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TRANSPORTATION SYSTEM AND LAND PRICE: AN INVESTIGATION ABOUT ITS RELATIONSHIP BASED ON SPATIAL ANALYSIS

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ABSTRACT

Lack of urban accessibility and mobility are transportation systems problems caused, mainly, by the saturation of the road system capacity. This is materialized in terms of congestions, pollution and traffic accidents, threatening the life quality and competitiveness of urban areas, as well as have negatively affected sustainable development. The costs arising from such imperfection of the transportation system (externalities) affect, among other economic sectors, the real estate market. One of the reasons is the absence of planning support tools. In order to fill this gap, this paper aims to investigate geoprocessing tools to land use – land price analysis, through transportation database.
The article discusses how the concentration of origins and destinations of urban trips shape land use and influence land price. The study area São Paulo City, a megacity with more than 11 million inhabitants, and the database consists of a thematic map of land use generated through remote sensing satellite imagery classification, data from an Origin / Destination Home-interview Survey held in 2007 by the São Paulo Metropolitan Company (METRÔ - public company responsible for operating the subway trains), São Paulo city highway network, and georeferenced data about the official value of land and edification provided by the Municipality of São Paulo (2010).
It is performed a spatial analysis by using origins – destinations data, and is identified the areas with the high number of urban trips, the accessibility and mobility are assessed, and is compared with the land price that the municipality uses in order to calculate fees and taxes. Besides, the socioeconomic aspects of the traffic zones such as number of jobs, number of households, information about the population (average family income, education, gender, age, etc.), amount of school enrollment, and so on, are taken into account in order to characterize the sites regarding to real estate market.

Key-words: transportation system; urban origins and destinations; land use / land price; satellite imagery; spatial analysis.

1. INTRODUCTION

The urban environment is highly complex and heterogeneous, and changes quickly your patterns, settings and features. Urban growth is not synonymous with urban development. While the first one only indicates an increase in quantity, the second one indicates an increase in quality. However, urban growth hardly ever is accompanied by the urban development, situation which is quite common, mainly in megacities, which according to United Nations (2012) are cities with over than 10 million inhabitants, as is the case of the city of São Paulo - SP, Brazil, which has a population of more than 11,3 million people (IBGE, 2013).

In order to have urban growth followed by urban development, actions of territorial management must be present, which highlights the need for urban planning. Urban planning is the technical and political process related to the control and management of land use and territorial arrangement of the urban environment, including the transportation system, in order to guide and assure the orderly development of settlements and communities (NIGEL, 2007).

The lack of urban planning leads to disordered urban sprawl that causes continuous sociospatial degradation with negative consequences for urban life, influencing the quality of life of its inhabitants, especially in terms of the use of public spaces.

The interaction between the transportation systems and land use occurs, mainly, in terms of accessibility, since it is associated with ease of movement between places. Accessibility is a measure of effort (or ease) of overcoming a spatial separation (ALLEN *et al*. 1993). The more accessible an area is, for the various types of activities performed therein, the greater will be the potential growth and development of this area. The intensity of the development of land use and occupation patterns of a locality is related to their accessibility level (HANSEN, 1959). The greater the accessibility measure of a location, the more value is aggregated to the land, which interferes in the location of activities that, consequently, leads and guides the urban land use. The higher the level of accessibility, the lower will be the transport costs involved, and more attractive is the location (KHISTY and LALL, 1998).

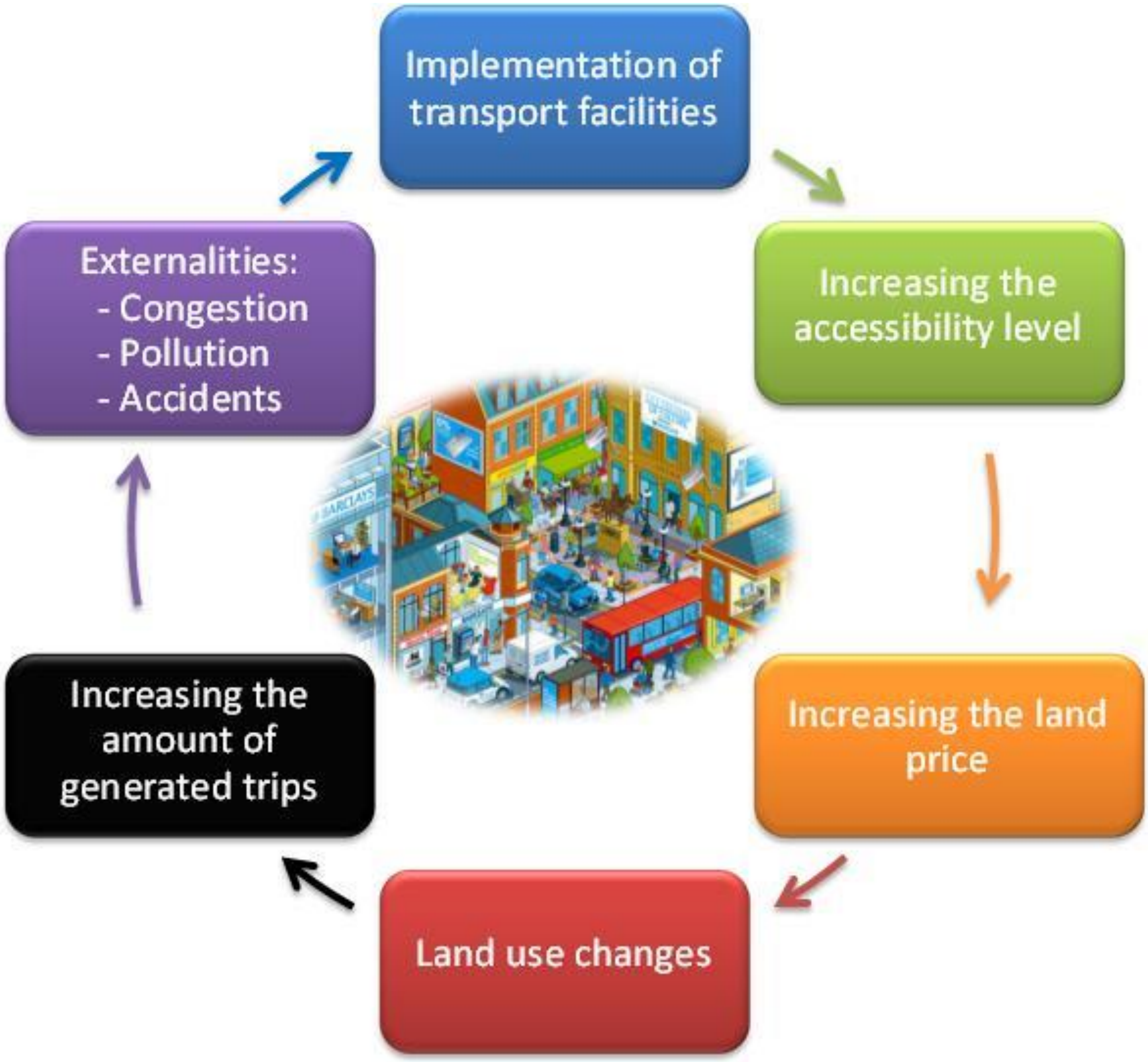
Gualda (1994) presents the concept of the cycle of land use and transport. The author states that the implementation of transport facilities leads to increase the accessibility level, which leads to increase the land price, which in turn generates changes in land use, which influences the increase in the amount of generated trips that causes the negative effects of the transportation externalities (congestion, pollution and accidents), and then the cycle restarts (fig. 1).

According to Shyr *et al*. (2013) the improvement in accessibility in an area through the implementation of transport facilities (for instance transit stations, Bus Rapid Transit – BRT corridors) increase land and house prices, because they reduce commuting costs and attract retail activities. On the other hand, externalities such as noise and pollution, and better access for criminals can also affect the prices. The authors affirm that the accessibility to transit nodes becomes most important as a consideration for buyers (or renters) of real estate in cities where the transit network is concentrated along a few corridors with vastly superior accessibility to both the urban core and parts of its hinterland.

The transportation network is a set of origins and a set of destination of the urban trips. Urban land use and transportation interaction have long been key issues in the search for the sustainable transportation; also, the land use and transportation cycle is a well-known phenomenon for urban planners and transportation engineers, which is important for the formulation of effective urban transportation strategies, as well to land use analyses (YIM *et al*., 2011).

There are two general approaches to the integrated analyses between land use and transport: the planned allocation approach (KOOPMANS and BECKMAN, 1957; and HERBERT and STEVENS, 1960), whose purpose is to achieve certain objectives, such as cost minimization and welfare maximization (YIM *et al*., 2011); and the market simulation approach (LOWRY, 1964), which models the transportation system user's responses to the land use policy has been used to simulate land use patterns (YIM *et al*., 2011).

Figure 1: Cycle of transport and land use
Source: Adapted from Gualda (1994)



The planned allocation approach developed by Koopmans and Beckman (1957) is an urban planning model for determination of land use analysis, focused in the equilibrium theory of allocation of economic activities that assumes the indivisibility of the resources in the process of production. According to Sharpe and Karlqvist (1980) this model assigns a fixed amount of activities in an area in order to maximize total net revenue from activities, which equals gross revenue associated with establishing and operating the activities, less the cost of transporting flows between pairs of activities. The approach developed by Herbert and Stevens (1960) is designed to locate land-using activity through transportation studies. The model projects future population distributions and thereby transportation demands by assuming that residential choices are made on the basis of certain rational economic considerations (MEYER, 1963).

In the early 1960s Lowry (1964) introduced the land use and transportation modeling for spatial organization of human activities within a metropolitan area with the market simulation approach, highlighting the robust e complex interrelationship among: land use, transportation system, population characteristics, economic activities, tax revenues, and demand for public services.

After, it was incorporated in the market simulation approach the congestion externality, in order to get the equilibrium among land use, transportation system and activity system (YIM *et al*., 2011).
More recently, the congestion externality was incorporated into the land use and transportation models. This approach, known in literature as combined network equilibrium models, is able to overcome some inconsistencies present in the traditional methods of transportation planning, such as the four-step modeling that according to Boyce (1998) does not take into account the interaction with land use policies and, as a consequence, does not describe an equilibrium among travel demand, network travel time, and costs. Boyce *et al*. (1988) state that an urban transportation system operating during congested periods is characterized by time delays and added operating costs resulting from the heavy flows of people and vehicles. Under such operational condition, the choices of the transportation system users include not only travel options such as mode and route, but also location options including place of residence, employment, shopping, and so forth, which are hypothesized to depend in part on travel times and costs. Thus, these location and travel choices, which result in the integration of land use and transportation, determine the flow of people/goods and vehicles on the elements of the transportation system, and accordingly the travel times and costs of using these elements (BOYCE, 1988).
Yim *et al*. (2011) argue that even though a large amount of research has been devoted to the integration of the network equilibrium model with land use issues, little attention has been paid to the optimization of land use and transportation. Therefore, it is highly desirable to move forward by developing a comprehensive model for the joint land use and transportation network design problem. Among the studies conducted to promote the integration of land use and transport highlights the theory introduced by Lucas and Rossi-Hansberg (2002) that developed a model of urban spatial structure (LHR model) in which businesses and housing can both be located anywhere in the cities, reduce the costs and travel times, mainly to commutes for workers.
Hoster and Rouwendal (2013) point out that the urban areas are characterized by dispersed employment patterns and mixed land use, but a clear understanding of the forces and determinants of the urban spatial structure of contemporary cities is lacking. The authors, based on LRH model, affirm that the urban design should provide a mixed land use i.e., a decentralized pattern of employment/housing location, in order to reduce transportation costs and time travel, and as a result, reduce the negative effects of the transportation externalities.
Matthews and Turnbull (2007) examines the relationship among neighborhood street layout, retail proximity and property values, and they conclude that people value mixed use neighborhoods with easy walking accessibility to retail and other nonresidential sites. Also, the land value considering the whole transportation system (mass transit, individual vehicles, and pedestrians) comprises the positive effect of convenient access to retail and services offset by the negative externalities effects (congestion, noise, trash, etc.), which are associated with commercial and industrial use.
All of these aspects related to land use and transportation; for example, the locations of the activities, proximity to transportation facilities, accessibility level, and so on, as well as average household income; influence the real estate market behavior (HAIDER and MILLER, 2002). According Ibeas *et al*., (2012) areas with better access to the central business district (CDB)[1] of a city have higher land values because certain agents are more willing to pay higher prices for

[1] According to Murphy (1972) the Central Business District (CBD) is the premier region of the city, it is central, at least in terms of accessibility, and has a greater concentration of offices buildings and retail stores. It is the area where vehicular and pedestrian traffic are likely to be most concentrated. It averages higher assessed land values than any other part of the city. On the other hand, it provides business and services for the whole urban area and for all income classes of people.

them. Therefore, the real estate can be seen as goods priced as a function of the group of their characteristics, which may not only refer to the structural aspects of the properties; but also, to the characteristics of the surrounding area and their access to different land uses (IBEAS *et al*., 2012).

There is a vast literature about how transport condition influence real estate prices, and most of these studies have concentrated on the relationship between real estate prices and access to the transportation system and its interaction with land use (IBEAS *et al*., 2012).

Krause and Bitter (2012) had identified trends in real estate valuation, and according to them, the most prevalent is the increased use of advanced spatial methods. Hence, ways to map and investigate land uses become relevant to the study of real estate. It is when the tools of remote sensing and spatial analysis become useful in the analysis.

Musakwa and Van Nierkerk argue that data to monitor sustainable land use management is often lacking, mainly in developing countries. The authors advocate the use of Earth observation data for supporting sustainable land use planning and they affirm that this database can be used as indicators of land use to effect policy change and to support land use decisions.

According to the international literature the use of remote sensing techniques to map land use and to monitor land use changes is a method well established. This is because in recent decades remote sensing has evolved dramatically to include a set of sensors that operate in a wide variety of image scales and have potential interest to planners and managers in the allocation of land use. With the advent of remote sensing imagery with high spatial resolution, analyzes and studies involving land use / cover is no longer restricted to studies of natural resources or urban studies only in global and regional scales. From that moment, urban studies could be done with great detail. The land cover classes could to be identified in more detail, what it also enabled that the mapping and monitoring of the urban land use could be done systematically.

A general global trend of studies about land use / cover changes (LUCC) has been the expansion of construction land, including land for urban and rural settlements, industry, and transportation, and this has been a focus of much global change researches. Some factors play an important role in LUCC, such as political, economic, cultural, technological, and spatial ones, besides the influence of human activities. Among these aspects there are some relevant attributes linked to the spatial location that has the potential to influence land use patterns and land price, for instance the distance to transportation facilities and to the CBD. A common phenomenon that has been found is the rapid urban growth / expansion and the conversion of the natural land into build-up areas, which occurs preferentially closer to transport networks, in order to allow the development of the activities system (YE *et al*., 2013).

Several researches to study and to analyze LUCC are conducted through the use of the remote sensing tools. In this sense, Xiao *et al*. (2006) who studied the urban trends in Chinese cities by the detection of the land use changes through multitemporal analyses of the LANDSAT imagery and spatial analyses in a geographic information system (GIS); Pacifici *et al*. (2009) that used remote sensing imagery from the satellite QuickBird to map e classify land use in some cities in the United States and Italy; and Alfasi *et al*. (2012) who conducted a research to assess the performance of the land use plan of a region of Israel through remote sensing images and GIS.

The GIS technology has been introduced in the real estate management to improve the traditional manual property management and to achieve specialization, one of the indispensable measures of modern property management (QIAN, 2012).

Real estate researches have been developed using GIS tools. Ibeas *et al*. (2012) verified the existence of the relationship between the accessibility conditions and the dwelling real estate market through GIS analysis; Dillard *et al*. (2013) used GIS to examine the effects of the property taxes and levies on real estate values in order to incorporate in the analysis locational variables, including surrounding land cover, proximity of urban areas, population density, transportation access, and so forth.

According to Anselin (1998) one of the aspects of the real estate market (housing) is locational fixity. This implies that access to employment opportunities, shopping, public service facilities (including the transportation system), and other centers of activity is obtained jointly with the dwelling unit's physical characteristics. Thus, the importance of the spatial aspects of real estate market is unquestioned. There is the prevalence of spatial dependence in the database used in real estate analysis that requires the application of appropriate techniques of spatial statistics and spatial econometrics. The nature of spatial interaction (or spatial autocorrelation) of the real estate data demonstrates that studies conducted in an GIS environment, i. e., an explicit spatial treatment, may lead to efficient estimates and inferences.

The purpose of this article is to verify and analyze how the concentration of local of origins and destinations of urban trips influence land price, and consequently the real estate market. The study area is the city of São Paulo, the largest city in Brazil which according to the definition of the UN (2012) is a megacity with over 11 million inhabitants.

2. DATA AND METHODOLOGY

2.1. Data Source

The land use data were derived from Landsat TM images with spatial resolution of 30 meters, acquired in April/2010. Besides the remote sensing imagery, the database is made up an origin destination home-interview survey held in 2007 by the São Paulo Metropolitan Company (METRÔ - public company responsible for operating the subway trains), São Paulo city highway network, and georeferenced data about the official value of land and edification provided by the Municipality of São Paulo (2010).

2.2. Data Processing

The first stage of data processing involved applying a geometrical image correction, a cartographic standardization, and a georeferenced correction. The land cover map from the TM images was generated using the object-based image analysis (OBIA) to perform the digital image classification. The OBIA uses the spectral information present in the image pixels, and also the context information such as geometry (shape, size, etc.), color, texture, topology (positioning, association, pattern, etc.), in order to label the pixels in classes of land cover/use (CAMPBELL, 2005).

In the OBIA approach the analyst's knowledge about the feature represented in the image is fundamental, because it is incorporated in the process to compose the decision rules that comprise the classification (GERKE, 2002; BALTSAVIAS, 2004; HEIPKE *et al*., 2004). In this study it was used eCognition 8.0.2 a software program developed by Definiens Developer – Trimble to process the remote sensing images and to get as a result the land cover/use map of the study area.

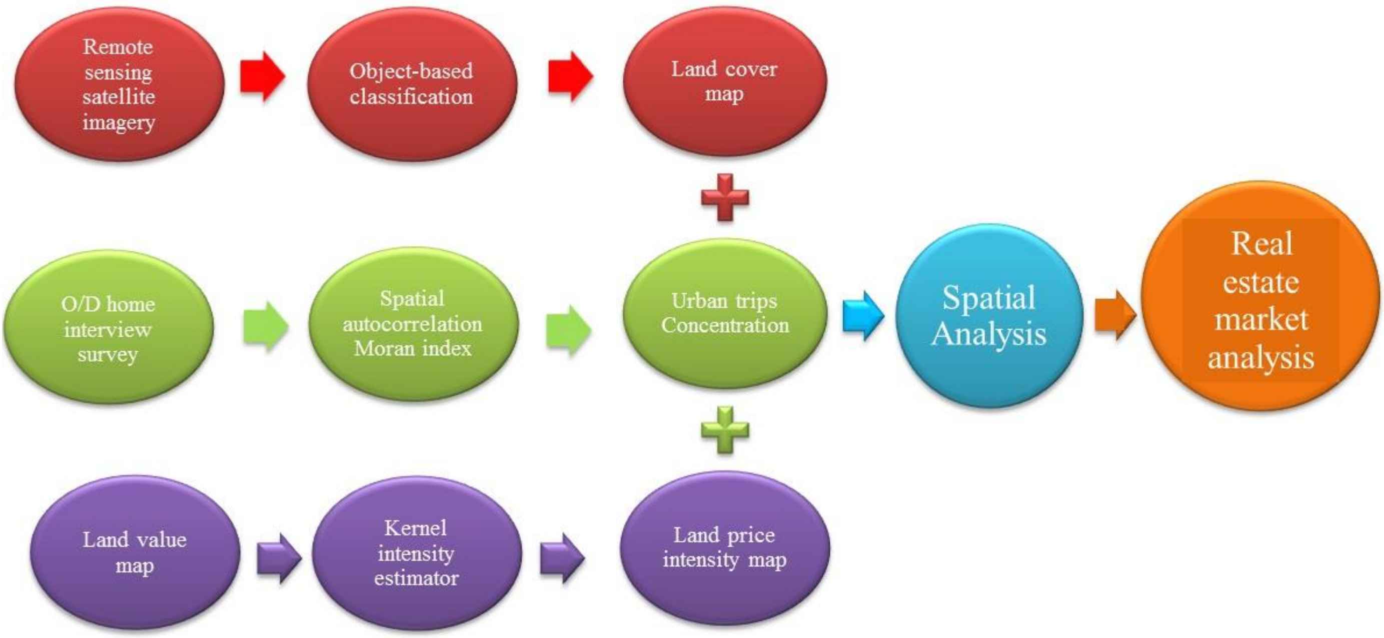
The second step was the geocodification of the OD home-interview survey that shows the traffic zones with greater amounts of generated trips (attracted or produced). This phase was performed in a Geographic Information System (GIS) environment, using the software ArcGIS Desktop 10 Service Pack 4 (ESRI Inc.) for the spatial analysis. It was generated a vector map containing the amount of travel (places of origin and destination), the number of inhabitants per traffic zone. That is, the density was used to calculate the rate of travel of origin (number of trips produced ÷ number of inhabitants) and travel destination index (ID - number of trips attracted ÷ number of inhabitants) to be represented on the map Moran. Moran's index was used to identify the spatial correlation structure that best describe the data by estimating the autocorrelation between traffic zones.

The third stage was the georeferencing of the land values. It was used a generic map of values adopted by the Municipality of São Paulo to calculate taxes and fees levied on the ownership of real estate. This database was georeferenced in the software ArcGIS, using the coordinates of each city block. That means, each block was associated to a price, and each value of the blocks is represented by a point on the georeferenced map. Thus, in the georeferenced points collection was applied a density estimator in order to get the areas with the highest prices. This study adopted the Kernel estimator. The density function of the kernel estimator employs a circular neighborhood as a research area to perform density calculations. According to Carvalho and Câmera (2004) kernel estimator characterizes the distribution of the location of the event, ignoring its association with values. This distribution is characterized by the density of events that occur around a centroid, representing behavior patterns of points or lines.
After these three steps it was performed a spatial statistical analysis, investigating the spatial correlation between numbers of generated urban trips and land price.

2.3. Methodological Flowchart

The methodology adopted follow the flowchart presented in fig. 2

Figure 2: Methodological Flowchart

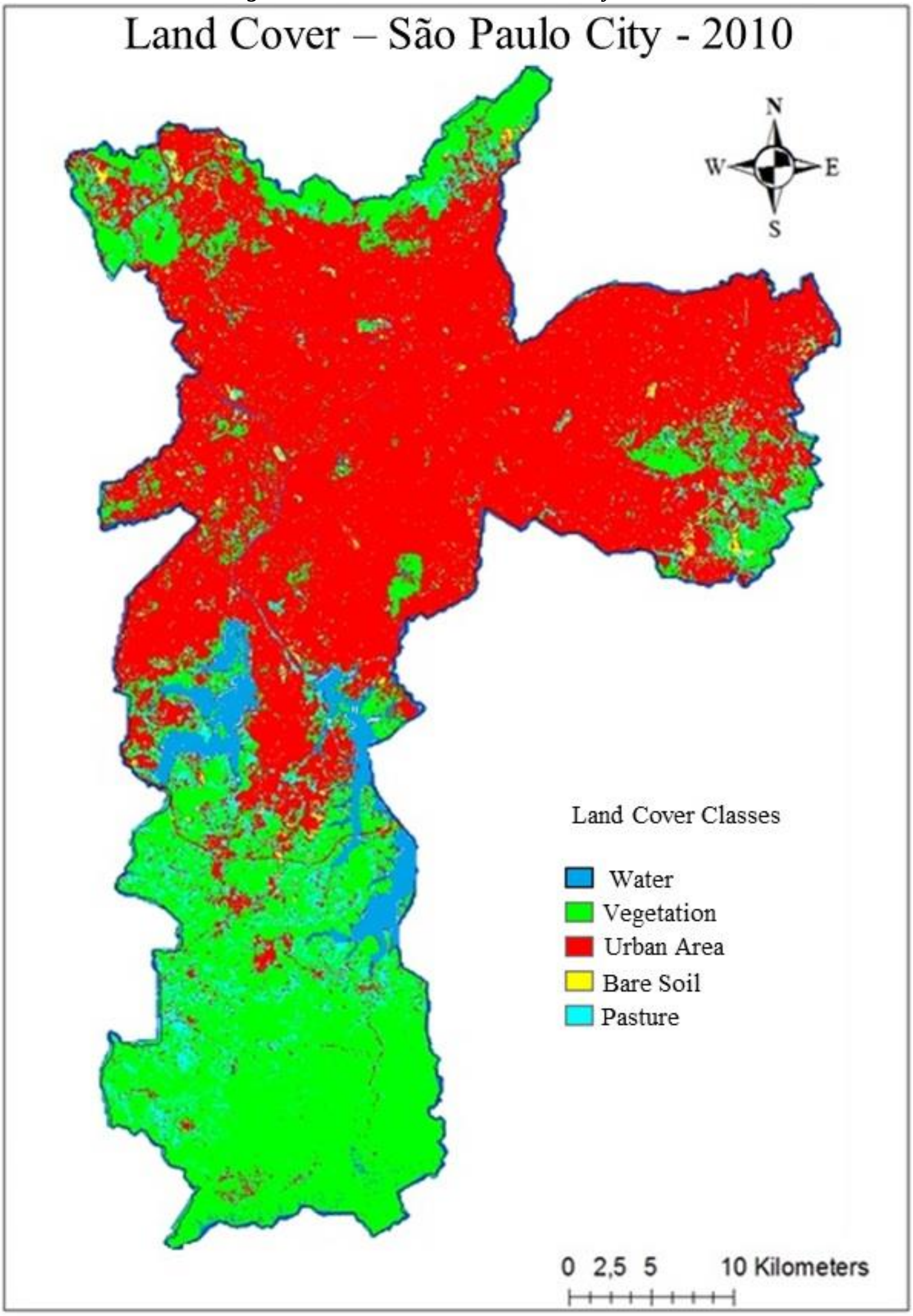


3. RESULTS

3.1. Land Cover / Use Map

The process of satellite image classification resulted in the thematic map presented in fig. 3.

Figure 3: Land Cover – São Paulo City – 2010

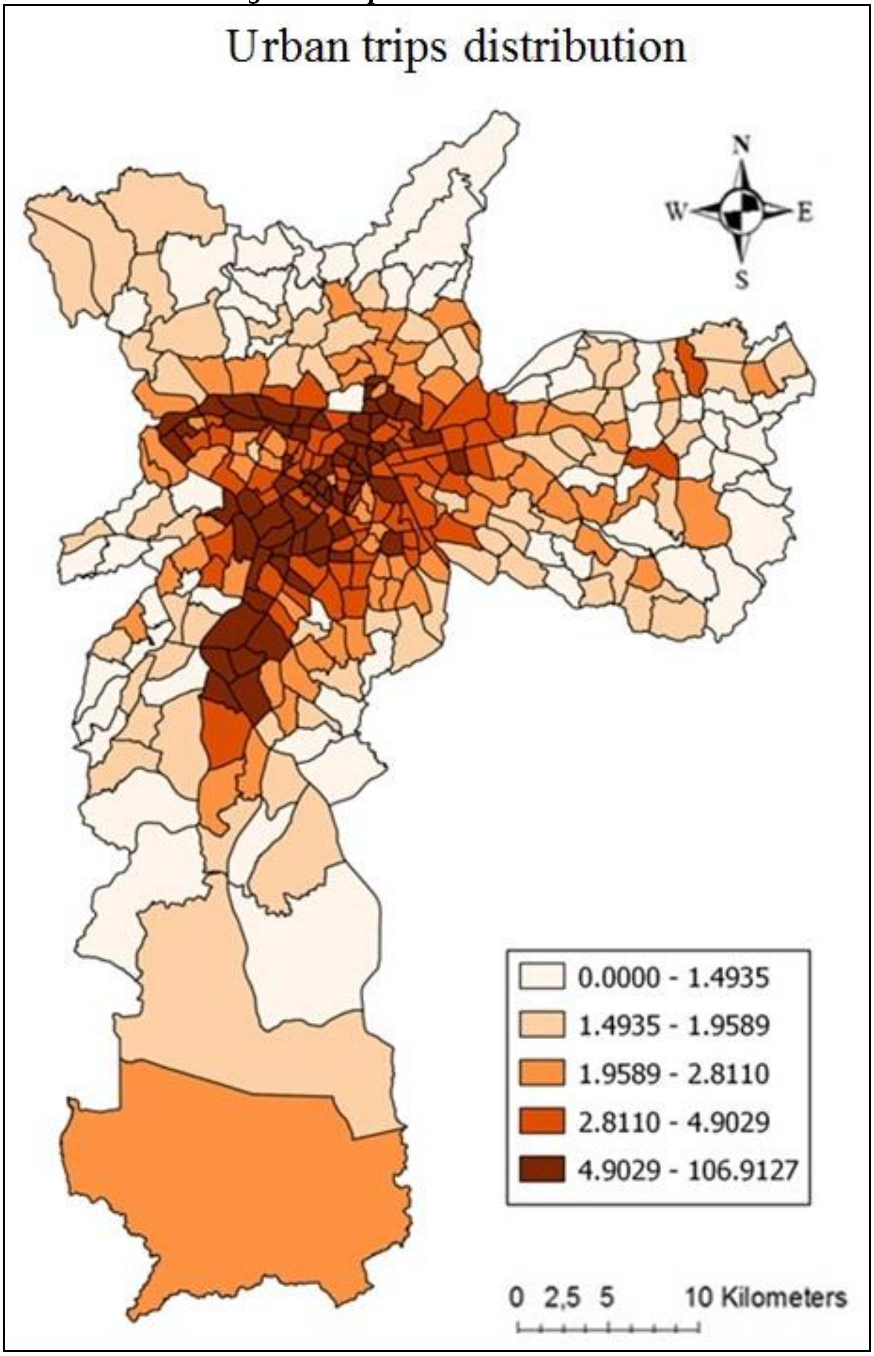


The map demonstrates that the urban area class (represented by the red color) is predominant all over the city, with the exception of the southern portion, the extreme northern and extreme eastern, where there is the presence of vegetation and water resources.

3.2. Traffic zones – Origins and destination of urban trips

The analysis made about the OD database provided the results show in the fig. 4 that is a map of the urban trips distribution in São Paulo, calculated by quartiles. The distribution maps for origins and destinations were very similar, emphasizing the pattern of commuting trips. Thus, only the origins map was used for application of the Moran index, aimed to identify the spatial correlation structure that best describe the database by estimating the autocorrelation between areas.

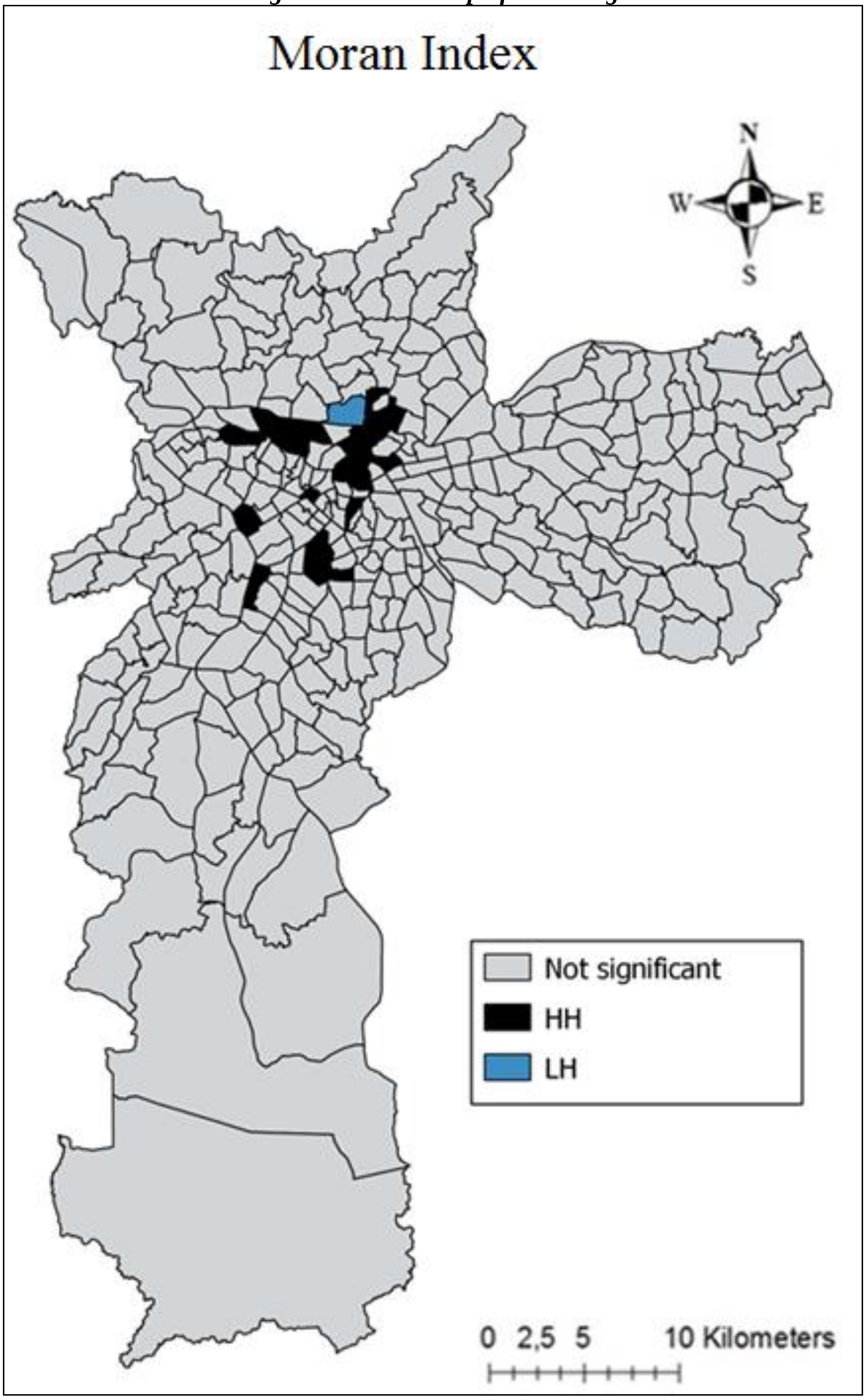
Figure 4: Trip Distribution –O/D 2007



The urban trips distribution map by quartiles represents the quantity of produced trips divided by the number of inhabitants in each traffic zone.

The Moran map of scattering showed only some areas in the central region as relevant in terms of produced urban trips. Most have the pattern H – H (high – high), indicating locations with high values and neighbors also with high values. Whereas, only one area of the central region showed L – H (low – high) that indicates it is a zone with a low value surrounding by neighbors with high values (fig. 5).

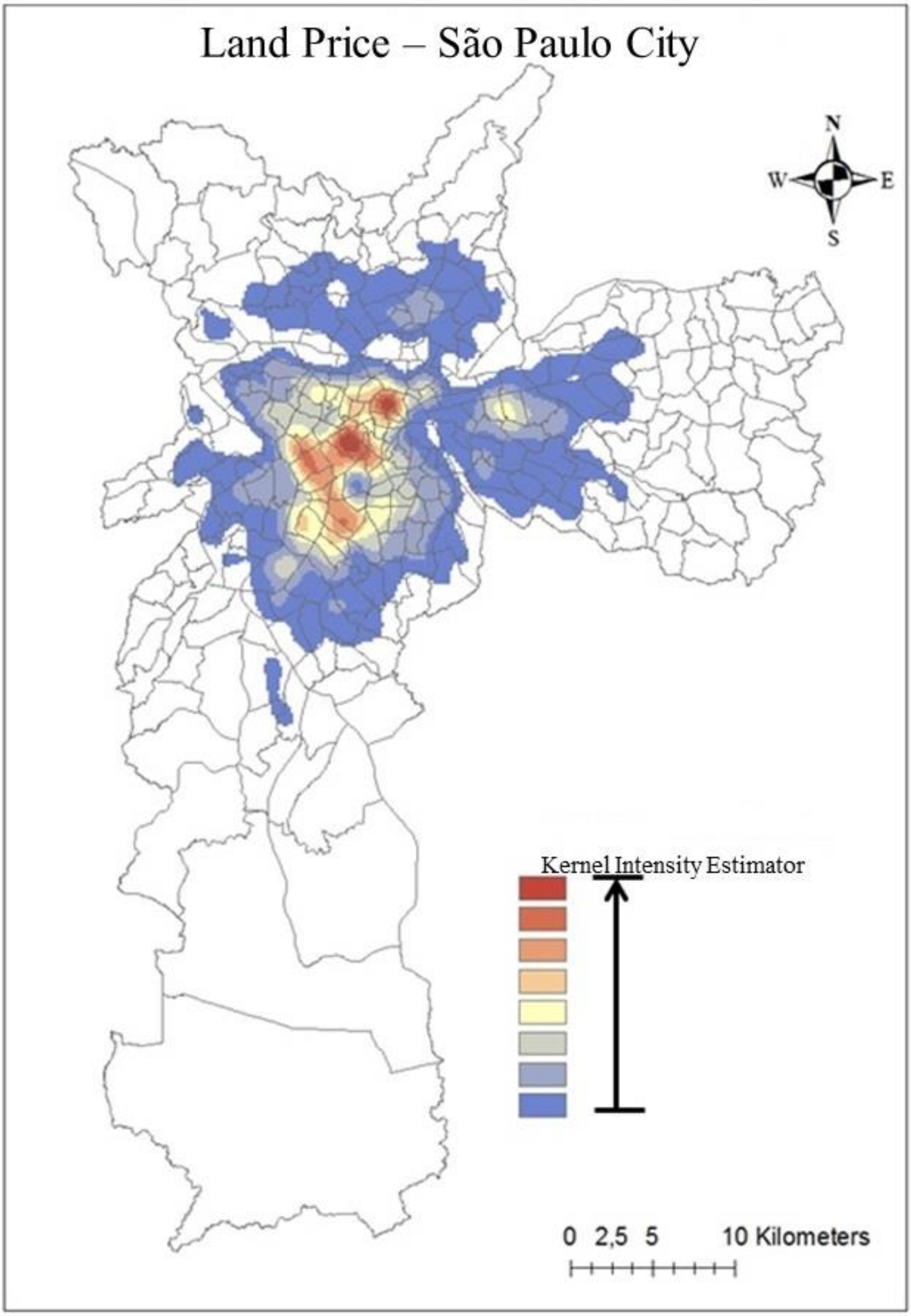
Figure 5: Moran map of scattering



3.3. Land Prices

The vector data containing the points that represent the land price in each block of the city was used as input of the density analysis by kernel intensity estimator, which can be used to understand the distribution of the first order events (CARVALHO and CÂMARA, 2004). The results showed that the land prices in São Paulo have a regular pattern, with higher values grouped in the central region, as can be seen in figure 6.

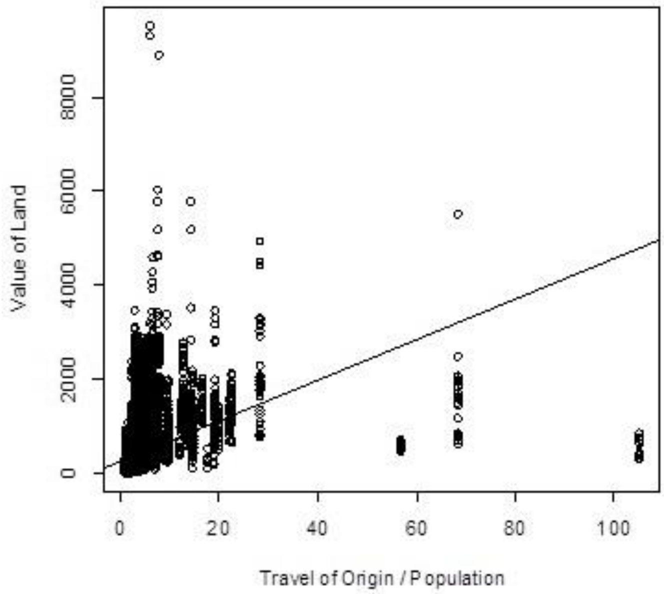
Figure 6: Kernel Intensity Estimator



3.4. Spatial statistical analysis

For each point of the land price map was taken the value regarding to the number of trips of the traffic zone, which was in overlay. These were used to apply the Pearson correlation coefficient. In fig. 7 it is possible to see that there is a trend that the higher land prices happen in locations with higher number of trips.

Figure 7: Graph LandPrice x Number of Trips – Trendline Correlation



4. DISCUSSION

Densely urbanized areas consolidated in terms of land use exhibit little change regarding to land coverage (fig. 3), as is the case in the central region of São Paulo City. These central regions have the highest diversity of economic activities and mixed land use, with industry, commerce and services. Thus, these are regions that generate a large number of urban trips (mainly commuting trips), have high accessibility level, which favors the urban mobility. The São Paulo's central region (CDB) is served by rail transport system (subway and light rail), public bus service (with segregated lanes, exclusive lanes, etc.), and a dense road network, and therefore have the highest trips concentration (fig. 4 and fig. 5). These transportation facilities reflect in the real estate market, causing the land and the buildings located in these areas have the highest values. Besides, it is possible to observe that the areas with the highest land values indicated by the Kernel estimator map (fig. 6) in the central region were coincident with the traffic zones with the highest amount of trips, indicated by the Moran map of scattering (fig. 5).
The estimated value of the Pearson correlation coefficient[2] between land price and number of trips is r=0.416, that means a highly significant correlation (fig. 7). Thus, it is possible to infer that there is a positive and significant correlation between both.

5. CONCLUSION

The results show that the hypothesis that transportation facilities and mixed land use interferes in the land price is valid, and have a significant influence on the real estate market. Areas with greater accessibility are most valued, both in relation to housing as business. Land use maps derived from Earth observation data can be used to study and measure LUCC, and further

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[2] The Pearson correlation coefficient is a measure of bivariate association of the degree of relationship between two quantitative variables, measuring the direction and degree of linear relationship between them. The Pearson correlation coefficient (r) varies from -1 to 1. The signal indicates positive or negative direction of the relationship and the value suggests strength of the relationship between variables. A perfect correlation (-1 or 1) indicates that the score of a variable can be determined exactly to know the score of the other. On the other hand, a correlation value of zero indicates no linear relationship between the variables (FIGUEIREDO FILHO and SILVA JUNIOR, 2009).

analysis can be conducted in order to better understand the relationship among land use, transportation system and real estate market.

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