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DEVELOPING SUSTAINABILITY INDICATORS FOR WATER RESOURCES MANAGEMENT IN TIETÊ-JACARÉ BASIN, BRAZIL

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Abstract: This paper describes a tool to assist in developing water resources management, focusing on the sustainability concept, by a Basin Committee. This tool consists of a set of sustainability indicators for water resources management denominated CISGRH, which was identified by a conceptual and empirical review to meet the specific needs of the study herein - the basin committee of Tietê-Jacaré Rivers (CBH-TJ). The framework of CISGRH came about through consecutive consultation processes. In the first consultation, the priority problems were identified for the study objectives, listing some possible management sustainability indicators. These preliminary indicators were also submitted to academic specialists and technicians working in CBH-TJ for a new consultation process. After these consultation stages, the CISGRH analysis and structuring were introduced. To verify the indicators' adaptation and to compose a group as proposed by the study, these were classified according to specific sustainability principles for water resources management. The objective of the CISGRH implementation is to diagnose current conditions of water resources and its management, as well as to evaluate future conditions evidenced by tendencies and interventions undertaken by the committee.

Keywords: Water resources management; sustainable development; basin committee.

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INTRODUCTION

In Brazil, water resources management has been frequently discussed in the last years, addressing, for example:

(a) the 1934 Water Code promulgation (Ordinance No. 24.643 of July 10, 1934) with a centralized view on some sections, mainly the electric power generation section;
(b) the Brazilian Constitution of 1988, that stipulated the institution of a National System of Water Resources Management; and
(c) the Water Resources National Politics in 1997 (Federal Law No. 9.433, BRASIL, 1997), the latter responsible for instituting effective legal instruments in Brazil, as transcribed below.

In agreement with Article 5 of the Water Resources National Politics, the instruments of the Water Resources National Policies are:

(a) Water Resources Plans;
(b) Formulating water bodies in classes, according to the importance of water use;
(c) Grants rights for the use of water resources;
(d) Levy collection for the use of water resources;
(e) Compensation to municipal districts;
(f) Water Resources Information System.

The use of river basins as water resource management units is foreseen as one of the foundations for the Water Resources National Policy (Federal Law No. 9.433/1997) and also as one of the principles of the State Policy for Water Resources in São Paulo State (State Law No. 7.663, SÃO PAULO, 1991). Monitoring water resources management is also contemplated in these legal instruments.

In 2007, the Environment Ministry of Brazil (MMA), the Water National Agency – ANA, also a Brazilian agency, and the United Nations Program for the Environment - PNUMA launched the first publication of the global project of environmental evaluations, denominated GEO (Global Environment Outlook), created by PNUMA in 1995.

This publication, denominated GEO Brazil: Water Resources (MMA, 2007), helps to understand and evaluate the concepts and foundations, as well as the agency's framework, legal instruments, and other water resources management instruments, which comprise the National System of Water Resources Management (denominated SINGREH).

Some of the structural problems detailed in MMA (2007) are: disorganization in the legislation of water resources and in the juridical-administrative substratum; deep-rooted difficulties correlated to the administrative culture of the State; standstill situations related to the domain of rivers; and deviations of concepts and fundamentals that should guide the implementation of SINGREH, with a greater focus on implementing management instruments.

The document also introduces suggestions and questions to improve the water resources management process, seeking, among other aspects, to increase the participation of civil society and users of water, and to consolidate proposals that should be assessed within the scope of the basin committee.

The publication of Water Resources Conjuncture in Brazil (ANA, 2009), requested by the Water Resources National Council (denominated CNRH) through the resolution no. 58/2006, promoted a progress analysis of water resources management and the evaluation of recently implemented instruments as proposed in the Water Resources National Policies.

The conclusions of the Water Resources Conjuncture in Brazil (ANA, 2009) emphasize the need of considering the planning as a continuous process of perception, listening, interactions and concretizing the opportunities and effectuation of the plan by means of negotiation and a participative management.

It emphasizes that this is the responsibility of the Basins Committees, the monitoring actions proposed in the State's Plans and in the Basin's Plans through instruments not mentioned in the applicable legislation, but that can be annually reported, presenting data on: the quality and amount of water resources; and evaluation of the implemented programs foreseen in the aforementioned plans, as well as adjustment proposals.

Figure 1 presents the situation of the Brazilian states concerning the institution of basin committees, as shown the home page of the Basin Committee (www.cbh.gov.br) in 2010.

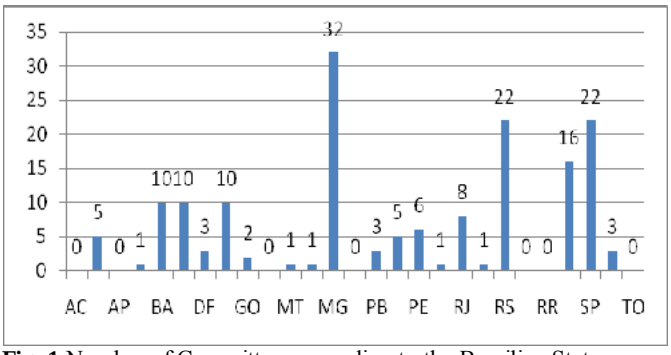

Fig. 1 Number of Committees according to the Brazilian States.
Abbreviations of Brazilian States:
AC: Acre; AL: Alagoas; AP: Amapá; AM: Amazonas; BA: Bahia; CE: Ceará; DF: Distrito Federal; ES: Espírito Santo; GO: Goiás; MA: Maranhão; MT: Mato Grosso; MS: Mato Grosso do Sul; MG: Minas Gerais; PA: Pará; PB: Paraíba; PR: Paraná; PE: Pernambuco; PI: Piauí; RJ: Rio de Janeiro; RN: Rio Grande do Norte; RS: Rio Grande do Sul; RO: Rondônia; RR: Roraima; SC: Santa Catarina; SP: São Paulo; SE: Sergipe; and TO: Tocantins.

This research also discussed concepts related to sustainability, from the apprehensive viewpoint with the exploratory use of the natural resources. The sustainability or sustainable development concept was discussed in several international conferences, which culminated in documents and definitions such as "Our Common Future" and "Agenda 21".

Besides the concepts in these documents there are sustainability indicators as monitoring tools, which can be used for water resources management, as suggested at "Agenda 21".

The indicators calculate the progress of water resources management under the optics of sustainability, observing the results of actions implemented in the basin, the water resources management unit adopted in Brazil and in the State of São Paulo, in accordance with the Federal Law no. 9.433/97 and State Law no. 7.663/91, respectively.

Tunstall and Van Bellen (2002) highlight as important indicator characteristics, the capacity to evaluate existing conditions and tendencies; the possibility to make comparisons in spacial and temporal scales, and to evaluate the conditions and tendencies in relation to goals and objectives; and the ability to supply information, conditions and tendencies. Van Bellen (2002) describes indicators as variables, in other words, a simplified representation of an attribute belonging to a system, or an abstraction of a real attribute.

For Hezri (2004), the choice of sustainability indicators should follow some criteria, as described below:

(a) robustness (scientifically accepted, measurable, sensitive to changes, the practical focus is limited to a number of themes and comparisons with the objectives, based on appropriate perspectives);
(b) democratic inclusion with all inclusive participation, including society, specialists and stakeholders; transparent, with accessible methods and explicit analysis;
(c) longevity (capacity to be repeatedly calculated, to be interactive and adaptable to change; and to have positive cost-effectiveness);
(d) relevance (institutional capacity to obtain, to maintain and to document the necessary data; assist the public and users; present simple structure; and guided by a clear view of sustainability).

Steinemann and Cavalcanti (2006) define indicators as variables that characterize drought conditions, stating: specific values of indicators for activating drought responses. The authors used this concept for Georgia's first state drought plan.

According to Brugmann (1997) cited at Ioris et al (2007), the sustainability in water resources management requires using indicators that can describe and communicate conditions (with current information or of forecast of tendencies), besides proposing the necessary actions and facilitating the participation of several stakeholders in the decision process.

Thus, to verify if the indicators proposed for a certain place are enough to calculate all aspects of sustainability to this specific case, it was proposed to verify the compliance to specific principles of sustainability within the context, as systematized by Corrêa and Teixeira (2006). In the present study the specific principles of sustainability were used for water resources management in basins, as presented below.

(a) Universal access to Water Resources;
(b) Responsible use of Water Resources and preventive management performance;
(c) Integrated planning, systematic and including Water Resources use considering: Economical, Social, Ecological, Political and Cultural aspects in Water Resources Management;
(d) Decentralized basins management;
(e) Management participation in Water Resources;
(f) International and inter-regional cooperation;
(g) Organization and supply of information;
(h) Economical value of Water Resources;
(i) Education for Water Resources management;
(j) Negotiated solution of conflicts.

OBJECTIVES

The main objective of this research was the development of a group of sustainability indicators as a tool for water resources management, in the management of the basin or unit (UGRHI).

For this main objective, the specific objectives were:

(a) Identify previous experiences or indicator proposals for water resources management;
(b) Identify priority problems in UGRHI Tietê-Jacaré in the State of São Paulo - Brazil;
(c) Identify and present guidelines to implement the proposed indicators, with emphasis on UGRHI Tietê-Jacaré.

METHODOLOGY

The process to structure CISGRH was executed in three main phases. In the first phase, the conceptual base was studied, with a discussion on sustainability aspects and water resources management found in the literature and the management model adopted in Brazil and in the State of São Paulo. In this discussion, the attributions of the Basin Committee and guidelines for water resources management were analyzed. In this phase, the definitions of the general indicators and sustainability indicators were discussed and the international and

national experiences of indicators used and proposals were presented.

With these experiences, a list of possible indicators to be used on water resources management was obtained. It was observed from this preliminary list that many indicators would not be appropriate to the needs of the empiric objective (CBH-TJ – Basin Committee of Tietê-Jacaré Rivers). Thus, the conditions of the water resources management was characterized in CBH-TJ, then came the second phase of the research, corresponding to the consultation processes.

Three consultation processes were systematized, different publics and, therefore, different focuses and approach strategies. In the first process, five consultations took place with the committee members - CBH-TJ and other participants, two of these correspond to meetings and three to public audiences were held in 2006. The three public audiences intended to gather information and suggestions to assist in the elaboration of the Basin Tietê-Jacaré River Plan.

This first consultation was to contextualize the problems regarding the water resources and its management at CBH-TJ, with the agreement of the committee members and the participants of meetings and public audiences. The consultation used a questionnaire containing a list of possible problems in the committee. They were requested to prioritize the agreements with regards to the reality observed at Tietê-Jacaré River basin or the municipal district where the respondents reside or work.

After the problems were identified and prioritized, a set of sustainability indicators were selected to monitor them. In the second consultation process, specialists and academic members, involved or not with CBH-TJ, evaluated the acceptance for each indicator proposed, and indicators that presented a level of acceptance lower than 57% were eliminated (except for some exceptions).

In the third consultation process, the results were evaluated, verifying the indicators related to the respective problems and to water resources management in CBH-TJ. This consultation was accomplished in the form of discussions among the CISGRH participants, guided by the researcher.

Finally, the correlation between the CISGRH' sustainability indicators and the specific principles of sustainability to water resources management previously defined (Corrêa & Teixeira, 2006) were identified.

STUDY AREA

The management unit named UGRHI-13 under the responsibility of CBH Tietê-Jacaré was founded in 30/12/1991. It has 37 municipal districts and a population of 1.484.078 inhabitants for 2010 (PERH, 2004-2007). The major municipal districts are: Bauru, São Carlos, Araraquara and Jaú.

In agreement with PERH (2004-2007), UGRHI-13 is located in the central area of the State of São Paulo, and it is defined by the rivers basins Tietê, Jacaré-Pepira, Jacaré-Guaçu, Jaú and Bauru. The main land uses are urban activities, industrial and agricultural, pastures and cultivation areas, such as coffee, sugar-cane, corn and citrus.

The recommendations of CETESB (2004) for this unit prioritizes domestic waste treatment, forest recovery and soil conservation to avoid erosion process. The State Basin Water Resources Report in 2000 pointed out the following main problems:

(a) high demands of irrigation water;
(b) risks of intense lowering of underground water levels in the urban areas of Bauru and Araraquara;
(c) risk of pollution of underground waters in the urban areas of Bauru and Araraquara and surrounding areas;
(d) low rates of sewer treatment;
(e) average discharge susceptibility to floods in sub-basins of the rivers Jacaré-Guaçu and Jacaré-Pepira, mainly in urbanized areas;
(f) susceptibility to erosion process in the northwest and southeast of the management unit.

RESULTS

In the first consultation stage, prioritized problems were obtained for Tietê-Jacaré basin, presented in **Table 1**, already associated to sustainability indicators. The committee members and other participants of the plenary meetings and public audiences were consulted in this process.

It was observed that the participants were from 20 municipal districts of CBH-TJ, mostly members of the municipal public administration and higher education institutions.

The main problems pointed out were: absence of riparian vegetation; occurrence of erosive process; small society participation in the decision processes; problems in the water supply system; irregular occupation in protected areas (margins, hillsides, riparian); pollution sources (wastewater and solid waste); the need for environmental education; and the lack of planning.

In the second consultation, 73 indicators were proposed to the specialists, and the result obtained was: 12 indicators were accepted by 100% of the participants; 30 indicators were accepted by 86% of the participants and 12 indicators were considered as pertinent by 71% of the interviewees.

In agreement with the answers, approximately 75% of the proposed indicators had a positive answer. The remaining, about 25%, correspond to cases in which the

indicators were considered inadequate (15%) or the interviewee did not have a technical opinion (10%).

The selection of indicators submitted to consultation was carried out using national and international bibliographical revisions, such as the indicators proposed by PERH (2004–2007), used to formulate the State Report of the basin committees in the State of São Paulo. The international bibliography studied to propose the sustainability indicators area were summarized below:

(a) Network of Cities and Towns towards Sustainability in Barcelona;
(b) Department of Australian environment and the Council of Conservation and environment of Australia and New Zealand (ANZECC) in Australia (Fairweather, 1998) and New Zealand;
(c) Environmental Protection Agency (EPA) Technical Report in the United States of America.

Once the consultation phase was concluded, a discussion was promoted based on the degree of acceptance levels by the specialists of the academic area and technical area, as well as the positive and negative points identified in the literature experiences studied. Based on this discussion, the CISGRH was proposed as presented in Table 2, related to the problem previously prioritized.

Table 1. CISGRH – Set of Sustainability Indicators for Water Resources Management

Associated Problem	Proposed Sustainability Indicator	Unit of Sustainability Indicators to be calculated
1 – Absence of riparian vegetation	Ratio between vegetation area and total basin área	%
1 – Absence of riparian vegetation	Ratio between stream length with riparian vegetation and total stream length	%
2 – Occurrence of erosive processes	Number of significant erosion process	Un.
3 – Low society participation in decision process	Number of civil society entities registered in the committee	Un.
6 – Excessive groundwater extraction	Number of wells with significant water level decrease	%
8 – Pollution or contamination in water bodies use as source to human supply	Index of water supply quality	0−100
9 – Losses in water supply system	Index of physical losses in water supply system	%
10 – Solid Waste (SW) inadequate disposition	Ratio between amount of SW without correct destination and total amount of SW	%
13 – Absence of management instruments (license and payment)	Ratio between licensed outflow and total outflow susceptible to license	%
	Ratio between paid outflow and total outflow susceptible to payment	%
16 – Occurrence of problems in storm water drainage (SWD)	Number of occurrences of significant problems in SWD	Un.
19 – Water resources Pollution and contamination	Index of water quality	0−1100
22 – Insufficient wastewater system	Ratio between population serviced by wastewater system and total population	%
23 – Groundwater pollution and contamination	Index of groundwater quality	0−1100
24 – Insufficient water surface availability	Ratio between demand and water surface availability (domestic, agricultural and industrial uses)	%
25 – Insufficient water supply system	Ratio between population serviced by water supply system and total population	%
26 – Occurrence of diseases related to wa resources (WR)	Number of occurrences of diseases related to WR	Un.
29 – Conflicts due water resource multiple use	Number of conflicts managed by basin committee	Un.

The CISGRH should be structured from existing data sources, using consistent scientific methodologies, assuring reliability and validity for the obtained results. The research then proposed a correlation of specific principles of sustainability for water resources management, previously presented, and the CISGRH (**Table 2**), to verify if the sustainability indicators proposed are sufficient to calculate all aspects of sustainability for this specific case.

Some principles, like Decentralized management by Basins, Organization and supply of information and Education for Water Resources Management could be related in all indicators. Thus, only the International and Inter-regional cooperation principle was not considered.

Table 2. Sustainability Indicators and corresponding Specific Principles.

Sustainability Indicator	Specific Principles*
Ratio between vegetation area and total basin area	b, d, g, i
Ratio between stream length with riparian vegetation and total stream length	b, d, g, i
Number of significant erosion process	c, d, g, i
Number of civil society entities registered in the committee	e, d, g, i
Number of wells with significant water level decrease	a, d, g, i
Index of water supply quality	b, d, g, i
Index of physical losses in water supply system	b, d, g, i
Ratio between amount of SW without correct destination and total amount of SW	c, d, g, i
Ratio between licensed outflow and total outflow susceptible to license	h, d, g, i
Ratio between paid outflow and total outflow susceptible to payment	h, d, g, i
Number of occurrences of significant problems in SWD	c, d, g, i
Index of water quality	b, d, g, i
Ratio between population serviced by wastewater system and total population	a, d, g, i
Index of groundwater quality	b, d, g, i
Ratio between demand and water surface availability (domestic, agricultural and industrial uses)	a, d, g, i
Ratio between population serviced by water supply system and total population	a, d, g, i
Number of occurrences of diseases related to WR	c, d, g, i
Number of conflicts managed by the basin committee	j, d, g, i

** Specific Principles:*
a) Universal access to Water Resources;
b) Responsible use of Water Resources and preventive management performance;
c) Integrated planning, systematic and including Water Resources use considering: Economical, Social, Ecological, Political and Cultural aspects in Water Resources Management;
d) Decentralized basins management;
e) Management participation in Water Resources;
f) International and inter-regional cooperation;
g) Organization and supply of information;
h) Economical value of Water Resources;
i) Education for Water Resources management;
j) Negotiated solution of conflicts.

CONCLUSIONS

A set of sustainability indicators structured in the context to be implemented enables the researcher to consider specific localities, hence facilitating information and systematization to an appropriate scale. Thus, it can be concluded that the consultation processes in this research collaborated to propose coherent indicators for the empiric object, CBH-TJ.

These consultation processes enabled, for example, the problems to be prioritized by committee members and participants interested in the subject. The analysis and selection of sustainability indicators, always associated to prioritized problems, were also the consultation objectives for specialists related to basin activities, with professional performance in academic and technical areas.

However, the participation was relatively limited, hence recommending a greater involvement and accompaniment of the entire process by the participants.

The participation of society is also recommended in the process of the continuous revision of sustainability indicators, guaranteeing that members assume the roles of controllers and stakeholders in the water resources management.

CISGRH enabled to diagnose the current situation of water resources in the Tietê-Jacaré River Basin, by the implementation and subsequent analysis of the obtained data, enabling to propose goals and actions to deficient areas or to prioritize previously proposed goals. The continuous CISGRH application could enable efficient evaluation of these actions, seeking for continuous improvement of the sustainability aspects, which are foreseen in future studies, collecting and adapting other indicators.

It is recommended that CISGRH be systematized to be implemented in CBH-TJ, and this understands the following stages: development of a methodology to obtain or calculate the indicators, specification of existing sources and information gaps, establish standards to be reached and determine a certain time to define the responsibilities, calculations and verification

trends in relation to the previously established standards.

This procedure should obtain characterization conditions of the water resources and the tendency of these conditions with regards to the standards or goals established. This evaluation of tendencies for each indicator shows to stakeholders the gaps and priority areas that should be undertaken in the next stage.

It is recommended that sustainability indicators should be annually implemented for their progress and verification, as well as an effective evaluation of the actions proposed in the previous period. Spatial comparisons (other committees or inside the Tietê-Jacaré River Basin, and municipal districts) can also be accomplished.

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