Article

Urban green areas in Córdoba, Veracruz. quantity, location and access: an orthogonal analysis

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Abstract

The objectives of this work were to register the green areas, their location, surface area and distribution, with respect to the areas of high population density, the distances necessary to access them and the endowment per person in the city of Córdoba, Veracruz, Mexico. This with respect to the standards established by the World Health Organization. An orthogonal analysis was applied, based on the interpretation of Google Earth satellite image and Geographic Information Systems. An analysis of distances was also made from areas of influence of each green area. The results show that the green areas of the city of Cordoba are located without an apparent relationship with the locations of the areas with the highest population density, the area of green areas is very heterogeneous, the average distance to them is recommended; however, there is no certainty that this destination meets the needs of the users, the proportion of green area per inhabitant was 4.02 m^2. It is concluded that the methodological approach used is suitable for the management of green area AV at urban scale. It is also concluded that its surface and distribution in the city is very heterogeneous; the distances to the nearest green area from any point, although acceptable, are not an indicator of reaching an area that meets the user's needs; the allocation of green area per inhabitant in the city is below half of what WHO recommends.

Keywords: access, GIS, management, open spaces, provision.

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Introduction

The green areas (AV) in the cities are important according to the World Health Organization (WHO) and this suggests an endowment of 9 m^2 per inhabitant (Sorensen, *et al*., 1998; Briceño, *et al*., 2010). Although there are other recommendations (Salvador, 2003; Dahl and Molnar, 2003; Wang, 2009), this is an important and widely disseminated reference. The 2030 Agenda for sustainable development approved in 2015 with the participation of 193 countries (including Mexico), has stated in its objective 11: 'to make cities and human settlements inclusive, safe, resilient and sustainable' (ONU, 2015a).

Considering as an axis of action the promotion of AV that promote a better quality of life for citizens and counteract the emerging effects of climate change, among other problems. Therefore, these recommendations have to do with various aspects related to human well-being, since their presence in cities, and the ecosystem services they provide to human (and non-human) communities (Mendonça and Szlafsztein, 2019), they allow balancing the losses in well-being, which the population obtains as a result of the uncontrolled and sometimes unplanned growth of the urban spot (Muñoz, 2014; ONU, 2015b).

According to the United Nations Organization (ONU, by its acronym in Spanish), currently, 55% of the world's population lives in cities, and by 2050, it will increase by 13% (Debnath *et al*., 2014; ONU, 2018), in this context, it is necessary think of a planned urban development, framed in sustainable proposals, which requires an appropriate urban infrastructure and equipment, and among them, an adequate provision and distribution of AV (Veléz, 2009). Public spaces, such as streets, squares and parks, are necessary to achieve a society that lives with adequate standards for its physical, social and spiritual health (Pérez-Medina and López-Farfán, 2015; Martinez-Soto *et al*., 2016; OMS, 2017).

According to the WHO, there is a clear relationship between the characteristics, locations and access to the AV and the quality and social comfort (OMS, 2017). This investigation analyzes the situation that the AV have in the city of Córdoba, Veracruz, Mexico. Try to understand, how they are distributed, and access, with respect to the distance to the centroids that each block has with its closest green area. This work is framed in a concern because this city tends towards a state in which its population reaches a state of well-being in its development. That is why this research is involved with various concepts that are described below and form the theoretical framework in which it is developed.

The first concept is 'quality of life'. WHO defines quality of life as 'the individual's perception of their situation in life, within the cultural context and the values in which they live and in relation to their objectives, expectations, values and interests (Rodríguez, 2012). It is a concept that involves the physical, social and emotional dimensions (Stokols, 1992). On the other hand, Ferrer (2008), integrates in the quality of life, objective and subjective aspects of satisfaction, dependent on each individual and their circumstances, so that all 'living' is done within a personal margin and is in that margin it is where, if carried out, the concept of quality of life that, at the beginning is individual, is fulfilled.

In a direct link between urban space and quality of life, Salas-Zapata *et al*. (2016) point out the importance of the (urban) environment since it is a direct factor between the quality of life of the inhabitants of a city and the strategy of sustainable development in it. It seeks to improve these environments, to turn them into conditions to reduce social inequities. You can then comment that the quality of life in cities, considers the qualities of the environment, as a means that allows its inhabitants to meet their objectives and expectations in their physical, social and emotional dimensions.

With respect to the concept of 'sustainable city', it should be based on the definition of sustainable development, proposed by the WCD (1990), as one that 'meets the needs of the present without compromising the needs of future generations'. López (2004) It indicates that the concept of sustainable development not explicitly defined starting position against urbanization, however, it indicates three important elements for planners: 1) it is inscribed in a physical environment, that of habitat in all scales; 2) is inscribed in time, in history: it has to remain; and 3) must inaugurate a new era of sustainable prosperity; that is to say, transmissible and patrimonial (Ruano, 2000).

It is up to the World Habitat 2 Conference in Istanbul and within Agenda 21, where the role of cities and their governments is highlighted, in their commitment to the global environment and the achievement of the appropriate quality of life, highlighting mainly, the generation of adequate housing for all and the consideration of sustainable development in the design and management of cities (López, 2004). Flores-Xolocotzi (2017), proposes two dichotomies to understand sustainable development in cities, the first being the theoretical approach to rationality, and the second, the theoretical approach to what is understood as sustainability (Flores-Xolocotzi, 2017).

In the first case, it is an orientation towards an approach of instrumental rationality and rational action; that is, that strongly related to purely technical academic domains, and their action. In the second case, these are three ways to define sustainability: weak, strong and super strong (Maldonado-Villalpando *et al*., 2018), which have a preponderant role in building approaches related to environmental economics, the ecological economy and the social and solidarity economy.

Super strong sustainability considers the multiple valuation of the environment, so it is not limited only to its economic or ecological value, and considers, among others, the limitations of science and technology, recognizing the precautionary principle, and resulting in more transformations radicals in contrast to conventional development approaches (Gudynas, 2011). With regard to strong sustainability, it considers social, economic, political and cultural dimensions, starting from the territory, with the purpose of considering the complexity of socio-ecosystems.

It also maintains a relationship with the ecological economy, the ecosystem approach and that of the socio-ecological systems (Maldonado-Villalpando *et al*., 2018). Finally, weak sustainability considers the assumptions of the neoclassical environmental economy with a certain Keynesian nuance (Pierri, 2005). According to Flores-Xolocotzi (2017), it is represented by environmental economics, with an instrumental rationality approach, representing a neoclassical planning vision. Emphasizes short-term planning processes. It is considered that the research presented in this study is framed in a weak sustainability, given that it is a work that considers the value (not necessarily of the market, but value) that society imposes towards the AV and which is shown in their presence and current distribution in the urban area.

Regarding the concept of 'smart cities', Sikora-Fernández (2017) states that the contemporary city is not only about its physical structure, but also about a large network of interconnections that aim to optimize the consumption of urban resources and processes of prevention of negative effects as a result of its operation, all within the idea of sustainable development. This concept is identified with the role of information and communication technologies (ICT), in the functioning of cities.

In addition, Anguluri and Narayanan (2017) indicate that it is necessary, in a context of sustainable cities, to consider smart green cities, in order to reach that state. In this framework, the role of green infrastructure (Austin, 2014). In this analysis, the provision of AV and walkable distance are the main concepts of work. The endowment, we define it as the amount of minimum green area (public access), per inhabitant (in m^2 hab^{-1}), present in a certain urban demarcation. These proposals rest on the benefits (ecosystem services) that these green spaces have for the city (Vásquez, 2016; Morales-Cerdas *et al*., 2018; Yan *et al*., 2018; Xiao *et al*., 2018; Vugcic *et al*., 2019). Flores-Xolocotzi (2017) makes an extensive review of these indicators. Table 1 counts them.

Table 1. Green area endowments (AV) suggested by different authors (based on Flores-Xolocotzi, 2017).

Endowment	Source	Observations
40 m^2 hab^{-1}	Wang (2009)	It is not specified if they are open access areas
8 to 12 m^2 hab^{-1}	Salvador (2003)	It is not specified if they are open access areas
9 m^2 hab^{-1}	ONU (2015b)	
40.5 m^2 hab^{-1}	Dahl and Molnar (2003)	They indicate that it is a park system

However, Garvin (2016) argues that the recommendations or standards do not generate an adequate system of this type of infrastructure. It is politics and leadership that can generate a more laudable AV system in a city, and this cannot be replaced by standards. Sometimes these can work in situations of low urbanization and with available land for this, but in areas where urban development already exists, this is more complicated, which coincides with OMS (2017). Regarding distances, there are also several recommendations, such as Sorensen *et al*. (1998), who recommend a maximum distance of 15 minutes on foot.

On the other hand, the ITDP (2017) suggests a maximum walking distance of 500 meters to a park or playground. The suggested data are also different, in addition to being proposed or in units of time, or distance. Research on various aspects related to AV in cities is vast and relates to various issues, ranging from environmental to social. Here are some of them that are considered relevant and related to the research presented here, focused mainly on Mexico and Latin America.

Ayala-Azcarraga *et al*. (2019), analyzed users of nine parks in Mexico City, to determine the patterns of use and their effect on their well-being. The authors found a very close relationship between the way in which users use these areas and the components such as distance, abundance of trees, security, cleanliness and quality of space. Morales-Cerdas *et al*. (2018) develop a study that aimed to determine the environmental conditions of AV, using indicators as a tool for urban management in two cities in Costa Rica.

The main methods include the use of Rapid Eye satellite images, supervised classification and photointerpretation. Eleven indicators were determined, highlighting the percentage of public and private AV, type and size, effective green areas per capita, proximity of the villages to them and accessibility to them. The results include: 24.6 m^2 hab^{-1} and 2.7 m^2 hab^{-1} for the two cities respectively. With regard to physical accessibility, they determined that, in both cases, there was a medium situation, according to the index developed by the authors for this. Vargas and Roldan (2018), develop a work in Barranquilla, Colombia, to determine the relationship between satisfaction with life and distance from the place of residence to the nearest park.

Among the results they indicate that they found high levels of satisfaction in the inhabitants who were closer to AV, highlighting their importance within the urban infrastructure. Rojas *et al*. (2016), analyze the potential of accessibility to AV, in the cities of Valdivia and Temuco, in Chile. They based their work on the analysis of daily mobility patterns and modes of transport, particularly walking, based on a statistical analysis of the duration of travel. The authors find that the variations in accessibility for the two cities are related to age and gender.

On the other hand, they report better accessibility for Temuco as a result of the residents of said settlement making longer foot transfers as part of their daily mobility. Barros *et al*. (2015) develop an exploratory investigation, in terms of surface, of the Potengi Neighborhood AV, Natal-RN, Brazil, based on bibliographic reviews, Google Earth consultation and field verifications. They find that the total green area is 2.2 km^2, which corresponds to 27.54% of the area of the region’s territory. In addition, they report that most of that area is in squares and ridges.

For its part, Pérez-Medina and López-Farfán (2015) perform a measurement of woodland surfaces in Merida, Yucatan, Mexico, and the conditions that determine their presence and distribution, based on the use of Landsat ETM images (30 m resolution) and field trips. This study was conducted in four areas of the city, with specific housing typologies in different areas of the city. From a supervised classification in a generated image of the standardized vegetation index (NDVI), the 'tree' class was extracted and correlated with housing density, population density, housing typology, and development stages, in the study areas.

The surfaces were obtained; through Google Earth. The authors find that the AV and the coverage of the tree stratum are directly linked to the types of housing and the real estate market, in addition to the management processes, local government and participation of society. Reyes *et al*. (2010) perform an AV analysis in Chile, based on landscape metrics. For this they digitized them from aerial photography and GIS. The metrics used were total area, number, largest fragment index, and cohesion index, among others.

For accessibility analysis, this was measured using the ArcGis 9.2 Network Analyst module, at 300 linear meters, measured from the centroid of each block to the centroid of the nearest green area. This situation is related to the socioeconomic level of the population, resulting in the less affluent sectors had less access, than those in a better situation in that regard.

With respect to the works related to the subject of this research in the study area, these are scarce, highlighting the work of Olavarrieta (2001), who analyzed the proportion of green area per inhabitant in the city of Córdoba, Veracruz, in the year 1998, and determined an endowment of 1.1 m^2 hab^{-1}. It is used physical means, such as analysis of city plans and field visits.

This review highlights some important methodological aspects, such as the use of remote sensing (Google Earth and other satellite and aerial images), the digitization of the analyzed spaces, the relationship of census data with centroids and distances between AV, also from of its centroids, and with the apples or residential areas analyzed. On the other hand, different endowment situations are reported, including disparate, having as little as 2.2 m^2 hab^{-1}, up to more than 20. Access to the AV considers among others the uses that a community has in its modes of transfer.

Materials and methods

The study was conducted in the city of Cordoba, Veracruz, Mexico, in the summer of 2018. This is located between parallels 18° 50' and 19° 00' north latitude; the meridians 96° 52' and 97° 01' west longitude and with an average altitude of 900 m. It has a warm humid climate with abundant rains in summer (gobierno del estado de Veracruz, 2018). This analysis considered only the municipal seat.

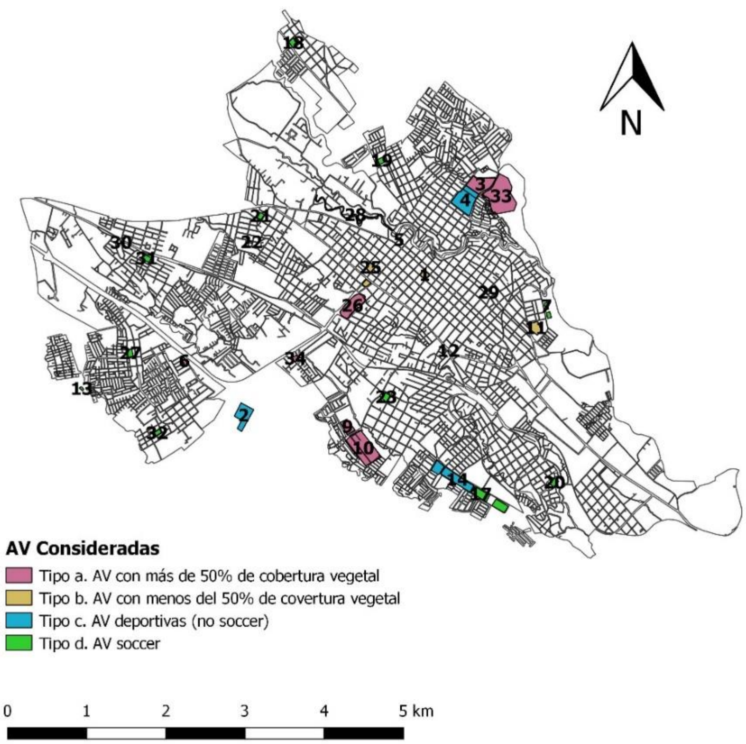
The objectives of this study were: a) to identify and quantify the location of public AVs in the city; b) determine its distribution; c) verify their coincidence or not, with the location of the population concentrations (areas of greater or lesser population density); d) determine the distances that exist from each point of the municipal capital to its nearest AV; e) obtain the public AV provision for the population of that city; and d) analyze the results obtained with respect to the WHO recommendation.

The orthogonal analysis to analyze the size and location of the areas studied consisted in determining on an imaginary horizontal surface, the projections of the contours or boundaries that delimit those areas. These were digitized in a GIS. Google Earth was used as the basis for that task. From this it was possible to determine the geo-referenced location of these spaces and their sizes. Free access AVs were selected, excluding private areas. Only public parks, plazas and sports areas were included. The choice of these was based on the criteria shown in Table 2.

Table 2. Green areas (AV) of the city of Córdoba, Veracruz, Mexico considered in this study.

Typology and aspects considered in the choice of AV in the study
a) AV (parks) with more than 50% vegetation cover, on paved areas
b) AV (paved parks) with less than 50% vegetation cover, on paved areas
c) Sports AV, for the practice of sports other than soccer (baseball, basketball, among others)
d) courts for soccer practice

The criteria of Table 2 threw 34 spaces (Figure 1), through the interpretation of Google Earth© satellite image (dated 7/5/2016), based on aspects of texture and tone. For orthogonal analysis, a GIS was constructed, with QGIS® ver. 2.16.0. Urban geostatistical cartography, developed by INEGI (INEGI, 2017a), was considered. This cartography is available in vector format. The projection of that information is based on the ITRF_1992_Datum parameters: D_ITRF_1992. It is worked with information of Basic Geostatistical Areas (AGEB) (INEGI, 2017b).



Nombre	Número	Tipo
21 de Mayo	1	b
30 Caballeros Beis	2	c
Alameda MV	3	a
Beisborama	4	c
Cañas	6	a
Carriles	7	d
Carriles	8	d
DIF	11	b
Estaciones	12	b
Fredepo	13	d
Huilango Beis	14	c
Huilango Beis	15	c
Huilango Soccer	16	d
Huilango Soccer	17	d
N.I.	18	d
N.I.	19	d
N.I.	20	d
N.I.	21	d
Palomar	23	d
Parque Bicentenario	24	b
Parque San José	25	b
Paso Coyol	26	a
Quebradora	27	d
Río San Antonio	28	b
San Miguel	29	b
San NIcolás 2	30	b
San Nicolóas	31	d
San Roman	32	d
USBI	33	a
Villa Verde	34	a

Figure 1. Green areas (AV) identified in the city of Córdoba, Veracruz, Mexico using Google Earth© satellite images.

Through joining processes between attribute tables and vector files, AGEB information was linked with each city block, so that the population present in each of them was calculated, this was done based on the determination of the centroids of each apple. From this, and by geostatistical processes the densities of the population were determined, generating raster format maps where these concentrations are appreciated. Likewise, the surfaces of each AV were quantified, and the population each served, according to the determination of their area of influence, by means of an analysis of Thiessen polygons (or Voronoi diagrams) (Tabios and Salas, 1985).

Finally, a raster of distances from all points within each area of influence to its nearest AV was determined. From this, information on availability, location, distribution in the city, and distance to them was generated. With the data collected, an exploratory statistical analysis was performed. The results yielded various maps and data related to the objectives set. Field trips were also carried out to verify the totality of the analyzed VAs, since the relatively small size of the city allowed it.

Results and discussion

Location of AV with respect to population density

The analysis shows that the arrangement of the 34 spaces does not coincide with the locations of the areas with the highest population density. There is some coincidence to the north of the urban area (Figure 2). This suggests inadequate planning in their location as urban equipment for the city. The total area of AV found (667 044.72 m^2) is not arranged in a homogeneous manner, as suggested by the value of the variance in Table 3. There are areas as small as 88.71 m^2, as well as others of 125 496.27 m^2, showing high variability in surface.

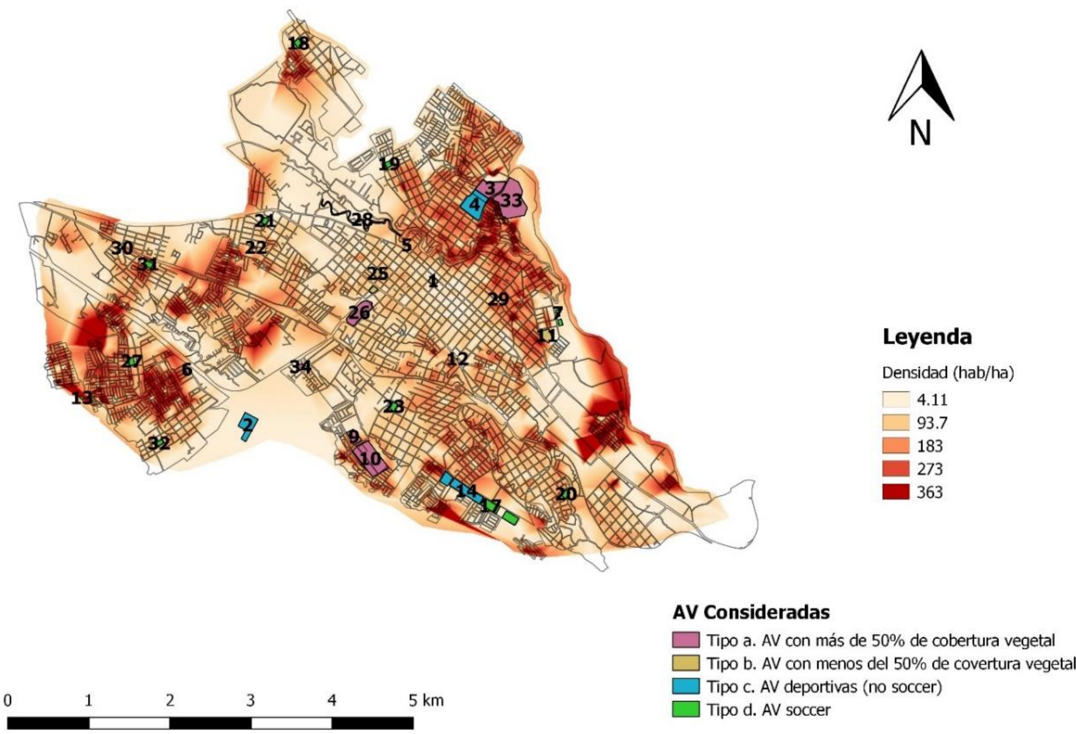


Figure 2. Map representing the green areas (AV) and population densities in the city of Córdoba, Veracruz, Mexico.

Table 3. General statistics obtained by the orthogonal process of green area analysis (AV) in the city of Córdoba, Veracruz, Mexico.

	Park name and green area	Surface of AV (m^2)	Total population serving each AV	Area of influence of each polygon Voronoi (m^2)	Average distance to the nearest park (linear m)
1	21 of May	7186.05	4 651	638 801.08	322.51
2	30 Caballeros Beis	41521.85	71	835 456.6	369.63
3	Alameda MV	48220.28	8 695	844 838.37	577.34
4	Beisborama	69060.93	8 592	601 419.48	353.42
5	Bolsillo	88.71	4 754	470 471.22	289.35
6	Cañas	4 642.6	6 924	1 126 987.83	289.15

	Park name and green area	Surface of AV (m^2)	Total population serving each AV	Area of influence of each polygon Voronoi (m^2)	Average distance to the nearest park (linear m)
7	Carriles	3 260.3	2 135	327 348.02	444.79
8	Carriles2	3 486.4	42	388 994.48	345.15
9	Cementerio J. de Paz	17 734.9	765	574 574.96	605.49
10	Cementerio municipal	97 883.99	2 643	514 997.83	344.09
11	DIF	15 184.07	5 024	1 112 270.98	314.94
12	Estaciones	100.97	9 845	1 242 835.32	595.3
13	Fredepo	1 372.3	5 982	759 908.55	458.96
14	Huilango Beis	41 899.14	6 605	801 607.15	485.4
15	Huilango Beis2	15 345.55	3 799	487 949.97	432.93
16	Huilango Soccer	17 892.52	1 542	367 019.06	414.2
17	Huilango Soccer2	20 204.74	1 229	540 334.4	383.4
18	N.I.1	6 957.01	3 514	1 468 680.12	339.8
19	N.I.2	6 263.37	3 863	1 420 029.24	638.95
20	N.I.3	5 769.2	14 981	3 797 998.34	574.9
21	N.I.4	4 392.32	4 058	1 206 046.6	1003.92
22	Nuevo Córdoba	463.69	8 253	1 218 086.59	595.48
23	Palomar	6 270.91	6 725	868 905.46	496.44
24	Parque Bicentenario	5 582.72	1706	277 071.03	375.53
25	Parque San José	7 457.88	1 759	307 595.6	413.67
26	Paso Coyol	46 160.03	3 849	844 005.99	432
27	Quebradora	5 669.11	9003	987 800.63	391.92
28	Rio San Antonio	23 330.27	1339	829 338.78	283.22
29	San Miguel	1 592.95	10 632	782 171.33	351.92
30	San Nicolás	6 689.35	7 256	1 007 503.27	686.78
31	San Nicolás 2	253.48	4 372	1 556 109.3	443.67
32	San Román	5 377.38	4 003	806 365.27	347.47
33	USBI	125 496.27	2 195	516 822.25	343.02
34	Villa Verde	4 233.48	5 018	1 247 095.37	441.41
	Totals	667 044.72	165 824	30 777 440.47	15 186.15
	Average	19 618.96	4 877.18	905 218.84	446.65
	Variance	833 115 243.9	11 541 703.18	384 630 826 936.14	21 587.72
	Minimum	88.71	42	277 071.03	283.22
	Maximum	125 496.27	14 981	3 797 998.34	1 003.92

If, as indicated above, WHO recommends that the maximum walking distance to a space such as those analyzed should not be more than 15 minutes walking (Tabios and Salas, 1985; Sorensen *et al*., 1998) and if considered an average speed of 5 km h^{-1}, the distance that can be traveled in that time would result in 1 250 m.

To travel 446.65 m, at a speed of 5 km h^{-1}, the required walking time would be around 5.5 min, which would indicate that, on average, the distances found would be acceptable. The same is true, with the recommendation of ITDP (2017). However, as already mentioned, the physical or structural characteristics of the destination AV are not involved, so that distance does not necessarily guarantee access to one that meets the needs of a user in terms of the use of that space. This information indicates a weakness in the offer of equal access to these areas. Also, considering the role of these spaces in the well-being of the quality of life of the inhabitants, the situation analyzed is not positive in a framework of urban sustainability (Flores-Xolocotzi, 2017).

Endowment of AV per inhabitant

The results of the orthogonal analysis are shown in Table 4. It can be seen that the data indicates an allocation of 4.02 m^2 hab^{-1}. from AV to the city. This means an area larger than that found in 1998 by Olavarrieta (2001). However, it is still below half of the area recommended by WHO.

Table 4. Numbers resulting from the orthogonal analysis of green areas (AV) in the city of Córdoba, Veracruz, Mexico.

General results	
Total population (inhabitants)	165 824
Green area (m^2)	667 044.72
Green area/inhabitant (m^2)	4.02

The analysis presented is orthogonal; that is, we worked on the projection of the limits of the spaces analyzed in a horizontal environment, therefore, the data found correspond to that projection and not to the three-dimensional reality of the AV. However, this type of analysis is useful as an exploratory tool, for planning and managing them. The physical survey of each area, which includes, among other aspects, its planimetry and altimetry, design, floristic composition, preference orientation and use of these spaces, is a pending work.

On January 25, 2017, the Municipal Urban Development Plan of the City of Cordoba, Veracruz (Gobierno del Estado de Veracruz, 2017) was published in the Gazette of the State of Veracruz. Relating to the endowment and access to AV of the city, it indicates in its diagnosis, a deficit state. Although the methodology used is not indicated, it manifests, among other aspects, a very low provision of open spaces, and equal access problems. It establishes as strategies, a series of actions that the authorities must carry out to solve the WHO situation, and ITDP (2017).

You must comply with, 1) be open to any user; 2) offer something for everyone; 3) attract and retain market demands; 4) provide a framework for successful urbanization; 5) maintain a habitable environment; and 6) nourishes and supports civil society. It is worth asking whether, with the situation found in this investigation, the AVs comply in some degree with these 6 proposals, in order to understand if alternatives are offered for an improvement in people's living standards. The answer seems to be no, for the community.

This moves to consider the action to try to solve the situation to start acting towards a city that has a less fragmented AV system. This will allow progress in the achievement of elements towards sustainability. It will be necessary to tend towards a super-strong sustainability, in order to assess the situation in a comprehensive way and promote radical changes.

Conclusions

The territorial location of the AV in Córdoba, Veracruz, does not present a distribution that coincides with the concentrations of the population in the city, which can generate inefficiencies in the use and access to them, as well as social inequality. The endowment of AV per inhabitant found is lower than recommended by international organizations such as WHO. Although the same organization suggests that there is really no basis to consider the 9 m^2 indicator as valid, it can be said that the presence of such areas in the city is adequate in times of global change, as an element of adaptation to it, in a context of sustainable urban development.

The distance found to access a nearest AV, from any point of its area of influence, is adequate in accordance with the recommendations of the WHO and the ITDP (2017). However, this does not indicate that said AV necessarily meets the needs that certain users require of it. This analysis establishes bases, to understand the way in which authorities and society value and manage their AV. Of course, the current situation in Córdoba does not point towards urban sustainability.

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