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Change Detection applied to the identification of anthropic areas in the city of Rio de Janeiro - Brazil, between 2000 and 2015 - Case Study for Planning Area 4

Vandré Soares Viegas [1], Ana Paula de Oliveira[2,] Elizabeth Maria Feitosa da Rocha de Souza [3]

1,2,3, - Federal University of Rio de Janeiro - Department of Geography (v.vegas18; oliveira.apdo; Corresponding Authoir: Vandré Soares Viegas

Abstract: *With the advent of remote sensing techniques, there are a large number of tools that can contribute directly to the analysis of the modified urban environment, since the expansion of a certain occupied area as well as its occupation can be easily detected through images of satellite. The objective of this research is to evaluate the changes occurred in Planning Area 4 - in Rio de Janeiro, using TM / LANDSAT Image Detection techniques to detect soil cover changes occurring in the period from 2000 to 2015. The images were submitted to specific curves with the spectral response of the targets to verify the adjustment of the images. Finally, the GEOBIA model was generated for the identification of urban areas, using the descriptors NDBI, NDWI and NDVI. After the modeling of the descriptors and the mapping of urban areas in the AP 4 it was possible to identify changes and social characteristics of the results.*

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I. Introduction

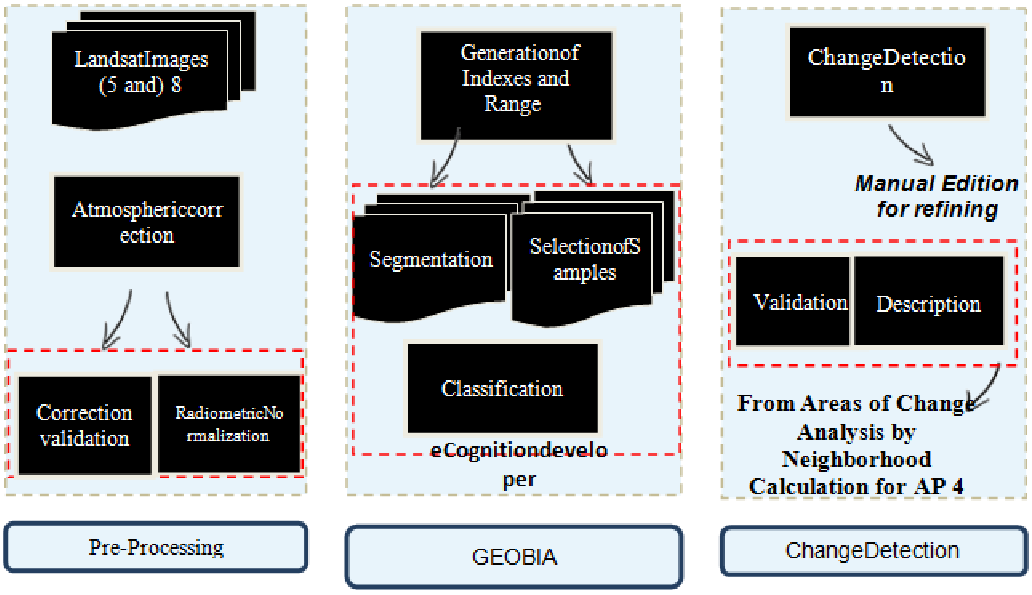
The urban areas are characterized as a much diversified space, in function of the spatial and social dynamics in which it is inserted. As these environments are in constant modification, understanding such changes allows us to understand how the occupation process took place, and in a more complex way how its growth will take place. The State of Rio de Janeiro is characterized by an extremely heterogeneous physical structure, where great coastal massifs, hills and mountains contrast with the occupation around them. The heterogeneity of the state goes even to the social formation of the population, which is often distributed locally as a function of environmental conditions.

With the advent of Remote Sensing techniques, there is a great allowance of tools that can directly contribute to the analysis of the modified urban spot, since the expansion of a certain occupied area as well as its occupation can be easily detected through satellite images [1]. In addition to contributing to public policies and understanding of the city itself, mapping and urban monitoring initiatives of municipalities such as Rio de Janeiro are essential for analyzes at larger geographical scales. It is in this respect that the changes that have occurred in the State of Rio de Janeiro in the last 15 years become so remarkable. The West Zone of the Municipality of Rio de Janeiro represents one of the most modified regions of the State, since its exponential growth in the 70's. This race, which already showed a very fast pace, ended up having its apex until then with the arrival of Rio de Janeiro, starting with the Pan American Games (2007), the World Cup (2014) and the Olympic and Paralympic Games (2016).

This paper aims at identifying the changes that occurred in Planning Area 4 (PA 4), which encompasses 19 districts in the Administrative Regions of Barra da Tijuca, Jacarepaguá and Cidade de Deus, in Rio de Janeiro, Brazil. For this purpose, the TM / LANDSAT image change detection technique was used to identify the changes in soil cover occurring in the period from 2000 to 2015, contributing with representations in the form of spatial and statistical analyzes that support public policies focused on occupation and urban planning.

II. Material And Methods

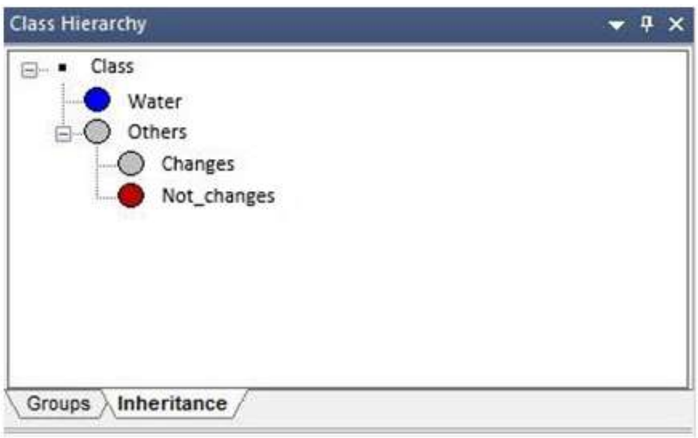
The work methodology is divided between the stages of preprocessing, modeling of changes, as explained in Figure 1.



The methodology developed was initiated by the acquisition and processing of Landsat 5 and Landsat 8 images from the download available in the United States Geological Survey (USGS). The scenes were chosen for near periods, searching for seasonal equivalence and low clouds. The first stage consisted of the atmospheric correction of the images, aiming to attenuate the scattering and absorption effects caused by the atmosphere, which can alter the spectral response of the targets, especially when performing a multi-temporal study [2].

The subsequent process consists in the radiometric normalization of the images that have already been treated with respect to the atmospheric components. According to Ponzoni (2000), the normalization process is a relative calibration technique consisting of linear regression between multispectral images in a time series in relation to a reference image [3]. In the present work, the free software R. was used, opting for the distribution of 300 invariant points in the temporal clipping scattered throughout the scene, favoring most of the analyzed region, as well as its environments.

With the images already corrected, the process of classification of the images was started, aiming the detection of changes. Using the eCognition developer ® software, we chose to separate the general classes (water and others), since the main interest is to map what has changed between the dates and to evaluate the changes that have occurred. The detection of changes occurred from the subdivision of the classes change and not change and the differentiation of light and dark areas, because the applied models end up detecting differences in the shadows as change, but that in fact are only differences in the illumination of the place, to eliminate these problems we defined the hierarchy of classes presented in Figure 2.

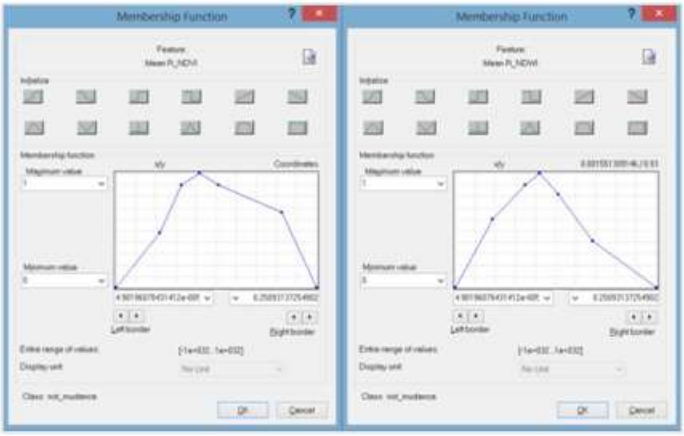


Using the GEOBIA (Geographic Object-Based Image Analysis) approach, sampling was performed according to the choice of different descriptors, however when adopting basic classes it was preferred to follow the creation of individual specific indices able to differentiate the segments: urban, vegetation and water.

The descriptors chosen were the normalized difference indices capable of highlighting the chosen targets in the images, separated as follows: Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Index of Normalized Difference Built up Areas (NDBI).

From the calculations of these indexes, the tool Cell statistics in ArcGis 10.1 was used (defining as a range) a method that estimates the reach value that each pixel represents among the indexes generated from the images of the 4 dates used, generating 4 different ranges for each index. The "not_change" class was modeled with the descriptors referring to the mean of the amplitude of the calculated indexes, NDVI and NDWI, while for the "change" class the inversion of the similarity of the "not_change" class was attributed. The graphs of the chosen descriptors are shown in Figure 3.

Figure 3 - Modeling Charts - NDVI and NDWI



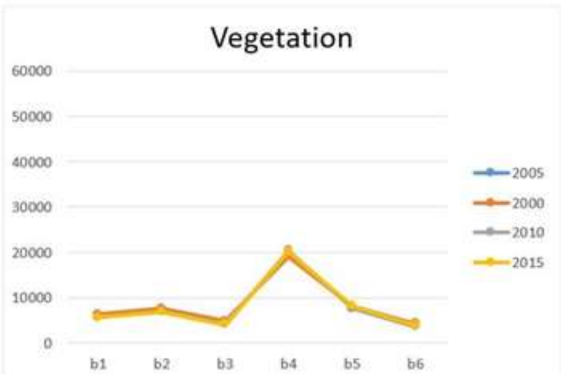
These parameters were shown to be the most adequate for the differentiation of the targets in the images, including vegetation, water and non-agricultural anthropic areas (urban area, exposed soil and mining, for example). It is worth noting the good coverage found by the near infrared (NIR) bands, and also with adequate response of the amplitude of the NDVI and NDWI indices. The mapping was validated from 150 random points in the study area, based on Google Earth images for validation.

III. Results

Using the 2005 image, after the atmospheric correction, as a reference for radiometric normalization, it was possible to verify that the targets compared in the different images presented spectral responses consistent with the expected and according to the bibliographic review.

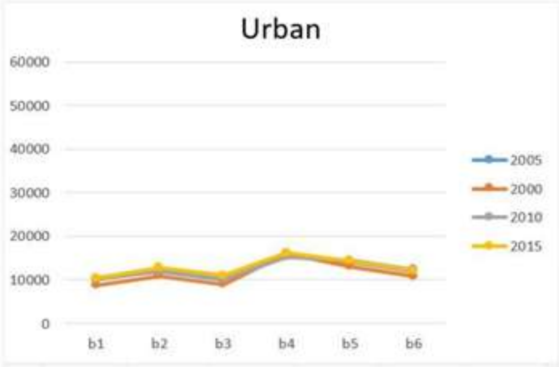
The graphs were elaborated according to the digital levels (Axis y) and the respective values for each band (Axis x), for both the TM sensor and the OLI, 6 bands were used, excluding the Landsat 8 thermal springs. Figure 4 illustrates the radiometric normalization validation graph for the Vegetation class. As the class analyzed is extremely homogeneous, as soon as the validation graph of the same tends to approach at all wavelengths, from this, it is also possible to affirm that the normalization process had its success.

Figure 4 - Validation of Radiometric Normalization - Vegetation Class



For the "Urban" class, there is a greater differentiation between the images (Figure 5), a fact supported by the high heterogeneity of this class, mainly because of the coverage that composes them and the difference among dates spaced in 15 years, even though this is a small difference of be observed, corroborating with the adequacy of the curves also found in the vegetation class. It should be noted that the same graphical behavior, appropriate, had also been obtained for the Water class.

Figure 5 - Validation of Radiometric Normalization - "Urban" Class



According to the classification made, the detection of changes was quite pertinent, as shown in Figure 6. Through the parameters used in the modeling, the final classification was shown to be adequate, visually illustrating the numerous changes that have occurred in recent years in the PA 4.

Figure 6 - Areas of Changes in PA 4

Throughout PA 4, the area of change totaled 28.50 km², following some standards. Through tabular transformations, it is possible to verify the occurrence of particular change of each neighborhood of the Planning Area. The changes often occur at the intersection between two or more neighborhoods, as shown in Table 1. It was decided to analyze only those occurring within a single neighborhood, since a percentage of variation within a single locality is sought.

Some neighborhoods account for most of the changes that have occurred compared to others, no matter how natural, there is a clear direction for this expansion. In a simple relationship with the total area of change, it was possible to identify the percentage of changes, evidencing some disparity between the transition of the 15 years analyzed, this questioning instigated the idea of relating the changes occurred with other social indicators, such as income, supported In the case of 4 districts, with no intersection, they added approximately 66% of the total change of the Planning Area, as seen in Table 1. Table 2 lists the same districts with the Average Nominal Income category, which excludes residents with no income, obtained through the Warehouse of the Instituto Pereira Passos (IPP) [4].

Table 1 - Percentage of Neighborhood Change in AP 4

Neighborhood	Change (%)	Neighborhood	Change (%)
Anil	1%	Joá	1%
Barra da Tijuca	24%	Pechinha	0%
Camorim	2%	PraçaSeca	1%
Cidade de Deus	0%	Recreio	22%
Curicica	0%	Tanque	1%
Freguesia	2%	Taquara	2%
Gardênia Azul	0%	Vargem Grande	4%
Grumari	0%	VargemPequena	4%
Itanhangá	1%	Vila Valqueire	0%
Jacarepaguá	20%	Intersection	14%

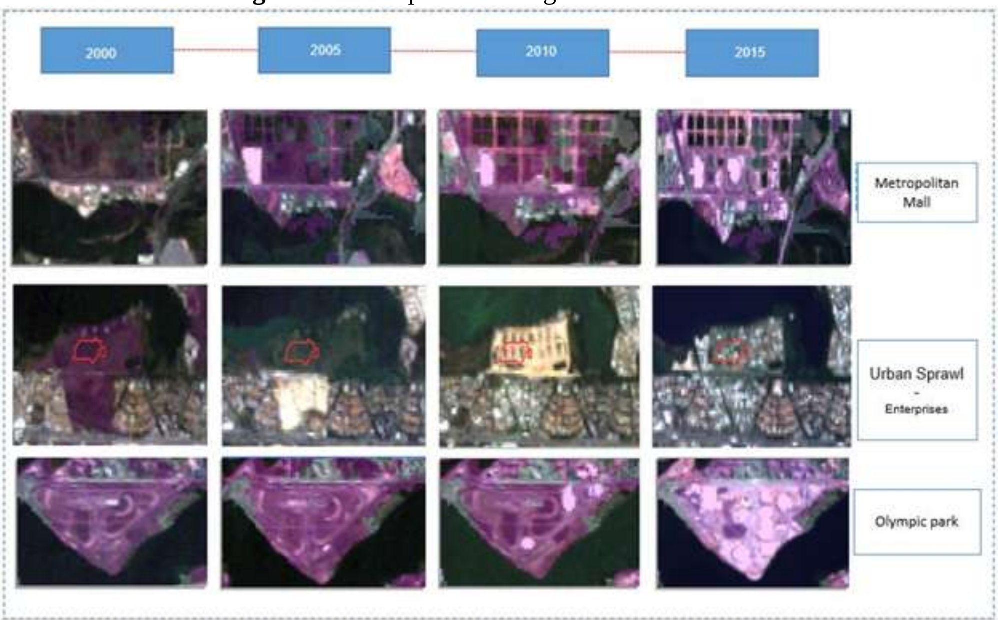
Table 2 - Percentage of Neighborhood Change in AP 4

Neighborhood	Average yield Nominal (R$)	Neighborhood	Average yield Nominal (R$)
Anil	1 500	Joá	7 891
Barra da Tijuca	6 835	Pechinha	2 465
Camorim	2 261	PraçaSeca	1 561
Cidade de Deus	823	Recreio	3 808
Curicica	1 271	Tanque	1 467
Freguesia	2 673	Taquara	1 769
Gardênia Azul	1 069	Vargem Grande	1 456
Grumari	571	VargemPequena	1 273
Itanhangá	1 763	Vila Valqueire	2 279
Jacarepaguá	1 351	EmInterseção	-

A good example of a social indicator inherent to the changes is the Cidade de Deus, a subnormal cluster that has the second lowest income for districts of the said Planning Area, only losing to Grumari. However, according to the 2010 IBGE Census, the inhabitants of Cidade de Deus this year accounted for 36,515 people, while Grumari has 167 inhabitants on the same date [5]. In addition, Planning Area 4, which has 3 Administrative Regions (Barra da Tijuca, Jacarepaguá and Cidade de Deus), had a concentration of changes distributed as follows: Administrative Region: 0% Cidade de Deus, 27% Jacarepaguá and 58% Barra da Tijuca. While the distribution of Average Nominal Income by Region, has R $ 823 Cidade de Deus, R$ 1 793 Jacarepaguá and R$ 4 682 Barra da Tijuca.

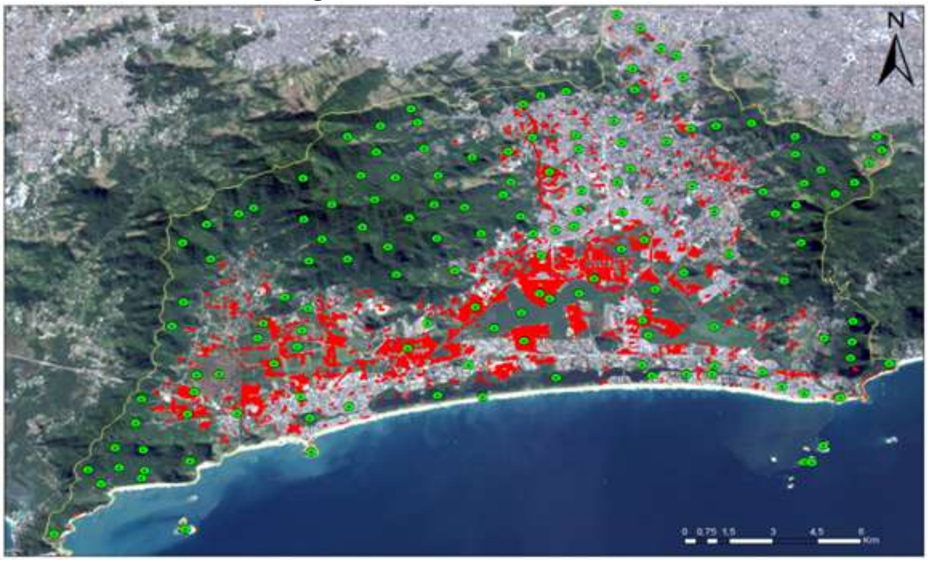
In visual analysis of the mapping, it is also possible to identify the creation of many shopping malls, luxury condominiums, usually near beaches, works coming from the planning of the Olympic Games and infrastructure such as BRT, the scheme illustrated in Figure 7 exemplifies some of the changes found.

Figure 7 - Examples of Changes occurred in AP 4



Regarding the validation of the mapping, using ArcGis 10.3, 150 points were distributed through out the study area, so that the classes of change and non-change could be encompassed (Figure 8). Subsequently, these points were exported to Google Earth, which, through the years' toggle function, allowed us to indicate which areas actually changed, of the 150 sample points created 122 were indicated as correct, providing an accuracy of 81.3%, a high value that indicates an adequate mapping and that meets the criterion of precision adopted in the work. It is noteworthy that the validation classes were only change and not change, which encompasses both green and anthropic areas, since changes in water bodies were considered only in their extension, if it happened.

Figure 8 – Points for Validation



IV. Discussion

Since 1980, when there has been a great demographic explosion in the Carioca West Zone, more specifically in Barra da Tijuca, Rio de Janeiro has been experiencing an even more intense expansion in recent years, as a result of several investments and interests of contractors who found an area prone to without the need to explore a region with a lower income or already fully urbanized that does not allow the construction of new enterprises with large idle spaces, the PA 4, recently, still represented a relatively unoccupied area, in opposite the City Center, for example. Specifically, Planning Area 4 has undergone numerous transformations, it is true that since the opening of the Avenida Governador Carlos Lacerda Avenue (LinhaAmarela) in 1997, ease of access to commercial enterprises, shopping malls and other service providers ended up by strongly replacing the commercial use of industries, even residential occupancy became more upright, from the 2000s there was an abrupt expansion with the arrival of major events in the municipality of Rio de Janeiro, such as Pan Americans who was the precursor of the next, so grandiose, that the change in land cover and demographic increase, have become major future concerns.

Since the occupation plan, carried out by Lúcio Costa in 1969, according to the City Hall of Rio de Janeiro, AP 4 shows a fantastic growth, especially in the administrative region of Barra da Tijuca, which increased from 5,779 residents in 1970 to 174,353 in 2000, in a variation of 2,917% in 30 years. With data from the 2010 IBGE Census it is possible to verify that in the last two censuses (2000-2010), the West Zone as a whole (also includes the AP5), grew about 150%, these figures indicate a direction of growth still more developed by the Rio 2016 Olympic Games, this region has received from new sports arenas to the athletes' facilities, an advance not only in the sports arena, since after the Games, a consortium of 3 contractors will be able to explore regions of the Olympic park for real estate purposes.

Considering the local offer of free spaces, it is natural that there is a very intense and targeted real estate spread, however, the creation of infrastructure and the protection of the most needy residents should not follow such a high disparity model, which seeks to generate much more a region aimed at wealthier classes than truly expanding by advancement and sustainability.

With the Remote Sensing techniques, more specifically the Detection of Changes method, we were able to visually identify how the process of occupying a given area occurs, and even to associate with other factors and data that end up fostering a diverse range of studies. In addition to the identification of some large complexes, we have also been able to identify areas that have become denser, such as the construction of shopping malls such as the Metropolitan, the Olympic Park, the Athletes' Village and others, which unfortunately are not mainly aimed at structuring the neighborhoods, but focused on economic interests. One of the few changes associated with urban mobility, the BRT, and the Trans-Olympic, represents a good advance towards infrastructure, but they still lack an auxiliary structure, such as the recently opened subway.

The creation of public policies that foster research, social development, can also be associated with the urban environment and its unbridled expansion, so identified in the present study, with more research and scientific bases it is possible to create new expansionist models that can accompany the necessary evolution with the arrival of public policies of sanitation and transport, for example. Planning Area 4 is a region that has not yet been explored for sustainable purposes; however, we are increasingly seeking to support the most diverse sciences for the well-being and maintenance of the population, understanding

V. Conclusion

With the Remote Sensing techniques, more specifically the Detection of Changes, was the process of identifying some areas of interest of the research, and was also included with other factors and data that end up being a gamma variable. Studies. In addition to the identification of some large complexes, it was also possible to identify the areas that became denser, a construction of shopping centers such as the Metropolitan, Olympic Park, Village of Shows and Arboreal Areas, being replaced by urban complexes.

The creation of media that foster research, social development, can also be associated with the urban expansion identified in the present study.

It is important to replicate and validate the results in other contexts and areas. It is suggested the validation of the mapping with some field activities and also the evaluation of the method of use of new sensors, with higher spatial resolution.

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