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Urban drainage of the large cities in the Hydrographic Basins of the Piracicaba, Capivari and Jundiaí Rivers

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ABSTRACT
The intense transformation of the landscape has been occurring dynamically in the Hydrographic Basins of the Capivari, Piracicaba and Jundiaí Rivers. This work aims to perform a survey of indicators related to the drainage of some municipalities inserted in these watersheds in order to point out the relationship of these indicators among the selected municipalities. The methodology used was a descriptive approach and case study. The indicators were selected and collected in the Stormwater section of the Historical Series of the National Sanitation Information System for the municipalities of Campinas, Indaiatuba, Jundiaí, Limeira, Piracicaba and Sumaré, years 2017 to 2020. The results suggest that the municipality of Campinas slightly outperforms the others. Moreover, the analysis of the indicators referring to urban drainage in the analyzed period revealed the need for reliable data to be later used in appropriate decision-making.

KEYWORDS: Drainage System. Landscape. Sustainability.

1 INTRODUCTION

The transformation of the landscape in the urban and cultural sphere has occurred mainly due to the increase in impermeable areas to the detriment of green spaces, which affects the environmental quality of cities, such as urban drainage.

The traditional urban drainage system is inefficient in overcoming the difficulties of water control and it is difficult to expand the network. For its function is limited to the control of water to reduce the impact of floods, focusing only on an anthropocentrist mode where structural and non-structural measures predominate, thinking about the collection and immediate removal of rainwater (CHRISTOFIDIS; ASSUMPÇÃO; KLIGERMAN, 2020).

Allied to this issue, climate change contributes to the discussion about urban water, considering the need for cities to become resilient to environmental impacts, i.e., with the ability to return to the original form and characteristics after suffering dynamic interferences. Green infrastructure can be an ally in the improvement of urban drainage, making it more efficient, assisting in the conservation of natural resources and built heritage, in the search for the direction of sustainable drainage (MEDEIROS; AFONSO, 2017).

Topography is known to correlate with soil properties and is considered a strong regulator of soil moisture and groundwater dynamics. In this regard, Nobre et al. (2011) presented a new model called HAND (Height Above the Nearest Drainage), which identifies flood-prone urban areas, levels all waterways to zero, and remaps topographic points based on relative vertical distance. According to the Center for Earth System Science (CCST) of the National Institute for Space Research (INPE), this process persists in more than 20% of the total area of urban expansion, risk areas and may be affected by natural hazards caused by rainfall until 2030, and on average 4.27% of the expansion areas may be new landslide risk areas. Therefore, studies of hydric systems and local vulnerability conditions that consider urban sprawl can help address problems caused by rainfall events that may become more intense, frequent and long-lasting if sustainable urban planning is not considered (NOBRE et al., 2011).

The environmental impacts on urban infrastructures, especially the intensity and frequency of extreme rainfall events, call for the construction of more sustainable technologies to mitigate these problems, resulting in more resilient urban areas. Thus, climate change, altering the intensity of extreme events and rainfall throughout the Earth, coupled with the emission of Greenhouse Gases, reinforce the need for adaptation in urban centers, where most of the world's population lives (MOURA; PELLEGRINO; MARTINS, 2014).

Thus, one can think of the public open spaces of cities as urban drainage enhancers when linked to green infrastructure. One should think of more permeable landscapes with the implementation of an innovative design of the urban landscape, thinking about the most effective management of water. Thus, it is important to develop water landscape projects for parks and squares including urban vegetation (PELLEGRINO, 2017).

In the case of watersheds with high urbanization it becomes important to apply Green Infrastructure for collaboration of regional ecological planning. In this line, Bonzi (2015) highlights that works focusing on the social and spatial reality of Brazilian cities that cover the theme of the city and its urban fabrics, aiming at the implementation of Green Infrastructure, collaborate for the sustainable development of these regions.

Pellegrino (2017), highlights that there are recent but scarce projects where the linear park is applied, as a form of green infrastructure, for the preservation of floodplains, such as the Ecological Park of Várzeas do Tietê, in São Paulo, aimed at the conservation of floodplain remnants upstream and downstream of urbanized areas in the São Paulo Metropolitan Region.

The need for long-term urban planning is emphasized, by allying engineering with green infrastructure, creating strategies to avoid drainage-related problems in the near future (MOURA; PELLEGRINO; MARTINS, 2014).

2 OBJECTIVE

The present work presents a survey of indicators related to drainage in the municipalities inserted in the Hydrographic Basins of the Capivari, Piracicaba and Jundiaí Rivers, in order to point out the relation of these indicators among the selected municipalities.

3 METHODOLOGY

The present study is characterized as descriptive and case study. For Gil (2017) the descriptive study aims to identify and/or describe the characteristics of a given population, phenomenon, or establish relationships between variables. The case study, on the other hand, aims to deepen the study of "one or a few research objects, in order to allow the deepening of their knowledge" (ZANELLA, 2013, p. 38).

The object investigated in this study comprises the urban drainage of the municipalities of Campinas; Indaiatuba; Jundiaí; Limeira; Piracicaba and Sumaré. The municipalities chosen were those with the largest number of inhabitants, i.e., located in tracks 4 and 5 according to the SNIS (2022), Track 4, 250,001 to 1,000,000 inhabitants and Track 5 comprises 1,000,001 to 3,000,000 inhabitants. It is noteworthy that only the municipality of Campinas is in Track 5. Moreover, the choice of these municipalities as a case study is due to the expressive socioeconomic and demographic arrangements, making them more susceptible to extreme weather events.

In complement, the Stormwater indicators in the Historical Series of the National Sanitation Information System (SNIS) for the period 2017 to 2020, related to climate change, were selected. The data collection included the following indicators (Table 1).

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Table 1 - Selected Indicators

Código SNIS	Descrição	Unidade de Medida
IN001	Share of Own Personnel in Total Personnel Allocated to Drainage and Urban Stormwater Management Services	Percent
IN009	Average Expenditure for Urban Drainage and Stormwater Management Services	R$/Units/Year
IN021	Coverage rate of public roads with networks or underground rainwater channels in the urban area	Percent
IN042	Share of urban area in relation to total area	Percent
IN049	Per capita investment in drainage and Urban Rainwater Management	R$/Inhabitants/Year
IN051	Density of stormwater catchments in the urban area	Un./km²
GE005	Total population living in the municipality (Source: IBGE)	Inhabitants

Source: The Authors (2022).

It should be noted that the availability of data related to climatic events is still relatively scarce with regard to urban drainage. This occurs due to the difficulty of continuous monitoring, compromising the availability of data at the local level, as was the case of the object of this study.

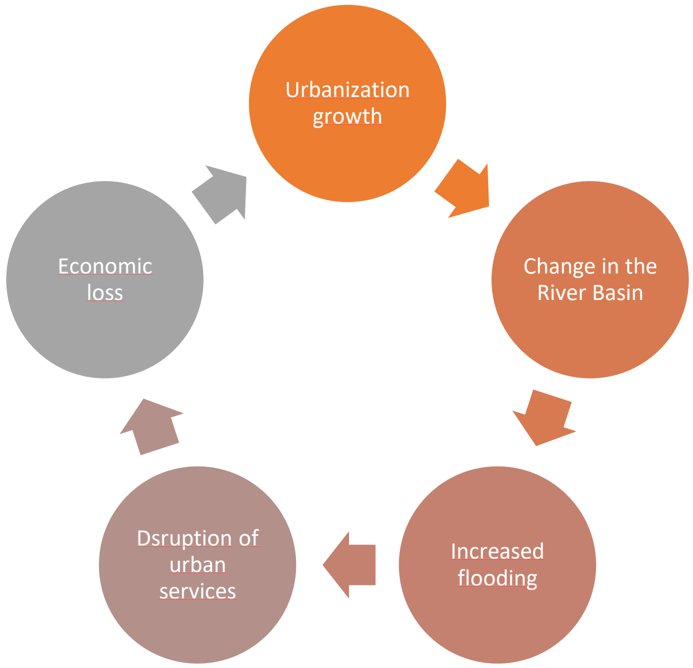
4 RESULTS

In urban space, the drainage system occupies a key position, as it is important in the urban spatial analysis and represents the interface between the built environment and natural demands.

It is noteworthy that floods are defined as the increase in river water level above normal flow, which in turn cause physical impacts on the structure of cities and mental impacts on the health of the affected population, forcing people to leave their homes to seek refuge.

As Oliveira et al. (2022) point out, resilient cities must be thought of to combat these damages. The lack of planning in the system can cause a cycle of urban degradation (Figure 1).

Figure 1 - Process of degradation of cities caused by failures of the urban drainage system



Source: Adapted from Oliveira *et al.* (2022).

According to the National Sanitation Information System, SNIS (2019), rainwater flows on the surface through watersheds and the modification of natural environments that has been occurring intensely interferes with the water cycle and the natural drainage process. Sugahara, Ferreira and Guedes (2022) point out that the Brazilian reality of social inequality increases the need for the universalization of water supply, sanitation and urban drainage services.

Law nº 14.026 of July 15, 2020 establishes that Drainage and management of urban rainwater consists of activities for the service and maintenance of operational infrastructure for the drainage of "rainwater, transport, detention or retention for the damping of flood flows, treatment and final disposal of drained rainwater, contemplating the cleaning and preventive monitoring of networks" (BRASIL, 2020, n/p).

Hydrological events such as floods, mudslides, and flooding, which generally occur in urban areas, can be mitigated by stormwater drainage and management. The National Sanitation Information System, SNIS (2019, p. 29) presents the concepts of such hydrological events:

> **Flooding:** Water accumulated in the bed of streets, depressions and flat areas in the urban perimeter resulting from heavy rainfall in cities.
> **Torrent:** Volume of water resulting from heavy rains. The water runs off the surface of the land with great speed.
> **Inundation:** Overflow of water from the normal channel of rivers, lakes and reservoirs or accumulation of water in areas not normally submerged. Caused by intense and concentrated rainfall. Among the causes are intense and concentrated rainfall, saturation of the water table, silting up of river beds and compaction and sealing of the soil, intense rainfall with high tides, dam bursting, and poor drainage of areas upstream (above) embankments.

The SNIS associated with the National Sanitation Secretary of the Ministry of Regional Development (SNS/MDR) has monitored the evaluation and evolution of Drainage since 2002. From the data provided by the municipalities, the SNIS makes available information for torrents, floods, floods, and hydrological events of specific characteristics, in order to prevent and mitigate the human, social, economic, and environmental impacts of such events (SNIS, 2019).

In order to analyze some indicators related to urban drainage, data on some municipalities of the Hydrographic Basins of the Piracicaba, Capivari and Jundiaí Rivers were collected in the SNIS. The period selected for the analysis was from 2017 to 2020. Table 2 presents this data in a summarized form.

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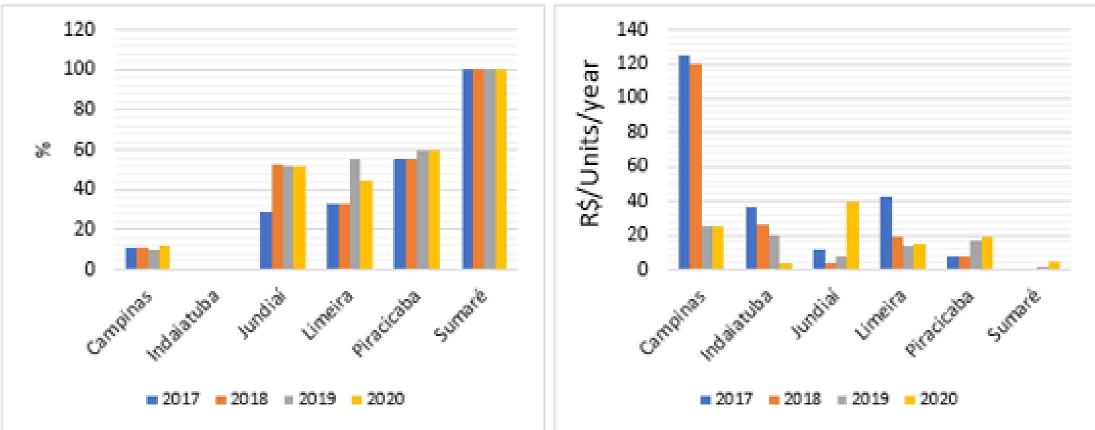
Table 2 - Indicators selected for the analysis

Município	Período	GE005	IN001	IN009	IN021	IN042	IN049	IN051
Campinas	2020	1.213.792	12,30	25,36	57,70	52,75	20,06	169
	2019	1.204.073	10,40	25,20	57,50	52,75	8,35	168
	2018	1.194.094	11,00	119,86	56,40	52,75	35,13	163
	2017	1.182.429	11,00	125,48	56,20	49,20	94,46	172
Indaiatuba	2020	256.223	-[1]	3,72	60,10	78,64	12,62	143
	2019	251.627	-	20,57	61,00	50,93	14,65	82
	2018	246.908	-	26,29	0,00	50,93	10,64	82
	2017	239.602	-	36,41	0,00	50,93	15,18	77
Jundiaí	2020	423.006	51,70	39,44	33,30	40,00	16,77	147
	2019	418.962	51,50	7,99	33,70	40,00	12,45	140
	2018	414.810	52,90	3,45	33,70	40,00	1,51	134
	2017	409.497	29,10	11,79	33,30	40,00	4,38	133
Limeira	2020	308.482	45,00	15,17	26,80	32,78	16,31	42
	2019	306.114	55,60	13,65	26,80	31,89	0,80	43
	2018	303.682	33,30	18,77	26,80	28,36	1,93	49
	2017	300.911	33,30	42,43	26,60	28,36	15,13	47
Piracicaba	2020	407.252	60,00	18,67	0,80	19,62	6,34	12
	2019	404.142	60,00	17,10	0,80	19,62	5,65	12
	2018	400.949	55,60	7,68	0,80	19,62	3,93	10
	2017	397.322	55,60	7,59	0,80	100,00	2,60	2
Sumaré	2020	286.211	100,00	4,86	36,70	50,37	0,53	34
	2019	282.441	100,00	1,78	36,90	50,37	0,00	34
	2018	278.571	100,00	0,00	36,90	50,17	0,00	34
	2017	273.007	100,00	0,00	36,90	31,93	0,00	53

Source: The Authors (2022) as of SNIS (2022).

The Figure 2 highlights, on the left, the visualization of data for indicator IN001 - Share of Own Staff in Total Staff Allocated to Urban Drainage and Stormwater Management Services; and on the right, for indicator IN009 - Average Expenditure Practiced for Urban Drainage and Stormwater Management Services.

Figure 2 - Graphical representation of indicators IN001 (left) and IN009 (right)



Source: The Authors (2022).

It can be observed that the municipality of Sumaré stood out regarding the IN001 indicator throughout the period, while Indaiatuba had an exempt position for this indicator in

[1] At the time of collection, the municipality Indaiatuba did not present data.

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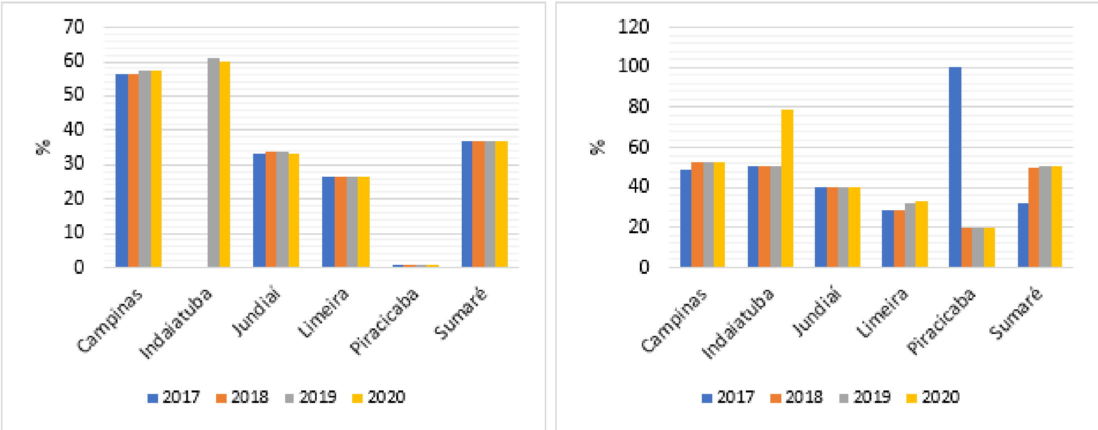
view of the fact that the municipality did not present data for the analyzed period. On the other hand, regarding the IN009 indicator, the municipality of Campinas played a relevant role especially for the years 2017 and 2018, while the municipality of Sumaré showed a small representation in the years 2019 and 2020, and in 2017 and 2018 had no participation.

Figure 3 highlights, on the left, the data visualization of the IN021 indicator - Coverage rate of public roads with underground rainwater networks or channels in the urban area; and on the right, the IN042 indicator - Share of urban area in relation to total area.

Figure 3 - Graphical representation of IN021 (left) and IN042 (right) indicators

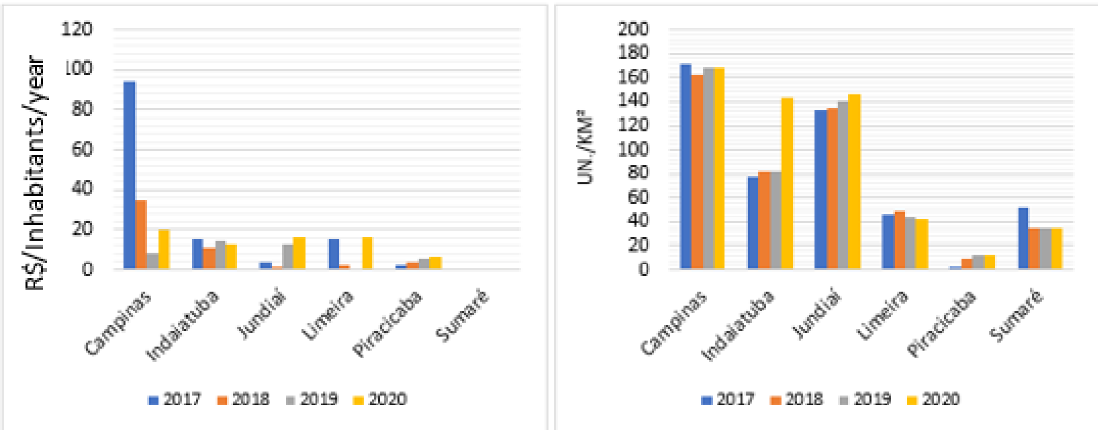


Source: The Authors (2022).

From Figure 3 it is possible to observe that the municipality of Campinas remained relatively constant with regard to the IN021 indicator, the municipality of Indaiatuba stood out only for the years 2019 and 2020 and the municipality of Piracicaba had a shy position. As for the IN042 indicator, the municipality of Indaiatuba stood out in the year 2020 and Piracicaba showed a significant reduction from 2017 to 2020.

Figure 4 highlights, on the left, the data visualization of the IN049 indicator - Investment per capita.

Figure 4 - Graphical representation of IN049 (left) and IN051 (right) indicators



Source: The Authors (2022).

In Figure 4 shows that the municipality of Campinas showed a significant reduction between 2017 and 2020 regarding the IN049 indicator, while the other municipalities had a small representation in this aspect, especially the municipality of Sumaré that remained exempt in the period 2017 to 2019, with a small participation in 2020 as can be seen in Table 1. As for the IN051 indicator, the municipality of Campinas stood out approximately constantly throughout the period.

It is noteworthy that the municipality of Campinas in 2016 recorded the largest rainfall event of high magnitude, which resulted in a flow of 186.77 m^3/s in the Atibaia River. This flow was the highest in sixteen years (PCJ COMITÊS, 2020). And subsequently, in 2017 it showed significant per capita Investment in drainage and Urban Stormwater Management, however, this interest was not maintained in the other years analyzed (Figure 4).

As occurred in the municipality of Campinas in 2016, Jundiaí also recorded rainfall of approximately 164.5 millimeters in the western region of the municipality in 2016, which caused the overflow of the Jundiaí River (COMITÊS PCJ, 2020). However, it is possible to see that the IN049 indicator showed an increasing pace of investments in other years (Figure 4).

It is worth noting that the challenges of urban drainage and stormwater management depend on management plans and monitoring of hydrological events. In developing countries, the lack of planning aligned with low investments exacerbates such problems, making management precarious. As in developed countries, Brazil lacks the use of tools that allow the mapping of flood susceptibility. This occurs especially due to the resistance of public management in the application of these tools, in addition to the lack of investments in infrastructure and technical knowledge (CAPRARIO; FINOTTI, 2019).

The aforementioned authors call attention to the diffusion among the popularization and socialization of environmental susceptibility tools. And from this, its application strengthens the technical-scientific knowledge, enabling an interchange between public entities and participatory management of municipalities. Because it deals with natural events, this does not prevent susceptible areas to go through extreme events, but it helps the way to face the problem, aiming to minimize any kind of impact (CAPRARIO; FINOTTI, 2019).

5. CONCLUSION

The study made it possible to compare the indicators related to the drainage of some large municipalities of the Hydrographic Basins of the Piracicaba, Capivari and Jundiaí Rivers. Based on the data, even though the municipality of Campinas presents the largest population contingent, relatively it stands out for most indicators when compared to the others. However, it calls attention to the fact that the municipality of Campinas presents the biggest reduction regarding the IN049 indicator - Investment per capita in drainage and Urban Rainwater Management.

The analysis of the indicators related to urban drainage in the analyzed period revealed the need for reliable data to be used for appropriate decision making. It is noteworthy the absence of data from the IN001 indicator for the municipality of Indaiatuba in the period of analysis. It was also observed quite heterogeneous values for indicators for some municipalities in the analysis period, which leaves doubt as to whether the value actually corresponds to reality or if there was a mistake in the information recorded.

Rainwater drainage and management was the last dimension to be implemented in the SNIS, and for this reason it still has weaknesses regarding the monitoring of these data. Municipalities supply information to the SNIS voluntarily. Therefore, in addition to questioning the reliability of the data, many municipalities do not even provide data for this dimension.

Furthermore, the implementation of Green Infrastructure can contribute to landscape modification, seeking permeable soils and vegetation that contribute to a landscape as water infrastructure and sustainable management.

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