, by river basin, portraying the current reality of water resources in the State. It is also recommended that other studies shall be carried out to address the issue of water sustainability indicators at the site, including a greater number of indicators that consider other water sustainability criteria.

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REFERENCES

[1] ABRELPE - Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais. (2017): Ranking nacional sobre lixões e vazadouros em operação no Brasil. Relatório Técnico. – Abrelpe, São Paulo.

[2] ANA - Agência Nacional de Águas. (2017): Atlas Esgotos - Despoluição de Bacias Hidrográficas. – ANA, Brasília.

[3] Araújo, S. C., Filho, J. A. S., Silva, G. M. S., Filha, M. C. S. C., Nogueira, V. F. B. (2016): Distribuição espacial de indicadores operacionais de serviço de abastecimento de água no Nordeste Brasileiro. – Revista Verde 11: 20-28.

[4] Barros, J. D. S., Silva, M. F. A. P. (2012): Aspectos teóricos da sustentabilidade e seus indicadores. – Polêmica 11: 104-112.

[5] Bolcárová, P., Kološta, S. (2015): Assessment of sustainable development in the EU 27 using aggregated SD index. – Ecol. Indic. 48: 699-705.

[6] Bragatto, R. D., Martini, C. A., Steffani, M. A., Zorel Júnior, H. E., Barreto-Rodrigues, M. (2012): Indicadores ambientais de sustentabilidade sistematizados pelo modelo pressão-estado-resposta (PER): análise de águas superficiais na microbacia hidrográfica Passo da Pedra, em Pato Branco-PR. – Revista Brasileira de Agroecologia 7: 87-103.

[7] BRASIL. Ministério das Cidades. Secretaria Nacional de Saneamento Ambiental - SNSA. (2016): Sistema Nacional de Informações sobre Saneamento: Diagnóstico dos Serviços de Água e Esgotos - 2014. – SNSA/MCIDADES, Brasília.

[8] BRASIL. Ministério de Minas e Energia - MME. Secretaria de Geologia, Mineração e Transformação Mineral-SGM. (2009): Análise das informações sobre recursos hídricos subterrâneos no país. Relatório Técnico. – MME, Brasília.

[9] Cambrainha, G. M. G.; Fontana, M. E. (2015): Análise da aplicação de investimentos em perdas de água no nordeste brasileiro. – Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental 19: 983-994.

[10] Campos, M. V. C. V., Ribeiro, M. M. R., Vieira, Z. M. C. L. (2014): A Gestão de Recursos Hídricos Subsidiada pelo Uso de Indicadores de Sustentabilidade. – Revista Brasileira de Recursos Hídricos 19: 209-222.

[11] Carvalho, J. R. M., Curi, W. F. (2013): Construção de um índice de sustentabilidade hidro-ambiental através da análise multicritério: estudo em municípios paraibanos. – Soc. & Nat 25: 91-106.

[12] Carvalho, R. G., Kelting, F. M. S., Silva, E. V. (2011): Indicadores socioeconômicos e gestão ambiental nos municípios da bacia hidrográfica do rio Apodi-Mossoró, RN. – Sociedade & Natureza 23: 143-159.

[13] Catano, N., Marchand, M., Staley, S., Wang, Y. (2009): Development and Validation of the Watershed Sustainability Index (WSI) for the Watershed of the Reventazón River - Commission for the Preservation and Management of the Watershed of the Reventazón River. – COMCURE, Cartago.

[14] Chaves, H. M. L., Alipaz, S. (2007): An Integrated Indicator for Basin Hydrology, Environment, Live, and Policy: The Watershed Sustainability Index. – Water Resources Manage 21: 883-895.

[15] Cornescu, V., Adam, R. (2014): Considerations regarding the role of indicators used in the analysis and assessment of sustainable development in the E. U. – Procedia Econ. Financ. 8: 10-16.

[16] Corrêa, M. A., Teixeira, B. A. N. (2006): Indicadores de sustentabilidade para gestão de recursos hídricos no âmbito da bacia hidrográfica do Tietê-Jacaré-SP. – Rede SIADES: 145-158.

[17] Cortés, A. E., Oyarzún, R., Kretschmer, N., Chaves, H., Soto, G., Soto, M., Amézaga, J., Oyarzún, J., Rötting, T., Señoret, M. and Maturana, H. (2012): Application of the Watershed Sustainability Index to the Elqui river basin, North-Central Chile. – Obras y Proyectos 12: 57-69.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1604_37293754

[18] Costa, W. D. (1994): Água subterrânea e o desenvolvimento sustentável do semi-árido nordestino. Projeto Áridas Recursos Hídricos. – SEPLAN/PR, Brasília.
[19] CPRM (2018): Serviço Geológico do Brasil. Total de Poços Cadastrados no Estado do Maranhão. – http://siagasweb.cprm.gov.br/layout/uf_pocos.php. Accessed on 22 Jan 2018.
[20] Cunha, C. F., Silva, L.M; Leite, A. A. L., Correa, H. M., Estrela, L. A., Rego, P. F. F. (2013): A importância do SIAGAS como instrumento de gestão no Estado do Maranhão. – CONGRESSO INTERNACIONAL DE MEIO AMBIENTE SUBTERRÂNEO, 3. ABAS, São Paulo.
[21] Dias, I. C. L. (2018): Overview of groundwater management in the state of Maranhão. – Journal Tchê Química 15: 277-293.
[22] ESRI (2011): ArcGIS - ArcMap 10 Help On Line. – ESRI, Redlands.
[23] Fernandes, J. R. A. (2002:) Instrumentos para a Avaliação da Sustentabilidade Hídrica em Regiões Semiáridas. – Dissertação (Mestrado em Engenharia). Escola Politécnica, Universidade de São Paulo, São Paulo.
[24] He, C., Malcolm, S. B., Dahlberg, K. A., Fu, B. (2000): A conceptual framework for integrating hydrological and biological indicators into watershed management. – Landscape and Urban Planning 49: 25-34.
[25] Hooper, B. (2010): River basin organization performance indicators: Application to the Delaware River basin commission. – Water Policy 12: 461-478.
[26] IBGE - Instituto Brasileiro de Geografia e Estatística. (2017): Estimativas da população residente para os municípios e para as unidades da federação brasileiros com data de referência em 1 de julho de 2017. – IBGE, Brasília.
[27] IBGE - Instituto Brasileiro de Geografia e Estatística. (2010): Atlas do Censo Demográfico 2010. – IBGE, Rio de Janeiro.
[28] Instituto Trata Brasil. (2015): Perdas de Água: Desafios ao Avanço do Saneamento Básico e à Escassez Hídrica. – Instituto Trata Brasil, São Paulo.
[29] Ioris, A. A. R.; Hunter, C.; Walker, S. (2008): The development and application of water management sustainability indicators in Brazil and Scotland. – Journal of Environmental Management 88: 1190-1201.
[30] Juwana, I., Perera, B. J., Muttil, N. A. (2010): Water sustainability index for West Java. Part 1: developing the conceptual framework. – Water Sci. Technol. 2: 1629-1640.
[31] Lee, Y. J., Huang, C. M. (2007): Sustainability index for Taipei. – Environmental Impact Assessment Review 27: 505-521.
[32] Loucks, D. P., Gladwell, J. S. (1999): Sustainability Criteria for Water Resource Systems. – Cambridge University Press, Cambridge.
[33] Loucks, D. P., Stakhiv, E. Z., Martin, L. R. (2000): Sustainable water resources management. – Journal of Water Resources Planning and Management 126: 43-47.
[34] Magalhães Júnior, A. P. (2010): Indicadores Ambientais e Recursos Hídricos: Realidade e Perspectivas para o Brasil a partir da Experiência Francesa (2 ed.). – Bertrand, Lisboa.
[35] Maranhão, Estado. Secretaria de Estado das Cidades e Desenvolvimento Urbano - SECID (2014): Resumo Diagnóstico do Plano Diretor da Bacia Hidrográfica do Mearim/MA. – SECID, São Luís.
[36] Maynard, I. F. N., Cruz, M. A. S., Gomes, L. J. (2017): Aplicação de um índice de sustentabilidade na bacia hidrográfica do rio Japaratuba em Sergipe. – Ambiente & Sociedade 20: 207-226.
[37] Mays, L. W. (2006): Water Resources Sustainability. – McGraw-Hill Professional, New York.
[38] Moldan, B., Janoušková, S., Hák, T. (2012): How to understand and measure environmental sustainability: indicators and targets. – Ecol. Indic. 17: 4-13.
[39] Morais, D. C., Cavalcante, C. A. V., Almeida, A. T. (2010): Priorização de áreas de controle de perdas em redes de distribuição de água. – Pesquisa Operacional 30: 15-32.

[40] Mukherjee, A., SAHA, D., Harvey, C. F., Taylor, R. G., Ahmed, K. M., Bhanja, S. N. (2015): Groundwater systems of the Indian sub-continent. – Journal of Hydrology Reg Stud 4: 1-14.
[41] NUGEO - Núcleo Geoambiental da Universidade Estadual do Maranhão - UEMA. (2010): Estimativa das demandas e da disponibilidade hídrica das bacias hidrográficas do Estado do Maranhão. Relatório Técnico. – UEMA, São Luís.
[42] NUGEO - Núcleo Geoambiental da Universidade Estadual do Maranhão - UEMA. (2011): Bacias Hidrográficas: Subsídios para o Planejamento e a Gestão Territorial. Relatório Técnico. – UEMA, São Luís.
[43] OECD - Organisation for Economic Cooperation and Development. (2003): Improving Water Management: Recent OECD Experience. – OECD, Paris.
[44] OECD - Organisation for Economic Cooperation and Development. (2014): Green Growth Indicators 2014: OECD Green Growth Studies. – OECD, Paris.
[45] Oelkers, E. H., Hering, J. G., Zhu, C. (2011): Water: is there a global crisis? – Elements 7: 157-162.
[46] ONU - United Nations Organization. (2007): Indicators of Sustainable Development: Guidelines and Methodologies (3 ed.). – UNO, New York, New York.
[47] OSE - Observatorio de la Sostenibilidad en España. (2008): Agua y Sostenibilidad: Funcionalidad de las cuencas. – OSE, Madrid.
[48] Pellicer-Martínez, F.; Martínez-Paz, J. M. (2016): The Water Footprint as an indicator of environmental sustainability in water use at the river basin level. – Science of The Total Environment 571: 561-574.
[49] Peterson, J. M., Schoengold, K. (2008): Using numerical methods to address water supply and reliability issues: discussion. – Am J Agric Econ 90: 1350-1351.
[50] Pires, A., Moratoa, J., Peixoto, H., Boteroc, V., Zuluaga, L., Figueroa, A. (2017): Sustainability assessment of indicators for integrated water resources management. – Science of the Total Environment 578: 139-147.
[51] Pires, K. S., Sousa, W. K. B., Cutrim, F. J. (2016): O plano estadual de resíduos sólidos do Maranhão: As estratégias de gerenciamento de resíduos sólidos urbanos orgânicos. – Revista Jus Navigande <https://jus.com.br/artigos/54354/o-plano-estadual-de-residuos-solidos-do-maranhao>. Accessed on 5 Jan 2017.
[52] Policy Research Initiative. (2007): Canadian Water Sustainability Index. – Government of Canada, Ottawa.
[53] Pompermayer, R. S., Paula Júnior, D. R., Cordeiro Netto, O. M. (2007): Análise Multicritério como Instrumento de Gestão de Recursos Hídricos: O Caso das Bacias dos Rios Piracicaba, Capivari e Jundiaí. – Revista Brasileira de Recursos Hídricos 12: 117-127.
[54] Qu, X. L., Alvarez, P. J., Li, Q. L. (2013): Applications of nanotechnology in water and wastewater treatment. – Water Res 47: 3931-3946.
[55] Ross, A. (2017): Speeding the transition towards integrated groundwater and surface water management in Australia. – Journal of Hydrology. DOI: http://dx.doi.org/10.1016/j.jhydrol.2017.01.037. Accessed on 27 Jan 2017.
[56] Santos, L. C. A. (2010): Reflexões sobre água subterrânea do estado do Maranhão. – Revista Águas Subterrâneas suplemento especial: n. p.
[57] Silva, F. B., Santos, J. R. N., Feitosa, F. E. C. S., Silva, I. D. C., Araújo, M. L. S., Guterres, C. E., Santos, J. S., Ribeiro, C. V., Bezerra, D. S., Neres, R. L. (2016): Evidências de Mudanças Climáticas na Região de Transição Amazônia-Cerrado no Estado do Maranhão. – Revista Brasileira de Meteorologia 31: 330-336.
[58] SNIS - Sistema Nacional de Informações sobre Saneamento. (2015): Aplicação da Web série histórica. – http://www.snis.gov.br/aplicacao-web-serie-historica. Accessed on 6 Jan 2017.
[59] Starkl, M., Brunner, N. (2004): Feasibility versus sustainability in urban water management. – J Environ Manage 71: 245-260.

[60] Sun, S., Wanga, Y., Liu, J., Cai, H., Wub, P., Geng, Q., Xu, L. (2016): Sustainability assessment of regional water resources under the DPSIR Framework. – Journal of Hydrology 532: 140-148.
[61] UNESCO, Organização das Nações Unidas para a Educação, a Ciência e a Cultura. (2008): Evaluación objetiva de la aplicación y cálculo del Índice de Sostenibilidad de Cuenca en la Cuenca Hidrográfica del Canal de Panamá. – UNESCO, Paris.
[62] United Nations. (2007): Indicators of Sustainable Development: Guidelines and Methodologies (13th ed.). – United Nations, New York.
[63] United Nations. (2015): The Millennium Development Goals Report 2015. – United Nations, New York.
[64] Vieira, P. M. S.; Studart, T. M. C. (2009): Proposta Metodológica para o Desenvolvimento de um Índice de Sustentabilidade Hidro-Ambiental de Áreas Serranas no Semiárido Brasileiro - Estudo de Caso: Maciço de Baturité, Ceará. – Revista Brasileira de Recursos Hídricos 14: 125-136.
[65] Vieira, V. P. P. B. (1999): Água Doce no Semi-Árido. – In: Rebouças, A. C., Braga, B., Tundisi, J. G. Águas Doces no Brasil - Capital Ecológico, Uso e Conservação. Escrituras, São Paulo.
[66] Vieira, V. P. P. B., Gondim Filho, J. G. C. (2006): Água doce no semiárido. – In: Rebouças, A. C., Braga, B., Tundisi, J. G. (3 ed.) Águas Doces no Brasil - Capital Ecológico, Uso e Conservação. Escrituras, São Paulo.
[67] Watto, M. A., Mugera, A. W. (2015): Econometric estimation of groundwater irrigation efficiency of cotton cultivation farms in Pakistan. – Journal of Hydrology Reg Stud 4: 193-211.
[68] WBCSD -World Business Council for Sustainable Development. (2000): Measuring Eco-Efficiency: A Guide to Reporting Company Performance. – WBCSD, London.
[69] WWAP - World Water Assessment Programme. (2003): The United Nations World Water Development Report: Water for People Water for life. – Earthscan, UNESCO, London, Paris.
[70] WWF - World Wide Fund for Nature. (2010): Living Planet Report 2010: Biodiversity, Biocapacity and Development. – WWF, Gland.

APPENDIX

Annex 1. *Data used for the calculation of WUEI indices by municipality of River basin Mearim, State of Maranhão*

Municipality	Total number of households	% households supplied by wells	% households supplied by a water supply system	% households with a sewage network or a septic tank	% households with sewage treatment	% households with waste collection	Average percentage of physical losses water in the network
Açailândia	27,473	20.28	76.55	95.95	43.02	86.98	60.19
Altamira do Maranhão	2,632	30.01	51.13	76.75	0	17.04	51.23
Alto Alegre do Pindaré	7,282	23.05	76.79	78.97	28.44	25.39	68.7
Amarante do Maranhão	9,267	39.05	57.45	58.25	18.31	33.19	55.02
Anajatuba	6,503	46.71	42.77	59.16	19.15	14.01	55.71
Araguanã	3,051	62.3	37.05	81.02	0	46.39	64.51
Arame	6,961	58.44	38.37	51.02	15.49	41.02	7.6
Arari	6,915	25.76	66.8	71	17.41	45.2	11
Bacabal	26,215	15.11	81.15	76.37	68.98	65.71	48.64
Bacabeira	3,660	19.2	72.54	69.8	69.55	39.93	79.04
Barra do Corda	21,597	31.76	58.53	65.45	45.11	50.71	68.34

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Municipality	**Total number of households**	**% households supplied by wells**	**% households supplied by a water supply system**	**% households with a sewage network or a septic tank**	**% households with sewage treatment**	**% households with waste collection**	**Average percentage of physical losses water in the network**
Bela Vista do Maranhão	2,979	29.31	69.39	84.69	41	22.58	0
Bernardo do Mearim	1,496	59.93	38.24	66.01	6.98	40.59	86.88
Bom Jardim	9,610	36.46	58.79	75.82	51.12	27.14	74.14
Bom Jesus das Selvas	6,220	52.74	43.19	53.33	35.8	24.1	67.86
Bom Lugar	3,514	67.71	29.05	59.51	43.09	14.89	0
Brejo de Areia	1,276	55.66	41.24	52.26	11.22	3.44	0
Buriticupu	14,968	19.03	76.75	82.54	0	27.72	86.01
Buritirana	3,778	16.82	82.77	87.59	7.12	34.29	2.86
Cajapió	2,594	73.65	25.31	67.07	8.97	0.76	82
Cajari	4,306	75.22	16.85	52.14	21.1	11.67	91.17
Capinzal do Norte	2,884	31.61	66.72	59.54	44.63	24.49	0
Centro Novo do Maranhão	3,951	79.42	10.45	66.02	22.43	8.08	0
Conceição do Lago Açú	3,336	32.04	61.52	41.04	11.05	20.96	61.91
Dom Pedro	6,208	16.8	76.59	75.44	0	69.06	62.4
Esperantinópolis	4,806	25.34	70.39	67.81	15.18	53.26	69.81
Fernando Falcão	1,883	68.16	15.53	30.61	33.13	3.88	0
Formosa da Serra Negra	3,884	60.21	34.59	38.32	18.02	2598	0
Governador Newton Bello	2,831	63.91	34.84	65.48	11.3	22.22	56.18
Grajaú	14,913	23.06	72.3	63.49	39.01	58.59	9.46
Igarapé do Meio	3,022	29.91	64.5	49.65	14.32	3.01	0
Igarapé Grande	2,853	38.84	60.73	62.1	10.37	62.2	66.68
Itaipava do Grajaú	3,293	20.75	70.41	55.46	0	24.33	0
Jenipapo dos Vieiras	3,636	61.8	31.59	51.81	0	6.16	20.73
João Lisboa	5,407	15.27	84.13	92.42	31.7	53.58	72.45
Joselândia	3,913	19.08	77.34	58.98	12.39	17.81	53.43
Lago da Pedra	11,463	77.38	18.62	84.37	5.4	73.25	62.69
Lago do Junco	2,594	86.84	11.59	50.85	12.35	17.85	79.38
Lago dos Rodrigues	2,060	69.21	28.88	74.59	0	43.54	0
Lago Verde	3,684	46.78	47.5	48.19	9.33	18.75	78.55
Lagoa Grande do Maranhão	2,407	33.09	52.36	65.03	3.47	37.85	0
Lima Campos	3,185	34.61	61.72	67.67	7.06	53.55	65.23
Marajá do Sena	1,759	90.47	7.28	20.62	2	7.45	0
Matinha	5,579	62.68	37.15	88.9	13.9	27.22	74.5
Matões do Norte	2,519	23.82	45.32	33.35	10.7	16.99	81.44
Miranda do Norte	5,196	17.73	76.85	51.83	5.44	55.57	61.74
Monção	7,470	48.44	37.4	55.25	15.76	1.62	88.59
Montes Altos	2,381	37.69	61.42	59.23	6.32	48.48	48.91
Olho D’água das Cunhãs	4,857	55.91	39.19	64.31	31.4	18.07	91.14
Olinda Nova do Maranhão	3,264	44.54	52.9	48.2	8.22	26.26	0
Paulo Ramos	4,746	66.76	27.89	65.16	5.69	38.41	89.77
Pedreiras	10,630	16.83	78.79	59.18	9.13	66.3	72.43
Pedro do Rosário	5,294	94.78	3.71	75.69	5.06	13.5	0
Penalva	7,889	57.44	38.14	71.56	14.65	8.47	69.63
Peritoró	5,593	47.32	51.55	40.94	4.31	17.66	73.42
Pindaré-Mirim	7,750	6.25	92.38	76.66	6.38	53.35	61.53
Pio XII	5,399	26.09	60.02	63.4	31.49	34.9	50
Poção de Pedras	5,309	72.49	26.76	64.2	7.22	38.07	73.61
Presidente Dutra	11,923	2.17	95.99	83.81	13.11	59.37	58.84
Santa Filomena do Maranhão	1,753	12.26	82.3	15.18	0	0.97	73.17
Santa Inês	20,264	4.52	93.9	78.75	58.77	77.33	65.09
Santa Luzia	17,466	48.62	44.21	50.36	44.36	9.67	69.53

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Municipality	Total number of households	% households supplied by wells	% households supplied by a water supply system	% households with a sewage network or a septic tank	% households with sewage treatment	% households with waste collection	Average percentage of physical losses water in the network
Santa Rita	7.887	46.53	51.45	62.85	22.47	17.37	69.37
Santo Antônio dos Lopes	3,708	44.49	51.05	52.87	32.25	38.24	73.1
São Francisco do Brejão	2,672	24.97	73.93	81.69	11.78	63.08	18.28
São João Batista	5,069	50.51	20.91	71.92	0	7.46	98.06
São João do Carú	2,615	54.19	39.85	71.96	0	24.76	0
São José dos Basílios	1,870	35.92	59.66	46.49	3.09	13.34	79.57
São Luís Gonzaga do Maranhão	5,236	54.74	34.57	47.08	17.03	13.43	96.4
São Mateus do Maranhão	9,818	41.44	55.56	78.08	12.28	60.14	67.82
São Raimundo do Doca Bezerra	1,397	26.82	46.35	59.35	2.75	42.18	0
São Roberto	1,317	39.3	60.14	46.73	0	41.37	0
São Vicente Férrer	5,131	76.29	20.65	54.49	17.03	12.06	74.34
Satubinha	2,491	33.33	65.27	53.44	21	13.95	82.49
Senador La Rocque	4,530	9.14	90.4	74.2	12.86	41.02	76.62
Sítio Novo	4,097	49.76	41.02	45.08	8.9	41.49	0
Trizidela do Vale	5,101	13.55	80.29	70.08	6.97	68.6	73.6
Tufilândia	1,373	38.99	59	50.03	33	1.34	8.46
Tuntum	10,440	16.01	77.24	74.13	11.78	60.43	73.4
Viana	12,347	58.28	31.78	78.97	13.2	34.13	14.23
Vitória do Mearim	7,547	15.59	81.56	89.32	10.77	35.83	93.92
Vitorino Freire	8,222	57.92	40.64	80.24	8.05	40.64	80.73
Zé Doca	11,887	48.96	48.48	71.96	9.56	48.76	71.39

Annex 2. *Data used for the calculation of WUEI indices by municipality of River basin Itapecuru, State of Maranhão*

Municipality	Total number of households	% households supplied by wells	% households supplied by a water supply system	% households with a sewage network or a septic tank	% households with sewage treatment	% households with waste collection	Average percentage of physical losses water in the network
Aldeias Altas	5,795	67.64	24.74	35.63	4.7	19.2	83.2
Alto Alegre do Maranhão	7,282	26.6	72.08	77.64	33.21	47.82	75.51
Arari	6,915	25.76	66.8	71	17.41	45.2	20
Axixá	2,542	57.3	38.45	53.8	12	11.02	54.63
Bacabal	26,215	15.11	81.15	76.37	68.98	65.71	48.64
Bacabeira	3,660	19.2	72.54	69.8	69.55	39.93	79.04
Buriti Bravo	5,702	28.86	61.81	51.66	0	16.46	73.34
Cantanhede	4,713	25.96	67.63	56.21	10.03	31.63	38.75
Capinzal do Norte	2,884	31.61	66.72	59.54	44.63	24.49	0
Caxias	40,172	21.18	75.41	65.12	47.21	55.41	60.28
Codó	29,594	28.89	69.8	60.89	34.76	64.78	33.05
Colinas	9,855	42.27	51.01	60.43	31.27	30.56	82.89
Coroatá	15,930	23.62	72.4	57.89	7.2	50.36	73.6
Dom Pedro	6,208	16.8	76.59	75.44	0	69.06	62.4
Fernando Falcão	1,883	68.16	15.53	30.61	33.13	3.88	0
Formosa da Serra Negra	3,884	60.21	34.59	38.32	18.02	25.98	0
Fortuna	3,926	10.46	68.69	84.55	4.34	42.11	72.69
Gonçalves Dias	4,558	34.34	61.9	52.12	12.11	37.13	66.08
Governador Archer	2,582	15.02	84.31	70.88	8.32	55.68	30.34
Governador Eugênio Barros	4,093	18.22	79.73	57.3	0	29.16	91
Governador Luiz Rocha	1,891	6.37	91.65	56.3	6	4.3	81.4

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Graça Aranha	1,696	2.24	96.99	83.11	17.34	44.47	79.56
Itapecuru Mirim	15,710	37.56	58.52	63.79	15.24	34.1	58.43
Jatobá	2,139	8.71	89.45	99.61	0	3.68	81.56
Lagoa do Mato	2,687	26.04	65.9	50.72	1.98	15	5.29
Lima Campos	3,185	34.61	61.72	67.67	7.06	53.55	65.23
Loreto	2,669	33.14	61.47	66.57	3.44	45.18	73.79
Matões	7,598	50.42	46.62	55.4	4.47	13.12	0
Matões do Norte	2,519	23.82	45.32	33.35	10.7	16.99	81.44
Mirador	4,894	8.05	86.67	74.84	11	55.02	59.97
Miranda do Norte	5,196	17.73	76.85	51.83	5.44	55.57	61.74
Paraibano	5,291	12.25	82.67	69.25	5.91	61.72	65.63
Parnarama	8,654	42.91	53.17	51.89	0	22.42	20
Passagem Franca	4,562	12.83	85.08	52.95	7.54	32.3	0
Pastos Bons	4,694	20.48	76.59	68.26	14.65	50.91	18.94
Peritoró	5,593	47.32	51.55	40.94	4.31	17.66	73.42
Pirapemas	4,157	38.08	54.68	56.76	9.3	22.84	80.92
Presidente Juscelino	2,495	70.87	23.94	43.18	4.87	8.09	83.01
Rosário	9,448	28.22	64.07	71.15	19.07	49.23	56.65
Sambaíba	1,370	55.31	40.79	48.05	12.37	3.14	88.52
Santa Rita	7,887	46.53	51.45	62.85	22.47	17.37	69.37
Santo Antônio dos Lopes	3,708	44.49	51.05	52.87	32.25	38.24	73.1
São Domingos do Azeitão	1,679	38.58	57.33	79.04	9.44	49.84	46.6
São Domingos do Maranhão	8,853	26.53	65.06	74.81	13.2	32.9	79.46
São Félix de Balsas	1,213	85.31	10.16	46.46	5.87	10.93	91
São Francisco do Maranhão	3,289	51.58	39.24	22.62	0.87	15.62	43.81
São João do Soter	4,268	46.48	50.14	37.15	1.23	1.94	15.38
São João dos Patos	7,007	12.95	84.42	77.28	7.26	56.35	65.36
São Luís Gonzaga do Maranhão	5,236	54.74	34.57	47.08	17.03	13.43	96.4
São Mateus do Maranhão	9,818	41.44	55.56	78.08	12.28	60.14	67.82
São Raimundo das Mangabeiras	4,443	32.37	61.87	47.11	14.09	50.06	49.24
Senador Alexandre Costa	2,573	91.26	6.65	62.48	13.54	23.33	0
Sucupira do Norte	2,696	24.07	62.91	63.69	0	19.08	92
Timbiras	6,549	44.28	41.02	47.73	8.51	13.11	58.76
Timon	40,477	11.76	85.55	80.01	48.93	71.1	43.98
Tuntum	10,440	16.01	77.24	74.13	11.78	60.43	73.4
Turiaçu	7,784	83.09	12.93	65.81	5.87	15.1	15.8
Vargem Grande	11,100	48.39	37.43	41.96	14	14.7	69.13

Annex 3. *Data used for the calculation of WUEI indices by municipality of River basin Parnaíba, State of Maranhão*

Municipality	Total number of households	% households supplied by wells	% households supplied by a water supply system	% households with a sewage network or a septic tank	% households with sewage treatment	% households with waste collection	Average percentage of physical losses water in the network
Água Doce do Maranhão	2,730	71.45	26.72	60.47	3.97	16.11	0
Alto Parnaíba	2,647	37.9	59.16	31.69	12.22	33.2	29.09
Anapurus	3,328	37.32	57.69	50.31	5.88	12.9	68.19
Araioses	10,241	82.89	12.47	58.98	7.39	11.49	81.31
Balsas	21,310	32.57	65.47	75.37	43.2	73.95	28.69
Barão de Grajaú	4,735	22.75	66.38	46.79	0	41.51	79.9
Barreirinhas	12,162	72.16	21.27	77.99	15.43	19.17	71.43
Benedito Leite	1,424	15.4	70.01	51.19	1.54	41.67	74.21
Brejo	7,953	51.7	40.73	26.18	0	3.47	91.67

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Municipality	Total number of households	% households supplied by wells	% households supplied by a water supply system	% households with a sewage network or a septic tank	% households with sewage treatment	% households with waste collection	Average percentage of physical losses water in the network
Buriti	6,044	66.7	22.84	26.24	13.74	8.38	80.64
Caxias	40,172	21.18	75.41	65.12	47.21	55.41	60.28
Coelho Neto	11,110	20	72.15	79.03	4.21	48.13	85.52
Duque Bacelar	2,387	53.57	45.72	39.12	11.65	12.23	73.51
Feira Nova do Maranhão	1,988	80.2	18.62	46.7	0	27.64	0
Fortaleza dos Nogueiras	2,851	48.29	44.98	49.57	9.11	46.6	53.78
Lagoa do Mato	2,687	26.04	65.9	50.72	1.98	15	5.29
Loreto	2,669	33.14	61.47	66.57	3.44	45.18	73.79
Magalhães de Almeida	4,033	16.3	77.21	66.76	18.12	41.29	74.89
Matões	7,598	50.42	46.62	55.4	4.47	13.12	0
Milagres do Maranhão	1,800	51.97	40.79	32.76	10.54	10.75	0
Nova Colinas	1,186	40.49	50.08	50.79	12.2	29.08	13
Nova Iorque	1,202	40.56	55.44	46.26	0	26.68	67.05
Parnarama	8,654	42.91	53.17	51.89	0	22.42	20
Passagem Franca	4,562	12.83	85.08	52.95	7.54	32.3	0
Pastos Bons	4,694	20.48	76.59	68.26	14.65	50.91	18.94
Riachão	5,277	46.77	51.98	55.05	16	43.46	68.3
Sambaíba	1,370	55.31	40.79	48.05	12.37	3.14	88.52
Santa Quitéria do Maranhão	6,364	57.57	41.17	45.71	6.73	26.92	71.9
Santana do Maranhão	2,500	9.85	89.71	56.26	23.4	5.94	0
São Bernardo	6,289	53.19	37.31	57.56	12.66	25.69	49.07
São Domingos do Azeitão	1,679	38.58	57.33	79.04	9.44	49.84	46.6
São Félix de Balsas	1,213	85.31	10.16	46.46	5.87	10.93	91
São Francisco do Maranhão	3,289	51.58	39.24	22.62	0.87	15.62	43.81
São João dos Patos	7,007	12.95	84.42	77.28	7.26	56.35	65.36
São Raimundo das Mangabeiras	4,443	32.37	61.87	47.11	14.09	50.06	49.24
Sucupira do Riachão	1,213	22.97	72.83	56.26	9.45	0.07	42.18
Tasso Fragoso	1,935	35.77	62.19	55.13	13.04	55.13	59.97
Timon	40,477	11.76	85.55	80.01	71.1	71.1	43.98
Tutóia	11,344	66.54	27.64	53.86	20.65	14.92	27.7

Annex 4. *Data used for the calculation of WUEI indices by municipality of River basin Tocantins, State of Maranhão*

Municipality	Total number of households	% households supplied by wells	% households supplied by a water supply system	% households with a sewage network or a septic tank	% households with sewage treatment	% households with waste collection	Average percentage of physical losses water in the network
Açailândia	27,473	20.28	76.55	95.95	43.02	86.98	60.19
Buritirana	3,778	16.82	82.77	87.59	7.12	34.29	2.86
Campestre do Maranhão	3,529	8.13	91.44	89.4	6.31	68.43	0
Carolina	6,284	24.2	68.31	55.83	16.98	53.43	51
Cidelândia	3,515	19.2	80.19	84.62	0	45.89	53.6
Davinópolis	3,326	38.85	60.6	69.83	0	27.99	75.66
Estreito	9,117	22.52	76.17	61.4	11.6	70.77	0
Feira Nova do Maranhão	1,988	80.2	18.62	46.7	0	27.64	0
Governador Edison Lobão	4,243	18.67	80.12	80.07	17.09	67.67	0
Igarapé Grande	2,853	38.84	60.73	62.1	10.37	62.2	66.68
Imperatriz	68,537	6.32	93.29	67.83	56.34	89.22	71.59
João Lisboa	5,407	15.27	84.13	92.42	31.7	53.58	72.45

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Municipality	Total number of households	% households supplied by wells	% households supplied by a water supply system	% households with a sewage network or a septic tank	% households with sewage treatment	% households with waste collection	Average percentage of physical losses water in the network
Lajeado Novo	1,825	36.12	56.77	48.79	6.74	44.77	0
Montes Altos	2,381	37.69	61.42	59.23	6.32	48.48	48.91
Porto Franco	5,638	20.23	79.71	90.11	13.21	78.49	27.26
Riachão	5,277	46.77	51.98	55.05	16	43.46	68.3
Ribamar Fiquene	1,899	39.28	59.13	73.32	12	59.28	0
São Francisco do Brejão	2,672	24.97	73.93	81.69	11.78	63.08	18.28
São João do Paraíso	2,876	37.42	58.11	56.57	14.71	42.88	9.09
São Pedro da Água Branca	3,017	24.47	72.84	87.38	9.43	57.46	81.37
São Pedro dos Crentes	1,105	45.65	54.17	55.84	7.52	50.31	0
Senador La Rocque	4,530	9.14	90.4	74.2	12.86	41.02	76.62
Serrano do Maranhão	2,734	53.35	31.98	75.84	7	1.07	0
Sítio Novo	4.097	49.76	41.02	45.08	3.65	41.49	0
Vila Nova dos Martírios	2.728	17.76	75.3	90.7	0	71.51	0

Annex 5. *Data used for the calculation of WUEI indices by municipality of River basin Munim, State of Maranhão*

Municipality	Total number of households	% households supplied by wells	% households supplied by a water supply system	% households with a sewage network or a septic tank	% households with sewage treatment	% households with waste collection	Average percentage of physical losses water in the network
Afonso Cunha	1,301	51.53	42.04	46.18	11.53	50.25	83.2
Aldeias Altas	5,795	67.64	24.74	35.63	4.7	19.2	83.2
Anapurus	3,328	37.32	57.69	50.31	5.88	12.9	68.19
Axixá	2,542	57.3	38.45	53.8	12	11.02	54.63
Belágua	1,263	40.71	41.64	58.67	0	0.12	25
Brejo	7,953	51.7	40.73	26.18	0	3.47	91.67
Buriti	6,044	66.7	22.84	26.24	13.74	8.38	80.64
Cachoeira Grande	1,763	78.87	10.75	40.11	5.67	5.96	60
Caxias	40,172	21.18	75.41	65.12	47.21	55.41	60.28
Chapadinha	17,658	45.74	40.14	71.77	16.87	30.52	52.35
Codó	29,594	28.89	69.8	60.89	34.76	64.78	33.05
Coelho Neto	11,110	20	72.15	79.03	4.21	48.13	85.52
Duque Bacelar	2,387	53.57	45.72	39.12	11.65	12.23	73.51
Icatu	5,782	81.46	14.68	51.66	17	11.6	70.58
Itapecuru Mirim	15,710	37.56	58.52	63.79	15.24	34.1	58.43
Mata Roma	3,537	19.81	76.12	65.96	12.23	14.94	71.56
Milagres do Maranhão	1,800	51.97	40.79	32.76	10.54	10.75	0
Morros	3,774	46.94	33.42	44.58	7.32	19.79	78.75
Nina Rodrigues	2,541	75	22.56	75.56	13.17	13.43	73.9
Presidente Juscelino	2,495	70.87	23.94	43.18	4.87	8.09	83.01
Presidente Vargas	2,514	85.8	6.47	31.57	0	4.2	97
Santa Quitéria do Maranhão	6,364	57.57	41.17	45.71	6.73	26.92	71.9
Santa Rita	7,887	46.53	51.45	62.85	22.47	17.37	69.37
São Benedito do Rio Preto	3,918	62.17	31.1	77.57	0	3.68	97
Timbiras	6,549	44.28	41.02	47.73	8.51	13.11	58.76
Urbano Santos	5,324	55.72	26.8	59.12	6	13.49	74.35
Vargem Grande	11,100	48.39	37.43	41.96	14	14.7	69.13

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Annex 6. *Data used for the calculation of WUEI indices by municipality of River basin Gurupi, State of Maranhão*

Municipality	Total number of households	% households supplied by wells	% households supplied by a water supply system	% households with a sewage network or a septic tank	% households with sewage treatment	% households with waste collection	Average percentage of physical losses water in the network
Açailândia	27,473	20.28	76.55	95.95	43.02	86.98	60.19
Amapá do Maranhão	1,504	19.73	75.05	90.62	10.12	22.06	0
Boa Vista do Gurupi	1,812	96.05	2.83	74.5	4.57	40.89	0
Carutapera	5,078	61.14	33.76	32.69	20.3	21.8	60.07
Centro do Guilherme	2,593	72.19	26.17	65.65	2.33	32.15	0
Centro Novo do Maranhão	3,951	79.42	10.45	66.02	22.43	8.08	0
Cidelândia	3,515	19.2	80.19	84.62	0	45.89	53.6
Itinga do Maranhão	6,601	18.93	78.14	89.5	13	68.9	49.57
João Lisboa	5,407	15.27	84.13	92.42	31.7	53.58	72.45
Junco do Maranhão	988	51.61	46.53	89.14	8.77	29.59	0
Maracaçumé	4,605	59.55	30.12	53.93	6.25	56.23	25.67
São Francisco do Brejão	2,672	24.97	73.93	81.69	11.78	63.08	18.28
São João do Carú	2,615	54.19	39.85	71.96	0	24.76	0

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