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VERY HIGH RESOLUTION SATELLITE DATA FOR THE ANALYSIS OF SOCIO-SPATIAL INEQUALITY MEASUREMENTS, TEST SITE SÃO JOSÉ DOS CAMPOS, BRAZIL

Imagens de Alta Resolução Espacial para Análise de Medidas de Desigualdade Socioespacial. Estudo de Caso: São José dos Campos - SP

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ABSTRACT

The objective of this study is to measure the socio-spatial inequalities in residential areas of São José dos Campos, based on an intra-urban analysis, using QuickBird-2 satellite data. The residential space was considered to connect economic, social and political dimensions, in order to verify the corresponding stratification in space. The stratification can be observed at the configuration of different residential areas, showing the social division of space. Initially the following elements were considered in the concrete space: Size of lots, Vegetation cover, Population density, Materials of roofs, Swimming pools, Shadow, Bare Soil, Organization of blocks and lots. In this work, the establishment of a correlation among spatial differentiation elements and the living space allows to understand both the social contents and the variation of social phenomena in space. The measurement of differentiation elements was possible with QuickBird-2 image data. The Object-based Image Analysis (OBIA) concept was used for the classification of differentiation elements, while the visual analysis and data crossing was considered for others. The results obtained present the distribution of these elements and the identification of patterns in residential areas, corresponding to different spatial occupation forms by social classes. This study shows that high resolution satellite images contribute with new and relevant information about the concrete space, at intra-urban scale and it opens new possibilities for the analysis of the inequality dimension: the socio-spatial differentiation.

Keywords: Socio-spatial Differentiation, Remote Sensing, Object-based Image Analysis, Socio-inequality, Data Mining.

RESUMO

A finalidade desta pesquisa é fazer uma de análise intraurbana, utilizando imagens de alta resolução espacial do satélite QuickBird-2, para apreensão da desigualdade socioespacial no espaço residencial de São José dos Campos. Utilizamos o espaço residencial como objeto de estudo para conectar as dimensões econômicas, sociais e políticas visando verificar a estratificação correspondente no espaço. No território, esta estratificação pode ser observada na configuração de áreas residenciais diferenciadas, mostrando a divisão social do espaço. Há vários estudos de desigualdade que realizam seus trabalhos tendo como base dados secundários e de pesquisa de campo. O estudo aqui proposto tem como ponto de partida, para caracterizar a diferenciação socioespacial, elementos presentes no espaço concreto como Tamanho de lotes, Cobertura vegetal, Densidade de ocupação, Materiais dos telhados, Piscinas e Sombra, entre outros, que no espaço respondem pela diferenciação e também pela desigualdade. Os avanços tecnológicos na área de sensoriamento remoto apresentam-se como instrumentos que permitem a mensuração dos elementos da diferenciação. Nesta pesquisa, a técnica de análise orientada a objeto (OBIA) foi utilizada para a classificação de alguns elementos da diferenciação enquanto a interpretação visual e o cruzamento de dados para outros. Os resultados obtidos permitiram conhecer como se dá a distribuição dos elementos da diferenciação na área de estudo e identificar padrões que nas áreas residenciais correspondem também a diferentes formas de ocupação do espaço pelas classes sociais. O estudo realizado mostrou que as imagens orbitais de alta resolução espacial trazem novas formas de produção de informação sobre o espaço, na escala do intraurbano, assim como também, novas possibilidades de análise de uma das dimensões da desigualdade: a diferenciação socioespacial.

Palavras chaves: Diferenciação Sócio-espacial, Sensoriamento Remoto, Análise de Imagem Baseada em Objeto, Desigualdade Social, Mineração de Dados.

1. INTRODUCTION

In many Brazilian cities, the urban land use for housing presents a differing landscape, whose origin is due to a contradiction in the social relationships: at one side there is the value for its use and at the other the exchange value of urban land and housing as merchandises (HARVEY, 1980, RODRIGUES, 1988, 2001). The fragmentation and inequality point out and reproduce the structure of the society within the city. Accordingly the built-up home space connects economical, social and political dimensions with the spatial dimension of reality, creating an urban stratification of different areas, characterizing inequality and socio-spatial segregation. Inequality is understood as the result of a non-equitable distribution of social richness and consequently of the benefits it can provide, and both segregation and socio-spatial differentiation are two faces of this process.

Social inequalities were studied by several authors and among them we detach those whose objectives are to clarify a certain social aspect based on indicators or indices (JANUZZI, 2006). The data used to prepare these socio-inequality indices were obtained mainly from information available from the decennial census. Our working hypothesis is that recently available very high resolution satellite images opens new options for the inequality analysis, by the differentiation bias observed in the residential areas of many Brazilian cities.

Correlation analysis between built-up space and social/economical characteristics using remote sensing data started in the seventies. They are related mainly to population estimates, such as Lindgren (1971), Hsu (1971), Adeniyi (1993), Ikhuoria (1996) among others, using aerial photographs and Dureau (1989), Souza (2003) and Gonçalves et al. (2006) using satellite images. These studies presuppose a relation among residential density and family dimension, expressed by different textures observed on photographs and satellite images, respectively in the former and latter case. Other works, such as Estevam (2006), Kux et al. (2009), Novack & Kux (2010), Novack et al. (2011) emphasize particular aspects of land cover in areas occupied by slums (*favelas)*, while Antunes & Cortese (2007) identify patterns which characterize irregular occupation types, delivering subsidies for public actions. Souza et al. (2007), Almeida et al. (2009), and Avelar et al (2009), also emphasize the high correlation among elements within an intra-urban land cover map and economic characteristics of the population. Besides establishing a correlation among concrete space and socio-economic characteristics of the population, these studies consider the OBIA (Object-based Image Analysis) paradigm for image classification, according to Blaschke et al. (2007), and Blaschke (2010).

The OBIA approach, associates spatial (form and topology) to spectral aspects in the formation of segments. The resulting segments constitute a hierarchy at several levels, participating at a network with neighbors and close segments (BLASCHKE, 2010). The behavior of the segment is defined by a set of statistical and form attributes, grouped by classes and organized in a semantic structure. Modeling of each segment is made by fuzzy logic rules. This approach allows a higher efficiency to explore the informative content of very high resolution images. In Brazil it was used by Pinho (2005), Novack (2009), Estevam (2006), Novack & Kux (2010), Novack et al. (2011), Antunes & Cortese (2007), Souza et al. (2007), Almeida et al. (2009), Ribeiro (2010), Ribeiro et al. (2011) among others.

With very high resolution images it is possible to obtain information from both the spatial organization of the cities and space inferences. In this sense, they are an option to detect inequality within a concrete dimension, besides income and education. They permit the identification of several elements, such as: size of lots, arboreal or grass vegetation, different roof cover materials, the density of occupation from residential blocks, swimming pools, bare soil and shadow which, in concrete space, indicate as well homogeneity as differentiation in residential areas. These elements were measured, allowing the recognition of patterns which correspond to distinct distributions of social classes in space.

Based on the aforementioned, the objective of this study is to contribute to studies on the socio-spatial inequality, exploring the information content of a high spatial resolution satellite image. Different from similar works which frequently use small areas and aggregate data from several sources, this study analyzed the entire residential area from a medium-size city. The intra-urban land cover classes or differentiation elements were evaluated inasmuch they are helpful to determine social patterns of residential occupation, and so how they contribute for the analysis of the spatial dimension of social inequality.

2. AREA UNDER STUDY

São José dos Campos (SJC) is localized at the eastern portion of São Paulo State, on the São Paulo-Rio de Janeiro highway. The fast city growth during the 60s and 80s required housing, transportation and other urban services which the local administration was unable to provide. This city, like many other ones in Brazil, has lots of social problems. In spite of that, the wider indicators of social inequalities show that SJC is classified among the 25 Brazilian municipalities with the best living conditions according to the São Paulo Index for Human Development – IDH-M (PNUD, 2009). It is also part of a selected group of municipalities from São Paulo State performing the best wealth, longevity and education conditions, according to the São Paulo Index of Social Responsibility – IPRS (SEADE, 2002).

However, when analyzing data from the Decennial Census, more realistic social conditions of SJC emerge. The São Paulo Index of Social Vulnerability - IPVS, elaborated with the variables Income, Sanitation condition, Longevity and Education, points out that 35% of the city inhabitants are subject to some type of vulnerability. In the Poverty Map, elaborated by Borges (2003), the “Poverty” definition was a composite of social conditions variables from the person responsible for the domicile, education and sanitation of the residents. This study localized those areas within SJC where the accumulation of social needs is “Critical” to “Very critical”, according to the classification of this author. Genovez (2002), adapted the methodology proposed by Sposati (1996) in the Map of Social Exclusion/Inclusion and used a set of variables to establish these conditions, considering the following factors: Income autonomy, Education, Longevity, Home Comfort and Sanitary Conditions to locate the excluded and included in this city. According to these indicators the vulnerabilities, poverty and exclusion are concentrated at the N, S and E peripheries. The main information source for these indicators is the Decennial Census, organized and made by IBGE (Brazilian Institute for Geography and Statistics), which is a temporal limitation for such an analysis. For these purposes very high spatial resolution satellite images are an alternative tool for the analysis of socio-inequality, because differences observed at residential areas (Figure 1) can be measured, allowing the achievement of further information on socio-spatial inequality beyond conventional surveys.

3. MATERIAL AND METHODS

A QuickBird-2 satellite image, OR Standard, acquired in 2003, with 4 multispectral channels at 2,44 m spatial resolution and one panchromatic channel with 0,61 m was used. The image was ortho-rectified using the Ortho Engine

Fig. 1 – Color composite of QuickBird-2 image from Oct. 3rd 2003 showing different textures of residential blocks in São José dos Campos. The photos were taken at places with respective textures.

Model from PCI-09 for the geometric correction, considering as reference the Digital Elevation Model (DEM) from the SJC city administration, with 22 control points, obtained during a field campaign with D-GPS. Afterwards images were fused by the Principal Components procedure, which presents the best transference of detail and conserves the spectral information from the original images (PINHO, 2005; NOVACK, 2009). The processed image was integrated to the SJC city database "Cidade Viva" (PMSJC, 2003) through the software SPRING 4.3, which contains the socio-economic sectors for planning and the city blocks. These are groupings of allotments or contiguous districts with similar socio-economic characteristics of Income, Education, Population, among others. A qualitative analysis allowed the regrouping of the initial 28 sectors down to 19 units. Those sectors with vertical buildings, areas of slums and sectors with beginning occupation were excluded from the analysis. The slums were excluded because they constitute those neighborhoods of extreme social needs and have quite distinct characteristics of roof cover. These areas were studied, among others, by Estevam (2006) and Kux et al. (2009). For the year under analysis (2003) the vertical areas were not yet representative for the city, since 85% of the population then lived in one-family houses (IBGE, 2000).

After grouping the blocks within each sector, those ones of exclusive residential use were identified and a proportional stratified sampling was performed, resulting in 404 blocks which correspond to 10% of the one-family houses from SJC (Table 1, Figure 2).

Afterwards a mask was created to isolate in the image only the sample blocks to measure the differentiation elements at each sector. Figure 3 illustrates the sampling process in one of the southern socio-economic sectors of the city.

In order to analyze residential areas from spatial differentiation elements, an initial subdivision in Group 1 and 2 was necessary. The first one constitutes the differentiation elements of intra-urban land cover classes obtained by image classification, such as: Roofs (ceramics, asbestos, concrete and others), Swimming

Table 1: Socio-economic classification of planning sectors, including localization, income, number of residential blocks and sampled blocks

Geographical region	Sector Socio-economic	Monthly income Preponderance in the sector***	Number of Residential blocks	Number of residential block sample
North	1	C e D	353	35
Center*	2	B e C	272	27
	3	A e B	110	11
	4	B e A	48	5
South	5	B e C	245	25
	6	C e B	143	14
	7	C e B	174	17
	8	C e B	442	44
	9	D e C	398	40
	10	D e C	106	11
East**	11	C	267	27
	12	B, C, A e D	168	17
	13	D e C	190	19
	14	D e C	165	16
	15	C e D	139	14
West*	16	B	173	17
	17	A	281	28
Southeast	18	C	161	16
	19	C e D	210	21
Total			4045	404

*Except building areas

** non consolidated occupation

*** Value for reference year 2003 (R$ 240)

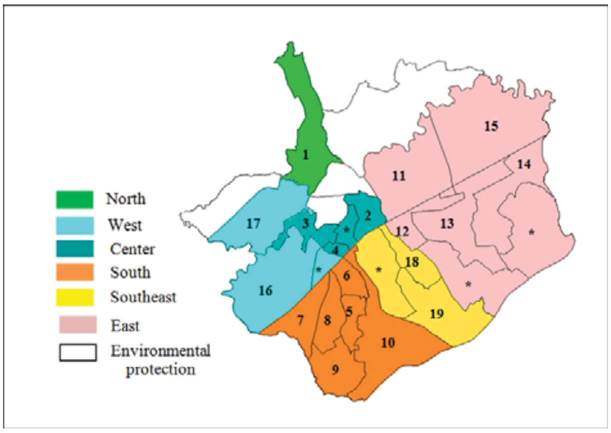

Fig. 2 - Border of urban area from São José dos Campos and socio-economic sectors according to spatial location.

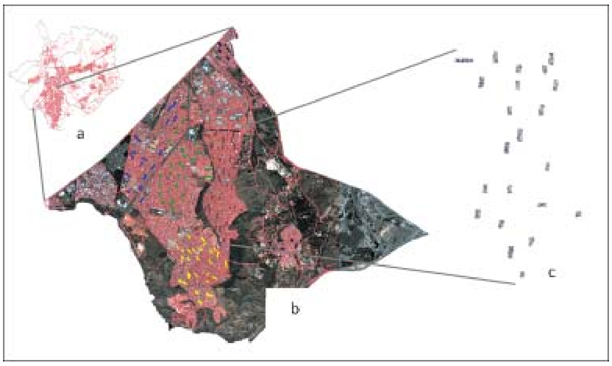

Fig. 3 - (a) Borders of residential blocks and socio-economic sectors (Southern location); (b) QuickBird-2 image with blocks, enhancing (in color) the sample blocks within each sector; (c) zoom of image with sample blocks at sector 5.

pools, Vegetation (arboreal and grass), Shadow and Bare soil. Class "Bare soil", although an important differentiation element, was not included in the analysis, taking into account that the selected sampled blocks were those with consolidated occupation. Class "Roofs" was subdivided in Ceramics, Clear roofs and Dark roofs. The two last classes mentioned were associated to asbestos roofs or equivalent material, while at those areas occupied by high income population they were associated to enameled concrete roofs without painting (dark roofs) and roofs with painting (clear roofs).

Image classification was done with the Definiens Professional 5.0 software package, where each socio-economic sector was considered as an individual project. For the 19 projects considered, a hierarchy net of segments, connected to a semantic net of classes was established (Figure 4). To map these classes of interest, two segmentation levels were defined, namely at level 1 with scales varying from 10 to 20, which discriminated small segments like Swimming pools, Vegetation and Shadow; at level 2 with scales between 30 and 35, the segments of class Roofs were delimited. For the definition of segmentation parameters at both levels, the highest weight was given to the spectral attribute of images instead of the form attribute (0.9 and 0.1 respectively). At level 2 the different residential cover types were mapped as subclasses of roofs (Clear and Dark ceramics). The attributes used for the classification were previously identified by Antunes (2003), Pinho (2005), Alves (2005), Pinho et al. (2009), Araújo (2006), Novack (2009), Kux et al. (2009) and Novack & Kux (2010). For the classification, samples were selected from each class at different segmentation levels.

Since there was no reference data to evaluate the map, it was necessary to establish a set of samples which would describe concomitantly the internal variability of each class. The definition of the sample number was done after the analysis of relation between the classes and the spectral average at the 4 bands. After several tests it was verified that the maximum of 20 samples for each class would encompass all the internal class variability, except for Grass vegetation and Swimming pools, with 5 samples each, due to its lower occurrence. The attributes used for image classification are summarized at Figure 4.

The samples of class Vegetation were modeled by NDVI, brightness and spectral average at bands 2 and 3. Grass vegetation, was defined by the lowest NDVI values and in some cases by a texture attribute proposed by Araújo (2006). At this attribute, the discrimination between Arboreal and Grass vegetation considers the number of sub-segments in Level 1, contained at the segments of interest in Level 2 (Object attribute based on texture). Since the Arboreal vegetation presents a higher complexity of coverage (Shadow among the leaves), it would theoretically present a larger number of sub-segments than the grass vegetation (ARAÚJO, 2006). The class Shadow was defined by its low brightness presented in all spectral bands. Due to the high brightness values of class Swimming pool at band 1, the attribute ratio of band 1 was used to describe it. For the discrimination

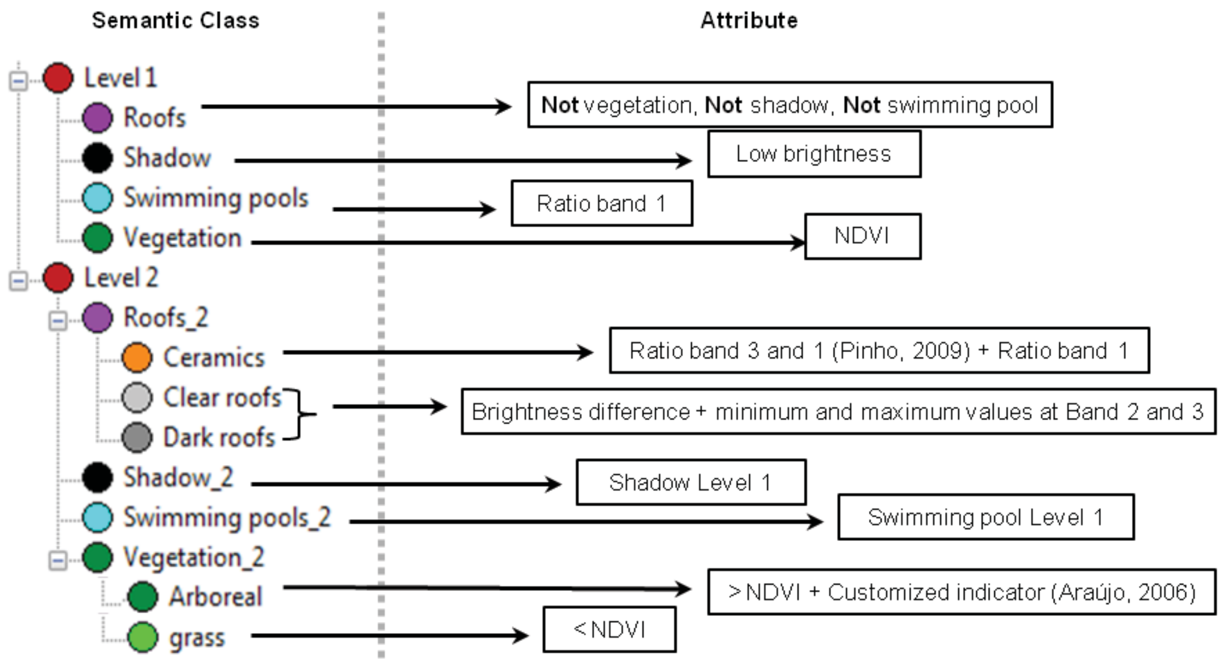

Fig. 4 – Semantic net and attributes used for image classification.

of class Ceramics, the ratio between bands 3 and 1 (PINHO et al., 2009), and the ratio of band 1 was used. At classes Clear and Dark Roofs, the brightness difference among them was considered as well as the minimum and maximum values at bands 2 and 3, and in some cases the maximum difference. All attribute values were adjusted in accordance with the sample analysis for each socio-economic sector.

The differentiation elements from Group 2 correspond to those classes obtained from the visual image interpretation and results of mapping from Group 1. The average size of lots in the socio-economic sector was acquired from the ratio between the area of sampled residential blocks and the average number of houses per block, by visual analysis, adapted from Souza (2003). The occupation density of residential blocks was got by a ratio of the sampled blocks area by the area occupied by sub-classes of Ceramics Roofs, Clear Roofs, Dark Roofs, within the block. Referring to the organization of blocks and lots, a qualitative analysis was done at the sampled blocks, and it was found out that only two blocks, located at sectors 1 and 2, presented these characteristics, allowing the exclusion of this analysis element.

In order to identify tendencies among data generated, the Data Mining technique (WITTEN et al., 2011) was applied, using WEKA (Waikato Environment for Knowledge Analysis) algorithm J48, which chooses statistically the set of attributes that best represents the data.

4. RESULTS AND DISCUSSION

The ortho-rectification procedure was evaluated automatically by the system, based on 12 GCPs collected during field survey and on the DEM. The Root Mean Square Error (RMSE) was 1.85 pixels. The image fusion was evaluated qualitatively by observation of sharpness from objects at the fused image and quantitatively by resample of next neighbor at the synthetic images, aiming to leave them at the same spatial resolution as the original images for the statistical images. The fused images, due to an increase of variance, present a higher contrast than the originals indicating that, in general, the data don't show significant distortions of averages and variances. The high correlation between images is also an indicator of similarity among them (0.89 at band 1; 0.90 at band 2; 0.92 at band 3 and 0.88 at band 4).

The qualitative evaluation of classification results for each sector showed that many segments from classes Dark Roofs, Ceramics and Shadow, were classified as Vegetation. Pinho (2005) verified that those areas under shadow presented high NDVI values in images with 11 bits radiometric resolution. The ceramic tiles also have lower NDVI values, because they frequently present a thin layer of bryophytes (a kind of moss), a problem also identified by Araújo (2006). Due to that, probably many Dark Roofs were classified as Vegetation. It was also observed that, in some sectors, Dark Roofs were classified as Shadow, possibly due to the superposition of values from the functions of the Brightness attribute, which required the adjustment of this function. Some Dark Roofs were also classified as Ceramics. The best results obtained were for Swimming pools and Clear Roofs. Since class Swimming Pool was classified at Level 1 and it is restricted to some socio-economic sectors, the attribute values were adjusted until they reached almost all classification segments pertaining to this class. However some segments of class Clear Roofs were still classified as Swimming pools at Level 1. At Level 2 Clear Roofs presented the best result, because these roofs had a high brightness in comparison to other classes.

The qualitative analysis evidenced also some errors at the delimitation of segments. One observes that in those sectors with low-income population, the heterogeneity of roofs is high, with variable size, types and disposition of cover objects, which influenced the segmentation of these areas. In spite of delimiting correctly most objects, some Shadow and Vegetation areas, smaller than a pixel at the image (0.60 m), were not discriminated at the finest segmentation level (Level 1) and due to that, they were included in segments of other classes. Although in sectors where the size, the regularity of features and the cover of houses presented a better segmentation, some cover types, due to size, illumination and age, are a problem for both the segmentation and classification. Furthermore it was observed that the delimitation of Swimming pools was non-defined in some areas, confusing with the paving surrounding them. To circumvent the errors observed, which increased the classification difficulties, the automatic classification was refined by a hybrid classification. This approach is a mixture of automatic procedures, followed by an intervention for error correction, allowing a higher control of the analyst to correct errors found at the object delimitation and class association (CASTRO FILHO, 2006). The results of the hybrid classification, from one of the socio-economic sectors are presented at Figure 5.

The evaluation of results at the final classification, including all 19 sectors, showed a good thematic precision and minimum Kappa index of 0.76 for sector 13 and maximum of 0.88 for sector 8. At sample blocks from sectors 13 and 19 there was less Vegetation and Shadow. At the first one, the Shadow presents the highest omission error, while at the second it was the Arboreal Vegetation. Class Shadow also exhibits the highest omission error at Sectors 12 and 13. At Sector 3 the land cover classified as Arboreal Vegetation corresponds to 85% of the cases. Some samples of it were included in the class Grass, indicating the difficulty to discriminate both classes. These classes show the highest inclusion and omission errors among themselves. In some cases the class Arboreal Vegetation showed persistent omission errors, confusing with class Shadow in areas with shadowed vegetation and Dark Roofs, reinforcing the idea of bryophytes on such roofs. The roof sub-classes presented a higher confusion among them, except for some areas of Dark roofs and Ceramics which mixes with classes Vegetation or Shadow, as mentioned earlier.

After mapping the elements of Group 1 (Vegetation, Shadow, Types of roofs, Swimming pools), data obtained were inserted at the SPRING 4.3 software package where, through spatial analysis, those elements of Group 2 (Average size of lots and Occupation density) were obtained. These data allowed to determine both the percentage of occurrence from each differentiation element within the sample blocks, in each economic class, and to show graphically the patterns and its distribution in the residential space of the city (Figure 6).

According to Figure 6, occupation densities of lots below 35% are typical for high income sectors, whereas densities above 40% are found in residential areas of population with medium to low income. Swimming pools are a constant in the residential blocks of socio-economic sectors with high income. They appear with certain regularity at blocks and as a few units at medium to high income and are inexistent in sectors occupied by population with low to very low income.

The homogeneity/heterogeneity presented by roofs of houses is due to different building materials, and is an important factor for the

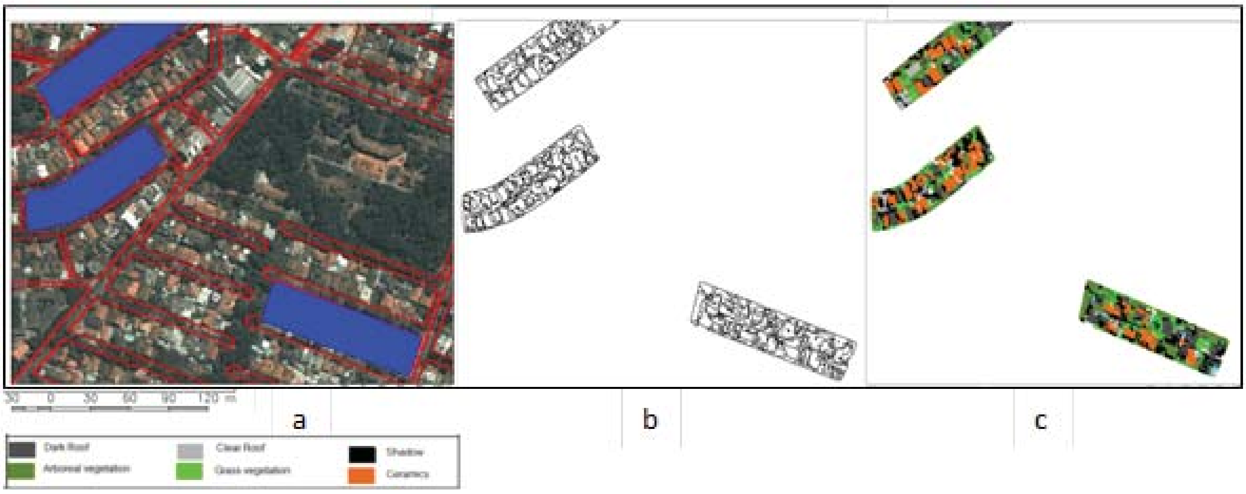

Fig. 5 - (a) Enlargement of the borders from the sampled residential blocks of a socio-economic sector; (b) Enlargement of segmented sampled blocks at Level 2; (c) Enlargement of classified blocks.

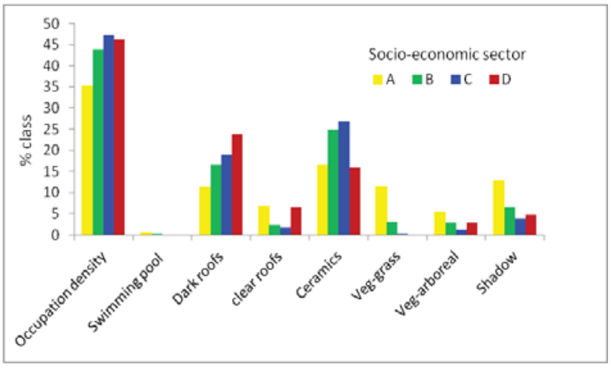

Fig. 6 - Class distribution per social-economic sector.

discrimination at very high resolution satellite images, and also an important element for the economic characterization of sectors. The main roof cover materials are tiles of ceramics, clay, concrete, asbestos, aluminum and galvanized steel plates, except for areas of slums. According to Lee (2000) depending on the combination of materials, structure and labor, a significant increase of total construction costs can occur. One of the cheapest combinations is the asbestos plate with 4 mm thickness, supported by a slab. Although this material is prohibited for construction, it is still used in Brazil, except for São Paulo State where Law Nr. 12684/07 forbids its use. Because it is the cheapest option as a roof cover, according to Souza (2003), the asbestos cement is still widely used in districts with very low-income, in the area under study.

The tiles of ceramic or enameled concrete are the most expensive cover materials because they demand an improved structure and consequently higher labor costs. Considering the above mentioned and the spectral limitations of the images used to identify materials of clear and dark roofs, we verified that those districts occupied by low and very low-income population are associated to asbestos or equivalent materials (for dark and clear roofs), while those areas occupied by medium to high income are associated to enameled concrete tiles (for dark and clear roofs).

Through this finding, three types of roofs were determined, shown at Figure 6. Those areas of predominant ceramic and enameled concrete roofs are districts concentrating the high income population. At sectors with predominant asbestos roofs there are frequently housings of low to very low-income population, except for sectors 7 and 8, where there are medium income households. At sectors 9 and 3 there is a high concentration of asbestos roofs, where low to medium income households predominate. The high percentage of ceramic roofs in sectors with low and very low-income is due to the fact that many blocks from sectors 12, 19 and 1 are housing blocks, built by governmental agencies for very low income families.

Sectors 3 and 17 were those ones which present the highest percentage of Grass vegetation per block; both are areas of very high income population. The arboreal vegetation presents a similar occurrence as the Grass vegetation. Those areas inhabited by very low income population present the minimum tree cover percentage (from 0 to 4%), whereas the highest percentages (till

9%) appear in those areas of high to medium income. This is due to the fact that many quarters are recent allotments, with arboreal vegetation still in growing phase. However, some sectors inhabited by very low income, present higher averages than those of low income, because these are quarters with a longtime consolidated occupation. Nevertheless in these places the vegetation distribution is not equitable among the blocks. The vegetation distribution within São José dos Campos is not homogeneous, as pointed out by former studies from Souza (2003) and Gonçalves et al. (2005).

The shadows within the blocks analyzed are due to: lateral backing between houses, gaps among the roofs of houses with more than one floor, arboreal vegetation and due to the side view of the satellite. So the distribution of class Shadow can indicate, besides that, possible classification errors. One observes that there is a balanced percentage distribution among both shadow and income characteristics of inhabitants. At the extremes the highest percentages of class Shadow are found in the blocks of high income population (15%) and the lowest ones (4%) at sectors 2, 13 and 15, occupied predominantly by low-income population.

Referring to the lots with different sizes, this is mainly the result of a different legislation for land subdivision. Based on Federal Law Nr. 6766 from 1979, it is the municipality's responsibility to define the rules for permission of use and the urban indices (minimum size of lots, backing of constructions, area for use, etc.). In residential districts of the city, the distribution of class Size of lots was subdivided in 5 units of average lot size. Sectors with lots with sizes of 350 to 450 m^2 include sectors 3 and 17 which correspond to high income areas. Lots with 300 m^2, found at sectors 4, 5, 6, 12 and 16 are also areas of population with high to medium income. At these sectors, the lots have normally just one building, presenting all the backing in accordance with the urban legislation, with space for garden and garage. At sectors with lots between 200 and 250 m^2, such as 2, 7, 8, 11 and 15, there are lots with only one construction but also with a considerable amount of semi-detached houses. Finally at sectors 1,9,10,13,14,18 and 19, with an average size of 150 m^2, lots are almost completely occupied by constructions and frequently there are no backings to allow for air circulation and sunshine. In some places within these sectors there is a high concentration of houses with two floors.

The class Swimming pool and the internal organization of the blocks was punctual. Swimming pools indicate availability of terrain and, when analyzed together with other objects, they can be considered as a factor of life quality increment as well as a wealthy indicator.

The data with the percentage of each intra-urban land cover class per block was inserted in a data mining program, totaling a set of 154 evaluation samples and 50 test samples. The algorithm J48, which generates decision trees from a previous training set, was used. The total precision of the model was 82% for the correct classified instances and 18% for the incorrect ones, and a Kappa value of 0.75. The results of this evaluation are shown in the decision tree at Figure 7. The decision tree is a supervised statistical model for the classification and forecast of data.

The decision tree obtained confirms earlier observation in the qualitative analysis and on the knowledge of the city under study. The low occupation density of the sample blocks is the element which best defines class A (78% of all samples correctly classified). This is an indirect indication of other land cover types (e.g. Arboreal vegetation and Grass, Shadow and Swimming pools). The high occupation density, the occurrence of grass and low thresholds of clear roofs define class B (100% of correctly classified samples). The high density of occupation, the absence of grass vegetation, high thresholds of clear roofs and especially dark roofs, are tendencies observed at class D (83% of samples correctly classified). Class C, with 78% of samples correctly classified, was the one which presented the most unpredictable behavior with the data used, appearing in different leaves of distinct branches from the decision tree, that are different from classes A, B and D which present clearer rules for its characterization as intra-urban land cover classes. Class C was correctly classified as for the high occupation density, absence of Grass vegetation (65% of hits) or less (8% of hits) of clear roofs. But this class also presents a hit rate (14%) referring to the high occupation density, grass vegetation and

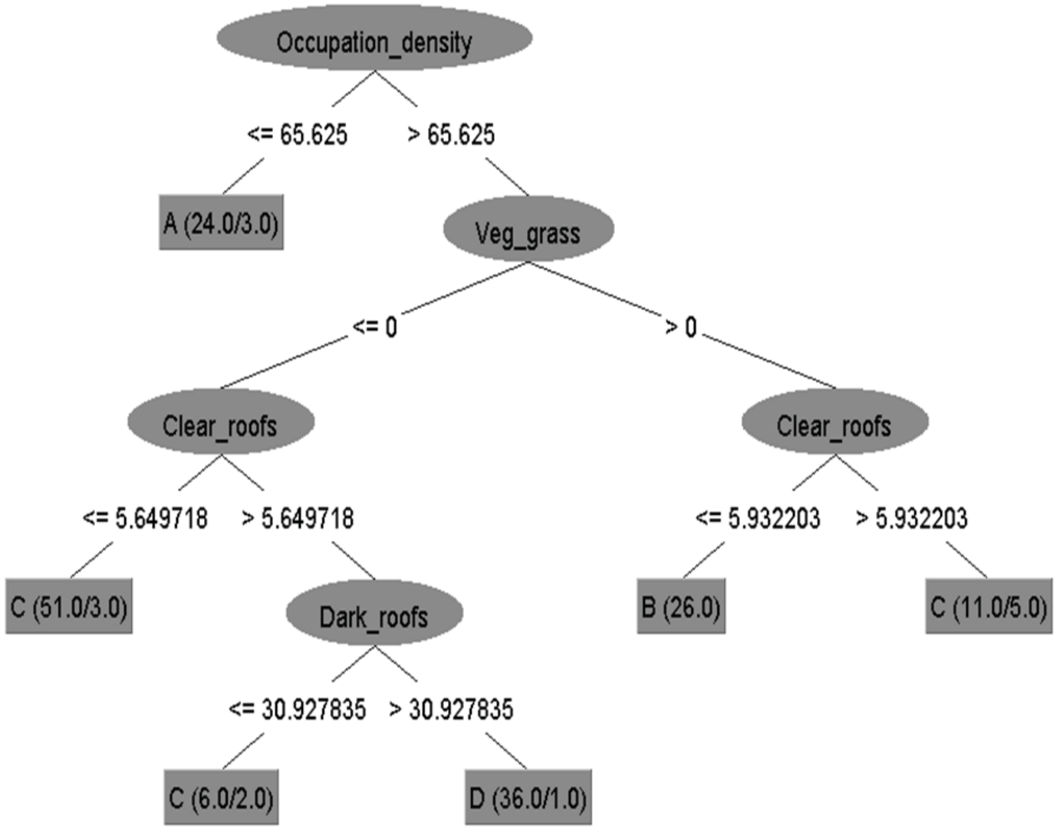

Fig. 7 - Decision tree obtained by selected features at WEKA.

higher incidence of clear roofs.

It must be emphasized that the automatic exclusion of intra-urban land cover classes Swimming pools, Arboreal vegetation and Shadow are due to redundancies or inconsistencies identified in these classes during the model generation. Although class Shadow presents extremes of occurrences between classes A and D, it appears only in classes A and B, not being significant for the data set. Class Grass defines clearly the differentiation between social-economic classes. At class D it is absent and at the others the thresholds are distinct. Probably a more complex model could include these classes. In this study however the simplified net was used as a support for the qualitative analysis, showing that there are important factors which describe the behavior of these classes, considering the objectives proposed in this study.

5. CONCLUSION

In spite of advances of techniques for automatic information extraction of remote sensing images and of increase on the accuracy of intra-urban surveys, as shown by studies from Pinho (2005), Araújo (2006) and Novack (2009), using the Object-based Image Analysis paradigm, it is still to represent automatically the entire complexity of territory at intra-urban scale. On the other side, a hybrid classification is slow when an analysis of an entire city and not only from a small section is done.

The analysis of the distribution from each differentiation element, when aggregated to the contents of social-economic sectors, shows that some elements are insufficient for the evaluation of the variability of social inequality. In spite of that, some elements such as Occupation density, Arboreal vegetation, Shadow and Roof materials evidence clearly the separation among sectors of high and low income population, while other elements such as Swimming pools, Grass, Vegetation and Size of lots allowed the identification of a higher variability of inequality, besides the social extremes.

In former studies on inequality from SJC, such as the Poverty Map (BORGES, 2003), the Inclusion/Exclusion Index (GENOVEZ, 2002) and the Atlas of Life Conditions (NEPO/UNICAMP/PMSJC, 2003), Sectors 1,9,10 and

13 were identified as high concentration of poverty and exclusion. Our study shows that the same districts present most precariousness of life conditions on a spatial dimension. These results also confirm the social-economic characteristics of the Zoning from the Urban Area of SJC, indicating that from the social-spatial differentiation analysis, it is possible to analyze the spatial inequalities.

In this study, the starting point to verify the spatial differentiation was the space, which is the geographer's object of analysis. It is not an opposed approach to those researchers who start their analysis with social-economic data and afterwards map them. On the contrary, these are complementary analysis methods, because they evidence different dimensions of social inequality.

The social inequality in the intra-urban space has been studied based on field surveys and secondary data, whereas this study is grounded on landscape elements obtained from high spatial resolution satellite images. Field surveys characterize first the living conditions of people from a place, its territory and its space. The use of these satellite images allows initially identify some conditions of the place and territory where people live. Both starting points allow understanding the social-spatial dynamics. These methodologies are not exclusionary; they are complementary to understand the contradictions and conflicts at the capitalist production and reproduction of urban space, expressed by differentiation, inequality and social-spatial segregation.

The differentiation elements used were limited to represent a major diversity of inequality found in the city. This is due to the methodological approach on the use of sample blocks as the analysis unit, rather than the information content of the very high resolution satellite images. Such images allow the identification of other landscape elements such as areas for leisure (e.g. parks and clubs), commercial centers and hangars, types of road systems, among other characteristics of the concrete space which were not considered in this study. When one disregards the broader social context where the social-economic sector is inserted, there is a loss of all other elements which influence the housing conditions of residential areas as well as the differential urban land appreciation. In this sense other image elements must still be explored, while fundamental data about the intra-urban space are explicit by the geographic differentiation.

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