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Papers

The Influence of Land Use and Land Cover on Surface Temperature in a Water Catchment Sub-Basin

Arthur Pereira dos Santos [1]
Henzo Henrique Simionatto [2]
Letícia Tondato Arantes [3]
Vanessa Cezar Simonetti [4]
Renan Angrizani de Oliveira [5]
Jomil Costa Abrel Sales [6]
Darllan Collins da Cunha e Silva [7]

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Abstract
Faced with the recent crises of water capture and distribution, managing water resources is a practice that has been gaining prominence in discussions and debates about environmental issues. Thus, this article aims to analyze, in a spatio-temporal way, the Changes in Land Use and Occupation (LULC) and Surface Temperature (LST) in the water catchment sub-basin of Ribeirão Santa Isabel, located in the municipality of Paracatu, Minas Gerais (MG), between the years 1990 and 2020. The choice of the area is justified by the conflicts of use that encompass the sub-basin and by the fact that this is the only source of capture in the municipality, which has already carried out the alteration of the water resource responsible for the capture of water due to the intensity of agricultural practices in the region in the previous area. Through geoprocessing and Remote Sensing (RS) techniques, images from the Landsat-5 and Landsat-8 satellites were used to perform the LST calculations. Regarding usage and occupancy data, the images provided by the Mapbiomas platform were used. It was verified, through the increase in the percentage of the water class and vegetation and the decrease in the agricultural class, that the practices implemented in the study area, in order to conserve the remnants of the biome and maintain a good water availability to the municipality, are having an effect. It was also possible to conclude that LST is affected by LULC, and that the greatest variations occur in non-vegetated areas.

[1] Universidade Estadual "Júlio de Mesquita Filho" – UNESP, Sorocaba, SP, Brazil. arthur.p.santos@unesp.br
[2] Universidade Estadual "Júlio de Mesquita Filho" – UNESP, Ilha Solteira, SP, Brazil. henzo.h.simionatto@unesp.br
[3] Universidade Estadual "Júlio de Mesquita Filho" – UNESP, Sorocaba, SP, Brazil. leticia.tondato@unesp.br
[4] Universidade de Sorocaba – UNISO, Sorocaba, SP, Brazil. va_simonetti@hotmail.com
[5] Universidade de Sorocaba – UNISO, Sorocaba, SP, Brazil. renan_angrizani@hotmail.com
[6] Universidade Estadual "Júlio de Mesquita Filho" – UNESP, Sorocaba, SP, Brazil. jomilc@gmai.com
[7] Universidade Estadual "Júlio de Mesquita Filho" – UNESP, Sorocaba, SP, Brazil. darllan.collins@unesp.br

INTRODUCTION

The growing demand for water resources means that their management is increasingly improved, especially in regions where water is in conflict of use or scarce. Given the periods of water scarcity that have affected Brazil in recent years, LULC management and planning practices are increasingly important issues for the protection of this natural resource (VARGAS et al., 2021).

Approximately 24% of the world's total geographic area is severely affected by land degradation, and in Brazil, this scenario is no different (PACHECO et al., 2018; ROMSHOO et al., 2020). Studies indicate that the Brazilian Cerrado is recognized as one of the most threatened biomes in the world, because, in addition to having undergone a marked change from natural vegetation to intense agricultural production (HUNKE et al., 2015), it is a biome that has extensive areas occupation of economic interest for agriculture (CUNHA; BRAVO, 2022).

As much as research estimates that the natural Cerrado, outside protected areas, may disappear by the year 2030, there are projects throughout the biome that aim to encourage its preservation, but there is uncertainty as to whether these incentives have provided for its conservation (CUNHA; BRAVO, 2022; MACHADO et al., 2004). Therefore, this situation becomes even more complex when it comes to areas responsible for supplying water to the population (MALAV, 2022). This is the case of the water catchment sub-basin of the Ribeirão Santa Isabel, belonging to the Paracatu River basin and thesource responsible for the public supply of the municipality of approximately 94 thousand inhabitants.

Aiming at its conservation, even an Unidade de Conservação Integral (UCI), called Parque Estadual de Paracatu, was created in the place, through State Decree nº 45.567 of March 22, 2011, with the purpose of preserving the typologies that still exist in the region and guarantee the water resources necessary for the municipality's water supply, as well as ensuring local biodiversity (IEF, 2011).

However, other factors still cause several conflicts over the use of water to occur at the site, most of which are not related to water scarcity, but to the insufficiency of planning procedures for the management of resource conflicts. The Instituto Mineiro de Gestão das Águas (IGAM), the state water resources management body responsible for planning and promoting actions aimed at preserving the quantity and quality of Minas Gerais waters, declared the basin and its sub-basins as a Área de Conflito (DAC), following the request of the Ministério Público de Minas Gerais (MPMG).

The situation exposed was due to the water deficit of the watershed components of the basin, that is, the flow of water demanded for irrigation, in these places, is higher than the flow offered by the water resources. It is worth noting that, in Paracatu, the grants granted for human consumption, animal watering and other uses, are considered insignificant compared to the grants for irrigation (COSTA et al., 2021).

In view of this scenario, in 2017, the municipality experienced the biggest water crisis in the last 100 years due to the decrease in the water flow of the Ribeirão Santa Isabel sub-basin. On that occasion, the water utility that manages the municipality adopted a rotation system to supply the city's neighborhoods. Water trucks were used to supply the health sectors and some public agencies, in order not to carry out their stoppages, as many schools and establishments canceled their activities due to the lack of water.

In order to guarantee the water security of the municipality, the construction of a water accumulation reservoir was started, with delivery expected for the year 2022. With the completion of the work, even if there is a drop in the volume of Ribeirão Santa Isabel, the Companhia de Saneamento de Minas Gerais (COPASA) will still have water to treat and distribute to Paracatuenses for up to two consecutive months.

It is important to mention that the concessionaire has already been forced, due to the great agricultural expansion, to replace the place where the water supply system of the municipality was collected, originally located in the Córrego Espalha. On that occasion, as presented by Pruski et al. (2007), the irrigations implemented in the area caused the flow of the catchment to pass from 50 L/s to 8L/s.

Currently, there is an extensive demand in the sub-basin, however, focused on the use of water for irrigation of large areas with pivots, and its last Zoneamento Ambiental Produtivo (ZAP), which is an instrument of planning and territorial management for the sustainable use of natural resources by agroforestry and pastoral activity in the state of Minas Gerais, presented an area of approximately 2% of pivots in this location. However, the validated official data show a view that is incompatible with the reality of the sub-basin under study, because, in addition to the existence of expired processes without renewal, there are catchments observed in the field that are not at the base of the

Sistema Integrado de Informações Ambientais (SIAM), which aims at the integration and decentralization of authorizing and inspection systems through modern technology tools, with the objective of implementing the integrated environmental information system (ZAP, 2018).

Given the complexity of conflicts over water and soil use in this location, this article aims to analyze, in an interval of 30 years (1990 - 2020), the influence of LULC on the variation of LST in the sub-basin of Ribeirão Santa Isabel, as well as to verify, in a spatio-temporal way, the behavior of surface temperature in each class of use and occupation, in order to evaluate, through these parameters, the possible causes of these alterations.

This research is justified by the fact that land use and land cover are fundamental in the regulation of the water cycle, and changes in its use directly influence the radiation balance and the alteration of three biophysical parameters: a) albedo; b) vegetation index and; c) LST (MARTINS; GALVANI, 2020). Furthermore, nothing is known, so far, about the role that the LULC played in the LST of the study area, and very little has been verified about the effectiveness of conservation techniques in the area.

MATERIALS AND METHODS

Study area

The Ribeirão Santa Isabel sub-basin (Figure 1) is located in its entirety in the municipality of Paracatu, MG, and is part of the Unidade de Planejamento e Gestão de Recursos Hídricos do Rio Paracatu (UPGRH SF7). Its main course, Ribeirão Santa Isabel, flows into the Ribeirão Escurinho, which, in turn, flows into the Rio Escuro, until reaching the Paracatu River, one of the most important tributaries of the São Francisco River (ZAP, 2018).

The predominant climate in the catchment sub-basin is the tropical climate of the Aw type, with summer rains and a poorly defined or absent winter season and strong annual precipitation. Its average temperature is 23.1 °C and its average rainfall is 1305 mm/year. The month that represents the lowest and highest rainfall are, respectively, June and December (ÁLVARES et al., 2013).

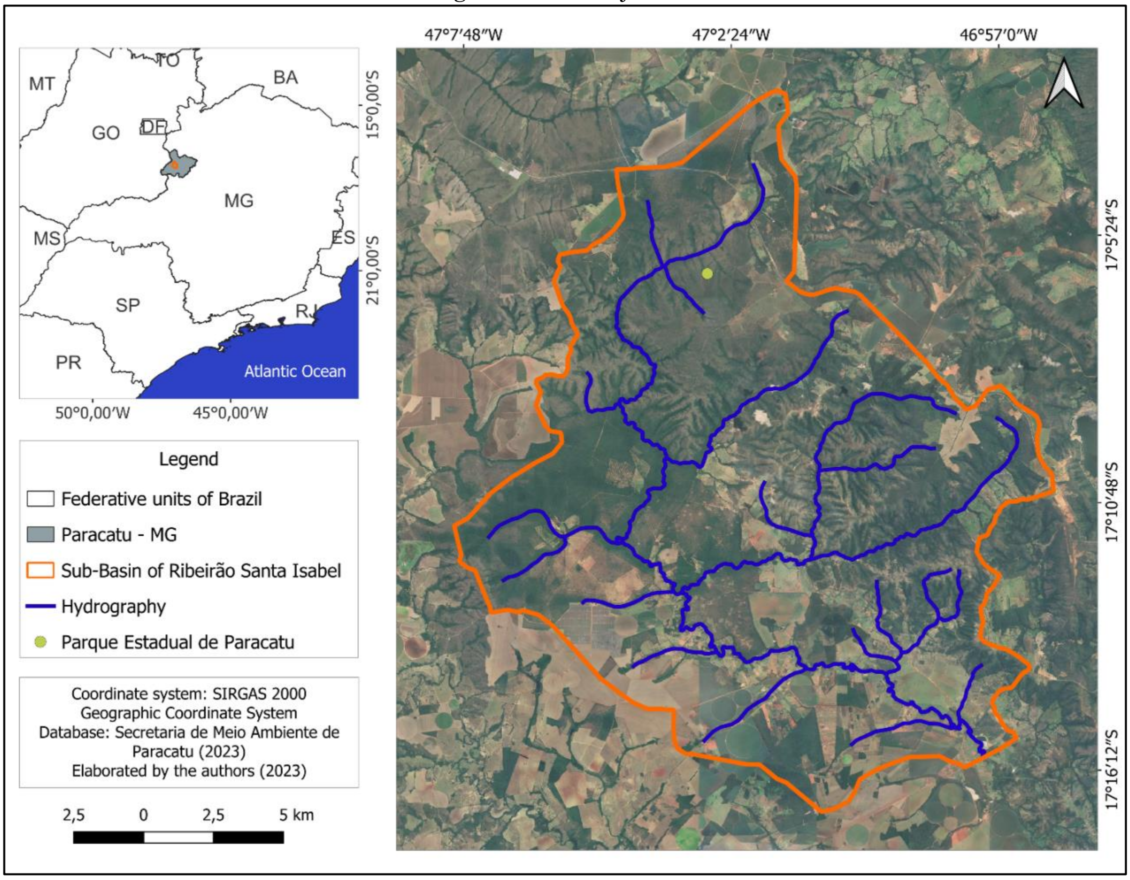
The soils identified in the sub-basin, according to the Departamento de Solos do Centro de Ciências Agrárias - DPS – Universidade Federal de Viçosa – UFV, are represented by the classes of Haplic Cambisols, Red Latosols, Red-Yellow Latosols, Fluvic Neosols and Litholic Neosols. Among these, the Dystrophic Litholic Neosol, with the highest occurrence in the sub-basin area, concentrates on the occupation of pastures and extensive agriculture, while in the Red Latosols, intensive farming is observed (UFV, 2022).

Period analyzed and data collection

To achieve the proposed objective, images dating from the years 1990, 2005 and 2020 were analyzed. This interval of 15 years was considered so that it was possible to verify the spatio-temporal variation of the analyzed parameters, as well as to analyze a possible effectiveness of the creation of the UCI for the preservation of the vegetation and, consequently, in the increase of the LST. Thus, periods before and after the creation of the State Park on the site were evaluated.

In addition, for each year analyzed, 2 images were used to perform the extraction of the LST representative of that period, and this decision is justified by the fact that, due to the temporal resolution of the Landsat satellite, studies involving RS data and spatio-temporal variation of surface temperature generally use a certain amount of images to represent the period of one year, according to related studies (GUILHERME et al., 2016; WANG et al., 2018; GOVIND; RAMESH, 2019; ALMEIDA et al., 2020; CARRASCO et al., 2020; SANTOS et al., 2022; ULLAH et al., 2023).

Figure 1 – Study area.



Source: The authors (2023).

However, although RS techniques can quickly obtain information about LST, it is greatly affected by the presence of clouds and the occurrence of rain at scenes, especially when it comes to wet periods, making it difficult to obtain reliable data (NOURELDEEN et al., 2020). Moreover, as discussed by Souza et al. (2020), given the temporal resolution of Landsat images, defining a single classification system remains a challenge for RS.

Finally, given the difficulty in obtaining scenes from the Landsat satellite capable of representing all periods of the year, the images used in this study were chosen for the dry period of the region analyzed, considering the presence of fewer clouds in the place and similar predominant weather conditions, so that these parameters do not significantly influence, in the extraction of LST, as the moisture of the material tends to alter the albedo of the surface (ERMAN et al., 2018; ROY et al., 2020; GHAUSI et al., 2023).

Still as highlighted by Roy et al. (2020), although it is evident that LST varies greatly with the seasons, it validates the use of scenes in dry periods because this is when the sky and the environment remain stable, with the air temperature relatively without many variations and precipitation and wind speed low, thus, these parameters do not influence the surface temperature.

Therefore, the method used by this research stands out for presenting 2 images analyzed to represent a period (Table 1), performing the average, pixel by pixel, among them, in order to improve its representativeness and bring a new form of analysis to the studies involving LST obtained through the RS.

Table 1 – Dates of images used.

Year	Date of image 1	Date of image 2
1990	23/07	08/08
2005	30/06	01/08
2020	05/09	12/09

Source: USGS (2023).

Subsequently, images were obtained from the LANDSAT-5 and LANDSAT-8 satellites through the United States Geological Survey (USGS) website. Images without the presence of clouds were used in the study area and the process of Resampling and Resolution Reduction was carried out, with the nearest neighbor technique, from the QGis 3.2.12 software (QGIS, 2021) to standardize in 30 meters all the pixels of the different satellites used, because there is a discrepancy between the spatial resolutions of the thermal bands used (120 meters of LANDSAT-5 and 100 meters of LANDSAT-8).

Obtaining, extracting and analyzing the LST and LULC

To calculate the LST, the equations and recommendations suggested by the USGS (2018) were applied. For this, the QGIS 3.2.12 software (QGIS, 2019) was used to analyze each image obtained and the average between the two images in Table 1 was performed using the raster calculator.

To calculate the LST of the LANDSAT-8 satellite, a value of –0.29 was added for each pixel of the image resulting from the average, as recommended by the USGS, since thermal bands 10 and 11 receive scattered light interference from areas adjacent to the imaged scene and therefore require this adjustment. The USGS recommends using band 10 during temperature estimation, as the stray light problem occurs, with greater intensity, in band 11 (USGS, 2023). Still, the data obtained through the ambient temperature measured in a conventional station of the Instituto Nacional de Meteorologia (INMET), federal agency that has the mission of providing meteorological information through monitoring, analysis and forecasting of weather and climate, (code 83479; altitude 711.41 m; latitude: -17.244166 and longitude: 46.881666), accessed from its official website, were validated.

Subsequently, a mask that represents the study area in its entirety was used, which was obtained from the Secretaria de Meio Ambiente de Paracatu (SEMEA) and with a scale of 1:50000. After cropping the image, the files were exported to the ArcGIS (10.5) software (ARCGIS, 2022) to join the attribute tables with the LULC classes containing the respective results, in order to analyze the possible cause of the LST variations.

For LULC, it was chosen to select the validated data from the Mapbiomas Annual Land Cover and Land Use Mapping project, which brings together a collaborative network in the areas of RS, biomes, land use, GIS and computer science. Using cloud processing and automated classifiers, developed and operated from the Google Earth Engine platform, allowed the generation of a historical series of annual maps and land use in Brazil (MAPBIOMAS, 2022).

The annual classification of land use of Mapbiomas is carried out using the Landsat satellite image (spatial resolution of 30 meters). Pixel-by-pixel classification algorithms and Machine Learning (ML) are used (SOUZA et al., 2020).

The LULC rasters were downloaded for the chosen years and, later, the study area mask was used to cut out the area of interest. In this study, Level 6 of the Mapbiomas classification was considered and the following classes of use and cover were found for all periods: a) Forest Formation; b) Savanna Formation; c) Forestry; d) Grassland Formation; e) Pasture; f) Mosaic of Agriculture and Pasture; g) Other non-vegetated areas; h) River, Lake and Ocean; i) Soybean; j) Other Temporary Crops and; k) Coffee.

The cut files were exported to the ArcGis software (ARCGIS, 2022) to join the attribute tables containing the LST results with the LULC. Finally, the mean of each year of the LST was calculated and the MAPBIOMAS classes were separated into: a) vegetation (Forest Formation, Savanna Formation and Grassland Formation); b) agriculture (Forestry, Pasture, Agriculture and Pasture Mosaic, Soy, Other Temporary Crops and Coffe); c) Other non-vegetated areas (Other non-vegetated areas) and; d) water resources (Water resources). Then, the data were crossed to verify the spatio-temporal variation of LST in each class of use and occupation.

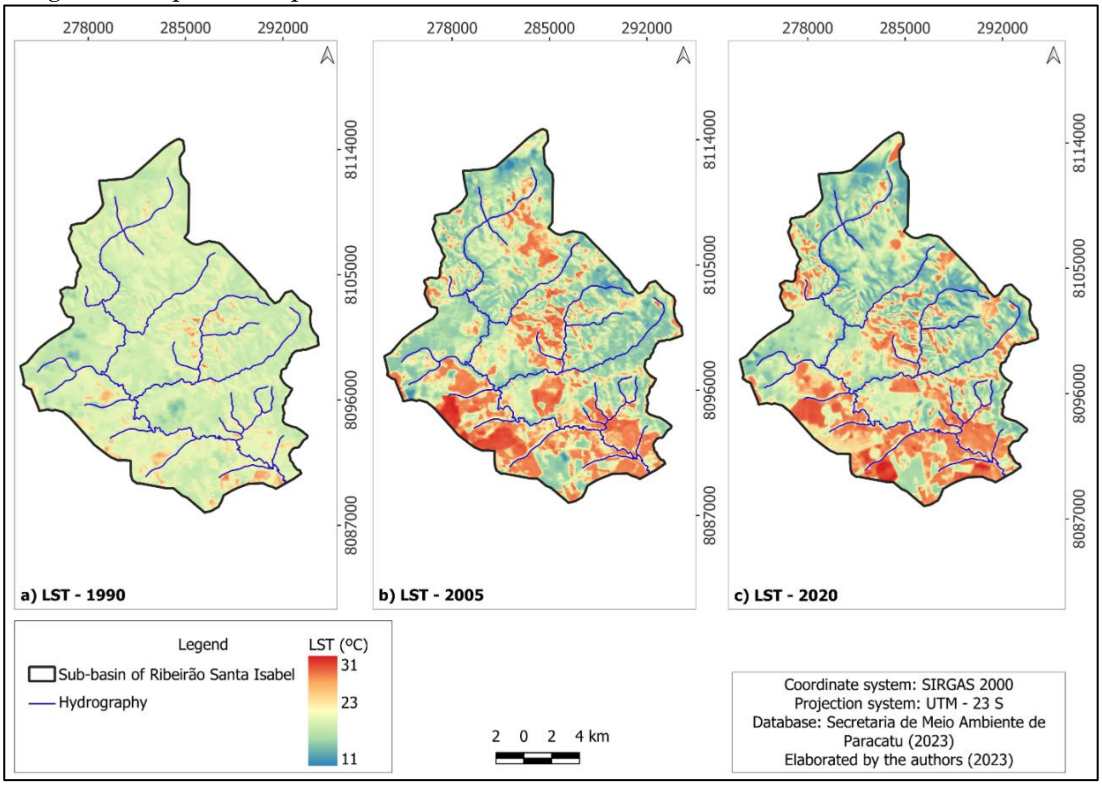
The behavior of vegetation and livestock classes was verified between the first and last year of the analyzed series and, in order to verify the influence of LULC on the behavior of LST, statistical analysis was carried out through the test of Tukey and at a significance level of 5%, the analysis between the mean values of the respective classes.

Finally, a layout containing the LST and LULC of the study area during the analyzed years was elaborated. Regarding the elaboration of the LST layout, these images were separated into classes – ranging between the minimum (11) and maximum (31) of the analyzed years, with their values expressed in degrees Celsius (°C). The values were classified so that it was possible to visually verify the variation of the parameters analyzed over the years.

RESULTS

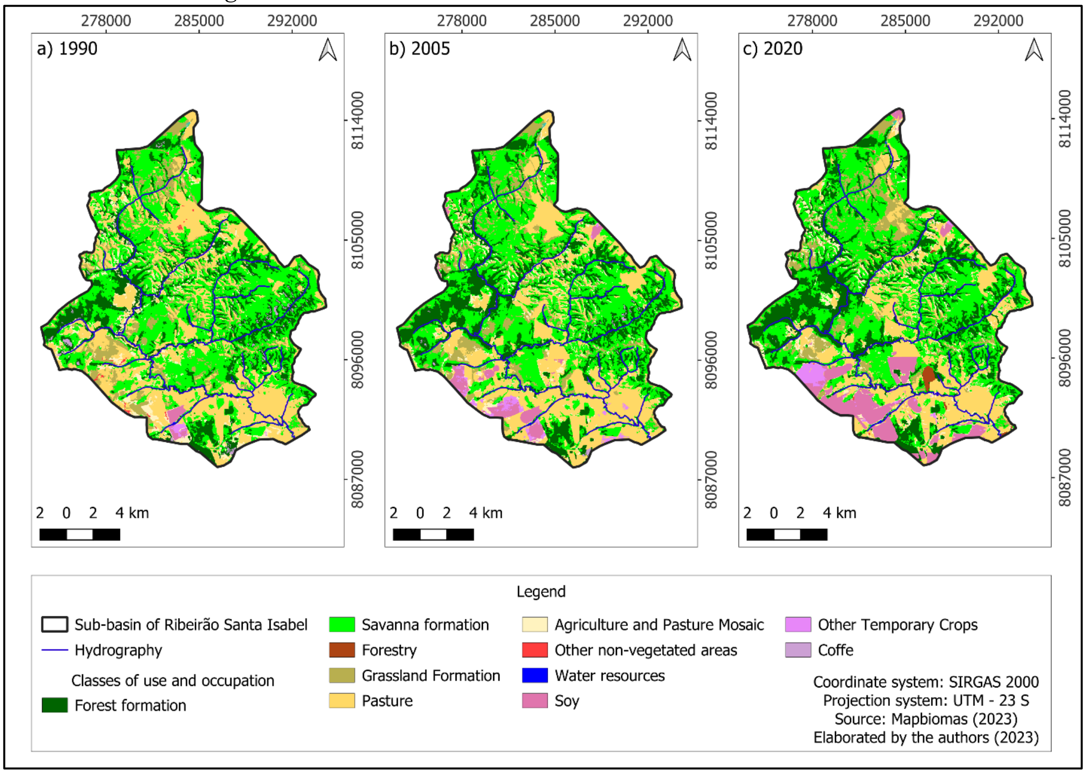
Figure 2 shows the results obtained for the spatio-temporal variation of the LST and, Figure 3, the LULC during the analyzed period. Table 2 presents the quantifications of LST due to LULC in the study area.

Figure 2 – Spatio-temporal variation of LST in the sub-basin of Ribeirão Santa Isabel.



Source: The authors (2023).

Figure 3 – LULC in the Ribeirão Santa Isabel sub-basin



Source: The authors (2023).

Table 2 – Quantification of the area (km²), percentage representation of the class (%), and the behavior of the minimum, maximum, mean LST, as well as its standard deviation.

1990						
	Area		LST			
Thematic class	Km²	%	Minimum (ºC)	Mean (ºC)	Maximum (ºC)	Standard deviation (ºC)
Vegetation	796,5	64,84	12,74	18,58	24,11	1,28
Agriculture	429,3	34,98	14,15	20,21	25,19	1,44
Unvegetated area	0,9	0,09	21,72	21,72	21,72	0,00
Water resource	0,9	0,09	23,20	23,20	23,20	0,00
Total	1227,6	100	17,95	20,93	23,55	0,68

2005						
	Area		LST			
Thematic class	Km²	%	Minimum (ºC)	Mean (ºC)	Maximum (ºC)	Standard deviation (ºC)
Vegetation	810,9	66,05	17,84	22,29	28,14	1,11
Agriculture	414,9	33,80	20,59	24,38	30,20	1,48
Unvegetated area	0,9	0,075	24,22	24,22	24,22	0,00
Water resource	0,9	0,075	22,82	22,82	22,82	0,00
Total	1227,6	100	21,36	23,42	26,34	0,64

2020						
	Area		LST			
Thematic class	Km²	%	Minimum (ºC)	Mean (ºC)	Maximum (ºC)	Standard deviation (ºC)
Vegetation	819	66,71	18,86	20,93	24,18	0,77
Agriculture	405,9	33,06	20,18	22,55	27,78	1,19
Unvegetated area	1,8	0,18	26,07	26,53	26,53	0,33
Water resource	0,9	0,05	21,77	21,77	21,77	0,00
Total	1227,6	100	21,72	22,98	25,06	0,57

Source: The authors (2023).

In general, the results corroborate those presented by the ZAP of the study area, which verified that the most expressive classes in the hydrographic sub-basin are related to the vegetative state, followed by the areas of culture and pasture, while the least expressive class was the water (ZAP, 2018).

It was possible to verify an association between the variation of the LST and the LULC. NourEldeen et al. (2020) and Guilherme et al. (2020) noted that LST is very sensitive to LULC. For example, in areas of forest formation, there was the presence of lower temperatures when compared to areas of exposed soil and savanna vegetation, and this remains to the detriment of agricultural areas. Another aspect in this sense occurs around the water resources, whose LST showed milder variations and values in relation to the other classes of LULC.

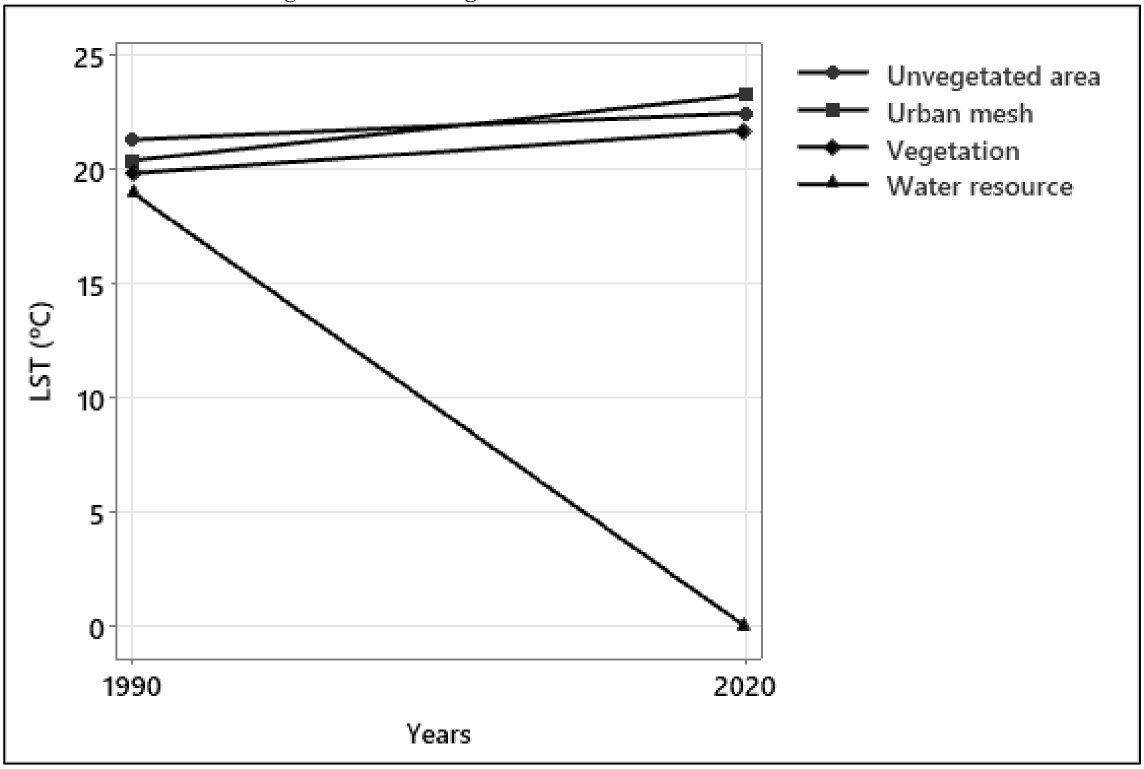
In relation to the non-vegetated area, there was an increase in the average variation of the LST, as well as an increase in the total area, as verified by Guha and Govil (2022), who concluded that the behavior of LST is closely related to the presence or absence of vegetation. These results are also similar to those presented by Carrasco et al. (2020), who concluded that while a certain amount of LST change may be related to external aspects and climate change events, changes in LULC types have significant implications for LST variation.

It is important to emphasize about the behavior of the average LST of the non-vegetated area class, in which the values presented an average growth close to 5º C. In opposition to this, the water class presented a decrease of approximately 1.5 ºC. These results corroborate the findings of Pal and Ziaul (2017), who found lower temperatures in regions of water resources and arboreal vegetation.

Regarding the LST water resources and its surroundings, in addition to considering that this class is relatively small, in relation to the other categories of LULC, changes in its LST may be related to its sensitivity to environmental water conditions. For example, areas that are silted or covered by hydrophytic vegetation, which is characterized by the eutrophication process, may present LST distinct from better quality and/or deeper water resources. Given this scenario, linked to the growth of the vegetation area, it is assumed that there has been an improvement in the environmental quality of the surroundings of this natural resource.

The increase in LST, caused by the conversion of areas from vegetation to agricultural production, reduces the volume of evapotranspiration. As it is a cycle, this directly interferes with the water availability available for consumption, as it changes the flow regime of the surface channels (MARTINS; GALVANI, 2020). The Figure 4 shows the variation of each class of LULC, in relation to LST, between the first and the last year of analysis.

Figure 4 – Average LST variation of LULC classes.



Source: The authors (2023).

The Table 3 presents the result of the statistical test applied between the classes and Figure 5, the spectral behavior of the vegetation and agriculture classes between the first and the last year of analysis.

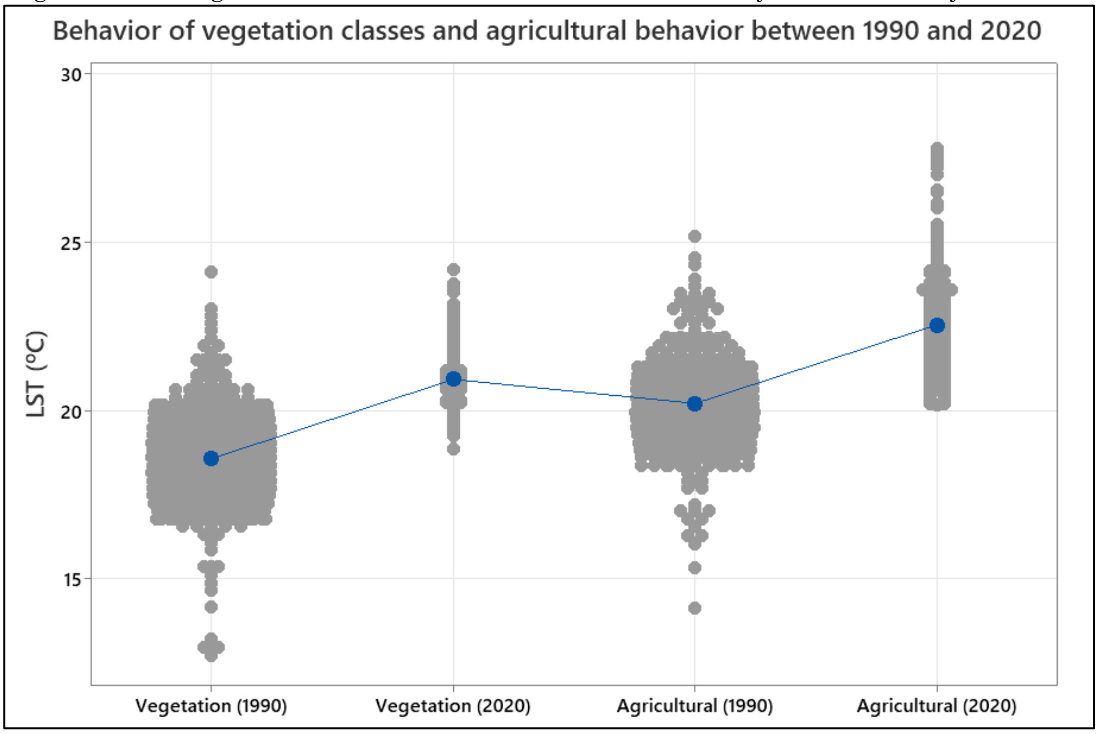
Table 3 – Tukey's test between the classes of agriculture and vegetation.

Factor	Sample number	Mean	Grouping
Agricultural (2020)	577	22,55	A*
Vegetation (2020)	885	20,93	B*
Agricultural (1990)	603	20,21	C*
Vegetation (1990)	885	18,58	D*

* Indicates that the difference between these means is statistically significant.

Source: The authors (2023).

Figure 5 – Graphical representation, through the Box Plot, presenting the spectral behavior of vegetation and agriculture classes between the first and last year of the analyzed series.



Source: The authors (2023).

The results of this study show an increase in vegetation areas and a decrease in the class of agriculture. According to Moisa et al. (2022), the conservation/conversion of the LULC is the main factor for the increase or not of the LST, and this is corroborated by verifying the Tukey test with the referred data, confirming that the LST's between the classes are, at a level of significance of 5%, different from each other, as well as Sarif and Gupta (2022), who found, when analyzing the influence of LULC on LST, greater vulnerability in agricultural land, followed by forests.

The agriculture class showed an average growth of 2.34 °C of its LST over the years. According to Fathizad et al. (2017), the presence of vegetation is associated with thermal comfort and the maintenance of the balance of the environment. However, given the scenario of a decrease in the percentage of the area in the sub-basin, it is possible to state that, most likely, the increase in LST is related to the intensity of activity and to the drastic changes of LULC in the area, according to related studies Wang et al. (2022), Wang et al. (2018), Lemes et al. (2020), Carrasco et al. (2020).

However, in addition to the externalities involving LST variations, the scenario exposed may also be related to the characteristic vegetation of the biome (Cerrado) and to the temporary crops present in the area, which are intermediate in size and are drier in relation to the forest formation, which depending on its physiognomic state, leads to greater variation in LST. Another consideration to be made is that, although the occurrence of fires was not considered in this study, the present ecosystem is more prone to fire, which plays an important role in defining the composition and structure of this type of vegetation (MIRANDA et al., 2018; BELMOK et al., 2019).

Finally, it is possible to affirm that the hydrographic sub-basin currently has a good level of protection of the springs, with a significant amount of vegetation throughout its extension, presenting a good Conservation Index (69.61%) (ZAP, 2018). It is also important to emphasize that soil and water conservation takes place in an integrated manner, that is, water is conserved by conserving the soil, and the growth of the percentage of vegetation area, as well as the decrease of the agricultural area in the watershed, indicates that conservation techniques for the Cerrado biome, as well as preservation measures through the regulatory and inspection body, such as the creation of the Parque Estadual de Paracatu, are having an effect.

CONCLUSIONS

It was possible to conclude that LULC changes are closely related to LST variations, mainly in non-vegetated areas.

In view of the increase in the percentage of the vegetation area and the decrease in agriculture, it is concluded that the conservation techniques implemented for the conservation of the Cerrado biome and the measures taken by the regulatory and environmental inspection body of the state of MG are having an effect on the sub-catchment basin of Ribeirão Santa Isabel.

The method used can be used as an important tool to analyze the effects of the spatio-temporal variation of the LULC, as well as its effects on the variations of the LST, providing a reliable database for the management and planning by the supply concessionaire and of the municipal executive power.

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AUTHORS CONTRIBUTION

Arthur Pereira dos Santos, Henzo Henrique Simionatto and Letícia Tondato Arantes were responsible for the research, methodology, writing, revising and editing. Renan Angrizani de Oliveira, Vanessa Cezar Simonetti and Jomil Costa Abreu Sales were responsible for project administration, resources, programs, supervision and formal review. Darllan Collins da Cunha e Silva was responsible for curation, data validation and work orientation.