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Digital Image Processing Techniques for Landslides Characterization in Rio de Janeiro Region, Brazil.

Thiago Peixoto de Araújo[1]; Fernando Machado de Mello[2]; Essaid Bilal[3]

RESUMO

O uso de imagens oriundas do sensoriamento remoto orbital têm se mostrado de grande utilidade em geologia ambiental e engenharia através de levantamentos para mapeamento e pesquisas. As vantagens do emprego de tais técnicas de sensoriamento remoto se devem não somente ao fato de suas abrangências de amplas áreas mas também por sua alta resolução, levando a uma gama de possibilidades através de operações entre bandas eletromagnéticas. O objetivo principal deste trabalho é de realizar comparações entre imagens Landsat de sensores TM e ETM+, no Estado do Rio de Janeiro (RJ) através de composições coloridas advindas de transformações IHS-RGB e composições oriundas de operações de razões entre bandas. Neste trabalho observamos que as imagens ETM+ apresentaram melhores resultados em estudos de deslizamentos por sua melhor precisão com relação àqueles dados oriundos de sensores TM.

Palavras-chave – Sensoriamento Remoto, Transformações IHS-RGB, Deslizamentos, Rio de Janeiro, Geologia Ambiental.

ABSTRACT

The use of images by orbital remote sensing has shown great utility in environmental geology and engineering by mapping surveys and researches. The advantage of employing such remote sensing technique is due not only to its wider coverage area but also to its high spatial resolution quality, allowing a range of possibilities by means of operations among electromagnetic bands. The main purpose of this paper is to do comparisons among Landsat images of TM and ETM+ sensors, in Rio de Janeiro Region, Brazil, by means of color compositions that come from IHS-RGB Transformation and compositions that come from Ratios Band as well. Our studies point that ETM+ images presented better results in landslides studies due to their better accuracy in comparison to TM images.

Keywords – Remote Sensing; IHS-RGB Transformation; Landslides, Rio de Janeiro; Environmental Geology.

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1. INTRODUCTION

In recent years there has been a growing demand for environmental geotechnological information applied to geology, geotechnics and other related areas, especially where it is intended to carry out projects for the implementation of conservation units, intervention or environmental restoration of degraded areas. The production of reliable GIS maps is an indispensable stage either to the supply of technical analysis or to planners to support important regional decisions, where they propose, for example, assessments of environmental sustainability of an enterprise that must take into account physical, economic and social, beyond environmental impact.

By integrating both alphanumeric and geographical data through surveys and satellite images, and even aerial photographs, it is possible to make corrections in those images, providing they have a radial distortion, because the center of an image perspective is not met in the infinity, thus giving a conical projection in response. By correcting these images, we can make several characterization studies of the environmental areas and even monitor these areas as well.

Remote sensing data by orbital sensors can be used for motion studies of gravitational mass movement in both direct detections of the consequences of these processes (scars, exposed rocks, landslides) and through the identification of indicators, such as: use of land, morphology and dissection of relief (King and Delpont, 1993; Berger, 1996). Changes in spectral characteristics of surface, detected by sensorial systems, are the result of the vegetation removal and surface layers of soil by either natural or anthropogenic processes.

Differences in spectral behavior among soil, vegetation (type and size) and anthropogenic features are observed in the bands of visible and infrared data obtained by Landsat TM and ETM+ sensors. Differences between scars with soil or exposed rocks and scars with resumption of vegetation (grasses, ferns) can be detected by the sensors.

For Drury (1993) and Walsh et al. (1998) processing such as Ratio Band, for example, highlights those differences, serving as indicators of the geomorphologic processes and geotechnical problems.

McKean et al. (1991) and Gao and Lo (1995) say that for landslides, the vegetation covers removal and consequent exposure of soil or rock and deposited transported material along the slope, producing variations of shade, color, tint and texture in image. Specific forms are observed, thus allowing direct interpretation of these features.

The shapes of the scars caused by landslides, according to Hansen (1984) and Patton (1988), are elliptical or conical and when new, are observed from the head to the base by sliding. These features usually develop either in concave slopes along the drainage line or close to sites with anthropogenic changes, such as roads, extending over high or medium slope and depositing the removed material in low valleys, where formation of talus occurs, altering the topography of the place (Patton, 1988; Gao and Lo, 1995; Sestini, 1999). However, sites susceptible to landslides can be identified through the interpretation of direct and indirect elements in the orbital images.

So, the study and development of techniques of remote sensing through the operations IHS-RGB Transformation and Ratio Bands is justified because these techniques allow us to individualize targets/objects to be studied, by using electromagnetic band (Araujo and Mello, 2010).

However, the main objective of this study is to demonstrate not only the advantages but also the disadvantages of the techniques of IHS-RGB Transformation and Ratio Bands held on Landsat images. Through images and some indications, it is observed that they are more efficient for certain studies, such as landslides (Sestini, 1999), characterization of geoenvironmental areas, erosion and many others.

The area chosen for this study is in the State of Rio de Janeiro, southeastern Brazil, bordering the states of São Paulo, Minas Gerais and Espirito Santo. The State of Rio de Janeiro is famous all over the world for its peculiar natural beauty. However it has greatly suffered by environmental problems (landslides, for example) and many social problems as well. **FIGURE 1** shows the location of Rio de Janeiro in the context of southeastern Brazil.

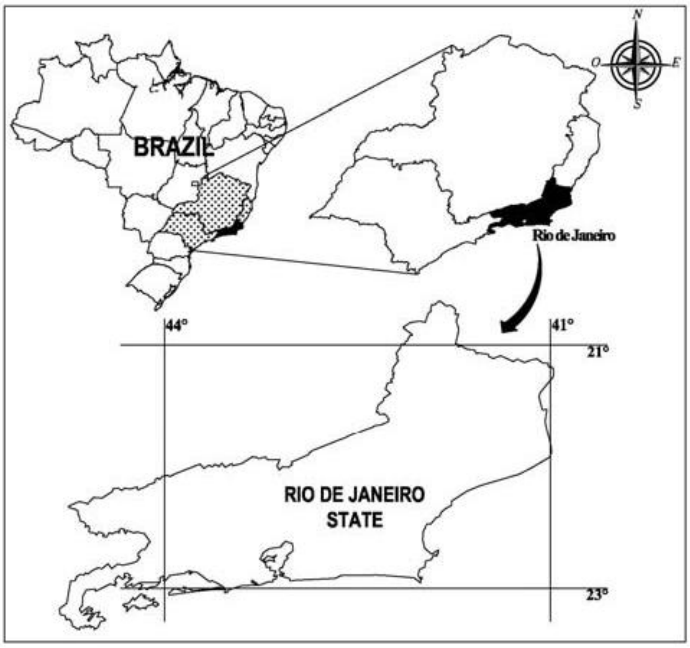

Figure 1. Location of the study area, state of Rio de Janeiro, in the context of southeastern Brazil.

2. MATERIAL AND METHODS

In this work, satellite images by Landsat 5 with the sensor TM (Thematic Mapper) and Landsat 7 with the sensor ETM+ (Enhanced Thematic Mapper Plus) have been used. The scene of Rio de Janeiro state used in this study was 217/76. These images are available free of charge on the website of National Institute for Space Research - Brazil (INPE). According to the issued report and to the attached images, the features in the acquisition of the scenes are: Scene 217/76 - Datum SAD 69; SAD 69 reference ellipsoid; unit in meters; UTM cartographic system; zone -23 South; and Product Framing Method Path 217 and Row 076.

The methods used in this study were the operations of IHS-RGB Transformation and the Ratio Bands, both procedures performed in the program ENVI™ (Environmental for Visualizing Images).

3. IHS-RGB TRANSFORMATION

To make the operation of IHS-RGB Transformation, it is necessary to have the individualized electromagnetic bands and then scroll through the sequence of commands in the program main menu: "File - Open External File - Landsat – GeoTIFF". Afterwards load these bands. After that, select which band will be in R, G or B and load the image (in "Load RGB"). The transformation will take place and you will get a color composition as result.

4. BAND RATIOS

For Ratio Bands operation, the procedure for charging the electromagnetic bands is the same as previous, but the sequence of commands to be covered is as follows: "Transform - Band Ratios". Then we should indicate which band will be in the numerator and which band will be on the denominator, then click "Enter Pair" and "ok". After that, you must provide a name and place of exit and "ok". Then you should proceed as done in IHS-RGB Transformation, in other words, indicate what reason will be in R, G or B and click "Load RGB".

5. RESULTS

When processing a satellite image in color composite, a transformation IHS-RGB is held. IHS are the initials of intensity (I), hue (H) and saturation (S), where I, or brightness, is the measure of total energy involved in all the wavelengths, being responsible for the sensation of brightness of the incident energy on the eyes; H, or color of an object is a measure of the average wavelength of light that is reflected or issued, defining the object color; and S, or purity, expressed the range of wavelength around the mean wavelength at which energy is reflected or transmitted. A spectrally pure color is the result of a high value of saturation, whereas low value of saturation indicates a mixture of wavelengths producing pastel tones.

However, the transformation is done through the mathematical algorithms, performed by the program, which lists the RGB space to IHS space. The equations 1, 2 and 3 show these mathematical algorithms used to make the transformation.

$$I = \frac{1}{3}(R + G + B) \qquad (1)$$

$$H = \cos^{-1}\left\{\frac{0{,}5[(R-G)+(R-B)]}{\left[(R-G)^2+(R-G)\cdot(G-B)\right]^{1/2}}\right\} \qquad (2)$$

$$S = 1 - \frac{3}{(R+G+B)}\left[\min(R,G,B)\right] \qquad (3)$$

The electromagnetic bands are nothing else but a portion of the electromagnetic spectrum bounded by two wavelengths.

Landsat 5 shows the scanner TM (Thematic Mapper), with features such as 7 bands with a spatial resolution of 30 meters, in the infrared channels (channels 1, 2, 3, 4, 5 and 7), and 120 meters, in thermal channel (band 6). As for Landsat 7 the channels of the visible and infrared regions (bands 1, 2, 3, 4, 5 and 7), remained with the same spatial resolution of 30 meters. However, the thermal infrared bands, now in high (H) and low (L) frequency (bands 6H and 6L), have a resolution of 60 meters, against 120 meters, the thermal channel (band 6), in Landsat 5.

And a major advance in the ETM + of Landsat 7, was the channel panchromatic (band 8), offering a spatial resolution of 15 meters. On **TABLE 1** it is illustrated a comparative table of maximum and minimum limits of wavelengths (μm) of spectral bands of TM and ETM + sensors by their respective satellites, Landsat 5 and Landsat 7. A mathematical operation Ratio Bands discriminates subtle differences in spectral behavior of different targets because in the original bands only gross differences are observed. Thus, observing the spectral behavior of targets of interest for the application of ratio bands is selected aiming at their maximum and minimum values of reflectance, so that they express the gradients of the spectral curve of the objects of interest giving the highlight of these targets (Sestini, 1999).

According to some authors, the Ratio Bands has advantages (Harrison and Jupp, 1989; and Envi Guide, 2006) and disadvantages (Mather, 1987; Crosta, 1993; Drury, 1993).

The main advantages are: (i) The difference in spectral response of the same target in different bands; and (ii) this difference to different targets in a band. The latter takes according to the difference in illumination caused by the topography of a scene.

The disadvantages of the Ratio Bands are: (i) Exaggeration of noise and loss of texture due to the attenuation of shading; and (ii) Failure to distinguish between targets with similar spectral behavior. The first is caused because the shading is highly correlated in all bands, so, when shading is deleted, no loss of information concerning the topography.

Table 1 - Comparison of wavelengths (μm) of the spectral bands of sensors TM and ETM+ (Maia and Cavalcante, 2005).

SENSOR	1	2	3	4	5	6	7	8
TM	0,45	0,52	0,63	0,76	1,55	10,4	2,08	-
	0,52	0,60	0,69	0,90	1,75	12,5	2,35	-
ETM+	0,45	0,53	0,63	0,78	1,55	10,4	2,09	0,52
	0,52	0,61	0,69	0,90	1,75	12,5	2,35	0,90

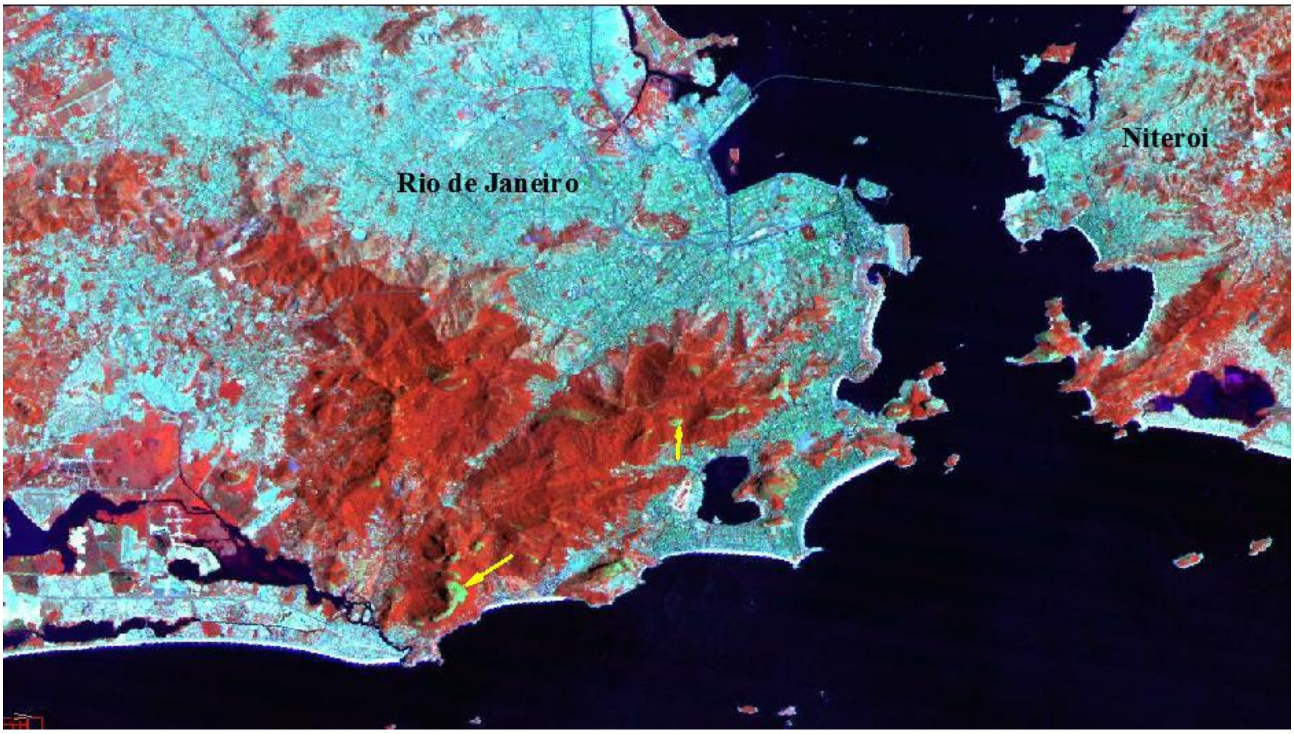

Figure 2. Landsat 5 image, composition 4-7-3 (IHS-RGB Transformation) showing scars with rocky outcrops. Image width is 35km with the true north at the top.

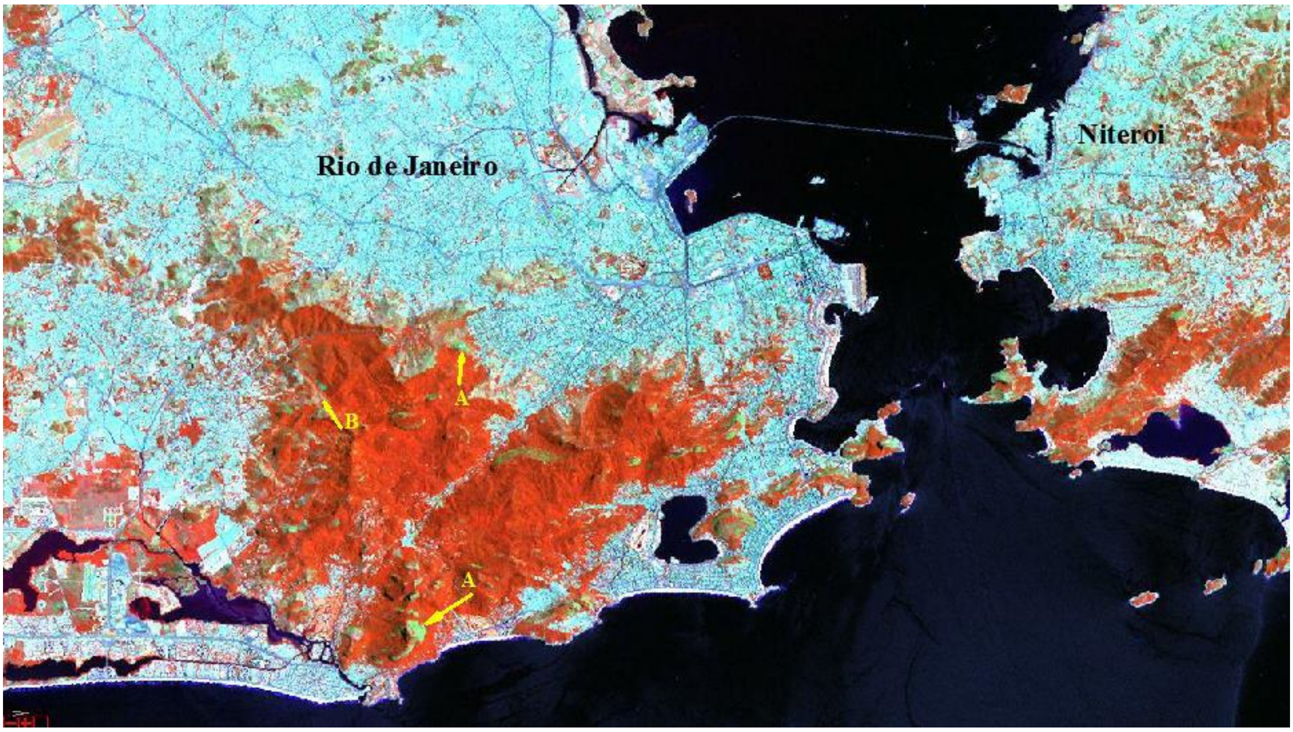

Figure 3. Landsat 7 image, composition 4-7-3 (IHS-RGB Transformation) showing scars with exposed rock (A); and grass (grass cover) (B). Image width is 35km with the true north at the top.

6. DISCUSSION

A comparison between the methods of IHS-RGB Transformation and the Ratio Bands with image of two sensors used in this study is shown below. In **FIGURE 2**, composition 4-7-3 of IHS-RGB Transformation of Landsat5, landslides scars can be observed with exposed rocks at various locations throughout the cities of Rio de Janeiro and Niteroi are indicated.

In **FIGURE 3**, the same composition, but taken by Landsat 7, these scars are also observed, but due to better image clarity, places where there is the appearance of vegetation on sites of former landslides are also distinguished. In **FIGURE 4**, the Ratio Bands of composition 5/7-4/3-4/1 RGB (Landsat 5), the region of Angra dos Reis, south coast of Rio de Janeiro, it is noted that the process of Ratio Bands highlights sites with exposed rocks, which are widespread in the region (A), pasture (B) and two points of recent fires (C).

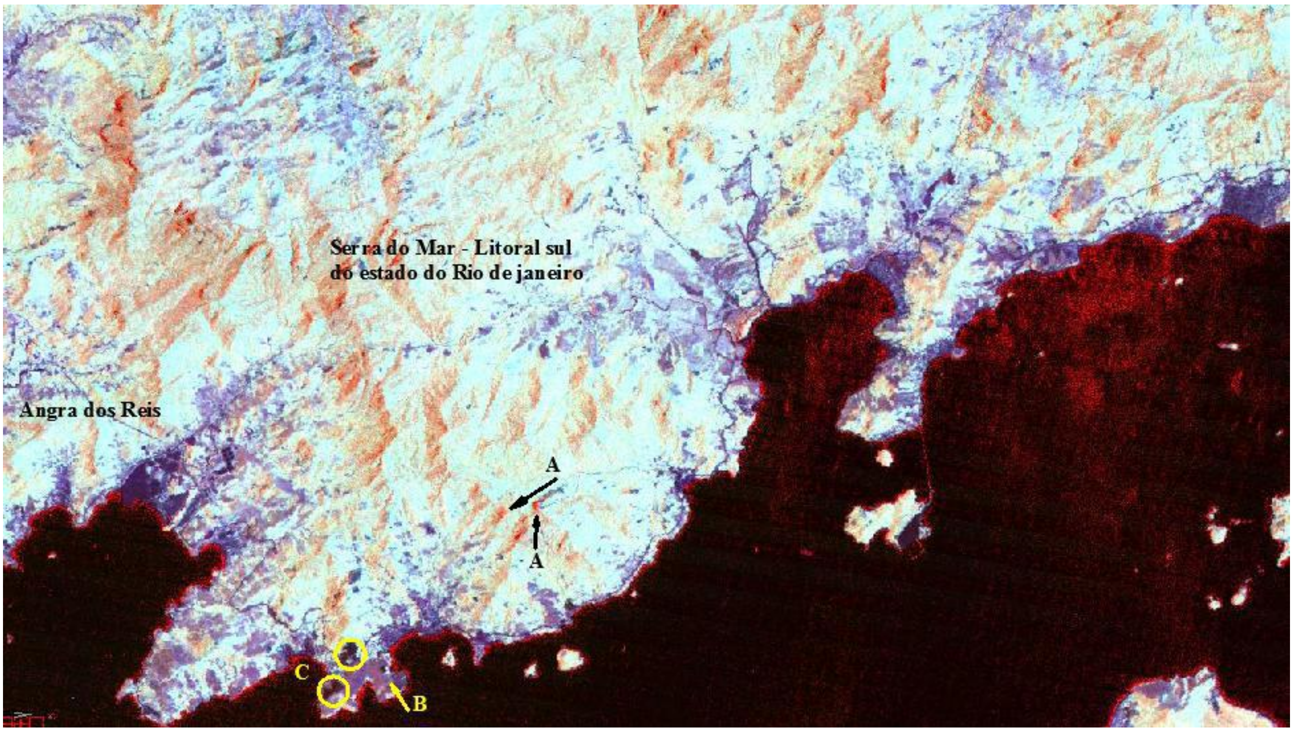

Figure 4. Landsat 5 Image, 5/7-4/3-4/1 composition (RGB) showing scars with exposed rock (A), pasture (B), and recent local fires (C). Image width is 35km with the true north at the top.

The same composition (5/7-4/3-4/1 RGB), but by Landsat 7 satellite, in **FIGURE 5**, due to a sharper image, allows us to observe landslides beyond the scars in the exposed rocks (A) and pasture (B), very common in that region (C).

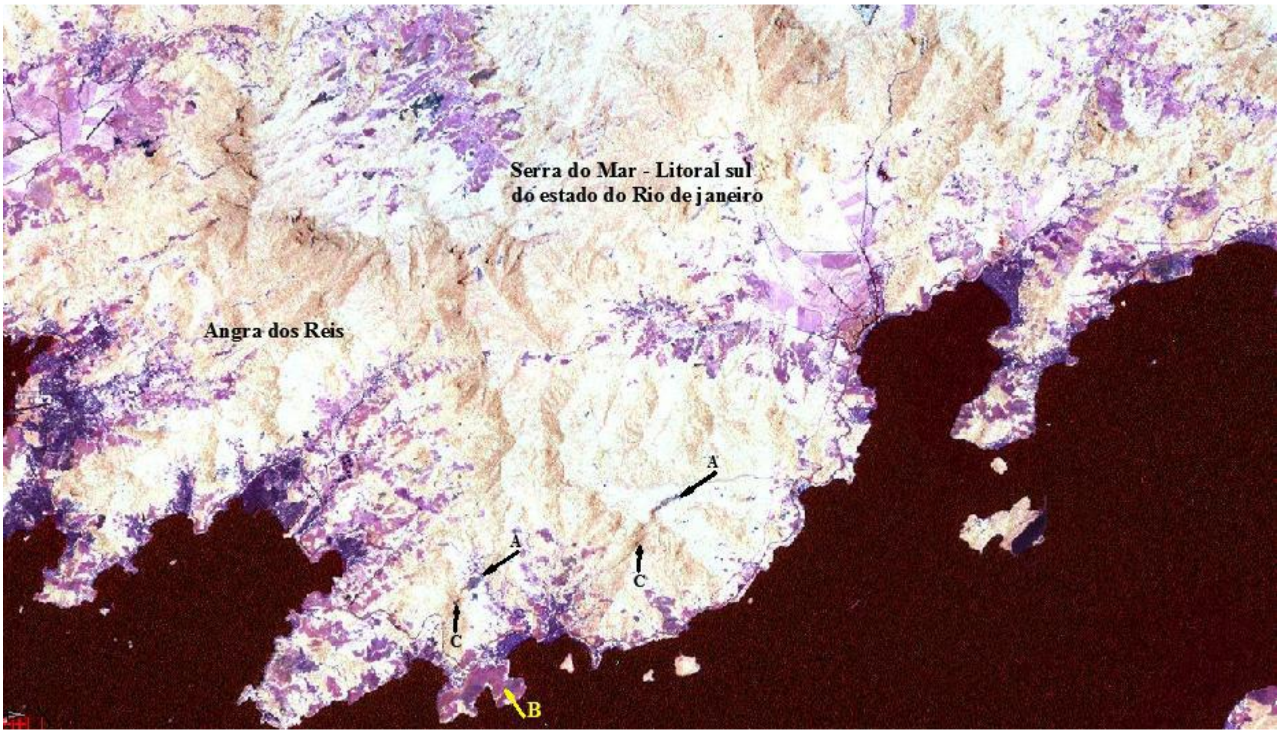

Figure 5. Landsat 7 Image, 5/7-4/3-4/1 composition (RGB) showing scarring with exposed rock (A), pasture (B) and landslides (C). Image width is 35km with the true north at the top.

7. CONCLUSIONS

Currently, due to countless orbiting satellites and the great technological advances, the images have been becoming better with spatial resolutions of the order of centimeters. For being older, the Landsat satellites series still present a poor spatial resolution of the order of 30 meters, making this the great disadvantage related to other satellites. However, there is a great advantage of their images being distributed for free to all individual bands. In Brazil, through the website of INPE, it is possible to make a register and download the needed images. Thereby, better cost-benefit relation of the data isgenerated. Despite the high spatial resolution presented by the Landsat images, the images were good to several studies, such as landslides, mainly on the coast of Rio de Janeiro. Images of the TM sensor (Landsat 5) have a poorer clarity in relation to images obtained from ETM+ sensor (Landsat 7), which coupled with the spatial resolution of 30 meters, makes images of TM sensor less suitable for some studies. It is observed that the ETM+ sensor shows improvements in geometrical, radiometrical and clarity with respect to TM sensor. Images by Landsat 7 are more interesting for imaging with direct applications in studies of up to 1:25,000 scale. However, a disadvantage from Landsat 7 to Landsat 5 happens because the first one has no longer been in operation since 2003 and the second has been running until the present.

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