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The impacts of urban sprawl on soil sealing of Feira de Santana through comparative analysis of satellite image classification

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Abstract

Soil sealing in large urban centers and their effects on the environment and society is increasingly present in cities. This study aims to analyze the soil sealing process of Feira de Santana due to urban expansion. The Bahian municipality is the second largest population in the state, has a relatively flat topography and lacks studies to guide urban planning to promote environmental education and the implementation of urban sanitation. The collection of satellite images of the urban area of the city was utilized for dereferencing, through segmentation and classification of the images and a statistical analysis of the data was accomplished through spatial analysis. The modeling and image processing were performed by GIS SPRING software. This research sought to portray the area's most affected by the waterproofing of the soil and other areas within the city that are in the process of waterproofing due to urban growth for the classification of satellite images..

Keywords: Waterproofing, GIS, Urban Growth, Classification, Feira de Santana

1. Introduction

The municipality of Feira de Santana, the second largest city in the State of Bahia, has been suffering an accelerated process of urban expansion. Despite the rapid growth in population, the replacement of permeable pavements (interlocked blocks, parallel, etc.) and soil with waterproof flooring (such as concrete and asphalt) and the increasing development of buildings has transformed the soil to become totally impermeable.

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The main issue amongst the development of waterproofing the soil in the city, is that the topography of Feira de Santana is flat. As a result, this topography lacks a proper drainage system to sustain this urban transformation.

The tessellations used in urban centers alters significantly the dynamics of soil infiltration, as such, the impact of the urbanization can produce a significant increase in the runoff coefficients of a basin (VENDRAME; LEE, 2005). These changes are also observed in the silting of the lacustrine system of Feira de Santana and the reduction of green areas. As the removal of vegetation cover creates vacancy for new developments, without adequate monitoring of the established functioning infrastructure, investment regarding rainwater management and minimal preservation of urban green areas are deplored.

Understand that, with the process of urbanization, the impacts on soil are identified even though the landscape is not paved and resealed. That's because the soil exposed due to the removal of vegetation exposes albedo and reduces infiltration, because it comes to clay soils, which infiltration of water is minimal. Finally, because it comes, for example, from clay soils the water infiltration is minimal (SANTOS, 2008).

The city of Feira de Santana becomes a challenge to projects and urban sanitation infrastructure development projects. Its location on such a planar landscape is in the midst of problems of soil sealing, with an ever-growing population through immigration promoted by investments in the region in the areas of education, trade and industry.

Remote sensing techniques were used to determine changes in land use and land cover in urban areas for decision-making and landscape management (Yildiz and Doker, 2016). Thus, it is necessary to model the soil sealing level of the urban area of Feira de Santana through identification of different classes of urban land use, relating the level of waterproofing to urban land use classes and quantifying them.

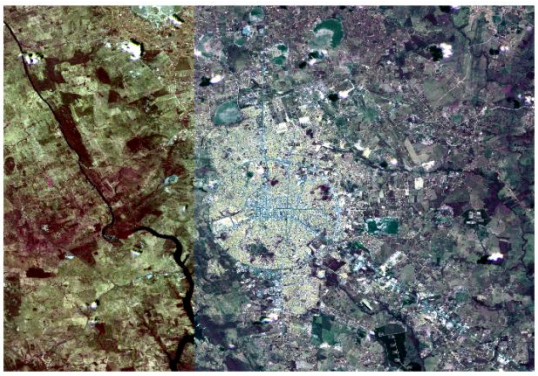
1. Methodology

The urban space of Feira de Santana was modeled through the use of Rapid Eye image with application of image classification (segmentation - Battacharya and maximum likelihood) and comparative techniques to identify the modifications of the systems of land use and soil cover.

According to the division of official neighborhoods of 2010, the urban region of Feira de Santana was bounded as the study area. Due to having an urban area with two scenes that were encompassed with mosaics which present a difference of color balancing (**Figure 01**), it was preferred to delete the additional scene on the left which correspond to a small extension of the urban area in order to avoid misinterpretations by the algorithms during the classification process. The current dynamic of the georeferencing was evaluated through fieldwork with characterization of the blocks of urban land where it was classified and categorized in to the different areas of the city in relation to classes of use and occupation of the soil used.

Sorting is the process of extracting information in images to recognize patterns and homogeneous objects. From the choice of images, it was sought to assess the methods being employed to sort the images, which were more consistent with the objectives proposed. Of the different methods evaluated, two different techniques were chosen: one per pixel, maximum likelihood (MaxVer); and the other by regional categorization of targeting, the use of the algorithm to perform the classification of Bhattacharyya image segmented. The "pixel to pixel" classifiers are based only on spectral information that is separate for each pixel to find in homogeneous regions. The end result of a classification process is the digital image that is a map of classified pixels represented by graphic symbols or colors. Multispectral classification techniques that are "pixel to pixel" are the most common for the maximum likelihood (MAXVER), for being a robust method and very well described in the literature.

Figure 01: Rapid Eye Scenes with difference in contrasts. Colour composition 4-3-2 (RGB)



Another form of classification is through the classifiers for regions that use, in addition to spectral information of each "pixel", the spatial information that involves the relationship between the "pixels" and their neighbors. These classifiers seek to simulate the behavior of a photo-interpreter in recognizing homogeneous areas of images based on spectral and spatial properties of images. The edge information is used initially to separate regions and the spatial and spectral properties will join areas with the same texture.

The first step to carry out the classification of regions is the generation of a segmented image. Segmentation constitutes the first step of an object-oriented classification. However, the algorithm used is based on the similarity of pixels, taking into consideration the interior of objects by analyzing similar properties between the pixels, with the criterion methods of segmentation by regions, growth, and threshold detection of bowls, pyramids and clustering.

For the classification on the image segmentation algorithm used was the Bhattacharyya, which uses the Bhattacharyya distance, which measures the similarity of two probability distributions.

2. Results and discussion

After several tests in the images using the preprocessing methods (registry, filtering, highlighting, composition of bands and equalization of histograms), it was opted for the use of the image (spatial resolution of Rapid Eye, 5 m with 4 spectral bands - blue, green, red and near infrared - and a classification technique: a per pixel (maxver) and region (segmentation classification processing by the Batthacharya algorithm). The image Rapid Eye (17 June 2010) used is presented in **Figure 02**.

Figure 02: Rapid Eye Scene used at work. Colour composition 5-3-2 (RGB)

After a study of the region and the use of waterproofing, this presented 8 defined classes for training, based on the use and occupation of the soil, namely:

- ✓ Urban 1 – Area of the city center, a denser, high concentration of buildings, concrete and slab roofs, and streets paved. Little or no afforestation;
- ✓ Urban 2 – The area adjacent to the Urban1. Lower concentration of buildings. Greater afforestation. Concrete slabs and ceramic roofs. Paved and cobbled paved streets;
- ✓ Urban 3 – The peripheral area; predominance of ceramic roofs; houses with 1 or 2 floors; constructed in a smaller area than the area of the property, with existence of gardens and backyards; predominance of unpaved streets;
- ✓ Water – Stone Horse Lake; River Bank; dams; urban ponds with water.
- ✓ Exposed soil – No noticeable vegetation and areas without coating of any kind.
- ✓ Vegetation 1 – Dense vegetation on the banks of rivers and lakes.
- ✓ Vegetation 2 – Natural vegetation of caatinga.
- ✓ Vegetation 3 – Pastures.

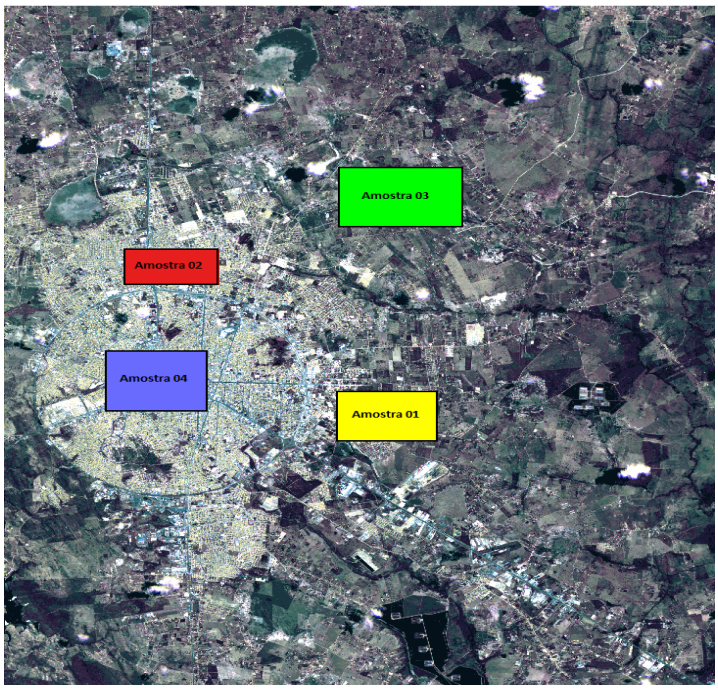
Four clippings of images (samples) were collected in different points of the city (Figure 03) by the field work that predominates one of the classes of soil use and occupation for sorting and comparison between the methods of classification and the reality on the spot.

The clippings of the RapidEye scene were removed from the Center regions of Feira de Santana (local with densification of buildings), the Airport (peripheral region and in expansion), The Salgada pond – Noide Cerqueira Avenue (a new avenue and new vector of urban growth) and the new town (next to the ring and contour the middle too).

For the generation of segmented images, the attempt to find various combinations of similarity and area were actualized, most of them were recognized through literature (PEREIRA and RIBEIRO, 2008; Cross and RIBERIRO, 2008; SOUTO, 2003; OLIVEIRA, ZEILHOFER, SANTOS, 2007). However, it is implied the use of a system of trial and error would find the best parameters for each image. The images were then converted through the SPRING software to be worked on 8 bit. As a result, 4 combinations of similarity of areas were realized, namely:

- Similarity of 8 and 12 area;
- Similarity of 8 and 20 area;
- Similarity of 12 and 20 area;
- Similarity of 12 and 50 area.

Figure 3 - Scene with local ID Rapid Eye of samples for sorting.



In **Figure 4**, the results for targeting with the classification through the Bhattacharyya algorithm sample 1, correspond to the region of the Salgada pond in an urban area in Feira de Santana. In Figure 05, it shows the results of the maximum likelihood classification (MaxVer).

For the classifications presented in **Figure 4**, the one that best represented the reality in the field was the segmentation with similarity of 12 and 20, as portrayed with better vegetation around the pond as well as the exposed soil in the peripheral and central areas of the cropping of the image. For the validation and measurement of accuracy of the results were used testing specimens. Was collected for each sample used for grading a test sample equivalent and made the comparison of the results.

Figure 4-Classification for segmentation with sample 1 of the Bhattacharyya algorithm. a) classification by similarity of segmentation 8 and 12; b) targeting 8 similarity rating and 20 area; c) classification by similarity d) segmentation segmentation 12 similarity rating and 50 area; e) Legend class.

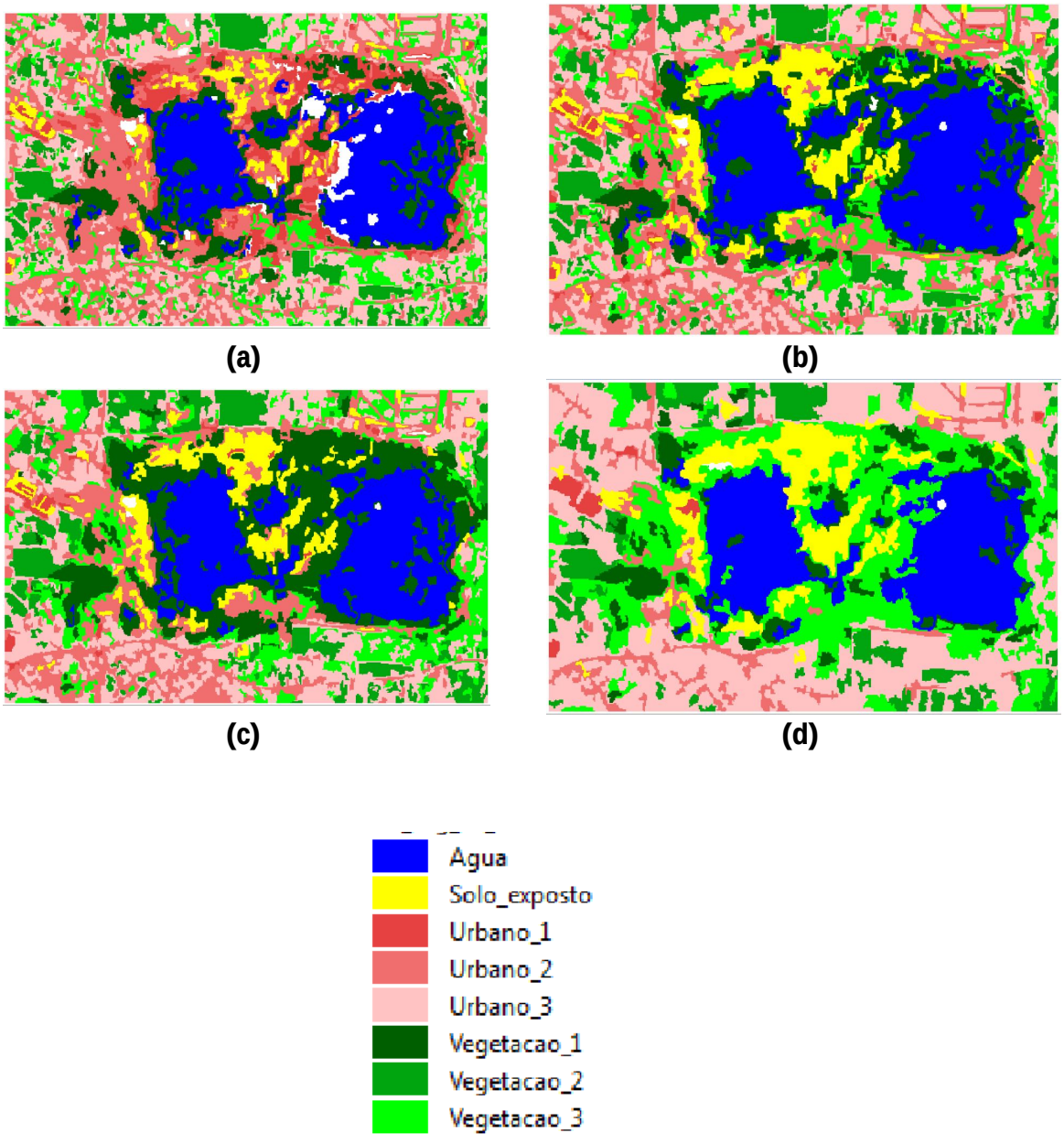
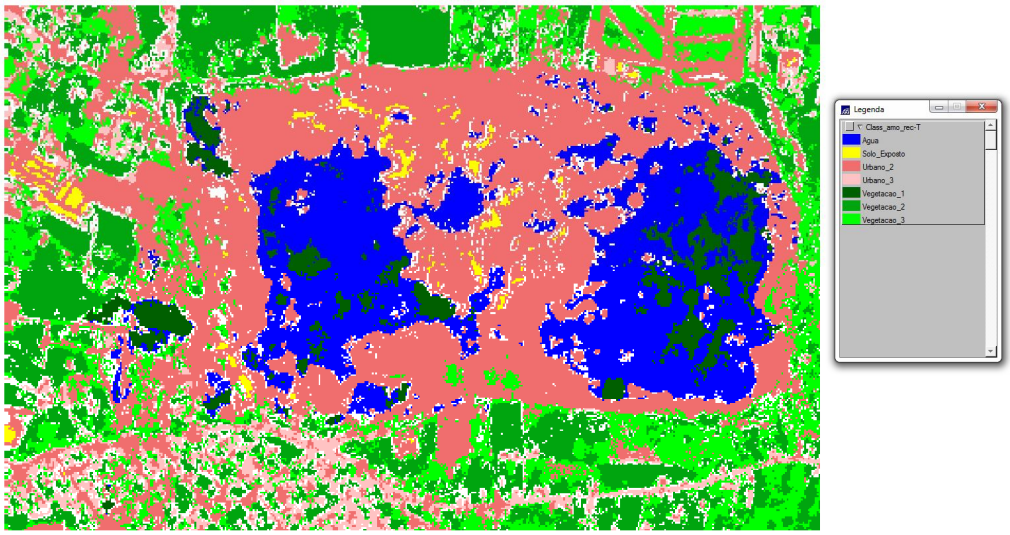


Figure 5- Sample 1 of the MaxVer rating.



Statistical results for each of the classifications were presented by obtaining measuring using the SPRING software. In this report the value of the area was presented to each class, in which it was also the total for the classes for the polygons not classified beyond the total area of the active Information Plan.

In **Table 1**, the values are represented for the measurement of classes in addition to their percentage in relation to the total area ranked by km² for the sorting by MaxVer and by regions according to the degree of similarity and work in segmentation.

For the statistical values that were carried out as described previously, it is observed that the classification for the segmentation Bhattacharyya algorithm presented variations in relation to the classification of MaxVer from 5% to 10%, except for the classes Urban 3 and Exposed Soil which presented higher values. This is one of the difficulties of the work, whose values of Exposed Soil and Urban 02 confused, even with a contingency table with values above 95% degree of acceptance. These values of the classes presented a classification not expected because the spectral values of the pixels were very close.

In truth, as seen from **Table 01-c** the comparative analysis with test samples, since the image represented a better reality of the area and the predominance of Urban 03 (green area greater than 50% and unpaved streets) and Vegetation 03 (rangelands or undergrowth).

Table 1 – classes measured. a) classification by similarity of segmentation 8 and 12; b) targeting 8 similarity rating and 20 area; c) classification by similarity of segmentation 12 and 20; d) classification by similarity of segmentation 12 and 50 area; e) MaxVer rating.

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,548475	16%
Vegetacao_1	0,385450	11%
Vegetacao_2	0,258675	8%
Vegetacao_3	0,305675	9%
Urbano_1	0,241875	7%
Urbano_2	0,837100	25%
Urbano_3	0,681175	20%
Solo_exposto	0,106650	3%
Similaridade 8 - Área 12	**3,365075**	**100%**

(a)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,664775	19%
Vegetacao_1	0,439650	13%
Vegetacao_2	0,293925	9%
Vegetacao_3	0,452250	13%
Urbano_1	0,054725	2%
Urbano_2	0,613550	18%
Urbano_3	0,643600	19%
Solo_exposto	0,264125	8%
Similaridade 8 - Área 20	**3,4266**	**100%**

(b)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,58105	17%
Vegetacao_1	0,67095	20%
Vegetacao_2	0,33620	10%
Vegetacao_3	0,38478	11%
Urbano_1	0,03078	1%
Urbano_2	0,54243	16%
Urbano_3	0,65515	19%
Solo_exposto	0,22778	7%
Similaridade 12 - Área 20	**3,4291**	**100%**

(c)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,600175	10%
Vegetacao_1	0,240800	4%
Vegetacao_2	0,276150	5%
Vegetacao_3	0,760275	13%
Urbano_1	0,033425	1%
Urbano_2	0,202100	3%
Urbano_3	1,025150	17%
Solo_exposto	2,920750	48%
Similaridade 12 - Área 50	**6,058825**	**100%**

(d)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,519225	11%
Vegetacao_1	0,145650	3%
Vegetacao_2	0,540800	11%
Vegetacao_3	0,467400	10%
Urbano_1	0,000000	0%
Urbano_2	1,176550	25%
Urbano_3	1,890750	40%
Solo_exposto	0,028875	1%
MaxVer	**4,76925**	**100%**

(e)

The results for targeting with the classification by the Bhattacharyya algorithm (**figure 06**) sample 2, corresponded to the region of the neighborhood new town on the edge of the ring and contour figure 07 the result to the maximum likelihood classification (MaxVer) are expressed below.

For the classifications (**Figure 06**), the one that best represented the reality in the field was the segmentation with similarity of 12 and 20, as it best illustrated urban classes properly with reality as well as the vegetation and the exposed soil. Similarly the first sample, for validation and choosing the best classification, samples were taken for each test sample used in the classification. In targeting with similarity of 8 and 20 soil exposed area was confused with the Urban 2 class.

Figure 06-Segmentation classification with sample 02 Bhattacharyya algorithm. a) classification by similarity of segmentation 8 and 12; b) targeting 8 similarity rating and 20 area; c) classification by similarity of segmentation 12 and 20; d) classification by similarity of segmentation 12 and 50 area; e) Legend class.

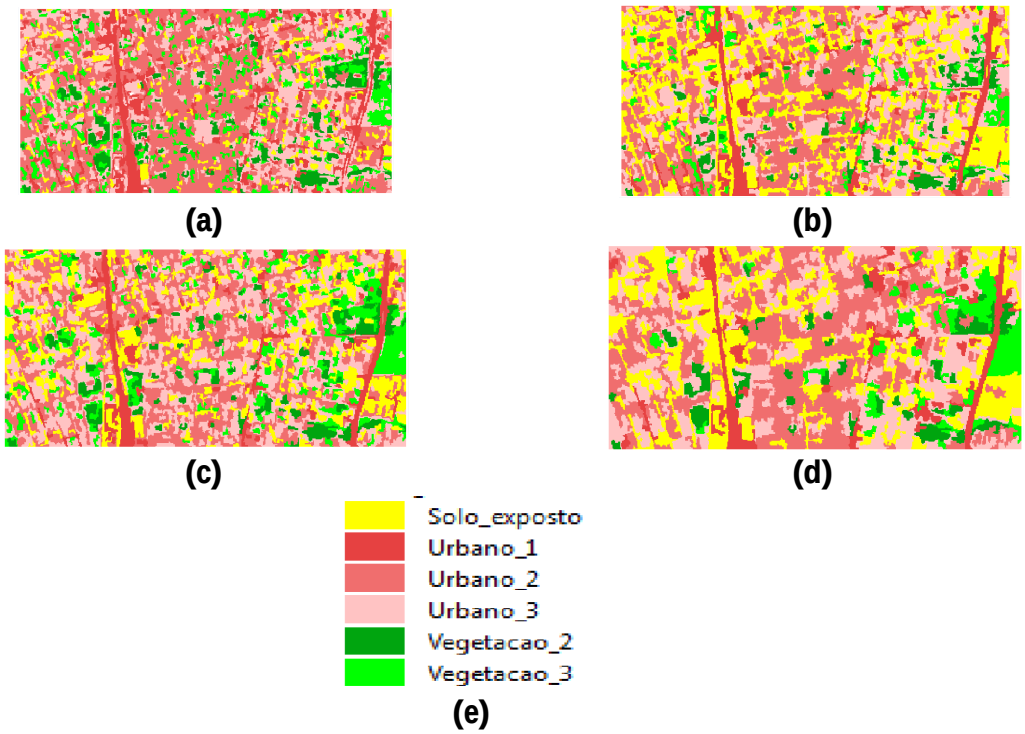


Figure 7- Sample 2 Max Ver rating.

In **Table 02**, the values are represented for classes plus their percentage in relation to total area ranked km ² to sorting by MaxVer and by Targeting according to the degree of similarity and worked. The rating table with Bhattacharyya segmentation algorithm with similarity of 12 and 20 area was adopted as truth once which best represented the reality on the spot according to the validation by sample test.

Table 2: measured classes. a) classification by similarity of segmentation 8 and 12; b) targeting 8 similarity rating and 20 area; c) classification by similarity of segmentation 12 and 20; d) classification by similarity of segmentation 12 and 50 area; e) MaxVer rating.

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0	0%
Vegetacao_1	0	0%
Vegetacao_2	0,14615	6%
Vegetacao_3	0,234375	10%
Urbano_1	0,275125	12%
Urbano_2	0,852475	38%
Urbano_3	0,63255	28%
Solo_exposto	0,131825	6%
Similaridade 8 - Área 12	**2,2725**	**100%**

(a)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0	0%
Vegetacao_1	0	0%
Vegetacao_2	0,10385	5%
Vegetacao_3	0,123225	5%
Urbano_1	0,206875	9%
Urbano_2	0,6257	28%
Urbano_3	0,561725	25%
Solo_exposto	0,65215	29%
Similaridade 8 - Área 20	**2,273525**	**100%**

(b)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,000000	0%
Vegetacao_1	0,000000	0%
Vegetacao_2	0,134775	6%
Vegetacao_3	0,242450	11%
Urbano_1	0,173050	8%
Urbano_2	0,662475	29%
Urbano_3	0,678125	30%
Solo_exposto	0,382650	17%
Similaridade 12 - Área 20	**2,273525**	**100%**

(c)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,000000	0%
Vegetacao_1	0,000000	0%
Vegetacao_2	0,123650	5%
Vegetacao_3	0,139650	6%
Urbano_1	0,193000	8%
Urbano_2	0,676625	30%
Urbano_3	0,623400	27%
Solo_exposto	0,517200	23%
Similaridade 12 - Área 50	**2,273525**	**100%**

(d)

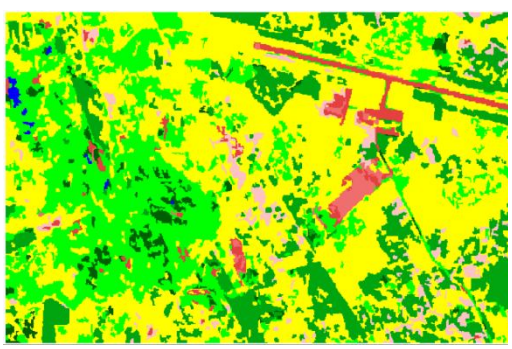
Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,000000	0%
Vegetacao_1	0,000000	0%
Vegetacao_2	0,249050	12%
Vegetacao_3	0,220400	10%
Urbano_1	0,290450	14%
Urbano_2	1,073625	51%
Urbano_3	0,040425	2%
Solo_exposto	0,249025	12%
MaxVer	**2,122975**	**100%**

(e)

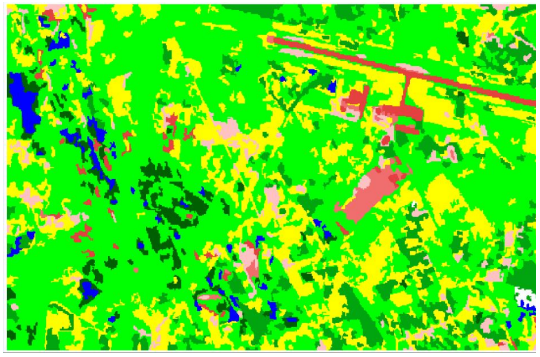
For the statistical values calculated above, sorting by targeting the algorithm introduced in relation with the variations of the Bhattacharyya classification, MaxVer values up to 05%, with the exception of the classes in Urban 2 and Urban 3 presented larger values. The biggest difficulties in this classification consisted of separating the classes of Exposed Soil above the classes Urban 2 and Urban 3. All values of the training sets MaxVer and Bhattacharyya contingency table values presented above 95%.

Finally, the results from targeting with the classification by the Bhattacharyya algorithm (**Figure 8**) of sample 3, correspond to the area at the airport and Figure **09** corresponding to the result of the maximum likelihood classification (MaxVer.).

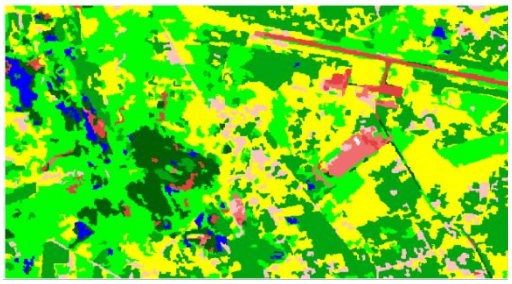
Figure 8-Classification for segmentation with sample 3 of the Bhattacharyya algorithm. a) classification by similarity of segmentation 8 and 12; b) targeting 8 similarity rating and 20 area; c) classification by similarity of segmentation 12 and 20; d) classification by similarity of segmentation 12 and 50 area; e) Legend class.



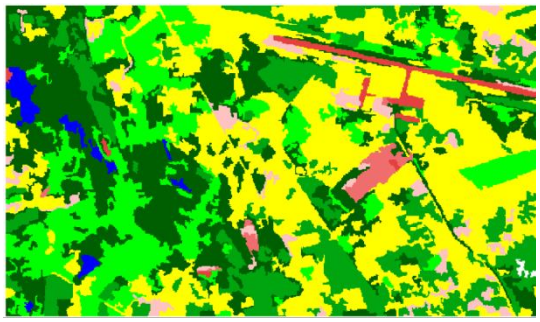
(a)



(b)



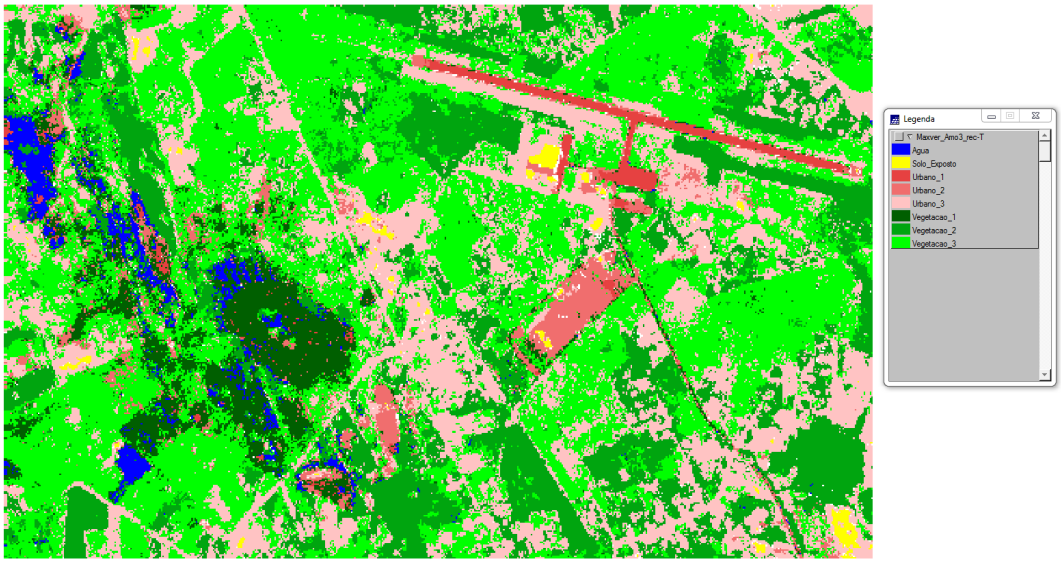
(c)



(d)

(e)

Figure 9- Sample 3 MaxVer rating.



The area depicted in the images sorted represents an area with predominance of vegetation and the new vector of urban expansion in the city of Feira de Santana. The images above, the one that illustrates the reality were the classification algorithm with similarity from the Bhattacharyya criteria of value 12 being the minimum area out of 50, according to the validation through the collection of test samples. It is observed in this sample a difficulty in separating areas of exposed soil from Urban 3 in all classifications. Once the spectral values of the pixels are within a close proximity, even with the result achieved in the contingency table, there is a degree of acceptance from samples greater than 95%.In the following **table 3**, the values represented are the classes plus their percentage in relation to total area ranked km ² to sorting by MaxVer and Segmentation according to the degree of similarity and worked.

Table 3: measure of classes. a) classification by similarity of segmentation 8 and 12; b) targeting 8 similarity rating and 20 area; c) classification by similarity of segmentation 12 and 20; d) rating by Yes 12 similarity segmentation and 50 area; e) MaxVer rating.

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,011775	0%
Vegetacao_1	0,117025	2%
Vegetacao_2	0,858500	17%
Vegetacao_3	1,150225	23%
Urbano_1	0,133375	3%
Urbano_2	0,048650	1%
Urbano_3	0,207475	4%
Solo_exposto	2,475650	49%
Similaridade 8 - Área 12	**5,002675**	**100%**

(a)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,099025	2%
Vegetacao_1	0,167925	3%
Vegetacao_2	0,469050	9%
Vegetacao_3	2,720675	54%
Urbano_1	0,125400	3%
Urbano_2	0,059125	1%
Urbano_3	0,193250	4%
Solo_exposto	1,158975	23%
Similaridade 8 - Área 20	**4,993425**	**100%**

(b)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,09155	1%
Vegetacao_1	0,27358	4%
Vegetacao_2	1,27060	17%
Vegetacao_3	1,42358	19%
Urbano_1	0,11285	2%
Urbano_2	0,07493	1%
Urbano_3	2,62925	36%
Solo_exposto	1,49273	20%
Similaridade 12 - Área 20	**7,36905**	**100%**

(c)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,05755	1%
Vegetacao_1	1,19600	24%
Vegetacao_2	0,86655	17%
Vegetacao_3	0,84763	17%
Urbano_1	0,07358	1%
Urbano_2	0,05540	1%
Urbano_3	0,17555	4%
Solo_exposto	1,72680	35%
Similaridade 12 - Área 50	**4,99905**	**100%**

(d)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,09855	2%
Vegetacao_1	0,31313	6%
Vegetacao_2	1,05488	21%
Vegetacao_3	1,93055	39%
Urbano_1	0,06710	1%
Urbano_2	0,20585	4%
Urbano_3	1,25558	25%
Solo_exposto	0,02785	1%
MaxVer	**4,953475**	**100%**

(e)

For the tables above, the values of the classes Urban 3, Vegetation 3 and exposed soil differed over 10% between the MaxVer results and the results of the segmentation. During the classification phase there were difficulties to separate classes Urban 3 and Exposed Soil and classify them as these presented pixel values very close.

In the classifications by segmentation there was a predominance of areas classified as Exposed Soil, whereas in the classification by MaxVer this has not occurred. Both classifications have a predominance of all vegetation. The classification table by the Bhattacharyya segmentation algorithm with similarity of 12 and 50 was aceepted once the best reality of the area represented the results with the test samples.

The results for targeting with the classification by the Bhattacharyya algorithm (**Figure 10**) sample 4, corresponded to the region of the center of the city of Feira de Santana and the result for the maximum likelihood classification (**Figure 11**) are represented below.

Figure 10 – Threading with rating algorithm sample 04 Bhattacharyya. a) classification by similarity of segmentation 8 and 12; b) targeting 8 similarity rating and 20 area; c) classification by similarity of segmentation 12 and 20; d) classification by similarity of segmentation 12 and 50 area; e) Legend class.

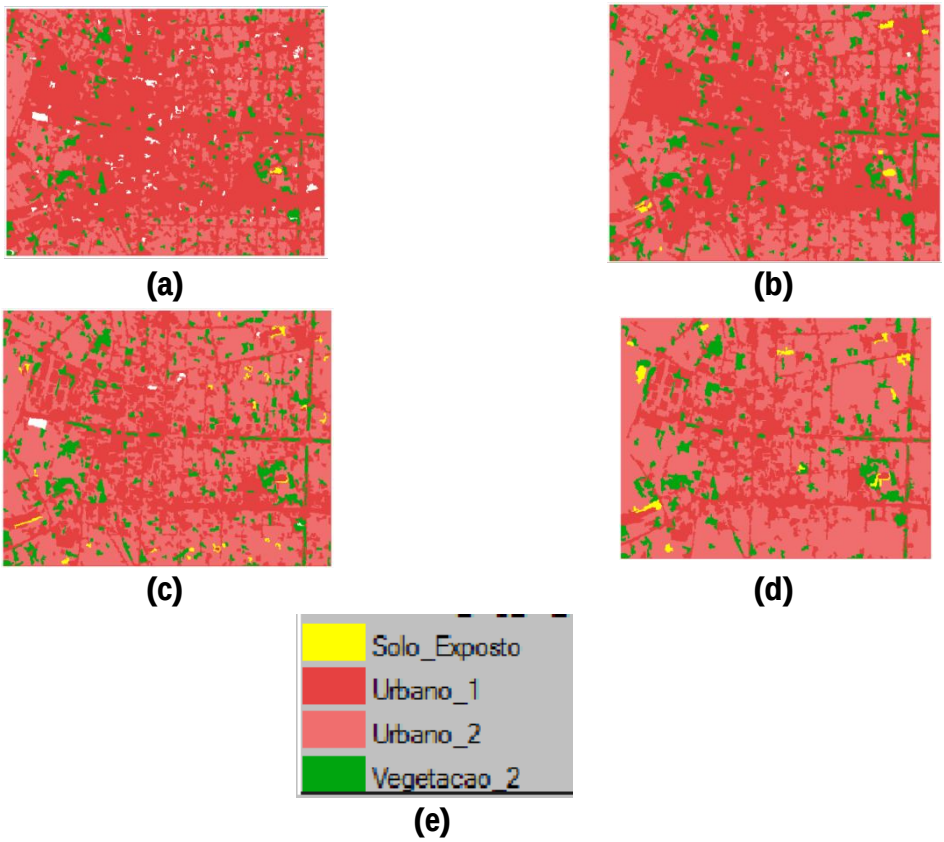
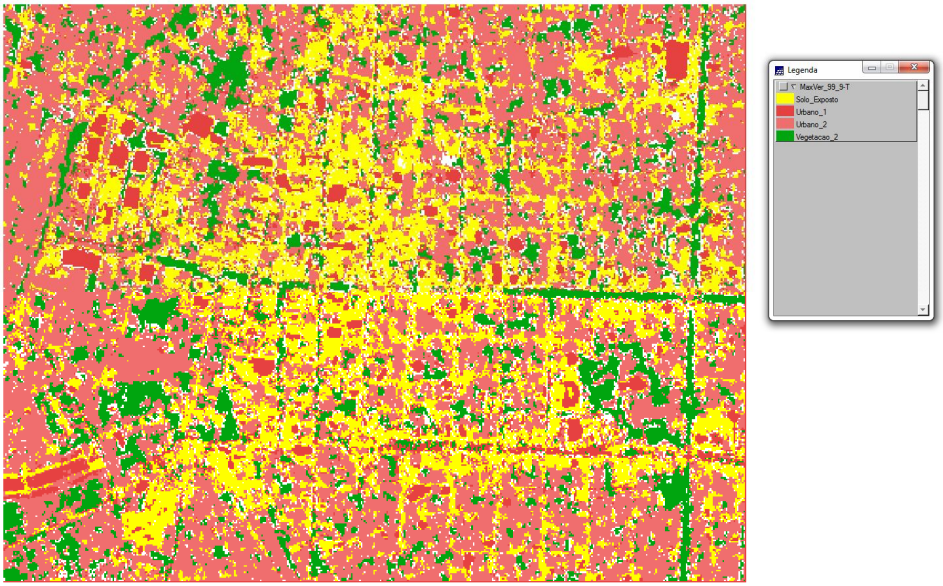


Figure 11- Sample 04 MaxVer rating.



The images classified above portray well the reality of the center of Feira de Santana as a dense region composed of buildings with high concentration of impervious areas, as shown here represented by the urban classes 1 and 2. The classification MaxVer presented values of a larger soil area as listed above which, however, doesn't portray the reality of the study area. There was similarity between the pixels as classified in classes Urban 2 and Exposed Soil in the MaxVer classification.

The classification by segmentation presented better results for similarity parameters of 12 for an area of 50. This was more accurate to illustrate the sample as this since it is presented in the field and obtained the best results compared with the test sample. The **table 04** values for the classes represents for classification by MaxVer and by segmentation according to the degree of similarity and area tabulated and the percentage of each class according to the total number of pixels classified in the sample.

Table 4: measure of classes. a) classification by similarity of segmentation 8 and 12; b) targeting 8 similarity rating and 20 area; c) classification by similarity of segmentation 12 and 20; d) classification by similarity of segmentation 12 and 50 area; e) MaxVer rating.

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,000000	0%
Vegetacao_1	0,000000	0%
Vegetacao_2	0,207575	5%
Vegetacao_3	0,000000	0%
Urbano_1	2,782300	67%
Urbano_2	1,146475	28%
Urbano_3	0,000000	0%
Solo_exposto	0,002450	0%
Similaridade 8 - Área 12	**4,1388**	**100%**

(a)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,00000	0%
Vegetacao_1	0,00000	0%
Vegetacao_2	0,29283	7%
Vegetacao_3	0,00000	0%
Urbano_1	2,36218	56%
Urbano_2	1,51755	36%
Urbano_3	0,00000	0%
Solo_exposto	0,01370	0%
Similaridade 8 - Área 20	**4,18625**	**100%**

(b)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,000000	0%
Vegetacao_1	0,000000	0%
Vegetacao_2	0,378850	9%
Vegetacao_3	0,000000	0%
Urbano_1	1,551375	37%
Urbano_2	2,219525	53%
Urbano_3	0,000000	0%
Solo_exposto	0,025750	1%
Similaridade 12 - Área 20	**4,1755**	**100%**

(c)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,00000	0%
Vegetacao_1	0,00000	0%
Vegetacao_2	0,33603	8%
Vegetacao_3	0,00000	0%
Urbano_1	1,22953	29%
Urbano_2	2,58305	62%
Urbano_3	0,00000	0%
Solo_exposto	0,03900	1%
Similaridade 12 - Área 50	**4,1876**	**100%**

(d)

Classes de uso do solo	Área (kmxkm)	(%)
Agua	0,000000	0%
Vegetacao_1	0,000000	0%
Vegetacao_2	0,543500	14%
Vegetacao_3	0,000000	0%
Urbano_1	0,417825	11%
Urbano_2	1,780325	47%
Urbano_3	0,000000	0%
Solo_exposto	1,042625	28%
MaxVer	**3,784275**	**100%**

(e)

The differences displayed in **Table 4**, refer to the values from classes Urban 1, Urban 2 and Exposed Soil. In the MaxVer classification, it was portrayed that a larger area of Exposed Soil, on which the spectral values of their pixels are close to the values of the pixels that represent the class Urban 2, caused different results observed in regions classified field. For the Bhattacharyya segmentation algorithm classification, this major urban area was portrayed by classes Urban 1 and Urban 2, according to the local reality.

Table 4.d presents the results of the Bhattacharyya segmentation classification for grade algorithm similarity of 12 and 50 was adopted since it best represented the reality of the region in accordance with the test sample.

3. Conclusion

Comparatively analyzing the classification, it's perceived that the classification by regions based on segmentation was portrayed the reality of samples analyzed better, with both degrees of similarity as the formation of the minimum areas of the regions did not generate good separability between classes since these values were too small.

Samples of the areas to be studied in more detail (Samples 1, 2, 3 and 04) were chosen according to the representation of areas with different degrees of permeability to verify the response of the classifiers the degree of separability from the classes of use and occupation.

It's perceived by the classified images that there is a breakthrough of civil construction driven by urban growth in green areas and margins of water bodies (Salgada Pond), causing negative impacts on the environment and proofing larger areas, even if only for the removal of vegetation (exposed soil). Of the algorithms used, it was realized that the segmentation with similarity of a minimum area of 12 of 20 pixel region presented the best results when it is ranked with the Bhattacharyya algorithms, enabling the separability of classes for use in all the different conditions, with the exception of the sample 4, when the best results were expressed by targeting a similarity of 12 as the minimum training area of the 50 pixels region.

The MaxVer classifier was lower on its results in all 4 samples, and, in particular, mistaking the class "Exposed Soil" with "Urban 2" and "Urban 3". This result was partially expected due to high spatial resolution of the image (5 m) where a statistical classifier, such as the MaxVer, begins to fail in the separation of classes due to great detailing and variability of scenes. The segmentation, although it is also a technique, at its base, statistical, presents a mixed character, related to object-oriented classification, which allows better differentiation of the classes in high spatial resolution images.

In this way, from the results obtained in this work, we can emphasize that remote sensing techniques are presented as a viable solution for the determination of levels and degrees of waterproofing in the urban space, what validates as an efficient tool to urban planning.

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