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EVALUATION OF DEGRADATION OF VEGETABLE COVER IN THE MUNICIPALITY OF TRINDADE-PE

AVALIAÇÃO DA DEGRADAÇÃO DA COBERTURA VEGETAL NO MUNICÍPIO DE TRINDADE-PE

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ABSTRACT
The caatinga is a plant formation that occurs in the northeast region of Brazil, located over an area of depression, its reliefs are composed of to a huge rocky outcrop mostly composed of crystalline rocks, some plateaus in the case of the inselbergs that in allusion to the ice iceberg this refers Borborema Plateau, several plateaus such as those of Araripe/Ibiapaba composed of sandstone rocks, depending on the location and topography, humid environments such as high-altitude swamps and or islands of Atlantic forest may arise in the case of the Araripe plateau. The soils of the morphoclimatic domain of the caatingas are generally shallow soils with the presence of rock outcrops in several regions, in these environments the caatinga vegetation is composed in a more stunted way, sometimes without arboreal individuals on the landscape but a notorious presence of cacti in its vegetal composition, in environments where the presence of well-developed soils occurs, the most arboreal formations of the vegetation can be observed, in the case of Araripe in Pernambuco, which is the region where the municipality of Trindade-PE is located, it presents several physiognomies not only from arboreal caatinga but also from savannahs, in this case the carrasco, which would refer to the dense vegetation at the top of the Chapada do Araripe in the state of Pernambuco, several areas of seasonal deciduous forest, this formation being classified as part of the Atlantic forest and in a more restricted way. those considered to be carnauba paths generally close to lagoons and intermittent streams. This article aimed at evaluating the degradation of vegetation cover in the municipality of Trindade-PE, presenting topographic data, historical rainfall, and hydrography and among other characteristics that contribute to plant behavior. Something also analyzed as a factor of change in the natural land cover is human activity being carried out through agricultural, urban or industrial activities, which in the case of the studied area is the mining of gypsum, a raw mineral extracted from the earth. However, improper use can be harmful, causing damage to the environment and impacting the economy, as it reduces the ability to regenerate new nutrients for new food productions.

RESUMO
A caatinga é uma formação vegetal que ocorre na região nordeste do Brasil, localizada sobre uma área de depressão demarcada por feições erosivas aplanadas com pedimentos e formações residuais denominadas de inselbergs constituídos por afloramentos rochosos predominantemente cristalinos. Há de se destacar também outras morfoestruturas presentes na paisagem como o Planalto da Borborema, chapadas sedimentares como as do Araripe/Ibiapaba, além dos maciços isolados com feições de serras e morros testemunhos com topografia elevadas e de exposição orográfica onde foram ambientes úmidos como os brejos de altitude e ou ilhas de mata atlântica, presentes na chapada do Araripe. Os solos deste domínio morfoclimático das caatingas geralmente são rasos com presença de afloramentos de rochas, com vegetação constituída mais raquítica, por vezes não

apresentando indivíduos arbóreos, mas com notória presença de herbáceo-arbustivas, sobretudo cactáceas. Entretanto, nos locais com solos mais desenvolvidos nota-se as formações mais arbóreas da vegetação, como no Araripe pernambucano, região onde está situado o município de Trindade-PE, apresentando diversas fisionomias não só da caatinga arbórea, mas também de cerrados tipo carrasco e rupestre no topo com formação vegetal adensada e bromélias. Outra característica são as áreas de floresta estacional decidual classificada como parte da mata atlântica e de maneira mais restrita considerada veredas de carnaúbas, geralmente próximas de lagoas e riachos intermitentes. O presente artigo teve como objetivo avaliar a degradação da cobertura vegetal no município de Trindade-PE, apresentando dados topográficos, pluviométricos, hidrográficos e dentre outros fatores físico-ambientais e antrópicos como o uso e ocupação das terras, sobretudo que interferem no comportamento e estabilidade deste bioma e seus ecossistemas. Para tanto, por meio do método fenomenológico, a pesquisa se deu pela observação e descrição da paisagem com conhecimentos perceptivos do pesquisador sobre o ambiente, proporcionando um novo meio de análise sobre o fator, adotando levantamento exploratório de campo, bibliográfico e documental. Nesse sentido, pode-se constatar como fator preponderante à degradação e a mudança da cobertura vegetal as atividades agrícolas, urbanas e indústrias, destacando-se a mineração da gipsita que pela exploração inadequada e desordenada é prejudicial e danosa ao ambiente e a própria economia, pois reduz a capacidade de regeneração dos nutrientes no solo essencial para as novas produções alimentícias.
Palavras-chaves: Caracterização; Cobertura vegetal; Caatinga; Degradação.

INTRODUCTION

The morphoclimatic domain of the caatinga vegetation in the northeastern region of Brazil has been undergoing various alterations in its natural physiognomies, currently exacerbated by uncontrolled anthropic action which extracts natural resources in a predatory manner. Not much different from the municipalities located in the Araripe Pernambucano region, Trindade over the years has been losing its natural vegetation cover, leading to incalculable biological losses, with extinctions of several species that were once considered common in its territory.

The caatinga is currently classified alongside deciduous seasonal forests because the methods used by researchers may not always evaluate or categorize it specifically according to reality. When evaluating vegetation physiognomies, a higher stature of its individuals is observed, and environments with "savanna" characteristics, defined as areas with almost isolated trees without a canopy presence, with shrubs and herbaceous layers, are almost rare or occasional. Such characteristics typical of the caatinga domain do not occur frequently, except in areas where vegetation has been removed or in pedological conditions that favor occurrence, or if the area is in stages of natural suppression (GRAEFF, 2015).

The use of the term "caatinga domain" is due to its complexity and heterogeneity, encompassing various physical and vegetational characteristics. In the research area, landscape changes can be visually observed, transitioning from a sertaneja depression relief with inselbergs to a plateau constituted by the Chapada do Araripe. In several works such as "Biogeography of South America" by Carvalho et al. (2010) and "Phytogeography of Brazil" by Graeff (2015), the caatinga is classified as SDTF (Seasonal Dry Tropical Forests). However, the organs responsible for this categorization further subdivide it into: Hypoxerophytic Caatinga (larger tree formation located on well-developed, calcareous and/or arenaceous soils, with gently undulating to flat relief); Hyperxerophytic Caatinga (smaller formation composed of shrub species situated on shallow soils, on formations of rocks of crystalline origin and relatively on sedimentary outcrops) (CONDEPE/FIDEM, 2008).

By associating both works, the distribution of SDTFs across the Neotropical region can be perceived, spanning from the southern and western parts of Mexico to much of South America. Concerning the Northeast region, in the Raso da Catarina, the Parnaíba/Araripe Complex, Dunas do Rio São Francisco, and the Bahian Agreste in the vicinity of what would be the Chapada Diamantina complex, are categorized as Sandy Caatinga due to their pedological characteristics, while the rest would be SDTF with fragments of Moist Forest (PENNINGTON, PRADO, and PENDRY, 2000). However, the delimitation method used by Velloso et al. (2002) is flawed for limiting the understanding of the caatinga to regions of sandy sedimentary basins only.

According to AB´Sáber et al. (2012), in their work "Nature Domains in Brazil," the semiarid climate caused by local factors, especially rainfall variation, and soil conditions directly alter biological processes and consequently the vegetation cover of the landscape. In the case of the Chapada do Araripe, within the state of Pernambuco, where soils are largely well-developed, it provides an environment with diverse physiognomies, varying from dense and stunted vegetation cover to low vegetation, depending on pedological and hydrographic factors, as well as larger individuals compared to those found in surrounding regions.

The vegetation formations found in the mountainous areas of the caatinga morphoclimatic domain have diverse physiognomic aspects. Areas situated on windward slopes are more humid and therefore present a denser and well-developed forest-like physiognomy, such as what occurs in the Chapada do Araripe, while those on leeward scarps have less favorable soil characteristics with more open formations and the presence of xerophytic species. (RODAL, 2002; PORTO, CABRAL, TABARELLI, 2004; DIOGO, MARTINS, COSTA, 2019).

These diversities of physiognomies have been attributed to the various climatic changes that occurred in the Northeast region of Brazil during the Pleistocene period when Amazonian and Atlantic forest formations advanced from the coast inland. (SAMPAIO, MARTINS, and COSTA, 2019). At the tops of the mountains, Amazonian vegetation prevailed, while in the lower areas, Atlantic Forest occurred. However, with changes at the end of the Pleistocene period, rainfall became scarcer and more unevenly distributed, leading to vegetational succession, especially on the tops, where cerrado species became established alongside some from the Atlantic forest. In the foothill areas of the plateaus, within the sertaneja depression environment, species adapted to seasonality, such as dense semi-deciduous seasonal forest, deciduous open seasonal forest, and open forest with vines, as well as arborescent caatinga formations, such as current arboreal and shrubby ones.

In the case of Chapada do Araripe, this succession occurred at the top with the remaining forest formations from this period, with the appearance of Carrasco related to the cerrado, or in narrow valley landscapes, as can be seen in the neighboring municipality of Ipubi - PE. This can be better understood in the work of NETO et al. (2013), which confirms the physiognomic diversity of these environments in the caatinga occurrence area

> “In the forest disjunctions of the Northeast, particularly in the semi-arid plateaus and plateaus, there are residual

> vegetation types that are little studied, such as the evergreen shrub vegetation of the sedimentary plateaus, which represents a vegetation refuge formed by species of caatinga, forest, rocky field and cerrado, of which little is known. Considering these different vegetation formations in the semi-arid region, the forests located in the mountains are, without a doubt, those with the greatest floristic richness" (Op Cit, 2013).

The physical-environmental factors that provide this plant and floristic diversity in the Northeast biome, as mentioned above, must highlight the importance of the morphogenetic balance between the events and processes that shape the relief and form soils typical of the semi-arid environment in conjunction with the biological aspects -ecological, as occurs in the work of Lyra (2003 p. 11), on the Geo-environmental analysis of the Brejo area in Serra das Varas in Arcoverde-PE:

> "The morphogenetic balance works as a process between the erosion and accumulation cycle that remodels the relief (morphogenesis) and forms the soil (pedogenesis). In the first, the actions of agents parallel to the surface plane, such as runoff and floods, remove and transport debris, excavating the soil and lowering the level of the earth's surface. In the second, agents perpendicular to the same plane, that is, physical-chemical weather, especially the infiltration of rainwater on the earth's surface, favored by the vegetation cover, promotes biochemical changes and the decomposition of rocks, developing soils."

In the case of the Brazilian Semiarid region, located in an area with water scarcity, landscapes become highly susceptible to environmental degradation due to vulnerability caused mainly by extreme climatic conditions (SÁ et al., 1994). The influence of climatic factors combined with anthropic activities significantly contributes to the increase in environmental degradation in these regions, as highlighted by Silva (2006, p. 19) who stated that "the lack of understanding of the complexity of the Semiarid led to the introduction of inadequate agricultural practices, causing or exacerbating environmental imbalances." This justifies the extensive degradation of landscapes caused by improper soil use.

However, this degradation is not only related to soil management and conservation but also to the inadequate use of mineral resources in the case of the gypsum mining region of Araripe. Thus, Sá et al. (1994, p. 134) conclude: "deficient planning and lack of conservation-oriented management further aggravate the current situation and project a problematic future," as occurs in the Araripe region with gypsum mining.

Sá et al. (2011) assessed the current stage of vegetation cover and the changes that occurred between 1998 and 2008 in the Araripe Pernambucano region through remote sensing, associating deforestation in this region with desertification processes. In their work, the authors affirm that "it is agricultural activities that cause a significant impact on soil cover and require special attention" (SÁ et al., 2011, p.1310).

The combination of these factors in the municipality and region makes the environment very challenging for regeneration in terms of complexity and sustainability. In this sense, one factor observed is the data collected from DNPM, which indicates the importance of the region where the municipality is located, responsible for over 90% of national gypsum production, through the 45 mines and 62 calcination plants existing, and the means used to transform gypsum into plaster, mainly with wood removed from native vegetation. Therefore, gypsum mining development in the region has extensively deforested much of the native vegetation because it is the energy source to feed the calcination plants, and even with IBAMA's actions, several species are often exploited.

The degradation of vegetation cover in territories with climatic characteristics classified as dry, arid, semiarid, dry sub-humid zones is characterized by the loss of cover in the affected area, where vegetation begins to thin out, opening clearings, and exposing the soil to intense erosive processes, where the most resistant species can no longer regenerate naturally, leading to losses of nutrients and soil thickness.

OBJECTIVE

The present study aimed to assess the degradation of vegetation cover in the municipality of Trindade, Pernambuco, presenting data collected both via satellite imagery and through on-site visits to research areas within the municipality's territory.

MATERIALS AND METHODS

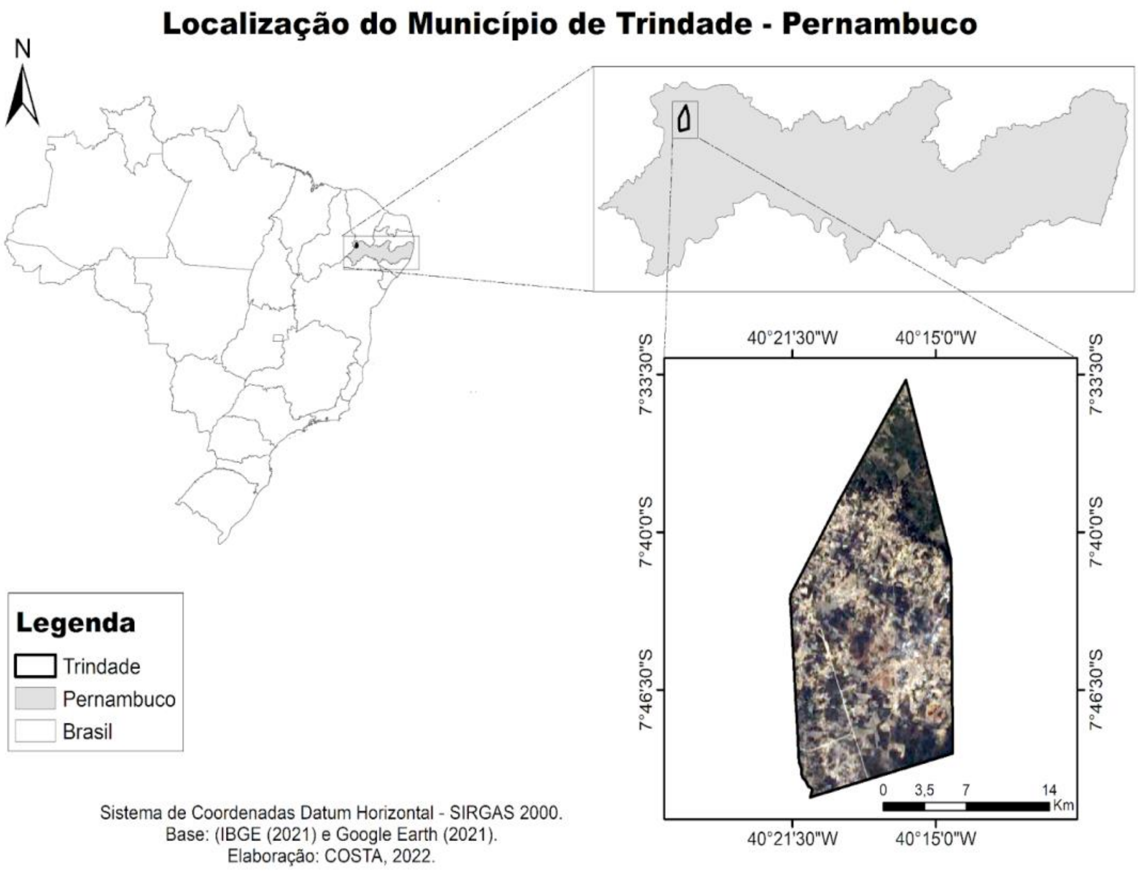
The object of study in this research, the vegetation cover and its degradation in the municipality of Trindade, Pernambuco, is at a significant level, particularly due to anthropogenic interventions, notably extensive agricultural and livestock activities, and mining associated with limestone lithology, with emphasis on gypsum extraction within the gypsum pole of Araripe (Figure 01). The municipal area covers a total of 295,765 km².

This degradation was observed through the characterization of the municipality's physical-environmental aspects, as well as the physiognomic conditions of the landscape and the distribution of tree species through documentary, biobibliographic, and field surveys, including a phytosociological survey that collected and selected over 50 relevant tree species from the local flora.

The research method is based on the phenomenological approach, i.e., it involves the observation and description of the landscape based on the researcher's perception and knowledge of the environment, providing a new means of analysis on the factor. A great example of the phenomenological method can be found in the period of the great geographical expeditions during the Brazilian empire, where several researchers made notes describing and analyzing the landscape, associating all the knowledge disseminated in Europe up to that point. One of the main authors is Auguste de Saint Hilaire, who, in his expeditions, even though romanticized in his work "Flora Brasiliae Meridionalis," provides new methods of analysis, offering a more specific descriptive character on the subject. This was done using field knowledge, describing the landscape, observing relevant local phenomena for vegetation behavior and physiological dynamics, as well as mapping its regional and local coverage.

The research involved multiple field trips where environmental characteristics were collected, including relief, soil, species found in the environment, and their propagation capacity, mainly due to environmental changes. After these procedures, the data were analyzed, and the areas of occurrence of each species under each environmental condition were deduced, corroborating the field findings. Mapping through geoprocessing of cartographic bases enabled the understanding of the evolution and change in the municipality's vegetation cover, as well as providing sketches to illustrate part of what the landscape was like in the past.

Figure 1 – Location of the study area



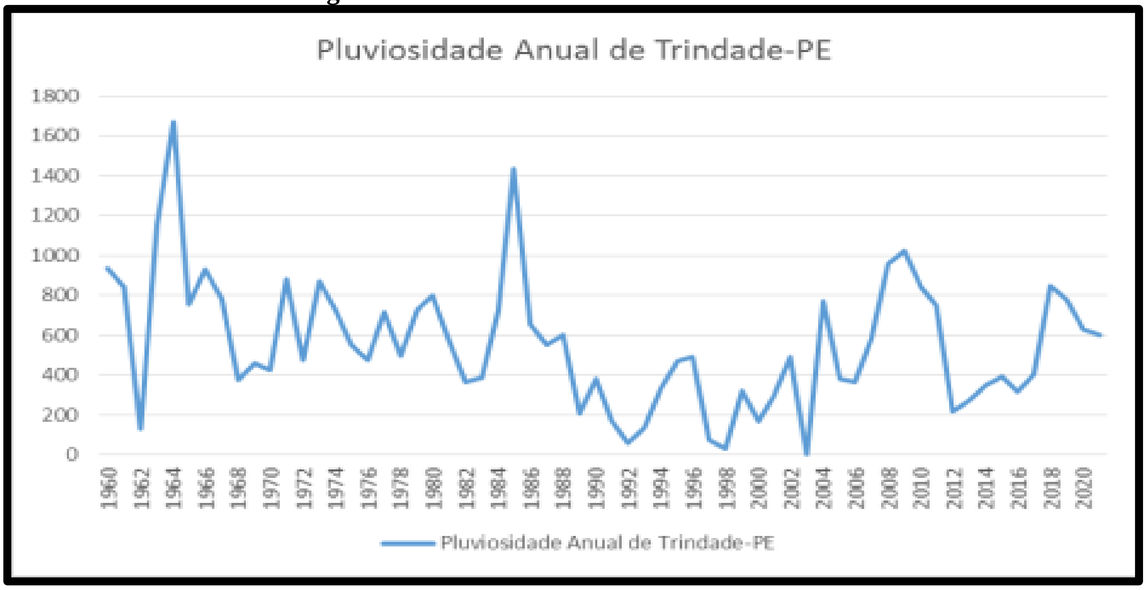
Souce: Google Earth, 2010. Organização: Autor, 2022**.**

RESULTS AND DISCUSSION

Climate

The climate of the municipality is semi-arid and according to Mendonça & Danni-Oliveira (2007, et.al.), it falls within the equatorial tropical climatic domain with 7 to 8 dry months and an annual average temperature ranging from 24º C to 26º C. The beginning of the rainy season occurs between October and November, and it ends between March and April, with sporadic and poorly distributed showers in mid-June. The average rainfall index of the municipality ranges from 610 mm to 750 mm, but according to data collected and analyzed, it can exceed 800 mm annually, with a dry season of 7 months and a rainy season of 5 months, with the strongest months being January, February, and March. It can be observed that the level of rainfall after the year 1985 was reduced, rarely exceeding 600 mm until the year 2019 (Figure 02). This result may have been influenced by the lack of measurements between the years 2005 and 2013; however, what is recorded in the field is that a period of drought was observed, which hindered part of the municipality's agricultural production during the mentioned period.

Figure 02: Annual rainfall in Trindade-PE



Source: APAC.PE. (2022)

Geology

The municipality of Trindade-PE is located in the region of Chapada do Araripe, which provides it with a certain degree of variety regarding its lithology (Figure 03). This region has experienced various events that altered part of its lithological structures, such as the Pernambuco Lineament fault, which altered part of the Itaizinho complex (PP2i), and during the formation period of the Araripe Plateau, which caused changes in the relief and landscape. The main lithostratigraphic units are:

- The Itaizinho Ouricuri/Trindade complex (PP2i): migmatized tonalitic to granodioritic and granitic orthogneiss, migmatitic, supracrustal remnants. This complex dates back to the Paleoproterozoic period.
- Indiscriminate chemistry granitoids (NP3 3i): various granitoids, 571 Ma U-Pb, from the Neoproterozoic period.
- Members of the Araripe Formation dated from the Mesozoic period, such as the Exu Formation (K2e): Kaolinic sandstone, siltstone, and conglomerates (interlaced fluvial); and the Santana Formation (K1s): shale, limestone, claystone, marl, and evaporite (marine and estuarine).
- Coluvio-eluvial deposits (NQc): sandy sediment, sandy-clayey, and conglomerates. Dated from the most recent period of the Cenozoic era.

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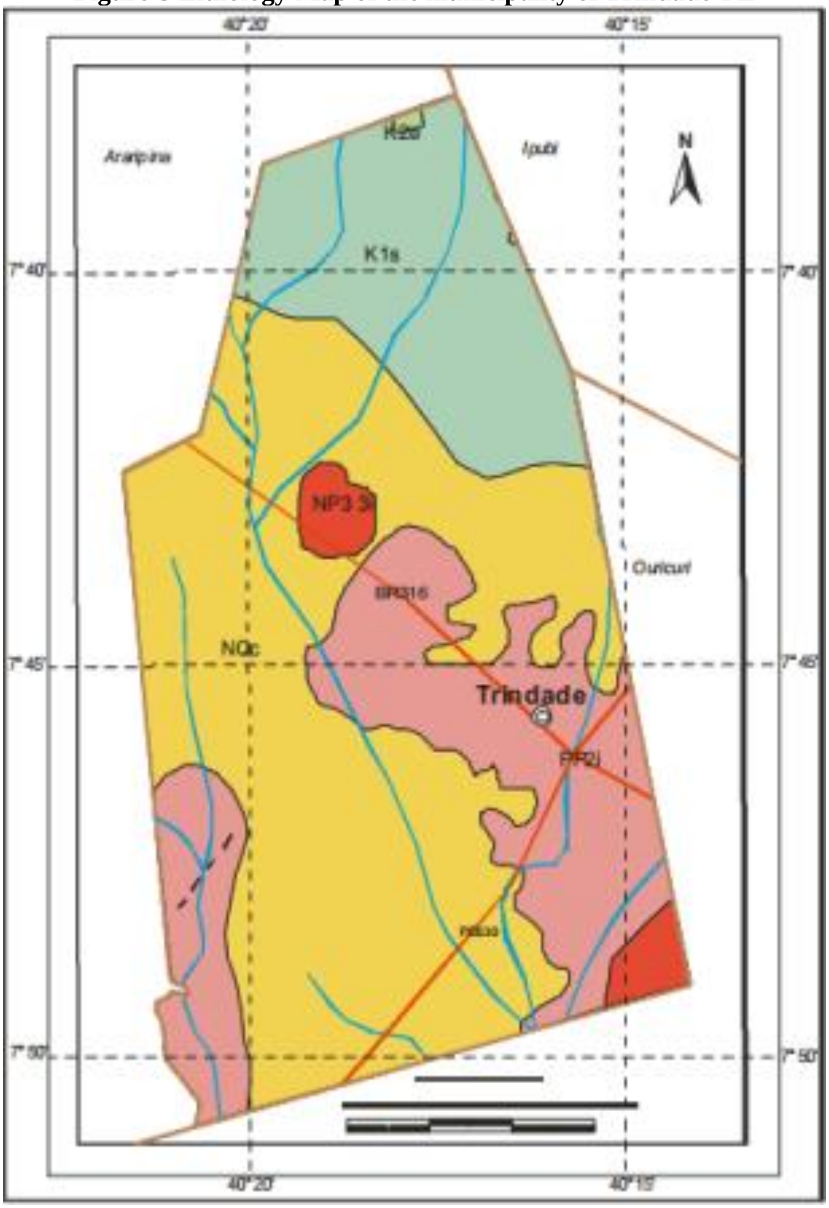
Figure-3 Lithology Map of the municipality of Trindade-PE

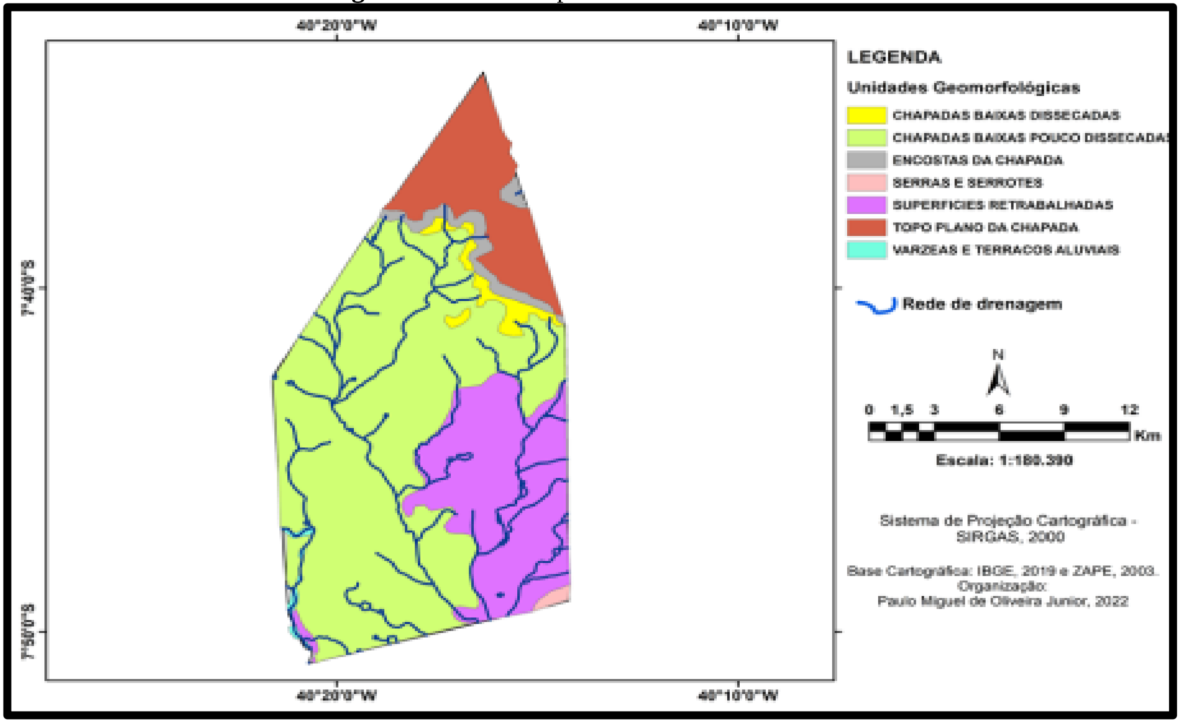


Sourcte: CPRM (2010).

Relief

The relief of the municipality is located largely in the southern sertaneja depression and in the northern part located on the Ibiapaba/Araripe Plateau, presenting the following geomorphological units: dissected low plateaus, the little dissected plateaus, the slopes of the plateau that have a certain escarpment, a set of mountains and saws mainly in the southeastern part, reworked surfaces that include the field area of Serra Preta and Lagoa do Espírito Santo, the flat top of the plateau mainly in the northern part, and the floodplains and alluvial terraces generally found near Riacho São Pedro (Figure 04).

Figure 04: Relief map of Trindade-PE



Source: ZAPE,2003, IBGE,2019. Organização: Autor, 2022**.**

Hydrography

The municipality is located in the sub-basin of the São Pedro stream, which is part of the Brígida river basin, one of the tributaries of the São Francisco River (Figure 05). The municipality contains several lagoons that are intermittent in nature, in addition to the stream that is named after the city (IBGE, 2012).

Figure - 05: Location of the municipality of Trindade-PE in the Brígida River basin

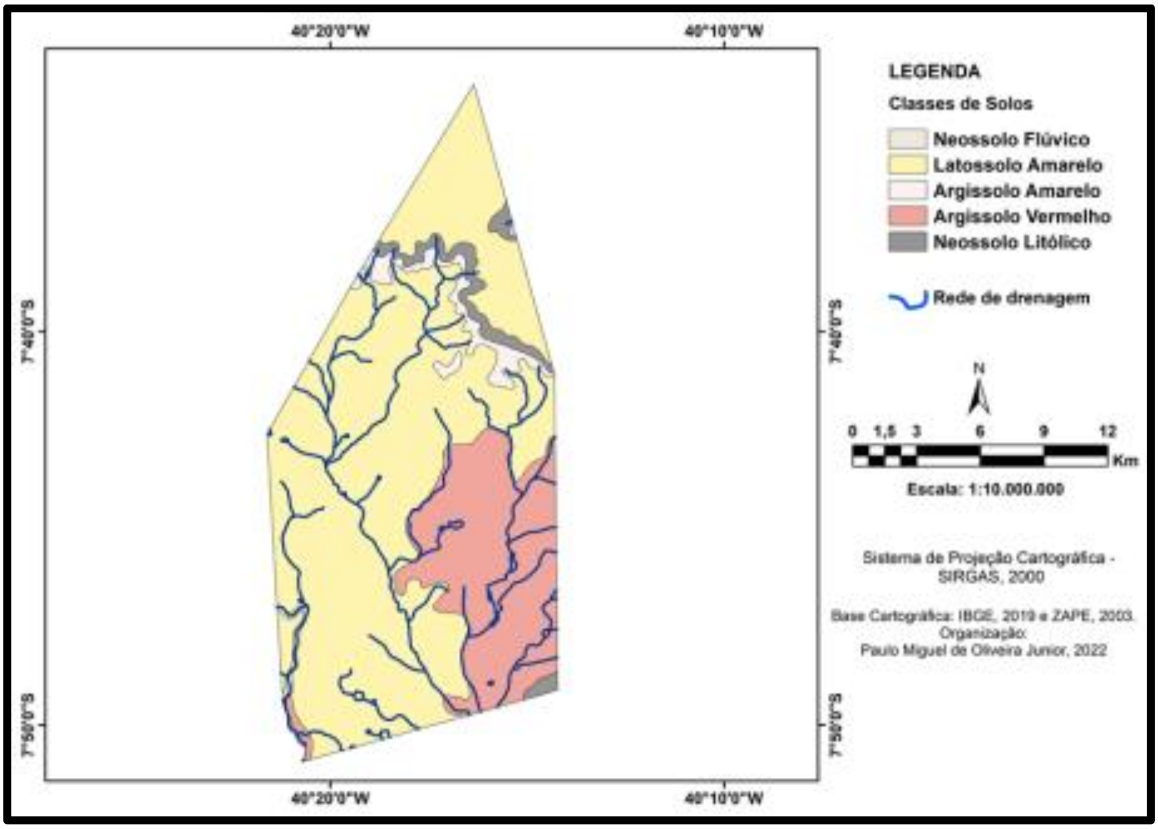
Source: Arruda, 2013 (Trindade se encontra em destaque na imagem na cor vermelha).

Solos

The main soil classes in the municipality of Trindade, according to the survey by ZAPE (2003) and compiled by IBGE (2019), are as follows: Fluvisols, Yellow Latosols, Yellow Argisols, Red Argisols, and Litholic Neosols.

Planosols can be found isolatedly in areas of long plateaus and low slopes of the gently undulating relief where there is poor drainage and they present medium natural fertility and problems related to salt action due to their liquid retention capacity. Shallow non-calcic Brown Cambisols with high natural fertility occur on the tops and upper parts of the slopes. Podzolic soils can also be found on types of slopes of gently undulating to undulating relief where they present medium natural fertility and good drainage. Shallow Litholic Neosols occur on residual elevations, being shallow, rocky, and of medium natural fertility. Yellow Latosols and Red Argisols can be found in much of the central area of the municipality covering parts of Lagoa do Espírito Santo, Baixa Velha, Sitio Bezerro, and Sitios Abóbora, Bonita, among other locations with gently undulating relief. The Yellow Argisol can be found mainly at the foot of the plateau near the village of Bonita.

Figure 06 – Map of Soil Classes in the municipality of Trindade – PE



Source: ZAPE, 2003; IBGE, 2019**.**

According to what was found in the field, it was possible to observe the presence of small patches of shallow soil in the area classified as Red Argisol, within the Lagoa do Espírito Santo. Here, rocks of crystalline origin such as quartz, gneiss, and others with highly altered reddish colors were found, some measuring up to 2 meters in area, and outcrops with rounded shapes up to 1.5 meters in height. In this lagoon environment, influenced by cyclical flooding and poor soil development, a predominant formation of grasses with small shrubs measuring no more than 2 meters in height was observed, sporadically forming a savanna landscape. However, on the edges of this lagoon in higher areas where the soil hardly shows any outcrops and is well-developed, it was common to find a dense forest landscape with trees easily exceeding 15 meters in height. Over the years, this landscape will also undergo anthropogenic alterations, and a regenerative area was identified, albeit in a shrubby manner.

In the Yellow Latosol, Cambisols with the presence of reddish gravel occur in isolated forms, mainly near the Baixa Velha community. In this environment, dense groves interspersed with stunted shrubs were found due to rapid drainage influenced by the relief. It also suffered from human actions, resulting in a mixed landscape of annual crops, pastures, and small secondary forests with initial stages of natural coverage. At Sitio Queimada Redonda, there is an abandoned mine, which allows understanding of soil specificity, as well as identifying part of the municipality's lithology consisting of gypsum from the Exu formation and some sandstones with a large number of limestone concretions.

In the area corresponding to the yellow Argisol, which usually occurs near the foothills of the Araripe Plateau in the Bonita village, a more forested environment with the presence of some springs can be found here and there. However, much of the area is also degraded due to overgrazing, rainfed agriculture, and vegetal extraction, mainly for the removal of hardwood for construction or fence building and for energy supply to companies in the gypsum industry. A decrease in agricultural productivity in the area is noticeable due to this degradation (Figure 08).

Figure 08 – Degrading activities in the village of Bonita, Trindade – PE.

Source: author 201.

The Red Argisol soil occurs in some areas associated with intermittent streams and large forest formations, which may have deciduous, sub-deciduous, or perennial characteristics depending on the location. Within this area, small areas with rocky outcrops of crystalline intrusive origin can be found, likely rocks originating from the Itaizinho Ouricuri/Trindade complex. These are soils of high fertility, providing a perfect environment for any crop production, whether perennial such as fruit cultivation or annual. However, in some areas where this type of soil is located, a decrease in production can be observed due to inappropriate agricultural techniques, as well as compaction from heavy machinery use in the initial production phases. In some areas, even during periods without cultivation or grazing, it can be observed that the vegetation cover cannot develop adequately.

The litholic Neosols are usually located in slope areas, characterized by strong erosive processes and rock falls. In this environment, large boulders with usually reddish sandstone rocks are noticeable, and in some locations of Serra Preta, crystalline rocks. The vegetation formation was not well developed due to the same factors mentioned earlier, predominantly composed of stunted shrubs varying from small to medium size, usually woody, and in various points with the presence of mosses and lichens on some rocks and sometimes exposed soil. This type of soil, due to its various limiting factors for agricultural production, was mostly destined for the rearing of goats, sheep, and cattle, mainly near the villages of Bonita and Saco Verde.

Vegetation

The municipality is inserted into the domain of Caatinga, which according to studies by various researchers characterizes it as xerophilous, a shrubby vegetation of medium to large size with isolated trees. This vegetation, according to IBGE (2012), is classified as a forested or shrubby steppe savanna physiognomy.

In general, the local vegetation is described as a hyper-thermophilic Caatinga with stretches of seasonal forest; however, field studies found other physiognomies that required a more appropriate classification system for the vegetation found. The classification methods used to generate the following conceptual maps were semi-open Caatinga (which also includes arboreal formations and stretches), open Caatinga (comprising grassland formations or in stages of ecological succession), and exposed soil (which included urban areas, mining areas, and others as well as areas where this soil lacks natural coverage).

In the northern part of the municipality, a more closed Caatinga area can be found, but it refers to the carrasco vegetation, which is a physiognomic formation of the Caatinga. The semi-open Caatinga, typical of a vegetation formation with trees that do not form a canopy, is in stages of regeneration. The open Caatinga is a physiognomy that depending on the author can be characterized as a savanna because the trees are low and spaced far apart, and exposed soil may appear, which may also be associated with gypsum extraction or refining, mining and extraction areas like the factories of the Araripe gypsum district, or by pasture/agricultural activity.

Figure 9 - Sítio Queimada Redonda, dense arboreal and shrubby caatinga vegetation in the regeneration stage

Source: Author, 2019.

Figure 10 - Redonda burn site, abandoned mining area with degraded open caatinga vegetation.

Source: Author, 2019

The expansion of areas of open Caatinga and exposed soil over areas of "semi-open" Caatinga, in the period from 1985 to 1998, is associated with the onset of mining and gypsum production in the municipality, as well as parts that suffered from the drier years recorded. However, in 2011, there was an increase in the coverage of open Caatinga and semi-open Caatinga due to the high rainfall in the region and the recovery of degraded areas, such as degraded pasture areas and abandoned dryland areas. However, in the following years from 2011 to 2021, the combination of various factors influenced the vegetation cover of the municipality, and in mid-2012, a severe drought began that lasted for a period of seven years, with considerable rainfall in 2018, and an increase in deforestation for the creation of new pastures and/or extensive agricultural areas with exposed soils. The sketches developed below illustrate the landscapes showing how the environment was before degradation in Figures 11 and 12.

The illustrations depict the richness of species found in an artistic way up to the year 2004, with the first showing the more xerophytic vegetation, low soil moisture in the sandy Yellow Latosol, and the second showing the more forested species with better soil moisture and a higher amount of nutrients contained in the Red Latosol with a certain clay content.

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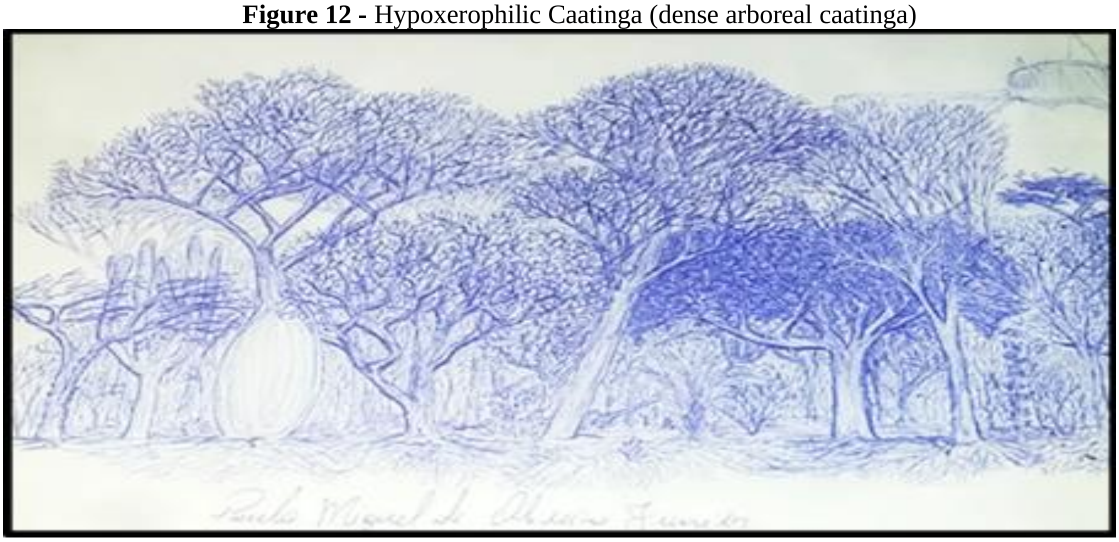
Figure 11 - Hyperxerophilic Caatinga (shrub-arboreal caatinga)

Source: Author, 2021

Figure 12 - Hypoxerophilic Caatinga (dense arboreal caatinga)



Source: Author, 2021

Uncontrolled deforestation for pasture creation and rainfed agriculture, along with native timber extraction for industry and the invasion of exotic species in the environment, have caused both environmental and social problems. Some of these species cause issues in agriculture and livestock farming, such as Algarobas (Prosopis juliflora), which can cause intoxication when consumed by livestock and various other problems in anthropized areas, including loss of pasture, invasion of cultivated areas, and damage to reservoirs. Along with this species, Leucaena leucocephala should also be mentioned, as it is another invasive species with similar issues.

Furthermore, climate change is also altering vegetation cover. Long periods of drought and irregular rainfall patterns are accelerating the process of savannization, as many species have adapted to specific periods of relatively frequent rainfall to initiate their reproduction and seedling propagation processes. With this change in rainfall patterns, this process also changes, leading to a deficit in vegetation cover regeneration (Figure 13)

Figure 13 - Area with natural regeneration problems at Serra Preta, Trindade – PE.

Source: Author, 2019.

Figures 20 and 21 depict the results obtained in the field regarding the number of species found and the characteristics of the vegetation cover in the municipality. One can observe a certain degree of thinning and expansion of areas with exposed soil related to rainfed agriculture, and to a lesser extent, urban expansion, meaning deforested areas for real estate purposes.

Figure 20 - Species found during field visits in 2004 and 2021

Source: Author, 2022**.**

Figure 21 - Species found in 2021 and their regenerative capacity

Source: Author, 2022**.**

Land use and occupation and degradation

The changes in human action in the municipality are quite clear, generating an unrestrained reduction in vegetation cover due to processes associated with industry and extensive agriculture.

Table 1 shows the numerical data relating to the physiognomies found in the region with the respective classifications: Ta (wooded steppe savanna), Ta/Reg (wooded steppe savanna in regeneration), Td (forested steppe savanna), STN (seasonal forest-n in regeneration), STN/Reg (seasonal forest in regeneration).

Table - 1 Quantification of existing physiognomies in the region divided by municipalities – Physiognomies (km2) in 2008.

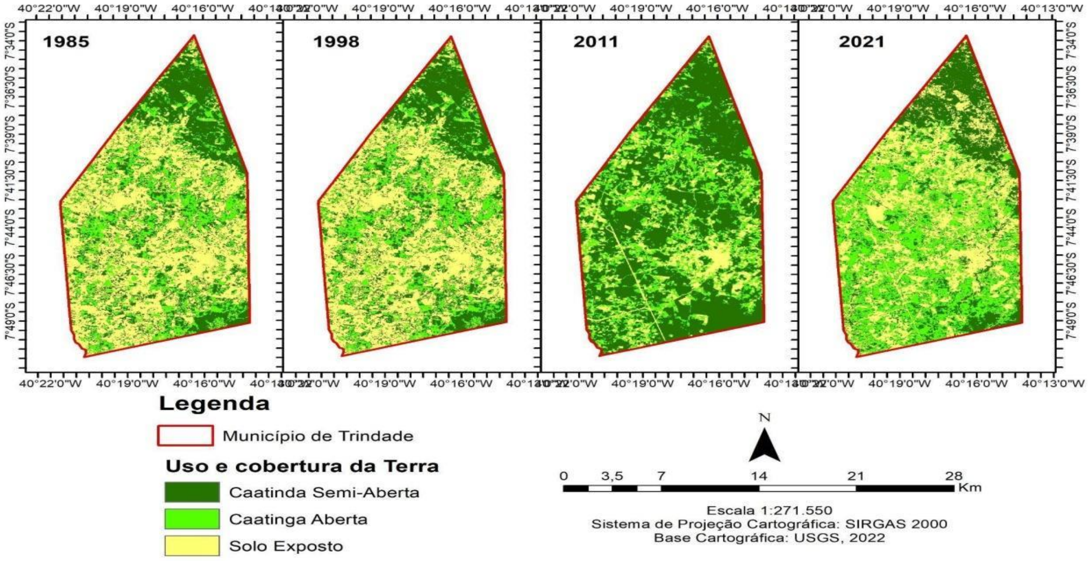
Quantificação das fisionomias existentes na região divididas por municípios - Fisionomias (km²) em 2008								
Municipios	Corpos hidricos	Solo exposto/ solo umido	AG/ZU	TA/Reg	STN/Reg	Ta	Td	STN
Araripina	5,16	1,68	321,21	367,85	571,14	207,47	83,75	349,79
Bodocó	1,99	1,52	96,26	384,57	96,27	318,15	167,65	531,71
Ipubi	0,52	0,67	43,41	28,55	161,94	63,07	124,24	547,97
Ouricuri	23,26	4,4	209,4	1090,96		891,53	156,06	
Trindade	0,12	0,07	13,48	61,82	0,3	111,21	41,15	1,09
Total	31,05	8,34	683,76	1933,75	829,65	1591,43	572,85	1430,56

Source: SÁ, I. I. S.; GALVÍNCIO, J. D.; MOURA, M. S. B. de; SA, I. B. (2010).

It can be observed that the vegetation cover in the municipality in the year 2008 consisted of 0.12 km² of water bodies, 0.07 km² of exposed soil, 13.48 km² of agriculture/urban areas, areas in a state of regeneration with Ta/Reg covering 61.82 km² and STN/Reg covering 0.3 km², and finally, vegetation covers such as Ta covering 111.21 km², Td covering 41.15 km², and STN covering 1.09 km². Some fragments of STN (deciduous seasonal forest) were found in the field, particularly near Lagoa do Espírito Santo, but currently only one area of Ta/Reg (Wooded Savanna in Regeneration) remains.

In the land use and land cover maps, degradation can be observed through satellite data, including in areas where regeneration was occurring, some of which have now been converted to pasture or agriculture (Figure 06). In the study area, particularly in Serra Preta, the advancement of deforestation and thinning of the cover through extractive activities is noticeable, where the Ta cover has lost much of its stature due to the felling of hardwood trees such as Schinopsis brasiliensis (Baraúna), Anadenanthera macrocarpa (Angico Vermelho), Myracrodruon urundeuva (Aroeira), Commiphora leptophloeos (Imburana de Cambão), and Amburana cearensis (Imburana de Cheiro).

Figure 06 - Map of land use and coverage in the municipality of Trindade-PE.



Source: SIRGAS, 2000; USGS, 2022.

When analyzing older data using satellite data and associating it with current periods, the following values can be seen (Table 02):

Table 02 – Areas per Km2 of land use and coverage classes in the Municipality of Trindade – PE, 1985-2021.

Year	CA	CS	SO
1985	184,18 km2	59,74 km2	51,72 km2
1998	55,96 km2	95,47 km2	144,22 km2
2011	175,96 km2	72,09 km2	47,61 km2
2021	101,87 km2	85,24 km2	108,54 km2

Source: SIRGAS, 2000; USGS, 2022. Organização, Autor, 2022.

One factor noted in the comparison of these land use and land cover maps was the rapid changes in the landscape within just 5 years. If we were to analyze older maps, such as those from the 1980s, a large part of the municipality was covered by dense and lush forest formations, and land use was also different, but less aggressive, with animals or field workers conducting processes with less damage to the soil compared to today.

Despite finding areas of exposed soil with a reduced area in the data, the field observations recorded a highly deteriorated environment with exposed soil and areas undergoing desertification processes, even at an early stage. Analysis of the dry mass and wet mass showed a reduced gradient, indicating soil fertility is concentrated in areas where water accumulates depending on the slope of the land.

CONCLUSIONS

From the obtained results, it was observed the degradation and loss of native vegetation cover, with the main culprits being a combination of factors, including climate change with reduced precipitation and consequent replacement of vegetation cover causing a relative savannization, especially with the loss of dense formations and the disappearance of native species less tolerant to changes in rainfall patterns. Another significant factor is human action and deforestation due to the activities of the gypsum industry, which uses wood as an energy source, leading to drastic reduction in vegetation cover and inadequate soil management exacerbating the desertification process in the municipality and throughout the Araripe region.

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