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Multitemporal analysis of land use and occupation with a focus on agriculture, livestock and pebble extraction in the municipality of Ourém/PA, from 2016 to 2020

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ABSTRACT

The studies of the forms of use and coverage of the earth's surface are essential to provide subsidies for the environmental monitoring of a given area. The present work aimed to analyze the dynamics of land use and land cover in the municipality of Ourém/PA in the period from 2016 to 2020, generating representative information of the landscape dynamics, influenced by the physical and socioeconomic aspects inherent to this municipality. Land use and land cover classes were quantified and mapped with Google Earth Engine from 2016 to 2020. Data processing was performed using the ArcgisPro software to classify land use and land cover classes and to make maps. With the products generated, an image was selected for each year, in order to determine the areas for each thematic class of urban area, vegetation, agriculture and livestock, and pebble extraction, so that it was possible to quantify the class measurements. The results of each year were compared and a thematic map was prepared with the images selected to determine the use and occupation of the land in the municipality. The results revealed that the agriculture and pasture classes are predominant during the analyzed period, with a slight reduction in vegetation cover and a slight increase in the area of agriculture and pasture. Therefore, the identification and analysis of the classes of use and occupation provide both the understanding of these modes of use and the degradation to the environment, understanding the function of Man as a potential cause of this degradation.

Keywords: Transition Dynamics, Amazon rainforest, Geotechnologies.

1 INTRODUCTION

For the evaluation of the occupation process of a given area, it is essential to use Geotechnology resources such as Remote Sensing and Geographic Information System, which provide the generation of updated and reliable information (FACCO et al., 2017), allowing periodic mapping to monitor phenomena of change in land use and land cover.

These resources, according to Vaeza et al., (2010) provide greater efficiency in the process and update data at a lower cost, making them useful and indispensable for monitoring the dynamics of land use and occupation. In view of this, the survey of land use in a given region becomes a fundamental aspect for understanding the patterns of spatial organization and planning of public policies (PRADO; NOVO; PEREIRA, 2009).

In the temporal analysis of land use and land cover in Remote Sensing images of a municipality, through digital processing techniques, it provides the recognition of changes in agricultural and livestock activities, as well as changes in native forest areas. In tropical forests, these changes have occurred mainly due to anthropogenic pressures associated with the exploitation of raw materials (SOUSA et al., 2017). For Facco et al., (2017), this type of mapping provides a systematic inventory of the land surface, making it possible to categorize different uses into classes, which, associated with the geographic information system (GIS), enables the knowledge of the evolution of the spatial dynamics of land use with the production of time series of maps for the same area.

The authors Cunha et al., (2012), highlight that the use of geoprocessing techniques through GIS is efficient in detecting changes in land use and land cover, as well as changes caused in landscapes in a given place and time scale, making it possible to diagnose anthropogenic and natural changes in the landscape.

The increase in urban agglomerations, the exploitation of natural resources and mining activities cause rapid changes in landscapes that, combined with continuous and poorly planned development, generate various environmental and socioeconomic impacts. Therefore, it is necessary to obtain precise information about the geographic space for regional and local planning, in order to identify and classify the changes that have occurred in the landscapes (ARAÚJO FILHO; MENESES; SANO, 2009).

According to Sousa et al. (2017), this identification is carried out through the photointerpretation of the image captured by the sensors through the analysis of the elements associated with the targets such as color, shade, size, shape, texture, pattern, context, and presence of shadows. In order to understand the information in the image, it is necessary to characterize the data contained in it. Thus, digital classification techniques are applied to the image provided by the satellite in order to assign each pixel of the image under study to a category of a group of classes (BAKR; WEINDORF; BAHNASSY, 2010; NOVO, 2011).

Bolfe, Batistella and Ferreira (2012) explain that the brightness factor is directly related to the amount of radiation reflected in a certain range of the electromagnetic spectrum. The ratio of the radiation, which is reflected, to the radiation falling on the target is known as reflectance. Thus, the different classes of land cover (soil, vegetation, water, etc.) present an identifiable pattern with the application of photointerpretation and/or image classification techniques (AMARAL et al., 2009). We can cite several studies that perform analyses on multitemporal scales, with the aim of monitoring land use and occupation, such as those of Fujaco, Leite and Messias (2010), Vascocellos, Terra and Cardoso (2013) and Santos et al., (2015).

Therefore, temporal analysis studies allow the seasonal monitoring of the earth's surface, such as, for example, the monitoring of the evolution of deforestation, urban growth, agricultural monitoring, among other applications (CARVALHO JUNIOR et al., 2005). Through the use of satellite images, multitemporal analysis is obtained, which allows the exploration of changes in the analyzed area, presented in the form of a map (BENEDETTI, 2010).

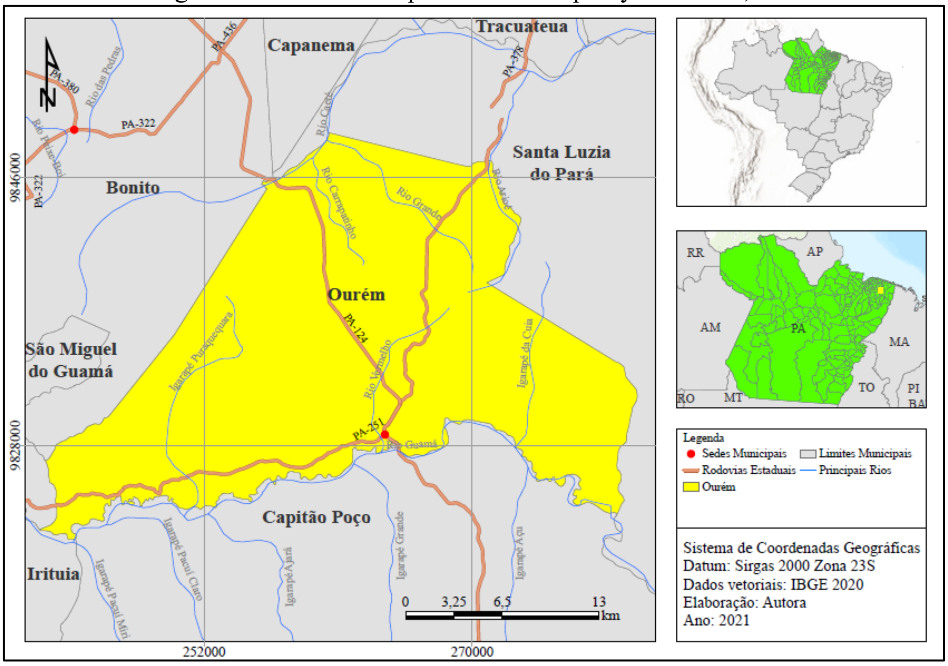
In view of the above, the objective of this work was to analyze the dynamics of land use and land cover in the municipality of Ourém in the State of Pará in the period from 2016 to 2020, generating representative information of the landscape dynamics, influenced by the physical and socioeconomic aspects inherent to this municipality.

2 MATERIALS AND METHODS

2.1 AREA OF STUDY

The municipality of Ourém is located in the state of Pará, in the Northeast Pará mesoregion, microregion of Guamá (Figure 1), whose headquarters are at coordinates 1° 33' 07'' S and 47° 06' 52'', with an area of 562,388 km2, with an estimated population of 17,842 inhabitants. It neighbors the municipalities of Santa Luzia do Pará, Capitão Poço and Bonito, located 23 km north-west of Capitão Poço, the largest city in the vicinity (IBGE, 2010).

Figure 1 – Location map of the Municipality of Ourém, PA.



Source: IBGE (2020).

The municipality's main drainage system is the Guamá River, which borders the municipality of Capitão Poço. In addition to the river, which is in the central part, there are 12 streams, all with crystal clear water filtered by the existing pebble deposit, the largest in the state of Pará. Because it has these peculiar characteristics , the municipality is also known as "The Pearl of Guamá", "Paradise of the Streams" and "City of the Pebble" (MATOS, 2007).

As it has the largest pebble production in the state, reaching more than 700 m3 per day, Ourém's economy is based on the exploitation of pebbles, gravel and sand. Becoming responsible for the supply of this material to the capital of Pará. In addition, more than 50% of the population of Ouremense lives from family farming, local businesses, provision of services, among other activities. It should also be noted that a part of the population survives because of the potteries, as well as a part of beekeeping, which are services recognized for their quality by the Northeast region of the state (OUREM, 2015).

The municipality has a temperature range ranging from 24.6º to 25.9º C and is part of the region of the Lowland Plateau of the Amazon, which has altimetry between 50-200 m (FURTADO; PONTE, 2013). It has a predominance of dystrophic soils, with medium texture and clay, with properties that enable the extractive exploitation of materials such as: sand, pebble, gravel, gravel, piçarra and clay (FAPESPA, 2012). In relation to the original vegetation cover, the municipality preserves only 9.2% or 46 km2 (ANUARIO DO PARÁ, 2017), leaving small stocks of original forest, which are mainly located near the southern border, with the municipality of Capitão Poço (SOUZA; FEATHER; SILVA, 2016). In these altered areas, successional forests and floodplain forests bathed by the Guamá River predominate (ANUARIO DO PARÁ, 2017).

Deforestation is quite visible both in the vicinity of the urban center and on the access roads to the municipal headquarters (SOUZA; FEATHER; SILVA, 2016), having as one of the factors that contribute to this problem the extraction of pebbles for civil construction, which, for decades, has been consolidated in the economic base of the municipality (GEOVANE; STOLEN; SOUZA, 2012; LOBELL et al., 2015).

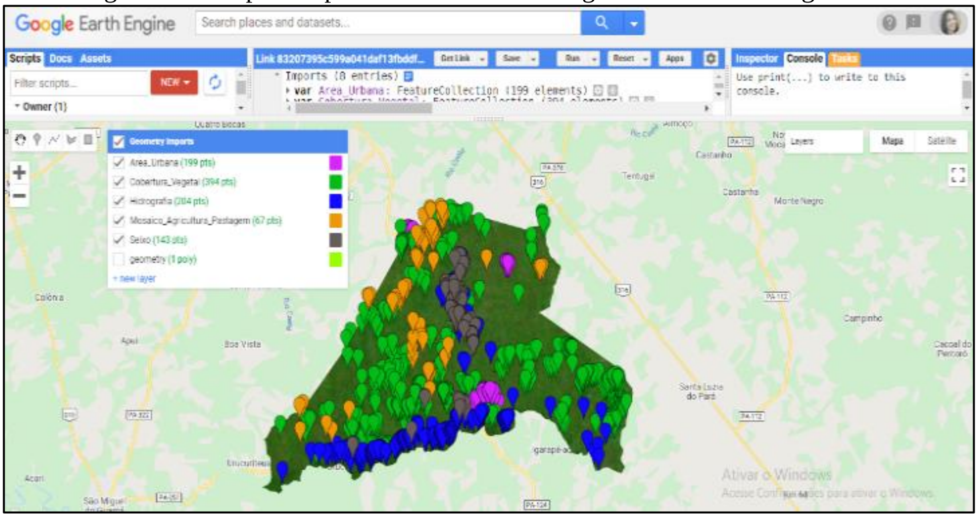
2.2 PROCEDURES

For the acquisition of satellite images for the municipality of Ourém, the Google *Earth Engine* application was used, from images, Landsat 8, OLI sensor, calibrated, atmospherically corrected and georeferenced in the Mercator Transverse Projection Plane Coordinate System (UTM) Datum Sirgas 2000 Zone 23S.

The data from the OLI sensor provides very important data and information, with 30 m of spatial resolution, which can be used in environmental studies for decision-making (ZHANG et al., 2015; SOULARD et al., 2016; CUTLER et al., 2007).

The land use and occupation classification procedure adopted by *Google Earth Engine* was based on the filtering of percentages of cloud cover and composed in mosaics of the spectral bands for the generation of the indices. The classification was supervised, where the user's prior knowledge of the area was obtained. Samples of pixels from each class were collected to generate their respective spectral signatures to classify all other pixels in the image, applying the *Random Forest* algorithm known as "decision trees". According to (GISLASON; BENEDIKTSSON; SVEINSSON, 2006), is a very effective statistical classifier with wide application. Very efficient in the classification of satellite images (BREIMAN, 2001), I have put together a set of methods, which uses several independent "decision trees", distributed in a similar way by random vectors according to an input pattern (ROUSE et al., 1973), with the aim of producing the most accurate classification possible (GISLASON; BENEDIKTSSON; SVEINSSON, 2006) (Figure 2).

Figure 2 – Samples of pixels of each class using Random Forest algorithm.



Elaboration: The author(s) (2021).

Its classification of satellite imagery according to (GISLASON; BENEDIKTSSON; SVEINSSON, 2006) is recommended, because in addition to including metrics that highlight the importance of variables, and the similarity between points, which can be grouped at different levels, classifying the entire image, assigning values when non-existent, producing a graphic result.

Five classes of land use and occupation were mapped between 2016 and 2020, divided into samples according to the variability of the spectral signature:

a) Urban area;

b) Vegetation cover;

c) Hydrography;

d) agriculture and livestock, and

e) pebble extraction.

From the junction of the spectral bands of interest, mosaics of spectral bands were created for the generation of the indices.

To calculate the vegetation indices, NDVI (Normalized Difference Vegetation Index), in *Google Earth Engine*, from the OLI sensor, the red B4 (640 – 670 nm) and near infrared B5 (850 – 880 nm) bands were used, its index varies from -1 to 1.

The NDVI, proposed by Polidorio, Imai and Tommaselli (2004), was calculated by the following Equation 1:

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \tag{1}$$

Where NIR is the reflectance of vegetation in the near-infrared band and R is the reflectance of vegetation in the red band.

For the calculation of the NDWI (Water Normalized Difference Index), the bands in green B3 and mid-infrared B6 were used, and this is since the spectrum of radiation reflected by water generally occupies the range of wavelengths between 400-900 nm, a fact that allows the water present in the pixel to be easily highlighted. being able to identify and separate water from soil particles (SILVA et al., 2019).

The index was calculated based on Equation 2 (POLIDORIO; IMAI; TOMMASELLI, 2004):

$$NDWI = \frac{(G - NIR)}{(G + NIR)} \qquad (2)$$

Where G is the reflectance in the Green spectrum band and NIR is the reflectance in the mid-infrared band.

In this study, the calculation of the NDBI (Built-up Area Difference Index) was based on the application of the method in the approach of the NDBI studies developed by Zha, Gao and Ni (2003). To calculate the NDBI, the near-infrared B4 (760 - 900 nm) and mid-infrared B5 (1550 - 1750 nm) bands were used, according to the following Equation 3:

$$NDBI = \frac{(B5 - B4)}{(B5 + B4)} \qquad (3)$$

The result of the ratio of the near-infrared and mid-infrared bands produces an image with values from -1 to 1. Where the highest values are expected to represent pixels contained in built-up areas and negative values represent pixels contained in unbuilt areas, such as vegetated surfaces.

After the image generation stage with the five classes, they were processed in ArcgisPro, including its plugins and extensions. The matrix files (raster) containing the classification of land cover use in a clipped mosaic, were converted into a vector file of the polygon type. The vector files containing the classification for 2016, 2017, 2018, 2019 and 2020 were used to define a color range for the classification of land cover use, assuming the color standards adopted for each class.

The land cover use classes were quantified, and the data were properly organized for the analysis of each area and year within Ourém (FERNANDES et al., 2021). It is at this stage that it validates the classification generated through the land use and land cover qualification process. According to Monteiro (2015), it is the phase responsible for the treatment of the knowledge obtained by the process of classification and interpretation of data by the user, whether through the elaboration of graphs, diagrams, tables, among others.

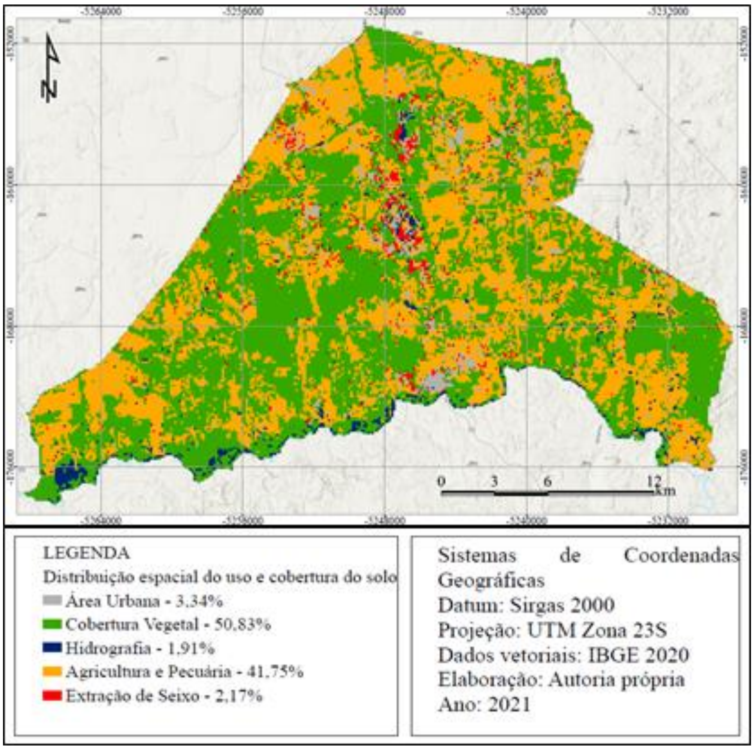
3 RESULTS AND DISCUSSION

From the survey of the acquired images, it is evident the change that occurred in this municipality, in relation to the use and occupation of the land, between the years 2016 and 2020. This time interval was chosen due to the high rate of silting of the municipality's main river and streams in the Amazonian summer.

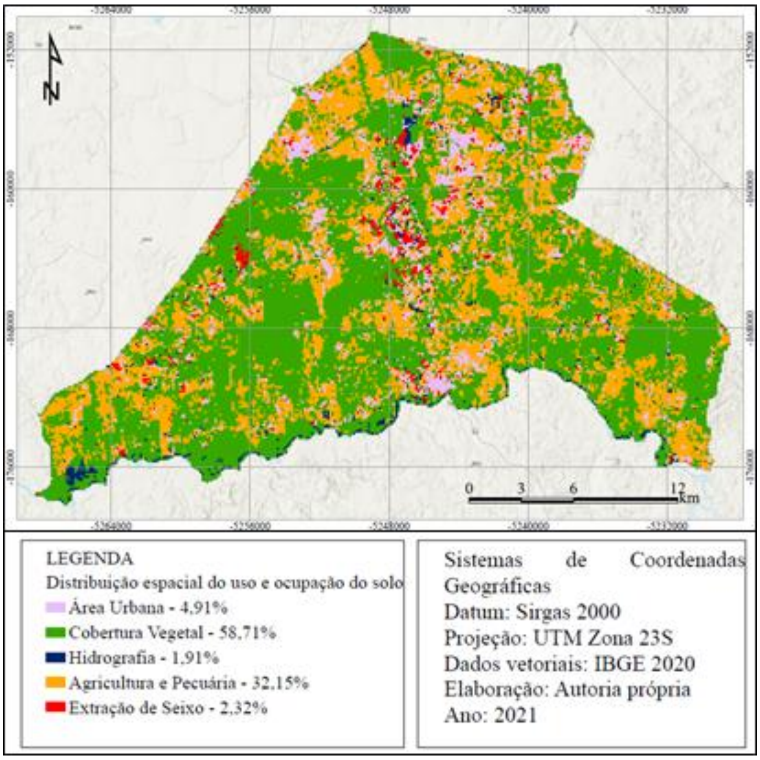
Figure 3A shows the variation of the five classes analyzed in 2016.Predominant areas in the municipality were Vegetation cover (50.83%) and Agriculture and livestock (41.75%). As in Figure 3A, Figure 3B presents the five classes of land use and land cover distribution for the year 2017.

Figure 3 – Spatial distribution of land use and land cover for the years 2016 (A) and 2017 (B) in the municipality of Ourém, PA.

A



B



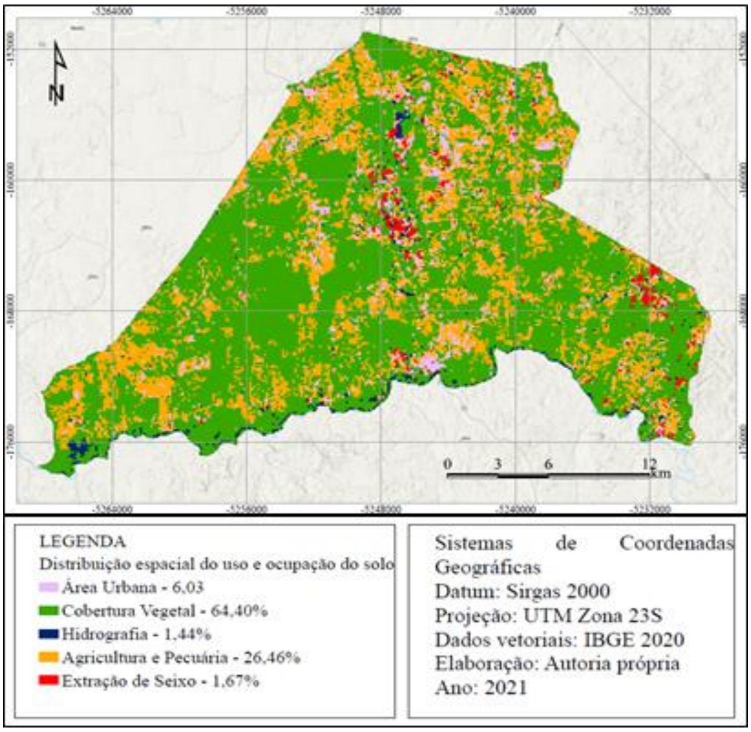
Source: IBGE (2020).

It was observed that there was an increase in the vegetation cover when compared to the area of the previous year (7.88%). In the same period, there was a reduction in agricultural activities in the region (9.6%), such as the cultivation of cassava, beans, corn and pasture. In addition, there was a significant increase of 1.57% in the urban area. As highlighted by Costa (2003), it is essential to know the history of the places, to understand the dynamics that transform the space, creating features that alternate over time.

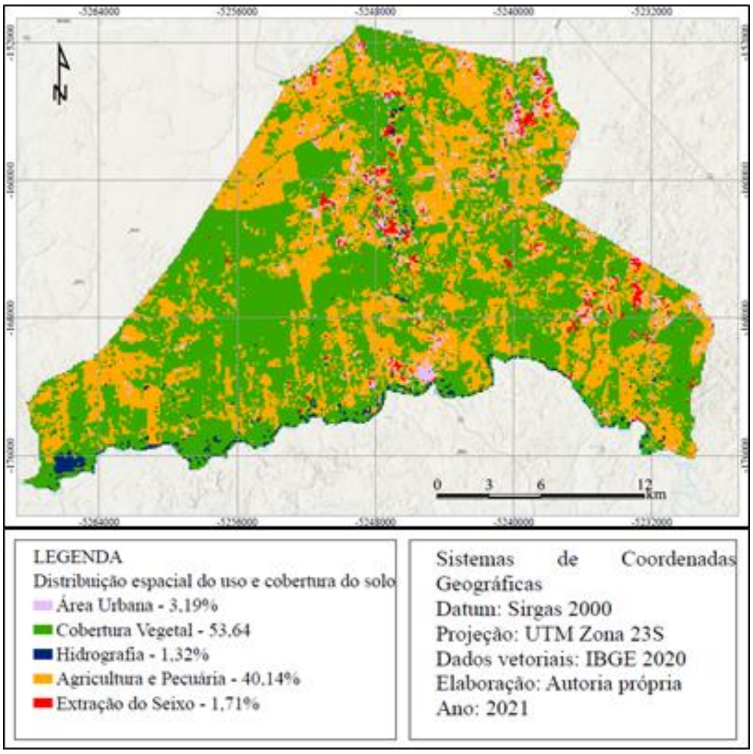
In 2018, it was verified in the spatial distribution map (Figure 4A) that the vegetation cover area increased in relation to 2017 (5.69%) and agricultural activities decreased (5.69%), because the inactivity of pasture classes that encompasses agriculture can generate vegetation regeneration area, which will later be characterized as secondary vegetation (NASCIMENTO; FERNANDES, 2017). Unlike what happened in 2018, in 2019 the area of agriculture and pasture was larger than the area of vegetation cover. Agriculture grew by 13.68% while vegetation cover decreased by 10.76%. This may be related to the inefficiency of Brazilian environmental legislation, in the lack of inspection of protected environmental areas that could not have been altered (DIEGUES, 2001) (Figure 4B).

Figure 4 – Spatial distribution of land use and land cover for the years 2018 (A) and 2019 (B) in the municipality of Ourém, PA.

A



B

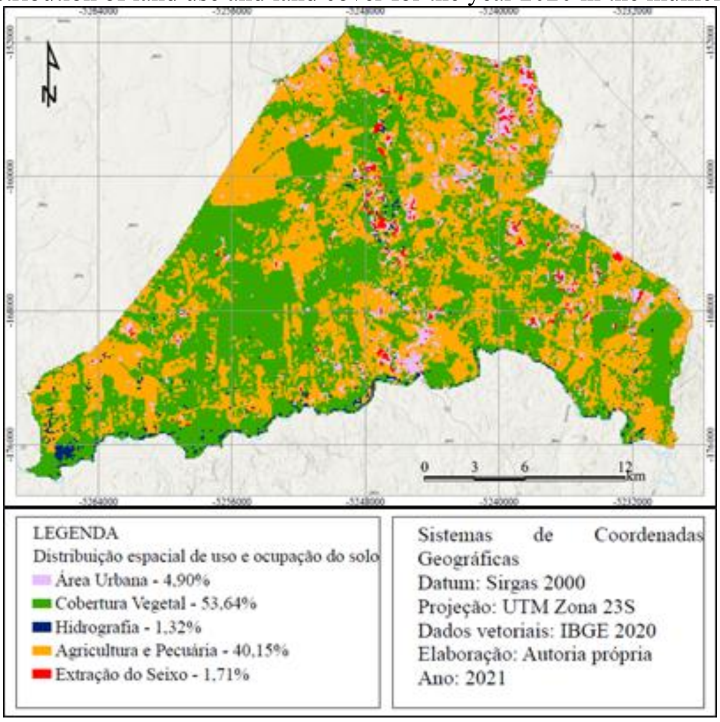


Source: IBGE (2020).

For Coelho et al., (2014), the physical characteristics of Brazilian municipalities have suffered from changes in land use and occupation, since such changes are directly related to the environmental quality of the most diverse matrices that make up a city. The present study is able to identify these changes in the municipality of Ourém.

It is observed that in the year 2020 (Figure 5), of the five classes analyzed, the changes occurred in the classes of urban area, vegetation cover, and agriculture and pasture are very evident. In a study on the dynamics of vegetation areas, Lemos and Cruz Junior (2013) point out that climatic variables are a major intervening factor in the changes in vegetation in an area, clearly reflecting on the use and occupation of a soil. This fact has been evidenced in the municipality of Ourém in recent years.

Figure 5 – Spatial distribution of land use and land cover for the year 2020 in the municipality of Ourém, PA.



Source: IBGE (2020).

This may be related to the expansion of the Brazilian agricultural frontiers, which evidenced the absence of proposals for regional development of family farming and strategies for the development of the domestic market. However, the economic focus was to ensure the expansion of the extensive margin of large enterprises aimed at the foreign commodity market, a trajectory marked by low economic efficiency, social imbalance and inadequate use of natural resources (MATTOS, 2011).

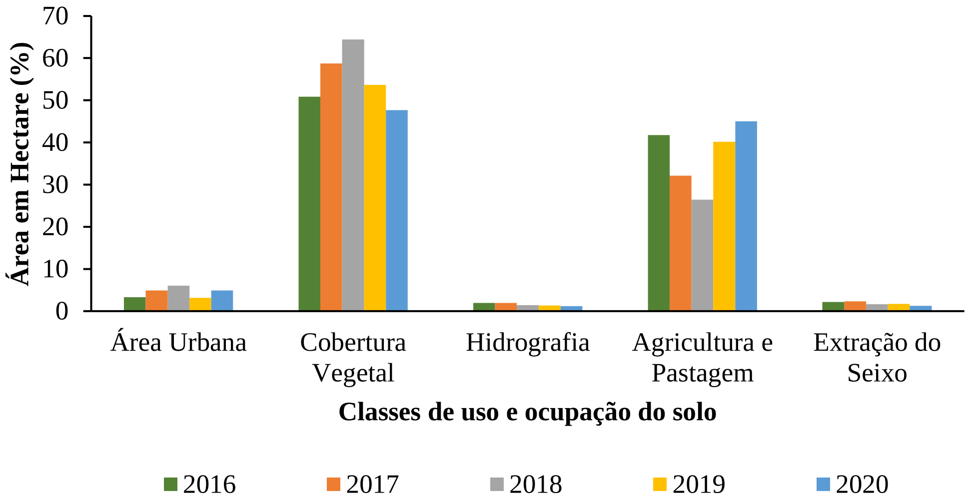
Table 1 and Figure 6 show the areas of land use and occupation classes between the years 2016 and 2020 in the municipality of Ourém, both in hectare (ha) and in percentage (%), respectively.

Table 1 – Variation of the areas of the land use and occupation classes between the years 2016 and 2020, in the municipality of Ourém.

Class	2016	2017	2018	2019	2020	Final balance of each class
	------------------------------------- a ------------------------------------					
Built-up area	1,88	2,77	3,40	1,80	2,76	880
Mulch	28,67	33,12	36,33	30,26	26,88	- 1,79
Hydrography	1,08	1079	815	743	664	- 413
Agriculture/Livestock	23,55	18,13	14,93	22,65	25,41	1,86
Pebble extraction	1,23	1,31	943	968	697	- 530

Elaboration: The author(s) (2021).

Figure 6 – Histogram of the percentage variation of land use and occupation classes in the municipality of Ourém, from 2016 to 2020.



Source: IBGE (2020).

When comparing the areas of the five classes analyzed in this study between 2016 and 2020, there was a reduction in the areas of vegetation cover (6.26%), hydrography (38.35%) and pebble extraction (43.19%) and an increase in the urban (46.73%) and agriculture and pasture (7.88%) areas (Figure 6). When checking the balance of areas of the classes at the end of the five years analyzed, it can be seen that urban areas and agriculture and livestock were the only classes with a positive balance, while the others had negative balances (Table 1).

These results, of land use and occupation for the municipality of Ourém, make it possible to understand in a deeper way the consequences to the environment, caused, mainly, by anthropic actions. The identification and analysis of the classes of use and occupation provide both the understanding of these modes of use and the degradation to the environment, understanding the role of human beings as a possible potential cause of negative impacts. For Pereira Neto and Fernandes (2015), this type of analysis, together with the understanding of its ecodynamics, would therefore be of fundamental importance for territorial and environmental planning.

We know that there are several forms of anthropogenic interference developed in the municipality of Ourém, such as agriculture and pasture, and pebble extraction. This, for the most part, is inserted, mainly, close to the places that are preserved, such as the APP's.

In this work, even verifying a sharp drop in the area of pebble extraction from 2016 to 2020, its activity is very intense and harmful to the environment, as research carried out by Souza, Pena and Silva (2016), Carvalho et al., (2013) and Coelho, Lucas and Sarmento (2020), in Ourém, pointed out serious environmental consequences from pebble extraction: The "mountains" of sterile waste, from the washing of the pebble, suffer the actions of wind and rain, such as: the silting of water bodies; the random dumping of pebble washing waste; the depletion of soil fertility, resulting from the movement of horizons; damage to the forest restoration process; the suspension of dust in pits and on roads, among others.

As pointed out by these authors, about the silting of water bodies. In this work, there was a sharp drop in the water bodies of the municipality of Ourém, 38.34% of area, from 2016 to 2020, reflecting on the use and occupation of its soil.

In general terms, what can be observed is that currently the indices of anthropic interference in the areas of the municipality of Ourém are intensifying more and more, with longer periods of drought and drought. The data generated from this research may provide subsidies for the implementation of actions for the development of measures to benefit the environment.

4 CONCLUSIONS

Through the analysis of the results, it was possible to obtain considerations about the current situation of agriculture and livestock, and pebble extraction under the use and occupation of the soil, detecting the transformations that occurred over five years. During this period, the use and occupation of the soil in the municipality of Ourém underwent changes, especially in the decrease of vegetation cover and water bodies, caused mainly by the activity of pebble extraction, causing silting of its main river (Guamá River) and tributaries (Igarapés), dumping of waste from the washing of the pebble forming the "mountains" of sterile waste, depletion of soil fertility, among others. The information presented is shown to be important subsidies to the government as a basis for environmental planning and zoning actions, linked to the search for a more balanced coexistence between society and the environment. In addition, it is a low-cost and easy-to-apply methodology, whose results can minimize the cost and time of the prospecting and research phase.

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