# Sustainable Human Development at the Municipal Level: A Data Envelopment Analysis Index

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**Abstract:** The development of indexes for human development and environmental sustainability issues are an emerging topic in the current literature. However, the literature has put less emphasis on municipal indexes, which is the focus of this research. In this paper, we considered municipal environmental management as the adoption of environmental activities and the development of infrastructural and technical capacities in municipalities. This article aims to create a sustainable human development index with municipal data from the state of São Paulo in Brazil. Using information from the Municipal Human Development Index (IDHm) and the GreenBlue Municipal Program (PMVA), we applied the data envelopment analysis (DEA) technique to connect human development and environmental sustainability in 645 Brazilian municipalities. Our findings show that regions with higher human development present better DEA scores on the Sustainable Human Development Index. In contrast, regions with a low or a middle level of human development do not present significant change considering both dimensions. Moreover, our findings reveal that PMVA certification has a different and statistically significant impact on the DEA score considering certified, qualified, or not qualified regions. We found similar results for urbanized and service-oriented municipalities. Our indicator is an essential and straightforward tool for regional policymakers, helping to allocate resources and to find human development and environmental sustainability benchmarks among developing regions.

**Keywords:** human development; sustainability; environmental program; environmental management; data envelopment analysis (DEA); index; infrastructure; urban management

## 1. Introduction

Development indexes that only measure economic aspects, such as gross domestic product (GDP), are increasingly being considered inadequate to measure the development of a region [1]. In this way, other important dimensions for human life were incorporated in development indexes, such as health and education, which are present in the Human Development Index (HDI) [2,3]. In the last two decades, however, besides the incorporation of social indicators, there was also the recommendation to consider environmental indicators in development analysis [2,4,5].

In this context, some authors have been proposing adaptations and new ways of measuring the HDI, including environmental sustainability indicators, in what can be called the Sustainable Human Development Index (SDHI) [2]. In addition, Furlan and Mariano [6] have developed a national environmental justice index by using data development analysis (DEA) with human development and environmental data.

Local governments are important for the achievement of sustainable development and require appropriate sustainability indicators [7]. Some initiatives have been considered at the local level, in different parts of the world, to improve environmental public policies and, therefore, environmental quality [8,9]. One important case is voluntary and regional initiatives that aim to increase the autonomy and responsibility of local governments towards aspects of public environmental management [8].

Within this context, in 2007, the Secretariat of Environment of the state of São Paulo, Brazil, created the Município Verde (Green Municipality) Initiative [10], currently named Programa Município VerdeAzul (GreenBlue Municipality Program (PMVA)). The program aims to stimulate the city halls of São Paulo to adopt environmental management practices, including the development of actions and infrastructure provisioning. The municipalities may receive certification for achieving the goals described in the program's guidelines, which facilitates access to financial resources from the state budget of São Paulo [11].

Sustainability is an important issue to be addressed by municipalities, which need to consider social, environmental, and economical aspects in order to be considered truly sustainable [12]. Discussions about sustainability should not disregard the social justice premises in environmental management programs. Although these programs are important, they are not sufficient to guarantee the sustainable development of the regions implementing them [13]. Therefore, there is the problem of how to better measure the sustainable development of municipalities that adopt environmental management programs.

The aim of this paper is to create an index that considers both human development and environmental indicators at the municipality level, named the Sustainable Human Development Index. To achieve this goal, this research relied on data envelopment analysis (DEA) to create an index using data from the Municipality Human Development Index (HDIm)—a Brazilian internal adaptation of the HDI to evaluate human development in the municipalities—and the grades from the PMVA. In this way, it is possible to increase social justice aspects in the PMVA, creating higher coverage for the index. As already highlighted by Sena et al. [14], social and environmental aspects need to be considered in order to achieve sustainable development in a region.

Aside from the importance of the theme from the practical perspective, this study also contributes to the literature by analyzing a Latin American country, which has fewer studies in the human development literature than more developed regions [4]. Other countries, that have environmental initiatives, can use the approach present in this research in order to develop an index that includes more aspects related to sustainable development in the local context. Moreno-Pires and Fidélis [7] highlighted how municipal sustainable indicators should consider a broad range of dimensions. According to the authors, composite indicators might consider several dimensions to represent social, economic, demographic, and environmental aspects.

Another important aspect of this research is that it is related to some of the Sustainable Development Goals (SDGs) promoted by the United Nations [15], especially goal 11—Sustainable Cities and Communities. The SDGs are an important instrument to promote the three sustainable development pillars (economics, environment, and social) to be achieved in the long term [16]. According to Moyer and Bohl [17], several of the SDGs are closely related to human development. This might indicate a tendency of developing programs to consider both human development and environmental elements together [18,19].

This study is structured as follows: Section 1 presents the introduction with the research problem and objective. Section 2 presents a theoretical background concerning sustainable human development and municipal environmental management. Section 3 presents the material and methods, describing the data used and how the index was

developed. Section 4 presents the results and discussion. Section 5 presents the conclusions of the research.

## 2. Conceptual Framework

In this section, we present the research framework (Figure 1), where we describe the relationship between human development and environmental action (here represented by municipal environmental management) in order to generate sustainable human development.
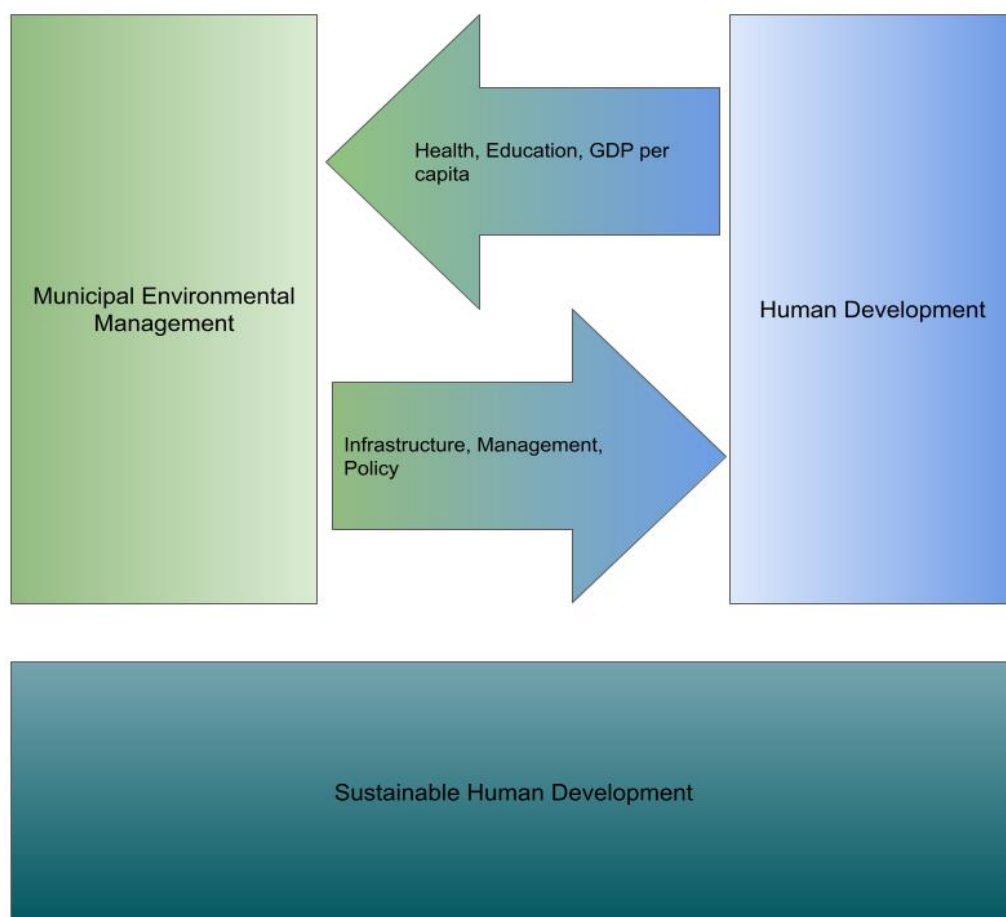


**Figure 1.** Conceptual framework.

Some studies posit that better levels of human development can increase the number of sustainable development actions, which, in turn, can support human development [6,20–22]. Furlan and Mariano [6] applied this idea to mitigation and adaptation strategies in the climate change context. Lima et al. [22] incorporated this idea in circular economy initiatives. Therefore, in this research, we suggest that the increase in human development, including better levels of health, education, and resources, positively affects municipal environmental management, which supports the development of better infrastructure, management practices, and policies, which in turn supports the increase in human development. This cyclical relationship can lead to the achievement of sustainable human development.

In this context, it would be important that environmental programs consider human development issues in its metrics. Next, we present the human development concept and its relationship with sustainability and the notion of sustainable human development. Then, we present the importance of municipal environmental management and briefly describe the PMVA, which was used as a proxy for the municipal environmental management in Brazil.

*2.1. Sustainable Human Development*

The idea of human development emerged as a way to complement the purely economic notions of development, such as the gross domestic product (GDP) [3]. "Human development is about enlarging freedoms so that all human beings can pursue choices that they value" [23], p.1. This definition is grounded in the capability approach, which is the main concept in the human development field [24]; according to this theory, development should be seen as the increase in the individual's freedoms in order to have and be whatever they value [24]. For the capability approach, freedom is both the means and the ends of development [3,24].

Sustainable development incorporates aspects of intergenerational justice into the intragenerational justice already present in human development [25]. Sustainable development is the "development that prompts the needs of present people without compromising the needs of future generations" [26].

In this way, it is not possible to minimize the privations currently faced, especially considering the poorest, to the detriment of the future generations; both need to have their capabilities and freedoms ensured [13,25,27]. According to Haughton [13], sustainable development does not require only the adaptation of human behavior, but also the adaptation of the infrastructures that influence these behaviors, which includes economic and social aspects.

The concept of environmental justice emphasizes the need to avoid the ones who have fewer resources, exactly the ones who pollute the least, being the ones who are the most affected by environmental problems [28]. Therefore, environmental justice also has a human development connotation [20]. Therefore, human development has a direct relationship with sustainable development, since the individuals' quality of life depends on a proper environment [27]. A feedback effect also occurs, that is, the increase in individuals' capabilities tends to increase the development of a better environment, due to the application of better behaviors, practices, and technologies that improve environmental quality [22]. Nagy, Benedek, and Ivan [29] found a strong correlation between local HDI in a Romanian region with the indexes of the SDGs achievement, which may indicate a positive relationship between investments in human development and the achievement of sustainable aspects. This may be related to sustainable human development, which is the relationship between human development and sustainable development [2].

The HDI is the most used approach to measure human development in the world. It was developed by Mahbub ul Haq, who had the capability approach as one of the main inspirations. The HDI has three dimensions (economic, education, and health) divided into four indicators (gross national capital per capita, school life expectancy, average years of schooling, and life expectancy at birth), being disclosed annually by the United Nations Development Programme (UNDP) [3,30–32].

According to Dalberto et al. [33], by incorporating these dimensions, the HDI kept the capability approach notion of the development of focusing not only on monetary aspects but also on the social one. As pointed out by Assa [2], the educational and health dimensions measure capabilities, while the monetary measure is a commodity.

The HDI has undergone a "natural selection" process of the indexes, that is, its indicators and manners of calculation have been adapted when necessary, in such a way that it continues to be used even years after its creation [34]. However, the HDI is not exempt from criticism, such as the simplicity of its dimensions; lack of qualitative analysis (for example, quality of education); and the lack of elements directly related to the environment [3,32,33].

Considering the limitations of the global HDI, some countries have been adapting the indicators to better represent the national context. The UNDP encourages this initiative for these countries to increase, substitute, or create new approaches to the HDI's indicators in order to develop more adequate measures for their realities. In Brazil, this index is called the Municipality Human Development Index (HDIm), and it has been applied at the municipality level since 1998 [35].

In 2013, the HDIm began to use the Demographic Census database from 2010, adapting the indicators of the global HDI for the indicators collected by the Brazilian Institute of Geography and Statistics (IBGE). The HDIm presents the same dimensions as the traditional HDI, although it uses different variables and measures to represent human development in Brazil. While the HDIm uses data collected by the IBGE, the HDI uses data from several agencies from the United Nations and other international agencies [35,36].

In the HDIm, the indicator for health is life expectancy at birth, the income is represented by the municipality income per capita, and education is measured by two indicators: (1) the population that is 18 years old or more that completed elementary school, with a weight of 1, and represents the schooling of the adult population; and (2) the population between 5 and 6 years old attending school, the population between 11 and 13 years old attending the last years of elementary education, the population between 15 and 17 years old that completed elementary school, and the population between 18 and 20 years old that completed high school; this indicator has a weight of 2 and represents the school flow of the young population. Therefore, the educational dimension is calculated by the geometric mean of indicators 1 and 2. The complete index is also calculated by the geometric mean of the three dimensions mentioned [35].

Considering the aforementioned indicators, São Paulo has the second largest Brazilian HDIm (0.783), only behind the Federal District (0.824) [33]. The HDI also has the importance of providing information to support development policies, which helps policymakers to map human development and decide how to allocate public resources to boost human development in Brazil [33].

### 2.2. Municipal Environmental Management

Municipal environmental management is the environmental activities performed by local authorities in the municipalities [37]. In this study, the actions developed by local governments to increase their environmental performance are considered, which include: urban management, infrastructure provision, waste management, development of policies, and environmental education and communication. All these actions are important to support sustainable human development [22,38–42].

Almost all countries face difficulties in achieving better levels of sustainable development, which is particularly difficult for developing countries, such as Brazil, that need to reconcile economic development with environmental preservation. This is hampered by the smaller amount of resources compared to developed countries and greater demand from society for aspects of infrastructures and essential services [43,44]. Tortajada [41] pointed out that developing countries still need to increase their investment in infrastructures in order to support human development.

One way to mitigate these challenges is not to concentrate all the responsibility on a single government entity, but to share responsibility among different administrative spheres, including local, regional, and national government participation [13,29,45,46]. Municipalities are key actors in fostering sustainable development [7,12]. Among possible advantages, local administrations have greater knowledge about their peculiarities and capabilities, while regional and national spheres can help with technical and/or financial support [8,47–49].

It is important to have ways to measure the progress in this kind of activity [49]. Indicators to measure municipality sustainability offer more information for decision makers; Moreno-Pires and Fidélis [7] suggest that these indicators should cover a broad range of dimensions, in order to fully consider sustainable development.

The PMVA is a municipal environmental management program in which the São Paulo State Government (regional sphere) encourages municipal governments (local spheres) to adopt environmental management measures [50]. The program is voluntary, so this flexibility in its adoption requires the program to be credible and have a performance measurement mechanism [9]. This point is present in the PMVA, considering that a database was created with the indicators of each municipality and supported by the presence of a

team that upholds and helps to train municipalities to develop environmental management actions and planning [11]. Thus, in addition to the generation of local data [8] that may reflect greater interest by the local population in matters related to the environment [43]; the municipality also does not see itself as alone in achieving the program's goals, since it receives support from the state sphere [46].

Currently, the PMVA has 10 dimensions, called directives: sustainable municipality, structure and environmental education, environmental council, biodiversity, water management, air quality, land use, urban forestation, treated sewage, and solid waste. Each directive has a number of tasks related to: development of municipal legislation to support the environmental management and practices, infrastructure and technical capabilities, and quality presented [11]. Table 1 presents a summary of the directives.

**Table 1.** Description of the PMVA directives.

| Directive | Tasks |
| --- | --- |
| Sustainable municipality | Incentive indicators for the generation and consumption of renewable energy sources, inspection of the commercialization of forest products, and incentives for the production and purchase of food from sustainable systems. |
| Structure and environmental education | Implementation of a minimum organizational structure within the administration that includes a specialized staff and specific legislation. It includes the creation of spaces and actions to promote environmental education among the population. |
| Environmental council | Implementation, through specific legislation, of the Municipal Environmental Council. The administration must prove the council's activities by means of meeting minutes, the year's goal plan, topics discussed, participation in PMVA events, and actions developed during the period. |
| Biodiversity | Actions for the conservation of fauna and flora through plans and municipal laws (institution of Payments for Environmental Services *). The resources for these actions must be inserted in the annual budget law.<br>* Mechanism that remunerates rural producers for environmental services that benefit the whole society, for example: conservation and restoration of forests. |
| Water management | Actions to protect and recover springs, educational actions regarding the conscious use of water, and measures to ensure the quality of the water distributed to the population through laboratory analysis. |
| Air quality | Actions to reduce air pollution generated by vehicles and fires. In the first case, the indicators focus on controlling vehicle emissions as well as encouraging the use of renewable fuels and public transport. For the second case, the actions involve the mitigation of urban and rural fires and the creation of a fire brigade. |
| Land use | Tasks related to erosion control in urban and rural areas, as well as the establishment of a Contingency Plan, through civil defense, to map regions susceptible to dangerous geodynamic processes. It also establishes the management and recovery of areas that are contaminated or at risk of contamination, and the management of areas showing exploitation or potential exploitation of minerals. |
| Urban forestation | Development of municipal legislation aimed at the process of afforestation and urban forestry, establishing norms, standards, and adequacy of road infrastructure. It also requires the municipality to carry out an inventory and diagnosis of the trees on the urban perimeter, calculation of the urban vegetation cover (in percentages), and publicity and environmental education actions related to urban afforestation. |
| Treated sewage | The directive considers both the coverage of the collection network and the percentage of treatment of the generated sewage. There are also indicators focused on the quality and efficiency of the treatment. |
| Solid waste | Actions for the correct disposal of solid waste generated in landfills, waste reduction or reuse programs, implementation of selective waste collection, and programs to institute composting (biodigestion) projects. There are also environmental education actions to promote and encourage the population to participate in selective waste collection. |

It is important to note that even if the directive did not explicitly mention the necessity for infrastructure, in order to accomplish its tasks it is necessary to develop proper infrastructure, especially in the directives related to sanitation [42]. For example, proper infrastructure is needed to provide appropriate water for the population as required in the water management directive. These kinds of directives not only impact the environment, but also exert influence on socio-economic systems [40]. Although the number of directives has not changed, the number of tasks has increased. In the beginning of the program, it ranged from two to three tasks per directive, now it is common to exceed seven tasks that cover action, management, and results related to the directive [11].

Annually, each municipality receives a final score, called the Environmental Assessment Index (EAI), which is the sum of the points for all tasks of each directive. There are also extra points for proactive actions and a reduction in the score if there are some pending issues or environmental liabilities. The municipalities deliver the documentation to prove and assess the grades, however, 13.73% of the total grades are automatically computed from data measured by other state agencies [50].

The certification is granted to municipalities that achieve an EAI score of 80 or more and facilitates the access to resources from the state Environment Secretariat [11]. There is also an intermediate classification for municipalities that reach an EAI score between 40 and 80, called qualification, in which the PMVA allocates special attention to ascertain whether they are "on the right track" to achieve the certification [11]. Thus, it is possible to classify the municipalities into: non-qualified (EAI score of 0.0 to 39.9), qualified (EAI score of 40.0 to 79.9), and certified (EAI score of 80.0 to 100.0).

The scoring method has undergone some changes over the years, making the requirements for certified municipalities more stringent. In addition to obtaining an EAI score of 80, a score of zero is not allowed in any directive and it is mandatory to implement a minimum municipal environmental legislation.

### 3. Method

The analyses were performed using DEA, as it is an appropriate method to develop an index ranging from 0 to 1 [6]. DEA is a non-parametric technique developed by Charnes, Cooper, and Rhodes [51], being a mathematical model based on linear programming capable of allocating the set of optimal weights to maximize the efficiency of a decision-making unit (DMU) [1], which is the DEA unit of analysis. Table 2 summarizes the research method that was based on the three steps proposed by Golany and Roll [52] to apply DEA, and in more three statistical tests.

**Table 2.** Method summary.

| Method | Step | Explanation |
|---|---|---|
| DEA | 1. DMU selection | • 645 municipalities from São Paulo, Brazil |
| | 2. Inputs and outputs definition | • Partial Index HDIm_PMVA:<br>　○ Input: HDIm;<br>　○ Output: PMVA EAI.<br>• Partial Index PMVA_HDIm:<br>　○ Input: PMVA EAI;<br>　○ Output: HDIm. |
| | 3. DEA application | • Variable returns of scale<br>• Oriented toward the output<br>• Multiplication of the two partial indexes to develop the Sustainable Human Development Index |

**Table 2.** *Cont.*

| Method | Step | Explanation |
|---|---|---|
| Statistical tests | 4. Normality check tests | • Kolmogorov–Smirnov and Shapiro–Wilk |
| | 5. DMU classifications and hypothesis development | • HDIm level (low, medium, and high), H1;<br>• PMVA (non-qualified, qualified, and certified), H2;<br>• Urbanization level (rural, intermediate, and urban), H3;<br>• Economic sector (agriculture, industrial, and services), H4. |
| | 6. Non-parametric test | • Jonckheere–Terpstra |

The first step of Golany and Roll [52] consists of choosing the DMUs, which were all the 645 municipalities of São Paulo, Brazil (Figure 2). The estimated population of the 645 municipalities is 44.7 million inhabitants, being the most populous Brazilian state, representing 21% of Brazil's population. The life expectancy is 79.5 years for women and 73.2 years for men. In the economic aspect, the state presented a GDP of approximately USD 582,18 billion in 2019, representing 31% of the national GDP. Considering the education indicator, the population's average years of schooling were 9.97 years in 2016 [53]. Regional initiatives, even if located in only one state, are important to be studied, since they can contribute to other locations or sectors with lessons and experiences [9].
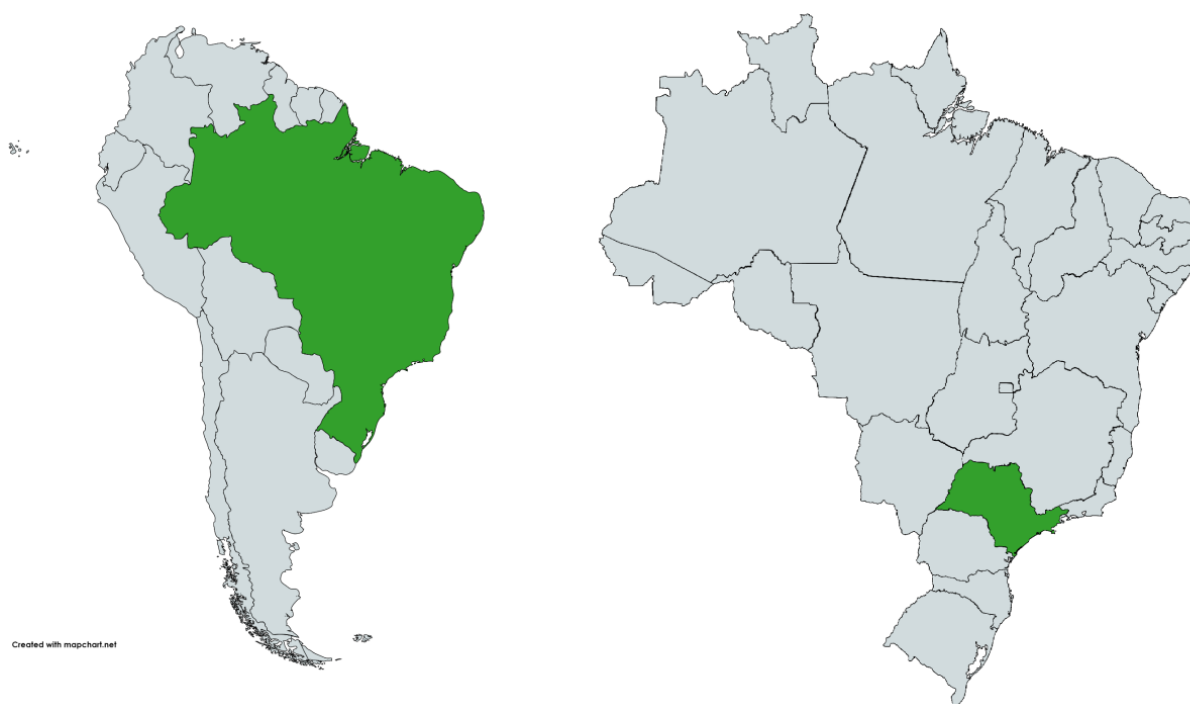


**Figure 2.** São Paulo location.

Socioeconomic analyses in specific regions of a country, such as the municipalities of São Paulo, are advantageous for having more homogeneous DMUs [4], which is considered an important aspect for DEA [8]. DEA has already been used in other studies that evaluated the efficiency in transforming economic and development-related resources into sustainable development [5,54], and has also been applied with HDI data [1,33].

The second step of Golany and Roll [52] is the definition of inputs and outputs suitable for the analyses. For human development, the three dimensions of the HDIm were used, and we used the 2010 version because it is the most up to date. The HDI is the main reference for this type of study in the field of human development [4]. The data were collected from the official website of the Institute for Applied Economic Research [55].

For municipal environmental management, we used data from the 10 dimensions of the PMVA. We decided to use the 2019 data instead of those from 2020 (most recent) since the pandemic caused by COVID-19 was an extreme and unexpected event that significantly affected society's way of life [56]. This phenomenon created several challenges in the environmental management of municipalities [57] that could affect the intended analyses in this study. The data were collected from the PMVA's official platform [58].

For the third and last stage presented by Golany and Roll [52], the application of the DEA and the subsequent analysis of the results were carried out. We chose the output-oriented model, called BCC, since it presents variable returns to scale, that is, the increase in the input does not interfere proportionally in the output. Considering that the objective is to maximize the output and not to minimize the input, the model was applied with the output orientation, as it is not the objective of any municipality to reduce its output (human development or municipal environmental management), but to increase its input (human development or municipal environmental management) [4–6]. Equations (1)–(3) show the output-oriented BCC model.

$$E = Min \sum_{j=1}^{n} v_j \cdot x_{j0} - w \tag{1}$$

Subject to:

$$\sum_{i=1}^{m} u_i \cdot y_{i0} = 1 \tag{2}$$

$$\sum_{i=1}^{m} u_i \cdot y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} + w \leq 0, \; to \; k = 1, 2, \ldots, hw \; \text{no signal restriction} \tag{3}$$

where: $x_{jk}$ is the amount of the input $j$ of the DMU $k$;
$y_{ik}$ is the amount of the output $i$ of the DMU $k$;
$x_{j0}$ is the amount of the input $j$ of the DMU under analysis;
$y_{i0}$ is the amount of the output $i$ of the DMU under analysis;
$v_j$ is the weight of the input $j$ for the DMU under analysis;
$u_i$ is the weight of the output $i$ for the DMU under analysis;
$w$ is the scale factor;
$m$ is the number of analyzed outputs;
$n$ is the number of analyzed inputs; and
$h$ is the number of DMU.

Since human development supports the adoption of environmental actions, and a better environment supports the increase in human development in a cyclical relationship [20,21], in this research, HDIm was the first input and PMVA EAI was the output. Then, we also considered the dimensions of PMVA EAI as the input, with the output being the dimensions of HDIm, similarly to what was carried out by Furlan and Mariano [6]. In this way, this research has two partial indexes: HDIm_PMVA and PMVA_HDIm. In both cases the 3 dimensions of the HDIm and the 10 dimensions of the PMVA were considered. Afterwards, the two partial indexes were multiplied to achieve the Sustainable Human Development Index (Equation (4)). Multiplication was chosen because it penalizes possible low results in one of the partial indexes [6].

$$SDHI = SDHI^{HDIm\_PMVA} \cdot SDHI^{PMVA\_HDIm} \tag{4}$$

where:

*SHDI* is the Sustainable Human Development Index;

SDHI$^{HDIm\_PMVA}$ is the Partial Sustainable Human Development Index (HDIm_PMVA direction);

SDHI$^{PMVA\_HDIm}$ is the Partial Sustainable Human Development Index (PMVA_HDIm direction).

Initially, the DEA index considered all 645 municipalities, generating an efficiency ranking of them. The normality test of the index (step 4) was performed using the Kolmogorov–Smirnov and Shapiro–Wilk methods. As in both tests the significance level was less than 5%, the index could not be considered to follow the normal distribution, so it was necessary to perform non-parametric tests [59].

After the normality test, we created some groups of municipalities in order to compare them and analyze specific variables (step 5). We considered four independent features: (1) classification in the PMVA, (2) level of HDIm, (3) degree of urbanization, and 4) sectoral participation in the municipal GDP.

This group's analyses were inspired by previous work in the area [6,60]. Next, the Jonckheere–Terpstra test (step 6), which is a test for ordered alternatives within independent samples, was applied in order to test the hypothesis created for each one of these features. This test is considered non-parametric and aims to verify differences between analysis groups and identify trends [61,62]. Thus, it was possible to verify whether or not there was a difference between the groups tested regarding the increasing order of analysis (low, medium, and high).

1. The classification of the municipality according to the three PMVA groups (non-qualified, qualified, and certified). From this, we develop the first hypothesis H1: municipalities with different classifications in the PMVA have different performances in the Sustainable Human Development Index.

2. The HDIm and its dimensions (HDIi, DHIh, and HDIe) were divided into three quartiles (low HDIm, up to 0.725; medium HDIm, between 0.725 and 0.753; and high HDIm, above 0.753). This does not mean that the HDIm itself is low or medium according to the UN classification, but that it is a relative measure among the municipalities of São Paulo. From this, we develop the second hypothesis H2: municipalities with different levels of human development have different performances in the Sustainable Human Development Index.

3. The degree of urbanization was divided into urban, intermediate, and rural according to the classification proposed by the Brazilian Institute of Geography and Statistics that depends on both the number of inhabitants and the rate of those living in urban areas [63]. From this, we develop the third hypothesis H3: municipalities with different degrees of urbanization have different performances in the Sustainable Human Development Index.

4. The sectoral participation in the economy considered which sector (agriculture, industry, or service) has more than 33% of participation in the municipalities' economy [64]. From this, we develop the fourth hypothesis H4: municipalities with different levels of sectoral participation in the economy have different performances in the Sustainable Human Development Index.

## 4. Results

### 4.1. Descriptive Analysis

First, we present the results from the descriptive statistics of the Sustainable Human Development Index. The index ranges from 0 to 1 and the study samples are composed of the 645 municipalities from São Paulo, with the highest value being 0.996 and the lowest 0.168. In this way, it is noticeable that none of the municipalities achieved 100% efficiency considering the final index. This happened because of the multiplication of the two partial indexes, as when using DEA there is always at least one DMU with 100% efficiency, and in the HDIm_PMVA there were 114 municipalities with 100% efficiency and

in the PMVA_HDIm there were 83. The complete rank is available in the Supplementary Material (Table S1).

It is important to highlight that achieving 100% efficiency or something close to it does not mean that the DMU should not improve its indicators, since the DMU can present a low output and be considered efficient by having a low input too. That is, the DMU can be efficient in transforming its low input into output and, in this case, it needs conditions to increase its input in order to increase its output, keeping the same level of efficiency [33]. In this way, the index will allow the municipality to track its value and compare it with other municipalities with similar demographics and human development conditions.

It is possible to notice this aspect regarding the two partial indexes (Table 3), considering that the municipalities with low EAI in the PMVA and with relatively high levels in the HDIm achieve high levels in the partial PMVA_HDIm, but in the inverse relationship of inputs and outputs, the partial HDIm_PMVA, these municipalities presented low levels in the index. The municipality of Nova Europa represents this case well, considering that it is one of the municipalities in the first position with a value of 1.000 in the partial PMVA_HDIm, but it is placed in position 643 with a value of 0.185 in the partial HDIm_PMVA. This aspect highlights the importance of applying the multiplication of the two partial indexes to achieve the final index, considering that this approach allows the development of indexes that better suit the municipalities' reality. In this scenario, the municipality of Nova Europa is only in position 641 with a value of 0.185 in the Sustainable Human Development Index.

**Table 3.** First and last places in the partial and final indexes.

| Municipality | Partial IDHm_PMVA | | Partial PMVA_IDHm | | Sustainable Human Development Index | |
|---|---|---|---|---|---|---|
| | Position | Score | Position | Score | Position | Score |
| Águas da Prata | 1 | 1.000 | 92 | 0.996 | 1 | 0.996 |
| Andradina | 1 | 1.000 | 98 | 0.994 | 2 | 0.994 |
| Taubaté | 1 | 1.000 | 104 | 0.992 | 3 | 0.992 |
| Santos | 1 | 1.000 | 125 | 0.987 | 4 | 0.987 |
| Vinhedo | 1 | 1.000 | 125 | 0.987 | 4 | 0.987 |
| Nova Europa | 643 | 0.185 | 1 | 1.000 | 641 | 0.185 |
| Igaraçu do Tietê | 641 | 0.189 | 173 | 0.977 | 641 | 0.185 |
| Paranapanema | 639 | 0.190 | 307 | 0.957 | 643 | 0.181 |
| Guaraci | 644 | 0.182 | 182 | 0.975 | 644 | 0.178 |
| Álvares Florence | 645 | 0.179 | 450 | 0.940 | 645 | 0.168 |

Regarding the Sustainable Human Development Index, the first five ranked municipalities were (with the respective values): Águas da Prata (0.996), Andradina (0.994), Taubaté (0.992), Santos (0.987), and Vinhedo (0.987). All these municipalities have the PMVA certification. The municipalities with the PMVA certification tend to be in the first positions of the index, and the worst ranked in this case is the municipality of São Miguel Arcanjo (0.898), in position 140. The last five ranked municipalities were: Nova Europa (0.185), Igaraçu do Tietê (0.185), Paranapanema (0.181), Guaraci (0.178), and Álvares Florence (0.168). All of them are non-qualified according to the PMVA classification. The last 360 ranked in the index are non-qualified municipalities.

The Sustainable Human Development Index proposed increases the social aspects that are barely present in the PMVA, in such a way that it makes it closer to sustainable development rather than only environmental sustainability. The index can be an important tool to support local governments to achieve the Sustainable Development Goals. Besides working as an improvement opportunity for the PMVA, the index has been shown to be feasible to be used in other regions with some adaptations.

### 4.2. Comparative Analyses of the Sustainable Human Development Index

A summary of the results found in this section is presented in Table 4, and each one of the hypotheses is further discussed.

**Table 4.** Summary of the hypothesis test.

| Hypothesis | Null Hypothesis | Test | Sig. [a,b] | Decision |
|---|---|---|---|---|
| H1 | Municipalities with different classifications in the PMVA have different performances in the Sustainable Human Development Index | Jonckheere–Terpstra | 0.000 | Accepted |
| H2 | Municipalities with different levels of human development have different performances in the Sustainable Human Development Index | Jonckheere–Terpstra | 0.000 | Accepted |
| H3 | Municipalities with different degrees of urbanization have different performances in the Sustainable Human Development Index | Jonckheere–Terpstra | 0.000 | Accepted |
| H4 | Municipalities with different levels of sectoral participation in the economy have different performances in the Sustainable Human Development Index | Jonckheere–Terpstra | 0.001 | Accepted |

[a] The significance level is 0.50; [b] the asymptotic significance is displayed.

#### 4.2.1. PMVA Analyses

The first analysis regarding the created groups considers the classifications of the PMVA: non-qualified, qualified, and certified. The non-parametric test of Jonckheere-Terpstra was applied, which is indicated for analyses of ordinal increscent and decrescent categories (Table 5). The results indicated that there were differences between the groups, with asymptotic significance (two-sided test) equal to 0.000 and, therefore, hypothesis 1 was accepted.

**Table 5.** PMVA independent-samples Jonckheere–Terpstra test for ordered alternatives summary.

| | |
|---|---|
| Total $n$ | 645 |
| Test Statistic | 101,580.500 |
| Standard Error | 2285.779 |
| Standardized Test Statistic | 21.516 |
| Asymptotic Sig. (2-sided test) | 0.000 |

Then, it was possible to perform the pairwise comparison (Table 6) and the construction of the error bar graphs (Figure 3), in which all the three classifications are statistically different. The non-qualified municipalities present the lowest values in the Sustainable Human Development Index, the qualified municipalities present intermediate values, and the certified municipalities present the highest values of the index. It is noticeable that the mean values of the non-qualified municipalities are much lower than the mean values of the qualified and certified municipalities.

**Table 6.** Pairwise comparisons of the PMVA classification.

| Sample 1 vs. Sample 2 | Statistical Test | Std. Error | Std. Test Statistic | Sig. | Adj. Sig. [a] |
|---|---|---|---|---|---|
| Non-qualified vs. Qualified | 50,313.000 | 1545.184 | 15.704 | 0.000 | 0.000 |
| Non-qualified vs. Certified | 40,760.000 | 1337.886 | 15.146 | 0.000 | 0.000 |
| Qualified vs. Certified | 10,507.500 | 462.302 | 10.062 | 0.000 | 0.000 |

Each line tests the null hypothesis that the distributions of the Sample 1 and Sample 2 are the same. Asymptotic significance (1-sided tests) is displayed. The significance level is 0.050. [a] The significance values were adjusted with Bonferroni correction for multiple tests.
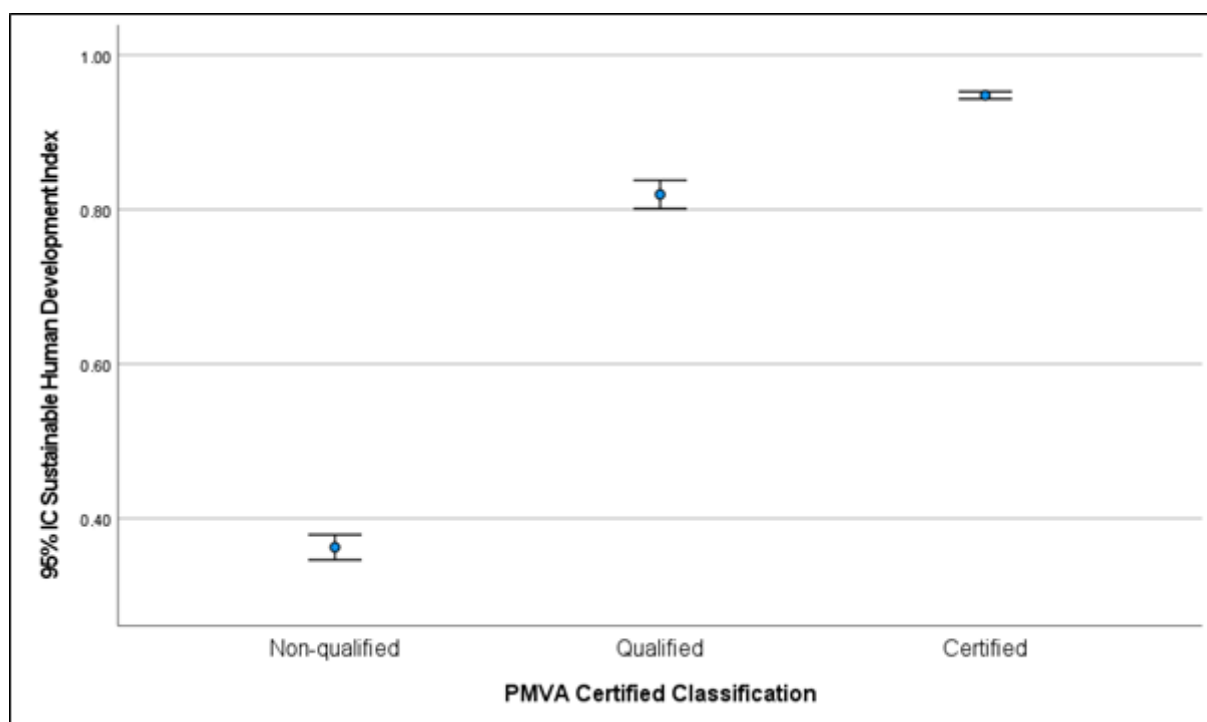
**Figure 3.** Error bar graph of the municipalities by classification of the PMVA.

Another important aspect regarding this analysis is that the municipalities in the same group present a very low variation between them, especially the certified municipalities (Figure 3).

Regarding the classification of the PMVA, the following maps were developed in order to illustrate the scenario of each group. To accomplish this, we created three stratification levels, with the values in the Sustainable Human Development Index ranging from 0.00 to 0.44, 0.44 to 0.72, and 0.72 to 1.00. The first map shows the municipality in the lower stratification (Figure 4). Only non-qualified municipalities appear in this context.

However, not all municipalities in the non-qualified group follow this trend. Porangaba is an interesting case in this group: the municipality has an EAI score of 31.79 in the PMVA and a value of 0.971 in the Sustainable Human Development Index (17th position), in such a way that Porangaba is the most highly ranked non-qualified municipality in the index. Porongaba features in the group of municipalities with a low level of HDIm (0.703), other municipalities in a similar condition are: Sete Barras (EAI score of 21.35 and HDIm score of 0.673) and Itobi (EAI score of 35.6 HDIm score of 0.717), with a value of 0.940 (74th position) and 0.934 (79th position), respectively, in the Sustainable Human Development Index. Since these municipalities present this peculiar feature, they can be used as benchmarks for municipalities in a similar situation, and future studies should analyze these municipalities more deeply in order to understand the reasons for their performance.

The best positions in the ranking are of the certified municipalities, followed by the qualified ones. However, some non-qualified municipalities also figure in the highest levels. Figure 5 illustrates all municipalities that have the highest stratification value of the Sustainable Human Development Index.

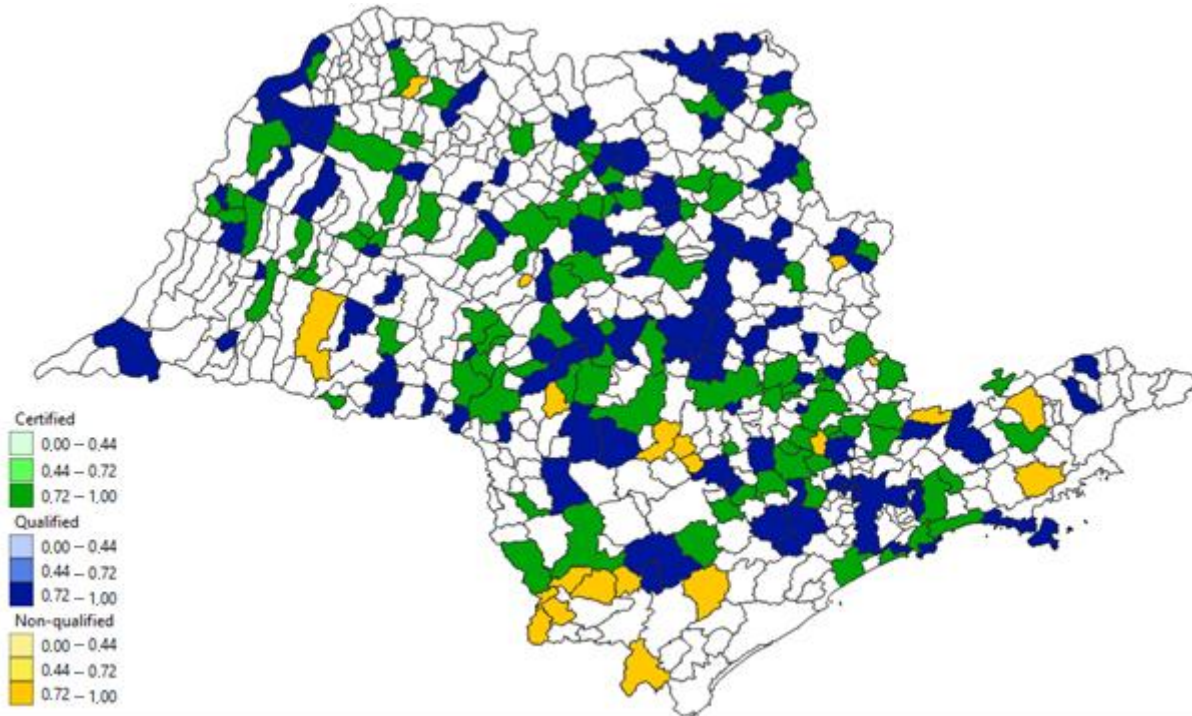**Figure 4.** Municipalities in the lower part of the stratification.



**Figure 5.** Municipalities in the highest stratification of the Sustainable Human Development Index.

Regarding the intermediate stratification of the index, Figure 6 presents how there are relatively few municipalities in this level, with a balance between the non-qualified and qualified municipalities. It is also noticeable that there are no certified municipalities in this scenario.
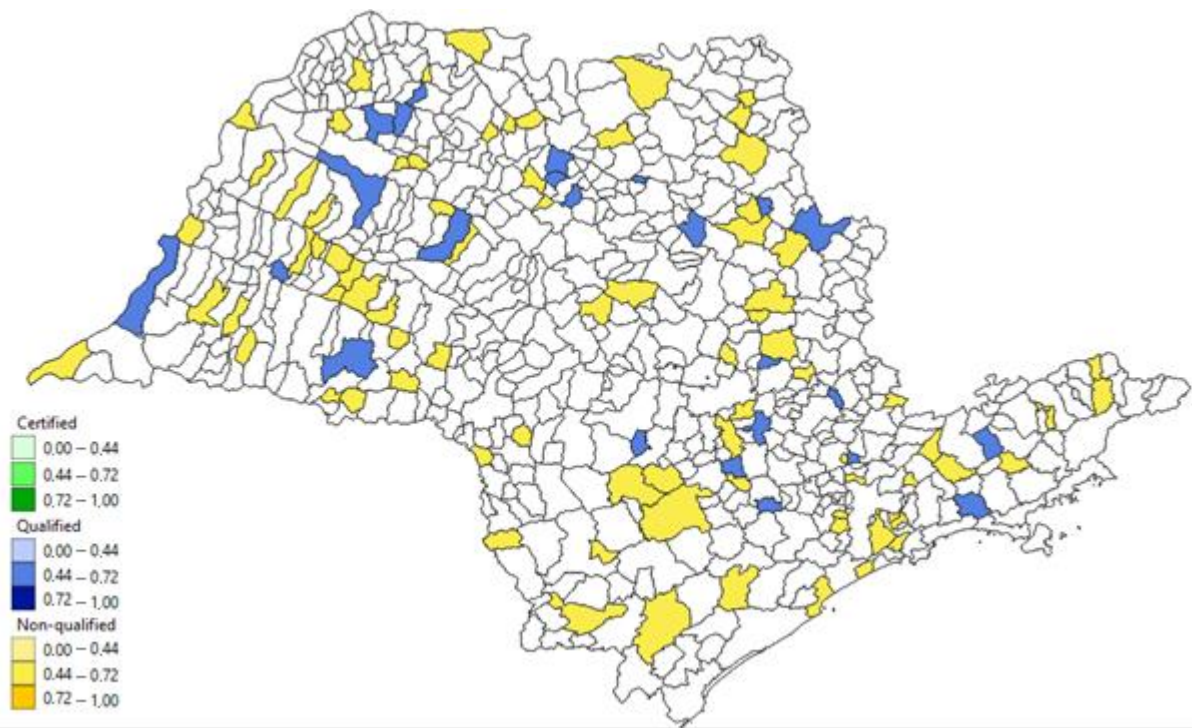
**Figure 6.** Municipalities in the intermediate range of the Sustainable Human Development Index.

In this way, all the certified municipalities present results in the highest level of the index, while the qualified municipalities are located in the intermediate and high levels, and the non-qualified municipalities have representatives in all levels of the index, with a higher number of municipalities in the lowest level (Figure 7).
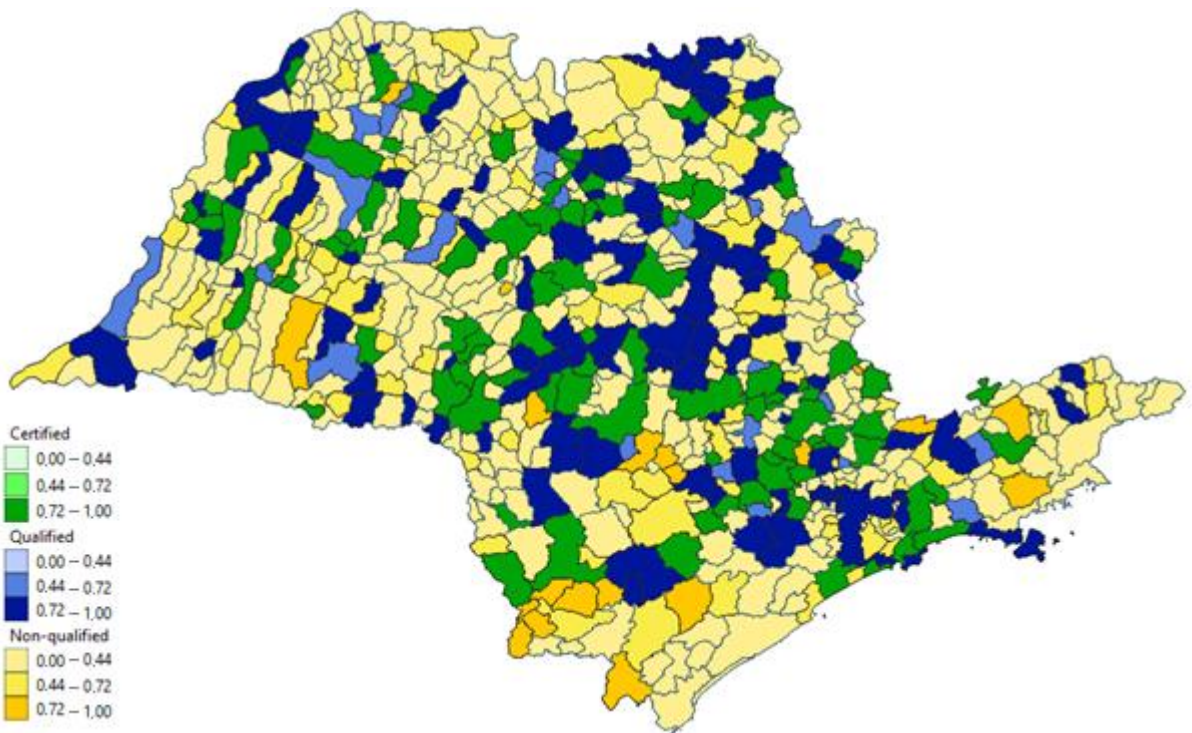


**Figure 7.** Sustainable Human Development Index.

Considering the geographical distribution of the municipalities in the index, the central and southeast regions of the state concentrate the municipalities with the highest values of the Sustainable Human Development Index. The west and northwest regions, on the other hand, present the highest concentration of municipalities with the lowest values in the index (Figure 7). Considering the two biggest metropolitan areas of São Paulo, it is interesting to note that from the 39 municipalities that comprise the São Paulo metropolitan area, only eight (21.51%) municipalities (Barueri, Guararema, Itaquaquecetuba, Mogi das Cruzes, Osasco, Santana de Parnaíba, São Paulo, and Suzano) are above the value of 0.72 in the developed index, and only Guararema, Mogi das Cruzes, and Osasco are certified by the PMVA. In the Campinas metropolitan area, on the other hand, from the 20 municipalities that comprise it, 12 (66.67%) municipalities (Americana, Campinas, Cosmópolis, Holambra, Hortolândia, Indaiatuba, Itatiba, Jaguariúna, Nova Odessa, Santa Bárbara d'Oeste, Santo Antônio de Posse, and Vinhedo) present values higher than 0.72 in the index, and only three of them are not certified, but qualified by the PMVA (Cosmópolis, Hortolândia, and Santo Antônio de Posse).

4.2.2. HDIm Analyses

Regarding the HDIm classification, the created groups are: low, medium, and high. The results of the Jonckheere–Terpstra test (Table 7) indicated that there were differences between the groups, with asymptotic significance (two-sided test) equal to 0.000 and, therefore, hypothesis 2 was accepted.

**Table 7.** HDIm independent-samples Jonckheere–Terpstra test for ordered alternatives summary.

| | |
|---|---|
| Total $n$ | 645 |
| Test Statistic | 80,188.000 |
| Standard Error | 2568.902 |
| Standardized Test Statistic | 4.224 |
| Asymptotic Sig. (2-sided test) | 0.000 |

In this way, the pairwise comparison represented in Table 8 demonstrates that the municipalities in the high HDIm group are different from the other HDIm groups. This indicates that when categorizing the municipalities according to their human development, municipalities that achieve a higher HDIm (above 0.753) ensure a certain level of environmental justice when compared to other municipalities. In this way, there might be a threshold point where a certain level of HDIm matches with better results in the proposed index, in such a way that the municipality may have surpassed basic barriers to development, such as low levels of education and health.

**Table 8.** Pairwise comparisons of Human_Development_Classification.

| Sample 1 vs. Sample 2 | Statistical Test | Std. Error | Std. Test Statistic | Sig. | Adj. Sig. [a] |
|---|---|---|---|---|---|
| Medium HDIm vs. Low HDIm | 21,228.500 | 1282.327 | −1.385 | 0.083 | 0.0249 |
| Medium HDIm vs. High HDIm | 29,978.500 | 1284.158 | 5.347 | 0.000 | 0.000 |
| Low HDIm vs. High HDIm | 28,981.000 | 1287.089 | 4.476 | 0.000 | 0.000 |

Each line tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same. Asymptotic significance (1-sided tests) is displayed. The significance level is 0.050. [a] The significance values were adjusted with Bonferroni correction for multiple tests.

The literature [18,21,65] presents cases of this threshold point of development for environmental performance in some countries, which may occur due to the level of priority given to different areas. Economic growth and political and social stabilization, for example, are usually preferred over environmental aspects.

The error bar graph (Figure 8) illustrates the difference between the performance of the municipalities when categorized for their human development. From the graph, it is possible to notice that there is a growing tendency toward the performance in the Sustainable Human Development Index from the increase in the human development of the municipality. It is also interesting to note that the differences between the mean values of the municipalities in the same group are higher than in the case of the groups from the PMVA classification (Figure 3). Municipalities in the same HDIm group presented scattered values related to the index.
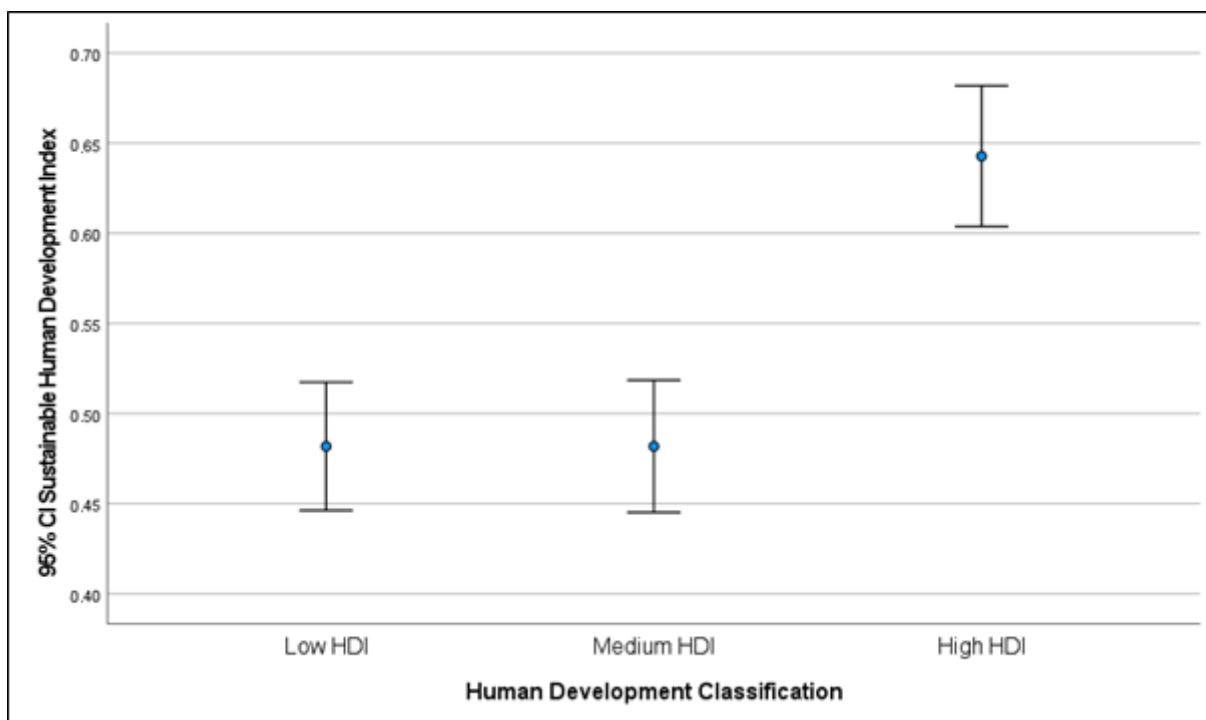


**Figure 8.** Error bar graph of the municipalities by classification of the HDIm.

Similar to some municipalities with a low level in the HDIm, as already mentioned, that presented good results in the Sustainable Human Development Index, other municipalities with high HDIm presented relatively low values in the index, such as São Caetano do Sul and Águas de São Pedro, which are the two municipalities with the highest HDIm in São Paulo, of 0.862 and 0.854, respectively, but that are only classified as non-qualified in the PMVA (37.11 EAI and 11.00 EAI, respectively). This resulted in low values in the proposed index: 0.679 (231st position) and 0.225 (574th position), respectively.

Municipalities that present good results in the index with low HDIm may be useful benchmarks for municipalities in a similar condition, and they can also be better analyzed by the PMVA. Special attention should be given to these municipalities with high HDIm but low performance in the index, in order to understand the reasons for the performance, for example, if it is due to lack of interest in the program or another specific difficulty in its implementation.

### 4.2.3. Urbanization Analyses

Considering the urbanization degree, the created groups are: rural, intermediate, and urban. The results of the Jonckheere–Terpstra test (Table 9) indicated that there were differences between the groups, with asymptotic significance (two-sided test) equal to 0.000 and, therefore, hypothesis 3 was accepted.

**Table 9.** Urbanization degree independent-samples Jonckheere–Terpstra test for ordered alternatives summary.

| | |
|---|---|
| Total *n* | 645 |
| Test Statistic | 71,630.000 |
| Standard Error | 2434.793 |
| Standardized Test Statistic | 5.208 |
| Asymptotic Sig. (2-sided test) | 0.000 |

In this way, the pairwise comparison represented in Table 10 demonstrates that urban municipalities are different from the other groups.

**Table 10.** Pairwise comparisons of urbanization degree.

| Sample 1 vs. Sample 2 | Statistical Test | Std. Error | Std. Test Statistic | Sig. | Adj. Sig. [a] |
|---|---|---|---|---|---|
| Intermediate vs. Rural | 6665.000 | 600.509 | −0.891 | 0.186 | 0.559 |
| Intermediate vs. Urban | 52,418.000 | 2010.023 | 5.482 | 0.000 | 0.000 |
| Rural vs. Urban | 12,547.000 | 836.602 | 2.626 | 0.004 | 0.013 |

Each line tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same. Asymptotic significance (1-sided tests) is displayed. The significance level is 0.050. [a] The significance values were adjusted with Bonferroni correction for multiple tests.

Considering the urbanization degree of the municipalities, it is noticeable that the ones considered urban have a better performance in the Sustainable Human Development Index, while the municipalities considered rural or intermediate did not present statistical differences between them (Figure 9). This result could be related to the different sets of opportunities and access to basic infrastructures that the urbanization process offers for sustainable human development, such as sanitation coverage and easier access to education and health facilities [66]. It is also possible that more urbanized municipalities have more infrastructural and technical capacities to develop more municipal environmental management actions.
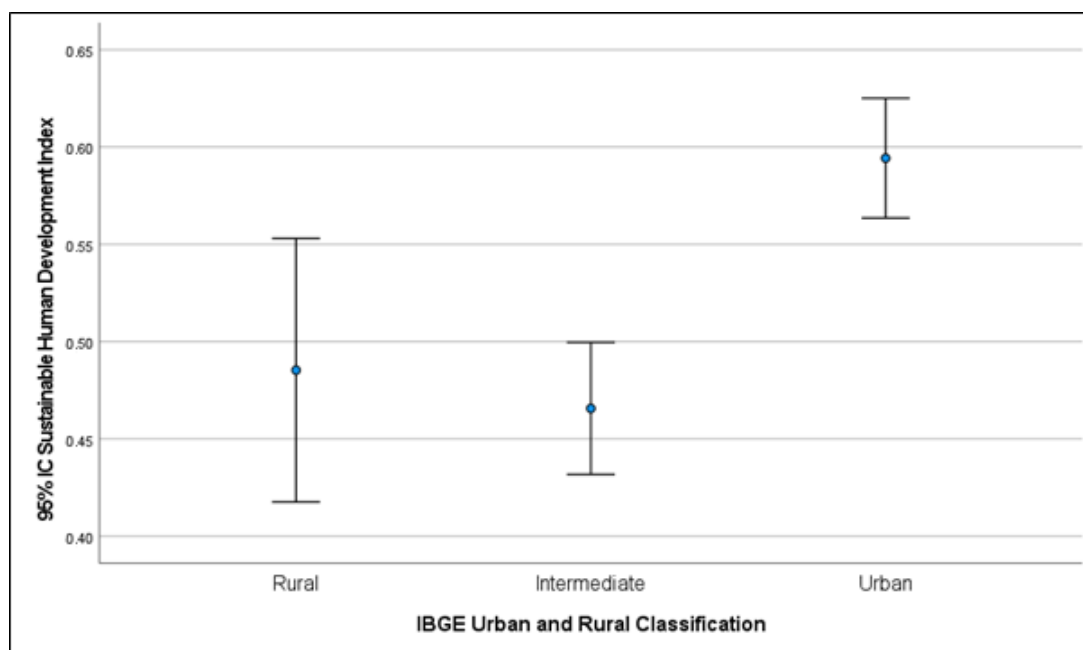


**Figure 9.** Error bar graph of the municipalities by urbanization degree.

Considering the classification of the municipality in the PMVA with its degree of urbanization, it is noticeable that municipalities with certification present similar values among the three degrees of urbanization. Regarding the qualified municipalities, the intermediate and urban municipalities present similar values, while the disproportion presented by the rural municipalities is due to the small sample of municipalities with this combination of features. An interesting aspect is that there is a difference among the non-qualified municipalities, as the rural ones have better performance in the index compared to non-qualified intermediate and urban municipalities (Figure 10).
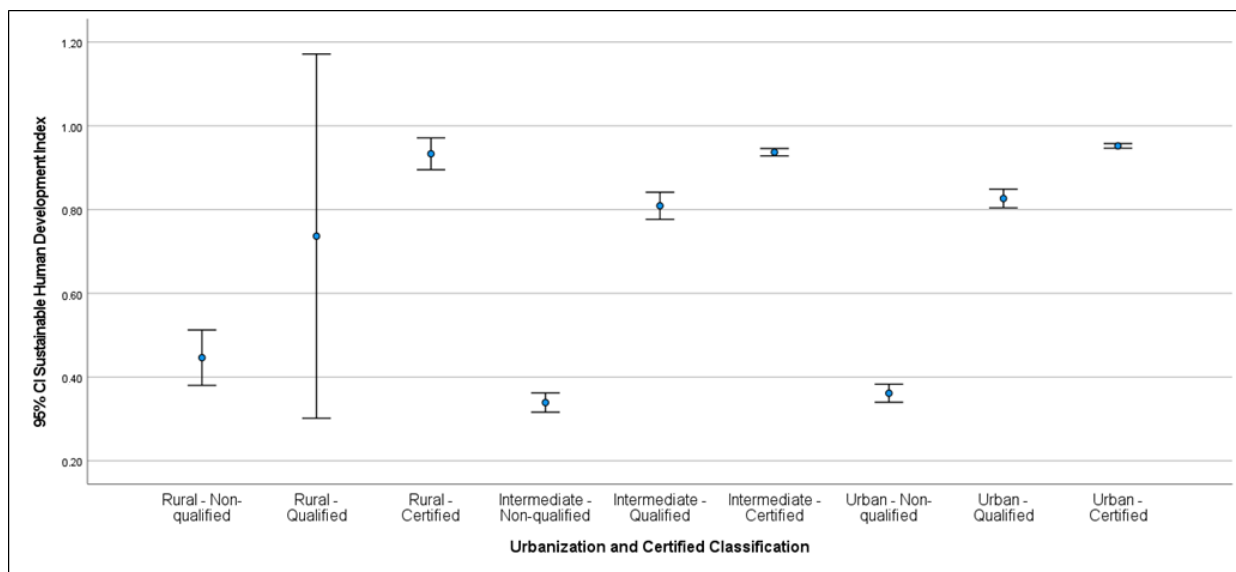


**Figure 10.** Error bar graph of the municipalities by degree of urbanization and classification of the PMVA.

### 4.2.4. Sectoral Economic Participation Analyses

Considering the sectoral economic participation, the created groups are: agriculture, industrial, and services. These results of the Jonckheere–Terpstra test (Table 11) indicated that there were differences between the groups, with asymptotic significance (two-sided test) equal to 0.001 and, therefore, hypothesis 4 was accepted.

**Table 11.** Sectoral participation in the economy independent-samples Jonckheere–Terpstra test for ordered alternatives summary.

| | |
|---|---|
| Total *n* | 645 |
| Test Statistic | 44,118.500 |
| Standard Error | 1958.866 |
| Standardized Test Statistic | 3.390 |
| Asymptotic Sig. (2-sided test) | 0.001 |

In this way, the pairwise comparison represented in Table 12 demonstrates that municipalities with higher participation of services in the economy are different from the other groups.

**Table 12.** Pairwise comparisons of sectoral economic participation.

| Sample 1 vs. Sample 2 | Statistical Test | Std. Error | Std. Test Statistic | Sig. | Adj. Sig. [a] |
|---|---|---|---|---|---|
| Industrial vs. Agriculture | 2278.500 | 231.965 | −0.136 | 0.446 | 1.000 |
| Industrial vs. Service | 16,589.500 | 1141.216 | 2.344 | 0.010 | 0.029 |
| Agriculture vs. Service | 25,250.500 | 1446.306 | 2.765 | 0.003 | 0.019 |

Each line tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same. Asymptotic significance (1-sided tests) is displayed. The significance level is 0.050. [a] The significance values were adjusted with Bonferroni correction for multiple tests.

Considering the main economic activity in each municipality, those that present higher participation of services in their economy presented better results in the Sustainable Human Development Index than the others. There were no statistical differences between municipalities with higher participation in agriculture and industry (Figure 11). These results could be related to the importance that the service sector may have in increasing economic growth, reducing poverty, and supporting job creation—including higher rates of women's employment [67].
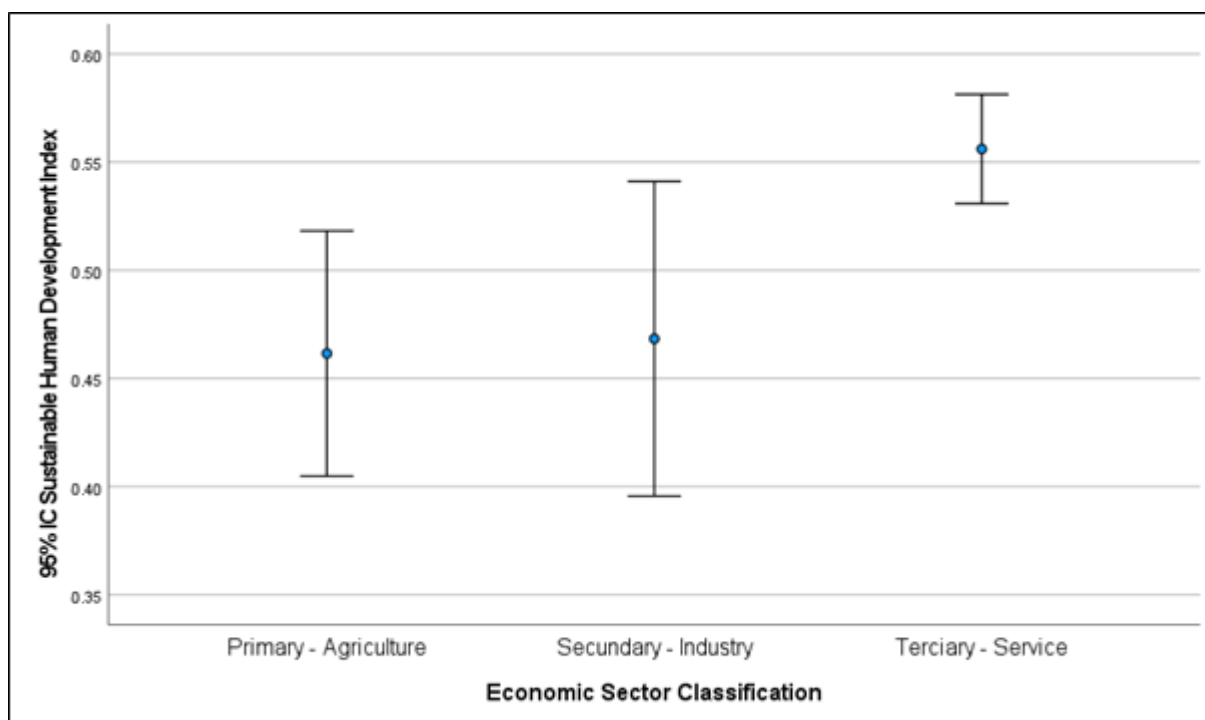


**Figure 11.** Error bar graph of the municipalities by sectoral economic participation.

**5. Conclusions**

This research presented the development of a sustainable human development index at a local level that portrays the idea presented in the research framework (Figure 1), that is, human development and municipal environmental management have a cyclical relationship. In this research, the index was developed using data from the HDIm and the PMVA, which are suitable for the Brazilian context. Other countries and regions can use the same method with specific data to cover human development and municipal environmental management—sustainable action—to develop an index suitable for their context.

The results found in this research indicate that municipalities with higher HDI levels obtained better results in the Sustainable Human Development Index. This may have occurred because the municipalities have reached a basic development level, from which more investments began to be made in the environmental area, such as in infrastructure. The results also indicate that more urbanized municipalities and with higher participation

of services in the economy presented a better performance in the index, which may be due to opportunities derived from urbanization and the higher maturity level required for a service economy. It is important to highlight that these considerations are related to the environmental aspects considered in this research, and other environmental elements need to be carefully analyzed; Polloni-Silva et al. [68], for example, found that the service sector is related to considerable $CO_2$ emissions in São Paulo.

In the results, we also identified differences between the three levels of classification in the PMVA, where certified municipalities tend to show better results than qualified and non-qualified ones. Future studies can analyze whether the fact that a municipality obtains a good sustainability index (or PMVA certification) provides some positive effect on neighboring municipalities.

For environmental justice, when considering that the PMVA certification depends on the score achieved by the municipalities, and that this achievement results in the preference for obtaining resources from the state Secretary of the Environment, it is important to understand if the municipalities that do not achieve this score are not interested in the program or if they do not have sufficient resources to do so. The results of the proposed index indicate that municipalities with high HDIm have the best performances, that is, the municipalities with better levels of human development would receive more resources to improve their environmental performance. Meanehile, the municipalities with fewer resources and lower HDIm—which most need these resources [61]—would continue to face difficulties to develop environmentally and, consequently, improve their HDIm.

The PMVA is an important initiative of the state of São Paulo, unique in Brazil, however, there is still space and opportunity for improvement. The program itself has undergone constant improvement processes. Thus, it is expected that this research can also contribute to the development of the program and others that may arise in other Brazilian states and in other countries. Therefore, it is believed that the contributions of this research are important from an academic and practical point of view. Another positive point is the incorporation of the environmental justice aspect, since, as indicated by Agyeman, Bullard, and Evans [28], many sustainability policies are implemented without incorporating this aspect.

Some limitations of this study are expected to open multiple avenues for future research. First, we proceeded with an empirical analysis by using secondary data. However, this study did not present a detailed analysis of case studies. In this sense, future research might incorporate some relevant case studies to explain the rank position of our indicator. Second, we did not explain the determinants of DEA scores, which is relevant to reveal how regions might increase sustainable human development. Future studies might use econometric models to understand which variables explain DEA scores. Third, we did not use financial resources as inputs in our analysis, which did not consider aspects of social and eco-efficiency. New studies can investigate new DEA rankings considering financial aspects to sustainable human development. Fourth, we considered regions in São Paulo. However, Brazil is a vast and heterogeneous country that allocates important areas for the environment (i.e., Amazonia). For this reason, we encourage future studies to apply our indicator to the whole Brazilian territory.

Finally, it is important to highlight the voluntary nature of the PMVA, so that all municipalities that obtained low values in the index do not necessarily present low sustainability aspects. However, this does not influence the proposal of the index combining human development and environmental management at the municipality level. Moreover, these results can support the improvement of this type of environmental management program, aiming to increase the participation of the municipalities and consequently their levels of sustainability.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/infrastructures7020012/s1, Table S1: Complete ranking of the Sustainable Human Development Index.

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