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ANTHROPIC TRANSFORMATION INDEX OF THE URUSSANGA RIVER WATERSHED, SANTA CATARINA, BRAZIL

Índice de transformação antrópica da bacia hidrográfica do rio urussanga, santa catarina, Brasil

Índice de transformación antrópica de la cuenca del río Urussanga, Santa Catarina, Brasil

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ABSTRACT

The multitemporal analysis of land cover and use within the context of studies of watersheds is a tool for gathering information and understanding socio-environmental dynamics. This study aims to analyze the transformations that occurred in the landscape of the Urussanga River watershed (URW), intermediate region of Criciúma, Santa Catarina, Brazil, in three dates: 1986, 2005 and 2020. The thematic classification used the method of regions, the images used derive from the LANDSAT 5 and 8 satellite, the software Qgis, ArcGis 10.3 and IDRISI Selva were used in the digital processing of the images. In the thematic mapping, eight classes of land cover and use were defined. As an instrument to understand the anthropic pressure exerted in the basin, the Anthropic Transformation Index (ITA) was used. The results showed, within the analyzed period of 35 years, that the Urban Spot class had an expansion of 4% and Agriculture presented a slight increase of 0.19%, showing that the agricultural frontiers in the basin are consolidated. The Arboreal and Shrub Vegetation class was the one that had the greatest reduction, as it represented 40.04% in 1986, and 37.13% in 2020, a reduction of 3%, which corresponds to a suppression of 20 km² in the analyzed period. The Mineral Extraction and Dunes classes reduced by an average of 0.50%, the Pasture and Undergrowth classes remained with coverage without significant changes. The ITA calculated based on the mapping of land use and land cover presented a regular classification as a general result for the BHRU, with the greatest pressure exerted on the basin derived from the Urban class, Arboreal and Shrub Vegetation, and Agriculture. The results obtained in this research may serve as subsidy for future projects of planning and sustainable integrated territorial management of the geographical space within the basin.

Key-words: Landscape; Remote sensing; Geoprocessing; Territorial Management.

RESUMO

A análise multitemporal da cobertura e uso da terra dentro do contexto de estudos de bacias hidrográficas é uma ferramenta para o levantamento de informações e compreensão da dinâmica socioambiental. Este estudo tem como objetivo analisar as transformações ocorridas na paisagem da bacia hidrográfica do Rio Urussanga (BHRU), região intermediária de Criciúma, Santa Catarina, Brasil, em três datas: 1986, 2005 e 2020. A classificação temática utilizou o método de regiões, as imagens utilizadas derivam do satélite LANDSAT 5 e 8, foram utilizados os softwares Qgis, ArcGis 10.3 e IDRISI selva no processamento digital das imagens. No mapeamento temático foram definidas oito classes de cobertura e uso da terra. Como instrumento para compreender a pressão antrópica exercida na bacia foi utilizado o Índice de Transformação Antrópica (ITA). Os resultados apontaram dentro do período analisado de 35 anos, que a classe Mancha Urbana teve expansão de 4% e de Agricultura apresentou um leve aumento de 0,19%, mostra que as fronteiras agrícolas na bacia estão consolidadas. A classe Vegetação Arbórea e Arbustiva foi a que teve maior redução pois representava 40,04% em 1986, e 37,13% em 2020, uma redução de 3% que corresponde uma supressão de 20 km² no período analisado. As classes de Extração Mineral e de Dunas reduziram em média 0,50%, as classes Pastagem e Vegetação Rasteira, permaneceram com a cobertura sem alterações significativas. O ITA calculado com base no mapeamento de uso e cobertura da terra apresentou como resultado geral para a BHRU a classificação regular, sendo a maior pressão exercida sobre a bacia derivada da classe Urbana, Vegetação Arbórea e Arbustiva, e Agricultura. Os resultados obtidos nesta pesquisa poderão servir como subsídio para projetos futuros de planejamento e gestão territorial integrada sustentável do espaço geográfico dentro da bacia

Palavras-chave: Paisagem; Sensoriamento Remoto; Geoprocessamento; Gestão Territorial.

RESUMEN

El análisis multitemporal de la cobertura y el uso del suelo en el contexto de los estudios de cuencas hidrográficas es una herramienta para recopilar información y comprender la dinámica socioambiental. Este estudio tiene como objetivo analizar las transformaciones ocurridas en el paisaje de la Cuenca del Río Urussanga (URW), región intermedia de Criciúma, Santa Catarina, Brasil, en tres fechas: 1986, 2005 y 2020. La clasificación temática utilizó el método de regiones, las imágenes utilizadas fueron derivadas del satélite LANDSAT 5 y 8, en el procesamiento digital de las imágenes se utilizaron los softwares Qgis, ArcGis 10.3 e IDRISI selva. En la cartografía temática se definieron ocho clases de cobertura y uso del suelo. Se utilizó el Índice de Transformación Antrópica (ITA) como herramienta para conocer la presión antrópica ejercida en la cuenca. Los resultados mostraron que en el período de 35 años analizado, la clase Mancha Urbana tuvo una expansión del 4% y la Agricultura presentó un leve aumento del 0,19%, mostrando que las fronteras agrícolas en la cuenca están consolidadas. La clase Vegetación Arbórea y Arbustiva fue la que tuvo la mayor reducción, ya que representaba el 40,04% en 1986 y el 37,13% en 2020, una reducción del 3% que corresponde a una supresión de 20 km² en el período analizado. Las clases Extracción Mineral y Dunas se redujeron en un promedio de 0,50%, las clases Pastizales y Vegetación Rastrera se mantuvieron con cobertura sin cambios significativos. El ITA calculado a partir de la cartografía de uso y cobertura del suelo presentó como resultado general para la BHRU la clasificación regular, con la mayor presión ejercida sobre la cuenca derivada de la clase Urbana, Vegetación Arbórea y Arbustiva, y Agricultura. Los resultados obtenidos en esta investigación pueden servir de subsidio para futuros proyectos de planificación y gestión territorial integrada sostenible del espacio geográfico dentro de la cuenca.

Palabras clave: Paisaje; Teledetección; Geoprocesamiento; Ordenación del territorio

1 INTRODUCTION

Understanding and evaluating changes in the landscape is a way to contribute to territory planning and management, since it enables decision-making regarding the rational use, protection and conservation of nature (MACEDO et al., 2013).

The main changes in landscape include potentially detrimental effects on land occupation and usage, such as the reduction and fragmentation of forests and undergrowth, as well as an increase in the number of areas allocated for forestry and agriculture. (HAINES-YOUNG; CHOPPING, 1996; PAVÃO, 2017). These activities, in turn, result in the destruction of primary vegetation, as well as water and soil pollution due to the change in land cover, thus contributing to loss of biodiversity, habitat destruction, to the reduction of ecosystem services and to climate change (HAINES-YOUNG; CHOPPING, 1996; SOARES FILHO et al., 2005; PAVÃO, 2017; FEARNSIDE, 2020).

Mapping the earth's surface using orbital imaging has been a commonly used method since the 1950s, and has gained ground with the advancement of remote sensing science, whose purpose is to aid researchers in understanding land cover and use, and in sustainable planning of the territory, monitoring, and rational and orderly management of the physical environment (RUDORFF, 2007; RODRIGUES, 2018).

This field of science enables an agile, reliable and recurrent acquisition of cartographic information, facilitating the continuous detection of changes that occur across space and time in the area of a watershed (the unit of analysis of this research), having applications in environmental studies on these areas, especially those with histories of environmental degradation in their territory.

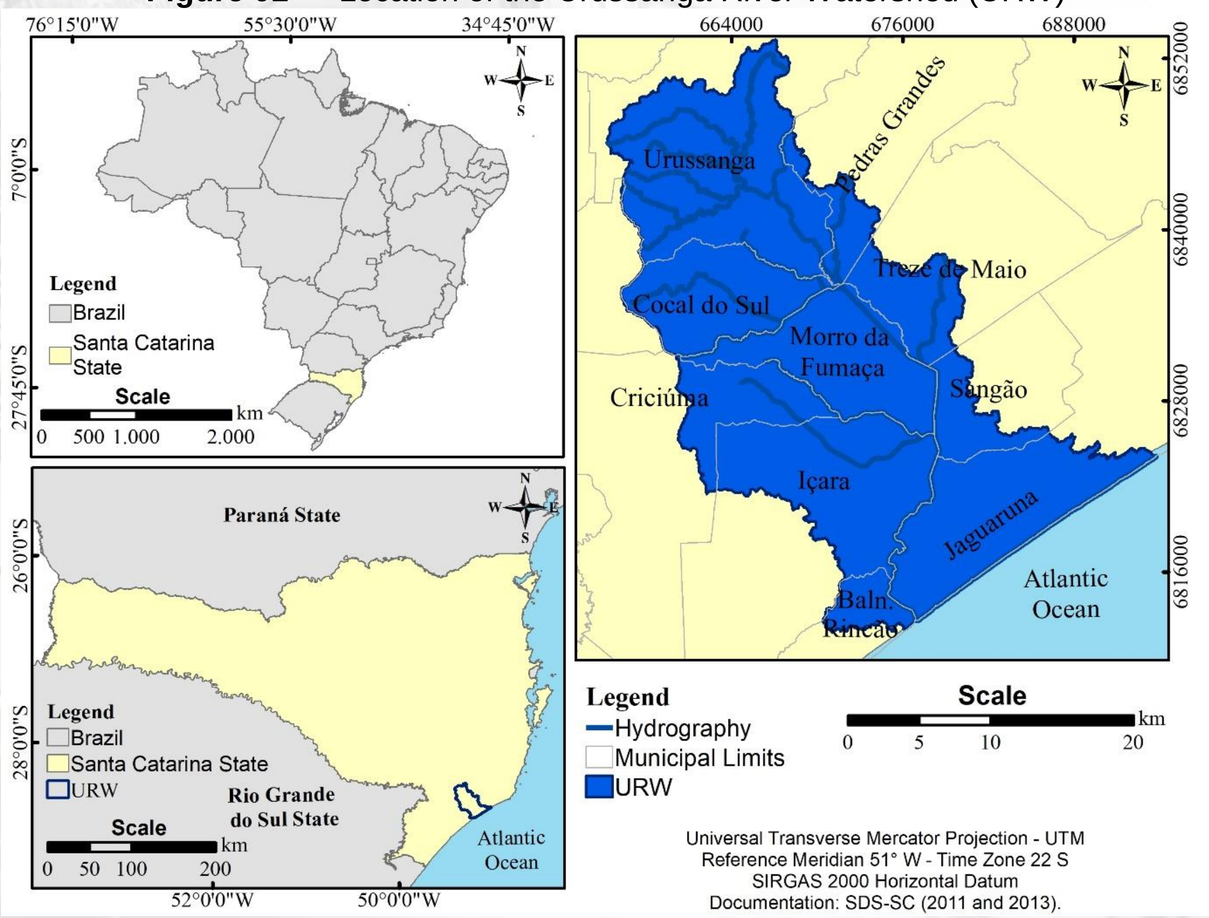
Combined with cartographic information, a type of methodology that contributes to the assessment of anthropic pressures on the environment exerted over the territory under analysis is the Index of Anthropic Transformation (ITA), proposed by Lémechev (1982) and modified by Mateo Rodriguez (1984), whose objective is to quantify the degree of landscape modification taking into account the land-use variable.

The Urussanga River watershed (henceforth referred to as "URW") has a history of environmental problems characterized by the intensive use of its natural resources, and resulting mainly from coal extraction, extensive agriculture and, more recently, from the expansion of urbanization. Given this scenario, this study aims to analyze the transformations in the URW's landscape, on three years — 1986, 2005 and 2020 —, as well as the anthropic pressures exerted on the watershed area, using the Anthropic Transformation Index (ITA).

1.1 Location and characterization of the studied area

The studied area comprises the URW, which is located in the intermediate region of Criciúma, in the southern portion of the state of Santa Catarina (Figure 01). There are ten municipalities situated in the watershed area.

Figure 01 — Location of the Urussanga River Watershed (URW)



Source: the authors.

The URW comprises Hydrographic Region 10 (RH 10) along with the Araranguá river watersheds and the left margin affluents of the Mampituba river, which are, in turn, part of the South Atlantic hydrographic region (BRASIL, 2017). The watershed has an extension of 679.68 km², constituting the smallest of the three basins in RH 10, corresponding to 0.70% of the territory of Santa Catarina (ADAMI, CUNHA, 2014; GALATTO et al., 2015).

Urussanga River, the main watercourse of the URW, is formed by the confluence of the Carvão River and the Maior River. These rivers meet in the neighborhood of Nova Itália, in the municipality of Urussanga. The quality of the waters in this watershed is highly impaired caused by the use of pesticides, urban and industrial sewage, pig waste and waste from coal extraction (DIAS, et al., 2020).

Coal mining was the most prominent activity in this region's economy, resulting in the degradation of the soil, air and water, in particular by acid mine drainage (AMD), composed of heavy metals sCarolauch as iron, manganese and zinc, in addition to high concentrations of sulfates (CAROLA, 2011; VOLPATO, et al., 2017; SCHNACK, et al., 2018).

The watershed houses economic activities represented by the ceramic, plastic, metal-mechanical, and mining (coal, clay, sand and fluorite) sectors, as well as agriculture, with the cultivation of rice and corn, which move the local economy, along with swine, poultry and cattle farming, compromising the quality of the URW and generating loss in the region's biodiversity (MATTEI, 2011; CITADIN, 2014).

2 METHODOLOGY

Initially, a spatial database was structured in vector and matrix formats necessary to carry out the study. Later, a multitemporal analysis of orbital images with data treatment in a digital image processing (DIP) environment was applied, and, subsequently, the ITA was calculated, based on the classes of land cover and use

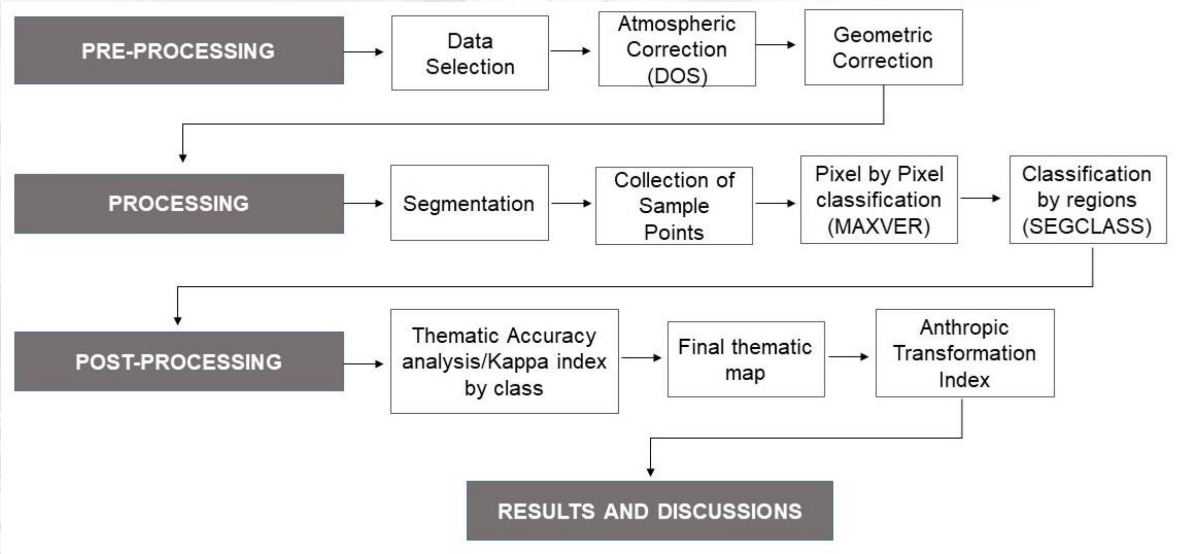
2.1 Processamento Digital de Imagens Digital Image Processing

In order to conduct the DIP and prepare the thematic maps of land cover and use, it was necessary to define the time series. The images were selected based on the following criteria: temporality, respecting a time space of 35 years; low cloud cover; same spatial resolution; and a seasonality between the end of April and the month of September.

The dates of the images were selected based on the history of change in land cover and use, on the expansion of the (open air) mineral coal industry in the 1980s, on the intensification of the urbanization process in the studied area and on the temporal seasonality of the period for the irrigated rice cultivation cycle in the watershed, which occurs between the beginning of August and the month of January.

The selected images correspond to the Landsat-5 sensor system, *Thematic Mapper* sensor (TM), on the following dates: 06/10/1986 and 05/29/2005; and to the Landsat-8 sensor *Operational Land Imager* (OLI), on the following date: 07/07/2020. The images have a spatial resolution of 30 meters. Figure 02 summarizes the steps of the DIP.

Figure 02 – Flowchart of the Digital Image Processing steps



Source: the authors.

Color composition (RGB) was applied in order to interpret the images and define eight classes of land cover and use: Agriculture, Dunes, Mineral Extraction, Water Mass, Urban Spot, Pasture and Undergrowth, Shade, Arboreal and Shrub Vegetation. The regional classification method was used to classify the images (MENESES; ALMEIDA, 2012). The results obtained with the adopted classification method were validated based on the Kappa index and on global accuracy (LANDIS & KOCH, 1977). The results obtained by the Kappa index can be found in table 01.

Table 01 – Kappa Values and Global Accuracy

Year	Kappa	Global Accuracy	Mapping Quality
1986	0,8514	0,8700	Excellent
2005	0,7981	0,8233	Very Good
2020	0,8857	0,9000	Excellent

Source: the authors.

In this index, the value closest to 1 indicates that there is (perfect) concordance and the closer to 0, the greater the indication that the concordance is random (null).

2.1 ITA Application of the Anthropic Transformation Index – ITA

The ITA was developed in 1982 by the scholar Lémechev, and Mateo (1984) applied it to environmental studies. The index's objective was to quantify the anthropic pressure on the environment, resulting from changes in land cover and use in relation to any environmental and spatial units — watersheds, environmental protection areas, and national parks (GOMES SOBRINHO, 2018).

The ITA is used jointly with geoprocessing and environmental monitoring. The quantification of changes in the environment through the ITA considers the cover and use of land as a variable. It also has advantages in terms of identifying areas with a high degree of modification, and assists in decision-making, maintenance and environmental preservation (COCCO; RIBBERY; GALVANIN, 2015).

According to Guglielmeli, et al., (2018), the ITA relies on the elaboration of thematic maps, taking into account land cover and land use variables. Ortega and Carvalho (2013) report that the ITA has been used in geoecological studies in order to quantify anthropic pressures on the environment, in addition to environmental protection areas, and to identify alterations in watershed and national park regions.

Based on the results of the classification, validation and final mapping, the ITA calculation was applied, as per Mateo Rodriguez's (1984) studies, in order to provide information on the changes that occurred within a time interval as a consequence of human actions. The index was calculated based on the classified map of land cover and use and took into account the area occupied by each class and the weight was determined by the degree of anthropization, which ranges from 0 to 10, providing an analysis of the landscape's transformation (GOUVEIA; GALVANIN; NEVES, 2013; SILVA et al., 2019).

Eight researchers from different research areas — Biological Sciences, Engineering and Geography — were consulted when assigning weights to the classes. After the questionnaires were answered and returned, the weights were tabulated and the results can be observed in table 02.

Table 2 – ITA weights assigned to the classes by researchers

Land cover and use classes	ITA weights
Agriculture	6,11
Dunes	2,50
Mineral Extraction	8,67
Water Mass	1,67
Urban Spot	7,78
Pasture and Undergrowth	4,67
Shade	0
Arboreal and Shrub Vegetation	1,22

Source: the authors.

In establishing the consensus of the ITA classification, the works of Cruz (1984), Silva et al. (2019), and Gouveia, Galvanin and Neves (2013) were considered, which classified and used the following class intervals: Somewhat Degraded (0 - 2.5), Regular (2.5 - 5), Degraded (5 – 7.5) and Very Degraded (7.5 – 10). The studies conducted by Mateo Rodriguez (1984) based on Lémechev (1982) propose the following equation for calculating the ITA:

$$ITA = \sum (\%\ USE \times WEIGHT)/100 \qquad \textbf{Eq.1}$$

Where:

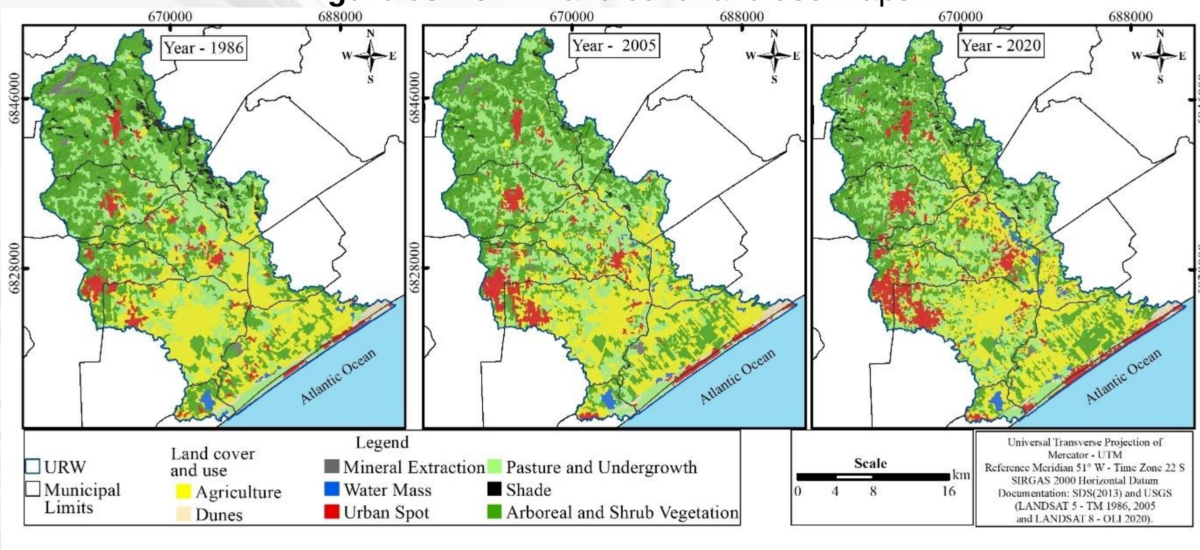
USE = area in percentage values of the cover and land use class;

WEIGHT = weight attributed to the different types of land cover and use in terms of the degree of anthropic alteration; it ranges from 1 to 10, where weight 10 indicates the greatest changes.

3 RESULTS AND DISCUSSIONS

The data presented here will be analyzed jointly, taking into account the land cover and use lasses identified in the URW. Figure 03 and table 03 show the results of the thematic classes for each year under study.

Figure 03 - URW land cover and use maps



Source: the authors.

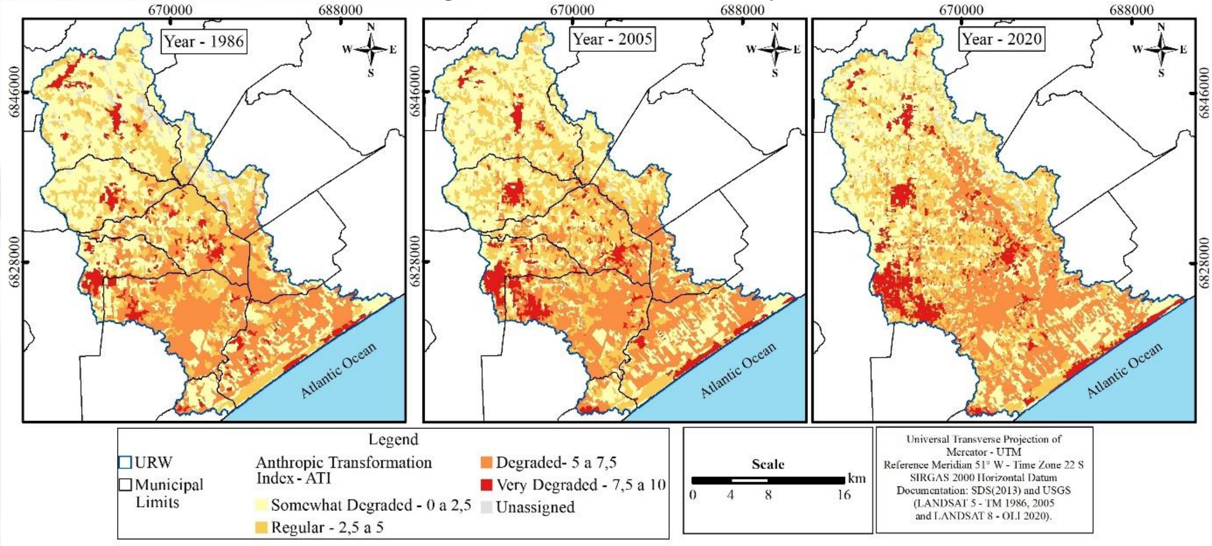
Table 03 – Measurement of the land cover and use classes in the URW

Land cover and use classes	Area (km²) 1986	Rate (%) 1986	Area (km²) 2005	Rate (%) 2005	Area (km²) 2020	Rate (%) 2020
Agriculture	183,23	26,96	178,53	26,27	184,52	27,15
Dunes	8,41	1,24	9,94	1,46	5,95	0,88
Mineral Extraction	6,55	0,96	3,55	0,52	2,24	0,33
Water Mass	6,19	0,91	5,87	0,86	9,94	1,46
Urban Spot	31,71	4,67	45,23	6,66	59,10	8,70
Pasture and Undergrowth	156,05	22,96	184,57	27,15	157,14	23,12
Shade	15,39	2,27	2,67	0,39	8,47	1,25
Arboreal and Shrub Vegetation	272,20	40,04	249,34	36,68	252,36	37,13
Total	**679,75**		**679,75**		**679,75**	

Source: the authors.

The results of the ITA based on the mapping of land cover and use are presented in order to understand the degree of anthropic pressure upon the territory over the years 1986, 2005 and 2020. Figure 04 and table 04 show these results.

Figure 04 – URWITA Maps



Source: the authors

Table 04 – Index of ITA areas

ITA	Area (km2) 1986	Rate (%) 1986	Area (km2) 2005	Rate (%) 2005	Area (km2) 2020	Rate (%) 2020
Somewhat Degraded	286,80	42,19	265,16	39,01	268,27	39,47
Regular	156,05	22,96	184,57	27,15	157,14	23,12
Degraded	183,23	26,96	178,53	26,27	184,52	27,15
Very Degraded	37,27	5,63	48,7	7,18	61,34	9,02
Unassigned	15,39	2,27	2,67	0,39	8,47	1,25
Total	**679,757**		**679,759**		**679,758**	

Source: the authors.

Table 05 shows the results obtained from the ITA for the three dates. The watershed was classified with a Regular index (2.5 – 5) on all analyzed dates. It can observed that the ITA during the analyzed period has been gradually increasing, due to the intensification in agricultural activities and urbanization.

Table 05 – ITA Results

	Rate (%)				ITA Results		
Classes of land cover and use	**1986**	**2005**	**2020**	**ITA weights**	**1986**	**2005**	**2020**
Agriculture	26,96	26,27	27,15	6,11	1,65	1,60	1,66
Dunes	1,24	1,46	0,88	2,50	0,03	0,04	0,02
Mineral Extraction	0,96	0,52	0,33	8,67	0,08	0,05	0,03

Water Mass	0,91	0,86	1,46	1,67	0,02	0,01	0,02
Urban Spot	4,67	6,66	8,70	7,78	0,36	0,52	0,68
Pasture and Undergrowth	22,96	27,15	23,12	4,67	1,07	1,27	1,08
Shade	2,27	0,39	1,25	0,00	0,00	0,00	0,00
Arboreal and Shrub Vegetation	40,04	36,68	37,13	1,22	0,49	0,45	0,45
Total	**100**	**100**	**100**	**-**	**3,70**	**3,93**	**3,94**

Source: the authors.

The Urban Spot (ITA 7.78), Mineral Extraction (ITA 8.67), and Agriculture (ITA 6.11) classes were attributed the highest values by the experts. In 1986, the aforementioned classes had an area of 221.5km², with an increase in 2005 to 227.3km², continuing to grow in 2020 to 245.8km²: about 36% of the watershed's territory.

The Mineral Extraction class refers to open-pit mining areas, such as the extraction of mineral coal, clay, loam, fluorite, sand, pebbles, among others. The main highlight in this context is the mining of coal and sand, as the distinction from other types of mining has not been mapped out due to the limitations imposed by the spectral resolution of the images, which do not enable a distinction of this activity in the URW.

The URW is located in the Carboniferous District of the Southern Region of the State of Santa Catarina, which is characterized as being a remarkable extraction center. In addition to the URW, the watersheds of the Tubarão and Araranguá rivers are also part of the Carboniferous District.

The Mineral Extraction class had a reduction, which corresponds mainly to a decrease in open-pit mineral coal extraction activities. This decrease occurs in the wake of Public Civil Action (ACP) No. 93.80.00533-4, popularly known as the Coal ACP, where the defendants were coal companies. As a result this public action, the defendants must recover the environmental passives generated by coal mining between 1972 and 1989 (LADWIG; DAGOSTIM, 2017; SUTIL, 2019).

In the URW, the ACP areas total 7.405 km2, being present in the municipalities of Urussanga, Cocal do Sul, Morro da Fumaça and Içara. Another factor that may be related to this spatial reduction is the crisis caused by the deregulation of the region's coal sector promoted by the Federal Government in 1990, the imposition and rigidity of environmental laws, and the organization of environmental movements (LADWIG, DAGOSTIM, BACK, 2018), factors that together contributed to the reduction of the areas of mineral coal extraction at the URW. The economic development of the region, based on Mineral Extraction, resulted in landscape changes that had significant impacts on the territory.

The Urban Spot is characterized by spots of networks and urban elements, such as buildings, road systems, plots, and buildings, which represent a city (BHERING, 2019). The Urban Spot class is present throughout the territory of the URW and over the analyzed period, it grew by 4.03%. In 1986, the Urban Spot represented 4.67% (31.715 km2) of the watershed's territory, increasing to 6.66% (45.239 km2) in 1986, and to 8.70% (59.106 km²) in 2020.

The increase in the urban population, as well as the Urban Spot, already evidenced in the 1980s, is related to the diversification of industrial production, motivated by the extraction of mineral coal and by the ceramic tile sector (DE LUCCA, 2015; GOULARTI FILHO, 2016). Since the 1990s, the coal sector has been in crisis. However, cities continued to grow, thanks to the economic diversification of the region, with the emergence of new industries, such as clothing, footwear, frames, metal-mechanics and chemistry (ADAMI; CUNHA, 2014). The highest concentrations of the Urban Spot are located in the western part of the watershed, encompassing the municipalities of Cocal do Sul, Criciúma and Içara. Among these, Criciúma holds greater importance in the state urban hierarchy, being considered the regional capital (SANTOS, 2021), attracting investments and population, due to the whole of its economic dynamics (DE LUCCA, 2015).

The Agriculture class remained stable, occupying around 27% of the watershed's territory during the analyzed period, demonstrating that the agricultural frontiers concentrated on the cultivation of irrigated rice and corn in the watershed are consolidated considering the management practices adopted.

Every region has its ecological capacity and support and the private and inappropriate use of the soil can cause negative effects on the environment (GOMES SOBRINHO, 2018). Given this context, the areas used for rice cultivation are predominantly irrigated by flooding and require a large volume of water (PINTO et al., 2016).

According to Back, Deschamps and Santos (2016), the development of irrigated rice activities (pre-germinated), when close to springs, pose serious risks of contamination by agrochemicals, generating concern for both underground and surface water resources. The mapping of irrigated rice in

Santa Catarina, carried out by EPAGRI (Agricultural Research and Rural Extension Company of Santa Catarina), in the 2018/2019 harvests, the area of cultivation of this cereal in the URW exceeded 33 km².

The floodplain areas were transformed into plots to receive the floodwater necessary for the development of irrigated rice cultivation. Furthermore, roads, irrigation and drainage channels, bridges and culverts, as well as leveling and flattening, necessary for cultivation, were built. Such construction works contributed to the flattening of the relief, to the removal of riparian forest and rectification of watercourses, increasing the flow speed of rainwater drainage and propitiating siltation (BELLOLI, 2016).

The Arboreal and Shrub Vegetation class comprises the forest formations in the process of succession (secondary vegetation) as well as the areas of pine and eucalyptus plantation, since it is not possible to separate the two formations due to the radiometric and spatial limitation of the images used. DIAS, et al. (2020) found the same limitation when conducting their study in the watershed. The Arboreal and Shrub Vegetation class had the greatest reduction as it represented 40.04% in 1986, and 37.13% in 2020 — a 3% reduction that corresponds to a suppression of 20 km² in the analyzed period.

This class is predominant from the north to the west of the watershed, especially around the water dividers. The relief in this area is predominantly of the steep slope and the mountainous types. These are steeper reliefs, which allow for limited accessibility, making it difficult to explore these areas.

The territory of the URW is encompassed by the Atlantic Forest biome, where the phytoecological regions of the Dense Ombrophilous Forest and Coastal Vegetation (*restinga*) stand out. This biome has suffered intense anthropic pressure since colonization, going through economic cycles even to present days with urban and agricultural expansion, activities that propitiated the fragmentation of the native forest, the insertion of exotic species and the reduction of forest cover (JUST et al., 2015).

The Dunes class is located on the banks of the watershed, in the municipalities of Balneário Rincão and Jaguaruna. This class has undergone quantitative changes over the years. In 1986, this class covered an extension of 8.410 km², which represented 1.24% of the total territory of the basin, exceeding 9.947 km² in 2005. This small increase may be related to the natural process of displacement of the sands that make up the dunes (PEIXOTO, 2017). In this case, possibly, a dispersion of the existing dunes. Between 2005 and 2020, the class in question had a reduction of 3.988 km²,

occupying 0.88% of the watershed's territory. While the Dunes class suffered a reduction in 1986, 2005 and 2020, other classes saw expansions in their areas. The Dunes were converted mainly into Urban Spot (28.09%) and Pasture and Undergrowth (14.47%).

In the municipality of Jaguaruna, the Urban Spot expanded over the Dunes area by 2.013 km2 (1986-2020). This process was also verified in the studies of Peixoto (2017) and Dias et *al*. (2020), exploring other coastal regions of Santa Catarina. According to Dias et al. (2020), the urbanization of Santa Catarina's coast occurred in an accelerated and disorderly manner, generating a series environmental impacts.

Coastal dunes play a key role in the constitution of the continent's first line of defense against the incidence of large waves and rises in the sea level during the passage of storms. In this way, dunes can guarantee the safety of properties and people who inhabit the region adjacent to them (LARSON et *al*., 2004). When they are removed, an imbalance is caused in the beach-dune system, exposing the beach to marine erosion (PORTZ et *al*., 2016). In the region, undertows are common, and, without the protection of the dunes, the sea is able to advance over the coastal cities.

The Water Mass class for 1986 was 6.191 km², decreasing to 5.876 km² in 2005, followed by an increase, in 2020, to 9.942 km², now occupying 1.46% of the basin's territory. This reduction between 1986 and 2005 may be related to the siltation of coastal lagoons, due to anthropic actions (PORCHER et *al*., 2010; BURGUEÑO et al., 2013).

Between 2005 and 2020, the Water Mass class expanded its area by 4.066 km². This expansion was identified on the banks of the Urussanga River, in the municipalities of Morro da Fumaça and Sangão. In these places, abandoned pits were filled with rainwater after clay extraction (SANT'ANA, 2008). Over the course of the analyzed period (1986-2020), the Water Mass class was converted mainly into Urban Spot (22.32%) and Pasture and Undergrowth (7.53%).

Regarding the quality of the waters of the Urussanga River and its tributaries, it is one of the worst in the state of Santa Catarina, due to its potability (PRHBRU, 2019). Among the agents responsible for the degradation of these resources are the use of pesticides, sanitary and industrial effluents, and, as a main pollution factor, the effluents from coal mining (DAM) (PRHBRU, 2019). Of the rivers that make up the URW, those located on the right bank — America, Carvão, Deserto, Cocal, Ronco D'água, Linha Anta, Três Ribeirões and Içara — have their springs or tributaries in areas close to the ACP. For this reason, they may present contamination resulting from the extraction of mineral coal.

It is important to emphasize that, just as surface resources are compromised by different sources of pollution, underground resources are little explored and are vulnerable to contamination by different industrial activities and urban effluents. Thus, it is important to determine the degree of vulnerability of aquifer systems, as a necessary tool in planning and executing measures for the protection these springs, as well as for the management of water resources for the watershed.

The environment can be degraded in several ways. The consequences of the Urban Spot, Mineral Extraction and Agriculture classes on the territory of the URW synthesize the degradation of soil, vegetation and water, associated with loss of environmental quality, directly impacting the transformation and quality of the landscape.

In general, these classes represent about 56.4% of the ITA in the watershed, documenting a situation of “Degradation” in the landscape due to the degree of anthropic interference, which becomes concerning with the advancement of urbanization.

Furthermore, the area of the Pasture and Undergrowth class remained stable, presenting only a small decline after 2005 so that the Agriculture class could expand. In 1986, this class occupied an area of 156.052 km² (22,96%), increasing in 2005 to 184.575 km² (27,15%), and reducing to 157.140 km² in 2020, occupying around 23.12% of the watershed's total area.

4 CONCLUDING REMARKS

The results obtained with this research achieved the objective outlined, as they demonstrate the changes in land cover and use in the analyzed periods, highlighting the Urban Spot class, which presented an expansion in its total area and a concomitant increase in the population residing in the watershed region without adequate territory planning and management.

Another highlight is the reduction in the Arboreal and Shrub Vegetation class, which is attributed to the expansion of agricultural activities, in conjunction with the shrinkage of the Dunes area. The latter being related to urban expansion mainly on the coast, and resulting, largely, in the conversion of areas that previously belonged to the Dunes class and which were converted into Urban Spot and Pasture and Undergrowth classes.

On the other, more positive, hand, 49.56% of the Mineral Extraction class was converted into areas of Arboreal and Shrub Vegetation, and 13.01% of the class was converted into areas of Pasture and Undergrowth. The reduction of this class, consisting primarily of coal extraction areas, is directly related to the advancement of the Environmental Recovery Plans (PRADs).

A concerning point in the analysis of the land cover and use classes that showed an increase in their area in terms of territorial extension within the analyzed period, however, is the Urban Spot class with a significant increase of 27.391 km². The expansion of these areas is related to the intensification of the urbanization process that has emphatically been occurring since the 1980s, thus increasing the impacts on the territory.

The results of the research demonstrate a tendency towards an expansion of URW Urban Spots, especially taking over other classes such as Pasture and Undergrowth and Agriculture, and towards a reduction of Mineral Extraction areas (coal).

These results allowed us to understand the multi-temporal dynamics of land cover and use within the analyzed period. An increase in anthropic pressures on various covers and uses presented here was observed, as well as a general increase in ITA values between the beginning and end of the analyzed period from 3.70 to 3.94.

Based on the results obtained, the use of other methods and studies that aim to characterize in a more detailed and precise way the changes in land cover and use in the URW is recommended. The use of orbital images with a higher spatial resolution, aiming at the differentiation of forest cover into native species and areas of reforestation and forestry is also recommended. Furthermore, studies that analyze the current quality of water resources and existing vegetation (native areas and forestry) are needed as well. Lastly, monitoring and adequate territorial planning of the URW, linked to scientific research aimed at the proper management of this territory and its conservation and preservation are also advisable.

Finally, the expectation is that the methodology used in achieving this research's results will be able to aid projects that can contribute to the planning and integrated territorial management of the geographical space.

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