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IDENTIFICATION OF URBAN SETTLEMENT PATTERNS USING CBERS IMAGES AND ITS RELATIONSHIP WITH THE URBAN PROPERTY LEGAL REGISTRATION IN A SMALL AMAZONIAN CITY

Identificação de Padrões de Ocupação Urbana Utilizando Imagens CBERS e sua Relação com a Regularização Fundiária em uma Pequena Cidade da Amazônia

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ABSTRACT

This research aims to verify the relationship between the urban settlement patterns and the legal registration of urban property in the small Amazonian city of Ponta de Pedras, located in Marajó Island in the state of Pará, Brazil. To define the urban settlement patterns, the authors considered some specific characteristics, such as paved streets, land parcel size, the presence or absence of parks, the distance from the downtown area, and flood susceptibility. After these characteristics were defined, we produced a map showing the urban settlement patterns, which was integrated with a map showing the distribution of registered properties. The final results confirmed the data indicating that urban settlement patterns and the legal registration of urban property are highly related. For instance, the number of registered properties is much higher in areas that have better infrastructure and urban services, such as paved streets, have low flood risk, are far from the forest, and are close to the commercial area.

Keywords: Amazonian Small City, Urban Settlement Pattern, Legal Registration of Property, Land Property.

RESUMO

Essa pesquisa tem o objetivo de verificar a relação entre o padrão de ocupação urbana e o registro de imóveis urbanos em uma pequena cidade na Amazônia, Ponta de Pedras, localizada na Ilha de Marajó, no Estado do Pará. Para a definição dos padrões de ocupação urbana os autores levaram em consideração um conjunto de características, tais como ruas pavimentadas e sua largura, presença ou ausência de áreas verdes, tamanho do lote, distância do centro de compras, se é área alagada ou não, etc. Após estas definições, foi elaborado um mapa dos padrões de ocupação urbana, que posteriormente, foi cruzado com um mapa de localização de imóveis registrados na cidade. Os resultados finais confirmaram que ambos os dados, padrão de ocupação urbana e número de registros de imóveis, estão fortemente relacionados. Por exemplo, o número de imóveis urbanos registrados é maior em áreas onde há melhor infraestrutura e serviços urbanos, como ruas pavimentadas, áreas de terra firme, distantes da floresta e próximas do centro de compras.

Palavras-chave: Pequenas Cidades da Amazônia, Padrões de Ocupação Urbana, Registro de Imóveis, Propriedade da Terra.

1. INTRODUCTION

The following events are not exactly new in Amazonia: expropriation of lands owned by local habitants; illegal possession of public lands (“*grilagem*”); document falsification; and an increase in the irregular occupation of forest areas, properties, parks, and other places (SAUER; ALMEIDA, 2011). Since the mid-1960s, there has been an intensification of disorganized occupation in the region.

Gouvêa, Ávila, and Ribeiro (2009) affirm that the occupation of the Amazon region, even today, whether in rural or urban areas, has many of the characteristics that have marked the process of occupying and owning land in Brazil since the time of the Sesmarias [the colonial land grants], a system that was fundamental in structuring land ownership in the country. The land situation in the Amazon region presents problems of all sorts. For example, in many cases, the owners of specific parcels of land are unknown, and there are also many instances of title displacement, overlapping titles, and falsifications (Gouvêa, Ávila, and Ribeiro, 2009, p.74-75).

This situation is worse in the small towns of Amazonia, where monitoring of the land transfer process is almost nonexistent.

However, a question that must be answered is whether there is a relationship between the land registry situation and the urban settlement pattern. Satellite images can be an important source of information for mapping urban settlement patterns, particularly those images with appropriate spatial and spectral resolution.

According to Miller and Small (2003), remote sensing can improve our understanding of urban environments and our ability to manage them in the future. Satellite images have been used as an important source of data for urban studies. (COSTA et al. 2011, ROSENFELDT and LOCH, 2012, ROSENFELDT and LOCH, 2013).

Thus, this research aims to verify the relationship between the land registry situation and the urban settlement pattern of a small city in Amazonia. For this purpose, we produced a map showing the urban settlement pattern, using CBERS 2 (China-Brazil Earth Resources Satellite) images. Once the settlement pattern

was determined, it was possible to analyze the relationship between this pattern and the locations of the registered properties.

2. STUDY AREA

The municipality of Ponta de Pedras was chosen as the study area because it has features that well represent small cities in the Amazon, as described below.

Ponta de Pedras is located in the Mid-Region of Marajó Island, Pará (Figure 1). Situated along the Marajó-Açu River, the city was founded in 1737 and was originally called Freguesia. Currently, it is considered a small city, with a population of 25,999 inhabitants, according to the IBGE 2010 census (IBGE-Instituto Brasileiro de Geografia e Estatística).

The urban settlement has expanded to areas susceptible to periodic flooding caused by river dynamics, which is very intense in the region. In a period of almost 40 years, from 1969 to 2007, the urban area of Ponta de Pedras grew 0.89 km², corresponding to an increase of 248% compared to the area in 1960.

According to the IBGE census, in 2000, 27% of the Amazonian urban population lived in 639 cities with populations under 20,000 inhabitants. These small cities correspond to approximately 84% of all 760 cities located in the region (Costa et al. 2009). Although this percentage decreased to 82% in 2010, the small cities continue to predominate.

In relation to land tenure, Montoia (2010) attests that there is a sprawling urban growth and that occupations are not regulated. According to the author, this is reflected in the collection of property taxes, which have not been assessed normally by the Ponta de Pedras administration.

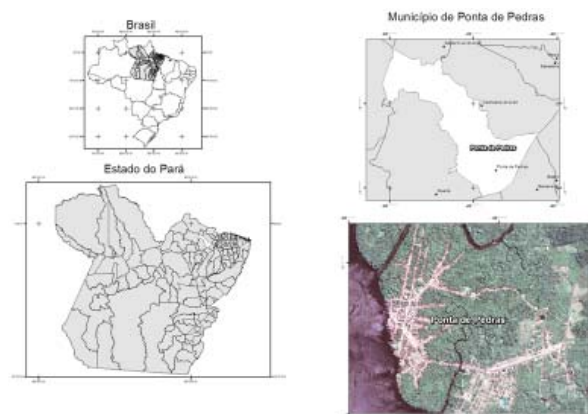


Fig. 1 - Ponta de Pedras location.

From data collected through questionnaires applied to the population, Costa et al. (2012) affirm that the availability of electricity, piped water, and access to the sewer system varies according to the sector of the city, depending on the stage of occupation and public investment. They found that 100% of the urban houses have electricity, and 87% have running water, despite the precarious service. However, less than 20% of houses are connected to the sewage system, and the effluents are discharged with no treatment in the rivers and streams.

3. SOME DEFINITIONS

3.1 Urban patterns

It is important to clarify that these patterns consist of some quite contrasting factors, for example, dimensions, the condition of the urban infrastructure and services. For this study, the authors defined some urban patterns according to characteristics such as street paving and width, the presence or absence of parks, land parcel size, the distance from the downtown area, and flood susceptibility.

3.2 Urban irregularity and urban real estate registry

Because this research aims to correlate the urban pattern with the number of properties registered, it is necessary to discuss the definition of land registry and how this system functions in Brazil.

The Federal Constitution (BRAZIL, 1988) establishes that the land ownership right has to meet its social function, which means that public interest takes supremacy over individual interest.

Considering that it is essential to this research to evaluate the situation of the urban land registry, it is first necessary to define urban irregularity. According to Cardoso (2003), there are several types of urban irregularities, such as land ownership discrepancies, cases of partial irregularity, misconceptions of land development projects, and building construction disagreements with the city's master plan. There is also a complementary type, which refers to the superposition of different types of irregularities in relation to the agrarian structure and residential settlements.

For this research, we considered only cases

of partial irregularity, which are cases not related to problems in the occupation process, but have land registry irregularities, such as inadequate or nonexistent documentation of real estate.

Maricato (2003) affirms that local governments are responsible for controlling land use; however, this task tends to be neglected. The exception occurs when specific actions are defined in political bargains or pre-election periods.

The Chapter II, Article 172 of Law Number 6216, June 30, 1975, contains the definition of "Real Estate Registry":

"Real Estate Registry is the act of registering and annotating property titles or constitutive, declaratory, translative, and extinct actions concerning the real property defined by law."

There are some principles that guide the Real Estate Registry Law, such as the unitarity and continuity principles (TIERNO; CARVALHO, 2007). The unitarity principle requires that each property have an identification number, which is assigned to it at the time of the first registration. The continuity principle establishes the owners' succession of a property.

4. METHODOLOGY

4.1 Field survey and data acquisition

In July 2011, a group of researchers who worked in the project called "The Importance of Small Cities in Amazon Urban Network: Urban Growth, Infrastructure, and Public Policy" went to Ponta de Pedras to conduct a survey in the city. The survey included data collection from the municipal administration and from the notary's office. The data included information about municipal tax collection and about real estate registration, mostly since 1920.

With proper authorization, the registry office documentation was reproduced in 1208 digital photographs. The reproduction included documents relating to rural and urban properties.

4.2 Preparing the database

To prepare the database, the materials were initially examined and organized. After that, we designed the most appropriate database structure and transferred the data to Microsoft Access

Software tables.

Data transfer was performed using an image-editing program to display each digital photograph, where the data concerning the real estate registry could be read. Simultaneously, the data were transferred to Microsoft Access tables.

4.3 Mapping the number of registered properties

Once the database had been created, we started performing the queries. Initially, we verified that the notary's office documentation comprises 456 urban real estate registry numbers, recorded in books 2, 2A, 2B, 2C, and 2D. The documents also contain 1,432 ownership transfers, which occurred between 1899 and 2011.

Although there are only 456 urban registry numbers in the period, as mentioned above, we observed that they correspond to 722 properties. This situation occurred because in some cases, the land had been parceled out and the notary did not create new numbers for the subdivisions; that is, they disagreed with the principle of unitarity established by law (see item 3.2).

To map out these urban settlements, we considered the 722 urban lots because this number is closest to reality. The plotting was performed using the software ArcGIS 10 and was based on two shapefiles: one containing the census sectors of Ponta de Pedras and another containing the street map of the city (Figure 2).

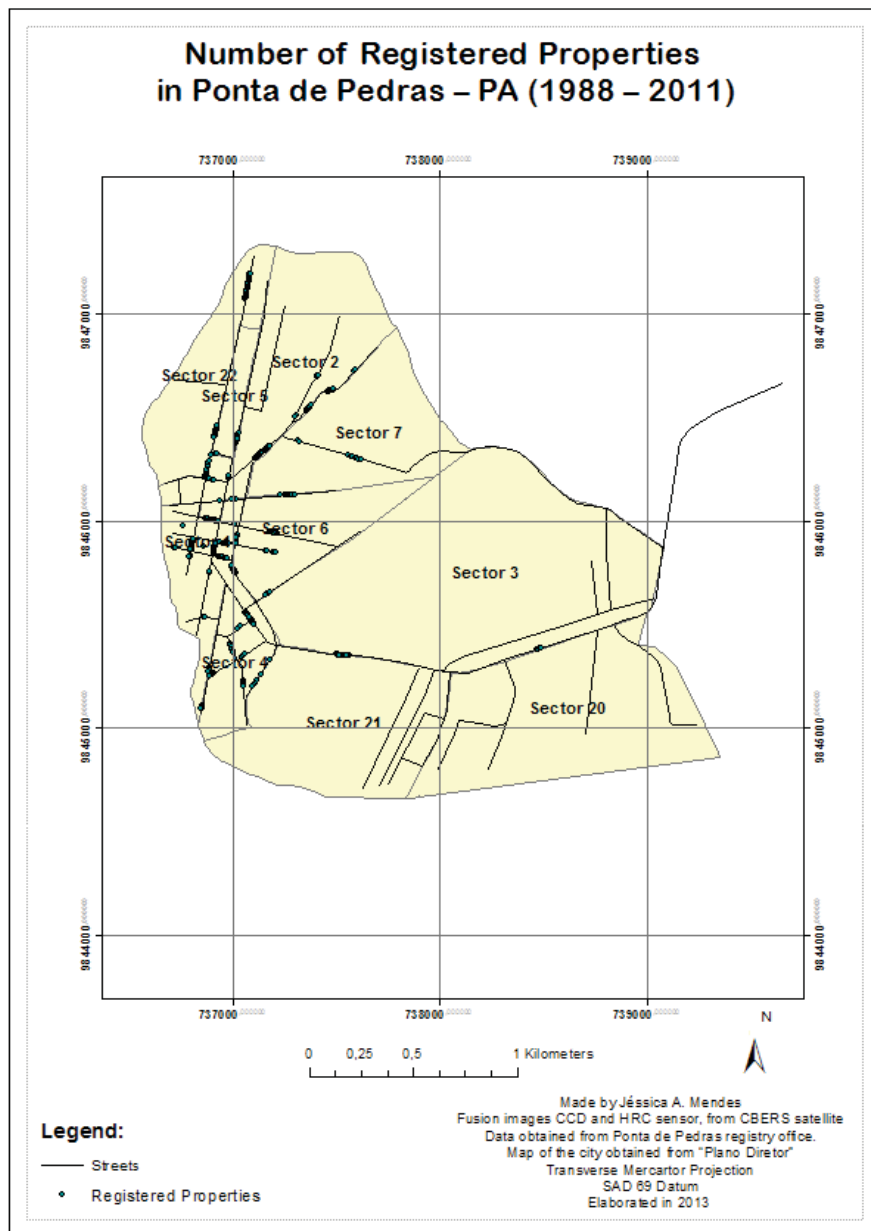


Fig. 2 - Number of Registered Properties (1988-2011).

Some urban lots could not be plotted because the file “shape” with the streets was based on an incomplete map provided by the city administration. However, this did not interfere with the results.

4.4 Mapping the Urban Settlement Pattern

To create a thematic map showing the urban settlement pattern, we applied an image fusion technique using CBERS 2 satellite images.

The fusion technique allows for the combination of better spatial resolution images with better spectral resolution images.

To determine whether the image fusion process allows more precise defining of the urban area of Ponta de Pedras, three classified images were generated: one applied to an RGB color composite from CCD bands 3, 4, and 5; another applied to the panchromatic HRC band; and a third applied to the fused image.

With the Kappa statistics application, it was possible to select the best fusion image, in terms of discrimination of the urban area and the land use of previously defined classes. Considering the Kappa statistic values (showed in Table 1) and the error matrix with normalized Kappa values (Table 2), the fused image presents the highest value (K=0,49), which corresponds to the “good” level.

Table 1: Kappa Statistics Values

| Kappa Values | Classification Quality |
|--------------|------------------------|
| < 0 | very bad |
| 0.00 - 0.20 | Bad |
| 0.20 - 0.40 | Moderate |
| 0.40 - 0.60 | Good |
| 0.60 - 0.80 | very good |
| 0.80 - 1.00 | Excellent |

4.4.1 Defining the urban settlement pattern categories

Considering that the fused image classification resulted in a better Kappa coefficient, we used this image as a base to define the four urban settlement patterns and their characteristics, described as follows:

- Pattern 1 – This region is located in the commercial center of the city. It contains parks, wide paved streets, and larger land lots (nearly 300 m²). The property density in this area is approximately two properties in 1000 m².
- Pattern 2 – This region is located close to the commercial center. It contains narrow streets and has no parks. Its land lots are smaller than those from pattern 1 (nearly 125 m²). The property density in this area is approximately four properties in 1000 m².
- Pattern 3 – This region is located near the forest and far from the center. It contains narrow streets and has no parks. However, the land lots are larger than those from pattern 2 (nearly 300 m²). The property density in this area is approximately one property in 1000 m².
- Pattern 4 – This region is located near the forest and distant from the center and it is susceptible to flooding. It has no parks and contains narrow streets. The land lots are smaller than those from pattern 3 (nearly 125 m²). The property density in this area is approximately two properties in 1000 m².

The result after the urban settlement definition is shown in the map bellow (Figure 3).

Table 2: Error Matrix – Normalized Kappa

| | | Classifications | | | | | | | | | | | |
|--------------|---|-----------------|---|----------|-------|------|-----|----------|-------|--------|-----|-----|-------|
| | | hrc | | | | ccd | | | | fusion | | | |
| | | 1 | 2 | 3 | Total | 1 | 2 | 3 | Total | 1 | 2 | 3 | Total |
| Ground Truth | 1 | 723 | 0 | 77 | 800 | 608 | 67 | 125 | 800 | 644 | 61 | 95 | 800 |
| | 2 | 107 | 0 | 93 | 200 | 144 | 10 | 46 | 200 | 108 | 89 | 3 | 200 |
| | 3 | 1373 | 0 | 27 | 1400 | 854 | 181 | 365 | 1400 | 950 | 15 | 435 | 1400 |
| Total | | 2203 | 0 | 197 | 2400 | 1606 | 258 | 536 | 2400 | 1702 | 165 | 533 | 2400 |
| k = 0,31 | | | | k = 0,41 | | | | k = 0,49 | | | | | |

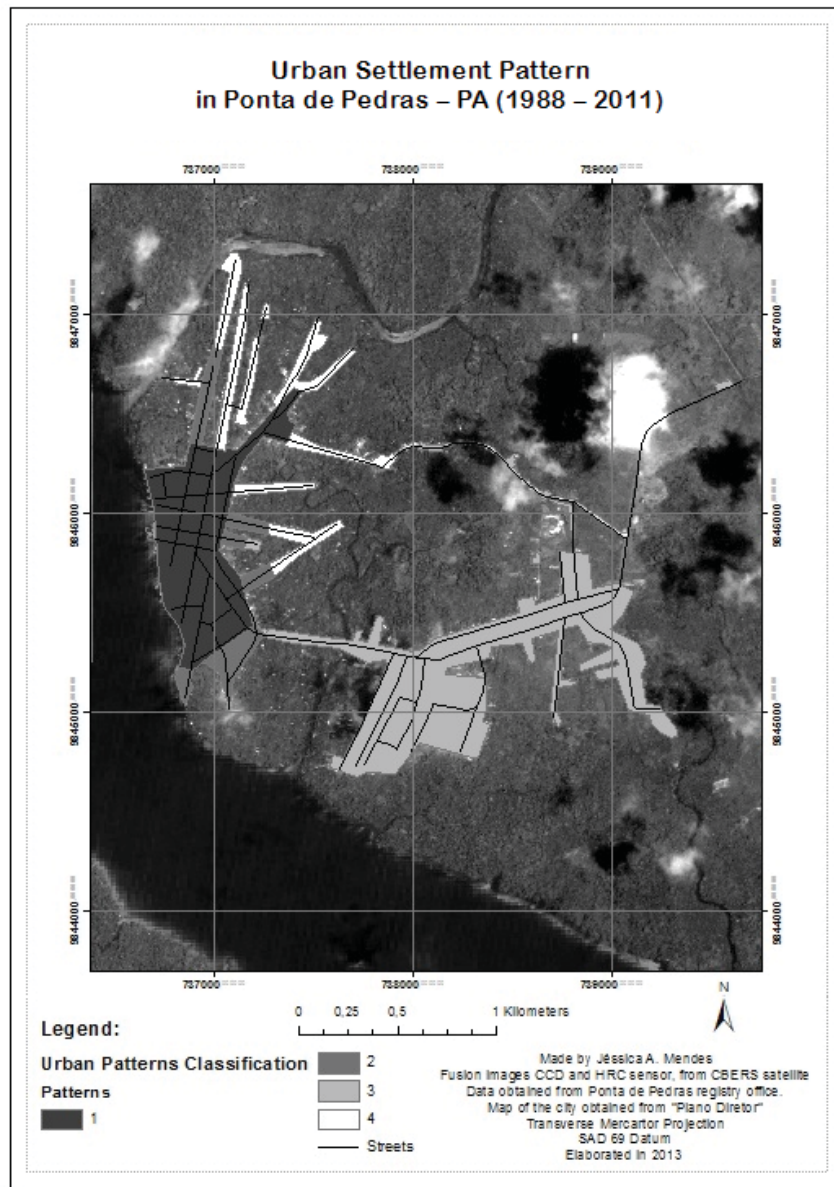


Fig. 3 – The settlement pattern distribution (1988-2011).

5. RESULTS AND DISCUSSION

Continuing to use the ArcGIS software, the urban settlement pattern map and the urban property registries map were loaded together. Using the function “intersect”, both maps were integrated, and we could analyze the distribution of registered properties over each settlement pattern. A part of the map is shown in Figure 4, and the results are summarized in Table 3.

The table values show that more than a half of the registered properties (57.9%) are located in the urban settlement pattern classified as number 1. This pattern covers an area that corresponds to 29.2% of the total urban area. As mentioned in item 4.4.1, pattern 1 is the region located in the center of the city and contains parks, wide

paved streets, and larger land lots.

Pattern 3, despite covering most of the urban area (47.5%), corresponds to the lowest number of registered properties (13.2%). Pattern 3 consists of the region with narrow streets and no parks. This region is near the forest and away from the center of the city.

Pattern 2 covers the smallest area of the city (7.8%), and it corresponds to 14.8% of the registered properties. This region has narrow streets and no parks, and it is located close to the center of the city, which separates it from the most precarious areas.

Pattern 4 covers 15.5% of the city and it corresponds to 13.9% of the registered properties, a value very close to the registered properties

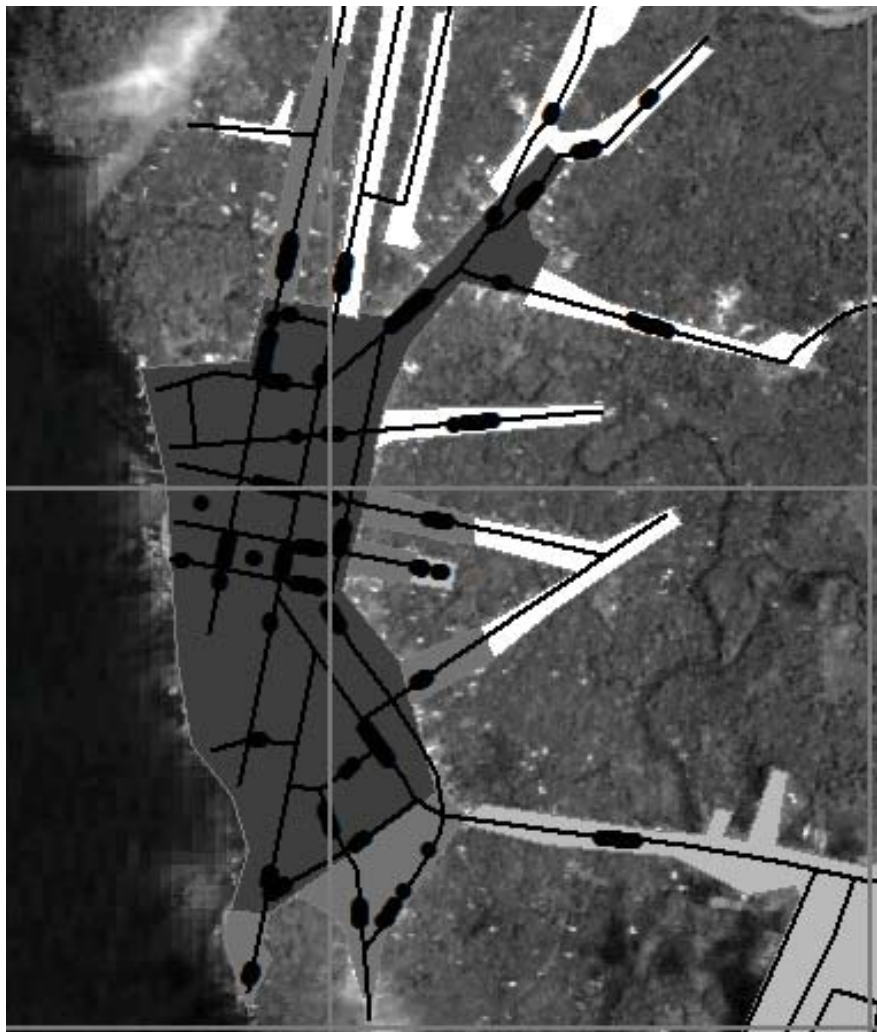


Fig. 4 - Urban settlement pattern map and the integrated urban property registries map.

Table 3: Relation between the Urban Settlement Pattern and the Number of Registered Urban Properties

| Patterns | % Registered properties | Area | % Area |
|----------|-------------------------|----------|--------|
| 1 | 57.91246 | 0.424095 | 29.2 |
| 2 | 14.81481 | 0.112119 | 7.8 |
| 3 | 13.29966 | 0.689422 | 47.5 |
| 4 | 13.97306 | 0.224612 | 15.5 |
| Total | 100.0 | 1.450248 | 100.0 |

verified in patterns 2 and 3. This region has narrow streets and no parks. It is distant from center and lies in areas susceptible to flooding.

6. CONCLUSIONS

According to the IBGE census of 2010, the number of existent urban properties in Ponta de Pedras at that time was 3,096 units. This research shows that until the year 2011, only 722 urban properties had been registered at the local Real Estate Registry Office, which corresponds to

23.32% of the existing properties.

When we consider the city administration data, there are only 1,888 properties listed in the municipal records, which corresponds to 60.9% of the existing properties.

The intersection of maps, urban settlement patterns, and legal urban property registration confirmed that there is a strong relationship between them. We observed that the number of registered properties decreases as the land location is farther from the center and consequently has poorer infrastructure.

The low number of registered properties confirmed with this study is adverse for the municipal community because it can create difficulties for the city, state, and federal administrations. The more the government institutions know about the urban reality, the more they can plan investments and improve the quality of life of local population.

We suggest a further study about the

reasons why people do not register their properties, particularly in small cities of Amazonia. This situation likely occurs due to the notary fees and municipal taxes, in association with the low-income of the population.

A possible solution to the issue is governmental actions with the purpose of encouraging people to register their properties.

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