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Multidimensional Characterization of Periurban Transects: Mexican Case Study

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Abstract

The objective of this essay is to report the establishment of the variables that define and characterize a Mexican peri-urban transect. This is based on urban theory and the literary review from 2015 to 2021 of peri-urban areas in India, Africa, Europe and Latin America. Thanks to this, the words "transect" and "peri-urban" were defined. This allowed us to establish characteristics that identify a peri-urban area in Mexico. Here, mobility, land use, demographics, well-being and socioeconomic aspects were considered as dimensions that need to be investigated and whose parameters would have to be addressed both from a theoretical and a practical basis.

To define the peri-urban transect, we began with the analysis of five dimensions through eleven indicators. The results show that 62.4% of the locations in the Mexican Republic are peri-urban. This analysis allows us to have a first approach to the peri-urban definition. The first results are shown in this work; however, it is observed that the definition is not absolute because there are different types of peri-urbanity.

This work is part of the "P-70: Validation of the strategy for empowering the use of solar energy" project of the “Centro Mexicano de Innovación en Energía Solar (CeMIE-Sol)”. It's a social innovation project whose general objective is to develop an empowerment strategy for everyone through the use of solar energy, from human rights and gender approaches; and to characterize and evaluate the sociotechnical potential of the use of technologies of solar energy (active and passive) within the different socioeconomic transects in Mexico. So the first step is to define what peri-urbanity consists of.

Keywords: transect, periurban, Mexico

1. Introduction

The identification and definition of the peri-urbanization process has been the object of study for urban planners and researchers; this in order to explore and find answers about its origin, development and rapid expansion. Today, the peri-urban concept is a common term that,

according to the presented research, can be approached from sample areas called transects, identifying their historical, physical and socioeconomic characteristics.

This investigation begins with the definition of the transect as a cross section that is used to identify the transitions that occur in a geographic area. In this sense, it is necessary to follow an interdisciplinary methodology that covers both the social and technical aspects. Regarding the social aspect, the methodology used was based on a disciplinary, multi and transdisciplinary approach by **Isabel Loupa Ramos (2013),** as proposed by **Goncalves et, al. (2017)** and **Andrés Montaño (2020)** for the definition of the peri-urban variables. Continuing with the technical approach, once the variables that define the peri-urban area were chosen, a quantitative value was assigned to them to allow evaluating the degree of peri-urbanity of the entities, for which a statistical analysis was carried out. This analysis appears in the second stage of the methodology, where through the variables and selected parameters show where it's based, that in Mexico there are peri-urban areas and that they represent more than half of the total localities in the country.

Peri-urban areas are vulnerable areas that are often neglected by the social programs that focus on rural or urban areas; the search for solutions must necessarily begin with the identification of the areas. That is why this work focuses on defining and identifying what a peri-urban area is. The identification of these areas in the territory is of utmost importance and in this case study, the Mexican one because this will allow us to know the needs and the potential that these areas of interest have. The ultimate objective, for the P-70, is to know the solar potential in the transect, for the management and proper use of solar technologies. Solar energy is a type of variable renewable energy, that can be managed locally in configurations known as Distributed Generation. This has shown to have the ability to democratize energy management. Currently there are commercial technologies that allow us to take advantage of it to cover basic needs at home or in the industry, such as water heating or electricity production. Since solar energy is available to almost anyone, it turns out to be a real alternative for peri-urban areas.

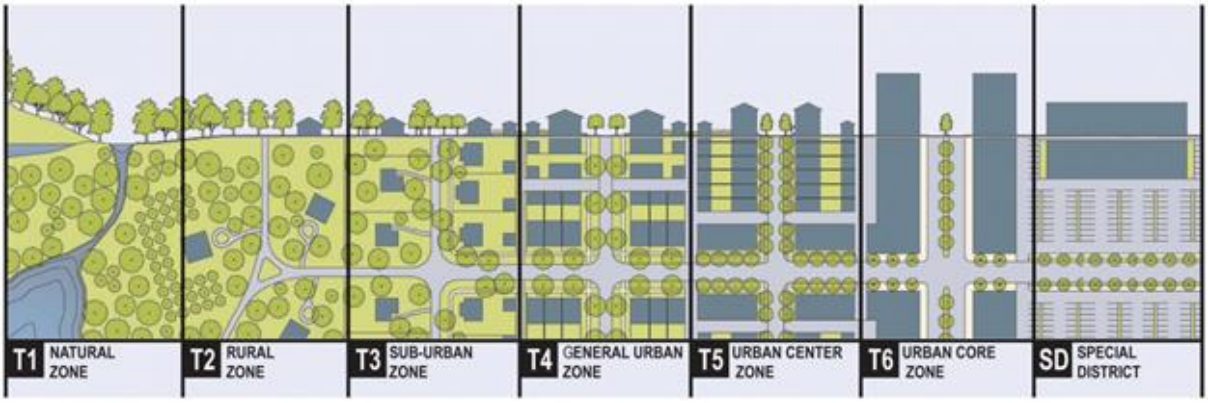
2. Definition and identification of a peri-urban transect

In ecology and environment disciplines the term “transect” is used as an observational technique to identify environmental sequences along an imaginary line that crosses an environment. In other disciplines such as biology, the transect is used for sampling a particular area where a space is selected and divided into parts in order to account for the diversity of organisms per transect. The term transect is also applied in human environments, “it can be used to identify a set of habitats that may vary from their urban character due to their level and intensity, and a continuum whose range is from rural to urban” **(Duany, 2005)**. In other words, the transect is the identification of a zone of gradual transition between the rural and the urban.

In this investigation, it is understood that the transect is a cross section that is used to identify the transitions that occur in a geographical area. Now, in Duany's quote, an element stands out that may be contradictory: if the urban character is typical of the city, why does the

transect start in the rural space and not in the urban one? since it radiates its features and its intensity outside of it. Duany seems to consider the peripheral space of cities according to the vector that has urban characteristics. However, the continuum has two directions, both from urban to rural and from rural to urban, due to there being urban characteristics in rural and vice versa. **Raymond E. Pahl (1965)** calls this relationship an overlapping mesh or network that has a multifunctional pattern, complex and that's difficult to identify in a geographic space.

Figura 1. Transectos urbanos



Source: Duany, 2008, Center for Applied Transect Studies https://transect.org/rural_img.html

There is a consensus on the definition of the peri-urban in the meeting of the rural and the urban (T2 to T4), that is, in an intermediate zone to these spaces. In this clash there are transformations in the economic and demographic organization, society, among others. Ansah and **Uchendu Chigbu (2003)** define it multidimensionally, since it points to a place (peri-urban), a process (peri-urbanization) and a concept (peri-urban). It's a concept when rural and urban activities meet; it is a place because it's a region between the rural and urban areas; and it's a process when rural areas gradually acquire urban characteristics. **Héctor Ávila (2009)** identifies two processes: the productive one, due to the change in landscape and economic activities; and the cultural process in which a generally isolated particular identity is built, where the local population loses sense of its history, roots and permanence. Other characteristics described in the literature are:

- transition zone between urban and rural **(Tiwari 2019; Entrena 2005; Csatári 2013; Rodríguez 2019, Ortizbáez 2020)**
- areas with fewer agricultural activities; higher secondary and tertiary activity **(Colledge, 1960; Ravetz, 2013, Rodríguez 2019)**
- areas that have a local government **(Almonte 2020, Aguilar, 2014, Marshall, 2009)**
- morphological changes **(Bazant 2015; Zárate, 1984; Pellicer, 1998; Font, 1997)**
- low income **(Entrena 2005; Dematteis, 1998)**
- development potential **(Novick, 2017)**
- dispersed settlements **(Carter, 1983; Entrena 2005; Dematteis, 1998; Ortibaez 2020)**
- high literacy rate **(Kunmar, 2019)**

However, three important aspects of peri-urbanization have been identified. First, the peri-urban is both a rural and an urban phenomenon. **Jadwiga Biegańska and others (2018).** Second, "the reciprocal flow of people, goods, financial and environmental services between specifically rural, peri-urban and urban areas are interdependent" **(UN Habitat 2019).** Third, the fact that the peri-urban area has an extensive open territory generates changes in land tenure due to the supply and demand for it.

3. Characteristics of a periurban transect

The selection of the dimensions that define the peri-urban is based on 35 articles indexed in Erih Plus and Latindex from the period 2015 to 2020, where it was observed that the dimensions selected for this study were constant in the articles. Table 1 shows the dimensions, aspects, indicators and selected parameters. Based on this theoretical validity, we used the following dimensions and established parameters according to the Mexican context. Initially, the ranges established by UN-Habitat in collaboration with Mexican institutions of geography and statistics (INEGI for its Spanish acronym), helped to define, on one hand, the rural and the urban; the first served as a lower limit, the second as an upper limit. The study of Metropolitan Zones in Mexico was also very helpful in pointing out the central municipalities, which are urban in a metropolis, and the outer ones that make up the metropolitan area, mostly peri-urban.

Thus, the first dimension explored in the analysis is mobility, understood as the set of movements of people and goods that occur in a physical environment. Similarly, for this dimension three indicators were considered: the distance to a city or metropolitan area, the inter-metropolitan flow (between central and outer municipalities) and the type of road **(Bazant, 2005), (SEDATU, CONAPO, INEGI, 2018).**

The second dimension is the socioeconomic one, which allows us to know in depth the social and economic characteristics of each person in an environment. The classification of the employed population was considered by the sector of economic activity, considering only commerce, service, manufacturing industry and agriculture.

The third dimension is well-being, which is the state of personal satisfaction, comfort and comfort in areas of health, economy, professionals, among others. For this dimension, three aspects will be considered: access to social security, the poverty line by monthly income per person and basic education **(Almonte, 2020), (Ávila, 2009), (Iracheta, 2019) and (Kunmar, 2019).**

The fourth dimension is population, which is defined by the set of people or dwellings that are in a certain geographical area. The population size and the identification of parameters for a peri-urban area were considered crucial for its characterization **(SEDATU, CONAPO, INEGI, 2018).**

The fifth and last dimension is soil, which explains the activities allowed in a given territory. For this dimension, the aspects of *ejidal* or communal land use and the type of settlements were considered.

Table 1: Dimensions that characterize a periurban transect in Mexico

Dimension	Aspect	Indicator	parameters
Mobility	Distance	Regarding the central city	0 to 15 km
	Road	Type	Extension, walkway, avenue, street, alley, collector road, diagonal, passage, pedestrian, living street, extension, return
	Inter-metropolitan flow	Employed population from 15 to 70 residing in the municipality that works in another municipality	0%-15%
		Employed population ages 15 to 70 that works in the municipality and resides in another	0%-10%
Socioeconomic	Economic activity	By the sector of economic activity	Commerce Service Manufacturing industry Agricultural
Well-being	Access to social security	Health benefits	No benefits Only access to health No access to institutions but does have benefits Access to institutions and benefits
	Poverty line for monthly income per person	Classification of the employed population by income level	Minimum wages from basic to 5 minimum wages and that does not receive income
	Basic education	5 years or more by level of instruction	Basic education
Population	Size	Total population	15,000- 150,000 inhabitants
Suelo	Ejidal and communal	Social structure	*Ejido* Community
	Human settlement	Type	*Ampliación, Barrio, Cantón, Colonia,* Condominium, Residential complex, Industrial Corridor, *Coto*, Headquarter, *Ejido, Ex Hacienda, Fracción, Fraccionamiento*, Farm, *Hacienda, Ingenio,* Apple, *Paraje, Privada, Prolongación*, Town, Harbour, *Ranchería*, Ranch, *Región, Residencial, Rinconada*, Housing Unit, Villa and Federal Zone.

Source: Own elaboration

4. Methodology

The proposed methodology for the identification of the different peri-urban areas is made up of two parts. In the first, a description of the meaning of a peri-urban area was formulated from a multidisciplinary approach, through the participation of different experts from both the social and technical areas. With this methodology it was possible to determine the dimensions, which according to the approach of different disciplines, it should take on greater weight when analyzing the transects of the peri-urban areas that were studied. The second part of the methodology consisted of quantifying the variables identified in the entities that make up the Mexican Republic, in order to identify which ones meet the most representative characteristics of a peri-urban area. The statistical analysis allowed us to identify that there are different types of peri-urbanism in the country.

Part I

The first part of the methodology was based on a disciplinary, multi and transdisciplinary approach by **Isabel Loupa Ramos (2013)**, as proposed by **Gonçalves et, al. (2017)** and **Andrés Montaño (2020)** to define the peri-urban variables. **Loupa Ramos (2013)** implies that any study whose objective is to understand peri-urban areas, must be based on the triple approach previously mentioned, since the complexity of the peri-urban landscape requires the combination and integration of different areas of knowledge.
The disciplinary approach corresponds to the sum of different areas of knowledge. The activities that are involved are: an individual survey with questions for the group made up of experts about the characteristics that define peri-urban and the identification of main dimensions carried out by the interested parties. The interdisciplinary approach aims to integrate concepts, practices and theories from different areas. In this stage, meetings between the experts were considered in order to agree on the dimensions and variables. In addition, the transdisciplinary approach transcends structures imposed by each discipline because it focuses on social actors and builds bridges between different parties to consolidate the matrix of variables to validate the results that were worked. In this approach, an individual survey is considered with the second working group, made up of stakeholders of the study area in order to find out their definition of peri-urban. Continuing with a thematic workshop for the group of stakeholders to provide information regarding the dimensions and indicators agreed upon by the group of experts and in the end the results are discussed and validated.

It's worth mentioning that the selection of the study area of the municipality of Temixco in the state of Morelos was mainly due to the fact that the headquarters of this work is located in that same location, as well as the knowledge acquired by the body of researchers about the social, governmental and economic behavior of the zone is valuable for the interpretation of the results in real terms. This research is based on the approach of the delimitation of the peripheral space as a differentiating element of the city and the countryside **(Obeso, 2019),** since the transition zone has sui generis qualities with regard to the city and the countryside. In addition, this hybrid area receives a population flow that comes from the city and also from other places surrounding it. Finally, this hybrid zone originates not only because it belongs to a geographic area or to demographic growth, but also to social, economic, and political issues, among others.

Due to the fact that the team that makes up this research is multidisciplinary, the development of the methodology juxtaposes two major areas of knowledge, the technical and social ones. In this sense, the procedure is outlined below:

- Identification of peri-urban dimensions based on expert knowledge
- Definition of a set of indicators for each dimension
- Redundant summarization of information of each indicator of each dimension

In order to address the first point, the multidisciplinary team discussed the answers to the following questions:

1. The peri-urban is… (complete)
2. How do you imagine a peri-urban area?
3. What do you think are the interests of the inhabitants of Temixco when starting a business?

Periurban characteristics were grouped based on the responses. Regarding the first question, the following stand out: transition zone, zone that is not complete (neither urban nor rural), inequity in terms of access to public services (transportation, electricity, piped water, drainage, medical services, educational institutions, etc.) and convergence of economic activities involving rural areas. Concerning the second question, the peri-urban area is imagined as something gray, blurred, without marked borders, with small businesses, small communities, with public services but not of quality. For the third question, we identified: a need for their businesses to prosper, satisfy their needs (those who are considered as such), self-generation of jobs, the need for an urban lifestyle and to earn money.
The characteristics reported in this exercise matched the theoretical definition of a peri-urban transect.

Afterwards, an exploratory approach took place with the interested parties of the project. It was found that the characteristics in practice corresponded to those formulated within the group. This multidisciplinary exercise allowed us to identify the main dimensions of the transect: location, the socio economic aspect, mobility and land use.

Part II

The dimensions mentioned to define a peri-urban area can be translated into quantifiable variables that make it possible to indicate whether an entity is peri-urban or not. When a variable meets the characteristics that define the peri-urban it takes the value of the unit, otherwise the value is zero. For those variables that consider more than one parameter, values between zero and unity are obtained, which indicates the level of peri-urban in that entity. So, to define a peri-urban area, m entities were selected and n variables were considered. Each variable has a defined interval that indicates which entities are considered as peri-urban, taking the value of one or zero depending on which one it belongs to, in a way that we obtain a matrix P_{ij} of dimensions $m \times n$, where the i-th index corresponds to the entities and the j-th to variables.

$$P_{ij} = \begin{bmatrix} P_{11} & P_{12} & P_{13} & \dots & P_{1n} \\ P_{21} & P_{22} & P_{23} & \dots & P_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ P_{m1} & P_{m2} & P_{m3} & \dots & P_{mn} \end{bmatrix} \quad (1)$$

Each row contains the information of an entity, which can be a state, a municipality or a locality. And each column in that row is affected by a weight that must satisfy the following equation:

$$\sum_{j=1}^{n} w_j = 1 \quad (2)$$

In this first analysis equal weights were considered, that is $w_j = 1/n$. By carrying out the matrix product divided by the matrix P_{ij} and the column vector w_j, we obtain a column vector known as c_i.

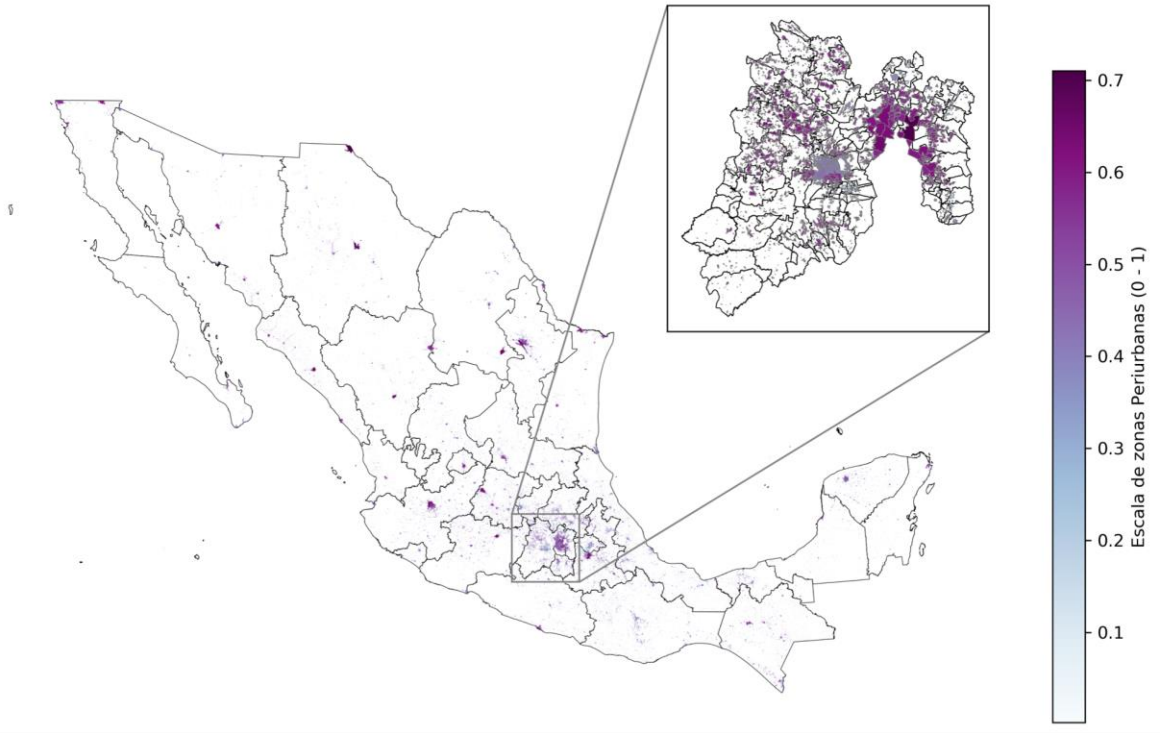
$$c_i = P_{ij} w_j \quad (3)$$

The vector c_i indicates the value of an i-th entity of interest, if the value c_i is close to one, then we know that it meets most of the parameters that define peri-urban and if the value tends to zero, then it moves away from it, being able to be urban or rural.

5. Results

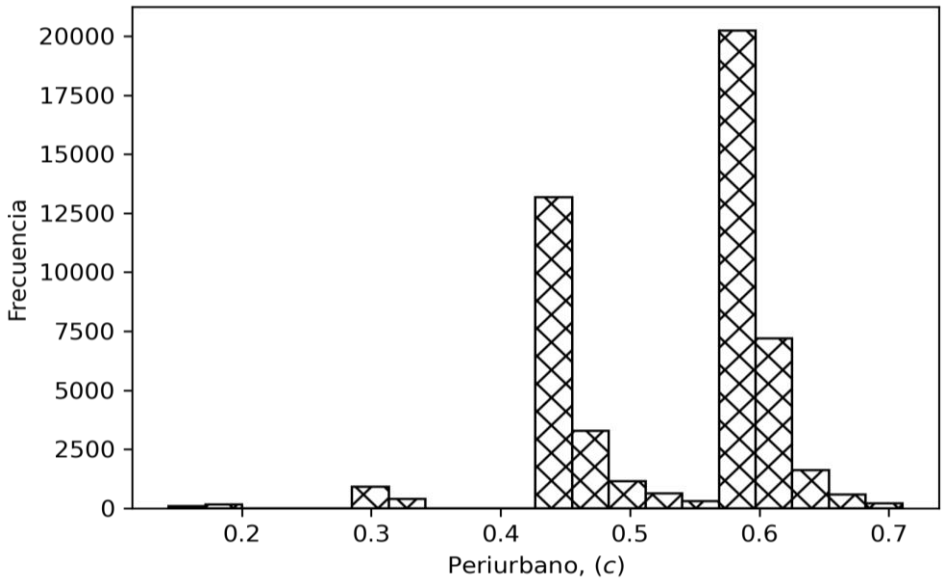
When carrying out the analysis, considering the variables that define the peri-urban, out of the 49,981 localities in Mexico, it is observed that for the parameter c_i there is a distribution where the first and fourth quartiles have the value of 0.44 and 0.59, with an average value of 0.57. Figure 2 shows the value of the parameter c_i of the localities in Mexico, those that have values closer to one better meet the indicators that define a peri-urban entity.

Figure 2: Peri-urban areas of the Mexican Republic by locality, depending on the parameter c_i. A close-up of the peri-urban areas obtained for the State of Mexico is shown.



When obtaining a map like the one shown in Figure 2, we prove that the parameters selected to define this type of peri-urban areas are adequate. However, it is necessary to choose a value that divides the peri-urban from what is not, this cut-off value is known as k and to select it, the behaviour of the values c_i were observed in a histogram. In the histogram, the value c_i of the localities of the Mexican Republic shown in Figure 3, four distributions can be appreciated, from which it can be inferred that there are four sets of localities defined from the parameter mentioned in the previous section. It is known that when the parameter c_i tends to the unit, the locality is periurban, which means that the distribution of interest should be the fourth, in Figure 3, from left to right.

Figure 3: Histogram of the value of c_i in each locality of the Mexican Republic.



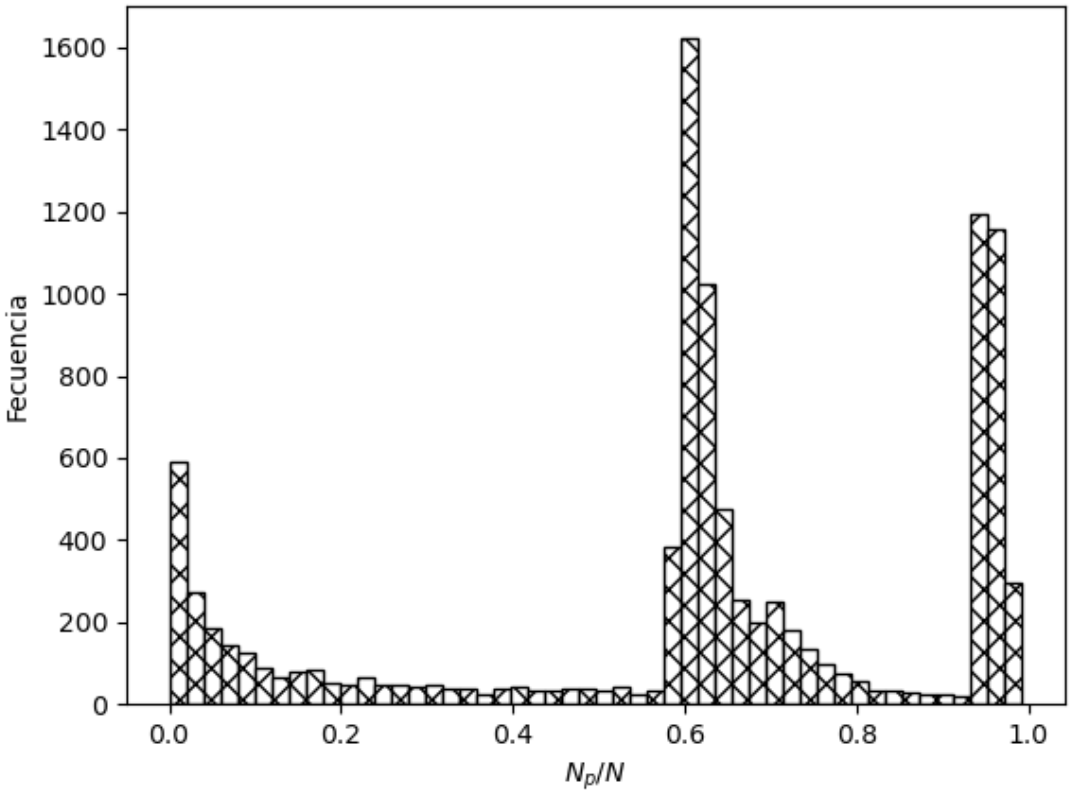
The average value of c_i is 0.53 and given that the distribution of interest is above the mean value of the parameter c_i, a cut-off k value of 0.5 was selected, that is, for a value k>0.5 the locality will be considered periurban. By making the cut in k>0.5, we obtained that 62.4% of the localities in Mexico are peri-urban. However, as previously mentioned, the previous analysis considers equal weights, but those weights shouldn't necessarily have the same value, in other words, different combinations of weights can give the same result. In this case, there should be a combination of weight values that would make it possible to consider that at least 62.4% of the localities are peri-urban.

In order to obtain this combination of interest, 10,000 combinations of weights were generated with a uniform distribution. For each of the combinations of weights generated, the parameter c_i that defines peri-urban was calculated based on the 49,981 localities in Mexico and taking into consideration the cut-off k>0.5 parameter, the number of peri-urban localities obtained from each combination of weight was calculated.

The number of periurban localities in each combination of weights is N_p and the number of periurban localities obtained when considering equal weights is N=49,981, so N_p/N defines the percentage of peri-urban localities that can be peri-urban. Figure 4 indicates that there's a combination of weights w_i that allows considering practically all peri-urban localities. This combination of weights can be found by selecting only the combinations of weights that generate a N_p/N > 0.95, although it's not an attractive combination because basically all of the localities are peri-urban.

In Figure 4, three distributions appear that indicate the number of peri-urban areas that were obtained according to the combination of the selected weights: the one that makes all of the localities tend to be peri-urban and those who are not, which are the extreme distributions; there is another distribution that contains between 59-93% of the peri-urban localities. It should be noted that this last distribution considers the value of equal weights, in which we obtained that 62.4% of the localities are peri-urban.

Figure 4 Frequency of the probability of considering peri-urban localities.



Considering the distribution of interest in the interval of 59-93% of Figure 4, it represents 60% of the total data. Because of this distribution, the mean value of the distribution of the weights is obtained, see Table 2. The mean value of these distributions indicates the weight of each variable shown in Table 1, in which an average ratio of N_p/N of 0.6093 with a standard deviation of 0.0102 is obtained.

Table 2: Weights that consider 60% of the localities as peri-urban.

w_1	w_2	w_3	w_4	w_5	w_6	w_7
0.1258239	0.1526117	0.1218720	0.1270473	0.1562005	0.1127644	0.2036798

Generally, the weights obtained from these 10,000 random combinations indicate that they are very close to the value of 0.1428, with a variation of ± 0.02, except the population size, which is much more relevant than the others by 42.5%. What we can observe is that the value selected for the weights, -equal weights-, when performing the analysis of what peri-urban means, where we obtained that 62.4% of the localities are peri-urban, is a value that falls within the interval obtained in the random combinations between 0.59-0.63. Using the weights obtained in this sensitivity analysis, the localities considered peri-urban are reduced to 60.93%; 1.47% fewer locations than when considering equal weights. It can be inferred that the use of equal weights is a good option.

3. Conclusion

In Mexico there are several case studies regarding peri-urban environments, however each author established a specific methodology for their case study that made it impossible to replicate on a national scale in search for a general characterization of a peri-urban area. Nevertheless, the Gonçalves peri-urban area characterization methodology implemented in the metropolitan area of Lisbon, Portugal, allowed us to identify general indicators that could also be considered in peri-urban areas in the Mexican Republic.

Undoubtedly, one of the greatest challenges was the establishment of ranges or parameters to the data found in the databases in order to have a clear delineation of a peri-urban area for any locality, municipality or federative entity that is managed. To be able to solve the definition of the parameters, the same parameters established by the institutions were used and in cases where the parameters were not available by the institution, these were identified within literature consulted by each variable. In this sense, according to the parameters that define peri-urban, we found that 62.4% of the localities in the Mexican Republic are considered peri-urban.

Figure 2 shows the peri-urban municipalities of the State of Mexico, such as those that adjoin Mexico City, which makes sense when considering that these municipalities are physically between urban and rural areas. On the other hand, Figure 3 shows us that, based on the selected data, the definition of the peri-urban is not an absolute concept, which means there are different types of peri-urbanity, as shown by the different distributions in the figure. It should also be noted that the maximum value registered in the study is 0.71, which is why, added to the above, it confirms that a peri-urban classification must be made, since at least one entity should obtain the value of unit or one very close to it, for it to be necessary to redefine the parameters based on the distributions found. Although there is no significant change between the weights chosen and those obtained from the simulation, it is advisable to assign them different weights from a social point of view, since it is logical that the parameters influence a peri-urban environment differently.

Recognition

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