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Study of Sustainability and Water Management Indicators in the Municipalities of Araraquara, Jaú and São Carlos

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RESUMO
Understanding and effectively managing the quantity and quality of water on a regional scale, especially in basin regions, is extremely important to ensure the resilience of a municipality in the face of climate change. In this context, the objective was to study sustainability and water management indicators in the municipalities of Araraquara, Jaú and São Carlos, located in the central region of São Paulo (SP). The method was based on the characterization of the study area through bibliographical research and documentary analysis of information and secondary data, of both qualitative and quantitative nature. Next, water availability (Falkenmark index), water security (Urban Water Security Index) and sustainable development (Sustainability and Cities Development Index) were analyzed. The results indicated that water availability in the basin presents some seasonal problems of water supply and quality, with adverse effects during severe droughts. Regarding water security, all municipalities had indexes classified as 'High'. The observed sustainability gave an overall “average” rating for the three municipalities studied. It was concluded that, through the analysis of the selected indicators regarding the effectiveness of their integrated application in water management in the municipalities of Araraquara, Jaú and São Carlos, this study provided a comprehensive understanding of each municipality. The individual analysis of the municipalities revealed distinct characteristics and opportunities for improvements in the water resources sector

KEYWORDS: Water Resources, Sustainability Indicators, Climate Change.

1 INTRODUCTION

Projections indicate that, in the coming years, the impacts of climate change, intensified by anthropogenic activities, will have the potential to significantly compromise various sectors that rely, either directly or indirectly, on water resources (NAITZEL, 2023). Given the seriousness of this issue, ensuring water availability has emerged as a topic of increasing relevance in international forums, with an emphasis on formulating strategic solutions and actions to promote the security of water resources in the face of climate change.

Studies indicate that progress in sustainable development is essential for achieving water security on a global scale (MISHRA *et al.*, 2021; POKHREL *et al*., 2021; RODELL *et al.*, 2018). To meet this goal, broad and sustainable approaches are required in order to address the challenges related to water security, necessitating a multifactorial integration of economic, social, and environmental dimensions (MISHRA *et al.*, 2021; RODELL *et al.*, 2018). Furthermore, the uniqueness of each geographical location highlights the need for data to measure water security, which has fostered the development of various tools with different definitions, including indicators (OCTAVIANTI; STADDON, 2021).

Awareness of water availability represents a crucial initial step in addressing the challenges associated to this resource. Such awareness is essential to enable transformations in water management practices, infrastructure development, modification of consumption patterns, and the formulation of public water management policies (RODELL *et al.*, 2018).

In the context of water availability, indicators are essential for providing a comprehensive view and enabling comparison across different levels of availability, ranging from scarcity to abundance of these resources (LAWRENCE; MEIGH; SULLIVAN, 2002).

Water availability refers to the amount of water accessible for human use without causing adverse impacts on aquatic ecosystems. This concept aims to meet the needs of the population while preserving the environmental integrity of the water system. Therefore, there are limitations both in terms of quantity and quality of water to meet various demands over time and space, with the goal of ensuring environmental sustainability (CRUZ; TUCCI, 2008).

The Falkenmark Index assesses the availability of water in a region relative to the water needs for various uses, including human consumption, agriculture and industry, among others. This index expresses the relationship between the amount of water extracted from water sources in a given area and the per capita water availability (FALKENMARK; WIDSTRAND, 1992).

The Urban Water Security Index (UWSI) incorporates the following dimensions, which are combined and considered in the formation of this index: Human, Economic, Ecosystem, and Resilience (ANA, 2023). The need for holistic approaches to address the challenges associated with water security becomes imperative, requiring the inclusion of social, economic, and environmental dimensions across various scales. These approaches can play a catalytic role in advancing sectors such as public health, energy security, climate resilience and poverty reduction, while also accelerating the achievement of the Sustainable Development Goals (SDGs) (MISHRA *et al.*, 2021).

The Urban Sustainability and Development Index (USDI) is a metric used to assess the level of sustainability and development in urban areas. This tool is essential for guiding public policies, urban planning, and initiatives aimed at sustainable development, with the goal of improving the quality of life for city residents (ICS, 2023).

By encompassing a variety of economic, social, environmental, and quality-of-life indicators, the Urban Sustainability and Development Index (USDI) provides a score that allows for relative comparison between different urban areas, helping governments, organizations, and researchers to understand the performance of cities across various aspects related to sustainable development (ICS, 2023).

Each SDG has specific targets and measurable indicators which allow for monitoring progress towards the established objectives. The 17 SDGs are designed as an integrated approach, recognizing the interdependence between social, economic, and environmental issues. They aim to ensure that development is sustainable, equitable, and inclusive, promoting global prosperity and the preservation of the planet (UNITED NATIONS BRAZIL, 2023).

Considering the intersection between water availability, the challenges associated with climate change, and the need for sustainable development, the central hypothesis of this study is that the integrated application of indicators such as the Falkenmark Index, the Urban Water Security Index (ISH-U), and the Urban Sustainability and Development Index (USDI) provides an effective approach for assessing and guiding water management in specific municipalities (Araraquara, Jaú, and São Carlos). These multifactorial indicators, by encompassing human, economic, ecosystem, and resilience dimensions, are essential for promoting sustainability, addressing climate challenges, and contributing comprehensively and conjunctionally to the achievement of the Sustainable Development Goals (SDGs).

The central question guiding this research was: how can the use of these indicators support the formulation of effective water management strategies, considering the challenges associated with climate change and the need for sustainable development?

2 OBJECTIVE

The objective was to study sustainability and water management indicators in the municipalities of Araraquara, Jaú and São Carlos, located in the central region of São Paulo (SP).

3 METHODOLOGY

3.1 General Characterization of Municipalities

The method used to characterize the study area included bibliographic research and documentary analysis of information. Sources examined included academic and scientific studies, current legislation, reports, and protocols, as proposed by Fonseca (2002) and Gil (2019). The literature review covers secondary sources, referring to materials that have been previously validated or critically analyzed, such as books and scientific articles (GIL, 2019; FONSECA, 2002). While documentary research shares similarities with bibliographic research, it is distinguished by the inclusion of a broader range of sources that are not systematically analyzed, such as newspapers, reports, official documents, and company reports, among others (FONSECA, 2002).

This research employs both qualitative and quantitative approaches. It is characterized as qualitative because its information aims to explain the reasons behind phenomena, suggesting appropriate actions and analyzing non-metric data (GERHARDT; SILVEIRA, 2009). This is combined with the analysis and interpretation of metric data from the quantitative research, which provides a realistic portrayal of the research target (FONSECA, 2002). The combined use of both approaches allows the researcher to gather more information about the study object than if each approach were used separately (FONSECA, 2002).

At this stage, the bibliographic survey focused on the following aspects, in conjunction with information about the municipalities of Araraquara (SP), Jaú (SP), and São Carlos (SP): sanitation information, demographic data, water resources, water availability, and indicators related to water resources.

The databases and sources consulted were: Google Scholar, Google Books, the Municipal Government of Araraquara, the Municipal Government of Jaú, the Municipal Government of São Carlos, the Autonomous Service of Water and Sewage of São Carlos (SAAE São Carlos), the Autonomous Department of Water and Sewage (DAAE Araraquara), the National Sanitation Information System (SNIS), and the Brazilian Institute of Geography and Statistics (IBGE).

The information obtained allowed for an understanding of the water availability and sanitation scenarios in Araraquara (SP), Jaú (SP), and São Carlos (SP). To achieve this goal, digitally available information pertaining to the municipal governments has been consulted, as well as information from state and national government agencies.

3.2 Creation of the maps used in the study

The QGIS mapping tool, version 3.28.12, was used to create the maps for this study, at a scale of 1:250,000. The shapefiles related to the municipalities studied were obtained from the IBGE platform, with data from 2022 and 2023, depending on the availability of the most updated version. Table 1 identifies the data used to prepare the maps and their respective sources and bases.

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Table 1 – Databases used to create the maps

Information/Data	Format	Source	Reference year
Municipal, state and national territorial limits	*Shapefile*	IBGE	2022
Urban Perimeters	*Shapefile*	IBGE	2022
Surface drainage of water bodies in Brazil	*Shapefile*	IBGE	2022
Limit of UGRHIs in the state of São Paulo	*Shapefile*	Sigrh	2023
Hydrography of the UGRHIs of the state of São Paulo	*Shapefile*	Sigrh	2023

Source: Elaborated by the authors, 2024.

3.3 Indicators Related to Water Resources

Considering the perspectives of demographic growth, increased water resource consumption, and the impacts of climate change, the use of indicators to monitor the water resource situation of a municipality is of utmost importance. In this context, the Falkenmark Index, the Urban Water Security Index (ISH-U), and the Urban Sustainability and Development Index (ISDC) were utilized to characterize the municipalities studied.

3.1.1 The Falkenmark Index

The Falkenmark Index is a useful tool for assessing water availability and water stress in a region, aiding in the sustainable management of water resources and decision-making related to water. The index values can vary to indicate different degrees and classes of water scarcity, as shown in Table 2.

Table 2 - Water situation classes according to the Falkenmark Index

Water Class	Description	Water avaliable (m³ / hab / ano)
Beyond the Water Barrier	Chronic and large-scale water supply problems, which become catastrophic during droughts.	< 500
Chronic Water Shortage	Chronic water supply problems that become worse during the dry season; severe droughts are frequent.	500 to 1.000
Water Stress	Frequent seasonal water supply and quality problems, accentuated by occasional droughts	1.000 to 1.666
Moderate Problems	Some seasonal water supply and quality problems, with some adverse effects during severe droughts	1.666 to 10.000
Adequate Endowment	Rare water supply and quality problems except during extreme drought conditions	> 10.000

Source: Adapted from Falkenmark and Widstrand, 1992.

3.1.2 The Urban Water Security Index (ISH-U)

The Urban Water Security Index (ISH-U), developed as an integral part of the National Water Security Plan (PNSH) by the National Water and Basic Sanitation Agency (ANA), aims to represent various aspects of water security within Brazil (ANA, 2023). This index is made available to the public by ANA through the "Atlas Águas" platform, which allows users to access information about the desired municipality via a water database.

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3.1.3 The Urban Sustainability and Development Index (ISDC)

The Urban Sustainability and Development Index (ISDC) was developed to evaluate and measure the performance of cities in terms of sustainability and development. This index ranges from 0 to 100, with higher values indicating higher levels of sustainability. The ISDC classification is based on color and numerical value, such as dark green (very high - 80 to 100), green (high - 60 to 79.99), yellow (medium - 50 to 59.99), orange (low - 40 to 49.99), and red (very low - 0 to 39.99). These categories indicate how close or far a municipality is from achieving each of the Sustainable Development Goals (SDGs). The closer the value is to red, the greater the distance from realizing the respective SDG (ICS, 2023).

Among the 17 SDGs as part of the 2030 Agenda for Sustainable Development, five of them are directly related to this study. The justification is presented in Table 3.

Table 3 - SDGs related to Water Resources studies

SDG	Justification of the SDG in this research
SDG 6 - Clean Water and Sanitation	This objective aims to ensure the availability and sustainable management of water and sanitation for all (ICS BRASIL, 2023). Therefore, this objective is the most relevant for this research.
SDG 3 - Good Health and Well-Being	Ensuring access to drinking water and adequate sanitation contributes to health promotion and disease prevention (IPCC, 2023; KYPRIANOU, LI *et al.*, 2023). Thus, this objective is related to this study because water quality is directly linked to human health.
SDG 11 - Sustainable Cities and Communities	Access to clean water and sustainable water resource management are essential for healthy and resilient communities (LI *et al.*, 2023; SITZENFREI; DIAO; BUTLER, 2022; NIKOLOPOULOS *et al.*, 2019). Thus, water quality directly affects the sustainability of cities and communities.
SDG 12 - Sustainable Consumption and Production	Water quality research can also be related to the sustainable use of natural resources, including water (SITZENFREI; DIAO; BUTLER, 2022). Reducing pollution and improving water use efficiency are key aspects of this objective.
SDG 13 - Climate Action	Changes in water quality can be influenced by climate change (IPCC, 2023; SITZENFREI; DIAO; BUTLER, 2022). Research can help understand and address the impacts of climate change on water availability and quality.
SDG 14 - Life Below Water	Preserving and renewing water quality in water bodies and oceans is crucial for aquatic life (IPCC, 2023). This objective aims to conserve and sustainably use the oceans, seas and marine resources.

SDG: Sustainable Development Goal
Source: Elaborated by the authors, 2024.

4 RESULTS

4.1 Characterization of municipalities

Water Resources Management Unit (UGRHI) 13 is located in the central region of the State of São Paulo and covers 34 municipalities, representing approximately 3.6% of the population of São Paulo (Figure 1). This unit borders UGRHI 5 (Piracicaba/Capivari/Jundiaí), UGRHI 9 (Mogi-Guaçu), UGRHI 10 (Tietê/Sorocaba), UGRHI 16 (Tietê-Batalha) and UGRHI 17 (Médio Paranapanema) (CBHTJ, 2023).

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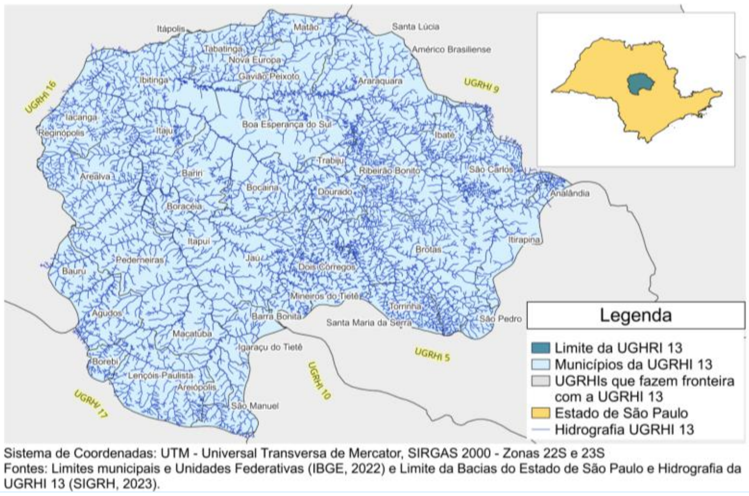
Figure 1 – Map of UGRHI 13, with division of municipalities.



Source: Elaborated by the authors, 2023.

With a drainage area covering approximately 11,779 km², this basin serves a population of 1,462,855 inhabitants and has a predominant economic base related to agroindustry in the municipalities within the region. This includes activities such as the production of sugar, alcohol, and citrus processing (SIGRH, 2023).

The basin region is delineated by its main rivers: Tietê, Jacaré-Guaçu and Jacaré-Pepira. Its main surface water catchment sources are: Lençóis, Itaquerê, Jacaré-Guaçu, Jacaré-Pepira and Jaú rivers; Potreiro stream; and Borralho stream (CBHTJ, 2023).

The case studies used for this research included the municipalities of Araraquara, Jaú and São Carlos, located in UGRHI-13 (Figure 1). These municipalities were selected, on a preliminary basis, based on the available data set, the population size of UGRHI-13 and their economic relevance in the state of São Paulo.

Araraquara, Jaú, and São Carlos stand out as some of the largest municipalities in the UHRHI-13, playing a significant role not only in agroindustry but also in other sectors, including paper, beverage, footwear, and metalworking industries, as well as technology and innovation (SIGRH, 2023). Some of the key demographic information for these municipalities is presented in Table 4.

Comentado [JP1]: Traduzir figura

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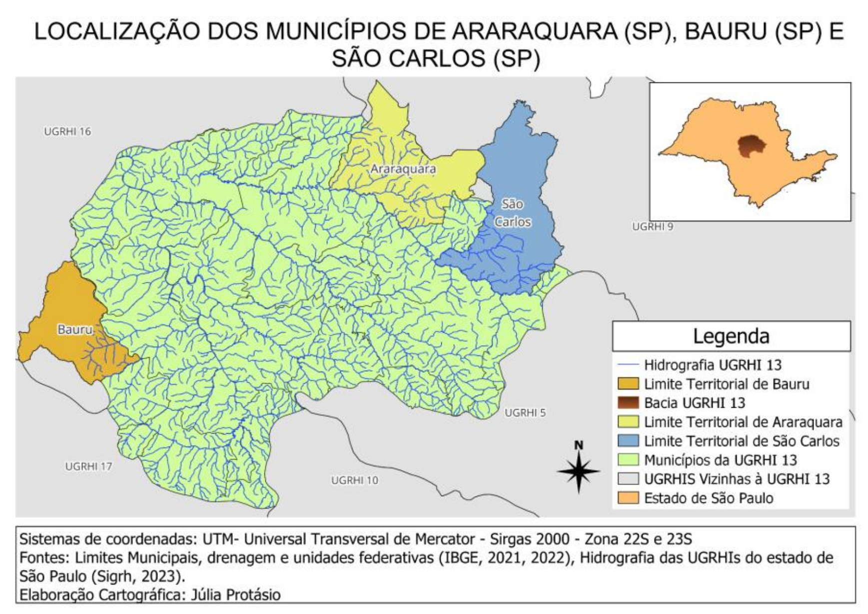
Table 4 - Demographic information for Araraquara, Jaú and São Carlos.

Demographic information			
Aspect	**Araraquara**	**Jaú**	**São Carlos**
Population in 2022 (inhabitants)	242.228	133.497	254.822
Territorial area (km²)	1.003,62	687,10	1136,94
Urbanized Area (km²)	80,17	34,99	79,87
Population Density in 2022 (inhabitants per km²)	241,35	194,29	224,14
Average Altitude (m)	664	541	856
IDHM (2010)	0,815	0,778	0,805

Source: Adapted from IBGE Cidades, 2024.

Jaú is entirely comprised within the URGHI 13, encompassing 100% of its territory, while Araraquara has 65.1% of its area within the UGRHI 13, with the remainder in the UGRHI 9. São Carlos, in turn, has 39.9% of its area in the UGRHI 13, with the remaining portion in the UGRHI 9. The geographical distribution of these municipalities can be viewed in Figure 2.

Figure 2 – Location of the municipalities of Araraquara, Jaú and São Carlos in the Jacaré-Tietê Water Resources Management Unit



Source: Elaborated by the authors, 2023.

Comentado [JP2]: Traduzir Figura

Sanitation and sewage treatment services in Araraquara are provided by DAAE Araraquara, which operates two Water Treatment Plants (WTPs): WTP Fonte and WTP Paiol. These plants perform surface water intake from three distinct sources: the Córrego das Cruzes, the Córrego Anhumas, and the Córrego Paiol. Additionally, the Department operates 25 wells for groundwater extraction from the Guarani Aquifer to meet public supply needs. The water intake

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process includes the use of pumps to convey water from surface sources to the respective treatment plants (DAAE ARARAQUARA, 2023).

In Jaú, sanitation and sewage treatment services are provided by a private company, the Águas de Jahu S.A. (CAJA). According to the local Basic Sanitation Plan, surface water is sourced from six distinct locations: the Santo Antônio and João da Velha streams, the São Joaquim stream, the Borralho stream, the Ribeirão Pouso Alegre, and the Pires stream. Additionally, nine tubular wells are maintained for groundwater extraction. The municipality hosts three Water Treatment Plants, identified as WTP I, WTP II, and WTP III (JAÚ, 2013). However, according to CAJA (2024), only WTP I and WTP II are currently in operation.

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Some of the information about the Water Supply systems of Araraquara, Jaú and São Carlos is summarized in Table 5.

Table 5 – Information on water supply systems in Araraquara, Jaú and São Carlos.

Information on Water Supply Systems			
Aspect	**Araraquara**	**Jaú**	**São Carlos**
Water service coverage (%)	96,98	96,90	100
Total length of water distribution network (km)	1519,30	952,67	1061,27
Volume of water consumed (1000 m³/year)	19579,65	9333,49	23895,23
Average per capita consumption (l/inhab./day)	229,14	183,93	261,9
Calculated loss rate (%)	37,14	33,53	41,66
Compliance with Ordinance 2.914/2011 of the Ministry of Health on water quality	Fully Serves	Fully Serves	Fully Serves

Source: Elaborated by the authors, based on SNIS (2023), IBGE (2024).

4.2 Indicator Analysis

The surface water extraction points, which are the focus of this research, are located within the Tietê-Jacaré River Basin. According to the Situation Report of the UGRHI-13 Basins, published in 2023 based on 2022 data, the water availability in this basin is 1,893.09 m³/person/year (Tietê-Jacaré River Basin Committee, 2023). The Falkenmark Index indicates that the water availability in the basin falls within the range of 1,666 to 10,000 m³/person/year, suggesting the presence of some seasonal issues with water supply and quality, with potential adverse effects during periods of severe drought (FALKENMARK; WIDSTRAND, 1992).

The research conducted on the official ICS online portal shows that the studied municipalities achieved the following results in the overall assessment of the Urban

Sustainability and Development Index, as presented in Table 6, according to the study carried out by the Institute for Sustainable Cities under the Sustainable Cities Program.

Table 6 – Sustainable City Development Index

	City Development Index		
	General Score	**Overall Rating**	**Level of Sustainable Development**
Araraquara	59,56	71st	Average
Jaú	59,33	79st	Average
São Carlos	57,78	198st	Average

Source: Adapted from ICS, 2024.

The data collection carried out for the SDGs of interest to this study, referring to the municipalities of Araraquara, Jaú and São Carlos, are presented in Table 7.

Table 7 – Performance by SDG in the object of study in 2023

	ARARAQUARA		JAÚ		SÃO CARLOS	
SGD	**Sdg**	**Performance by SDG**	**Sdg**	**Performance by SDG**	**Sdg**	**Performance by SDG**
SDG 6 - Clean Water and Sanitation	very high	84,87	very high	88,56	very high	85,21
SDG 3 - Good Health and Well-Being	high	67,7	high	63,76	high	68,44
SDG 11 - Sustainable Cities and Communities	high	70,23	high	75,97	high	70,87
SDG 12 - Sustainable Consumption and Production	high	68,27	Avera ge	55,78	Avera ge	45,24
SDG 13 - Climate Action	very high	80,93	very high	80,11	very high	82,41
SDG 14 - Life Below Water	very high	98,01	very high	92,33	very high	91,00

SDG: Sustainable Development Goal; Sdg: Sustainable Development Goal
Source: Adapted from ICS, 2024.

According to the analysis for the year 2021, the municipalities of Araraquara, Jaú, and São Carlos have their respective **ISH-U** indices classified as "**High**", indicating water security for these locations (ATLAS ÁGUAS, 2024). This result suggests that the region has a satisfactory level of water security, meaning that water availability is considered adequate to meet the demands of the population and economic sectors, addressing both qualitative and quantitative aspects of water. Additionally, it indicates a favorable situation in terms of management and sustainable use of water resources in the assessed municipalities.

The water availability indicator, as highlighted by the **Falkenmark Index** for the UGRHI 13 basin, ranges from 1,666 to 10,000 m³/capita/year, suggesting the presence of some seasonal issues in water supply and quality, which could lead to adverse effects during severe drought periods. With climate change, it is believed that the occurrence of these problems is likely to increase. In this context, the municipalities studied demonstrate a "**Very High**" performance in SDGs 6 (Clean Water and Sanitation), 13 (Climate Action), and 14 (Life Below Water), suggesting that they are potentially better prepared to handle water availability-related challenges.

The studied municipalities received an **average** ranking across all 17 SDGs in the **ISDC**. However, they still achieved prominent positions in the overall ranking compared to the 5,570 municipalities in Brazil.

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Araraquara excelled in its performance in the ISDC evaluation. Of the five SDGs directly related to this study, its classifications were higher than 'High.' For this municipality, the indices in this study showed high classifications and very positive sanitation data compared to the national average.

Araraquara and São Carlos have opportunities for improvement regarding the loss index and the average per capita consumption, which are above the national average. The index of losses of uncontaminated potable water in distribution is 37.8%, and the average per capita consumption is of 148.2 L/person/day (SNIS, 2023).

The municipality of Jaú demonstrated a positive performance in the evaluation of the Urban Sustainability and Development Index (USDI) and the five Sustainable Development Goals (SDGs) relevant to this study. According to the National Sanitation Information System (SNIS, 2023), Jaú has a potable water loss rate of 33.53%, which is below the national average, and a per capita water consumption of 183.93 L/person/day, slightly above the national average, indicating an efficient water supply management system. However, the data and indicators collected in this study highlight that Jaú has several opportunities for improvement in other areas of its water resources management. This includes the need to update the Jaú Municipal Sanitation Plan (PMSJ), which was conducted over 11 years ago, a period during which the water management landscape in the municipality has evolved.

Moreover, the scenario of water resource management in Jaú highlights a significant divergence in practices and recent changes, underscoring the urgent need to update the PMSJ for more effective strategic planning in the coming years. Additionally, in contrast to the other two municipalities analyzed, obtaining basic information and ensuring transparency about water management in Jaú revealed considerable challenges, such as a lack of clarity regarding the water extraction sites and their respective addresses.

São Carlos predominantly showed positive data regarding its Water Supply, as well as positive performance in the overall assessment of the USDI and the UWSI. However, in the individual analysis of the five SDGs, while most were rated above "High," SDG 12 (Responsible Consumption and Production) diverged with a "Low" rating. According to Rodell *et al.* (2018) and Mishra *et al.* (2021), implementing measures to promote conscious consumption and optimizing production processes to improve water use efficiency can enhance the municipality's resilience and increase water security.

5 CONCLUSION

The analysis of the selected indicators and the coherent interpretation of the results regarding the effectiveness of their integrated application in the water management of the studied municipalities brought to light the conclusion that the assessment provided a comprehensive understanding of each municipality analyzed. This understanding was achieved using sustainability and water management indicators in the municipalities of Araraquara, Jaú, and São Carlos, thus validating the effectiveness of the proposed approach.

The results obtained indicate that, despite seasonal challenges in water availability, as evidenced by the Falkenmark Index evaluation for the UGRHI 13 basin, the municipalities in question achieved a performance classified as "High" or better for SDGs 6, 13, and 14. This finding suggests potentially effective preparedness for dealing with water-related adversities, although it highlights the need to consider the impacts of climate change in the future.

The individual analysis of the municipalities revealed distinct characteristics. Araraquara demonstrated excellent performance in its water availability and management, with high ratings and notable results in the five analyzed SDGs. This study identified opportunities for improvement for this municipality related to water consumption, highlighting an average per capita consumption that is 54.61% above the national average.

São Carlos, although demonstrating positive performance, reveals a need for improvements in the sustainable approach to consumption and production, as evidenced by its "Low" rating on SDG 12. Given its status as a significant industrial and technological hub in the region, this indicator highlights the urgency for more effective measures aimed at enhancing sustainable consumption and production in the municipality. Additionally, the city presents opportunities for significant improvements in reducing the average per capita water consumption and minimizing water losses in its distribution.

The high level of water comfort evidenced by the Falkenmark, ISH-U, and ISDC indices for São Carlos and Araraquara, along with the unfavorable results related to high water consumption and wastage indicated by SNIS, may suggest the need for municipalities to adopt strategic approaches for more sustainable water use and management. It is relevant to highlight that, in addition to the region having water security, improving management, combined with environmental education measures on water resources, can prepare communities to deal with extreme climatic events, such as droughts and floods, and promote sustainable water management.

Jaú, despite showing favorable indices in some aspects, reveals opportunities for improvement, particularly in updating the PMSJ and in the transparency of water management. The score of 55.78 for SDG 12, slightly above the minimum required for a "medium" classification for this SDG, indicates a need for greater attention from the municipality towards this sector, as well as to SDG 3, which focuses on health and well-being.

Given the climatic complexity and diversity, as well as the variety of Brazilian biomes, this study also identified the need for specific indices and indicators tailored to the Brazilian context regarding water security and availability. These indicators, in conjunction with factors such as climate change and social vulnerability, are crucial for impact mitigation analysis and emergency planning.

In summary, sustainable water management must consider not only its availability but also social, economic, and environmental aspects. The use of the SDGs as a reference played an important role, and the indicators were valuable tools for translating these goals into practical actions. The differences between municipalities highlight the need for approaches adapted to local realities, emphasizing the importance of transparency, updating sanitation plans, and efficiency in water management.

Finally, sustainable water management should be a priority, integrating multifactorial approaches and considering the SDGs as guidelines. The current challenge lies in implementing specific measures to improve efficiency, transparency, and water resilience in each municipality, promoting a more sustainable and equitable future for its inhabitants. This study provides insights that can guide public policies, management practices, and local initiatives to address the challenges of water management in the context of climate change and sustainable development.

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