

Sustainability assessment of the Piracicaba Capivari and Jundiáí 2020-2035 River Basin Management Plan: analysis of water availability and demand indicators

Avaliação da sustentabilidade do Plano das Bacias dos rios Piracicaba, Capivari e Jundiáí 2020-2035: análise dos indicadores de disponibilidade e demandas hídricas

Cibele Roberta Sugahara¹

Orcid: <https://orcid.org/0000-0002-3481-8914>

Audrey Moretti Martins²

Orcid: <https://orcid.org/0000-0003-1883-1622>

Lorena Braga Quintella Jucá³

Orcid: <https://orcid.org/0000-0001-9313-9375>

Duarcides Ferreira Mariosa⁴

Orcid: <https://orcid.org/0000-0001-6552-9288>

Abstract

Water, a central natural resource for human life, is heterogeneously distributed on the planet. Regarding the river basins of the Piracicaba, Capivari and Jundiáí rivers, the concern with meeting the needs of the population in a permanent and sustainable way and improvements in the conditions of the water balance has given rise to actions by the regulatory Agencies. The objective of the work is to analyze the Water Resources Management Programs of the PCJ Basin Plan, specifically how the Gibson principles assessment model can be adopted in order to guarantee the sustainability of the basins. The adopted methodology is of qualitative, descriptive, and exploratory nature with documentary technical procedure. Among the results, there is the presence of actions that collaborate to identify demands by sub-basin and assist in the control of losses in water supply systems. It is concluded that Gibson's sustainability assessment model can contribute to monitor the evolution of goals and indicators regarding the spatialization of demands and the water balance.

Keywords: sustainability assessment; pcj basins; sustainability indicators; water availability; water demands.

Resumo

A água, recurso natural fundamental para a vida humana, está heterogeneamente distribuída no planeta. No âmbito das bacias hidrográficas dos rios Piracicaba, Capivari e Jundiáí, a preocupação com o atendimento das necessidades da população, de forma perene e sustentável, e melhorias das condições do balanço hídrico têm suscitado ações por parte das Agências reguladoras. O objetivo do trabalho é analisar os Programas de Gerenciamento de Recursos Hídricos do Plano de Bacias PCJ, visando apontar como o modelo de avaliação dos princípios de Gibson pode ser adotado a fim de garantir a sustentabilidade das bacias. A metodologia adotada é de natureza qualitativa, descritiva e exploratória com procedimento técnico documental. Dentre os resultados observa-se a presença de ações que colaboram para a identificação de demandas por sub-bacia e auxiliam no controle de perdas em sistemas de abastecimento de água. Conclui-se que o modelo de avaliação da sustentabilidade de Gibson pode contribuir para acompanhar a evolução das metas e indicadores quanto à espacialização das demandas e do saldo hídrico.

Palavras-chave: avaliação de sustentabilidade; bacias pcj; indicadores de sustentabilidade; disponibilidade hídrica; demandas hídricas.

¹ Pontifícia Universidade Católica de Campinas - PUC Campinas, Brasil. E-mail: cibesu@puc-campinas.edu.br

² Universidade de Araraquara – UNIARA, Brasil. E-mail: audreymartins@usp.br

³ Universidade de São Paulo, Brasil. E-mail: lorenabraga@usp.br

⁴ Pontifícia Universidade Católica de Campinas – PUC Campinas, Brasil. E-mail: duarcides@gmail.com

1 INTRODUCTION

In a web of increasingly complex relationships, in which the challenges imposed by modernity are difficult to solve, the sustainable management of resources essential to human life requires much more of human capital, “a construct composed of people's knowledge, talents and skills”, of what was once offered to us only by the accumulation of machines, equipment, constructions and labor (AMORIM et al., 2015, p. 151).

In this regard, even though in several historical moments imbalances between the environment, society and economic activities have become reality, the most recognized concept of sustainable development was presented years before, in the report *Our Common Future*, named the Report of the Brundtland Commission. This document released by the World Commission on Environment and Development - WCED (1988, p. 46) defines sustainable development as one that “meets the needs of the present without compromising the ability of future generations to meet their needs”. Nevertheless, the notions of sustainability and sustainable development acquired strength and solidity only from 1992, marking the official entry of the environment agenda in the political agendas of countries. This denotes that these concepts are relatively new and that they are consolidated as a political, social, economic, institutional, and cultural concern only after the perception of the signs of depletion of natural resources, the effects of climate change and the alteration of biotic rhythms that could lead to a collapse of civilizations (DIAMOND, 2005).

However, in spite of the growing concern with the balance between natural capital and economic progress, it is observed, as argued by Menezes, Dias, and Gomes (2010), the existence of a distance in terms of sustainable management practices supported by a social practice and responsible management culture.

The approach of managing limited, fundamental, and irreplaceable environmental resources or assets for the provision of life support services is adopted in Kates' works; Parris and Leiserowitz (2005), and Ayres, Van Den Bergh and Gowdy (1998) aligned with the concept of sustainable development used by the Brundtland Commission Report. The notion of sustainable development encompasses aspects related to global environmental challenges, the capacity to respond to the extent of environmental damage, political issues, among others. This concept, as designated by WCED, represents, according to Mebratu (1998), a conceptual political landmark. Furthermore, thinking about sustainability in different historical and geographical contexts involves the development of multi, inter and transdisciplinary studies. Achieving sustainability presents challenges, such as: integrating the “economy, environment and society” tripod, in addition to institutional issues; measure the impacts of the actions present in the future; and awareness, environmental education and social participation (SARAIVA et al., 2019; SARTORI; LATRÔNICO; CAMPOS, 2014).

In the research from which the present text was started, therefore, the concept of sustainable development is approached based on the orientation towards economic and social progress, regarding the dimension of natural capital and transversal policies for water management in watersheds.

The river basin is the fundamental element of analysis of the hydrological cycle, being described by Collischonn and Dornelles (2015) as the area of natural capture of water flows originated from precipitation, where the flows converge to a single exit point. According to Slimane (2012) and Sartori, Latrônico and Campos (2014), the conditions of sustainability on a regional and national scale are not necessarily the same, considering the mechanisms of geographical transfer. Therefore, it is important to acknowledge the territorial conformation for the application of the sustainable development concept in the context of sustainability and water security of river basins.

In addition, the corresponding indicators and index are extremely important tools for the management of water resources. Indicators simplify and quantify data in order to assess and measure water sustainability in the region, composing a diagnosis with the purpose of subsequently serving as a basis for assembling an action plan that will attack the weaknesses detected, propose improvements and elaborate solutions (HUESEMANN, 2004; SARTORI; LATRÔNICO; CAMPOS, 2014; SICHE et al., 2008). Therefore, when developing and applying sustainability indicators, they must consider the particularities of a region, otherwise, they will be subject to the inefficiency or compromise of the decision-making process (SARTORI; LATRÔNICO; CAMPOS, 2014).

On the other hand, the sustainability assessment is a dynamic, integrated process and encompasses systemic aspects, in addition to the social, environmental, and economic dimensions. Among the various options for evaluation models, the Gibson model contemplates a set of elements centered on the ecosystem that refers to social issues, such as justice and equity. The proposal based on the Gibson model allows an assessment of sustainability that considers, above all, the interconnections between issues, objectives, actions, effects, and results (GIBSON, 2006, p. 268).

In the case of the Piracicaba, Capivari and Jundiaí river basins (PCJ), the PCJ 2020-2035 Basin Plan, the result of a broad study carried out by professionals hired for this purpose, under the guidance of the Technical Chambers and public monitoring, designed several scenarios for implementation of projects with actions and goals until the year of 2035. However, in many cases, they extended it until 2050, since the study showed that some projects will need to be implemented in the longer term. Among the most immediate tasks for managers is the creation of a platform of indicators to monitor the effectiveness of planned and ongoing actions and the discussions that integrate the development and approval of a management model appropriate to the planned (AGÊNCIA DAS BACIAS PCJ, 2020; PROFILL-RHAMA PCJ CONSORTIUM, 2020b).

The sustainability approach adopted by the River Basin Committee of the Piracicaba, Capivari and Jundiaí rivers (CBH-PCJ) includes an integrated view of water resource management, as evidenced in the 2020-2035 Synthesis Report (CONSÓRCIO PROFILL-RHAMA PCJ, 2020b).

The notes on the sustainability of the PCJ Basins are based on information about the water balance. That being said, it is necessary to elucidate some hydrological concepts. As stated in the Synthesis Report, the water balance is considered to be “the balance between consumptive demands and return flows. Also considered are the transpositions and reversals in the Basins and the flow regulated by reservoirs” (CONSÓRCIO PROFILL-RHAMA PCJ, 2020b, p. 64). Collischonn and Dornelles (2015) define the consumptive use of water as the one that considerably changes the amount of water available to other users, such as the use for irrigation, for instance, while non-consumptive use does little to change the amount of water available, but that, however, can change water quality, such as the use for hydroelectric power generation. Return flows, on the other hand, correspond to the portion of flow removed for a given use, such as domestic use, that returns to the source (for example, sewage resulting from the use of water for human supply).

It is also relevant to highlight the water availability in relation to the demands of the urban supply sector, the industrial sector, the irrigated sector, and the demand for animal drinking. Water availability is adopted in the management of water resources as an estimate of the amount of water that is available for a variety of uses, namely, irrigation, supply, and discharge of effluents, based on minimum flows or drought flows (ANA, 2020). In this way, the “capacity of the environment to meet present and future needs” (MEBRATU, 1998 p. 501), regarding the supply of water in quantity and quality, must be approached based on the

supporting capacity of river basins. What is in a way supported by the Basin Plans, developed in the various agencies in charge of the management of water resources in the country (ANA, 2019), but which leaves a certain skepticism about the environmental capacity to support the population's ever-increasing consumption needs.

Given the above, the theme addressed in this text regards the possibility of assessing the sustainability of the water balance in the PCJ Basins, in order to propose reflections that contribute to meeting the water demand in different contexts, proposing to answer the following question : how the sustainability assessment model for the context of the PCJ Basins, based on the criteria and processes for sustainability assessment proposed by Robert Gibson and Selma Hassan (GIBSON; HASSAN, 2005), be used for this purpose?

Methodologically supported by documentary research, of a qualitative, descriptive, and exploratory nature, the objective of the work is to analyze the Water Resources Management Programs of the PCJ Basin Plan, aiming to show how the Gibson principles evaluation model can be adopted in order to guarantee the sustainability of the basins.

2 THEORETICAL FOUNDATION

2.1 Sustainability assessment

In view of the changes, risks, and uncertainties over the political, economic, environmental, social, cultural, and technological spheres of the global scenario, systems for measuring and evaluating sustainability were designed to support the development of public policies, programs, actions and in the decision-making process. The sustainability assessment emerges as a process that uses integration, synthesis, systemic approaches, compensation management (also known as trade-off), pluralism of tools and collaborative approaches to solve problems, based on new models or the optimization of existing models, aiming at the sustainable development (HODGE; HARDI; BELL, 1999; NESS et al., 2007).

Assuming that development is a social construction and depends on the long-term evolution of extremely complex systems, the human population and the economy incorporated into the biogeochemical flows of the planet's ecosystems, the indicators are imperfect, which is why we have as a challenge to reduce the uncertainty of this environment (MEADOWS, 1998, p. 7).

Conceptually, sustainability needs to be thought through models and processes. These are the models that can most easily guide decisions towards sustainable development. Each sustainability assessment model has attributes that allow it to assess the sustainability process itself. The sustainability assessment provides an overview with comparable data of the scenario to be examined, so that, through the scope of sustainability, such a scenario can be aligned with the concept of sustainable development, based on the management of indicators and the proposition of actions and goals.

A sustainability assessment can be carried out to assess an existing situation (*ex-post*) or before its conclusion (*ex-ante*). As a result, it provides warning signs for the elaboration of policies, plans, programs, and projects; behavioral changes; take responsibility; recognize good practices; facilitate the continuous learning process; identify knowledge gaps and act to fill them (HODGE; HARDI; BELL, 1999).

Hodge, Hardi and Bell (1999) highlight four problems or biases that are common to measurement methodologies: aggregation, weighting, units, and scale. For the analysis of the sustainability of the water balance in the PCJ Basins, aggregation refers to which variables or set of indicators will be considered; how they will be measured, that is, what measure will be given to each factor, variable, or indicator; which units will be considered in the analysis; and,

finally, the scale, related to the decision level. As the scale increases, so does the amplitude (in spatial, territory and people terms, for example).

Put in this way, and considering the limits and possibilities of each case, the tools used in the sustainability assessment offer approaches to measure and evaluate changes and progress, focusing on integration, which means, the union of environmental, social and/or economic aspects, at the strategic or project level (NESS et al., 2007). Within the context of a river sub-basin, reference is made to the work of Carvalho, Carvalho and Curi (2011) who explore this integration in the sustainability assessment of municipalities belonging to a sub-basin, using a multicriteria assessment model with indicators that involve the social, demographic, economic and environmental dimensions. This achievement made possible the creation of a sustainability index to assist in decision making. Given this, it is considered relevant to choose evaluation models that are transversal and have a systemic approach, as is the case of the Gibson model.

2.2 Gibson model

One of the tools for assessing sustainability is the Gibson model, composed by a set of criteria that breaks with the failures of conventional assessments. This is because this model considers the environmental, social, and economic dimensions of the sustainability, in an integrative manner and without causing overlaps between them, which enables greater integration of the social and ecological systems, without necessarily privileging trade-offs, that is, without mitigating its effects using any form of compensation.

The author proposes the following criteria or principles to assess sustainability (GIBSON, 2006):

- I) Integrity of the socio-ecological system.
- II) Sufficient resources for subsistence and access to opportunities.
- III) Intra-generational equity.
- IV) Intergenerational equity.
- V) Maintenance of natural resources and efficiency.
- VI) Socio-environmental civility and democratic governance.
- VII) Precaution and adaptation. and
- VIII) Integration between current and long-term situation.

The approach of Gibson's principles (2006) is supported by the interrelationship between its elements, in addition to privileging a participatory and dialogued process for its application, which considers, above all, the particularities of the context in the assessment of sustainability. The description of the attributes of each principle based on the work of Gibson (2006) is reported below.

The first principle - **Integrity of the socio-ecological system** - refers to the construction of human-ecological relationships that value the establishment and preservation of the long-term integrity of socio-biophysical systems (support capacity), in addition to caring for life support functions, irreplaceable for human well-being and the ecological level. Support capacity or load capacity implies that the resource of a given region can be used by a limited number of people, without harming the environmental quality (SILVA, 2009).

As for principle two - **Sufficiency of means of subsistence and opportunity** - the emphasis is on guaranteeing individuals and communities enough for a decent life, in addition to the opportunity for improvements that do not compromise the future of these and new generations.

Regarding principle three - **Intra-generational equity** - Gibson refers to the sufficiency of effective choices to meet the essential needs of all individuals (health, education, social recognition, esteem) and to reduce social inequalities.

Principle four - **Intergenerational equity** - refers to the choices that allow preserving or generating opportunities for new generations for a dignified, inclusive, and sustainable life.

The fifth principle - **Maintenance of natural resources and efficiency** - is to provide a broad basis for ensuring more sustainable livelihoods for all, while reducing threats to the integrity of socio-ecological systems in the long run, avoiding the generation of waste and reducing the consumption of matter and energy.

The sixth criterion - **Socio-ecological civility and democratic governance** - concerns the generation of capacity, motivation and propensity in individuals, communities, and other collective decision-making bodies to think and promote sustainability requirements, through an open and well-informed, more aware promoting a reciprocal awareness and sense of collective responsibility, in addition to more integrated practices in administrative, market, personal and usual decisions.

The seventh principle - **Precaution and adaptation** - contemplates uncertainties and avoids actions with potential risks that compromise the sustainability of the ecosystem. This criterion seeks to mitigate serious or irreversible damage to natural resources. Therefore, it is important to have adaptive and preventive management, promoting continuous learning.

Finally, the eighth principle - **Integration between current and long-term situation** - aims to apply all the principles of sustainability, simultaneously, in search of mutual benefits and multiple gains. It starts from the premise of integrating, in which the environmental issue, according to Hacking and Guthrie (2007), takes another approach, that is, it goes beyond biophysical aspects, also taking into account those related to quality of life and growth. According to Morrison-Saunders and Pope (2013), the integration of short and long terms can bring gains such as the reduction of the war between the pillars of sustainability, improvement and coherence in the actions adopted, in addition to providing help to identify “win-win” solutions between the pillars.

The assessment of sustainability with the Gibson approach seeks more than a balance between economic, social, and environmental criteria, by reinforcing collective construction, with social participation, and attaching equal importance to the eight principles in the evaluation process (MORRISON-SAUNDERS; POPE, 2013; GIBSON, 2006). The first aspect to be taken into account when applying the sustainability assessment refers to the development of guiding questions, built from a process of participation and dialogue between those involved, directly or indirectly, in the assessment. The aim is to analyze the questions and then, weaknesses and opportunities for improvement are identified, based on the analysis of the answers. Subsequently, it is possible to propose strategies and indicators that will guide the decision making of managers and other actors involved in the process (GIBSON, 2006).

3 METHODOLOGY

3.1 Research characterization

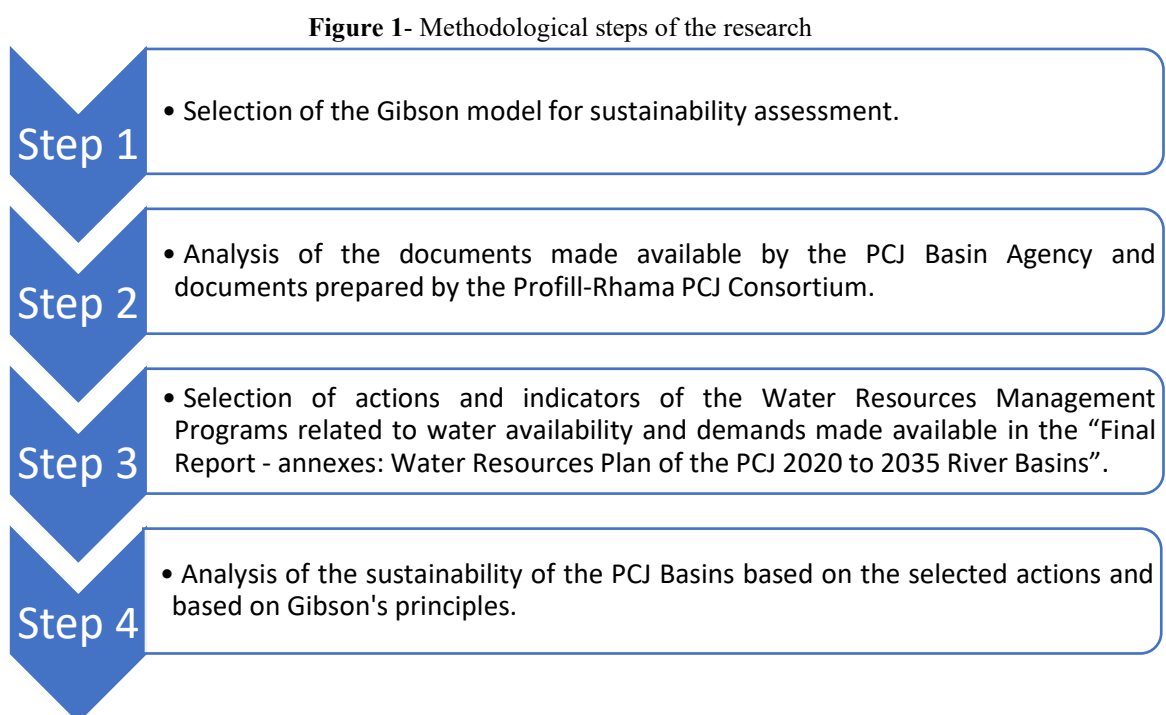
The working method of this study is characterized as qualitative, descriptive, and exploratory. Richardson (2017) highlights that studies of a descriptive nature aim to investigate the characteristics and aspects of a phenomenon. This type of work considers a specific reality, the behavior of a group or an individual, as an object of study, exploring the possibilities, nuances, and subjectivities in a qualitative approach. Therefore, the present study deals with the assessment of the sustainability of the PCJ Basins, based on the Gibson model (2006), with the cut-off indicators of water availability and water demands, which means, the water balance.

As for the technical procedure, documentary research was used, which, according to Gil (2008), refers to materials that have not received analytical treatment. As sources of data, the documents made available by the PCJ Basin Agency entitled “Building the Basin Plan as a process” and the documents prepared by the Profill-Rhama PCJ Consortium entitled “Final

Report - annexes: PCJ Watershed Water Resources Plan” were used. 2020 to 2035” and “Synthesis Report: Water Resources Plan for PCJ River Basins 2020 to 2035” (PCJ BASIN AGENCY, 2020; PROFILL-RHAMA PCJ CONSORTIUM, 2020a; PROFILL-RHAMA PCJ CONSORTIUM, 2020b).

The analysis of the results is based on the discussion about the indication of the Water Resources Management Programs - actions, goals, and indicators -, regarding the degree of priority assigned by the PCJ Basin Plan and the proposition of a relationship with the model of evaluation of the sustainability based on Gibson's principles.

The present study was developed based on four methodological steps, as shown in Figure 1.



Source: Elaborated by the authors (2020).

Step 1 focused on a literature review on the sustainability theme and sustainable development, seeking a model to support the sustainability assessment of the PCJ 2020-2035 Basin Plan, regarding the availability and demands from the indicators, their respective goals and actions. Thus, the Gibson (2006) model was chosen to indicate paths towards the sustainability of the basins in question.

In step 2, the documents made available by the PCJ Basin Agencies and those prepared by the Profill-Rhama PCJ Consortium were consulted. The selection of data from the documents had as a criterion to be related to the water balance of the PCJ Basins. The Final Report and Synthesis that deal with the Water Resources Plan of the River Basins of the Piracicaba, Capivari and Jundiá rivers from 2020 to 2035 (CONSÓRCIO PROFILL-RHAMA PCJ, 2020a; CONSÓRCIO PROFILL-RHAMA PCJ, 2020b) supported the discussion and analysis of the results.

As for step 3, it was adopted as a criterion for the selection of water resources management programs and respective actions listed in Table 1, the alignment with the Sustainable Development Objective (SDG) 6 - Ensure availability and sustainable management

of water and sanitation for all, 2030 Agenda. Universal action plan for Sustainable Development, which has as one of its goals to achieve universal and equitable access to safe, accessible, and safe drinking water for all by the year in question (UN, 2015).

The construction of the discussion on the sustainability of the PCJ Basins in the light of Gibson's principles (2006), in the fourth and last stage, had as main criterion the content accessed through the PCJ Basin Plan documents, from which it was proposed to evaluate their approach or achieve of Gibson's principles, based on the actions present in the programs listed in Chart 2.

3.2 Contextualization of the study area

The PCJ Basins cover an area of approximately 15,320 km², distributed in 76 municipalities (71 in the State of São Paulo and five in Minas Gerais), totaling an estimated population of 5.8 million inhabitants, mainly concentrated in urban areas. The Piracicaba River Basin is home to the majority of the population (66.99%), the other 16.55% are located in the Jundiaí River Basins and 16.45% in the Capivari River. It is an economically important region, with high levels of Gross Domestic Product (GDP) and Human Development Index (HDI). The economic activities carried out in the basin area include industrial, agricultural, trade and services activities, with emphasis on the continuous growth of the service sector and industry (CONSÓRCIO PROFILL-RHAMA PCJ, 2020b).

Figure 2- PCJ River Basins Map



Source: Profill-Rhama PCJ Consortium (2020b).

The River Basin Plan of the Piracicaba, Capivari and Jundiá Rivers (PBH PCJ) 2020 to 2035 was prepared by two companies, which worked together with the River Basin Committees of the Piracicaba, Capivari and Jundiá Rivers (PCJ Committees).

The construction of the plan took place in stages, the first of which focused on the revision and updating of the current PBH PCJ 2010-2020. Steps 2 and 3 were directed to the elaboration of five thematic notebooks on the following subjects: Guarantee of Water Supply; Environmental Education, Integration and Dissemination of Research and Technologies; Conservation and Use of Water in Rural Areas and Forest Recovery; Groundwater; and Framing of Surface Water Bodies. It was an open decision-making process, integrating the responsible technical team, the Technical Chambers of the PCJ Committees - through meetings and discussions between them - and society, through consultations in public hearings, before the delivery of the products. Finally, the Final Stage was approved by the PCJ Committees Plenary of the Final Report and the Synthetic Report of the PBH PCJ 2020-2035 (AGENCY OF THE PCJ BASINS, 2020).

4 PRESENTATION AND DISCUSSION OF RESULTS

This section presents the results of the study based on data obtained in the PCJ 2020-2035 Basin Plan, prepared by the Consortium Profill-Rhama PCJ (2020a). In order to verify how the studied sustainability assessment model can be applied in the PCJ Basins, in meeting the water demand in different contexts, it was first identified that the basin plan foresees actions related to the SDG 6 goal 6.1 of the 2030 Agenda (UN, 2015).

The selection of the SDG target 6.1 is justified because it deals with access to water in a universal and equitable way for all. Considering this goal, the Thematic Axes and respective programs that encompass SDG 6 were identified in the PCJ Basin Plan (Tables 1 and 2).

Among the main results, the availability of water in relation to demand is discussed; the importance of reviewing control plans and reducing losses, expanding water availability; and the existence of management plans with guidelines for the preservation and generation of opportunities and meeting the needs of current and future generations.

Chart 1- Strategic thematic axes and respective programs of the 2020-2035 PCJ Basin Plan selected

SUSTAINABLE DEVELOPMENT GOALS	CURRENT SITUATION	PCJ 2020-35 BASIN PLAN				
6. Ensure availability and sustainable management of water and sanitation for all	HYDRIC BALANCE	Guarantee of Water Supply and Drainage				
"Goal 6.1 United Nations By 2030, achieve universal and equitable access to safe and affordable drinking water for all. Brazil By 2030, achieve universal and equitable access to water for human consumption, safe and accessible for all."	The average water service index in the PCJ Basins is high, 94% for the total population and 98% for the urban population.	Thematic Axis 1: Institutional strengthening, planning and management of water resources	Program 1.1: Reduction of uncertainties in the water availability of the PCJ Basins		Program 1.2: Hydrodynamic simulation of critical stretches for water level	
		Thematic Axis 2: Special regional projects	Program 2.1: Reuse master plan for PCJ Basins	Program 2.2: Regional plans to minimize the risk of riverside floods	Program 2.3: Monitoring and support of projects under construction in the PCJ Basins	Program 2.4: Regional studies to increase water availability in the Atibaia, Jundiá and Capivari rivers
		Thematic Axis 3: Support to the municipalities of the PCJ Basins	Program 3.1: Alternatives to increase water availability in isolated systems	Program 3.2: Continuity and strengthening of actions in water and sewage	Program 3.2: Continuity and strengthening of actions in water and sewage	

Source: Elaborated by the authors, based on the PBH PCJ 2020-2035 (2020a).

The PCJ Basin Plan 2020-2035 reveals from its Programs that there are guidelines for guaranteeing water supply and drainage (Chart 1). It is noteworthy the situation of the water balance to have a high water demand response rate, when serving 94% of the total population and 98% of the urban population. These data reveal an orientation towards principle II “Sufficiency of means of subsistence and opportunity”, by indicating conditions to meet the demand for water for a decent life as recommended by this principle.

It is noticed that the PCJ 2020-2035 Basin Plan Programs oriented with a focus on guaranteeing the water supply, shown in Chart 1, are directed towards the integrity of the socioeconomic system and integration between current and long-term situations. This can be seen mainly in the actions derived from the Programs 1.1 Reduction of uncertainties in the water availability of the basins and 1.2 Hydrodynamic simulation of critical stretches for the water level.

The challenge of contemplating the management of availability indicators versus demands on the agenda of the municipalities, served by the rivers of the PCJ Basins, requires the clear definition of priority goals for guaranteeing water supply to the population. Considering the projection of growing demand from 2020 to 2035 for public supply (11%), industry (18%), irrigation (52%) and animal feed (72%), the PCJ Synthesis Report (2020) emphasizes the tendency towards an imbalance between demand and availability of water and the need to encourage municipalities to implement flow regularization projects, reduced demand, and reduced supply losses. In the long-term horizon, the proposal for the resumption of the water balance also includes the reuse of water, the transposition of rivers and the use of underground reserves with caution and through more specific studies, considering the uncertainties and risks regarding the exploitation of these water and the need for more accurate data (CONSÓRCIO PROFILL-RHAMA PCJ, 2020b).

Chart 2- Actions of the 2020-2035 PCJ Basin Plan in relation to the Gibson criteria

2020-35 BASIN PLAN					GIBSON CRITERIA METEED							
WATER RESOURCE MANAGEMENT PROGRAMS	PLANNED ACTION	GOAL	INDICATOR	PRIORITY	I	II	III	IV	V	VI	VII	VIII
Program 1.1	Maintenance and Improvement of a Rain-Flow Model for the PCJ Basins;	Availability of a template	"Execution documentation of the action"	Very high	x	x	x	x				x
Program 1.2	Improvement of the hydrodynamic simulation model of transit time and flow damping, preferably downstream of the Cantareira System;	Calibrated Model	Contracted months (current and expected)	Medium	x						x	x
	Estudo de regras de operação das PCHs para minimização do conflito com abastecimento; Study of rules of operation of the SHPs to minimize the conflict with supply;	Technical report	Contracted months (current and expected)	Very low					x		x	
	Forecast levels for energy, navigation and supply in the PCJ Situation Room.	Operational system	Contracted months (current and expected)	Very low					x			x
Program 2.1	Elaboration of the water reuse master plan for the PCJ Basins.	Elaborated plan	Contracted months (current and expected)	Medium						x	x	
Program 2.2	Development of studies of alternatives and interventions to minimize the risk of riverside flooding.	Elaborated plan by sub-basin and intervention	Contracted months (current and expected)	Medium					x	x	x	
Program 2.3	Monitoring and support to feasibility studies, engineering projects and environmental licensing of the Pedreira, Duas Pontes dams and the Pirai stream and the western stretch of the SAR;	GT definition; Periodic reports	No. of report journals regarding the expected total	Medium						x	x	x
Program 2.4	Development of a study of alternatives to increase water availability in the sub-basins of the Atibaia, Jundiá and Capivari rivers.	Elaboration of at least 01 study	Documentation of the execution of the action	Very high		x				x		x
Program 3.1	Feasibility studies to increase the regularization of flows in existing springs and new dams	Terms of reference; Study developed	Project prepared by municipality on the total number (33)	High		x	x	x			x	x
	Hydrogeological studies for sustainable groundwater exploration.	Terms of reference; Study developed	Contracted months (current and expected)	Low					x			x
Program 3.2	Loss control in water supply systems;	Achievement of the intermediate goals of the reference scenarios for planning, as described in Table 23.4 of the Basin Plan	Distribution loss index	High		x			x			x
	Diagnosis of the capacity and commitment of the municipalities;	Technical report	Contracted months (current and expected)	Low	x	x						x
	Preparation and review of Loss Control and Reduction Plans	All revised loss plans for municipalities in the PCJ Basins	Documentation of the execution of the action	High	x	x				x	x	
	Maintenance of the benchmarking project for the control of water losses in distribution systems.	At least 01 project maintenance performed	Documentation of the execution of the action	Very high	x	x						x
Program 3.3	Elaboration of a drainage and rainwater management guide;	Elaborated guide	Number of manuals prepared on the total number of priority municipalities	Medium					x	x		x
	Preparation of Master Plans for Urban Drainage and Stormwater Management	Elaboration of at least 01 Plan, considering the vulnerable sections indicated in the Basin Plan	Documentation of the execution of the action	High			x	x		x	x	

Source: Elaborated by the authors, based on the PBH PCJ 2020-2035 (2020a).

In relation to the water availability of the PCJ Basins, there is an increasing demand for water, a condition that affects the water balance, presenting a relationship with the principle of Integrity of the socio-ecological system. As pointed out in the PCJ Synthesis Report (2020), the indicators need to be analyzed considering the population variable. For the application of the first Gibson principle, it is necessary to observe the integrity of the water considering the availability versus demand, that is, the water balance. This can contribute to identifying the support capacity of the PCJ Basins to meet the demand with integrity, in the long run, without compromising the ecosystem, and putting other activities present in the context of these basins at risk.

To analyze the alignment of the integrity principle of the socio-ecological system with the actions provided in the PCJ 2020-2025 Basin Plan, the “diagnosis of the municipalities' capacity and commitments” is taken as an example, an action listed in the Plan as being of low priority. Here it is indicated that the continuous and adaptive monitoring of the support capacity of the PCJ Basins requires the internalization of this issue, at the local and regional levels of the government agendas. The action oriented to the elaboration and review of control plans and loss reduction is highlighted as a high priority in Program 3.2 (Chart 2). These examples allow us to illustrate the leverage points to accelerate changes in the water balance in order to reduce losses.

As for the second principle - Sufficiency of means of subsistence and opportunities -, the actions foreseen in the 2020-2035 Basin Plan indicate paths for the development of studies on alternatives for increasing water availability in the PCJ sub-basins, and this action is very high priority (Program 2.4). The study of operating rules for small hydroelectric plants to minimize the supply conflict (Program 1.2) has very low priority (Table 2). Although the water balance data from the PCJ Basins reveal the service provided by 94% of the population, as previously mentioned, Gibson's sustainability assessment model can contribute to indicate alternatives for expanding water availability, as advantage points in the Basin Plan 2020-2035.

Regarding the principle of intra-generational equity and inter-generational equity, guidelines for the preservation and generation of opportunities, with a focus on meeting the needs of current and future generations, are supported by the following actions highlighted in Chart 2: Master plans for urban drainage and water management rainwater and viability study to increase the regularization of flows from existing sources and new barrages. It appears that the sustainability of the basins is linked to the conditions of meeting the demands of society, without disregarding, for example, the capacity of urban drainage and water flows.

It is observed that the principle "Maintenance of natural resources and efficiency", which aims to ensure more sustainable livelihoods and reduce threats to the integrity of socio-ecological systems (GIBSON, 2006), can be applied to Program 2.2 Regional plans to minimize the risk of riparian floods within the Thematic Axis 2: Special regional projects when considering, as pointed out in the PCJ Basin Plan, the importance of regional plans in forecasting actions with a focus on managing the occurrence of extreme events, for the preservation of water. It should be noted, according to a report by the PROFILL-RHAMA PCJ Consortium (2020b, p. 44) that one way to contribute to the preservation of the water resource is the adoption of measures for risk control with the construction of “reservoirs, dikes and the increase in runoff capacity”, for this reason, “the main non-structural measures proposed are the zoning of floods, the preparation of Master Plans for Urban Drainage, the forecast of flow and the warning of floods”. This is one of the reasons why Program 2.2 was considered to be important in preserving water by combating, for example, floods in urban areas. (PROFILL-RHAMA PCJ CONSORTIUM, 2020b).

In this environment, the identification of the municipalities with the highest demands for sub-basins contributes to actions to control losses in water supply systems. An example of this is the preparation of Loss Control and Reduction Plans and their revision. In addition, the Plan provides for the preparation of Master Plans for Urban Drainage and Rainwater Management with high priority, highlighting the efficiency aspect of the Gibson principle. One of the actions of program 2.2 is the development of studies of alternatives and interventions to minimize the risks of riparian flooding - the studies are carried out by sub-basin, giving priority to the basins with municipalities that present recurrent problems of riverside flooding, and the interventions include measures structural issues such as cleaning and desilting river channels, which characterizes the maintenance of natural resources.

From the point of view of the principle of socio-ecological civility and democratic governance, which, according to Gibson (2006), is based on open decision-making and the

promotion of reciprocal awareness and collective responsibility in decision making, based on the PCJ Basin Plan, observed guidelines that encourage bodies such as municipalities and regulatory agencies and concessionaires, among other actors, in the joint development of studies to meet sustainability requirements.

In addition, there is an opportunity to make the water management process participatory, integrated, which can contribute to a society that is well informed, aware and with a sense of collectivity. In the PCJ Basin Plan, there is an emphasis on the participatory construction of studies to improve the conditions of water availability in the sub-basins of the Atibaia, Jundiá and Capivari rivers. As an example of democratic governance expressed in collective actions included in the Plan, there is the elaboration and review of Loss Control and Reduction Plans; and elaboration of Master Plans for Urban Drainage and Stormwater Management, which are aligned, for example, with Programs 2.1, 2.2 and 3.1 in Chart 2 (CONSÓRCIO PROFILL-RHAMA PCJ, 2020b).

Regarding the seventh principle "Precaution and adaptation", the data presented on water availability and demand in the PCJ Basins provide information on the quantities and needs of water for local supply. These data can help in the planning of water consumption in times of scarcity of this resource, enabling the planning of supply actions or the rationing of consumption in these periods, reducing the use in less important or less impacting activities for the functioning of the activities of the studied area, in compliance with Program 2.1. These actions can contribute to protection and adaptation in situations of insufficiency and encourage adaptive management.

Ultimately, with regard to the eighth principle, which is based on integrating the pillars of sustainability, taking into account the short and long term, it can be observed, through the Report prepared by the Profill-Rhama PCJ Consortium (2020a), emphasis on the increase in water availability (Programs 2.4 and 3.1). There was a concern to permanently assess the impact of the present activities and the conditions of the PCJ basins, in order to guarantee the conservation and recovery of water bodies and springs.

The works to regulate flows and transpositions can increase the flows available for water uses, while it is observed that the PCJ Basins are located on an axis with economic growth and consequent growth in water demands for supply, irrigation, and industrial activities in the long-term.

5 CONCLUSIONS

The study on the possibility of applying the sustainability assessment model based on Gibson's principles, in the context of the PCJ Basins, allowed observing this model's adherence with the Water Resources Management Programs, their actions, goals and indicators selected in the report by the Profill-Rhama PCJ Consortium (2020a).

Regarding the results obtained, the present study, in this section, referred to the fulfillment of the water demand by the PCJ Basins, based on the sustainability assessment criteria proposed by Gibson (2006). For this purpose, elements of the PCJ Basin Plan and its relationship with Gibson's principles were presented during the discussion.

Among the main results, the availability of water in relation to demand was discussed. The importance of reviewing control plans and reducing losses, expanding water availability, and the existence of management plans with guidelines for the preservation and generation of opportunities and meeting the needs of current and future generations.

Given this, it is suggested an integration between the pillars of sustainability, with emphasis on actions to reduce consumption. Starting, for example, from education programs and environmental policy applied to the population in each social context, contemplating the other pillars. This can contribute to a behavioral change, with the reduction of consumption, aiming at maintaining its level below the support capacity, guaranteeing access with the same quality for future generations.

Through the results, it can be said that the analysis of Gibson's principles regarding their viability for monitoring and the evolution of goals and indicators, in the context of river basin plans, is a challenge that can be overcome. The deepening of the study, as well as its replication in similar studies, can be conducted from the incorporation of detailed data not expressed in the Basin Plan. Such elements can reveal the context for the conception and design of each program and its respective actions.

In this study, the assessment of the sustainability of the PCJ river basins that considers an integrative model, as proposed based on Gibson's principles, proves to be very important as a management tool for the monitoring of water resources. Although the evaluation of the sustainability of the PCJ Basins is a present practice, complementary studies of evaluation models that discuss the dimensions of sustainability without trade-off compensation bring benefits due to its characteristic as a systemic approach.

The assessment method based on Gibson's principles also provides a foundation for identifying water resource management programs and goals that value civil society participation in decisions with collegiate bodies, as well as the interinstitutional articulation as essential factors for the collective construction of the sustainability of the PCJ Basins.

Indicating the priorities for the actions of each program in the PCJ 2020-2035 Basin Plan reveals the existence of leverage points to accelerate changes. These make it possible not only to quantify, but also to qualify the issues that involve, for example, the water balance. For this reason, it is recommended to be clear about the intended change in relation to the water balance in order to later define its adherence or not to the sustainability assessment model.

Fostering discussions about the behavior of variables that impact the water balance, such as the growth of urban and rural populations in the PCJ Basins and their sub-basins, requires planning to mobilize society agents and not just regulatory agencies, municipal, state, or federal. Such aspirations are intrinsically linked to socio-environmental civility and democratic governance. For this reason, apparently technical issues due to changes in protocols need to be foreseen when thinking about improving the process of assessing the sustainability of the PCJ Basins.

It is concluded that the sustainability of the PCJ Basins, regarding the water balance indicator, must consider the particularities of the balance dynamics in the different uses of each sub-basin. It is understood that Gibson's principles can contribute to evaluate the action proposals of the programs contained in the Basin Plan, by allowing the measurement of goals based on indicators related to the spatialization of demands and the water balance. Thus, it is possible to offer a direction to issues of integrity of the ecological system by mitigating risks of serious or irreversible damage, aligned with precaution and adaptation. In this sense, it can be seen that the support capacity of water resources to guarantee water in quality and quantity in the perspective advocated by the principle of integration between current and long-term situation is an element present in the programs of the PCJ Basin Plan and which is aligned to that recommended by goal 6.1 of the Sustainable Development Goals.

ACKNOWLEDGMENTS

This work was carried out with the support of the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) - Financing Code 001.

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ⁱ **Cibele Roberta Sugahara**

Doutora em Ciência da Informação. Universidade de São Paulo (USP).

Professora da Faculdade de Administração e Pesquisadora do Programa de Pós-Graduação em Sustentabilidade da Pontifícia Universidade Católica de Campinas - PUC Campinas.

ⁱⁱ **Audrey Moretti Martins**

Doutoranda em Engenharia Hidráulica e Saneamento na Universidade de São Paulo - EESC/USP. Professora da Universidade de Araraquara - UNIARA.

ⁱⁱⁱ **Lorena Braga Quintella Jucá**

Mestranda em Engenharia Hidráulica e Saneamento na Escola de Engenharia de São Carlos da Universidade de São Paulo (EESC/USP), São Carlos, São Paulo (SP), Brasil.

Bacharel em Engenharia Ambiental e Sanitária pela Universidade Federal de Alagoas - UFAL.

^{iv} **Duarcides Ferreira Mariosa**

Doutor em Sociologia. Professor e Pesquisador no Programa de Pós-graduação em Sustentabilidade da Pontifícia Universidade Católica de Campinas (PUC-Campinas), Campinas, São Paulo, Brasil.