ATELIÊ GEOGRÁFICO ISSN:1982-1956

# Relationship between quality of life and residential land prices: analysis of spatial segregation patterns in the main cities of Colombia

## *Relación entre calidad de vida y precios del suelo residencial: análisis de los patrones espaciales de segregación en las principales ciudades de Colombia*

## *Relação entre qualidade de vida e preços de terrenos residenciais: análise dos padrões espaciais de segregação nas principais cidades da Colômbia*

**José Mario Mayorga**
Pontificia Universidad Javeriana, Bogotá, Colombia
jose.mayorga@javeriana.edu.co

**Abstract:** The main objective of this research is to describe the influence of land value on the incidence and geographic patterns of segregation in Bogotá, Cali and Medellín. Based on a conceptual and methodological reflection, different geostatistical techniques are applied to calculate an indica lomerations and its relationship with the distribution of residential land values is evaluated. As tor at a micro scale that allows observing the spatialization of the quality of life index in the three urban agg a result, it is obtained that segregation presents particularities in the spatial trend present in Bogotá, Cali and Medellín, but in all three cases there is a statistically and spatially significant distribution with residential land values. The research presents significant contributions to the field of study as it is the first comparative study on residential segregation in the main cities of Colombia and makes a statistical and cartographic effort to generate indicators that can continue to be monitored.

**Keywords:** residential segregation; quality of life, land values.

**Resumen:** La presente investigación tiene como objetivo principal describir la influencia del valor del suelo en la incidencia y patrones geográficos de la segregación en Bogotá, Cali y Medellín. A partir

de una reflexión conceptual y metodológica, se aplican diferentes técnicas geoestadísticas para calcular un indicador micro que permita observar la espacialización del índice de calidad de vida en las tres aglomeraciones urbanas y se evalúa su relación con la distribución de los valores del suelo residenciales. Como resultado se obtiene que la segregación presenta particularidades en la tendencia espacial presente en Bogotá, Cali y Medellín, pero en los tres casos se tiene una distribución estadística y espacialmente significativa con los valores del suelo residenciales. La investigación presenta aportes significativos para el campo de estudio en tanto es el primer estudio comparado sobre la segregación residencial en las principales ciudades de Colombia y hace un esfuerzo estadístico y cartográfico por generar indicadores a los cuales se les pueda seguir realizando seguimiento.

**Palabras clave:** segregación residencial; calidad de vida, valores del suelo.

**Resumo:** O objetivo principal desta pesquisa é descrever a influência do valor da terra na incidência e nos padrões geográficos de segregação em Bogotá, Cali e Medellín. A partir de uma reflexão conceitual e metodológica, são aplicadas diferentes técnicas geoestatísticas para calcular um microindicador que permite observar a espacialização do índice de qualidade de vida nas três aglomerações urbanas e avaliar sua relação com a distribuição dos valores dos terrenos residenciais. Como resultado, obtém-se que a segregação apresenta particularidades na tendência espacial presente em Bogotá, Cali e Medellín, mas nos três casos há uma distribuição estatística e espacialmente significativa com valores de terrenos residenciais. A pesquisa apresenta contribuições significativas para o campo de estudo, pois é o primeiro estudo comparativo sobre a segregação residencial nas principais cidades da Colômbia e faz um esforço estatístico e cartográfico para gerar indicadores que possam continuar a ser monitorados.

**Palavras-chave:** segregação residencial; qualidade de vida, valores

# Introduction

Although research on the history of cities has shown that the separation between groups is as old as urban spaces themselves, residential segregation, as a concept associated with social research, emerged at the beginning of the 20th century and is strongly associated to the socioeconomic transformation driven by the consolidation of industrial capitalism and the distribution of racial groups in the United States (Ruiz-Tagle, 2016).

From a historical perspective, Ospino (2015) accounts for how the separation of housing and work can be observed in the industrial city, which generated a form of housing consumption that manifested itself in the claim to simulate the aristocratic lifestyle, with its large decorative gardens, exclusive residential areas and ornamental gardens. When suburbanization became the dominant consumption paradigm for middle and high income groups in the United States and part of Europe, a process of residential segregation began, which was observed and analyzed by the social sciences in the twentieth century.

Residential segregation is defined as the degree to which two or more social groups differentiate between their places of residence in the urban space, a notion to which different degrees of complexity are attributed, which are reflected in the variety of indices proposed for its measurement (Massey and Denton, 1988). As a spatial phenomenon, residential segregation is measured by relationships of proximity or distance between different social groups depending on the location of their home, which generates trends of homogeneity or concentration of areas of the city and generates low probabilities of social interaction between groups (Rodríguez and Arriagada, 2004).

Research on segregation in Latin America has led to the conclusion that in most metropolitan cities there are similar geographic patterns that allow for the construction of a typical model of segregation in the region (Griffin and Ford, 1980; Bahr and Mertins, 1982; Gormsen, 1991; Ford, 1996; Ortiz and Schiappacasse, 2000; Janoschka 2002; Borsdorf 2003). These geographic patterns have been explored in

various investigations throughout the continent, in which the most notable were carried out in Santiago de Chile by Sabatini (2000), in Montevideo by Katzman (2005) and Artigas, Chabalgoity, Garcia, Mediana and Trinchitella (2002), in Caracas by Carialo and Locabana (2001), in Buenos Aires by Prevot (2002) and Janoschka (2002) and in Mexico by Aguilar (2002). In recent years, the following investigations can be highlighted: The research carried out by Merengo and Elorza (2014) and by Rodríguez (2013) in Argentina, by Vázquez (2018) in Uruguay, by Sabatini, Rasse, Mora and Brain (2012), Ruiz and López (2014) and Rasse (2015) in Chile and by Mier, Velásquez and Zicardi (2012) in Mexico.

Mayorga (2019) identifies about 33 investigations carried out in Bogotá, which have been carried out both in academia and in public administration. The research by Salas (2008) stands out, in which a social classification index is calculated based on the years of education of the population. On the other hand, Aliaga and Álvarez (2010) infer quality of life conditions and their spatial distribution from the socioeconomic strata in the city and Dureau, et al (2015) develop an investigation in which they classify social groups according to a household social condition index (SCI) with three variables from the Census information and estimates some indicators of dissimilarity at micro scales in Bogotá.

In Medellín, the research carried out by Medina, Morales and Núñez (2008) is identified, in which multiple indicators are proposed based on the 2005 census to illustrate spatial segregation in the city. For his part, Velásquez (2012) identifies the relationship between territorial planning and residential segregation during the period 2006-2011, based on an analysis of social interest housing projects (VIS for its syllables in Spanish).

Finally, in Cali, the investigation by Vivas (2013) is identified, in which it is concluded that in the city a high level of segregation of the Afro-Colombian population is presented. On the other hand, Loaiza and Carvajal (2014) obtain as a result that in Cali there are homogeneous sectors in their socioeconomic composition, according to the calculation of the Spatial and Socioeconomic Segregation Index.

When comparing the segregation in the urban agglomerations of Colombia, Mayorga et al (2021) identify that when measuring the distribution of the population that presents multidimensional poverty based on the results of the 2018 Census, in all the urban agglomerations of the country there is residential segregation, but that it is more intense in the agglomerations that have a larger population size, that is, Bogotá, Medellín and Cali. In this sense, it stands out that the three agglomerations of the country with the largest population, that is, Bogotá, Medellín and Cali, present an intensity of spatial segregation that is higher than the rest of the agglomerations of the country, since there is a low incidence of poverty in central areas and there is an expulsion of poor households towards the borders and neighboring municipalities (Mayorga et al, 2021).

It starts from the question: How is residential segregation in Bogotá, Cali and Medellín related to the spatial trend of the value of residential land in the cities?

It is proposed as a main objective to describe the influence of land value on the incidence and geographic patterns of segregation in Bogotá, Cali and Medellín, under the hypothesis that one of the main impacts of segregation in these agglomerations has to do with a significant relationship of the distribution of social groups according to their quality of life and the distribution of land value for housing.

## Residential segregation and land prices

The debates around the role that the housing market plays in the processes of residential segregation, in general terms, have had two approaches. In the first place, an approach that assumes a position of the housing market as a factor that enables the distribution of groups according to their free choice of place of residence based on tastes and proximity preferences with other similar ones in their socioeconomic, ethnic or racial conditions. These models of individual choice find part of their argument in Schellin (1978), based on the fact that housing as a consumer good is chosen according to personal criteria. Second, a deterministic position of social structures and the exercise of power, in which access to housing is a structural problem in which individuals and groups do not have any type of

agency, as Massey and Denton thesis (1988) for US cities. However, recent research has shown that it is not necessary to step on both extremes, rather a vision of the process is important in order to not to assume absolute positions (Preteceille, 2012).

As a starting point to establish the role of the housing market in the residential segregation processes, it is necessary to review the basic concept of land rent, which is at the base of the definition of the market price and is important to establish the differences in access to housing as a consumer good.

Rent is understood as the proportion of a product that the owner of the land claims for himself in a transaction in which he delivers its use for rent or sale and that it varies as a function of the competitive advantages of the location. Jaramillo (2003, 2009) when presenting the concept of rent, indicates that two types can be recognized: the rents that have to do with the existing buildability of a piece of land, which he calls primary, and the rents that depend on the effective use it acquires, be it residential, public, commercial, industrial or others, which he calls secondary. The sum of the primary rent and the secondary rent results in the total price of the land with which it is traded in the market for rent or sale.

Taking the above into account, it can be stated that the role played by residential land rent in the segregation processes can be observed in the two approaches previously proposed.

On the one hand, in the first approach, the land rent that defines the price of the house is not determined in simple supply and demand relationships, since it depends on regulations for its buildability and use, as noted above, and of the willingness of the market to pay for a location based on its "prestige" and accessibility advantages. Therefore, land rent as a product of public decisions or actions becomes a factor to take into account in the production and reproduction of segregation, since it varies depending on the power relations between the agents.

For example, in the North American case, some research has shown that segregation is a product of the way in which white population groups have exercised power through different mechanisms (Ospino, 2017). In the emergence of residential segregation processes in North

American cities, it has been identified that urban policies affected the value of properties in various ways. More directly, cities limited the development of new housing or commercial property, thereby increasing land values in places where demand is high. In addition, in large sections of the suburbs, the development of housing at the lower end of the income distribution was restricted (for example, by implementing a minimum lot size requirement of one acre), resulting in the fact that the population with a higher socioeconomic level was the only one who managed to gain access to said properties.

In Latin America there are a variety of studies produced during the twenty first century in relation to access to urban land and housing by groups with lower socioeconomic capabilities. In general, they have in common that the location of the poor population is identified in peripheral areas of Latin American cities, either due to new territories generated by state public policies of social housing neighborhoods or due to the absence of the state in self-production processes of the habitat from the logic of informality (Elorza, 2019).

In the first place, regarding public decisions with respect to the location of social interest housing for the population with low socioeconomic conditions, the research carried out in the region shows a tendency to locate housing projects more and more distant from areas of good accessibility as an effect of land values that make it impossible to produce low-cost housing in central areas (Elorza, 2019). On this, Montejano et al (2018) point out that the massive production of social interest housing implemented in the region has led to the construction of distant housing complexes and bordering the urban area, taking into account the low capacity of the state for control of land values in schemes for the execution of housing projects in central locations. This has as a result that most of these housing projects break with the spatial continuity of cities and hinder accessibility to other services, such as employment centers, educational facilities, health, culture and recreation.

On the other hand, in the Latin American context, one of the most important forms of production of urban space to understand segregation patterns is urban informality, in the absence of the state as decision maker and regulator of the housing market and its

assets and complementary urban services. Although the concept of informality in its complexity includes variables associated with the normative, social, economic and urban aspects, a spatial definition linked to the origin of the settlement is assumed. It is understood, then, as the urban irregularity with respect to the formal norms with which an urban development process must take place (Camargo, 2013). This form of production of urban space generates the so-called dispersed informal city, fundamentally residential and functionally incomplete, located on the farthest edges of the metropolitan area and highly dependent on the central core (Elorza, 2019). Part of the explanation for this urban informality is found in the fact that access to the formal housing market for the population with socioeconomic deprivations has been conditioned and limited (Clichevsky, 2000; Sabatini, 2003; Jaramillo 2014.)

Both in the production of social interest housing, as well as in the production of housing in informal urbanization processes, the absence of the state in the control of residential land values and in the urbanization process, negatively impacts those who have fewer economic, cultural and social assets within the framework of power relations that structure the urban space. In this sense, it can be affirmed that segregation is far from being a product solely of free location decisions (Loaiza & Carvajal, 2014). Rather, it is linked, although not totally, to the difficulty of accessing cheap land where urbanization processes with adequate housing and sufficient facilities take place (Mier, et al 2012).

## Study Area and Method

There is no standardized requirement on how the main content is organized. However, we expect the author to divide it into several sections indicating literature review and analytical results and discussions.

## Urban agglomerations studied

The research was carried out in the three main urban agglomerations of Colombia, which together concentrate about 30% of the total population of the country and contribute more than 35% of the Gross Domestic Product (DANE, 2020), which is why they are considered the Golden Triangle of Colombia.

In the three study agglomerations, spatial transformation processes can be recognized in the last thirty years that lead to population settlements, functional relationships and economic dynamics exceeding political-administrative limits and creating a conurbation with other municipalities. In this sense, in the three agglomerations intense relationships are observed between a main city or nucleus of greater weight in the territorial dynamics with respect to other nodes of municipalities (DNP, 2014).

The scope of study is not limited to the political-administrative limits of the three capital cities, but rather involves the territory of the municipalities with which it has close socioeconomic dynamics and a functional integration in an urban continuum. For the study in Bogotá, a joint analysis was made with the municipalities of the western conurbation (Funza, Madrid, Mosquera), the northern conurbation (Chía and Cajicá) and the southern conurbation (Soacha), since they are conurbated and generate a continuum with intense functional relationships, although there is no constituted metropolitan authority. This conjunction of municipalities is distributed through a part of the Bogotá Savanna, taking the western hills as the limit and developing together mainly to the north and west of Bogotá. According to DANE population projections (2020), the agglomeration has about 9.2 million inhabitants, of which 99% are located in urban areas. The second urban agglomeration studied was Medellín, which includes the municipalities of Envigado, Itagüí, Bello, Caldas, Sabaneta, La Estrella and Copacabana, which together add up to about 4 million inhabitants (DANE, 2020), 98% settled in urban areas. Finally, in Cali, the agglomeration was analyzed together with Jamundí and Yumbo, since they are municipalities conurbated with the central city. It is estimated that for the year the research was carried out, the population was close to 2.9 million inhabitants (DANE, 2020), of which 98% are located in urban areas.

## Method

For the development of this research, it was identified that the appropriate source of information, taking into account the variables and scale of the results, is the National Population and Housing Census (CNPV for its syllables in Spanish: "Censo Nacional de Población y Vivienda") carried out in 2018.

The results of the CNPV of the year 2018 were used at the census block scale to later be interpolated and thus be able to establish what the distribution of social groups is like and whether or not residential segregation occurs. One of the advantages of handling data at this scale, is that it makes it possible to build neighborhood relationships and spatial contiguity between different social groups, in such a way that it is possible to observe how the distribution trend is in the urban environment (Garroncho and Campos, 2013).

The classification of social groups to estimate segregation indicators was assumed based on the methodological decision to build a Basic Quality of Life Index (ICVB for its syllables in Spanish: "Índice de Calidad de Vida Básico"). This decision is based on two key aspects for measuring the phenomenon in Colombian cities, on the one hand, the need to have multiple variables to measure the socioeconomic level of the population and, on the other, enabling comparison between the different urban agglomerations by having the same sources and variables to classify social groups.

For the construction of the ICVB, variables were used that account for the conditions of the groups according to the type and services of the dwelling, its conditions, composition of the household, overcrowding in the dwelling, activity carried out by the head of the household and educational level of the members of the household.

The ICVB was created with the following indicators contained in CNPV:

1. Number of Households per housing unit
2. Percentage of households in dwellings according to multi-tenant houses
3. Percentage of households that do not have sewerage service in the home

4. Percentage of households that do not have a water supply service in the home

5. Percentage of households that do not have energy service in the home

6. Number of people per household

7. Percentage of population with economic dependence (Under 15 and over 65 years old)

8. Percentage of population over 17 years of age who are looking for a job

9. Average years of study achieved

10. Percentage of population older than 17 years of age without any degree of education

Each of the indicators included was standardized on a scale from 0 to 100 for comparison and synthesis. Once standardized, a factor analysis by principal components was used to synthesize the eight indicators into an index. In the factorial analysis, the following elements were taken into account (Montoya, 2007; Vallejo, 2013; Yong & Pierce, 2013).

1. Correlation: establishes the degree of association between the variables. The p value is expected to be less than 0.05 to validate that there is a statistically significant relationship and that at least one variable is related to 70% of the others. Otherwise, it must be extracted from the model.

2. Kaiser-Meyer-Olkin (KMO) test: it is the first statistic to test the validity of the model. The test relates the correlation coefficients. The closer to 1 the value obtained from the KMO test implies that the relationship between the variables is high, which is why it is expected to be above 0.7 to validate the model.

3. Bartlett's sphericity test: with which it is evaluated if it is possible to apply the factorial analysis technique with the included variables. It is evaluated from a hypothesis test, in which it is expected to reject the null hypothesis with a P value less than 0.005.

4. Factor: is the result of the reduction of the variables.

5. Explanation of the variance: it is the percentage of the variables that is explained in the generated factors. The closer to 100% the model is, the better it manages to express the variables, thus it is expected to explain at least 70% of the initial variance of the included variables.

6. Varimax rotation: method that minimizes the number of variables related to each factor, in such a way that its denomination is facilitated.

7. Communality: percentage of the initial variable that is included in the model. The closer to 100% the model has, the better estimate in each variable, which is why it is expected to be greater than 60% to validate the model. It is less than the variance because there are variables that can achieve a greater explanation than others.

With the results of the ICVB at a block scale, an interpolation was generated for the best spatial reading of the trend. The identification of clusters or dispersion of the data was done with the Morán global index, to establish if there was significant evidence of conformation of areas in which the population with High, Medium or Low ICVB agglomerates.

To describe the influence of land value on the incidence and geographic patterns of segregation, the generation of market information on residential land values was carried out and social interest housing projects present in each study agglomeration were identified. In both cases, the databases of the housing market information portal, called “la Galería Inmobiliaria”, were used as a source.

The information was acquired for the period 2000 to 2020, with geographic coordinates, types of housing offered and commercial sale value of the built square meter. This portal offers paid services in which information for the real estate sector can be managed through the capture, processing and analysis of updated and truthful information on market dynamics. This information is produced for the main urban agglomerations in the country, including Bogotá, Cali and Medellín, with data on all the housing projects offered, both in the main city and in the municipalities in its area of influence.

With this information, four procedures were generated:

1. In the first place, a Kriging interpolation analysis was generated to identify the general trend of housing values in square meter ($m^2$)

in the three agglomerations. With the information from the Real Estate Gallery, which has the coordinates for each of these projects for georeferencing, the spatial characterization of the land values in the three study agglomerations was carried out. The information on the land values of the housing market was processed for the years 2018, 2019 and 2020 to have a larger universe, indexing the previous years to the value of 2020 to allow their comparison and subsequent analysis.

Based on the georeferencing of the housing projects, counting on the attribute of value per $m^2$ of dwelling, a Kriging interpolation model was built that could allow recognizing the spatial trend of housing market values in each agglomeration. This spatial model is based on the principles of autocorrelation, that is, the statistical relationships between the measured points. As a result, the model not only has the ability to produce a prediction surface, but also provides some measure of certainty or precision of the predictions (Mayorga, 2021).

The general formula has the following notation:

**Equation 1 Kriging interpolation model**

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

Where:

Z(si) = the value of $m^2$ of housing measured in the location i

λi = an unknown weighting for the value of mt2 of housing measured in the location i

s0 = The location of the prediction

N = the number of housing projects measured

The second procedure consisted of establishing a statistical relationship between the identified trend in land values and the previously calculated ICVB distribution, to identify if any recognizable spatial and statistical pattern in both cases exist. A logarithmic

regression and a geographically weighted regression were carried out, in both cases taking the land value as an independent variable to estimate if it has a significant influence on the levels of quality of life. These regressions were used taking the block as the spatial unit, of which the ICVB was already known, and the average value of residential $m^2$ was calculated according to the interpolation carried out.

The notation for the logarithmic regression that seeks to establish the influence of land value on quality of life is as follows:

**Equation 2 Logarithmic regression**

$$ICVB = a * \ logn(Value\, m^2) + b$$

The notation for the geographically weighted regression that seeks to establish the influence of land value on quality of life is as follows:

**Equation 3 Geographically weighted regression**

$$ICVB = \beta_0(Ui,Vi) + \sum_{j}^{k} \beta_1(Ui,Vi) Value\, m^2\, dwelling + e$$

As a differentiating element in this type of regression, it seeks to establish in which sectors of each agglomeration this relationship has greater significance, which allows defining whether or not there is a recognizable spatial pattern.

# Results

## Residential segregation in the three agglomerations according to ICVB

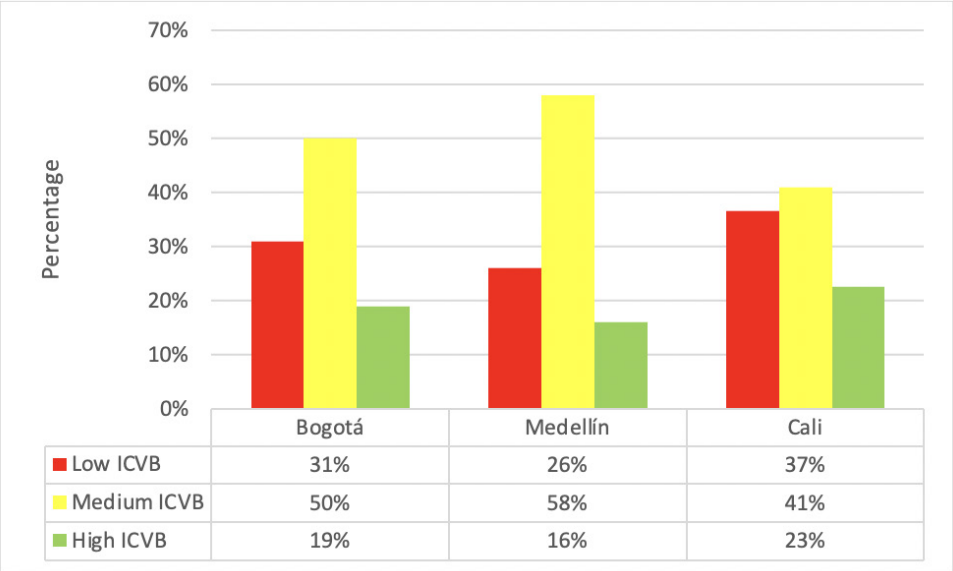
As a result of the factorial analysis, it was found that in the three study agglomerations the ICVB is valid, since it manages to explain 74% of the variance in the agglomeration of Bogotá, 71% of the variance in the agglomeration of Medellín and 73 % in the agglomeration of Cali.

When generating the ICVB in the three agglomerations, the model was valid, obtaining a KMO greater than 0.7, which allows us to affirm that the factors significantly express the variables included

in the model. In addition, Bartlett's sphericity test has a P value of (0.00)<0.05, with which it can be inferred that the index adequately collects the information of the variables. The communalities indicate that the model is valid as long as an extraction of more than 60% of the variance of the indicators used to build the ICVB was achieved.

By using the varimax rotation, it was possible to obtain a better relationship between the variables and the factors, which made it possible to denominate Factor 1 as socioeconomic characteristics of people, Factor 2 as housing characteristics, and Factor 3 as the demographic composition of the households. The composite index in the three agglomerations was calculated as a simple average between the three factors and expresses a value that ranges from -4 to 4 with a mean of 0. From the frequency distribution and the deviation of the data, a classification by natural cuts in each agglomeration in which it was considered that the ICVB is low when obtaining negative values, medium when it is between 0 and 2, and high when it is above 2.

In the case of the agglomeration of Bogotá, the distribution of the ICVB by amount of population indicates that 31% is in a low range, 50% can be classified as medium and the remaining 19% corresponds to a high ICVB. In the agglomeration of Medellín, 26% of the population is classified as having a low ICVB, 58% with a medium ICVB and 16% with a high ICVB. Finally, in Cali the results indicate that this city presents the highest proportion of the population with a low ICVB compared to the other two agglomerations, since 36% are in this classification, while the population with a medium ICVB is 41% and with High ICVB is 22%.




| | Bogotá | Medellín | Cali |
|---|---|---|---|
| Low ICVB | 31% | 26% | 37% |
| Medium ICVB | 50% | 58% | 41% |
| High ICVB | 19% | 16% | 23% |

**Figure 1 – Distribution of the population according to the results of the ICVB.**

*Self Production.*

When evaluating the spatial trend of the ICVB results, it was obtained that there is significant evidence to accept the hypothesis of spatial autocorrelation and the conformation of conglomerates or clusters of groups according to whether their ICVB is high, medium or low.

In the case of the agglomeration of Bogotá, the spatialized results of the ICVB allow us to observe in Figure 2 that there is a concentration of high groups in a high rent wedge that goes from the center to the north of the city, along the eastern edge, with a pronunciation towards the west along the axis of the road that leads to the international airport. On the other hand, it can be observed that there are some islands of groups with high ICVB to the northwest of the city towards the municipalities of Cajicá and Chía. An opposite trend can be observed in the distribution of the groups with low ICVB, since they tend to be concentrated in the south and west of Bogotá and generate a continuum with the municipality of Soacha and some sectors of the municipalities of Funza and Mosquera (Mayorga, 2021).

In figure 3 is shown the spatial trend of the ICVB in the agglomeration of Medellín and it can be noted that there is a distribution of groups with high ICVB towards the southeast of the agglomeration, which shows the most significant conglomerates in the municipalities of Envigado, Sabaneta, Itagüí and La Estrella. In addition, some high ICVB conglomerates of lesser intensity stand out in the center and west parts of the agglomeration. The low ICVB forms some conglomerates in the eastern and western extremes of the agglomeration, and they tend to be stronger to the north in the municipalities of Bello and Copacabana. However, some smaller conglomerates are also observed towards the valley of the city, in the vicinity of the Medellín River. (Mayorga, 2021).

Lastly, Figure 4 presents the distribution of the ICBV in the urban agglomeration of Cali, in which it is evident that the groups with high ICVB are located in a wedge that borders the agglomeration to the west in a south-north direction, in relation to the municipality of Jamundí. The distribution of groups with low ICVB shows that there is a higher concentration in the Agua Blanca District to the east of the city, on the edges of the Cauca River, and a lower concentration in the Siloé sector on the western mountain chain. A low ICVB conglomerate is highlighted in the municipality of Yumbo, which is located to the north of the urban agglomeration (Mayorga, 2021).

In the three agglomerations it can be observed how the groups with medium ICVB establish themselves as an intermediate buffer between the distribution of the group with low and high ICVB (Mayorga, 2021).

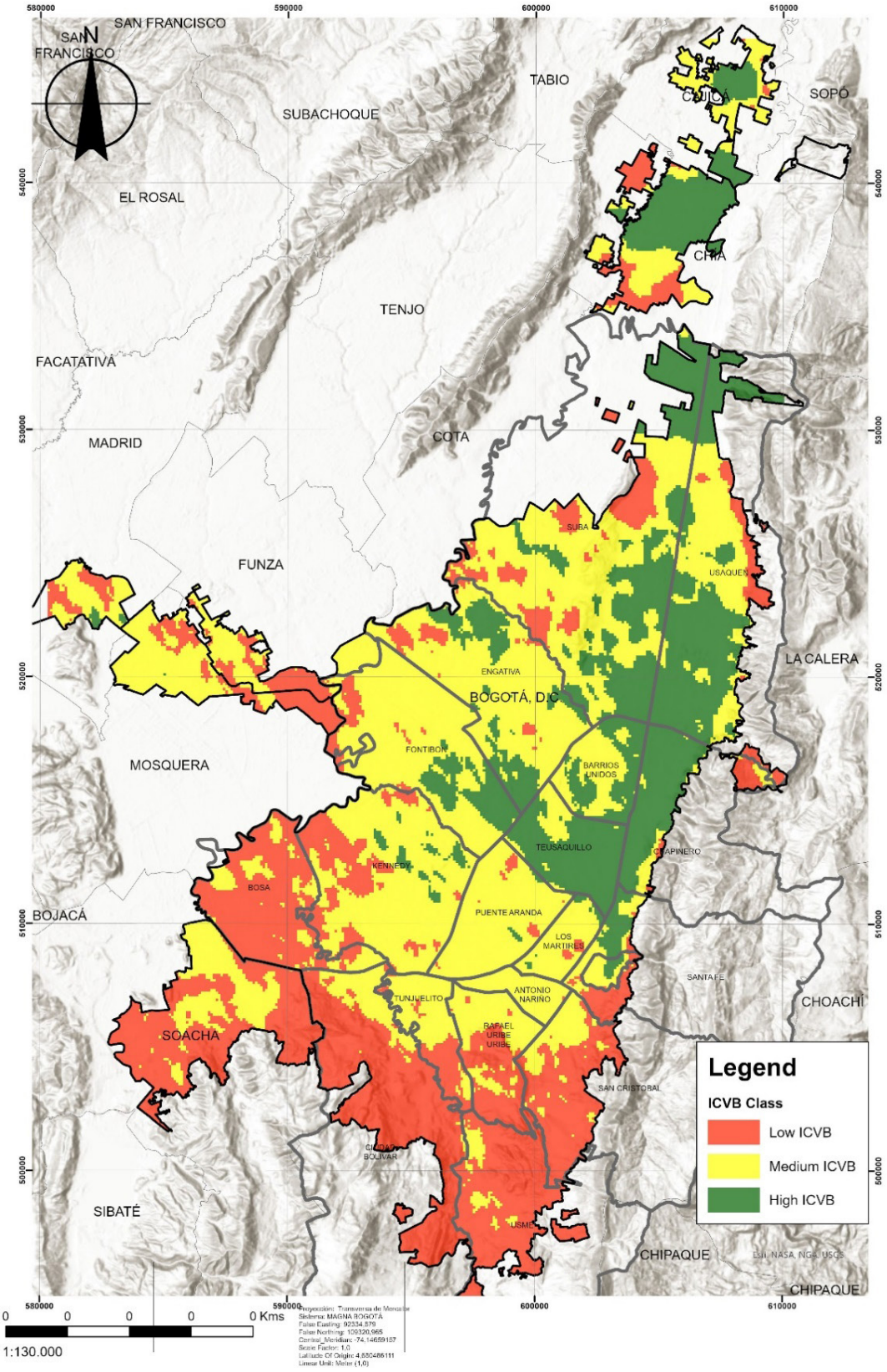



**Figure 2 – Spatialization of the ICVB in the urban agglomeration of Bogotá.**

*Self-Production.*

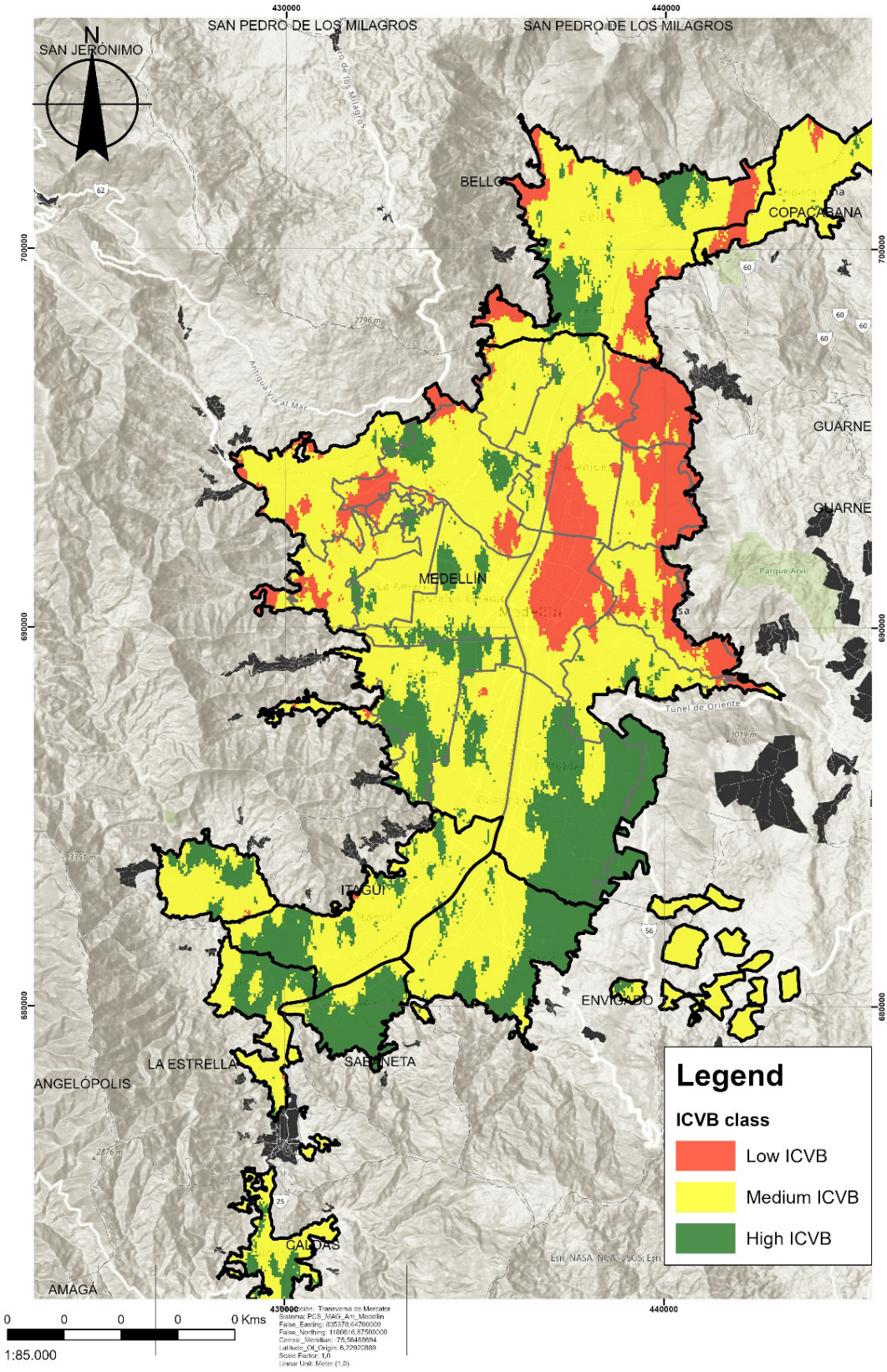



**Figure 3 – Spatialization of the ICVB in the urban agglomeration of Medellín.**

*Self-Production.*

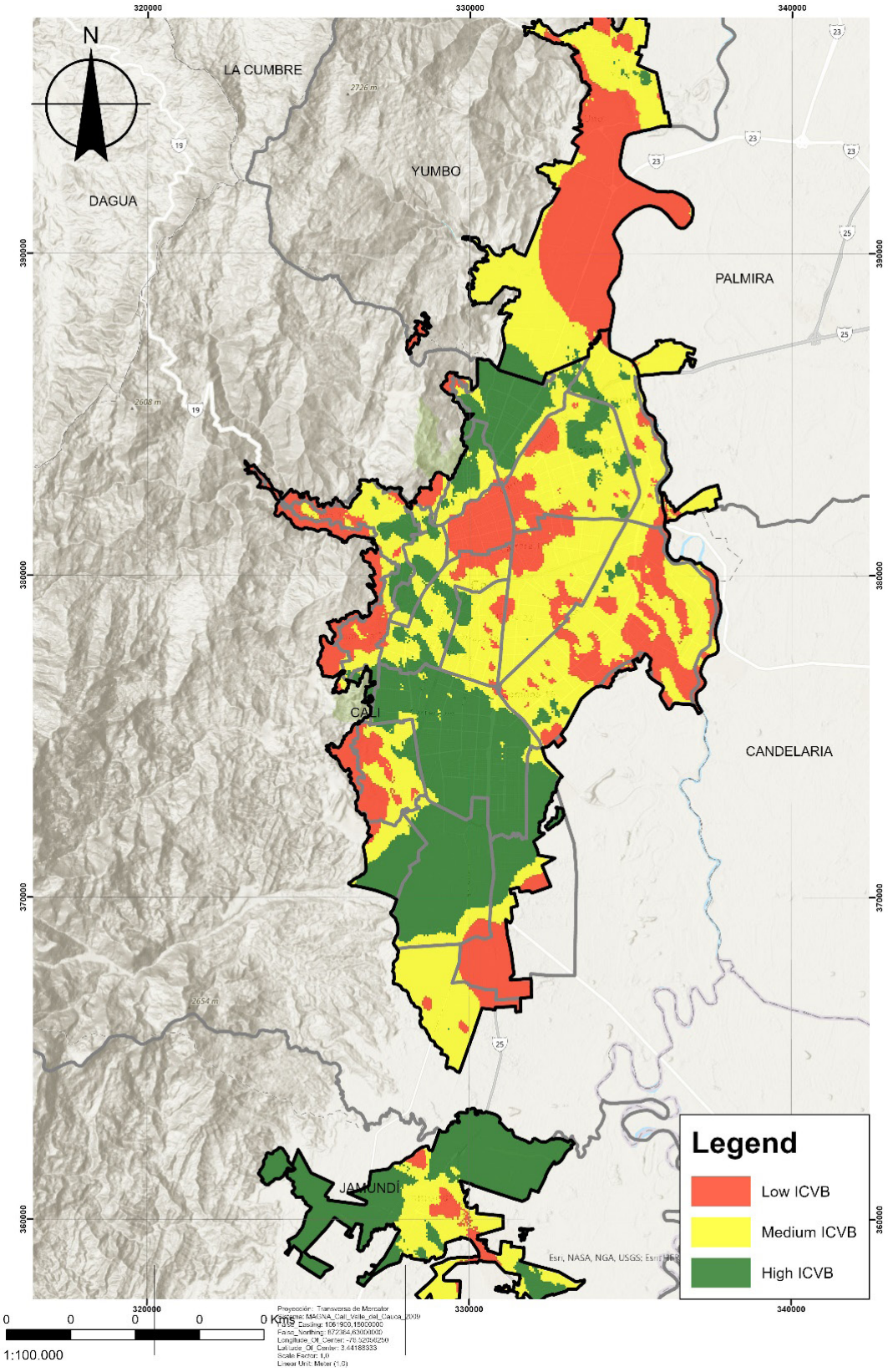



Figure 4 – Spatialization of the ICVB in the urban agglomeration of Cali.

*Self-Production.*

## Land Values

Once the values of residential land in Bogotá were spatialized and the hypothesis test for the Moran index was applied, with a spatial correlation value of 0.69 and a P value of less than 0.05, it was confirmed that the cluster-like behavior is statistically significant; that is, that the spatial distribution of high values and low values in the data set is more spatially clustered than would be expected if the spatial processes were at random. In this way, the land values in the city show a clear pattern of concentration of high values towards the eastern zone, with a tendency of decrease towards the perimeter edges, which is expressed with differential behaviors towards the western limit and the southern zone of the city. the city (Mayorga, García & Hernández, 2017). Regarding the municipalities of the agglomeration, a trend of higher land values to the north and lower land values in Soacha, Funza, Madrid and Mosquera are identified.

In the agglomeration of Bogotá, with respect to the distribution of the ICVB in the year 2018, the regression model between the variables indicates that there is a better adjustment with a logarithmic type curve, since the coefficient of determination R^2 is 0.49. With a P-value in the ANOVA table of less than 0.05, there is a statistically significant relationship between ICVB and Value ($m^2$) of land in Bogotá with a confidence level of 95.0% (Figure 5).

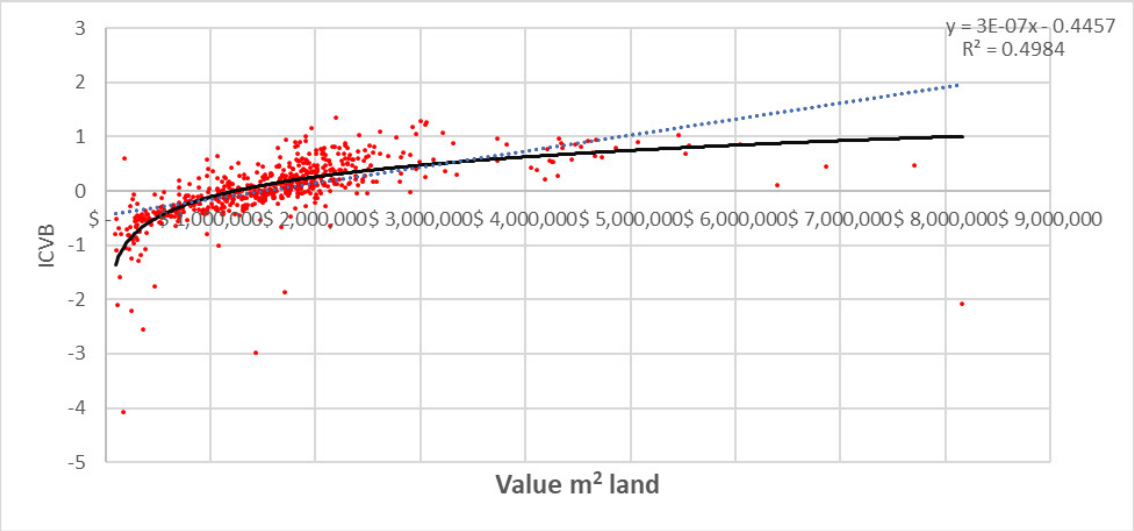



**Figure 5 – ICVB ratio and residential m2 values in the agglomeration of Bogotá.**

*Self-Production.*

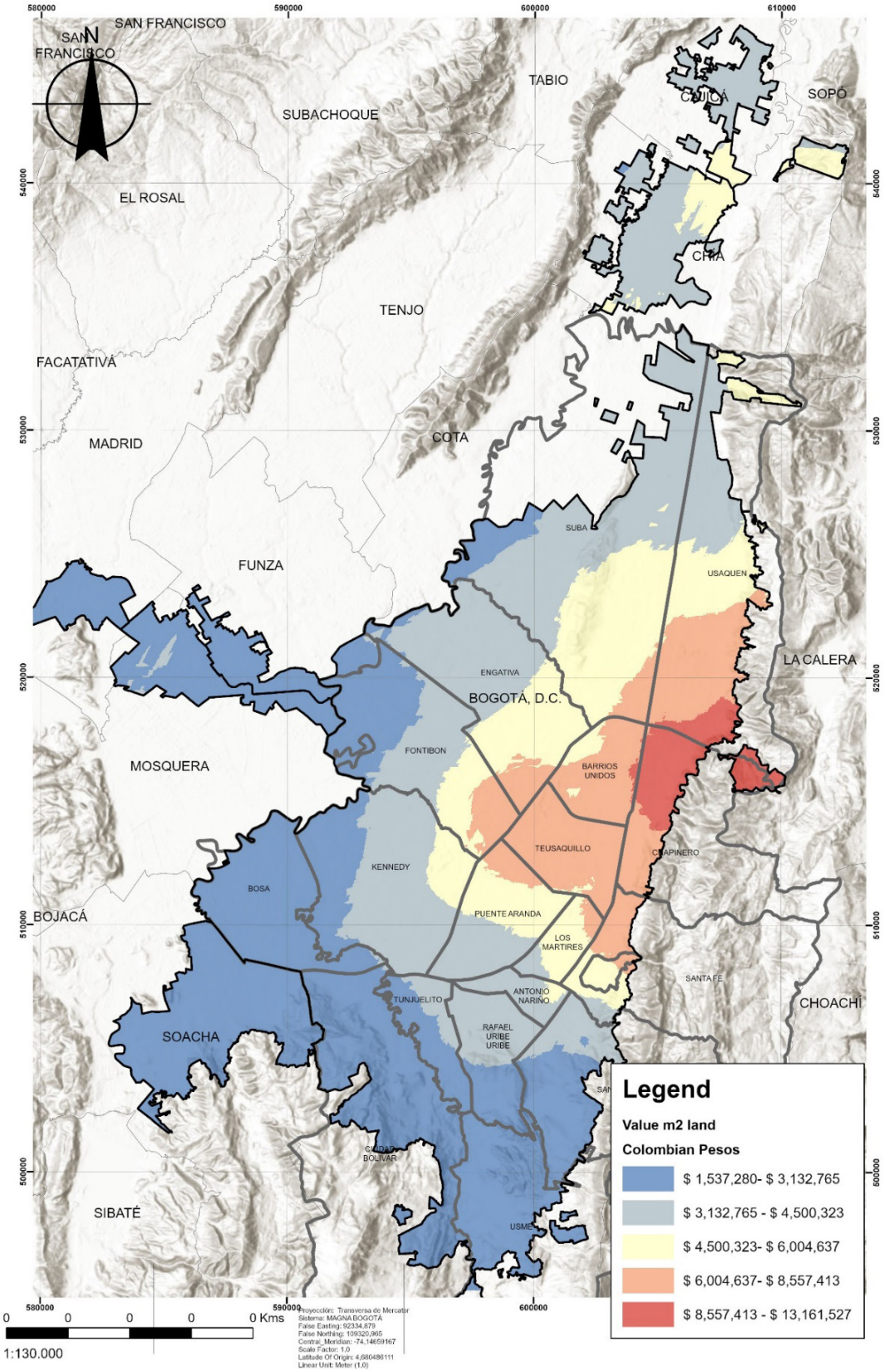



**Figure 6 – Value trend of residential m² in the agglomeration of Bogotá.**

*Self-Production.*

With that in mind, taking into account that the proposed relationship is a spatial problem that does not behave in a homogeneous way, a geographically weighted regression model was used to establish a local relationship between the variables. The explanatory model, locally adjusted with a relationship of 8 neighbors (taking into account contiguity at edges and corners), was able to explain 72% of the values of the dependent variable in Bogotá. The model is valid as long as the regression residuals, that is, the difference between the predicted and observed values, are randomly distributed. The hypothesis that housing values influence in the distribution of social groups according to their quality of life is accepted, and significant and direct relationship patterns are recognized, in which, the higher the value of the land, the better the quality of life of the population that resides there.

This relationship presents a greater statistical significance in the blocks that are classified with low ICVB and high ICVB. While in 48% of the former there is a statistically significant relationship, in the case of blocks with a high ICVB it is 71%, which allows to confirm the hypothesis that land values are generating an influence on the distribution of social groups in the agglomeration space. In the case of the average ICVB, the statistical significance of the relationship only occurs in 13% of the blocks, being the group in which it is found the greatest randomness (Figure 7).

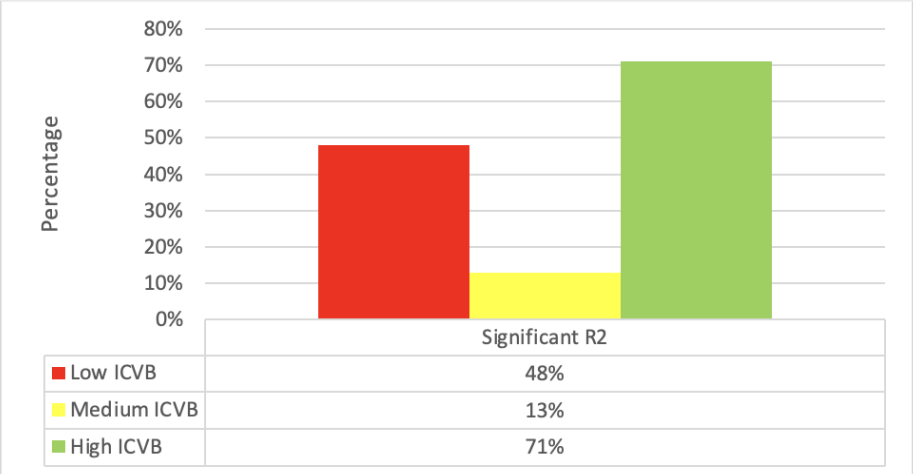



**Figure 7 – Blocks with statistical significance in the relationship between land value and ICVB according to the geographically weighted regression in Bogotá.**

*Self-Production.*

The results in the urban agglomeration of Medellín indicate that when applying the hypothesis test for the Moran index, with a spatial correlation value of 0.53 and a P value less than 0.05, it is accepted that the conglomerate type behavior is statistically significant. In this sense, the spatial distribution of the values has a behavior that is not random and recognizable patterns are generated in space. As such, the values of the land in the city show a radial relationship with respect to the flat areas around the "Río Medellín", in which the highest values are presented and gradually decrease towards the upper parts of the east and west. Likewise, there is a clear trend of high land values towards the south of the city.

In the urban agglomeration of Medellín, the regression model between the variables indicates that there is a better fit with a logarithmic type curve, since the coefficient of determination R^2 is 0.37. With a P-value in the ANOVA table of less than 0.05, there is a statistically significant relationship between ICVB and value $m^2$ of land in Medellín with a confidence level of 95.0% (Figure 8).

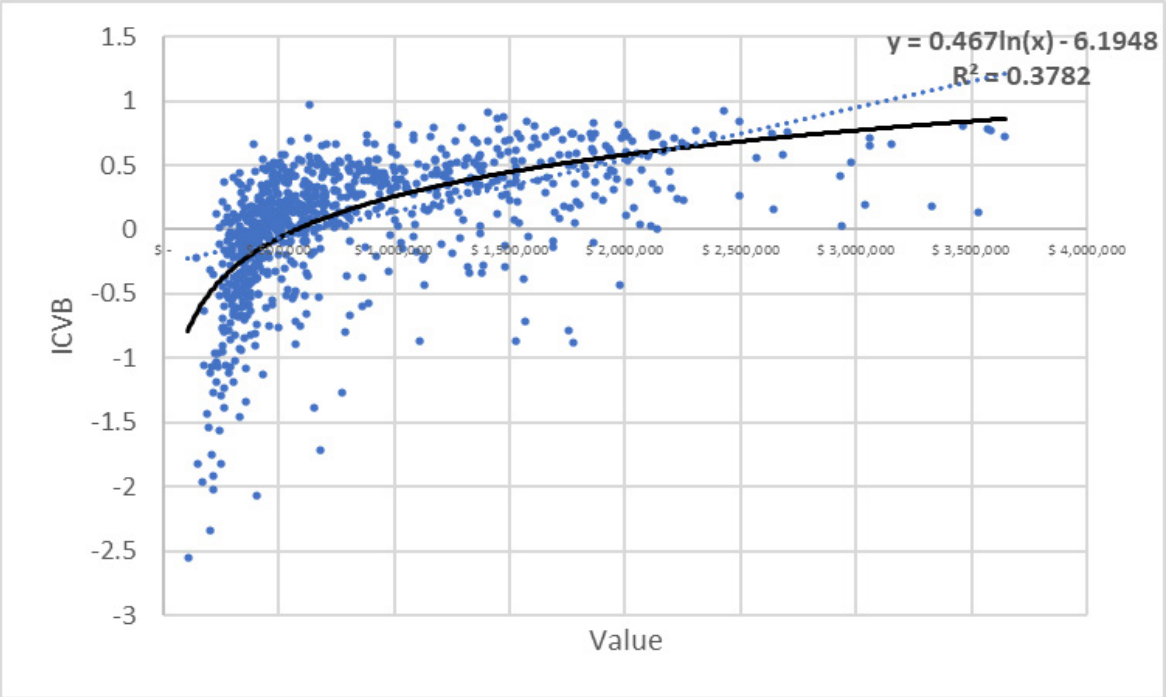



**Figure 8 – ICVB ratio and residential m2 values in the agglomeration of Medellín.**

*Self-Production.*

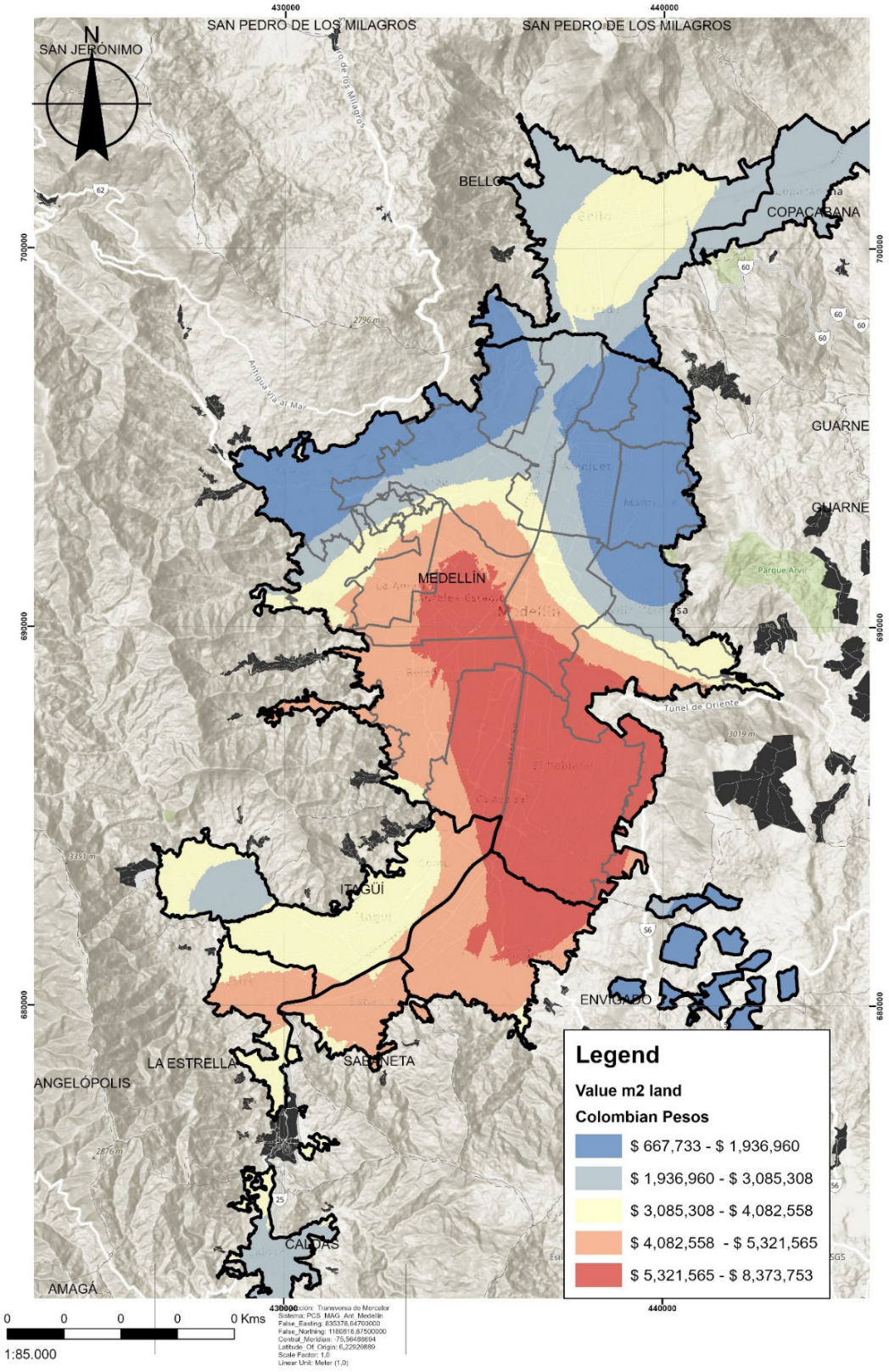



**Figure 9 – Value trend of residential m² in the agglomeration of Medellín.**

*Self-Production.*

With that being said, taking into account that the proposed relationship is a spatial problem that does not behave in a homogeneous way, a geographically weighted regression model was used to establish a local relationship between the variables. The explanatory model, locally adjusted with a relationship of 8 neighbors (taking into account contiguity at edges and corners), was able to explain 60% of the values of the dependent variable in Medellín. The model in the city is valid as long as the regression residuals, that is, the difference between the predicted and observed values, are randomly distributed.

This relationship presents a greater statistical significance in the blocks that are classified with low ICVB and high ICVB, although it is much lower than in the case of Bogotá. While in 35% of the former there is a statistically significant relationship, in the case of blocks with a high ICVB it is 42%, which allows to confirm the hypothesis that land values are generating an influence on the distribution of social groups in the agglomeration space. In the case of the average ICVB, the statistical significance of the relationship only occurs in 10% of the blocks, being the group in which it is found the greatest randomness (Figure 10).

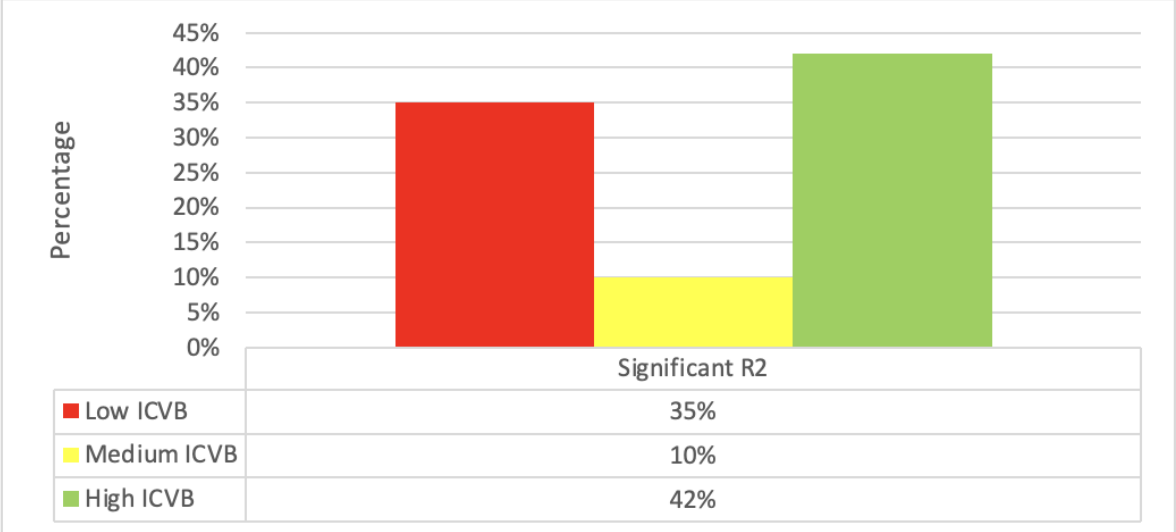



**Figure 10 – Blocks with statistical significance in the relationship between land value and ICVB according to the geographically weighted regression in Medellín.**

*Self-Production.*

The results in the urban agglomeration of Cali, with respect to land values in the city, show clearer patterns of grouping of high values in the south-north axis of the city, on the western side. As with the other agglomerations, when applying the Moran index, it is obtained that, with a P value less than a significance level of 0.05, the values present spatial autocorrelation and are grouped into clusters.

In Cali, the regression model between the variables also indicates that the best model to predict the relationship is the logarithmic one, since a significant coefficient of determination is obtained, in which R^2 is 0.357, while in a linear model it is of 0.296. In the case of Cali, it is also concluded that there is a verifiable and significant relationship as in the other two cities studied. However, it is the lowest of the three agglomerations.

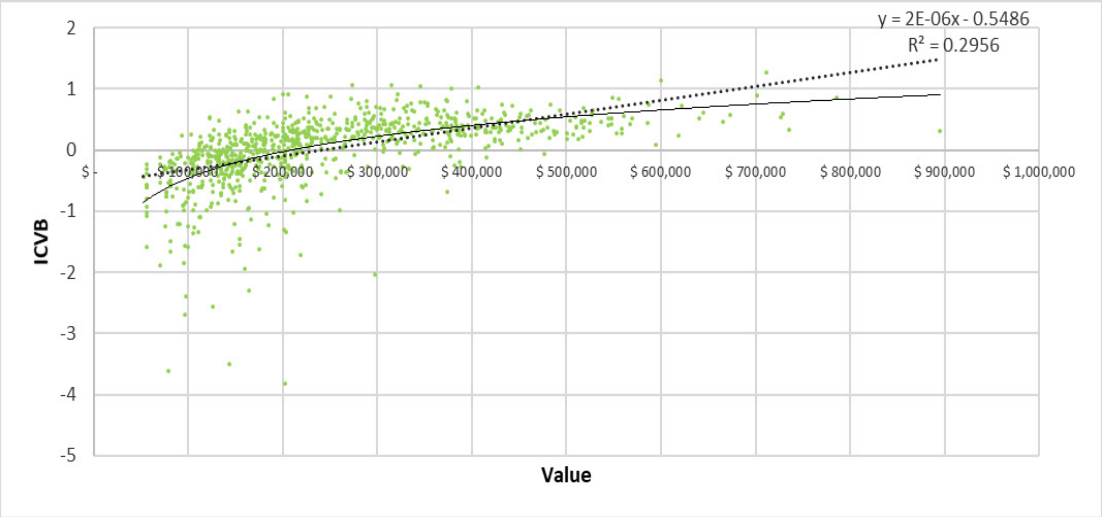



**Figure 11 – ICVB ratio and land values in Cali.**

*Self-Production.*

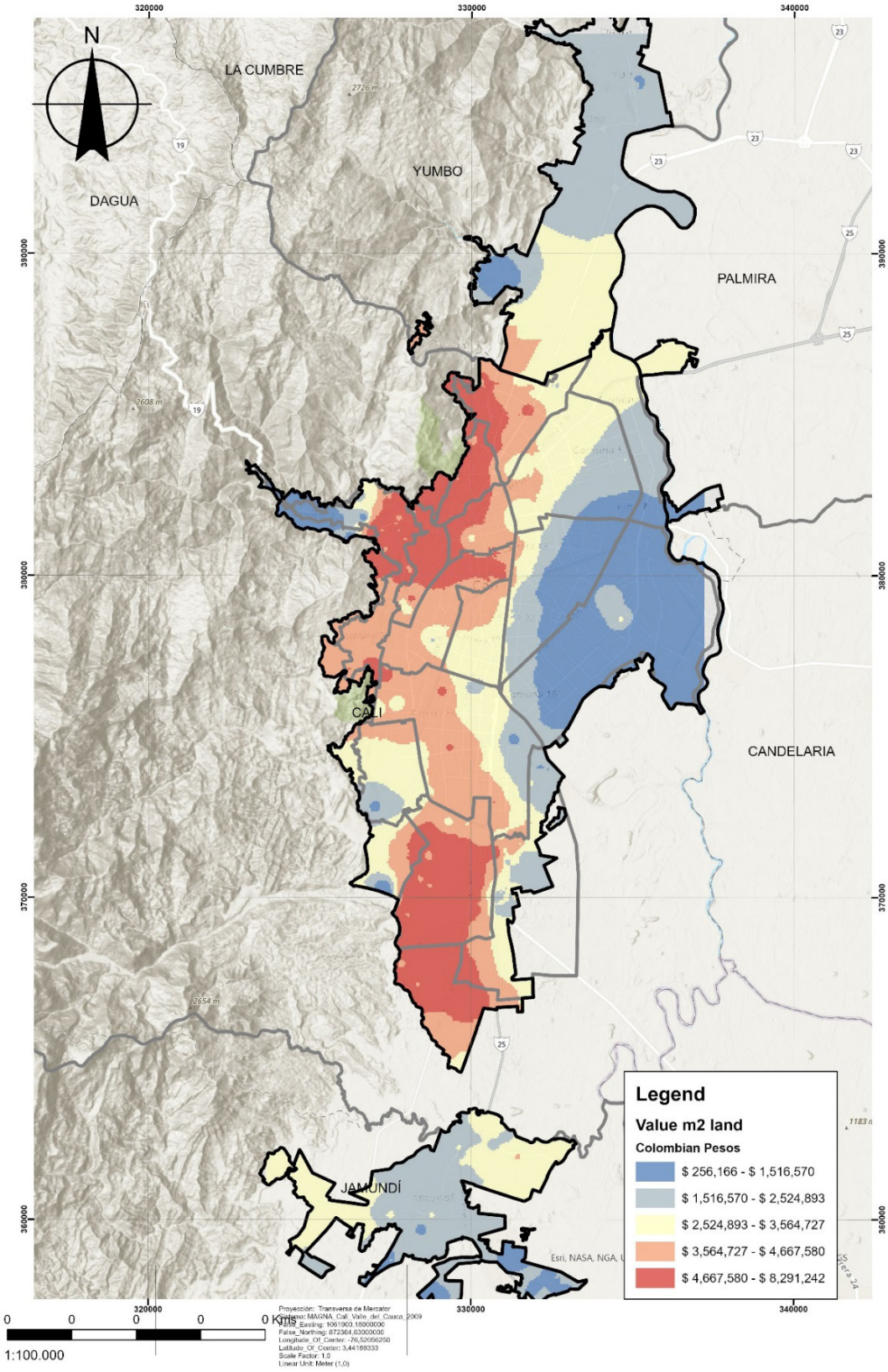



Figure 12 – Value trend of residential m² in the agglomeration of Cali.

*Self-Production.*

Bearing that in mind and taking into account that the proposed relationship is a spatial problem that does not behave in a homogeneous way, a geographically weighted regression model was used to establish a local relationship between the variables. The explanatory model, locally adjusted with a relationship of 8 neighbors (taking into account border and corner contiguity), was able to explain 58% of the values of the dependent variable in Cali. The model in this cluster is valid as long as the regression residuals, that is, the difference between the predicted and observed values, are randomly distributed.

This relationship presents a greater statistical significance in the blocks that are classified with low ICVB and high ICVB, although it is much lower than in the case of Bogotá and more similar to the case of Medellín. While in 39% of the former there is a significant statistical relationship, in the case of blocks with a high ICVB it is 40%, which allows to confirm the hypothesis that land values are generating an influence on the distribution of social groups in the agglomeration space. In the case of the average ICVB, the statistical significance of the relationship only occurs in 14% of the blocks, being the group in which it is found the greatest randomness (Figure 13).

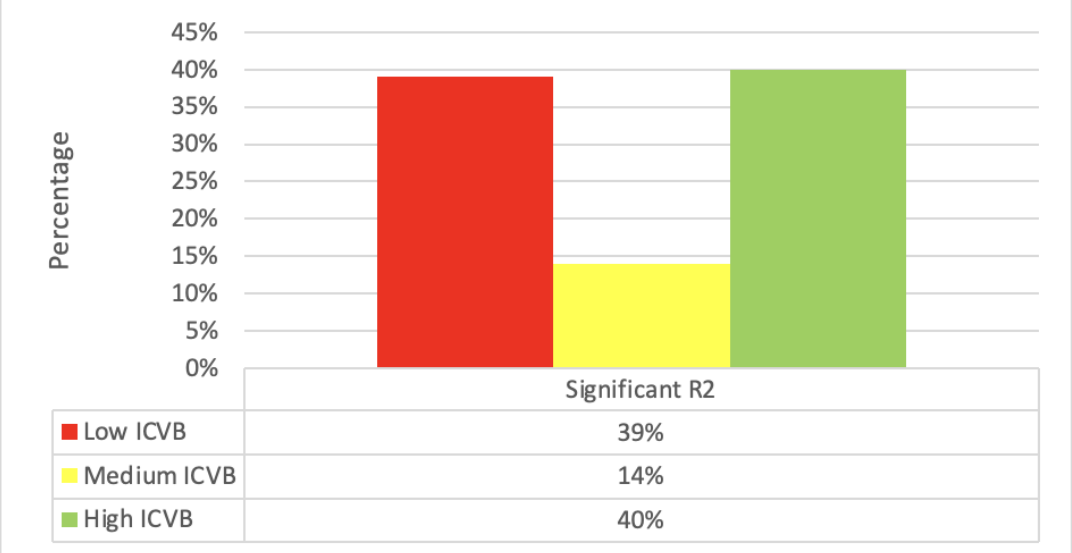



**Figure 13 – Blocks with statistical significance in the relationship between land value and ICVB according to the geographically weighted regression in Cali.**

*Self-Production.*

## Conclusions and discussion

Through the present work, empirical evidence has been generated on three phenomena.

The first of them corresponds to the analysis of the spatial behavior that presents the quality of life. This characterization was carried out at a block level, achieving much more specific levels of detail compared to the mesoscale generally used for this type of analysis. In this way, it is possible to identify at the spatial level the different degrees of concentration of groups with homogeneous socioeconomic conditions within them and a more heterogeneous general distribution pattern throughout the city, which tends to avoid the mixing of groups among themselves.

As a result of this analysis, it was found that the behavior of the quality of life conditions has recognizable patterns in Bogotá, Cali and Medellín, which allow us to recognize that vast areas of the city are inhabited by similar socioeconomic groups in their living conditions.

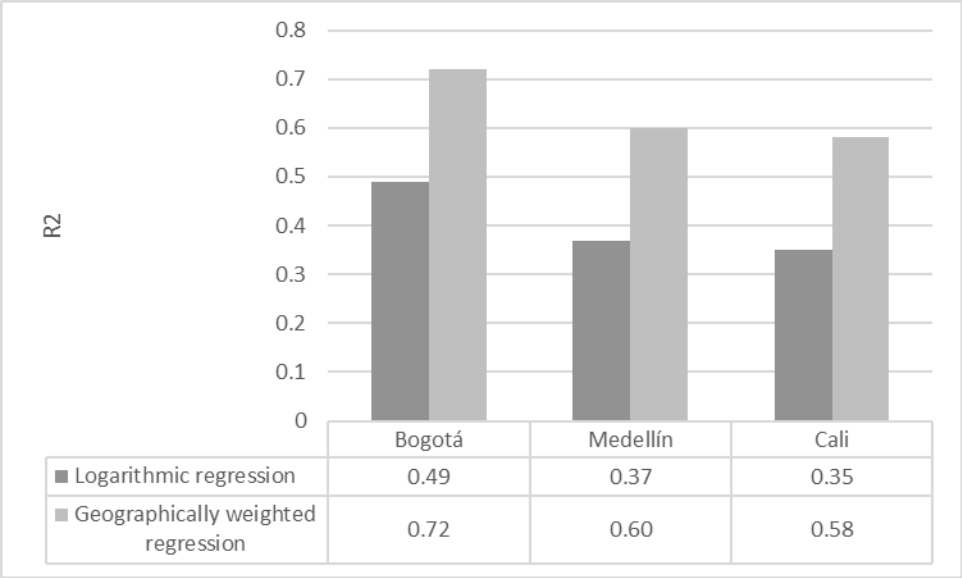
Secondly, in the three studied agglomerations there is empirical evidence to confirm that the real estate market presents a strongly agglomerated geographical pattern that has a significant statistical and spatial relationship with the distribution of social groups according to their quality of life.

In the third place, it is possible to demonstrate that there is a direct correlation between quality of life and land value, from which it is obtained that the higher the land value, the higher the quality of life. Although this conclusion is reiterated in the studies carried out in the region, it is highlighted that in the cases studied here there is empirical evidence that allows to understand the factors that influence in the geographical patterns of residential segregation.

There is evidence to affirm that residential land values are constituted as a determining factor in the distribution of social groups in the urban space of Colombian cities. In this way, the proven relationship between the variables indicates that the decision to locate the home is not exercised with full freedom from the demand and, therefore, they constitute a relative factor of segregation. From

this situation, an income-location of residence relationship is derived in which low income affects the possibilities of choosing the location, restricting spatial relationships with the city (Brain et al , 2010).

Therefore, in the three agglomerations studied there is empirical evidence to confirm that there is indeed a strongly agglomerated geographical pattern of low values that corresponds especially to the low quality of life group. On the contrary, the agglomerated pattern of high values is directly related to the concentration of the population group with high quality of life. This relationship is more intense in Bogotá, since the models indicate that the distribution of social groups by their quality of life is mostly related to housing values. In the case of Medellín and Cali, the relationship is lower, which is why it can be affirmed that the real estate market does not exert such strong pressure on the distribution of social groups.




| | Bogotá | Medellín | Cali |
|---|---|---|---|
| Logarithmic regression | 0.49 | 0.37 | 0.35 |
| Geographically weighted regression | 0.72 | 0.60 | 0.58 |

**Figure 14 – R2 comparison of the relationship between residential m² value and ICVB in the three agglomerations studied.**

*Self-Production.*

The foregoing allows to conclude that the social uniformity of a place and the deficiencies in the access to urban dynamics, as one of the identifiable characteristics of the phenomenon of segregation of groups located in the lower part of the social structure, is far from

being a product of the aggregation of totally free location decisions (Loaiza and Carvajal, 2014). Rather, it is directly linked to the difficulty of accessing cheap land on which to produce urbanization processes with adequate housing and sufficient resources (Mier, et al 2012).

In methodological terms, it is important to highlight the potential of applying statistical techniques and spatial analysis as a complement to the study of residential segregation, since to the extent that analyzes are carried out at different scales, it will be possible to obtain a more precise approximation of its behavior. In this regard, achieving measurements of the phenomenon in units more adjusted to the heterogeneity of a territory, allows the estimation of statistical measurement models that indicate the complex relationship between spatial variables and socioeconomic variables. This is in line with what was stated by Ortiz and Escolano (2013) regarding reflecting on the problem of the modifiable spatial unit in the study of residential segregation, that the results may vary depending on the disaggregation or spatial grouping of the observations. It is equally important to establish, based on the indicators, how potential isolation or interaction occurs due to contiguity or closeness (Garroncho and Campos-Alanis 2013).

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**José Mario Mayorga**

Sociologist, PhD in Geography. Holds a Master's degree in Urban Geography and a Master's degree in Urban and Regional Planning. Specialist in Urban Law and Applied Statistics. Professor in the Master's Program in Urban and Regional Planning at the Pontificia Universidad Javeriana, Bogotá, Colombia.
ORCID: https://orcid.org/0000-0002-1039-0407
Email: jose.mayorga@javeriana.edu.co.

Received for publication in September 2024.
Approved for publication in December 2025.