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Land use and occupation in the karst landscape of the Sergipe basin

Uso y ocupación del suelo en el paisaje cárstico de la cuenca de sergipe

Uso e ocupação da terra na paisagem cárstica da bacia Sergipe

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Abstract

Due to the geological context, the karstic landscape presents significant degrees of fragility constituting environments susceptible to environmental impacts. This paper aims to characterize the use and occupation of land in karstic landscape environments of the Sergipe Basin. The analytical bases of the research were based on secondary data made available by official government agencies in their three spheres, such as IBGE, UNDP, among others and field work. The investigative results show that the multiple uses of soil in the traditional karst of the Sergipe Basin, has been devoid of prior planning, occupying significant parts of the land in its most diverse economic practices without the slightest concern as to how activities can directly and / or indirectly affect natural systems.

Keywords: karst landscape; land use and occupancy; environmental fragility; Sergipe basin; Sergipe.

Resumen

Debido al contexto geológico, el paisaje kárstico presenta grados significativos de fragilidad constituyendo ambientes susceptibles a impactos ambientales. Este trabajo tiene como objetivo caracterizar el uso y ocupación del suelo en ambientes de paisaje kárstico de la Cuenca de Sergipe.

Las bases analíticas de la investigación se basaron en datos secundarios puestos a disposición por organismos oficiales de gobierno en sus tres esferas, como IBGE, PNUD, entre otros y trabajo de campo. Los resultados de la investigación muestran que los múltiples usos del suelo en el karst tradicional de la Cuenca de Sergipe, ha estado desprovisto de planificación previa, ocupando partes significativas de la tierra en sus más diversas prácticas económicas sin la menor preocupación en cuanto a cuánto las actividades pueden afectar directa y/o indirectamente los sistemas naturales.

Palabras clave: paisaje kárstico; uso y ocupación del suelo; fragilidad ambiental; cuenca de Sergipe; Sergipe.

Resumo

Devido ao contexto geológico, a paisagem cárstica apresenta graus significativos de fragilidade se constituindo em ambientes suscetíveis a ocorrência de impactos ambientais. Este artigo visa caracterizar o uso e ocupação da terra em ambientes da paisagem cárstica da Bacia Sergipe. As bases analíticas da pesquisa foram alicerçadas nos dados secundários disponibilizados pelos órgãos oficiais do governo em suas três esferas, a exemplo do IBGE, PNUD, entre outros e trabalhos de campo. Os resultados investigatórios mostram que os múltiplos usos do solo no carste tradicional da Bacia Sergipe, tem sido desprovido de planejamento prévio, ocupando partes significativas das terras em suas mais diversas práticas econômicas sem a menor preocupação do quanto as atividades podem afetar direta e/ou indiretamente os sistemas naturais.

Palavras-chave: paisagem cárstica; uso e ocupação das terras; fragilidade ambiental; bacia Sergipe; Sergipe.

Introduction

Environmental planning directed towards a territorial management policy in areas transformed by land use and occupation, increasingly shows the need to think about ways to balance socioeconomic activities with the potentialities and restrictions of nature, with a view to maintaining sustainable conditions. suitable for society.

It is known that negative aspects printed on the landscape mark the civilizing process. This process revisits the risks of the economic development models adopted, such as the expansion of agricultural and mining activities over natural areas; intense industrialization; military conflicts on a regional, national and global scale; high

consumption patterns; vertiginous demographic growth; large urban agglomerations; the degradation of water resources, soil, air, among others.

Among the landscapes in which some of these events occur are those developed on carbonate rocks of karst origin, consisting of diverse and fascinating environmental scenarios on a world scale. There are the largest springs and groundwater sources on the planet, they are unique 'habitats' for rare animals and their caves preserve prehistoric material for millennia.

Karst, according to Karmann (2003), is a landscape where chemical weathering through the dissolution of the host rock determines the relief forms. Due to the geological context that enabled its formation, it presents significant degrees of fragility, constituting environments susceptible to the occurrence of environmental impacts, allowing easy contamination of its groundwater. In Sergipe, this process does not occur differently, lacking in-depth studies on the subject.

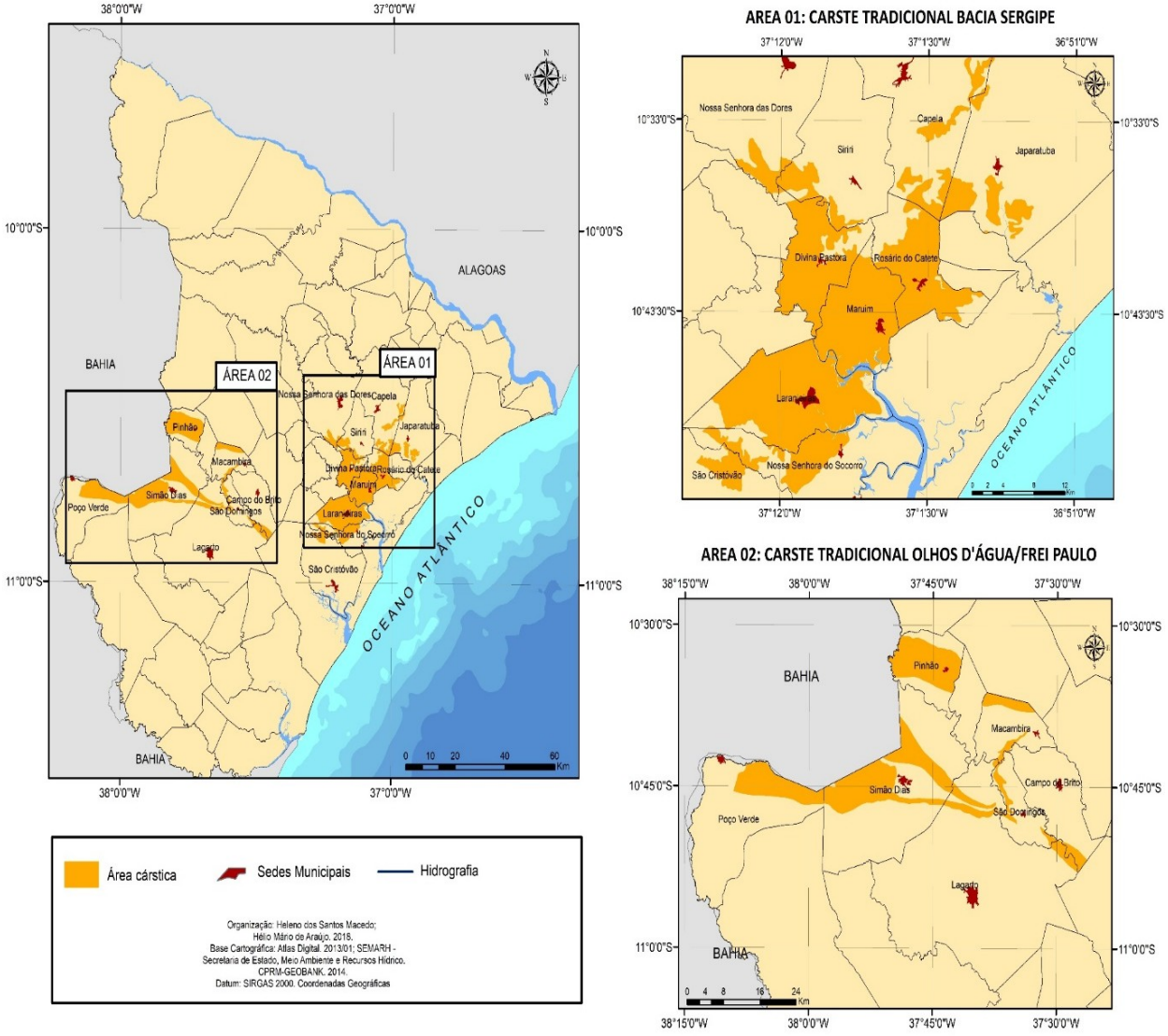
This article, for its pioneering approach to the subject at the state level, aims to characterize the use and occupation of land in environments of the karst landscape of the Sergipe Basin, to help in the search for a compatibility of the sustainable use of the environment in the face of urban expansionism and various activities implemented without rational concern for the sustainable conservation of natural resources. Thus, in its structuring, several aspects of the population reality inserted in the area covered by the aforementioned basin are approached, in addition to the economic activities associated with mineral, industrial and agricultural extractivism, as well as the disposal of sanitary landfills and dumps in the karst environmental system. .

Research Area

The traditional karst Sergipe Basin, is based on the bases of the Sergipe Sedimentary Basin, in the Sergipe and Piaçabuçu Groups (map 1). On the Sergipe Group are the Riachuelo and Cotinguiba Formations, and on the Piaçabuçu Group the Calumbi Formation (SANTOS, 2001). This sector is characterized by the Angico,

Taquari, Maruim and Sapucari Members, made up of limestone, dolomites, calcarenites, calcilutites, calcirudites, shales and sandstones, in some cases interspersed or in isolated levels, with deposition on a carbonate platform by alluvial fans- deltaic or on a slope (SCHALLER, 1969; FEIJÓ, 1994).

Map 1 – Sergipe Karst Areas



Source: authors (2019).

As it is the most occupied area of the Sergipe karst, it presents the main impacts caused by the disorderly occupation over the last decades, due to the abundance of non-metallic mineral resources, the historical process of colonization of the State and its approximation with Aracaju, capital and main city of Sergipe in the concentration of goods and services, where it adds a demand of workers from several

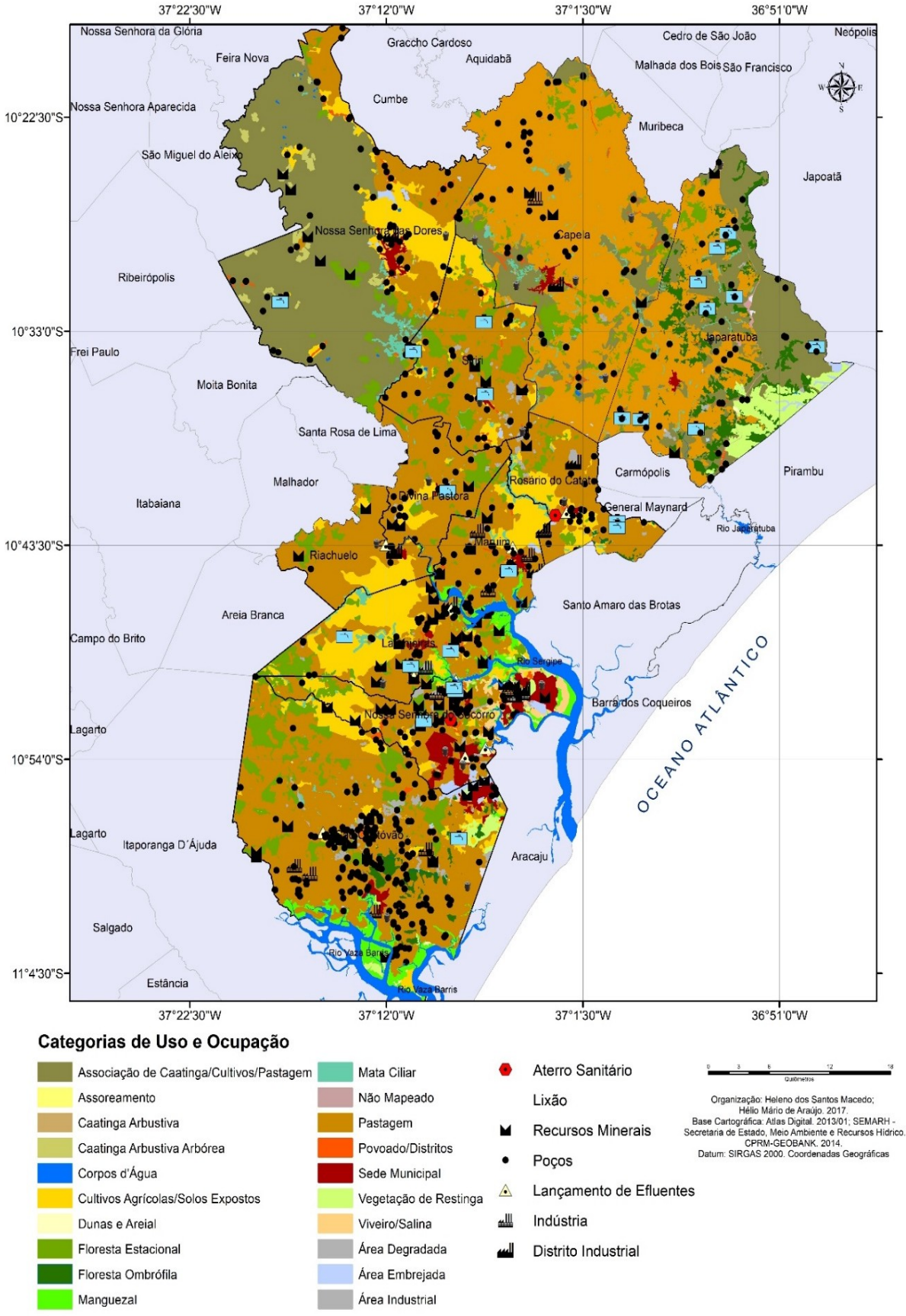
municipalities, some of them, by the proximity relationship and lower cost of living residing in the surrounding municipalities that form the Metropolitan Region.

Pastures for cattle raising and agricultural practices occupy vast extensions of the karst landscape, especially sugarcane, whose production of sugar and alcohol is aimed at supplying the domestic market and surrounding states.

In addition to this important aspect in the state economy, the area is characterized by dynamism in the industrial concentration of Sergipe. Several segments, such as mineral extraction companies, durable and non-durable goods industries, are found in the municipalities of Nossa Senhora do Socorro, Laranjeiras, Maruim, Rosário do Catete, São Cristóvão and Capela. Among the large companies, PETROBRÁS stands out, in the extraction of oil and natural gas, Companhia Vale S.A. in the extraction of potassium and Votorantim in the limestone beneficiation process.

Socioeconomic pressure directly affects natural elements, such as surface and groundwater, making them unfit for human consumption due to impacts from the release of effluents and the excessive use of pesticides (Map 2).

Map 2 - Karstic Area of the Sergipe Basin - Land Use and Occupation - 2018.



Source: Macedo; Araujo (2019).

Methodological procedures

The research followed the principles of the quali-quantitative approach, with investigative procedures conducted in three distinct stages: Bibliographic and cartographic documents survey; Office work, with laboratory analysis and Field work, with photographic record.

Bibliographic survey and cartographic documents

At this stage, a bibliographic survey was carried out to support the theoretical-methodological discussion of the investigated object, prioritizing specialized authors who discuss land use and occupation, with a focus on agricultural and industrial activities, in addition to population aspects associated with the evolution and structure occupational.

To support this phase, in addition to the use of books, magazines and other sources, some official government bodies were sought as a support base, such as the Brazilian Institute of Geography and Statistics (IBGE); National Human Development Program (UNDP); Secretary of State for the Environment and Water Resources (SEMARH/SE); Federation of Industries of Sergipe (FIES); Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) and Sergipe State Planning and Management Secretariat (SEPLAG), among others.

Laboratory analysis

At this stage, the aerial photographs were processed, as well as the elaboration of thematic maps of the location of the karstic areas in Sergipe and of Land Use and Occupation, in addition to other cartographic documents that proved to be important in the graphic communication process.

The geoprocessing techniques were carried out with the objective of subsidizing the grouping of data for the formation of a Geographic Information System (GIS) and the making of thematic maps elaborated in the same cartographic base and scale, with the use of the UTM projection system and SIRGAS 2000 Zona

24S, through the database made available in the Sergipe Water Resources Atlas (2013 version) by the Water Resources Superintendence (SRH). For this, the ArcGis 3.10.10 software, A Coruña version, was used, available at the Environmental Studies Laboratory (LEA) of the Geography Department of the Federal University of Sergipe.

Field work with photographic Record

For a better understanding of the socioeconomic reality of the municipalities inserted in the area of the Traditional Karst Bacia Sergipe and the process of anthropization of the environment, given the vulnerability of the karst, six field activities were carried out for local observations, aided by a notebook, map, GPS and a digital camera to record landscape scenarios.

Population dynamics of the Sergipe basin karst

In the traditional karst area of the Sergipe Basin, there is a total population of 376,692 thousand inhabitants (IBGE, 2010). Of this total, 311,247 thousand inhabitants are concentrated in the urban zone and 65,445 thousand inhabitants in the rural zone. The municipalities of Nossa Senhora do Socorro, São Cristóvão, Capela and Laranjeiras are the ones with the largest population groups, respectively, while the municipalities of Siriri and Divina Pastora have the lowest values, as shown in Table 1.

Such municipalities showed considerable growth in the total population between 1991/2000 and 2000/2010. In 1991, the total population was approximately 221,055 thousand inhabitants, increasing in the ten-year period about 94,836 inhabitants verified in 2000, which presented, according to the IBGE, 315,891 thousand inhabitants.

Table 1 – Sergipe Basin Traditional Karst – Total population, urban and rural – 2010.

Counties	Total population (thousand/inhab.)	Rural population (thousand/inhab.)	Urban population (thousand/inhab.)
Capela	30.761	11.019	19.742

Divina Pastora	4.326	2.227	2.099
Japaratuba	16.864	8.961	7.903
Laranjeiras	26.902	5.645	21.257
Maruim	16.343	4.302	12.041
Nossa Senhora das Dores	24.580	8.553	16.027
Nossa Senhora do Socorro	160.827	5.004	155.823
Rosário do Catete	9.221	2.712	6.509
São Cristóvão	78.864	12.199	66.665
Siriri	8.004	4.823	3.181
Total	376.692	65.445	311.247

Source: UNDP, 2018. Elaboration: authors, 2018.

In the following decade, this rhythm was not maintained, with a gradual decrease in the population quantity, since, in the 2000/2010 interval, there was an increase of around 60,801 thousand inhabitants, totaling 376,692 thousand inhabitants in 2010. considering the total population increase verified in the period 1991/2010, there is a positive index in the relative growth rate of the population around 70.40% (Table 2).

Table 2 – Traditional Karst of the Sergipe Basin - Population Growth – 2018.

Counties	Total Population 1991	Total population 2000	Total Population 2010	Growth rate (%)
Capela	25.105	26.518	30.761	22,53
Divina Pastora	2.645	3.266	4.326	63,55
Japaratuba	13.004	14.556	16.864	29,68
Laranjeiras	18.233	22.750	26.902	47,54
Maruim	14.683	15.454	16.343	11,30
Nossa Senhora das Dores	19.606	22.195	24.580	25,36
Nossa Senhora do Socorro	68.285	132.489	160.827	135,52
Rosário do Catete	5.639	7.102	9.221	63,52
São Cristóvão	47.558	64.647	78.864	65,82
Siriri	6.297	6.914	8.004	27,10
Total	221.055	315.891	376.692	49,20

Source: UNDP, 2018. Elaboration: authors, 2018.

On the scale of municipalities, Nossa Senhora do Socorro was the one with the highest population growth, with a relative rate of 135.52% in the period 1991/2010. The general total of its population in 1991 did not exceed the figure of 68,285 thousand inhabitants, demonstrating vertiginous dynamism in the population

contingent of approximately 100% in 10 years, that is, in the interval 1991/2000 (132,489 thousand inhabitants), including, maintaining the pace of growth in smaller proportions in the period 2000/2010 when it totaled 160,827 thousand inhabitants.

The reasons for this high population increase, being among the largest in Brazil and in the entire State of Sergipe, are sought, in the construction of several housing complexes implemented in the municipality from the 1990s, in a partnership between the State/Federal Government to meet the need for growing demand for housing triggered by the growth of the metropolitan region of Aracaju, where it operates. In addition, this municipality has become the main area of population attraction around Aracaju, due to the implementation or improvement in strategic sectors, such as transport and the installation of an important industrial park.

São Cristóvão, also showed significant growth in its population with a rate of 65.82% in the interval 1991/2010. This percentage increase in the increment is justified by the dynamism of the real estate sector, due to the saturation in the process of urban occupation in the municipality of Aracaju. In 1991, there were 47,558 thousand inhabitants, reaching 78,664 thousand inhabitants in 2010.

The municipalities of Rosário do Catete and Divina Pastora had a population growth of 66% between 1991 and 2010, driven by the implementation of important base industries, in addition to companies that process limestone for various sectors of the economy.

The municipality of Maruim had the lowest relative population growth rate over the period (11.30%), having a total population of 14,683 in 1991 and 16,343 thousand inhabitants in 2010. This low population growth is attributed to the closure of important manufacturing units, which opted to establish themselves in neighboring municipalities due to the concession of tax benefits offered.

With gradual rhythms of population growth verified in the last decades in these municipalities, it becomes necessary to expand the work fronts in all sectors of the economy to meet this growing demand, without causing new impacts on the dynamics of the natural elements that make up the landscape of the karst area.

Economic activities of the Sergipe basin karst

With regard to economic activities, it appears that the largest portion of the population of working age is found in the services, agriculture, civil construction and commerce sectors. The sectors related to the manufacturing industry, public utility industrial services (SIUP) and mineral extraction are those that absorb the smallest portion of the adult population employed in these municipalities (Table 3).

Table 3 - Sergipe Basin Traditional Karst - Occupied rate by sectors - 2018.

Counties	agricultural (%)	mineral extractive (%)	Transformation industry (%)	SIUP (%)	Construction (%)	Business (%)	services (%)
Capela	30,26	0,59	9,39	1,61	9,34	9,17	32,47
Divina Pastora	16,21	2,42	4,91	0,62	11,18	5,73	55,24
Japaratuba	28,81	1,23	4,63	0,97	9,31	6,78	39,95
Laranjeiras	8,83	0,69	14,6	1,32	12,09	8,37	43,41
Maruim	18,97	4,93	9,64	1,91	12,2	10,92	35,78
Nossa Senhora das Dores	32,85	0,23	7,85	1,16	5,89	16,43	31,39
Nossa Senhora do Socorro	2,48	0,73	8,24	1,02	11,77	20,04	48,95
Rosário do Catete	13,12	9,67	2,65	0,96	9,81	5,84	48,81
São Cristóvão	11,12	0,74	5,14	1,42	10,75	16,85	48,39
Siriri	25,2	1,88	14,8	0,7	11,31	7,08	35,02

Source: UNDP, 2018. Elaboration: authors, 2018.

Nossa Senhora das Dores and Capela are the municipalities that have most of their workers engaged in agricultural activities, amounting to 32.85% and 30.26% respectively. The population engaged in mineral extraction, is among the municipalities of Maruim and Rosário do Catete with the highest rates in the karst of the Sergipe Basin, being 9.67% for Maruim and 4.93% for Rosário do Catete.

Civil construction, service provision and commerce, together, are the sectors that have the largest share of the employed population. Maruim has the highest percentage of its economically active population engaged in civil construction (12.2%), followed by Laranjeiras (12.09%), Nossa Senhora do Socorro (11.77%), Siriri (11.31) and Divina Pastor (11.18%). With regard to commerce, Nossa Senhora do Socorro and São Cristóvão are the main highlights of the karst area, with rates of

20.04% and 16.85% of the population employed in this sector. Divina Pastora has the highest rate in relation to the population employed in the service sector with 55.24%, followed by Nossa Senhora do Socorro (48.95%), Rosário do Catete (48.81%) and São Cristóvão (48 .39%).

It is important to point out that even though it does not have the largest share of the employed population, industry is responsible for a significant part of the municipalities' GDP (Table 4). According to data from the Federation of Industries of the State of Sergipe - FIES (2014), the industry corresponds to 45.46% of participation in the economy. Industry's participation in GDP stands out in the municipalities of Divina Pastora, Japaratuba, Rosário do Catete, Siriri, Maruim and Laranjeiras.

Table 4 - Sergipe Basin karst - Participation of sectors in the composition of GDP - 2018.

Counties	GDP (BRL million reais)	Population (Thousand inhabitants)	PIB per capita (R$)	AND Agrop. %GDP	AND Serv. %GDP	VA Ind. %GDP
Capela	281.131	30.761	9.043	13,62	60,20	26,19
Divina Pastora	169.968	4.326	38.559	1,34	15,46	83,20
Japaratuba	483.969	16.864	28.399	4,57	20,72	74,71
Laranjeiras	1.061.185	26.902	39.047	1,49	60,21	38,31
Maruim	220.247	16.343	13.420	3,72	51,30	44,97
Nossa Senhora das Dores	169.514	24.580	6.845	11,76	75,38	12,87
Nossa Senhora do Socorro	1.761.045	160.827	10.801	0,26	81,62	18,12
Rosário do Catete	392.569	9.221	41.834	2,16	28,79	69,05
São Cristóvão	519.112	78.864	6.492	3,41	73,66	22,92
Siriri	132.529	8.004	16.386	6,16	29,58	64,26
Total karst area	5.191.269	376.692	21.082,6	4,85	49,69	45,46

Source: FIES (2014). Elaboration: authors(2020)

Still based on the data in table 4, it is noted that these municipalities in relation to the Gross Domestic Product (GDP) and GDP per capita, have the highest total values of approximately R$ 5 billion reais, with a GDP per capita average of R$ 21,082.60, considered the highest in the karstic areas of Sergipe.

The Municipality of Nossa Senhora do Socorro has the highest GDP among the municipalities in the karst sector, with a value of around R$ 1,761,045,000 (one billion, seven hundred and sixty-one million, forty-five thousand reais). In terms of GDP per capita, Rosário do Catete, orange trees and Divina Pastora have the highest

rates. The increase in these indicators is mainly due to the significant participation of industry in the economic activity of these municipalities, in line with their low demographic density.

The industry implemented on the karst of the Sergipe Basin plays an important role in the economy of the State of Sergipe, being one of the main sources of state revenue. As of 2014, with the severe economic crisis, some manufacturing units were closed, as well as the process of opening new units that decreased, leading to a reduction in the workforce located in this sector in recent years.

In the karst region, the sugar and alcohol, extractive (oil and gas), chemical, ethanol, food and beverage, civil construction and cement industries stand out. The main manufacturing units are installed in the municipalities of Nossa Senhora das Dores, Rosário do Catete, Japaratuba, Laranjeiras and Nossa Senhora do Socorro.

The sugar and alcohol industry in Sergipe is concentrated in the municipalities of Laranjeiras and Nossa Senhora das Dores. These municipalities are responsible for the production of crystal sugar, hydrated alcohol (used as fuel and also in the petrochemical, chemical and pharmaceutical industry), anhydrous alcohol (used as fuel for vehicles and raw material in the paint, solvent and varnish industry), as well as in the generation of electricity and bioenergy (bagasse, biomass left over from sugarcane grinding and burned in boilers to produce electricity).

The main industry in this sector is Usina São José do Pinheiro Ltda., located in the municipality of Laranjeiras. This plant provides services in the commercialization and manufacture of sugar, alcohol, molasses and energy generation for the entire Northeast of Brazil and some European and African countries. Owned by Albano do Prado Pimentel Franco, it comes from the foundation of the São José mills with other mills in the region.

In the 2007/2008 harvest, the mentioned plant reached its sugar production record, with 1,881,219 50 kg bags. In the 2010/2011 harvest, the plant offered the market the electricity obtained from the processing of sugarcane biomass, production that was expanded in the 2015/2016 harvest. Between 2014/2015 Usina Pinheiro had

its biggest harvest, harvesting 1,032,155 tons of sugarcane. Also in this harvest, the highest production of ethanol was obtained, producing a total of 9,140,830 liters of hydrated alcohol and 15,311,764 liters of anhydrous alcohol (UNICA, 2018).

In November 2008, Usina Gentil Barbosa was founded, owned by the company Agroindustrial Campo Lindo in Nossa Senhora das Dores, responsible for the production of ethanol and biodiesel. Occupying an area of 7,000 hectares and using state-of-the-art technology, the plant processed over 1.2 million tons of sugarcane per harvest, producing 600,000 liters of ethanol per day. The project depended on planting 16,000 hectares of sugarcane in the municipalities of Nossa Senhora das Dores, Capela, Japaratuba, Siriri, Muribeca and Neópolis.

The oil and natural gas extractive industry is represented by PETROBRÁS S.A. and its service providers. In 2017, the municipality of Pirambu had the highest transfer of royalties among all municipalities in Sergipe, receiving around BRL 39.7 million. Japaratuba, Carmópolis, Divina Pastora and Aracaju received respectively R$12.9 million, R$10.8 million, R$10.2 million and R$9.4 million. Other municipalities also received for the extraction of oil and gas in their areas, among them Itaporanga D'Ajuda (R$ 9.2 million), Siriri (R$ 8.7 million) and Riachuelo (R$ 7.8 million).

The main oil and gas extraction units on the traditional karst of the Sergipe Basin are: Campo de Sirizinho (Rosário do Catete); Campo de Mato Grosso and Campo de Riachuelo (Divina Pastora); Campo Castanhal (Siriri); Campo da Ilha Pequena and City of Aracaju (São Cristóvão) and Campo de Carmópolis (Japaratuba) – Photo 01.

In recent years, the production of oil and natural gas has been reduced in the extraction units, due, among other factors, to the reduction in the price of the commodity in the international market, the increase in production in the United States and Saudi Arabia, as well as the successive denunciations of corruption that involved the Brazilian state-owned company in recent years. This reduction has caused problems in the public finances of municipalities that, for the most part, depend on royalties paid by the state-owned company.

The cement industry plays an important role in the economic development of the state of Sergipe. Based on data from the National Union of the Cement Industry - SNIC (2018), the State occupies the 3rd position in the Northeast, with a production of 1,560,800 thousand tons in 2017, corresponding to 26.6% of all production regional.

Photo 1 – Oil extraction in the Mato Grosso field in the municipality of Divina Pastora

Source: Macedo (07/2016).

Until 2017, Sergipe had three factories operating in the market: Votorantim group (Laranjeiras), Itaguassu (Nossa Senhora do Socorro) and Mizu (Pacatuba). With these three units, cement production reached an average of 7.2%, higher than the Northeast (5.8%) and Brazil (5.9%) between 2003 and 2011. foreign market, one of the main export items of the State.

The Portland Cement Company of Sergipe, belonging to the Votorantim Group, was the first production unit in the State, installed on Rua Acre in the América neighborhood. According to Cajazeiras (2011), this area was chosen at the time for implementation because it was far from the main residential neighborhoods of Aracaju.

In 1983, Companhia de Cimento Portland de Sergipe was deactivated due to the rapid urban growth around the factory, being replaced by a new unit – CIMESA – in the municipality of Laranjeiras. This manufacturing unit became the largest in the Northeast region (photo 2). With over 35 years of experience, it maintains 360 direct jobs and has a production capacity of 2.8 million tons per year of Poty cement (SNIC, 2018).

Votorantim Cimentos, in Laranjeiras, produces four categories of cement under the Poty brand: Cement CP II F 32 (general use), cement CP II Z 32 (for aggressive environments, with pozzolan additive), CP IV 32 (for aggressive environments, mainly close to the sea, also with pozzolana additive) and CPP (special for oil wells).

Photo 2 - Votorantim Cimentos Production Unit in Laranjeiras/SE

Source: CIMESA, 2018.

The factory also meets part of the demand for clinker (one of the raw materials in cement) for other Votorantim Cimentos units in the Northeast, producing 2 million tons per year. In Sergipe, Votorantim Cimentos also operates a cement distribution center in Aracaju, with daily replenishment at the factory.

Another important factory that operated in the Sergipe market until 2017, located on the karst of the Sergipe Basin, belonged to the João Santos Group, Itaguassu Agroindústria S/A unit - (NASSAU). It was inaugurated in 1996, in the municipality of Nossa Senhora do Socorro, with the aim of promoting the economic development of the municipality and the State (CAJAZEIRAS, 2011). The unit went through serious financial and structural problems between 2013 and 2016, culminating in the closure of the factory in 2017.

Another industry segment operating in the Sergipe Basin karst is potash fertilizers. The main extraction deposit is Taquari/Vassouras located in the municipality of Rosário do Catete. The Sergipe deposits were discovered in 1963 in the evaporitic sub-basins of Taquari-Vassouras during oil prospecting work by PETROBRÁS (NASCIMENTO; MONTE; LOUREIRO, 2005), since the saline domes form typical structures for oil accumulation (MONTE et al. ., 2002).

The Nitrogen Fertilizer industry in Sergipe comes from an industrial unit of the Fábrica e Fertilizantes Nitrogenados (FAFEN), located in the municipality of Laranjeiras. FAFEN is the result of the incorporation of Nitrofértil to PETROBRÁS, the solution found to avoid the privatization of this sector, being subsidized in the price of the main raw material, natural gas.

In the process of obtaining urea on an industrial scale, the synthesis of ammonia with carbon dioxide is based, under special conditions of temperature and pressure. The ammonia used in the production process is obtained at the same manufacturing unit, from natural gas coming from oil wells in the region, processed at the Natural Gas Processing Unit (UPGN).

The products manufactured at FAFEN Sergipe, ammonia and urea, were destined for the northeastern market, also in recent years sold to other regions of the country and even abroad. Carbon dioxide, a by-product of the production process, was supplied by tube to Liquid Carbonic.

In June 2018, due to the crisis in the sector and, mainly, in the economic activities carried out by its sponsor, PETROBRÁS, the FAFEN unit in Sergipe was

closed, causing the unemployment of hundreds of workers who depended directly and/or indirectly on the factory. for its economic maintenance.

Still in relation to industrial performance in the process of land use and occupation in the karst of the Sergipe Basin, it is observed that the municipality of Nossa Senhora do Socorro has become, in recent decades, the main industrial center of the state of Sergipe. There are industries in the fields of food, mineral extraction, electronics; construction, among others. Currently, the main factory in the municipality is the manufacturer of electro-electronic parts for automobiles Yasaki (photo 3). Yasaki installed in Nossa Senhora do Socorro in 2013, was the sixth unit of the group in the country, with an investment of R$ 50 million in a constructed area of 19 thousand square meters.

Photo 3 – Yasaki unit in the municipality of Nossa Senhora do Socorro/SE

Source: PROJENC, 2018.

The company had tax and locational incentives provided for in the Sergipe Industrial Development Program (PSDI) and made available by the State Government, through SEDETEC and CODISE.

Agriculture as an economic practice plays an important role in the process of soil use and occupation in the karst of the Sergipe Basin. The area destined for pasture and permanent and temporary agricultural practices express the relevance of this economic activity, as shown in table 5.

Part of the land in the municipalities inserted in the karst of the Sergipe Basin is destined for the practice of planted pasture (30.32%). Another part of the territory is destined for crops, especially temporary crops (15.07%). In all municipalities, the smallest portion of the land is destined to woods and forests (5.22%), a worrisome characteristic, given the need to maintain the natural cycle of the environment.

Table 5 – Sergipe Basin Traditional Karst. Land Use, 2017

Counties	Total area (ha)	Land Use							
		Agriculture				Pastures			
		Permanent		Temporary		Natural		Planted	
		Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Capela	44.221,1	90,563	0,20	5.922,355	13,39	16.237,771	36,72	7.576,110	17,13
Divina Pastora	9.032,8	11,982	0,13	902,193	9,99	568,770	6,30	5.527,739	61,20
Japaratuba	36.562,1	1.280,180	3,50	7.431,892	20,33	1.612,238	4,41	5.962,385	16,31
Laranjeiras	16.227,3	634,660	3,91	8.481,746	52,27	218,311	1,35	3.542,676	21,83
Maruim	9.555,4	217,212	2,27	3.885,221	40,66	37,179	0,39	3.340,982	34,96
Nossa Senhora das Dores	48.239,9	830,569	1,72	3.107,526	6,44	2.473,436	5,13	30.335,512	62,88
Nossa Senhora do Socorro	15.501,8	216,605	1,40	625,166	4,03	366,407	2,36	3.100,454	20,00
Rosário do Catete	10.283,4	103,487	1,01	2.012,941	19,57	21,816	0,21	2.963,918	28,82
São Cristóvão	43.803,7	1.946,183	4,44	1.433,781	3,27	1.947,457	4,45	6.911,644	15,78
Siriri	16.837,2	189,069	1,12	3.919,572	23,28	2.337,123	13,88	6.625,753	39,35
CT BASIN SERGIPE	250.264,7	5.520,51	2,21	37.722,393	15,07	25.820,508	10,32	75.887,173	30,32

Source: Agricultural Census, 2017. Organization: Authors (2018).

Nossa Senhora das Dores is the municipality with the largest karst area in the Sergipe Basin, with 48,239.9 hectares. Of this total, 68.01% is destined for pastures (natural and planted), 8.61% for crops (temporary and permanent) and 8.79% makes up the total of forests and forests. Divina Pastora, has the smallest area among the municipalities, totaling 9,032.8 hectares, with 67.50% destined for natural and planted pastures, 10.02% are occupied by temporary crops and 9.63% are forests and forests.

The municipalities of Capela, Divina Pastora, Nossa Senhora das Dores, Nossa Senhora do Socorro, Rosário do Catete, São Cristóvão and Siriri allocate most of their land to pasture, on average 35.02% of their total territories. On the other hand, 11.42% of the areas in these municipalities are destined for crops, making up a small portion of land use.

The municipalities of Laranjeiras, Maruim and Japaratuba give a different destination to land use. In these municipalities, the largest portion of the land is destined to crops, both temporary and permanent, with emphasis on the sugarcane culture, whose production is intended, for the most part, for the sugar and alcohol industry in the state and neighboring states such as Alagoas and Bahia. With regard to the production of the main agricultural products, it is noted that the municipalities of the karst of the Sergipe Basin allocate most of their soil to temporary crops, highlighting the cultures of sugar cane (29,164.294 ha), cassava (1065, 394ha), maize (944.1ha) and beans (33,398 ha) respectively (table 6).

Table 6 - Traditional Karst of the Sergipe Basin - Production of Main Agricultural Products - 2017.

Counties	Sugar cane		Bean		Corn		Cassava	
	Harvested area (ha)	Quantity Product (t)	Harvested area (ha)	Quantity Product (t)	Harvested area (ha)	Quantity Product (t)	Harvested area (ha)	Quantity Product (t)
Capela	4.072,227	160.839,300	2,647	1,210	148,447	191,820	225,238	1.524,104
Divina Pastora	774,820	37.392,780	3,117	4,840	7,261	10,260	7,491	38,120
Japaratuba	5.311,482	196.125,975	1,273	0,952	119,017	64,849	277,721	1.585,412
Laranjeiras	8.350,334	454.965,759	1,106	0,123	11,046	43,850	23,940	80,458
Maruim	3.841,697	182.051,020	--------	--------	7,633	123,510	8,749	18,733
Nossa Senhora das Dores	268,629	7.684,300	15,374	6,226	555,094	1.998,705	86,329	685,944
Nossa Senhora do Socorro	509,163	38.383,322	--------	--------	1,213	2,970	84,135	328,077
Rosário do Catete	1.902,983	81.991,280	--------	--------	1,575	1,490	17,464	45,856
São Cristóvão	1.179,830	58.991,042	7,677	1,851	37,813	83,928	258,550	541,793
Siriri	2.953,129	133.531,140	2,204	2,105	55,001	122,100	75,777	566,405
CT BASIN SERGIPE	29.164,294	1.351.955,918	33,398	17,307	944,1	2.643,482	1065,394	5.414,902

Source: Agricultural Census, 2017. Organization: Authors (2018).

The municipality of Laranjeiras is the main producer of sugar cane among the municipalities, with a quantity of 454,965,759 tons. According to Araújo (2007), this position ahead of other municipalities was consolidated in previous decades, not

only due to the environmental conditions resulting from the presence of fertile massapê soils (Vertisols) and humid climate, but also due to the Usina São José do Pinheiro increasing production.

Japaratuba and Maruim occupy the second and third largest cultivated area of sugarcane, obtaining approximate respective amounts of 196,125.975 and 182,051.020 tons. Part of this production is destined for Usina Gentil Barbosa, owned by the company Agroindustrial Campo Lindo in Nossa Senhora das Dores, responsible for the production of ethanol and biodiesel.

As for Cassava, Japaratuba is the municipality that has the largest harvested area among the municipalities, with a total of 277.72 hectares and a produced quantity of 1,585.41 tons. São Cristóvão, with a harvested area of 258.55 hectares, occupying second place, has a lower production quantity than Capela (which occupies third position in the production of this crop). Capela, with a harvested area of 225.23 hectares, has a produced quantity of 1,524.10 tons, to the detriment of 541.79 tons produced by the municipality of São Cristóvão, a difference of 64.45% more.

Regarding the production of Corn and Beans, the municipality of Nossa Senhora das Dores is the leader in terms of quantity produced and harvested area. According to data from IBGE (2017), the municipality allocated a total of 555.09 hectares to the corn crop, with a produced amount of 1,998.705 tons. Regarding the production of Beans, 15.37 hectares were allocated, obtaining a production of 6.22 tons. The good performance in the production of these crops is due to the climate condition of the municipality, which is characterized by rainfall in specific periods of the year.

Regarding the number of main herds, poultry farming represented by chickens, a group that includes chickens, roosters, chickens, pullets and chicks, plays an important role in the economy of the karst area of the Sergipe Basin, where two of its municipalities – São Cristóvão and Maruim – are among the five largest producers in the state (table 7).

In 2017, this herd produced 1,301,662 head, ahead of the other herds in the karst area as a whole, reaching 91.79%, leaving only 6.25% for the cattle herd (88,868 head), 0.91 % for sheep (13,002 heads), 0.57 for horses (8,162 heads), 0.48 for pigs (6,946 heads) and 0.08% for mules (1,267 heads).

São Cristóvão stands out as the largest producer of this herd, with 708,281 heads, traditionally consecrated by the modern aviaries, which accompany the technological advances of the sector in the country. Maruim, with a production five times smaller (166,955 heads), is in second position (ARAÚJO, 2007). The joint production of these municipalities is destined for the internal market, to supply supermarket chains in Aracaju, in addition to local fairs spread throughout the state.

Table 7 – Sergipe Basin Traditional Karst – Livestock Production – 2017.

Counties	Staff of the Main Herds					
	Cattle	Swine	Equines	Mules	Sheep	Chickens
Capela	16.207	766	1.454	228	1.056	79.066
Divina Pastora	7.123	235	392	44	190	21.455
Japaratuba	5.861	305	1.034	110	662	102.954
Laranjeiras	3.014	60	270	60	209	2.949
Maruim	3.094	115	459	83	176	166.955
Nossa Senhora das Dores	27.328	1.528	1.616	343	2.437	80.164
Nossa Senhora do Socorro	4.393	451	557	30	453	5.738
Rosário do Catete	3.206	160	388	46	194	48.178
São Cristóvão	9.928	3.171	1.388	177	7.262	708.281
Siriri	8.714	155	604	146	363	85.922
CT BASIN SERGIPE	88.868	6.946	8.162	1.267	13.002	1.301.662

Source: Agricultural Census, 2017. Organization: Authors (2018).

The cattle herd represents the second largest herd, adding up to 88,868 heads, they are more numerous in the municipalities of Nossa Senhora das Dores, with 27,328 heads and Capela, with a herd of 16,207 heads. The municipalities of Maruim and Laranjeiras have the smallest herds in this herd, with a total of 3,094 and 3,014 head respectively.

Herds of sheep, horses and pigs have low numbers. The herd of sheep totals 13,002 head, with the municipality of São Cristóvão being the main producer with

7,262 head, followed by Nossa Senhora das Dores, which has a herd three times smaller (2,437 head).

Regarding the herd of horses, Nossa Senhora das Dores has the first and second herds in numbers, with 1,616 and 1,454 heads. The swine herd has a herd of 6,946 heads, with the municipality of São Cristóvão as the main producer, with a total of 3,171 heads. The production of mules is insignificant in the context of the Sergipe Basin karst, reaching a total of 1,267 heads, with Nossa Senhora das Dores (343 heads) and Capela (228 heads) the main producers of these herds in the karst area.

Mineral extractivism in the karst of the Sergipe Basin

The Mineral extractivism is a relevant economic practice in the Sergipe Basin karst. This economic activity causes direct impacts on the karst environments, through the mining intended for the extraction of limestone that put exokarst and endokarst features in constant threat, such as lapiá fields, sinkholes, caves, speleothems, among others.

Limestone is the main mineral resource extracted from the soil of the karst environment of the Sergipe Basin, located in the municipalities of Laranjeiras, Nossa Senhora do Socorro, Maruim and São Cristóvão. The carbonate rocks, classified petrographically as limestones and dolomites of sedimentary origin, have their most important deposits distributed in the Sergipe Sedimentary Basin, in the context of the Sergipe Group, differentiated in the Cotinguiba Formations (Sapucari Member) and Riachuelo (Maruim Member). These limestones are used in the cement industry and to a lesser extent in the civil construction industry, lime, gravel, among others (Photo 4).

Photo 4 – Limestone Mining in Povoado Muçuca in Laranjeiras/SE

Source: Macedo (06/2016).

The Mesozoic limestones and dolomites present in the karst of the Sergipe Basin, especially in the Sapucari and Maruim members, of the Cotinguiba and Riachuelo Formations, have satisfactory levels obtained in chemical analyzes for the use of these rocks in the manufacture of cement, soil amendment and other products with activities diverse economics.

Another well-exploited mineral resource is clay, with 14 deposits (SANTOS, 2001). The municipalities of São Cristóvão and Nossa Senhora do Socorro are the ones with the main exploration units for this mineral. The destination of this extracted material is the large cement factories in the State, as well as the ceramics transformation industry, such as blocks and tiles, among others (Photo 5).

In addition to limestone and clay, the karst environment also contains important deposits of manganese, potassium, magnesium, sodium, zinc, lead, sand, mixed minerals, sulfur, granite, gabbro oil and natural gas.

Photo 05 – Clay mining in the municipality of Siriri/SE

Source: Macedo (06/2016).

In Siriri, the extraction of potassium, magnesium and sodium stands out, mainly in the vicinity of taquari-vassouras / Santa Rosa de Lima; Oil and Natural Gas in the municipalities of São Cristóvão, Japaratuba, Siriri, Rosário do Catete and Divina Pastora; sand, in the municipality of Nossa Senhora do Socorro and São Cristóvão; lead and zinc in São Cristóvão and Capela, and mixed minerals in the municipality of Nossa Senhora das Dores.

Final considerations

From a use point of view, karst landscapes have great aesthetic and economic value as they support tourism activities and other aspects of leisure. Such activities can represent an important asset for the economy of certain regions or even countries.

In Sergipe, karstic areas are exploited for the manufacture of cement, in addition to the extraction of limestone blocks used in civil construction. The municipality of Laranjeiras, with one of the main speleological provinces in the State,

already had three cement production units, leading Sergipe to be one of the biggest sellers of this product in the late 1990s and early years of the 21st century. However, the main use of the land is carried out by agricultural practices, with emphasis on the cultivation of sugar cane and cattle raising.

The multiple land uses in the traditional karst of the Sergipe Basin have been devoid of prior planning by the government, or even by the private sector. Both occupy a significant part of the land in their most diverse economic practices without the slightest concern about how much the activities can directly and/or indirectly affect the natural systems present in that area.

In addition, the urban and population growth of the municipalities, linked to the lack of planning, can lead to problems in the society-nature relationship on the karst environment, causing irremediable consequences for both the existing abiotic and biotic systems.

It is important to point out that environmental problems, due to the underlying spatial expressiveness, become issues inherent to geographic analysis. Geography, in the human sciences, plays an important role in the discussion of environmental issues, highlighting the society-nature relationship as a central aspect of its concerns.

The karst landscapes of the Sergipe Basin need intervention actions to guarantee its dynamics, mitigate the impacts caused by the disorderly use and occupation, considering its natural fragility.

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Author 3- Assistance in cartographic production, text review, bibliographical research