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Papers

Urban Sustainable Development Index: a geospatial approach to add Tree Cover to HDI in São Paulo City

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Abstract
Human Development Index (HDI) has become an important tool to measure the basics aspects of human quality of living, being based on educational, economic and longevity dimensions. Over the years, criticism about the absence of an environmental dimension has emerged together with the need for knowledge about sustainable development at a local scale. For these reasons, this paper proposes a new approach for HDI, the Urban Sustainable Development Index (USDI), adding a Tree Cover indicator based on the most accepted criteria of 30% of tree cover to provide high quality of life and kept the balance between the other three dimensions of HDI. The normalized and weighted proposed index showed to be a promising alternative to complement existing sustainable indices impractical at local scale, mainly because they are based on carbon emission measurements. A Tree Cover indicator is more comprehensive, assessing greenhouse gases sequestration, heat islands attenuation, flora preservation, sustenance of fauna habitat, mitigation of extreme weather events and maintenance of water resources and soil stability. The case study in São Paulo city indicated that the transition from HDI to USDI resulted in a negative variation of almost 0.12, mostly in city central regions, and an increase up to 0.08 in peripherical regions - revealing how powerful can be geospatial analysis at a local scale, considering that USDI differs from the spatial distribution of HDI, valuing the importance of a sustainable urban index.

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INTRODUCTION

The Human Development Index (HDI) was first published in 1990, along with the Human Development Report published by the World Health Organization (WHO). Its objective was to measure national development in a more realistic way than the heretofore traditional Gross National Income (GNI) (CARVALHAL MONTEIRO et al., 2018). HDI is composed of three main dimensions – longevity, education and economy – then, indicating overall human development and quality of living (UNDP, 2020).

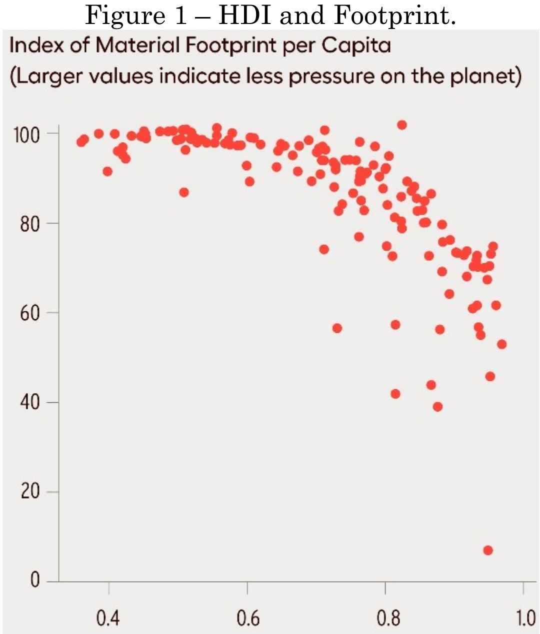
According to UNDP (2013), each dimension is based on normalized indicators and the geometric mean between these indicators results in HDI. In short, longevity is measured by the indicator of life expectancy at birth, education by expected and mean years of schooling and economy by GNI per capita (UNDP, 2013).

Although HDI is strongly widespread around the world, some criticism has emerged about the limitations of its three dimensions (ALKIRE, 2002). As a result of that, some studies have proposed alternative methodologies to measure human development, varying since the dimensions or indicators comprised, to the calculation method. Noorbakhsh (1998), for example, developed a modified HDI including infant survival rate, Hatefi and Torabi (2010) constructed a model based on weights and Do Carvalhal Monteiro et al. (2018) suggested a multicriteria way to calculate HDI instead of geometric mean.

Recently, most criticism refers to the absence of an ecological or environmental dimension, arising a discussion about the evaluation of a sustainable development, even before some authors do not specifically refer to the terminology sustainability (SAGAR; NAJAM, 1998; MORSE, 2003; HATEFI; TORABI, 2010; BLUSZCZ, 2015).

In practice, environmental factors are likely to impact quality of life and human development, mainly considering global warming, water crises and sanitation conditions (UNDP, 2006). However, countries which wield greater pressure on the planet are the ones with higher values of HDI (Figure 1), emphasizing why the fact of HDI to exclude sustainable behaviour is averse to quality of life assumptions (HICKEL, 2020).

Figure 1 – HDI and Footprint.



Source: UNDP (2020).

Despite this fact, according to Bellen (2004), the most widespread sustainability measurement methodologies are, in sequence, Ecological Footprint, Dashboard of Sustainability, Barometer of Sustainability and HDI – even HDI does not consider exactly an environmental indicator; only longevity, education and economy.

In 2011, the Human Sustainable Development Index (HSDI) has been proposed as a way to amend HDI by adding an environmental dimension. The indicator chosen to compose HSDI was CO_2 emissions per capita

(TOGTOKH; GAFFNEY, 2010). Assa (2021) warns of the efforts to create a 'green' HDI by adding new indicators, arguing with the possibility of change its functional form by converting commodities into capabilities. More recently, Hickel (2020) proposes the Sustainable Development Index (SDI), considering CO_2 emissions and material footprint, however, studies have indicated that SDI is suitable as an index of sustainability, but limited in terms of human development (ASSA, 2021).

In fact, as the proposed HSDI and SDI require values of CO_2 emissions, it seems to be more applicable at national scales or, in some cases, at city level. In the context of sub-city scale, such as districts, obtaining CO_2 emissions locally it is impracticable. Consequently, the desired scale can influence the viability of one or another index, mainly due to the indicators used.

Scale is also relevant in terms of HDI. The most traditional scale of HDI is national, however, in countries with continental magnitude, such as Brazil, HDI can vary too much and a national mean can generalize extreme conditions – for example, the 50^{th} most developed cities in Brazil have HDI over 0.75 and the 50^{th} less developed ones have HDI under 0.30 (UNDP, et al. 2013). Similarly, other indexes are expected to vary widely as well.

The importance of the measurement of indexes at local scale is justified by the opportunity of subsiding public decision-makers and urban planners to organize urban areas, once their actions also reflect directly on human and sustainable development. This fact is especially relevant considering that the world populations has becoming more urban (SAPENA, 2021).

Regarding to urban areas, tree cover is frequently related to human well-being once they provide landscape harmony, spaces for leisure and physical activity for population, shading for pedestrians and cyclists, fauna support, microclimatic stability, surface runoff rainwater mitigation and maintenance of air quality (DA SILVA et al., 2016; SCHEUER, 2016; ANJALI et al., 2020).

The WHO advises a minimum of $9m^2$ of green area per capita in the urban area (RUSSO; CIRELL, 2018). Oke (1973) estimates that a percentage of tree cover (PTC) around 30% is recommended to provide an improvement in the thermal sensation in urban areas. Agreeing with this author, the parameters determined by the WHO also indicates 30% of PTC as suitable for providing a high quality of living (Table 1).

Table 1 – PTC and quality of living (WHO).

QUALITY OF LIVING	PTC	CONDITION
Good	PTC ≥ 30%	Residents in areas with sufficient vegetation cover to ensure a high quality of life
Regular	5% < PTC < 30%	Residents in areas with sufficient vegetation cover to ensure a reasonable quality of life
Bad	PTC ≤ 5%	Residents in areas with sufficient vegetation cover to ensure a limited quality of life

Source: Adapted from Silva (2016).

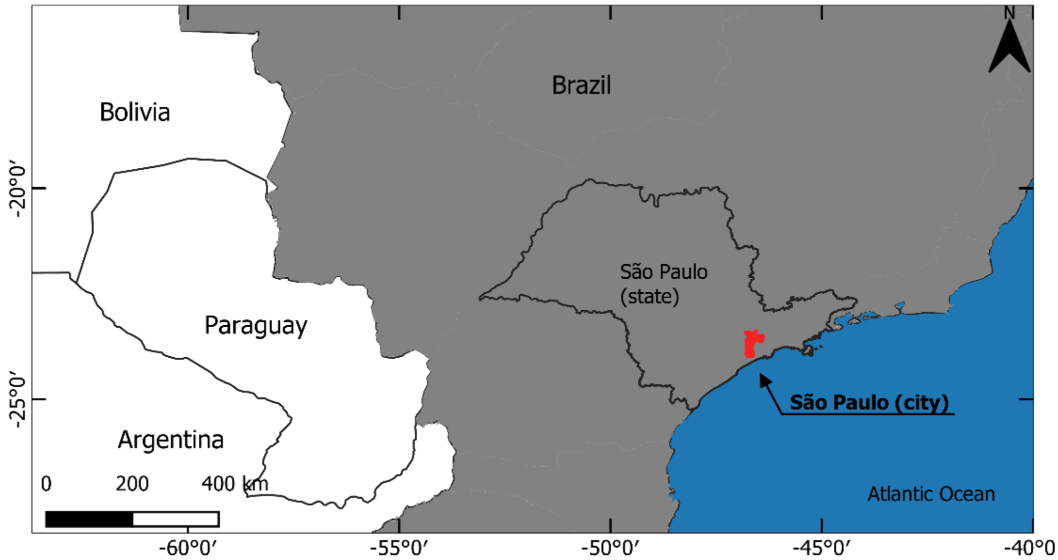
All considered, the main objective of this paper is to propose an alternative approach to the traditional HDI calculation, by adding an environmental dimension based on PTC. In this paper, the method called Urban Sustainable Development Index (USDI) was developed in a way to access sustainable development on a local scale, focusing on urban areas. The sustainable terminology was chosen due to the fact that the original dimensions of the HDI, which comprise economy and society, remained, and an environmental dimension relevant to the urban scenario was added. Also, aiming to allow a comparison between the new approach and the traditional HDI, a study case was conducted in the city of São Paulo, in Brazil.

METHODOLOGICAL PROCEDURE

Study Area Characterization

São Paulo is a city located in south-eastern Brazil (Figure 2), being the most populous capital of the country with an estimated population of 12.325.232 million and a demographic density of 8,102.79 people/km² (IBGE, 2020). The average City HDI (or HDI by city) is about 0.805, similar to cities such as Philadelphia and Dallas (U.S.) (AGOSTINI; RICHARDSON, 2003). However, it is worth mentioning that the São Paulo average HDI does not reflect its entire reality, once the values per sub-city halls range from 0.680 to 0.968 (SÃO PAULO, 2020)

Figure 2 – São Paulo city location.



Source: The authors (2021).

As a result of the urbanization process in Brazilian cities, São Paulo is considerably scarce in urban afforestation.

Between 1985 and 2020, there was a 13.39% growth in non-vegetated areas occupied by urbanization, being recorded an accumulation of 3,759 ha in the amount of vegetation suppressed in the period between 1987 and 2019. (MAPBIOMAS PROJECT, 2020).

Despite these numbers, the percentage of tree cover in São Paulo city is 48.18%: located in green areas generally attached to urban rivers, distributed between the city's 108 urban parks and among 74,8% tree-lined sidewalks (IBGE, 2010).

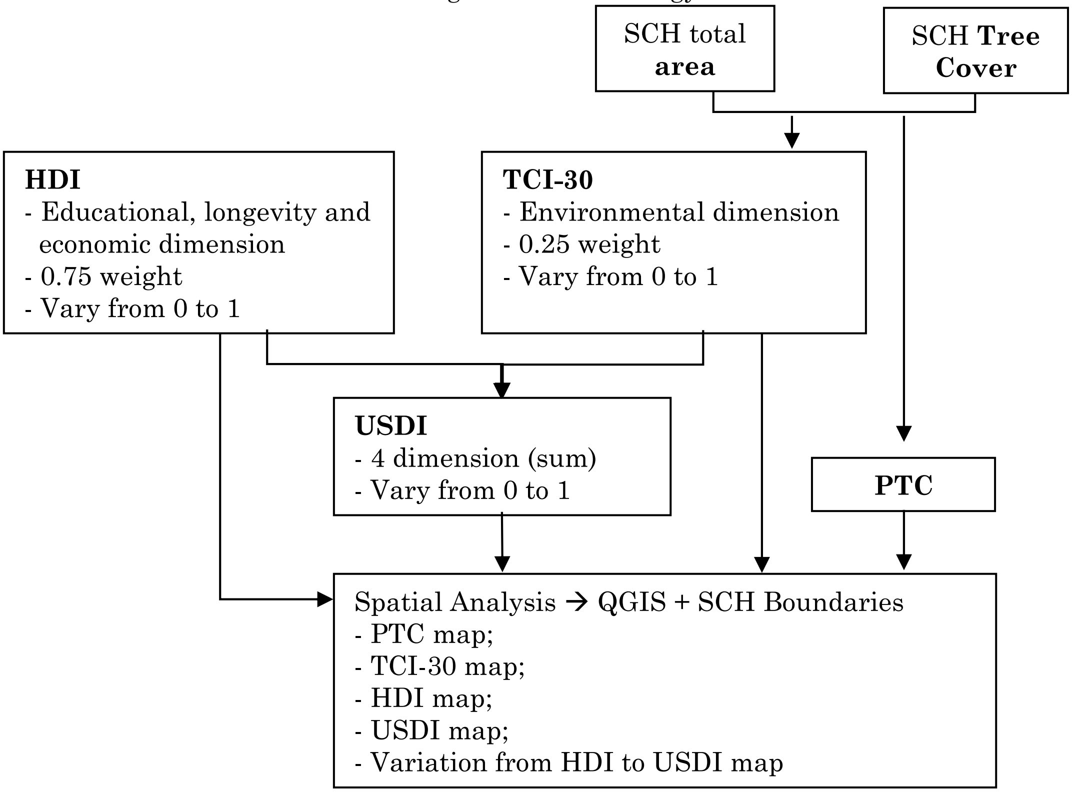
However, this percentage can be misleading once almost half urban canopy percentage (21.59%) is located in a single sub-city hall, Palheiros, where environmental reserves are located (SÃO PAULO, 2020). On the other hand, there several are sub-city halls with less than 0.1% of the city tree cover percentage, emphasizing the imbalance of distribution which has impacts on the population's quality of life, consequently, affecting HDI in each place. The unbalanced distribution of green areas also justifies the importance of a sustainability index on a regional scale.

Materials and Methods

The following flowchart (Figure 3) summarizes the overall methodological procedure adopted during this work.

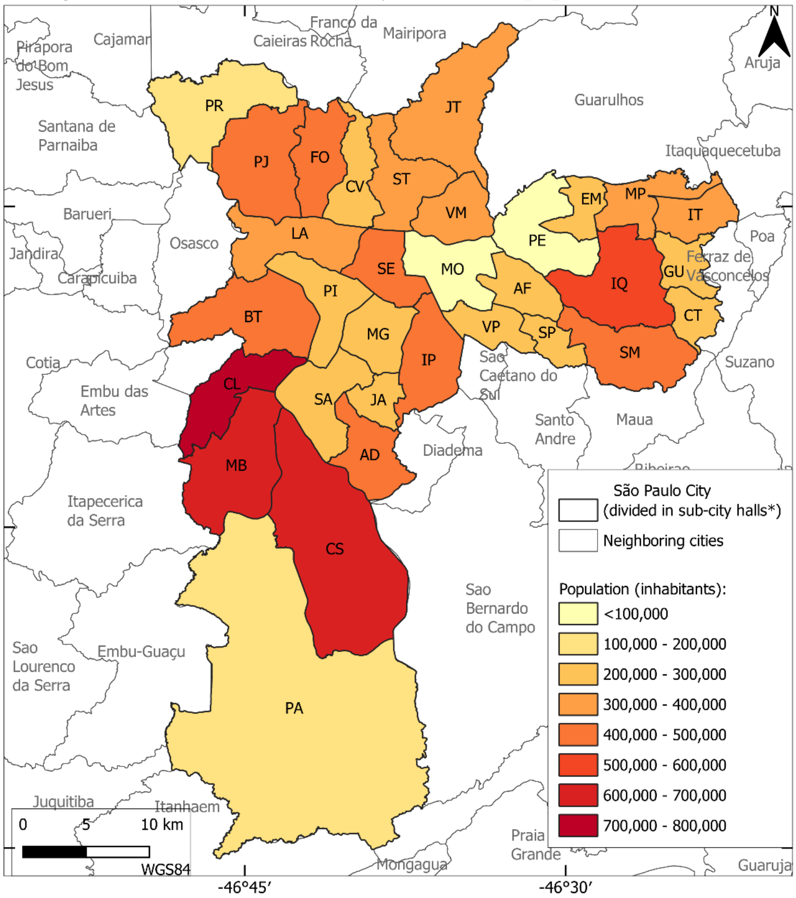
First step was to adopt a territorial unit in order to perform analysis. The 32 administrative units of São Paulo, called the sub-city halls (SCHs), were chosen for this work – SCHs are equivalent to districts. Their location and population strata are identified in Figure 4.

Figure 3 -Methodology flowchart.



Source: The authors (2021).

Figure 4 – São Paulo sub-city halls and population strata.



*Sub-city halls are designed by their acronyms, described in Table 2.
Source: The authors (2021).

SCH boundaries (shapefiles file format) and their respective population number were obtained from Brazilian census database made available by the Brazilian Institute of Geography and Statistics (IBGE, 2010). Data referring to tree cover area were obtained from an official government report, based on LiDAR imaging data (SÃO PAULO, 2020). Then, considering each SCH total area and its respective vegetation cover area, Percentage of Tree Cover (PTC) was calculated. HDI values were gathered from the Atlas of Human Development in Brazil (UNDP et al., 2013). Table 2 identifies the SCHs ID – as illustrated in Figure 4 – and their respective names, population number, values of total area, tree cover area and HDI.

Table 2 – Sub-city halls information (name, population, area, tree cover and HDI).

ID	SCH	ESTIMATED POPULATION (2019)	TOTAL AREA (KM²)	TREE COVER AREA (KM²)	HDI
AD	Cidade Ademar	434673	30.67	7.54	0.758
AF	Aricanduva-Formosa-Carrão	259284	22.34	2.71	0.822
BT	Butantã	465503	56.41	21.64	0.859
CL	Campo Limpo	708435	36.68	9.69	0.783
CS	Capela do Socorro	602292	132.64	62.49	0.750
CT	Cidade Tiradentes	223802	14.94	6.45	0.708
CV	Casa Verde-Cachoeirinha	294928	27.21	8.41	0.799
EM	Ermelino Matarazzo	202724	15.99	2.87	0.777
FO	Freguesia-Brasilândia	406586	32.10	12.95	0.762
GU	Guaianases	269853	17.76	4.01	0.713
IP	Ipiranga	479317	37.59	9.36	0.824
IQ	Itaquera	537855	55.10	21.70	0.758
IT	Itaim Paulista	372231	21.61	2.55	0.725
JA	Jabaquara	224446	14.01	2.18	0.816
JT	Jaçanã-Tremembé	318422	65.33	44.73	0.768
LA	Lapa	331765	40.57	8.47	0.906
MB	M'Boi Mirim	621915	63.46	21.96	0.716
MG	Vila Maria-Vila Guilherme	282126	26.90	3.15	0.793
MO	Mooca	36768	36.05	4.35	0.869
MP	São Miguel	348709	26.06	4.93	0.736
PA	Parelheiros	165245	360.81	329.86	0.680
PE	Penha	45681	43.36	9.80	0.804
PI	Pinheiros	295753	31.99	9.07	0.942
PJ	Pirituba-Jaraguá	471301	55.34	26.05	0.787
PR	Perus	189657	57.21	43.31	0.731
SA	Santo Amaro	248739	37.76	11.09	0.909
SE	Sé	473798	26.67	4.39	0.889
SM	São Mateus	458179	45.48	17.28	0.732
SP	Sapopemba	276228	13.63	1.44	0.786
ST	Santana-Tucuruvi	311446	35.78	12.99	0.968
VM	Vila Mariana	362684	26.99	6.12	0.938
VP	Vila Prudente	242228	19.26	2.46	0.785

Source: The authors (2021).

As the main objective of this work is to add an environmental dimension to HDI, a model to complement this index with PTC was proposed. In order to do that, as described in introduction section, a 30% of PTC was adopted as the ideal value. Then, equitably to HDI scale, to sub-city halls with 30% or more PTC were attributed value 1, composing what was called TCI-30 (Tree Cover Indicator relatively to 30% of the area). Thenceforth, proportionally, PTC values were converted to TCI-30, by doing:

$$\boldsymbol{TCI\_30} = \frac{\textbf{Tree Cover Area}}{\textbf{0.3} \times \textbf{Total Area}} \qquad \text{(Eq. 1)}$$

For example, if a sub-city hall has 15% of PTC, its TCI-30 is 0.5; and so on.

Consequently, similarly to HDI, TCI-30 ranges from 0 to 1, being the closer to 1, the better. Considering that HDI is already composed of 3 dimensions (longevity, education and income), TCI-30 was added to HDI with a 0.25 weight (1 of 4) composing the proposed Urban Sustainable Development Index (USDI), through:

$$\boldsymbol{USDI} = \frac{\textbf{0.75}\times\textbf{HDI}}{\textbf{0.25} \times \textbf{TCI\_30}} \qquad \text{(Eq. 2)}$$

Data referring to PTC, TCI-30, HDI and USDI for each SCH were then associated with their respective boundary (shapefile) as an attribute table in QGIS. In order to allow an investigation regarding to the spatial relationship between them, maps applying corresponding symbologies (color scheme) were elaborated: PTC and TCI-30; and HDI and USDI. Also, a map representing the transition from HDI to USDI was composed using the field calculator tool in order to calculate:

$$\boldsymbol{Variation} = \boldsymbol{USDI} - \boldsymbol{HDI} \qquad \text{(Eq. 3)}$$

RESULTS AND DISCUSSION

The main goal in designing the Urban Sustainable Development Index is to use the base logic of the HDI, nonetheless, considering an extension of that to include an environmental dimension. This proposal meets the most widespread concept of sustainability, based on social, economic and environmental pillars (BLACKBURN, 2007; MIKULČIĆ; DUIĆ; DEWIL, 2017).

Table 3 identifies the SCH ID as indicated in Figure 4 and their respective calculated values of PTC, TCI-30 and USDI.

Considering that HDI measures standard of living (UNDP, 2020), comparing it with PTC values directly is not really accurate – because the assumption of PTC equals to 100% being equivalent to 1 does not reflect an ideal setting. This fact justifies the need for TCI-30 composition, as a way to allow its comparison with HDI and enable USDI composition. Then, a 30% of tree cover or higher was considered equivalent to 1, in other words, suitable for a greater quality of life (SILVA, 2016).

Table 3 – Results of PTC, TCI-30 and USDI of Sub-city halls.

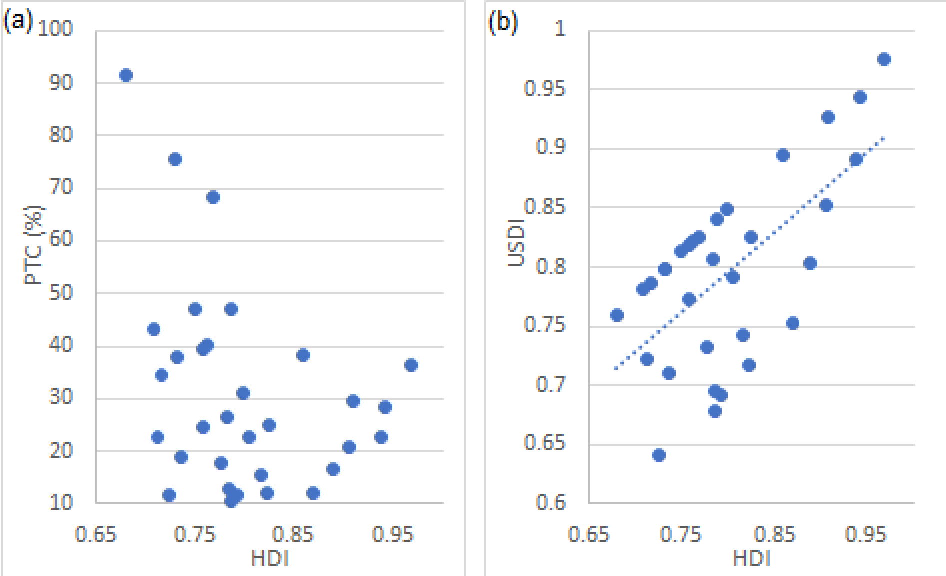
ID	SUB-CITY HALLS	PTC	TCI-30	USDI
AD	Cidade Ademar	24.58	0.819	0.773
AF	Aricanduva-Formosa-Carrão	12.13	0.404	0.718
BT	Butantã	38.36	1.000	0.894
CL	Campo Limpo	26.42	0.881	0.807
CS	Capela do Socorro	47.11	1.000	0.813
CT	Cidade Tiradentes	43.17	1.000	0.781
CV	Casa Verde-Cachoeirinha	30.91	1.000	0.849
EM	Ermelino Matarazzo	17.95	0.598	0.732
FO	Freguesia-Brasilândia	40.34	1.000	0.822
GU	Guaianases	22.58	0.753	0.723
IP	Ipiranga	24.90	0.830	0.826
IQ	Itaquera	39.38	1.000	0.819
IT	Itaim Paulista	11.80	0.393	0.642
JA	Jabaquara	15.56	0.519	0.742
JT	Jaçanã-Tremembé	68.47	1.000	0.826
LA	Lapa	20.88	0.696	0.853
MB	M'Boi Mirim	34.60	1.000	0.787
MG	Vila Maria-Vila Guilherme	11.71	0.390	0.692
MO	Mooca	12.07	0.402	0.752
MP	São Miguel	18.92	0.631	0.710
PA	Parelheiros	91.42	1.000	0.760
PE	Penha	22.60	0.753	0.791
PI	Pinheiros	28.35	0.945	0.943
PJ	Pirituba-Jaraguá	47.07	1.000	0.840
PR	Perus	75.70	1.000	0.798
SA	Santo Amaro	29.37	0.979	0.926
SE	Sé	16.46	0.549	0.804
SM	São Mateus	37.99	1.000	0.799
SP	Sapopemba	10.56	0.352	0.678
ST	Santana-Tucuruvi	36.31	1.000	0.976
VM	Vila Mariana	22.68	0.756	0.892
VP	Vila Prudente	12.77	0.426	0.695

Source: The authors (2021).

Thereafter, it is possible to analyses TCI-30 and HDI, however, HDI still does not reflect the impact of environment quality on levels of social and economic development. For this reason, the proposed USDI seems to be an opportunity for including some dimension of environmental context, resulting in a sustainable index. As a result of that, USDI is a four-dimension index, being composed of 3 dimensions prevenient from HDI, being assigned weight 3, and 1 dimension from TCI-30, being assigned a proportional weight of 1.

In addition, there is no perceptive relation or evident pattern between PTC and HDI (Figure 5a). On the other hand, when PTC is assimilated in a normalized and weighted way, though UDSI, it is possible to emphasize some level of linear relation between HDI and the developed index (Figure 5b).

Figure 5 – São Paulo sub-city halls values of PTC and USDI.



Source: The authors (2021).

As retrieved in the introduction section, tree cover has an important role in urban areas, exceeding the limits of carbon emissions and material footprint (DA SILVA et al., 2016; SCHEUER, 2016; ANJALI; et al., 2020). An intermediate alternative could include them, nevertheless, data specifically related to each SCHs were not available and the adoption of the entire city values would affect USDI equally, generalizing the results to the desired scale. Consequently, TCI-30, representing PTC, was prioritized.

Despite that, tree cover indicator still ponders several environmental aspects: carbon sequestration, habitat provision for fauna and flora conservation. In addition, for a large number of cities around the world extreme weather events, such as floods and droughts, are recurrent problems (BURNETT et al., 2021; TIAN; ZHONGWEI; ZHEN, 2021). In this sense, vegetated surfaces aggregate a significant amount of permeable areas, contributing to the interception and infiltration of rainwater and to the maintenance of water resources quality/quantity and soil stability.

In the case of urban centers, environmental aspects related to mobility – and its fuel sources – and energy usage can also impact in sustainability. Regarding to that, tree cover acts in greenhouse gases attenuation and heat island reduction. Furthermore, the presence of trees encourages active mobility, reducing carbon emission, and reduces energy consumption for indoor cooling. Thus, TCI-30 is able to incorporate these aspects too.

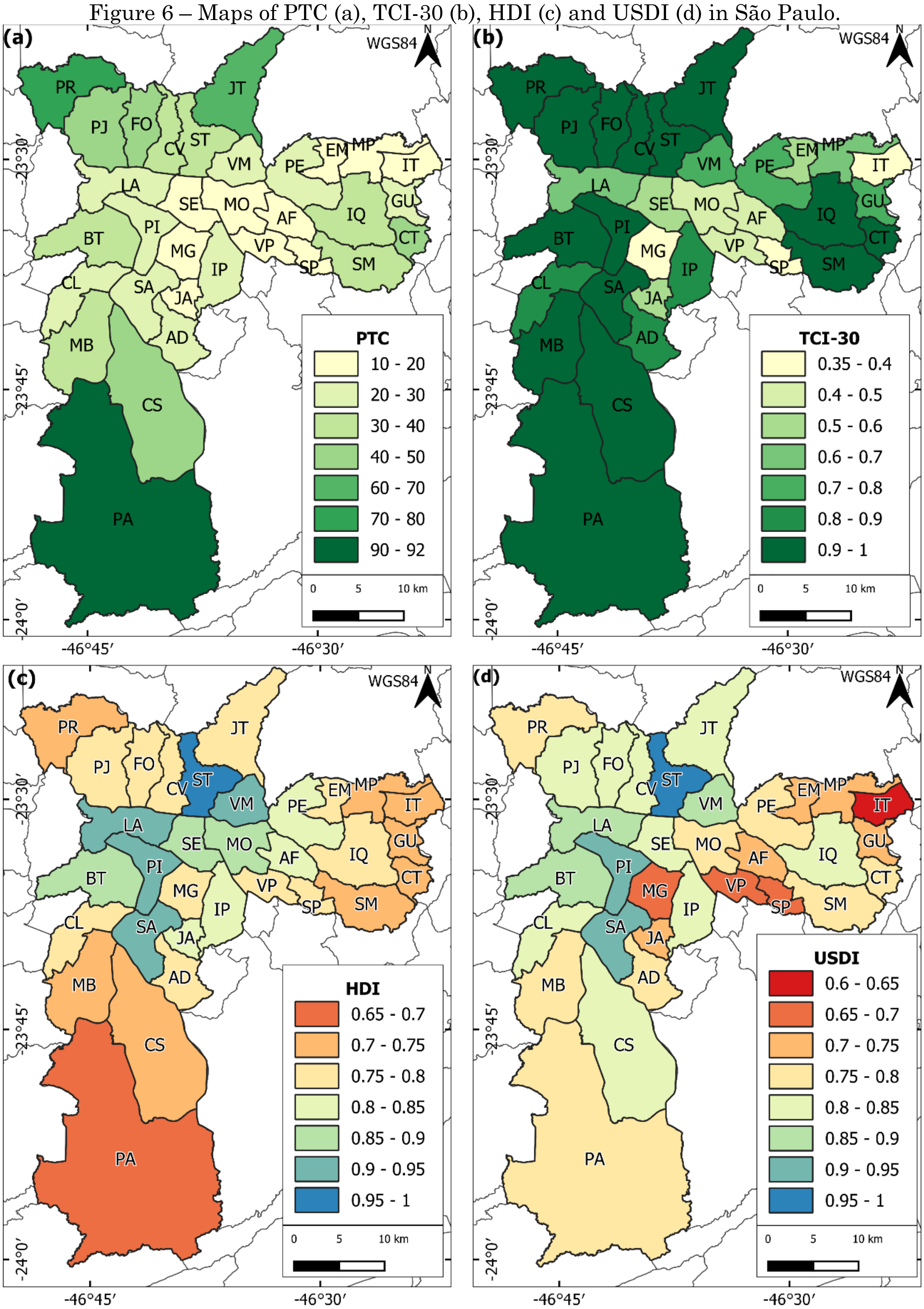
Besides environmental aspects, also as mentioned in the introduction section, the presence of urban green areas also access some aspects of society, including overall quality of life established by percentage of Tree Cover according to the WHO, access to leisure and exercise-friendly areas. From an economic perspective, some effects can be mentioned regarding to real estate speculation, job creation related to green areas management and promotion of local businesses.

Worth mentioning that, in a first moment, the inclusion of subjective indicators, such as happiness, were analysed. However, this option was discarded due to the relative nature of this indicator – "*the best possible life imaginable by someone in the UK is not comparable to the best possible life imaginable by someone in Bangladesh*" (HICKEL, 2020).

In addition to all these justifications for the incorporation of tree cover as an environmental indicator of HDI one, another important aspect can be mentioned. Considering the aerial imaging and remote sensing technologies currently available, obtaining vegetation cover data can be considered more accurate and attainable at local scale than measuring carbon emissions, for example. This happen because Tree Cover can be estimated directly from satellite data (GASPAROVIC; DOBRINIC, 2021), with spatial precision of the order of centimetres – or a few meters for free images. On the other hand, carbon emissions have been accurately quantified at a global scale while showing a discrepancy of up to 20% in case of national and regional measures (DUREN; MILLER, 2012).

All these aspects considered, the next analyses will focus on the case study developed in the city of São Paulo. To do that, understanding the spatial distribution of a phenomena is an important tool to support knowledge (DRUCK et al., 2004). Thus, the produced maps (Figure 6) can help to investigate the relationship between HDI and tree cover in different regions of São Paulo, and then evaluate how much the proposed index reaches the goal of representing real conditions for human development in a sustainable urban environment.

Figure 6 – Maps of PTC (a), TCI-30 (b), HDI (c) and USDI (d) in São Paulo.



Source: The authors (2021).

Then, the PTC map (Figure 6a) shows that PTC is higher in most peripheral locations whereas central areas are most deficient in this aspect. Looking into Figure 6c, which illustrates HDI, the opposite ensued: most promising HDI values occurs in central locations, while the lowest values are located in peripheral areas. TCI-30 spatial distribution (Figure 6b) indicates that 15 of the 32 SCHs have an adequate amount of tree cover – most of them located in city border locations. This is a result of the intense impermeabilization and densification of the city central areas. Lastly, the results of USDI final calculation are shown in Figure 6d.

HDI, TCI-30 and USDI averages are very similar, 0.80, 0.78 and 0.79 respectively. However, by analyzing the values of each SCH, the importance of local-scale investigation is highlighted, mainly in large cities where development occurs differently and inequality is a strong characteristic – as in Brazil, where inequality has reached extreme levels, despite being one of the largest economies in the world (GÓES; KARPOWICZ, 2017).

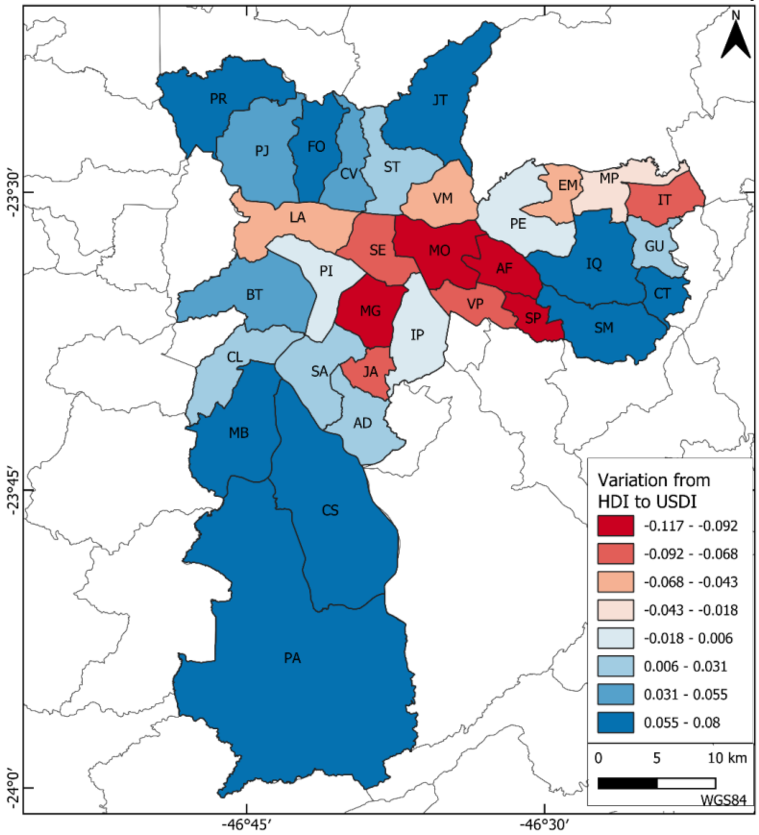
A comparison between Figures 6c and 6d evidences the influence of tree cover in the USDI. Considering all locations, 8 SCHs remained at the same level of development index (AD, BT, GU, IP, MP, PI, SA and ST); 12 SCHs have benefited from the addition of the environmental dimension (CL, CS, CT, CV, FO, IQ, JT, MB, PA, PJ, PR and SM); and 12 SCHs have their development index value decreased (AF, EM, IT, JA, LA, MG, MO, PQ, SE, SP, VM and VP).

These changes in the level of indexes can be an indication that HDI, by not including an environmental dimension, results in a false perception of reality, since human development does not occur without a habitat context. Taking for example the SCH PA which has PTC over 90%, the incorporation of TCI-30 culminates in a change of human development level, from HDI between 0.65 and 0.70 to USDI between 0.75 and 0.80. Without the normalized index TCI-30, PTC would increase USDI exaggeratedly, compromising the index effectivity.

Another interesting fact is that the transition from HDI to USDI reflected in the worsening of the situation when referred to most extreme values, both biggest and smallest. There is only 1 SCH with HDI under 0.70 and there are 4 USDI under this value. In the same way, there are 5 SCHs with HDI over 0.90, while there are only 3 USDI over this value.

The incorporation of PTC resulted in an average reduction of 0.004 in HDI values, however, the average does not represent the reality in all sub-city halls. In order to provide a better understanding of changes, Figure 7 illustrates the spatial variation of the increase and decrease in quality of life index, from HDI to USDI.

Figure 7 – Variation from HDI to USDI values in São Paulo sub-city halls.



Source: The authors (2021).

Through this figure can be attested that index values decreased predominantly in central locations, while in peripheral locations those values tended to increase. This fact is a direct result of the lower percentages of urban green areas in central regions – and higher percentages in peripherical areas – elucidating the need and importance of including environmental variables in the assessment of quality of life (not necessarily, but alternatively, PTC).

In this sense, PTC has proved to be effective at local scales, once there is no available CO_2 measurements or material footprint for Sub-city halls in São Paulo. The official – and most recent – inventory of anthropogenic emissions of greenhouse gases includes CO_2 emissions by economic sectors and services, not discriminating sub-city indicators (INSTITUTO EKOS BRASIL; GEOKLOCK CONSULTORIA E ENGENHARIA AMBIENTAL, 2013).

At first, the changes in HDI – when converted to USDI – and the spatial detailing of the information may not seem relevant, however, they impact thousands of people and can better drive decision-making in each location. For example, the 0.083 reduction in the SCH IT index affects almost 400,000 people and should indicate to local public managers the need for actions aimed at environmental-urban planning.

FINAL CONSIDERATIONS

Regarding the dimensions of the HDI, it is a fact that education and longevity are social indicators, framing into sustainability premises. However, HDI fails in adding the economic dimension without including the environmental one, assuming the erroneous idea of infinite economic growth, without acknowledging limitations imposed by the availability of environmental resources and ecosystem services. In this way, the USDI composed presents itself as an alternative to balance this approach.

After all, the USDI proposals of including an environmental dimension to HDI was achieved by including PTC, completing the three pillars of sustainability. The normalized method established to do that, TCI-30, agrees to the most accepted criteria of 30% of tree cover as suitable to provide a high quality of living. Also, the option for 25% weight to join HDI considered the already existing three dimensions of it.

Despite there are other sustainable indices among literature, most are based on carbon emission, making it difficult to implement them on local scales. In this sense, PTC seems to be more applicable, besides comprising relevant environmental aspects: incentive to the non-emission and dissipation of greenhouse gases, flora and fauna preservation, floods and droughts attenuation and sustenance of water resources and soil stability.

The case study in São Paulo city further highlighted the local scale and urban specialties. In addition, to indicate HDI and USDI value in each SCH, local scale allowed to assess the impacts of the environmental dimension addition, once by looking into the entire city average HDI and USDI the difference was not evident. Also, spatial analysis indicated that the occurrence of the highest values of HDI matches the lowest values of PTC – and vice versa. This fact evidences the need for elaborating a sustainable index, mainly because HDI has been misguidedly implying that unsustainable behaviour results in a better human development.

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AUTHORS' CONTRIBUTION

Tatiane Ferreira Olivatto established and applied the methodological procedures, composing the overall paper writing and results discussion. José Augusto Di Lollo validated data and information, as well as contributed to the analysis of results.