TEMPORAL ANALYSIS OF SOIL OCCUPATION IN MUCURI WATERSHED BETWEEN 1989 AND 2015

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ABSTRACT

Anthropogenic action has caused intense changes in land use and cover over the decades. Identifying and knowing these changes makes it possible to measure the impacts that can be generated as well as to identify patterns of the development of a particular region and the relationship between society and land use. Thus, it is intended to identify the changes made in the land use and occupation of the Mucuri river basin between 1989 and 2015. So, this study used remote sensing techniques and tools besides aerial photographs to map the region and to identify surface behavior. Within the Mucuri basin, the soil had been mostly occupied by classes of forest and agricultural area, consistent with the social and economic reality of the region over the last decades. The changes that have occurred indicate a reduction in water availability, growth in urban occupation and, in many cases, soil and vegetation cover deterioration.

ANÁLISE TEMPORAL DA OCUPAÇÃO DO SOLO DA BACIA HIDROGRÁFICA DO MUCURI ENTRE OS ANOS DE 1989 E 2015

RESUMO

A ação antrópica tem causado ao longo das décadas intensas modificações no uso e cobertura do solo. Identificar e conhecer essas alterações possibilita mensurar os impactos que podem ser gerados, bem como identificar padrões do desenvolvimento de uma determinada região e a relação entre a sociedade e o uso do solo. Deste modo, busca-se identificar as alterações realizadas no uso e ocupação do solo da bacia hidrográfica do Mucuri entre os anos de 1989 e 2015. Para isto, utilizou-se técnicas e ferramentas do sensoriamento remoto e fotografias aéreas para mapear a região e identificar o comportamento da superfície. Dentro da bacia do Mucuri, ao longo das décadas, o solo foi majoritariamente ocupado por classes de floresta e área agrícola, condizente com a realidade social e econômica da região. As alterações ocorridas indicam redução na disponibilidade hídrica, crescimento da ocupação urbana e, em muitos casos, desgaste do solo e cobertura vegetal.

INTRODUCTION

The impacts on the environment caused by the man have intensified over the years. Such actions are related to social dynamics and economic development, leading to constant changes in the earth's surface. The study of land use and occupation aims to understand the environment and the distribution of its various forms, such as vegetation removal, urban construction, preservation areas, farming and other activities (VAEZA *et al.*, 2010).

As a consequence, it is extremely important to study land use and occupation as a basis for environmental management projects, practices of zoning and other procedures that require a knowledge of the area of interest. Areas of natural vegetation are replaced by farming and pasture in a larger recurrence, causing great damage to natural resources. Therefore, there is a need for technologies that allow locating and monitoring such issues, so more environmentally friendly and sustainable practices with lower impact in environment are adopted.

Thus, Geographic Information Systems (GIS) combined with geoprocessing are shown as important tools (ZANATA, 2014). Remote sensing is a technique used for obtaining images of the earth's surface by detecting and quantitatively measuring the electromagnetic responses of terrestrial objects, mostly detected by imager satellites. Those images are a source of information for the production of representative maps of the earth's surface (DEMARCHI *et al.*, 2011; MENESES, 2012).

The Mucuri River Basin (MRB) is an important region located in the East Atlantic hydrographic group. It encompasses 17 municipalities, 13 in the state of Minas Gerais and 4 between Espírito Santo and Bahia states, totaling approximately 300 thousand inhabitants. It is characterized by farming and livestock activities, in addition to mining, mainly in the region of Teófilo Otoni - MG, which is the most important economic and urban center in the basin. The main river of the MRB stretches for 446 km from its source to its mouth in the Atlantic Ocean, with 78% in Minas Gerais and 22% between the states of Bahia and Espírito Santo, until it flows into the ocean. Its average width is 45 meters and its main tributaries are the Todos os Santos, Pampã, Marambaia and Negro rivers (IGAM, 2016).

Land use and occupation in this region occur mainly as farming practices, so areas that should be permanently protected (PPA), including hilltops, springs, slopes and riparian forests, are used for pastures and monocultures, directly influencing the amount and quality of water in the region, as these localities are responsible for the water recharge of the streams.

In this context, the Mucuri river basin was analyzed as it has been severely modified over the years due to its main sources of income, which are farming and livestock. Thus, the objective of this study was to evaluate the land use dynamics in the Mucuri watershed in the last three decades through remote sensing techniques.

MATERIAL AND METHODS

Study Area

Figure 1 shows the spatial location of the MRB, located in the eastern portion of the state of Minas Gerais, southern Bahia and northern Espírito Santo, in the southeastern and northeastern regions of Brazil.

The climate in the region where the Mucuri River basin is located extends from semi-humid to Aw-type according to the classification of Köppen (KOTTEK *et al.*, 2006), with an average annual temperature of 23°Celsius (IBGE, 2002).

Argisols are the predominant soils in the basin. They are moderately drained soils with low amounts of organic matter and high propensity to erosion. Also, Latosols are found in the basin, which have low fertility, but in contrast are well structured and very porous, the reason why they have adequate physical conditions for farming (ZARONI and SANTOS, 2016). The vegetation of the basin is composed of parts of forest allocated between pastures, highways and urban areas. It should be also stressed the high soil degradation due to the intense use in farming over the centuries (FELIPPE *et al.*, 2009).

### Images/ Software used in the study

This study was elaborated using ArcGis Geographic Information Systems (GIS) version 10.0. The analyzed images were obtained free of charge from the United States Geological Survey (USGS) Earth Explorer platform.

Four distinct periods were analyzed, defined according to the availability of USGS images. For the composition of the map of each period, three different images, also named scenes, were used and arranged as it can be seen in Figure 2.

Table 1 show the information from the scenes used in each of the period under analysis.
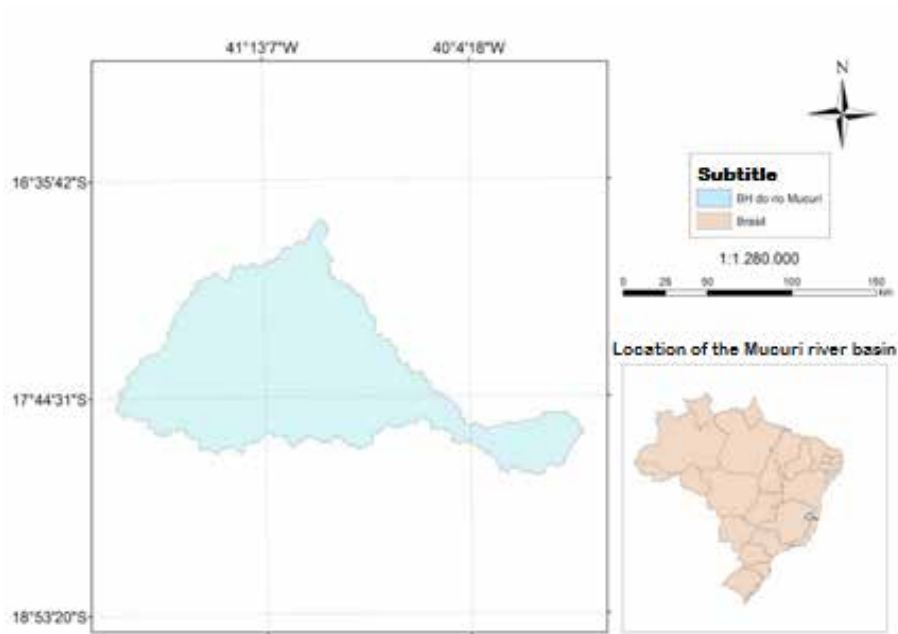
Figure 1. Spatial location of Mucuri river basin.
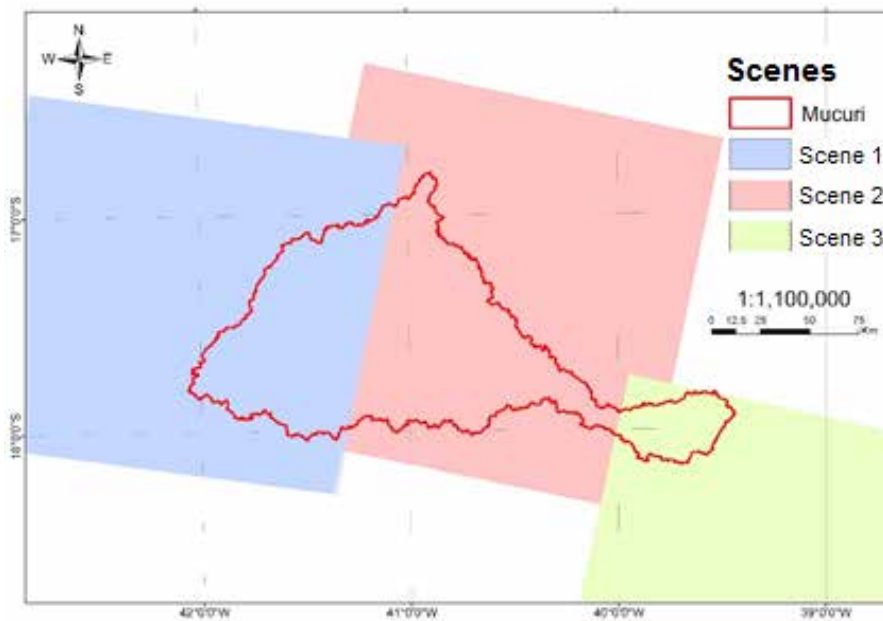
Figure 2. Layout of the scenes used in the map reefing to landSat satellite over the study period.

Table 1. Information regarding the periods of analysis

	Year	Satellite
Period 1	1989	LandSat 5
Period 2	2001	LandSat 7
Period 3	2008	LandSat 5
Period 4	2015	LandSat 8

Scenes from the same period are from the same satellite and preferably acquired in the summer (period between December 21st and March 21st) as there are fewer clouds (LI *et al.*, 2015), so as not to impair the land cover mapping.

Image classification

The composite images were referenced based on the Southern Hemisphere datum SIRGAS 2000, spindle 24 and with UTM coordinate system, where the units were in in meters. The classes chosen were, as follow: Forest; Water; Field; Exposed soil; Urban Spot and Farming Area. In each scene, 50 samples were collected for each class, following the CONGALTON (2005) guidelines, which suggests the use of 50 to 100 pixels for each class. Each training sample consisted of a 4x3 pixel rectangular polygon, as recommended by McCoy (2005). These training samples were later used to obtain the file of the scene signature.

The scene signature uses the spectral characteristics of the collected samples for setting standards for each class, enabling the original image to be classified into the same classes collected in training through the Maximum Likelihood Classification (MLC) tool (GONZALES and WOODS, 2000).

The analysis of the data quality obtained in the study needed some classification validation samples. Approximately 120 pixels were then collected in each class, making sure that no points used in the training samples were added in the new collection. The Tabulate Area tool compares validation samples with the result obtained from the MLC command. The results were expressed in the form of a matrix, denominated confusion matrix, which indicates the pixels selected for the same class in both classifications and those that had been changed.

The data from the confusion matrix were used to calculate the Kappa index, which evaluates the accuracy of the results found in the classification process. The mathematical formulation used to calculate Kappa is shown in Equation 1.

$$K = \frac{P_0 - P_c}{1 - P_c} \tag{1}$$

Where,

P_o=Proportion of the reference point in agreement; and
P_c=sum of the product of the elements of the marginal rows and columns, and indicates the proportion of elements randomly assigned to a given class.

However, the calculations were performed using an Excel spreadsheet. There is no theoretical basis for recommending the minimum Kappa Index levels in a classification (FIGUEIREDO and VIEIRA, 2007). Nevertheless, Table 2 shows the values normally accepted by the scientific communities.

The final image manipulation process followed the procedures described by ALMEIDA (2016). Changes that occurred over the years were analyzed by comparing each class percentage at the end of the procedures performed in the study.

With the objective of globally analyzing the changes in the land use and occupation in the last three decades, classifications of the Period 1 were compared to period 4. A map was also made with the objective of highlighting the points where the changes occurred.

Table 2. Kappa Index Quality

Kappa	Quality
< 0.00	Awful
0.01 – 0.20	Bad
0.21 – 0.40	Reasonable
0.41 – 0.60	Good
0.61 – 0.80	Very Excellent
0.81 – 1.00	Excellent

Source: Adapted from Landis and Koch (1977)

RESULTS AND DISCUSSION

The average Kappa index for image classifications for each period is shown in Table 3.

According to Table 2, the values obtained in the study show excellent quality, therefore, acceptable for further analysis.

The maximum Kappa index of 0.540 was achieved using MAXVER method, (LEÃO *et al.*, 2007), therefore indicating good quality. The presence of clouds in the image was indicated as one of the reasons for the relatively low index. On the other hand, BARBOSA (2011) reached an excellent quality index, in the value of Kappa equal to 0.881. However, when compared with previous results, a classification error of around 64% was observed. In the mapping done by NOVAIS *et al.* (2016), regarding land use in the Verruga river basin located in the state of Bahia, the classification was carried out using the MAXVER method from images obtained by the LandSat – 8 satellite, acquired between August and October 2015 and processed in ArcGis software version 10.2.2. A Kappa index of 0.73 was found and according to

the study, it had an accuracy considered to be very good, as it was within the 0.61 - 0.80 range.

In studies by PRINA and TRENTIN (2015), in which the study area was the municipality of Fortaleza dos Valos, state of Rio Grande do Sul, the classification by the MAXVER method was performed through images acquired by the LandSat – 8 satellite and manipulated in the ArcGis software, obtaining an index Kappa of 0.951 within the 0.81 - 1.00 range, thus the classification was considered excellent.

The results obtained after performing the described procedures are shown in the following maps.

Visual analysis shows the occurrence of several variations in the Mucuri river basin in the last three decades.

Figure 4 shows the classes of land use and occupation in the Mucuri River basin, the variation in area as a percentage of each class over the years. The field and farming classes are more representative in all analyzed years, followed by the forest, exposed soil, urban spot and water.

Table 3. Kappa index for the analyzed periods

Period	Kappa/Scene 1	Kappa/Scene 2	Kappa/Scene 3	Average Kappa
1	0.834	0.844	0.825	0.835
2	0.868	0.887	0.914	0.889
3	0.864	0.881	0.845	0.863
4	0.880	0.932	0.918	0.910

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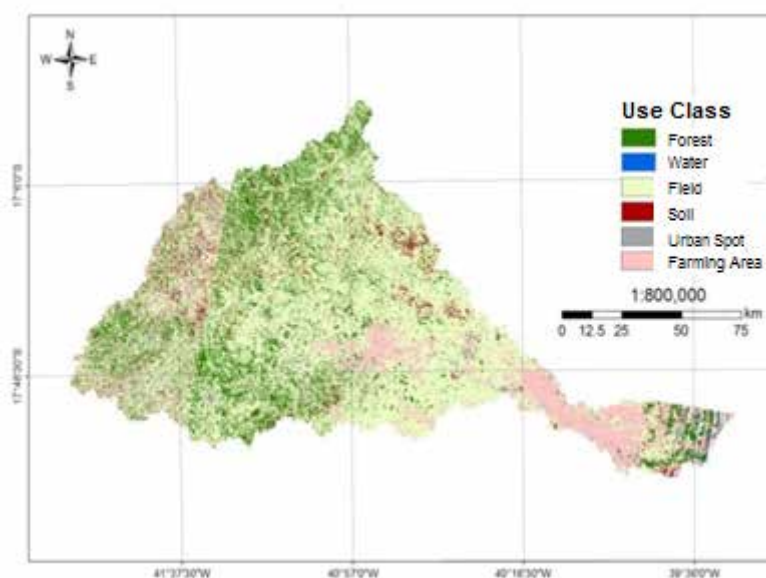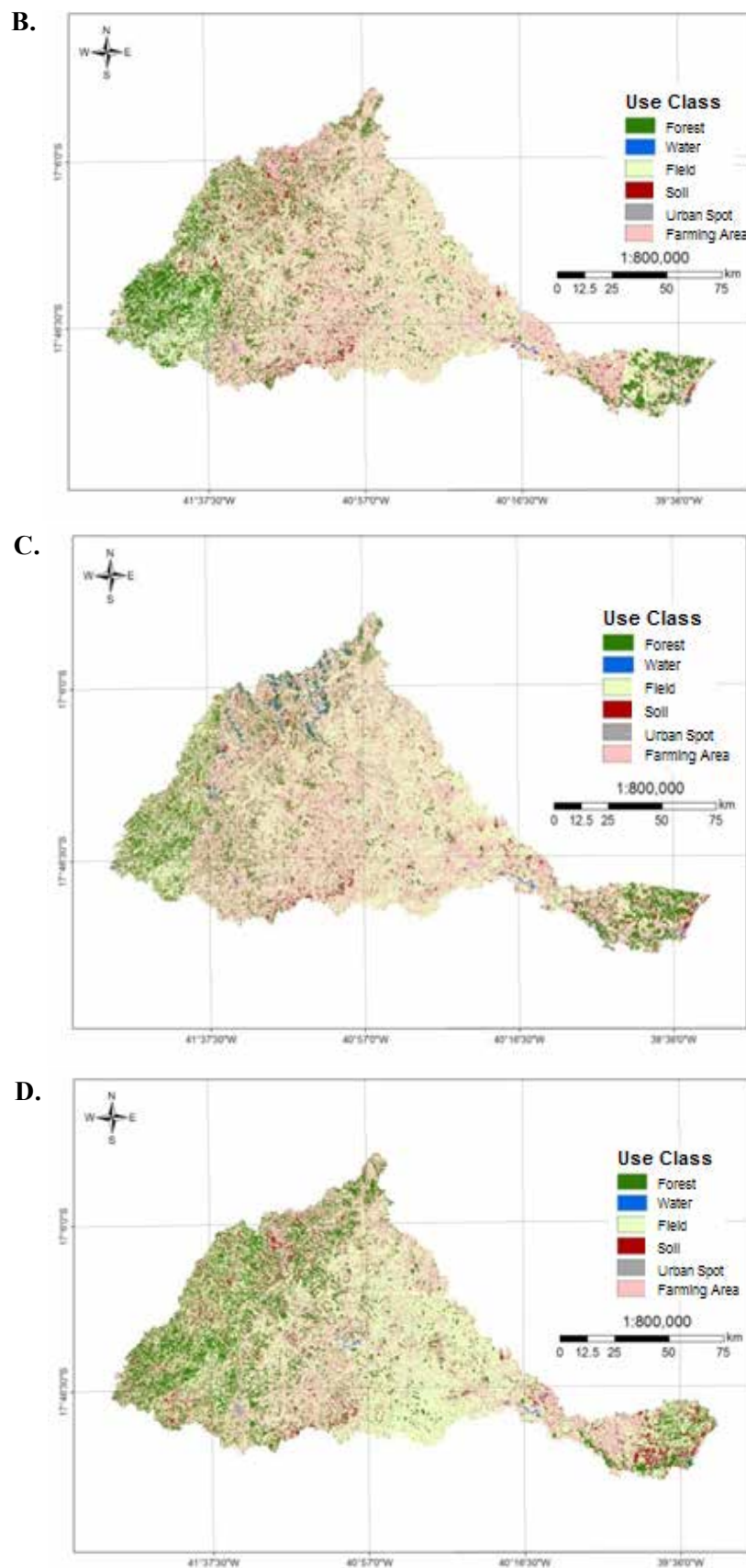
Figure 3. Supervised classification of the Mucuri river basin for the years: A. 1989; B. 2001; C. 2008; and D. 2015

Figure 4. Land use and occupation areas in the Mucuri river basin

Pasture areas and farming use have predominated over these three decades. This result was expected, as the economy of the region has been based in farming activities until nowadays. Alternations have occurred in the predominant occupation class over those periods, which may have resulted from economic changes, as well as measures to support livestock or farming (IEF, 2012).

Following 2001, the increasing occupation by field and pasture areas may have been encouraged by the increase in the purchase price of the *arroba* of cattle, which went up from 84.34 BRL in 2008 to 145.43 BRL in 2015, according to CEPEA (2019).

Also, it should be highlighted the constant reduction in the total area covered by water bodies, therefore indicating the reduction in water availability in the region. However, the water class increased in 2008. Such information may be justified by the presence of clouds in the classified image, coinciding with the local of highest water incidence, the northern portion of the basin. Shadow and water have similar spectral responses, resulting in some difficulties faced by the classifier to distinguish between these two classes (PEDREIRA *et al.*, 2011).

The decrease in the occupation by water bodies may influence the alterations that occurred in the exposed soil class, which is a class that includes areas of deforestation, rock formations, areas of scarce vegetation, among others. Thus, the decrease of water availability impairs the vegetation cover, making it drier and promoting the emergence of exposed soil, as observed in the study.

It is possible to observe the heterogeneity in forest distribution, which is more common in the eastern portion of the basin, decreasing as it approaches the central area, where pastures and farming areas predominate. It is highlighted the increase in forest percentage, compared between 1989 and 2015. This fact conflicts with the reduction found by FELIPPE *et al.* (2009), between 1989 and 2008, when the second period had a reduction by 18.44% in relation to the first. This may be related to the increase of the study area in this work, considering that the one proposed by FELIPPE *et al.* (2009) takes into account only the mining portion in the Mucuri basin.

A considerable increase was observed in the area occupied by woods and forests near the Mucuri River in the regions of the states of Bahia and Espírito Santo, which may indicate the effectiveness of forest protection measures adopted by these states. The implementation of the Mucuri environmental protection area, whose

work began in 2012, encompasses several cities in the basin (IEF, 2012), and may also influence these results.

The urban class includes the sealed areas occupied by buildings, especially the cities, small communities, villages and districts (REZENDE, 2009). The behavior observed in the urban class does not follow the expected patterns for the country, which grows in urbanization rates and urban population. This fact occurs mainly in the classifications of 1989 and 2001, and it can be explained because the urban class has features that are difficult to be identified besides being mainly confused with the exposed soil and field classes (CUNHA, 2009). On the other hand, the 2008 and 2015 classifications follow the expected behavior, showing a growth over the years.

Degraded pastures in the region interfere with the classification of the urban area, because, according to studies by EMBRAPA (2014), Brazil has a high incidence of degraded pastures, a phenomenon mainly caused by the absence of periodic fertilization, failures in pasture establishment, biotic problems and the occurrence of pests, weeds and, most importantly, the lack of

water in the soil. Therefore, the field presents a spectral response similar to the exposed soil and the urban area, which creates confusion in the mapping (NASCIMENTO *et al.*, 2016).

Another aggravating factor is that in the period of the images used in the study, cropped areas were at the planting preparation stage or postharvest period, generating large uncovered areas, as pointed out in Figure 5, thus, compromising the mapping of 1989 and 2000.

In an attempt to analyze in general the changes in land use and occupation between 1989 and 2015, the classification of period 1 (year 1989) was compared with period 4 (year 2015), in order to highlight the points where alterations had occurred, as shown in Figure 6.

The values obtained in the comparison are shown in Table 4.

It is observed that in 52.4% of the basin area, there was a change in land occupation and in 47.6%, there was the permanence of use. It should be emphasized that this data does not indicate that the land occupation has been the same over the three decades, and may have changed and returned to the use identified in the initial period.
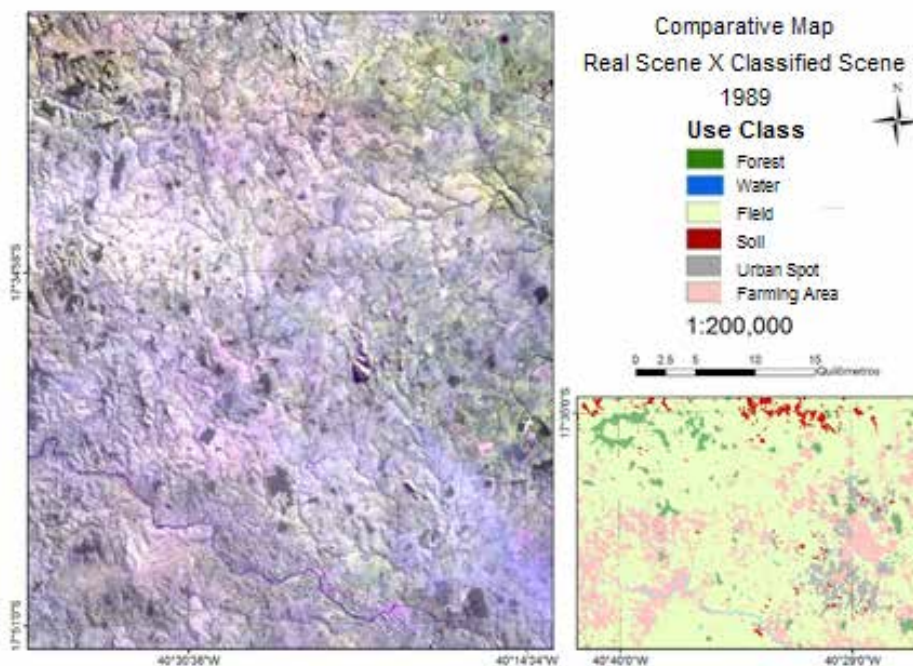
Figure 5. Classification And Reality Comparative
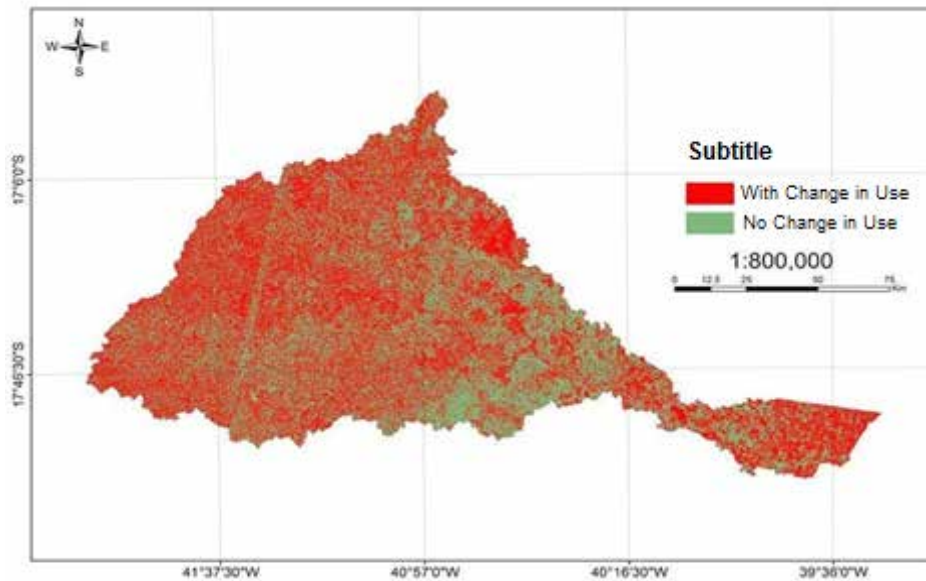
Figure 6. assessment of alteration in soil use between 1 and 4 periods

Table 4. Alteration between period 1 and 4

	With alteration in use	Without alteration in use	Total
Number of Pixels	9,459,813	8,566,323	18,026,136
Area (km²)	8,513.8	7,709.7	16,223.5
Percentage (%)	52.4	47.6	100

CONCLUSIONS

- The results achieved in this study show a constant change in the forest, field and agricultural classes, as they are directly modified by farming activities which is the main source of income in the region.

- A growing decrease in water bodies and an increase in exposed soil were observed, indicating a direct relationship between the two classes.

- The behavior of the urban area was different than the expected due to interferences, such as the presence of clouds and difficulty in distinguishing between classes; however, it gives adequate values for the periods between 2008 and 2018.

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