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Municipal public spending in environmental management: efficiency and determinants

Gastos públicos municipais em gestão ambiental: eficiência e determinantes

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Abstract. Brazilian public spending on environmental management is constant, being the state and the municipality of São Paulo the ones that have spent the most on this function. The preservation and care of the environment are becoming increasingly relevant in society and organizations. The public sphere manages and regulates this issue, being a key factor for public policies at all management levels. The objective of the study was to analyze the efficiency of São Paulo municipalities in managing environmental public spending, in the period from 2011 to 2015, and to identify the determinants of efficiency. The methodologies applied were Data Envelopment Analysis (DEA) to measure the efficiency and Multiple Linear Regression to identify the determinants. The DEA results indicated that the efficient municipalities each year were not those that allocated the least public resources in environmental management

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or those that obtained the highest environmental indicator score. The determinants of efficiency were: the overall municipal human development index; the percentages of people: with piped water and installed toilets, those with higher education above 25 years old, and the poor. Municipal efficiency was identified in municipalities that have lower impacts on the determinants. Furthermore, the results contribute to the decision-making process in the management of public spending and in the elaboration of public policies that can reduce the impacts of external factors on environmental management in the municipalities of São Paulo. And, with that, promote an increase in the environmental indicator, which consequently can bring improvements in the quality of life of citizens.

Keywords: Data Envelopment Analysis. Efficiency. Environmental indicator. Public management.

Resumo. Os gastos públicos brasileiros em gestão ambiental são constantes, sendo o estado e o município de São Paulo os que mais têm gasto nessa função. A preservação e o cuidado com o meio ambiente ganham cada vez mais relevância na sociedade e nas organizações. A esfera pública administra e regula esta questão, sendo um fator chave para as políticas públicas em todos os níveis de gestão. O objetivo do estudo foi analisar a eficiência dos municípios paulistas na gestão dos gastos públicos ambientais, entre 2011 a 2015, e identificar os determinantes da eficiência. As metodologias aplicadas foram Análise Envoltória de Dados (DEA) para medir a eficiência e Regressão Linear Múltipla para identificar os determinantes. Os resultados DEA indicaram que os municípios eficientes em cada ano não foram aqueles que alocaram menos recursos públicos na gestão ambiental ou aqueles que obtiveram a maior pontuação no indicador ambiental. Os determinantes da eficiência foram: o índice geral de desenvolvimento humano municipal; as percentagens de pessoas: com água canalizada e casas de banho instaladas, pessoas com ensino superior acima dos 25 anos e pobres. A eficiência municipal foi identificada nos municípios que apresentam menores impactos nos determinantes. Além disso, os resultados contribuem para o processo de tomada de decisão na gestão dos gastos públicos e na elaboração de políticas públicas que possam reduzir os impactos de fatores externos na gestão ambiental nos municípios paulistas. E, com isso, promover um aumento no indicador ambiental, que consequentemente poderá trazer melhorias na qualidade de vida dos cidadãos.

Palavras-chave: Análise Envoltória de Dados. Eficiência. Indicador Ambiental. Gestão pública.

1. Introduction

Over time, the condition of the environment for sustaining life has become a concern that permeates society. From individuals to groups and reaching nations, the environmental issue is an increasingly relevant issue, given the negative impact generated by environmental degradation, resulting, among other factors, from population growth, deforestation and contamination of soil, air, water, and unsustainable productive activities, taken as shortcuts to modernization. Measures to reduce the negative impact of nature on man should not only be taken by the private sector but also and mainly by the public sector, through environmental management and regulation.

Companies and public organizations are equally urged by society and the market to meet the demands related to environmental sustainability and, consequently,

to obtain rewarding economic advantages, such as cost reduction, increased competitiveness, the opening of new markets, and reduction of unforeseen costs. Then, from the 1990s onwards, private companies began to implement Environmental Management (EM) programs. For the certification of production processes within the standards, in 1996, the International Standard Organization (ISO) published standards with environmental guidelines: ISO 14001 and ISO 14004 (Barata *et al.*, 2007).

In the same decade, Brazilian public management underwent administrative restructuring determined by the Federal Constitution (1988). In the Magna Carta, the rights and powers of the environment were determined, bringing new directions to EM in the country, which were previously dispersed in other functions. At the same time, it imposed on the public power and society the duty to defend and preserve an ecologically balanced environment (Brasil, 1988).

To minimize unwanted interventions by people in the ecosystem and preserve the existence of its components, EM comprises various practices, behaviors, and designs of human beings, corporations, and public institutions (Piva, 2018). Seeking to achieve efficiency in sustainability, public management must be engaged in environmental issues (Silva *et al.*, 2015).

Implementation of EM planning can occur more quickly in the private sector, due to access to resources and immediate results within the production process. In the public sector, this scenario changes, since the bureaucratic-legal process of actions for the execution of environmental planning and the greater scope can be barriers. However, all actions are necessary and important for EM, whether public or private.

Efficiency can be demonstrated when evaluating the quality of public policies adopted in government spheres. Municipal actions are the ones that have the most impact on this quality, as the municipal public managers are closer to the reality and local environmental needs, being able to manage and direct actions, policies, existing resources, also, the capture of others from the state and the Union (Silva *et al.*, 2022).

There is a need for more studies on municipal environmental policies and more guidance from public managers on this topic. The studies that deal with expenses in Environmental Management are important, as they bring contributions to public policies, and consequently, to the elaboration of measures that guarantee health improvement, protection of environmental resources, reduction, and prevention of current and future socio-environmental risks for the community and other species (Guandalini *et al.*, 2013). The population is also interested in ambitious environmental policies, even under adverse economic conditions, which can be justified by the importance that a balanced environment brings to the health of the population, especially when it comes to air and water quality (Bakaki & Bernauer, 2018).

Brazilian public spending on Environmental Management has increased in the last ten years, except for some periods of economic crisis and environmental disasters. The state and municipality of São Paulo were the ones that spent the most on Environmental Management in recent years in Brazil, presenting significant distances when compared to other states and municipalities. Among the 100 municipalities that spent the most on this function, 30 are in São Paulo, with values above 30 million reais between 2013 and 2016 (WWF-Brasil, 2018).

Even with high investments in the state of São Paulo, some municipalities in São Paulo have a high level of pollution. Thus, in 2007, the Secretary of State and Environment (SEMA-SP) launched the VerdeAzul Municipal Program (PMVA) to measure and support the efficiency of Environmental Management with the decentralization and enhancement of the environmental agenda in the municipalities. This program encourages and assists São Paulo city halls in the preparation and execution of their strategic public policies for sustainable development annually,

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through scoring in the guiding directives with the Environmental Assessment Index (IAA) (PMVAb, 2018).

The importance of efficient management of public spending in EM, the positive impacts that the proper application of these resources can provide to the environment and the health of citizens, and the gap identified in the literature, inspired and justified the preparation of this study for the municipalities of São Paulo. As a result of this need, the objective of the study is to identify the municipalities in São Paulo that are efficient in managing public expenditure in EM and the variables involved in this efficiency, in the period from 2011 to 2015.

This study is organized into five sections. After this introduction, section 2 addresses aspects of public spending on EM in Brazil and studies that analyze environmental spending and its efficiency. In section 3, the methods and materials used to prepare this study are described. In the sequence, there are the results and analysis of these. Finally, the conclusions of the study are presented.

2. Aspects of public spending in environmental management m in Brazil

The first public discussions on environmental protection policies were organized by a group of Brazilian scientists, journalists, and politicians in 1933, resulting in the elaboration of the first Forest Code (Decree nº 23.793/1934), focusing on the preservation of plant heritage. Years later, national and international pressures to create governmental actions beyond plant concern emerged, then Law nº 6.938/81 on the National Environmental Policy (Almeida, 2002; Silva *et al.*, 2015).

The Public Civil Action-Law (Law nº 7.347/85) was the second major landmark of Brazilian environmental legislation, in which natural resources became a protected legal asset. Three years later, the Brazilian public administration went through the process of administrative decentralization with the promulgation of the Federal Constitution (FC-1988), which transferred federal functions to states and municipalities. Then, Article 255 of the FC, established that: "Everyone has the right to an ecologically balanced environment, a good for common use by the people and essential to a healthy quality of life, imposing on the public power and the community the duty to defend it, and preserve it for present and future generations". And to guarantee this right, it was up to the public power: the preservation, restoration, control, education, and other prerogatives related to the Environment. And in Article 24, items I, VI, and VII of the CF, determine to the Union, the states, and the Federal District the competence to legislate on the Environment (Brasil, 1988; Silva *et al.*, 2015).

The creation of the Ministry of the Environment (1992), the enactment of Laws nº 9.605/98 and nº 12.651/2012, dealing with Environmental Crimes, and the new Forest Code, respectively, are also considered a Brazilian environmental mark. Even with administrative decentralization and legal support, Environmental Management did not have a specific classification among the other functions in Public Accounting until 1999 (Brasil, 2012; IPEA, 2017; MMA, 1992).

However, the publication of Ordinance No. 42/1999 of the Ministry of Budget and Management (MOG) brought an update on the breakdown of public expenditures by functions and public expenditures on Environmental Management became part of Function 18. The sub-functions of the Environmental Management function include: Environmental Preservation and Conservation, Environmental Control, Recovery of Degraded Areas, Water Resources, and Meteorology Environmental expenditures can also be classified by government programs, such as: for example, Water Resources,

Climate Change, Environmental Quality, or by the responsible sectoral body (Brasil, 2017; IPEA, 2017).

Public spending on EM corresponds to public resources made available by public management in the three spheres to protect or manage natural resources (IPEA, 2017). The amount spent on EM does not demonstrate the effectiveness of protection or management but should be considered as an indicator in in-depth analysis for the implementation of environmental policies (Guandalini et al., 2013).

In Brazil, public spending on the EM function by the Union, states, and the Federal District fluctuated between 2007 and 2016, showing increases in investments in almost the entire period, with reductions in 2011, 2014, 2015, and 2016. The sum of the expenses of the municipalities increased annually, with a small reduction in 2016. The five states that spent the most, above one billion reais in Environmental Management between 2007 and 2016, were: São Paulo, Rio de Janeiro, Minas Gerais, Pernambuco and Paraíba. Among the Brazilian municipalities that spent the most, over 400 million in this period, were: São Paulo, Rio de Janeiro, Belo Horizonte, Curitiba, and Piracicaba (WWF-Brasil, 2018).

2.1. Analysis and efficiency of public spending in EM

Sustainable development and sustainability have been topics widely researched by professionals and academia in recent decades, according to the study by Zhou et al. (2018). In this one, the authors selected works that related sustainability to efficiency, identifying 320 publications aimed at analyzing regions, industries, companies, and supply chains. However, studies on public expenditures in EM are scarce in the national and international literature, according to research carried out in the main databases of scientific publications. Most of the few studies found are recent and make use of mathematical and statistical methods to analyze EM expenditures or to measure efficiency. Some studies also seek to identify exogenous factors in the management of expenditure in the public environment studied, to improve public management actions. This scenario is similar to the one identified by Guandalini et al. (2013), who claim the existence of works dealing with environmental public policies, however, quantitative analyses are scarce, especially those that include environmental public spending at the municipal level. They also highlight the benefits and relevance of these studies.

In Brazil, studies on environmental expenditures were developed only after 1990 and most of these studies were directed to the public sector and the federal sphere (IPEA, 2017; Tripadalli et al., 2011), probably due to the unavailability of data on state and municipal spending. However, in the study by Guimarães et al. (1992) the general balance sheets of the São Paulo state government between 1986 and 1990 were analyzed concerning environmental public expenditures, identifying a low volume of earmarked resources. And, the authors point out that, at that time, there was little transparency in public expenditures in EM, analyzing these expenditures was not so in-depth.

Years later, changes in Public Accounting and the approval of the Fiscal Responsibility Law (Law No. 101/2000) brought more transparency to public expenditures, thus allowing the elaboration of detailed studies of public expenditures in ME (Guandalini et al., 2013). Thus, Tridapalli et al. (2011) synthesized seven studies on public expenditures in EM in Brazil, published between 2001 and 2008, identifying that analyzes of most of these studies are directed to federal expenditures.

Dantas et al. (2014) analyzed expenditures on EM in Brazil, during the years 2004 to 2011, comparing these expenditures with those of China and European Union

countries. As a result of the study, the authors concluded that Brazilian spending on EM is reduced when compared to total expenditures or the expenditures of the countries being compared and that there is a need for improvement in the allocation of expenditure and the socio-environmental quality (Dantas *et al.*, 2014).

The study by Guandalini *et al.* (2013) analyzed public spending on EM in Brazilian capitals, from 2002 to 2010, through a quantitative and longitudinal approach. This analysis identified that the capitals were responsible for a large part of the municipal expenses of their respective municipalities, but that over time there was a reduction. Municipal expenditures did not show homogeneity in the application in each region and the regions that allocate more resources to EM were south and southeast. The authors concluded that the resources destined for AG are few so efficient public policies can be developed in this function (Guandalini *et al.*, 2013).

Public spending on the environment in the State of Paraná, between 2002 and 2009, showed instability and decline, showing cuts above the budget, according to Borinelli *et al.* (2011). Spending in this state was higher, on average than in the other states in the Southern Region in the same period (Borinelli *et al.*, 2011). Years later, the authors Hein *et al.* (2017) analyzed the 50 municipalities in Paraná that spent the most on EM, in 2015, and their relationship with the design of sustainable cities. The study identified that these expenses are directly related to the design of sustainable cities in some municipalities and indirectly in others (Hein *et al.*, 2017).

The analysis of public spending on EM in the municipalities of Goiás was prepared by Carneiro *et al.* (2013), in the period between 2005 and 2010. Through statistical tests, the study identified that some municipalities do not have regularity in the application of resources in EM and that the allocation is correlated with municipal revenue in some periods. Dantas *et al.* (2017) analyzed public expenditures on Health and Environment in São Paulo cities, carried out in 2011, comparing them with indicators and social variables. The study concluded that public expenditure management and its proper allocation are more relevant than the amounts invested and that municipalities with lower expenditures do not always achieve high scores in performance indices (Dantas *et al.*, 2017).

Studies on public environmental spending at the international level are also few. In the synthesis prepared by Tridapalli *et al.* (2011), the nine studies published between 1990 and 2008 analyzed the share of environmental public expenditures in the Gross Domestic Product (GDP) or the country's total public expenditure. However, none of these studies performed an efficient analysis of the amounts spent.

Meleddu and Pulina (2018) evaluated the efficiency in the allocation of public resources in compliance with three European environmental directives between 2004 and 2011, in 21 Italian regions, using the DEA methodology and the Malmquist Index. The results demonstrate different efficiencies between groups regarding intervention in air and water and biodiversity, even so, the regions comply with European environmental directives. And, that the increase in tourism and agricultural activity negatively impacts the public efficiency of air and water quality. The variable that had a positive impact on efficiency was the existence of technical subjects in higher education since the educational level leads to an increase in the sustainable economy and the development of the renewable energy sector (Meleddu & Pulina, 2018).

The study by Wang (2018) analyzed the efficiency of environmental expenditures in six cities in Central China with the DEA methodology and the Tobit Regression identified the positive influence of GDP and the negative influence of urbanization and industrialization. In this sense, Almamari and Hongwei (2018) evaluated the efficiency of spending on environmental governance in 15 Chinese cities

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using the DEA methodology, from 2012 to 2016 and concluded that the amount applied can effectively improve investment efficiency.

3. Methodology

The nature of this research is applied, as it seeks to promote practical knowledge to solve a given problem. The objective of the study is descriptive because it aims to describe the aspects studied, in which the researcher establishes relationships between the selected variables (Louzada & Nunes, 2018).

The approach is quantitative and qualitative, because it uses statistical methods and interpretation of results, aiming to demonstrate the resulting efficiencies and the identified determinants (intervening factors), justifying it with subjective factors of public management regarding environmental expenditures in the municipalities studied. And the procedures applied were bibliographic and documental research. Bibliographic research comprises the consultation of secondary sources, which are bibliographies arranged in written or unwritten format, published in magazines, books, websites, and others. The collection of data in public archives (statistical sources) corresponds to documentary research, which is a primary source (Marconi & Lakatos, 2021).

The instruments used in the research were Data Envelopment Analysis (DEA) and Multiple Linear Regression (MLR). To use these instruments, data were collected from public databases and tabulated in electronic spreadsheets, being applied in the Stata® software, version 14.1.

DEA model included the selection of an input variable and an output variable. The input variable is the annual GPGA of the municipalities in São Paulo per square kilometer, covering the period from 2010 to 2014. This expense comprises the accounting information of the amounts that the municipal management allocated in the EM function and informed the Finance of Brazil (FINBRA) of the Secretariat of the National Treasury (STN), through the Accounting and Tax Information System of the Brazilian Public Sector (SICONFI) and the Accounting Data Collection System (SISTN). EM expenditures were deflated (2015 current prices) by the General Price Index - Internal Availability (IGP-DI) of Fundação Getúlio Vargas (FGV, 2018) and divided by the size of the municipality in square kilometers (km^2).

The selected output variable was the Environmental Assessment Index (IAA) of the VerdeAzul Municipality Program (PMVA). The IAA comprises 10 municipal environmental directives: treated sewage, solid waste, biodiversity, urban afforestation, environmental education, sustainable city, water management, air quality, environmental structure, and environmental council (PMVAa, 2018). The years selected were between 2011 and 2015 because the scores used in each directive are similar and the indicator is already consolidated in the state of São Paulo. The universe comprises the 645 municipalities in São Paulo, but due to the lack of data for the two variables, 228 municipalities remained in the sample for the period selected for this study.

DEA methodology measures the efficiency of the decision-making units (DMU), which are the studied municipalities in São Paulo. With mathematical modeling of linear programming (Operational Research), it considers inputs (inputs) and outputs (outputs) of a production process. Mathematical models can be oriented to inputs (minimization of inputs) or outputs (maximization of outputs). The efficiency scores result in between 0 and 1 (or 0 and 100%), being efficient for the DMUs that reach 1. The DEA model applied to this study was the Variable Returns to Scale (VRS), by Banker *et al.* (1984), oriented to outputs (1), according to the mathematical model:

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$$max\ h_0 = \sum_{r=1}^{s} u_r y_{r0} - u_0$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - u_0 \leq 0, \quad j = 1, \ldots, n,$$

$$\sum_{i=1}^{m} v_i x_{i0} = 1, \quad u_r, v_i \geq 0$$

(1)

Where: h_0: efficiency; v_i: inputs weight; u_r: outputs weight; x_{ij}: inputs i of DMUj; y_{rj}: outputs r of DMUj; x_{i0}: inputs i of DMU 0; and y_{r0}: outputs r of DMU 0.

With the results of efficiency, Multiple Linear Regression (MRL) was applied, seeking to identify variables that interfere with the resulting efficiency in each municipality. Once, these are variables that are not in the control of the public manager when they allocate resources in EM. Secondary data were collected from public databases for the period from 2010 to 2015, as described in the variables shown in Table 1, which correspond to the following categories: structural (availability of water and electricity, water and bathroom, garbage collection, and energy) social (total population, rural and urban), economic (Global IDHM, Income, Longevity and Education, Higher education, municipal GDP, oil royalties, illiteracy rate, and percentage of poor population) and agricultural production (coffee, sugarcane, corn, and orange). The selection of these variables was based on studies by Dantas *et al.* (2017), Silva *et al.* (2022), Wang (2018), and Meleddu and Pulina (2018).

Table 1 – Determinants

Category	Variable	Description (Year)	Factor
Structural	POPaguaen	Percentage of population with water and electricity (2010)	+
	POPagBan	Percentage of population with water and toilet (2010)	+
	POPcolixo	Percentage of population with garbage collection (2010)	+
	POPener	Percentage of population with electricity (2010)	+
Social	POPTot	Total Population (2010)	+
	POPrur	Rural Population (2010)	+
	POPurb	Urban Population (2010)	+
Economic	IDHM_2010	Municipal Global Human Development Index (2010)	+
	IDHMR2010	Municipal Income Human Development Index (2010)	+
	IDHML2010	Municipal Longevity Human Development Index (2010)	+
	IDHME2010	Municipal Education Human Development Index (2010)	+
	EnSup25	Rate of people with higher education over 25 years old (2010)	+
	PIBM	Municipal Gross Domestic Product (2011-2015)	+
	RoyPetro	Oil royalties (2011-2015)	+
	TxAnal15	Illiteracy rates people over 15 years old (2010)	-
	PercPobre	Percentage of the poor population (2010)	-
Agricultural production	Coffee	Coffee production in hectares (2011-2015)	-
	Sugarcane	Sugarcane production in hectares (2011-2015)	-
	Corn	Corn production in hectares (2011-2015)	-
	Orange	Orange production in hectares (2011-2015)	-

Source: Atlas Brasil (2010), IBGE (2015a) and IBGE (2015b).

Thus, we seek to identify a positive or negative (factor) relationship between the variables and DEA efficiency. The positive relationship indicates that the higher the value of the variable, the greater the efficiency of EM in the municipality. And the negative relationship indicates that the smaller the value of the variable, the greater the efficiency in EM.

4. Results and discussion

The variables of the DEA model (GPGA and IAA) presented discrepant values in all periods, not following a pattern of expenditure by the size of the municipality. The municipalities with the lowest public expenditures in EM each year (2011-2015) were: Pedranópolis, Riversul (2012 and 2013), Cesário Lange, and Bofete, according to the values described in the Minimum column (Table 1) accordingly. And the municipality that spent the most on this function in all years was Barueri, except Poá in 2014, according to Maximum values (Table 2). The average value of public spending is high due to the amounts allocated by the municipalities of Barueri, Santo André, São Vicente, São Paulo, Cubatão, São José do Rio Preto, São Caetano do Sul, Osasco, and Poá, which in almost every year studied spent over one hundred thousand reais per square kilometer.

Table 2 – Descriptive statistics of DEA variables

Variable	Mean	Standard Deviation	Minimum	Maximum
GPGA2011	17.607,89	82.225,12	0,33	1.051.295,00
GPGA2012	17.230,11	87.382,70	3,94	1.191.143,00
GPGA2013	15.131,69	79.578,40	2,23	1.079.947,00
GPGA2014	22.743,46	104.391,20	1,36	1.058.308,00
GPGA2015	22.492,79	100.658,00	2,11	1.005.684,00
IAA2011	69,55	17,64	31,59	96,13
IAA2012	69,95	22,69	30,14	98,27
IAA2013	60,89	17,58	31,23	94,84
IAA2014	67,18	19,19	31,63	98,02
IAA2015	67,44	19,56	30,50	97,88

Source: Authors (2024).

Regarding the index achieved by São Paulo municipalities in the VerdeAzul Municipality Program (PMVA) in this period, it is noteworthy that Sorocaba, Botucatu (2012 and 2014), Jundiaí, and Novo Horizonte obtained the best scores, according to the Maximum (Table 1). The municipalities with the lowest scores in the period were: Cubatão, Bady Bassitt, Martinópolis, Aramina, and Águas da Prata, consecutively, according to minimum values (Table 2). The average in the IAA in the range of 60 points is due to the exclusion of municipalities with values below 30.

4.1. DEA model result

The DEA-VRS model run for each year resulted in 20 efficient municipalities (100%), as shown in Table 3. In the analyzed period, seven municipalities showed efficiency in more than one year, namely: Sorocaba, Aspasia, Botucatu, Piacatu, Santa Rosa de Viterbo, Capão Bonito and Lençóis Paulistas. The municipalities of Santa Rosa de Viterbo and Botucatu stand out for being efficient in three of the five years analyzed.

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Table 3 – DEA efficient municipalities

Year	Municipality	Efficiency	GPGA	IAA
2011	Cardoso	100%	R$ 14,79	85,71
	Guararapes	100%	R$ 121,78	95,54
	Magda	100%	R$ 144,35	92,41
	Pedranópolis	100%	R$ 0,33	72,31
	Queiroz	100%	R$ 1,83	74,62
	Sorocaba	100%	R$ 24.918,18	96,13
2012	Aspasia	100%	R$ 147,97	86,78
	Borborema	100%	R$ 131,14	93,07
	Botucatu	100%	R$ 983,20	98,27
	Piacatu	100%	R$ 528,51	95,44
	Santa Rosa de Viterbo	100%	R$ 2.429,24	95,90
	Sorocaba	100%	R$ 24.366,91	98,21
2013	Americana	100%	R$ 9.429,52	93,99
	Capão Bonito	100%	R$ 8,82	76,64
	Guzolândia	100%	R$ 172,32	84,17
	Jundiaí	100%	R$ 15.148,20	94,84
	Piacatu	100%	R$ 396,72	85,11
	Pirapozinho	100%	R$ 2,47	47,87
	Santa Rosa de Viterbo	100%	R$ 1.651,41	92,54
2014	Aspasia	100%	R$ 248,77	81,52
	Botucatu	100%	R$ 889,43	98,02
	Capão Bonito	100%	R$ 15,49	90,12
	Lençóis Paulistas	100%	R$ 90,10	95,23
	Santa Rosa de Viterbo	100%	R$ 2.113,62	93,79
2015	Amparo	100%	R$ 31,44	86,98
	Botucatu	100%	R$ 1.504,29	96,70
	Lençóis Paulistas	100%	R$ 502,31	94,39
	Novo Horizonte	100%	R$ 4.300,38	97,88
	Sertãozinho	100%	R$ 453,70	97,18

Source: Authors (2024).

For the year 2011, 168 municipalities were analyzed, which resulted in the efficiency of five municipalities. Among these, the municipalities of Pedranópolis and Queiroz stand out, which have the lowest public expenditures in EM per Km2 this year (Table 3 – 2011), with an AAI in the range of 70. The municipality of Cardoso was the sixth that least allocated resources in 2011 and obtained an IAA of 85.71. The municipalities of Magda and Guararapes, on the other hand, presented expenses well below the annual average but obtained an AAI above 90. Sorocaba was the municipality that spent the most among the efficient in 2011 and 2012, and it was also the one that had the highest expenditure in the sample in these two years.

In 2012, 162 municipalities were analyzed, resulting in six efficient ones (Table 3 – 2012). Five of these municipalities scored above 93 in the IAA, however, the amounts spent were discrepant between them, with a minimum of 131.14 (Borborema) and a maximum of R$ 24,366.91 (Sorocaba). The municipality of Botucatu, which was efficient in 2013, 2014, and 2015, showed an increase in the amounts spent and also in its IAA scores, which were always above 96, in the periods studied.

The municipality of Pirapozinho was the only efficient municipality with an AAI below 50 points among the efficient municipalities in all the years studied and also presented one of the lowest expenses in EM per Km2 (Table 3 – 2013). The municipalities of Santa Rosa do Viterbo, Americana and Jundiaí were the only ones that had an IAA score above 90 points among the efficient ones in 2013, but when comparing the amounts spent, disparities can be seen. The same occurs with the other two municipalities that had similar scores (Guzolândia and Piacatu) and discrepant expenditures. And the municipality of Capão Bonito, efficient in 2013 and 2014, showed an increase in the IAA score and almost doubled investment in EM from one year to the next.

In 2012 and 2014, the municipality of Aspasia was efficient, but even with an increase in EM spending, it failed to increase its IAA score (Table 3 – 2014). The municipality of Lençóis Paulistas, on the other hand, had the second-lowest expenditure and lowest score in the IAA in 2014. And Santa Rosa do Viterbo had the highest expenditure among the efficient ones that year but did not have the best score.

Among the efficient municipalities in 2015, the only one that scored below 90 was Amparo, however, it was the one that spent the least on EM (Table 3 - 2015). The municipality of Novo Horizonte had the highest expenditure and the highest IAA score. The municipality of Sertãozinho stands out, which spent almost ten times less than Novo Horizonte and obtained a similar score to this municipality. And, also, attention is paid to the expenses of Lençóis Paulistas that the previous year spent almost five times less than that year had a reduction in the IAA score.

The results of this study are in agreement with the findings of the analysis by Dantas and Passador (2020), who identified the municipalities of Novo Horizonte, Santa Rosa de Viterbo, Sorocaba, and Piacatu, among the ten that had the best environmental performance in the comparisons between 2008 and 2008. 2013. Even with the use of different methods between the studies, this comparison of results indicates that these municipalities perform efficient management of their resources because of their local characteristics, leading environmental management to good performances in the IAA.

4.2. Multiple Linear Regression Result

The variables involved in EM in the cities of São Paulo can impact the efficiency generated by the DEA methodology. Thus, to identify these variables to reduce their influence on the efficiency of public management, variables with structural, social, economic, and agricultural production characteristics were selected. Then, with the application of Multiple Linear Regression and DEA efficiency for each period, four determinant variables were identified among the 20 selected variables, as shown in Table 4.

Table 4 – Identified determinants variables

Year	2011	2012	2013	2014	2015
Variable	POPagBan***	POPagBan*	POPagBan**	POPagBan**	POPagBan***
	IDHM_2010*	IDHM_2010*	-	IDHM_2010*	IDHM_2010*
	-	-	EnSup25*	-	-
	-PercPobre*	-	-PercPobre***	-	-
R^2	22,1%	18,5%	17,8%	14,8%	9,6%

Source: Authors (2024). *Variable with statistical significance <1%. **Variable with statistical significance <5%. ***Variable with statistical significance <10%.

The variable that expresses the percentage of people with running water and a bathroom installed in the municipality (POPagBan) had statistical significance in all the years analyzed. This represents the importance that the basic structure of supply and sanitation installed in the municipality has concerning EM. The positive coefficient indicated that the greater the scope of this structure, the smaller the environmental impact caused. There is a reduction in the contamination of water sources (rivers, streams, lakes, streams, and others) and also by the water treatment carried out in the municipalities.

The Global Municipal Human Development Index (IDHM_2010) showed statistical significance in almost all periods, except in 2013. This variable showed with the positive coefficient that the higher its value, the lower the impact on EM, that is, the greater the efficiency of the municipality. This is due to better economic, educational, and health conditions. A municipality with people with higher incomes consequently has a better economy and higher revenue, allowing the government and population to acquire products and services that prioritize environmental quality, especially in waste management and control of ambient air pollution. Income can also be a limiting factor for the adoption of stricter environmental practices (Motta *et al.*, 1996). The same happens with the education issue, in which municipalities with people with more knowledge can put into practice the concepts of environmental preservation and conservation, resulting in benefits for the health of the population and the environment.

The variable that represents the percentage of people with higher education over 25 years old (EnSup25) showed positive statistical significance in 2013, also justifying that the greater the knowledge of the population, the greater the efficiency of the municipality. In some Higher Education courses, there are technical or specific disciplines on environmental issues and these disciplines can contribute to reducing municipal spending on environmental education for adults. Several studies, over the years, have addressed the issue of environmental education, such as the importance of environmental education (Roth, 1969), education as a solution for a sustainable and equitable economy (Diduck, 1999), the environmental education for environmental preservation and conservation and economic development in tourist locations (Walter, 2009) and environmental education in Higher Education (Meleddu & Pulina, 2018).

The fourth variable, the percentage of poor people in the municipality (PercPobre), showed negative statistical significance in 2011 and 2013, indicating that the greater the number of people in the poverty line (reference value: per capita income less than half a minimum wage) lower is the municipal efficiency in EM. For "human poverty and environmental degradation are associated in a regressive way", since "the poor pay more for environmental services, have more difficult access, and often live in areas of greater risk" (Motta *et al.*, 1996). Also, poor people do not have the economic conditions to purchase green products and services, such as food without pesticides, sanitation or piped water, higher education, among others.

The set of determinants identified for each year justifies the municipal efficiencies and inefficiencies between 9.6% and 22.1% in the years studied, according to R2 presented in Table 4. Thus, with the treatment of determinants, municipalities can reach the index of efficiency.

5. Conclusion

Analyzing the DEA input and output variables in the studied municipalities in São Paulo, it was identified that most municipalities presented variations in the amount spent in the EM function and also in the AAI of the PMVA. This can be justified by the

mismanagement of public spending on EM in these municipalities, by the failure to meet the targets proposed in the annual environmental directives, or even by the incorrect submission of public information in the financial or environmental systems of regulatory bodies.

In the analysis of the efficiencies resulting from the DEA-VRS model, it was observed that the efficient municipalities in each year were not those that least allocated public resources in EM per km^2 or those that obtained the highest score in the IAA. This is due to the application of the mathematical model of the DEA methodology, which uses the sum of the weighted average of inputs and outputs.

With the RLM, the variables that impact the efficiency of the cities of São Paulo studied in the period from 2011 to 2015 were identified: the percentage of people with running water and toilet installed in the city (POPagBan), the Global Municipal Human Development Index (IDHM_2010), percentage of people with higher education over 25 years old in the municipality (EnSup25) and percentage of poor people in the municipality (PercPobre). So, it is concluded that the municipalities in São Paulo that manage to treat their determinants to EM are more efficient than those that direct actions and public policies without considering local determinants.

Some results of this study are similar to recent findings of other national and international studies. The first one refers to the amount spent on EM, which, in most cases, does not justify the score achieved in the environmental or efficiency indicator (Dantas *et al.*, 2017; Dantas & Passador, 2020). That is, proper management and allocation can provide greater efficiency in public spending (Silva *et al.*, 2022). The second is the identification of an educational variable as a determinant of local environmental efficiency (Meleddu & Pulina, 2018). And the third is that, even with the application of different methods, the results of this study are in line with the results by Dantas and Passador (2020), regarding the performance/efficiency in the environmental management of five municipalities.

However, the results of this study differ from the findings of other international studies, such as, for example, that the amount applied can effectively improve investment efficiency (Almamari & Hongwei, 2018), that GDP (Wang, 2018) and agricultural production (Meleddu & Pulina, 2018) are determinants variables in EM efficiency.

In the private sector, resource management is efficient to maintain competitiveness, therefore, a performance evaluation is efficiently disseminated (Polat & Kiris, 2021). Thus, the results of the present study contribute to the decision-making process in the management of public spending and in the elaboration of public policies that can reduce the impacts of factors external to EM in the municipalities of São Paulo. And, with that, promote an increase in the IAA, which consequently can bring about an improvement in the quality of life of the citizens.

The main limitation found in the elaboration of the present study was the unavailability of data, mainly on the financial information of the municipalities, which were not available for all the years studied. This unavailability led to the exclusion of many municipalities, which caused a significant reduction in the initial sample, leaving only 35% of the 645 municipalities in São Paulo.

For future studies, we suggest the application of efficiency analysis for all São Paulo municipalities, analysis in other periods, and the search for the identification of other determinants. It is recommended to carry out studies to analyze the efficiency of public spending on EM in other Brazilian states. Finally, it is also suggested the implementation of municipal environmental assessment programs in other Brazilian states, given the importance of municipal development in EM and the positive impacts they provide on the environment and the population's quality of life.

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