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# Advances in Geospatial Data Science

## Selected Papers from the International Conference on Geospatial Information Sciences 2021

Springer

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# Preface

This volume consists of the selected peer-reviewed papers from the International Conference on Geospatial Information Sciences 2021 that took place on November 3–5, 2021. Initially planned to be held in person in Mérida, Yucatán, Mexico, due to the coronavirus pandemic it was decided to be an online event. These papers were selected by the Scientific Program Committee of the Conference after a peer-review process. They represent the vast scope of the interdisciplinary research areas that characterize the Geospatial Information Sciences. It represents a fabulous opportunity to showcase research carried out by young researchers, especially Mexican ones, show it to the rest of the world, and enhance the growth of the Sciences in the country.

iGISc 2021 is the second iteration of a successful conference that aims at bringing together international experts in the field of Geospatial Information Sciences (GISc) to foster the exchange of ideas, knowledge, and experiences. The conference hosts a broad array of subjects related to the acquisition, processing, modeling, analysis, visualization, and use of Geographic Information.

As an emergent conference in the country, the first edition brought together little less than 100 experts and students in the field. In contrast, the online version of the conference attracted more than 300 participants. Apart from the oral presentations of the selected papers, the conference boasted an interesting offer of workshops covering different topics and aspects of the use of Geospatial Information Sciences. Additionally, several keynote speakers were invited to share their knowledge and insights with the participants.

Please visit the iGISc webiste at http://igisc.org where you can find all about this interesting event.

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Special thanks go to our keynote speakers, Mateo Valero (Barcelona Supercomputing Center, Universitat Politècnica de Catalunya), Alberto Giordano (Texas State University), Ulises Cortés (Barcelona Supercomputing Center, Universitat Politècnica de Catalunya), Alison Heppenstall (University of Leeds), Andrew Crooks (University at Buffalo), and Daniel Arribas-Bel (University of Liverpool), as well as the workshop presenters.

We would also like to thank all the presenters and participants who put a lot of effort in being part of our *Gather* community. While trying to adjust to time differences all over the globe, we are grateful for those participants who were able to catch the presentations live, as this year's participants came from countries across different time zones.

Additional thanks go to the publisher, Springer, for their help and support throughout the editing process and for accepting publishing these proceedings.

# Contents

# Analysis of Geospatial Data

# Assessment on the Distribution and Accessibility to Green Spaces in Mexico's Most Populated Metropolitan Zones


**Edali Murillo-Gómez, Marisol Palomar-Ramírez, and Mariana Ramos-Flores**

**Abstract** This project's goal is to make an assessment of the access to urban green spaces in ten of Mexico's most populated metropolitan zones (MZ) by analyzing the relationship between the degree of poverty, social vulnerability, and consequently the access to the benefits these spaces provide that are directly linked to human well-being, as a source of recreational spaces, and places that promote physical and spiritual activities, also known as cultural ecosystem services (FAO 2021). This study consists of three scales of analysis.

- National scale, in which the degree of inequality in the distribution of green areas was assessed in regard to the population according to the Gini Coefficient.
- Metropolitan Zone Level scale, in which in every MZ the geographic location of the poverty and accessibility variables are compared in order to observe whether there is a relationship between green areas and poverty in every AGEB.
- At the local scale an algebra mapping method was employed to obtain the overall quantity of public infrastructure in six parks located in the three most unequal MZ (according to Gini Coefficient). Three are located in AGEBs where the poverty ratio is lower and three in which the ratio is larger, according to CONEVAL. In this case, the accessibility to each park is estimated from mobility and safety costs based on the inclusive public infrastructure that should favor different historically disadvantaged population groups (children, women, the elderly and people with different capabilities) so that they can move across the public space.

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## 1 Justification

The rapid growth of metropolitan zones in Mexico have spawned several social and environmental issues that decisionmakers have to face every year with the utmost seriousness (CIDE, LNPP, Centro Mario Molina, IMCO, Citibanamex 2018). The urban population is increasing and there is a global trend of growing cities that extend beyond the limits of their central municipality (Habitat 2020). In this sense, metropolitan areas are defined as a city and its zone of displacement, which consists of suburban, peri-urban and rural areas linked economically and socially, according to the UN Statistical Commission (ibid.).

In order to make cities more inclusive, safe, resilient, and sustainable, Mexico made the commitment to fulfill in 2015 the Sustainable Development Objectives so to attain the goals of the United Nation's Agenda 2030 (United Nations in Mexico 2021). Specifically, Goal 11.7 is a call to action to "provide universal access to green areas, and safe, inclusive and accessible public spaces, particularly for women and children, the elderly and people with different capabilities" (ONU 2015, p. 25).

However, the challenges to ensure everyone access to green areas within the urban space are enormous, because from an environmental justice perspective it is acknowledged that the distribution of natural areas in the built space is quite unequal, and greatly hurts historically disadvantaged peoples (Soja 2016; Bellver Capella 1996).

The concept of environmental justice refers to the equitable distribution of the services provided by urban green areas and their derived benefits (Buckingham & Kulcur 2009). The conceptual framework on environmental justice emphasizes the spatial aspects of the equitable distribution of those services or resources that are valuable to the population and the opportunity for people to use them. In other words, it indicates the access to the inherently urban rights of citizens, including the services that green spaces provide (Soja 2016).

In this sense, the analysis of the access to green areas will be performed from two hypothesis derived from the history of the issue at hand mentioned in the literature and in prior studies about environmental justice.

## 2 Hypothesis

I. The relationship between poverty and accessibility → there is a relationship between belonging to a socioeconomic class and access to green areas, since in Mexican cities the poorer zones lack many urban parks.
II. The relationship between poverty and inclusive infrastructure → Access to urban opportunities is conditioned by the urban milieu and the individual's specific autonomy within the space (Mei-Po 1998). Therefore, access to urban green areas is regarded as differentiated for persons from diverse ethnic, gender

and age groups, and green areas in the cities' poor neighborhoods have less inclusive infrastructure.

From these premises, this project seeks to conduct a thorough assessment of the access to urban green spaces in Mexico's most populated metropolitan zones to obtain useful information for decisionmakers so that they can undertake a sustainable socio-ecological-territorial planning as well as public social inclusion policies. In order to achieve this main goal the following secondary objectives have been set:

1. To estimate the degree of environmental justice in Mexico's ten most populated metropolitan zones, in regard to the relationship between the distribution of the poverty levels and the estimation of the accessibility to urban green areas in order to determine whether belonging to an assorted social class determines access, or lack of it, to green spaces.
2. To assess different degrees of environmental justice in the ten metropolitan zones through the estimation of the Gini Coefficient applied to the concentration of access to green areas.
3. To assess the degree of accessibility of two parks in the three most unequal metropolitan zones, according to the Gini Coefficient, through the presence and state of the infrastructure open to the disadvantaged population.
4. To design a new urban green area simulator in one of the most unequal metropolitan zone, located on the poorest AGEBs; so to show the likely growth in the levels of environmental justice.

## 3 Methodology

### *3.1 Obtaining Urban Green Areas*

To calculate the green areas by MZ, we followed the next procedure: first, the Geostatistical Framework (INEGI 2021) was downloaded, where the green areas were counted by metropolitan zone. It should be noted that only those green areas that comply with the type of small green area present in neighborhoods for daily use were taken. Subsequently, the OSM database was used to complement the database of green spaces taken from INEGI's Geostatistical Framework. In this case, the same criteria were also followed to select the green areas registered in the OSM database. Finally, the information of the two records was verified through the satellite images, and the union of both databases was made.

### *3.2 Accessibility Per Metropolitan Zone*

To analyze metropolitan zones in scale we will focus on Mexico's ten most populated cities, since, due to their size, they suffer most environmental and socioeconomic

problems. The selection of metropolitan areas was based upon the National Urban System (CONAPO 2021), which are listed according to population (Table 1)

To study each metropolitan zone, we made a bivariate coroplete map consisting in a comparison between to two layers of categorized information. In this case, variables of interest were poverty and accessibility to green areas, both disaggregated by AGEB, since it was the scale of analysis found for the poverty data.

To estimate the poverty variable, we took the CONEVAL data bases (2015) indicating the percentage of the population in poverty by AGEB. On the other hand, access to green areas was estimated from the 2020 INEGI Population and Housing Census data, and the database created that counts the green areas by MZ. In this case, the method used to estimate access takes the green areas' surface and the distance between the parks' centroids and AGEBs in consideration (Zhang et al. 2011), by applying the following formula:

$$H_p^i = \sum_{j=1}^{k} \frac{A_j}{r_{i,j}^2}$$

where:

| | |
|---|---|
| $H_p^i$ = accessibility of each AGEB ($i$) | $j$ = nearest $k$ Parks index |
| $A_j$ = area of j-nth nearest object | $r_{i,j}$ = distance between AGEB $i$ to object $j$ |

**Table 1** General data of Mexico's ten most populated metropolitan zones

| Metropolitan Zone | Municipalities | Number of inhabitants (2017) | Surface of the urban area km$^2$ | Green areas surface km$^2$ |
|---|---|---|---|---|
| Valle de México | 76 | 21,650,668 | 7,866 | 34.97 |
| Guadalajara | 10 | 4,909,287 | 3,600 | 14.153 |
| Monterrey | 18 | 4,603,254 | 7,657 | 21.228 |
| Puebla-Tlaxcala | 39 | 3,017,463 | 2,392 | 9.328 |
| Toluca | 16 | 2,260,149 | 2,412 | 5.157 |
| Tijuana | 3 | 1,996,587 | 4,423 | 5.644 |
| León | 2 | 1,743,903 | 1,760 | 5.779 |
| Ciudad Juárez | 1 | 1,448,859 | 3,547 | 4.240 |
| La Laguna | 5 | 1,342,139 | 7,889 | 5.116 |
| Querétaro | 5 | 1,250,429 | 2,427 | 4.519 |

*Source* Data from (SEDESOL, CONAPO, INEGI, SEDATU, SEGOB 2018) and (CIDE, LNPP, Centro Mario Molina, IMCO, Citibanamex 2018)

### *3.3 Gini Coefficient*

The Gini Coefficient is a measure originally created to estimate income inequality within a country. However, it can be used to appraise any sort of unequal distribution (Longfeng & Seung Kyum 2021). In this case, the Gini method was applied to two variables: the accrued population ratio and the accrued access to green areas, so to assess the degree of inequality within MZ, and then compare these measurements among the ten chosen MZ.

The Gini Coefficient is a number between 0 and 1, in which 0 means perfect equality, namely, that green areas are distributed equally among the population, and, on the other hand, 1 means perfect inequality, which means access to all goods and services by a single individual. Estimation is based upon obtaining the area between a curve of perfect equality and the Lorenz curve; the wider the area between both curves the more unequal society will be, and thus the result will be closer to 1 (Nordhaus 2005).

### *3.4 Accessibility Per Parks*

In this section we pondered on how complicated is that individuals from certain vulnerable groups can visit a park (urban green area) near to home, and can suitably enjoy the outdoor recreation. The infrastructure regarded as ideal for the mobility of these groups is such that ensures the use of space in an autonomous, safe and equal conditions (Gutiérrez Valdivia et al. 2011). So, mobility and population circulation can be unhindered.

In order to estimate optimal routes to access parks, various infrastructures were added through the algebra mapping procedure (ISO4APP 2021). These routes are those streets having an infrastructure suitable for children, women, the elderly and people with different capabilities. Regarding the urban milieu, we consider four road infrastructures, which are: sidewalks, wooden paths, ramps, and streetlamps, besides the shops near the parks. These databases were obtained from the National Housing Catalogue, (INEGI 2021) and the National Statistic Handbook of Economic Units (DENUE), INEGI, respectively.

We explicitly sought the most suitable streets to walk towards the park, namely, the streets with a minimal weigh reflecting a better infrastructure (López et al. 2019). We used the streets located on a 700 m radius from the studied parks, since people will rather walk if the place is located within 400 to 800 m away. Moreover, we considered the route taken by persons with different capabilities. We also took into consideration that if local urban milieus create a suitable environment to replace public and private transportation, then walking becomes a positive and desirable activity (Suárez Lastra & Delgado Campos 2015).

After the algebra mapping, radar graphics were made to compare the parks' infrastructure in order to see if there is any difference between the parks in less poor AGEBs

and those located in those where poverty is more widespread, and compare both parks so to look for likely inequalities associated to socioeconomic levels.

Infrastructure thus considered to create the register's matrix by park were: trees, benches, wastebaskets, bicycle ports, courts, shops, walkways, fountains, streetlamps, bus stops, wheelchair ramps, jogging tracks, and restrooms. Additionally, we considered the sidewalks that surround the park.

### *3.5 Green Areas Simulator*

To make the new green areas simulator in a metropolitan zone, and to be able to observe how accessibility measures change, we employed the following methodology: first, we chose the city on which we would develop the simulator, in this case, the MZ of Querétaro, because its Gini Coefficient, as it would be specified later, is one of the highest in the country; secondly, new parks were digitalized in QGIS, in places within the metropolitan zones identified as unbuilt terrain; finally, the third step was to estimate accessibility by taking into account the actual green areas in the zone as well as the newly added zones.

## 4 Results

### *4.1 Accessibility and Poverty in Metropolitan Zones*

The results concerning poverty and urban green areas state that in most metropolitan zones poverty is located on the environs, while green areas are concentrated in downtown areas. This relationship determined most of the results obtained in the accessibility measurements of urban AGEBs to green areas and in the results of the Gini Coefficient measurements at the metropolitan zone level.

What was found after measuring urban AGEB accessibility in green areas was that most AGEBs with more access are located downtown. On the other hand, those with less access are located on the vicinities. In regard to poverty in metropolitan zones, accessibility is similar, since poorer AGEBs were found mostly on the environs, thus confirming the hypothesis positing that the lesser the poverty in AGEBs the larger the accessibility of urban parks.

We must state that although this behavior was seen in most AGEBs, qualitatively speaking, there were metropolitan zones wherein this situation was more evident: Monterrey, Guadalajara, Puebla-Tlaxcala and Ciudad Juárez. On the other hand, AGEBs showing less were La Laguna, Tijuana, Querétaro and León.