CHAPTER 5

The water-energy-food nexus in local urban planning strategies: the case of São Paulo, Brazil

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1. Introduction

Cities play a pivotal role in the pursuit of sustainable development. Currently, 55% of the world's urban population lives in cities (United Nations, 2016), with an expected increase of 68% by 2050. Urban settlements demand a significant set of goods and natural resources to ensure water, energy and food supply, adequate housing, transportation and other basic services. As a side effect, this results into a substantial production of GHG emissions, solid waste and pollutants. Moreover, modern cities were planned and designed as if urban life were disconnected from rural life and natural environment (Barthel & Isendahl, 2013). On the other hand, empirical studies highlight that urban areas can also play an important role in addressing the environmental and climate crises (Bulkeley, 2010; Seto et al., 2010), promoting transformative urban processes with sustainable measures that potentially deliver multiple economic, social and environmental benefits (Broto, 2017; Romero-Lankao et al., 2018).

The Water-Energy-Food nexus (WEF nexus) approach emerged in the last decade as an attempt to address the complex interrelationships between water, energy and food resources with the aim of building synergies between sectors and minimizing trade-offs to ensure more efficient, equitable and fair use of natural resources (Bazilian et al., 2011; Hoff, 2011). Research often sees growing urbanization as a central issue for the security of the nexus elements considering its impacts on land use, population distribution, urban infrastructure and resource flows (Artioli et al., 2017). As a consequence, the urban dimension of the nexus has gained increasing attention, although scholars endorse the need for a more critical perspective on the nexus applicability to address major challenges in urban environments (e.g., Williams et al., 2014; Cairns & Krzywoszynska, 2016; Dalla Fontana et al., 2020).

While there is a growing recognition that the close interconnection between water, energy, food and materials supply systems in the urban context asks for integrate planning and resource management, and provide an opportunity for a "policy nexus" (Daher & Mohtar, 2015; Lehmann, 2018), the nexus approach has not been commonly adopted in urban planning (van Gevelt, 2020; Urbinatti et al., 2020). Hoff and Kasparek (2016) argue that one way to facilitate the inclusion of the nexus perspective in decision-making processes would be to broaden and give visibility to public policy analyses that enable more integrated actions. While there are examples of studies in this field focused on supranational policies (e.g., Venghaus & Hake, 2018;

Venghaus et al., 2019) and national policies analysis (e.g., Paim et al., 2020), there is still an underrepresentation of studies that conduct similar analysis at the local level (Wahl et al., 2021).

The nexus approach can make a contribution to urban sustainable development as long as policy-makers pay attention to critical aspects, including: (i) adopting a coherent macro development pathway planning; (ii) optimizing infrastructure spatial planning; (iii) and supporting other auxiliary interventions (e.g., financial incentives, promote awareness) (Fan et al., 2019). Concerning the first aspect, master plans are understood as overarching strategic plans, and communicative policy acts that provide a vision of how a city wants to develop and be in the future (Norton, 2008). Because they may address different flows in the city such as water, energy and food, but also waste, traffic, green infrastructure and other materials, master plans are critical instruments to determine areas that need integrative planning, identifying possible synergies and conflicts (Zengerling, 2019).

Starting from the hypothesis that the nexus could be integrated into existing local strategic plans and policies rather than applied as a dedicated approach or a new policy domain, we provide an insight into if and how nexus elements and principles are (or not) instrumental in urban strategic planning in the city of São Paulo, Brazil. We thereby aim at contributing to the question of how to link WEF nexus and local policy, municipal strategies and plans (Wahl et al., 2021; Hoff & Kasparek, 2016). From this perspective, this chapter aims to contribute to this direction by proposing an analysis of the 2014 Strategic Master Plan of São Paulo (SMP – São Paulo, 2014), through the lenses of the WEF nexus. This can therefore help identifying gaps and space for improvements to optimize policies and adapt existing government arrangements, considering local environmental, historical and regulatory aspects (Hoff & Kasparek, 2016; Venghaus & Hake, 2018; Weitz et al., 2017).

2. The case of São Paulo

2.1. Main features to understand the local context

Like other megacities in the Global South, São Paulo struggles with socioeconomic inequalities, lack of modernization of infrastructure networks and logistics, environmental and urban problems (Di Giulio et al., 2017; 2018). São Paulo has the largest national GDP (~ US$ 142 billion) and the

largest urban population in Brazil, close to 12 million people (SEADE, 2018). However, 15% of its population lives in precarious settlements, with about 25,000 homeless residents (SMADS, 2019), revealing the extreme inequalities that exist in its territory.

While this global city can be a source of innovation and lead transformative processes (Di Giulio et al., 2018), recent analyses indicate a set of challenges that still seriously affect communities' quality of life, such as river and soil pollution, lack of sanitation, changes in microclimates (e.g., urban heat islands), loss of biodiversity, impacts on precipitation and water production and storage capacity by reservoirs, among others (Jacobi, 2006; Bonduki, 2011; Franco et al., 2015). These challenges are closely related to the inability of local governments to develop public policies and implement urgent actions to sustain the city's growth process and to carry out the most appropriate territorial planning (Di Giulio & Vasconcellos, 2014; D'Almeida, 2016).

2.2. Urban policy and the Strategic Master Plan of São Paulo

The Strategic Master Plan of São Paulo approved in 2014 by the Law 16.050 (São Paulo, 2014), which revises the previous plan of 2002, is based on the 1988' Federal Constitution and on the 2001' Federal Law 10.257 (Brazil, 2001), known as the City Statute, which established the parameters for the elaboration and implementation of the national urban policy. The master plan is the main instrument for the deployment of urban development and expansion policy in the City Statute, and it is mandatory for all municipalities with more than 20 thousand inhabitants, for cities located in metropolitan regions or urban agglomerations, and other specific cases with fewer inhabitants (Brazil, 2001). The master plan aims to identify urban problems of the municipalities and propose solutions, with a wide set of guidelines, strategies and measures, through a public participation process (Franco et al., 2015; Piérola & Almeida, 2016; Andrade, 2017).

The SMP was designed to integrate urban development and environmental protection with an ecosystem approach, seeking to enhance the areas that provide environmental services (Sepe & Pereira, 2015). Other guiding components include the right to the city, the right to an ecologically balanced environment, sustainable and balanced urban development, the social function of the city and rural property, social and territorial inclusion and equity (Andrade, 2017).

3. Methodology

In concordance with Norton's arguments (Norton, 2008), who demonstrated that content analysis (Bardin, 1977) is a suitable tool for assessing the symbolic content of a local master plan, data used to inform this chapter is based on an objective, systematic, and critical description and analysis of the content of the SMP with its 393 articles, through the lenses of the WEF nexus.

Thorough a systematic reading of the document, we identified for each article whether and how the elements of the nexus were addressed. By adopting an inductive approach, the articles of the SMP were submitted to multiple rounds of analysis and iterative coding. In the first round, the articles were coded according to the categories: water, energy and food. Articles that did not fit these categories were no longer considered. The coding was then refined in subsequent rounds, leading to the identification of specific categories. Information found for each element was separated into specific tables in Microsoft Excel, which allowed us to identify how many articles were mentioned for each of the categories and organize the content of the identified articles in a systematic manner. A critical interpretation of the results also enabled us identify venues of integration and a common ground between water, energy and food.

During the analysis, it was possible to understand that water, energy and food are not always addressed explicitly, but also implicitly. For example, articles that address soil-sealing issues were considered in the analysis for the indirect effects of this process on the hydrological cycle. Therefore, we consider an article to explicitly treat water, energy and food when these are clearly stated and spelled out and there is no room for confusion. On the other hand, we also consider an article to implicitly treat water, energy and food when they are not clearly stated and spelled out, but the content of the article implies possible effects on the three elements.

4. Results

4.1. Water, energy and food in the 2014 Strategic Master Plan of São Paulo

In general terms, our results highlight how water, energy and food are critical elements in the strategic planning of the city of São Paulo. After a

SECTOR	CATEGORY	DESCRIPTION
Water	Basic Sabitation	The focus here is on the production of water for the city, the supply system, the wastewater collection, treatment system and the drainage infrastructure. The issue of water is explicitly addressed, and the main concern is the improvement and universalization of environmental sanitation.
	Protection	Water is considered a resource to be protected through measures of protection, conservation, recovery and preservation of nature. The issue of water pollution is a directly addressed issue. Soil contamination is also addressed, considering its indirect effects on water sources.
	Use of the resource	This category includes articles that consider the need to improve the use of water by the population, promoting rational use and reuse.
	Transport	Networks of rivers, dams, lakes and canals are considered for their potential to function as a transport infrastructure (e.g., waterways).
	Leisure	Water bodies and surroundings are considered as a space for leisure.
	Extreme Events	The SMP places the need for actions to protect the population, the infrastructure system and the territory from extreme events such as floods, soil erosion and slides that result from the combination of extreme weather events and social factors related to the occupation of the territory. Issues such as soil sealing, poor drainage systems and small plant cover can also be cited for their impacts.
Energy	Mobility	Urban mobility is a central topic in the SMP and it implicitly addresses the energy issue, for example in terms of: promoting the use of bicycles; control of less efficient modes of transportation; orienting real estate production to areas located along public transportation axes etc. Although these actions are more explicitly aimed at reducing air pollution and improving urban mobility, we argue that their implementation would also affect the city's energy consumption.
	Infraestructure	This category covers issues such as the installation, maintenance and extension of electric power, gas and public lighting networks.
	Use of the resource	Issues such as rational energy use and energy efficiency are here considered.
	Production	This category covers articles that encourage the use of cogeneration systems, alternative energy sources and renewable energies, and identify sites for the installation of energy utilities.
	Climate and Atmosphere	Although we acknowledge that emissions are not only a product of the energy sector, we have identified an implicit relationship between the energy issue and some topics addressed in the SMP, such as the reduction of air pollution emitted by transport systems and the mitigation of greenhouse gas emissions.
Food	Production	This category includes articles that address the rural areas of the municipality for their agricultural characteristics and their importance for food production. Measures to maintain and strengthen local food production are also here considered.
	Protection	Articles that consider areas characterized by agricultural activities for their role in the protection and preservation of vegetation and water springs are considered in this category.
	Organic Agriculture and Agroecology	Articles are focused on the production of healthy food in sustainable ways through the promotion of organic agriculture and the agro-ecological transition.
	Urban and Peri-urban agriculture	Articles tackle the need to support and encourage peri-urban and urban vegetable gardening.
	Food Security	It encompasses articles that deal with guaranteeing food security and social right to food.
	Land Regularization	The category covers the regularization of agricultural properties, which guarantees greater protection for agricultural producers, food production and the environmental compatibility of agricultural activities.
	Agritourism	It considers agricultural production activities for their potential to tourism.
	Organic Waste	Articles that address organic waste management are considered to treat implicitly the food (waste) issue.

Table 1. Description of how water, energy and food are treated in the 2014 São Paulo SMP.
Source. Elaborated by the authors.

first round of analysis, we identified 125 articles related to water, 50 articles related to energy and 47 articles related to food. However, water, energy and food are not treated uniformly, and different perspectives can be identified for each of the elements in further refined rounds of analysis. The categories in Table 1 summarize the different perspectives on water, energy and food that we identified, and they show how these elements are considered and described in the SMP.

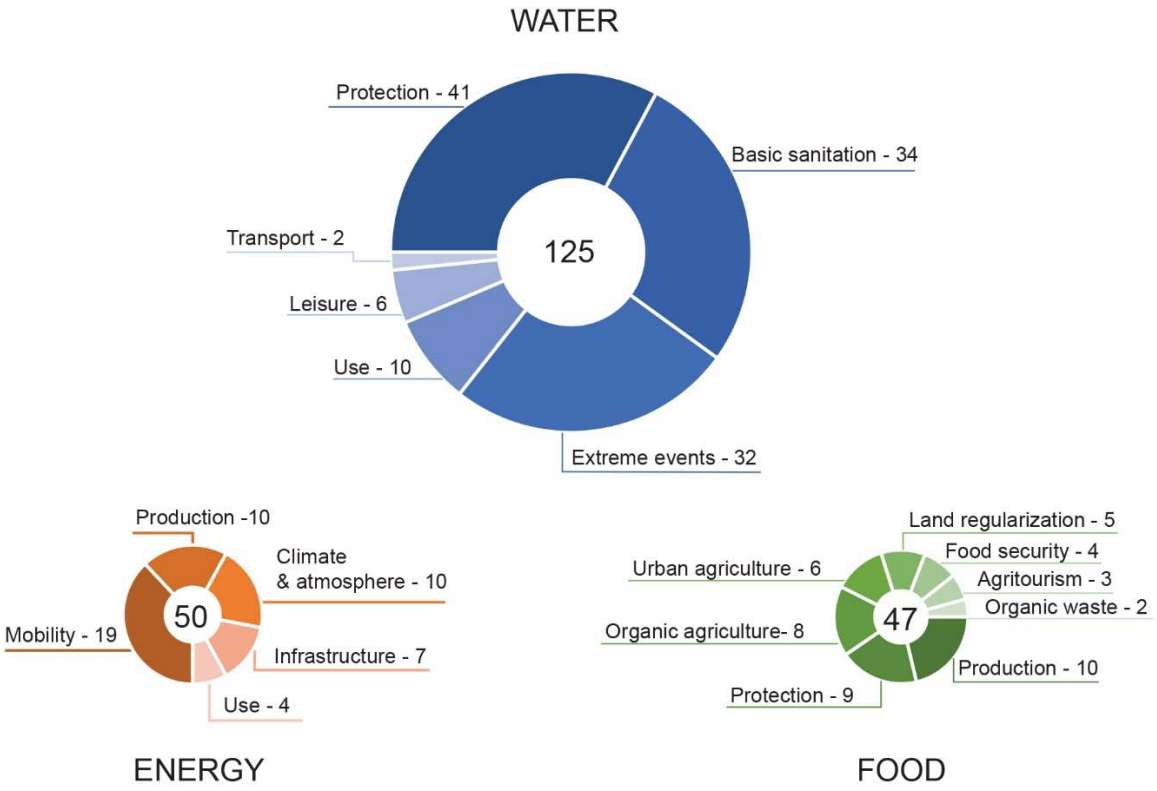

Figure 1. Number of articles in the 2014 São Paulo SMP dealing with water, energy and food.
Source. Elaborated by the authors.

After identifying the categories, it was possible to provide an overview of how the articles were distributed among such categories (Figure 1).

The water element, in its various perspectives, is central to the document and clearly predominant if compared to energy and food. Figure 1 shows the greater attention given to measures of protection, conservation, recovery and preservation of water bodies and the water resource (41 articles). Basic sanitation issues, such as water supply, wastewater collection and treatment are also often mentioned (34 articles). On the other hand, it is observed that water can also cause material and human losses, due to the combination of extreme weather events and land occupation (32 articles). Other topics are less considered.

Regarding energy, most of the articles deal with the issue of urban mobility (19) and emissions of air pollutants and greenhouse gases (10 articles). These articles are here considered for the possible impacts of these questions on the municipal energy system. In addition, 10 articles evoke the issue of energy production from alternative and renewable sources, while others are more focused on the infrastructure and the energy distribution system (7 articles).

For the food element, we identified 10 articles that address the issue of incentives for local agricultural production (in the rural area of the municipality). The topic of preservation of agricultural areas is developed in 9 articles, while the support for organic agriculture and agroecology is addressed in 8 articles. Other articles are less considered.

4.2. A common ground for water, energy and food: land use

The issue of land use planning is considered to be particularly innovative in the 2014 São Paulo SMP, and the analysis reveals that land use is in fact recurrently evoked when water, energy and food are addressed.

It is important to note that the SMP divides the territory into smaller parts, including macrozones, macroareas and special zones (Figure 2 a, b and c, respectively) according to their characteristics, priorities and designated uses. Furthermore, unlike the previous master plan (São Paulo, 2002), the current SMP delimits and identifies the rural area of the municipality, and clearly distinguishes it from the urban area (Figure 2 d). This new division is largely influenced by water and food resources, considered key components to define the limits of rural areas, which are seen as a multifunctional part of the territory, providing ecosystem services, such as water supply, food production, biodiversity maintenance, protection and conservation of natural areas, leisure and ecotourism (São Paulo, 2014). The analysis showed that both elements are often addressed with environmental protection, urban sprawl containment, sustainable use, and agriculture issues – all central elements in the SMP. The water element is here addressed mainly in the form of protection and recovery of water sources (see "protection" category in Table 1), and universalization of environmental sanitation through the expansion of the water and sewage network (see "basic sanitation" category in Table 1).

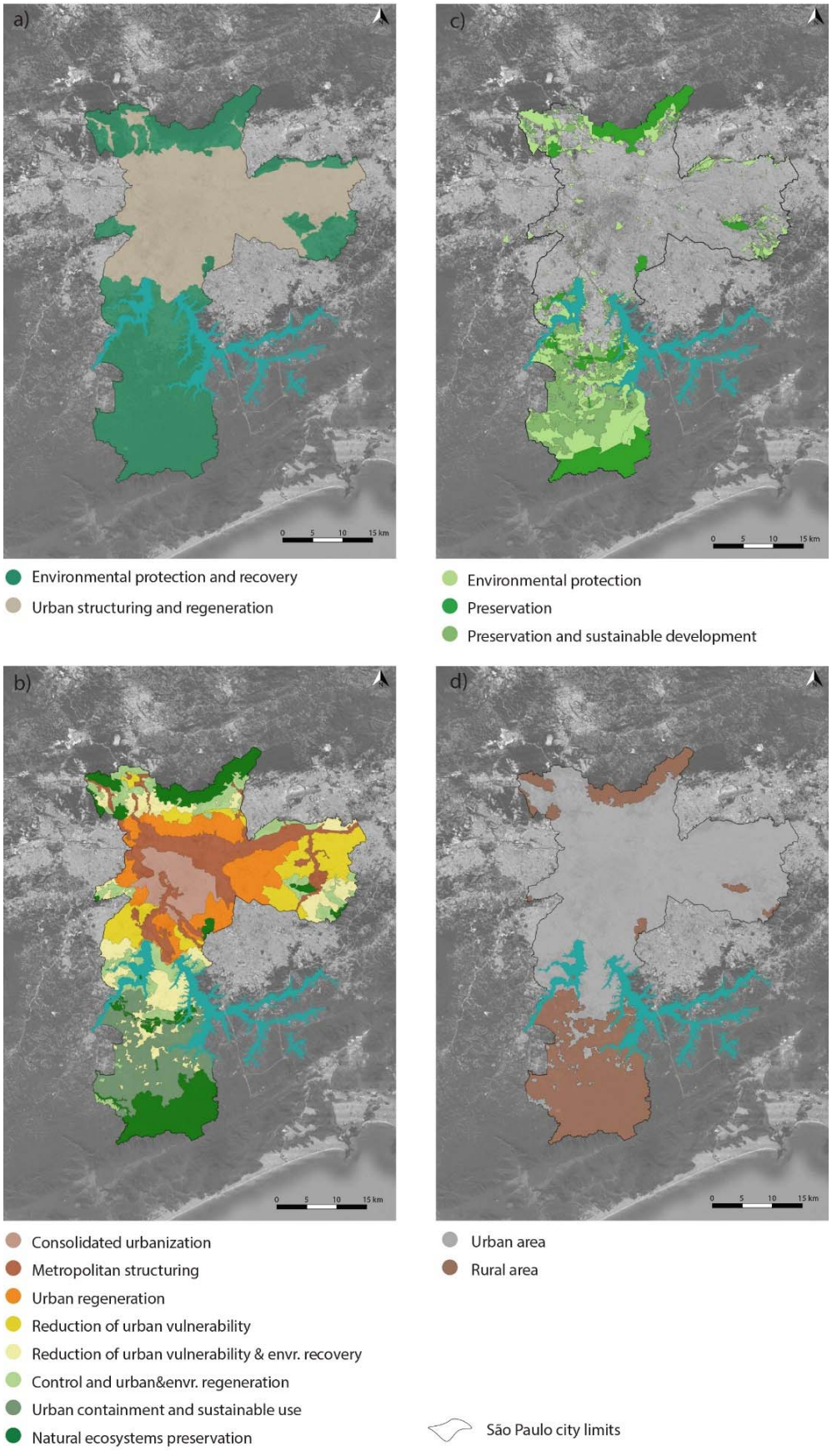

Figure 2. Maps of the: (a) macrozones; (b) macroareas; (c) special zones; and (d) urban/rural limits in the SMP.
Source. Elaborated by the authors, based on Ligue os Pontos, 2020.

Some special zones proposed by the SMP are clearly defined by activities focusing on environmental protection and recovery, and maintenance of natural resources (i.e., Special Zone for Environmental Protection; for Preservation; for Preservation and Sustainable Development - Figure 2c). Once again, water element emerges as a critical aspect in the definition of the zoning schemes, considering, for example, parameters and mechanisms related to rainwater drainage, which avoid network overload and flooding; soil occupation parameters related to geological, geotechnical, and hydrological aspects; implementation of activities that require the use of groundwater or interference with the water table; and water sources protection areas. Food is considered a central element as well, particularly in the definition of preservation and sustainable development zone in the territory. In this specific area, landscape preservation must be carried out through the implementation of economic activities (agriculture and tourism) that are understood as compatible with the maintenance and recovery of environmental services (see "protection" category in Table 1).

Land use also comes into play in the sections of the SMP that deal with water in relation to extreme weather events (see "extreme events" in Table 1). Land changes are critical to cope with urgent urban problems, such as floods, soil erosion and landslides, that can, to some extent, be linked to soil sealing, inefficient drainage systems, deforestation, and poorly organized land occupation (Travassos et al., 2020).

In addition, while it is not a major topic in the SMP, it is worth noting how the regularization of agricultural land (see "land regularization" category in Table 1) is considered to be an important measure to safeguard farmers, and consequently to guarantee food production, sustainable agricultural practices and environmental protection.

The analysis shows that energy is also connected to land use planning. In fact, we found that energy issues are, for instance, implicitly addressed in the SMP section called "Urban Transformation Structuring Axis", which aimed to stimulate housing policies to areas located along the public transport axes, improving the interactions between public and private spaces, and reducing travel times and distances. Furthermore, measures such as maximum standards for parking spaces are proposed to discourage the use of private cars in favor of public transport. Guidelines to stimulate the use of cogeneration systems in specific areas and the use of equipment that share electricity, wind, solar and natural gas, especially in large facilities are also included, however concrete measures in this direction are not foreseen.

5. Discussion

The analysis reveals that all three elements of the nexus are addressed in the 2014 São Paulo SMP in different ways and with different intensity. However, water has a central and explicit role in the document, while energy and food remain marginal. This is in line with the previous SMP of 2002, in which water was also considered a steering element for the development of local public policies (Sepe & Pereira, 2015). Three main issues related to water are addressed in the SMP and can therefore be considered priority concerns in the urban agenda of the city.

First, water is considered a precious resource that must be protected and preserved, which reverses the position of past public policies that privileged its consumption and considered it an inexhaustible resource (Ramos & Pollachi, 2019). Second, there is great emphasis on the maintenance and future development of the water supply system and universalization of wastewater collection and treatment. In this sense, the 2014-2015 water crisis has increased the concerns to improve the water supply system. Moreover, the deficit in wastewater collection and treatment has been an historical issue that has not yet been solved and it should be a strategic priority (Buckeridge & Ribeiro, 2018). Third, while water is a resource to be preserved, it can also be a destructive force when extreme weather events are combined with inadequate infrastructures and poor spatial planning (Travassos et al., 2020). That is why the SMP places a great emphasis on measures to protect residents, infrastructure systems and the territory from floods, landslides and similar events.

Our results show that the energy issue does not get as much attention as the water issue. We argue that this is related to the fact that, in Brazil, the energy sector is largely regulated on a federal level through the National Electric System Operator, which results in limited initiatives from municipalities. Furthermore, there is an existing dispute between the cheaper and more abundant national energy production and the local systems. Therefore, local energy strategies are less attractive, including the development of small solutions based on renewable sources that cannot stand the competition with the national production (Collaço, 2019). Despite the SMP providing some guidelines to stimulate the use of renewable energy sources in buildings, industries and municipal public bus system, other efforts have been made in the urban mobility sector with an implicit effect on the São Paulo energy matrix.

The definition of the rural area in São Paulo is a sign that food, or at

least food production, is a key component for the strategic development of the city. Other nuances of this issue are related to guaranteeing food security for all, supporting (peri-) urban agriculture, and encouraging the transition to agroecology, which reflects not only a concern for the socio-economic effects of these activities, but it still denotes an environmental awareness. An interesting fact is that agricultural activities are also recognized for their critical role in preserving the rural and natural landscape of the city, which is very rich in water springs and biodiversity (Ligue os Pontos, 2020).

At first glance, the analysis shows that, although water, energy and food are addressed in the SMP, there is no mention to the nexus or similar integrated approaches, and the nexus elements still seem to be considered in a sectoral way. Despite the fact that we did not perform a structured analysis of the synergies and tradeoffs between the elements of the nexus, the content analysis has proven to be sufficient in shedding light on the fact that the SMP does not address these issues systematically. However, while we can say that there is currently unused potential for a more integrated approach in the SMP of São Paulo, we cannot guarantee that nexus-type solutions are not included in sectoral plans or in policies developed by other local or supra-local authorities.

On the other hand, as our analysis demonstrates, the nexus elements are implicitly connected through issues of land use, environmental preservation and reorganization of urban development. For example, we identified the category protection for both water and food, which indicates that these two elements are, to some extent, linked and play together a critical role in the environmental protection and urban development strategy of the city. While water and water source areas are considered something to be protected, agricultural activities, mainly in the rural area, play a critical role in the local biodiversity protection. In addition, our analysis highlights that the SMP, in fact, supports organic agriculture, transition to agroecology, agritourism and other activities related to food production as important strategies to contain urban sprawl and to create a sustainable buffer to protect and preserve natural, vegetated and water-rich areas. We argue that water and food can create synergetic effects, driving the development of some particular areas, where environmental preservation is crucial to guarantee the provision of ecosystem services. This is particularly true in the case of the south zone of the city, where the largest portion of the environmental protection and recovery macrozone - the rural area - concentrates the most important remnants of Atlantic Forest, biodiversity, and water sources (including the Billing and Guarapiranga reservoirs, which are still used for water supply and energy production). The

preservation of these areas and their environmental services are key for ensuring water quality, supply and food production, as well as air quality and carbon sequestration, mitigating urban heat island effect, with potential effects beyond the city limits to the entire metropolitan region (Franco et al., 2015; Sepe & Pereira, 2015). While the incentives to the rural area are critical to preserve the city's green belt, they also are helpful to avoid the horizontal expansion of urban agglomeration, which is in line with the conceptualization of a compact city (Piérola & Almeida, 2016). Ultimately, the SMP explicitly recognizes the social function of rural property according to rational use and resource conservation parameters, which favors the well-being of its owners and the workers of these properties (Andrade, 2017).

Through our analysis, we recognize that land is also of great importance in the way the SMP deals with energy through the mobility issue. The urban expansion in the city of São Paulo towards the peripheries and the substantial increase in the vehicle fleet per inhabitant have led to increasing daily commuting between home and work. This resulted in increasing greenhouse gases emissions and air pollutants, and an urgent demand for non-renewable fuels, particularly for municipal public bus system (Di Giulio et al., 2018; Saldiva, 2018). It is no coincidence that the mobility strategy advocated in the SMP takes into account the influence of existing public transport infrastructure of high and medium capacity, such as subways, trains and buses, improving the urban development and increasing the density along these axes (D'Almeida, 2016), and also stimulates the use of public transport, biking and walking. The reorganization of urban development from a mobility perspective has the potential to improve the well-being of the population and the environment. Moreover, urban planning strategies are also very effective for energy savings and GHG emissions reduction (Collaço, 2019).

We recognize that, particularly in the context of large cities in the Global South, the disarticulation between sectoral policies hinders the integrated development of urban space (D'Almeida, 2016). The subdivision of responsibilities within municipal bureaucracies is a critical aspect, and frequently causes difficulties for effective collaboration, information sharing and coordinated action among municipal staff (Di Giulio et a., 2017; Jacobi et al., 2015; Aylett, 2014). The internal fragmentation, combined with the vertical and horizontal dimension of urban governance beyond their administrative borders, can limit the possibilities for cities to implement integrated or nexus approaches in strategic planning.

6. Conclusions

This chapter presented a content analysis of the 2014 Strategic Master Plan of the city of São Paulo through the lenses of the WEF nexus. Identifying land as the connection point between the nexus elements in a strategic planning instrument of a megacity such as São Paulo can both contribute to enrich the nexus literature and give insights on the role of local authorities in the nexus governance. Our findings add to other studies that identify land as the missing element to be added to the nexus approach (e.g., Ringler et al., 2013; Sharmina et al., 2016; Janssen et al., 2020). The nexus can be considered a starting point for including a broader set of resource interactions (Fan et al., 2019), and there is great potential to link the nexus with sustainable urban planning by acting on land use to simultaneously address water, energy and food. Furthermore, the option of tackling the nexus by acting on land can give agency to cities in those contexts in which local authorities are responsible for land use regulation management. Land can therefore be an entry point for local authorities to strategically operationalize the nexus. Moreover, the results show that identifying how water, energy and food are addressed in urban planning strategies can help to: (i) recognize and fill gaps in the local urban agenda; and (ii) suggest alternative paths of development in a cross-sectoral fashion.

We indicate that more studies should be carried out in different cities, investigating how integrated public policies and actions can potentially deliver multiple economic, social, and environmental benefits, which help cities to achieve sustainable outcomes. Future research is also needed to look at the implementation stage of policies covering water, energy and food as well as explore if synergies and tradeoffs between these elements are addressed in sectoral policies and plans at different government levels, since without this broader view, many disputes and interactions can be left aside or not fully understood.

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