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Compartmentation and geoecological analysis of landscape units in the serra da Meruoca-CE, brazilian semi-arid region

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A B S T R A C T
Geoecological analysis corresponds to procedures, methods and techniques, whose purpose is to obtain knowledge about the environment. Therefore, the present work aims to compartmentalize and analyze the landscape units that make up the Serra da Meruoca, using the geoecology of landscapes as a theoretical-methodological basis. To achieve this, initially, a physiographic characterization was carried out, describing the components that form the landscapes, using existing data from works published in theses, dissertations, books, scientific articles and, mainly, through fieldwork. Based on the characterization of the components that form the landscapes and the superimposition, in a GIS environment, of data relating to them, the compartmentalization and analysis of the landscape units that make up the Serra da Meruoca, located in a semi-arid environment, but which differs from such an environment, configuring itself as a humid massif. In this way, it is understood that Serra da Meruoca has specific landscapes with their own characteristics, but which are interrelated through the flow of E.M.I. Therefore, it is understood that, although it is a Conservation Unit, greater preservation of its landscapes is necessary, due to its environmental relevance in the semi-arid northeast.
Keywords: Analysis; Landscape; Serra da Meruoca; Semi-arid.

Compartimentação e análise geoecológica das unidades de paisagens da serra da Meruoca-CE, semiárido brasileiro

R E S U M O
A análise geoecológica corresponde a procedimentos, métodos e técnicas, cujo propósito é a obtenção de conhecimento sobre o meio ambiente. Assim, o presente trabalho visa compartimentar e analisar as unidades de paisagens, que compõem a Serra da Meruoca, utilizando como base teórico-metodológica a geoecologia das paisagens. Para isso, inicialmente, fez-se a caracterização fisiográfica, descrevendo os componentes formadores das paisagens, utilizando dados existentes em trabalhos publicados em teses, dissertações, livros, artigos científicos e, principalmente, através dos trabalhos de campo. Com base na caracterização dos componentes formadores das paisagens e na sobreposição, em ambiente SIG, dos dados referentes aos mesmos, realizou-se a compartimentação e análise das unidades de paisagens que compõem a Serra da Meruoca, localizada em ambiente semiárido, mas que difere de tal ambiente, configurando-se como maciço úmido. Desta forma, entende-se que a Serra da Meruoca, possui distintas paisagens com características próprias, mas que se inter-relacionam através do fluxo de E.M.I. Portanto, entende-se que, embora seja Unidade de Conservação, é necessário maior preservação de suas paisagens, devido a sua relevância ambiental em meio ao semiárido nordestino.
Palavras-Chave: Geoecologia; Paisagem; Serra da Meruoca; Semiárido.

Introduction

Landscape Geoecology can be understood as "a system of methods, procedures and investigation techniques whose purpose consists in obtaining knowledge about the natural environment [...]" (Rodriguez et al., 2022, p. 13). To this end, the landscape must be considered as an anthroponatural formation, composed of natural and anthropogenic elements interacting systematically with one another through inputs and outputs of Energy, Matter, and Information (E.M.I.).

This approach can be applied across different scientific fields, enabling an integrated understanding of the landscape in its entirety through the analysis of biotic, abiotic, and social elements, as well as the interactions established among them. Grounded in a systemic perspective, Landscape Geoecology contributes to broader interpretations of environmental dynamics, supporting actions aimed at the planning, management, and conservation of natural environments (Guerra et al., 2024).

Research based on landscape geoecology has been widely developed in different fields of knowledge, especially in Brazil, with emphasis on approaches focused on sustainability, environmental planning, and the mitigation of degradation processes.

According to Faria et al. (2021), between 1990 and 2019, studies guided by this perspective presented a strong multidisciplinary, interdisciplinary, and systemic character, becoming consolidated in graduate programs and scientific publications. In this context, Vidal (2014) applied landscape geoecology to environmental planning in the lower course of the Curu River, in Ceará, while Teódulo (2014) employed landscape metrics, remote sensing, and GIS in the geoecological analysis of the landscapes of the Gramame River, in Paraíba (Rodrigues, 2023).

Other studies also highlight the relevance of geoecology as a support tool for territorial and environmental planning. Seabra (2012) employed this approach in the analysis of the landscapes of the São João River watershed, in Rio de Janeiro, aiming at forest suitability and restoration, thus approximating studies in landscape ecology. Likewise, Farias (2015) used geoecology to propose an environmental zoning of the Palmeiras River sub-basin, in Ceará, while Cunha (2019) applied geoecological principles to geoecotourism by diagnosing landscape vulnerabilities in the Viruá National Park, in Roraima.

In general, these studies reinforce the theoretical and methodological importance of landscape geoecology as an instrument for environmental analysis. In this sense, it is understood that studies adopting this perspective are concerned with the structure of the natural environment viewed as a totality composed of interconnected and interdependent components, with the main interest being the distinction of the functioning of environmental systems (Richling, 1983). According to Jatobá and Silva (2017), this approach has become widely disseminated in Brazil. The authors consider it part of Physical Geography, providing highly relevant information for environmental planning.

Therefore, as stated by Farias et al. (2021), landscape geoecology adopts systemic analysis as its theoretical-methodological procedure, encompassing two biases or research perspectives: an ecological one and a geographical one (Rodrigues et al., 2024).

Thus, in the present study, the geoecological analysis of the landscape will adopt the geographical perspective; that is, methods and technical-analytical procedures will be employed that make it possible to study landscapes as manageable and administrable systems (Rodriguez et al., 2022).

Accordingly, the concept of Geosystem constitutes the central basis of this approach, defined by Sotchava (1971) as a natural and anthroponatural formation governed by the flows of E.M.I., which are inherent to open systems. Diaz and Peres Filho (2017, p. 416) consider it a spatial unit formed by homogeneous areas that “establish relationships with the socioeconomic sphere (anthropic system).” Thus, although geosystems are natural formations, they undergo interference from anthropogenic activities, which influence and alter their structure, determining their stages of transformation.

Based on the theoretical-methodological conceptions of landscape geoecology, systemic analysis, and the concept of geosystem, the present study sought to carry out the compartmentalization and geoecological analysis of the landscape units of the Meruoca Mountain Range.

Materials and methods

Study Area

The Meruoca Mountain Range is located in the northwestern portion of the state of Ceará. According to Mendes et al. (2021), it is situated in the northwestern portion of the state of Ceará. It is located between the geographic coordinates 3° 32′ 30″ South Latitude and 40° 27′ 18″ West Longitude (WGr), approximately 260 km from the state capital, Fortaleza, with average altitudes ranging between 500 m and 700 m (Figure 1).

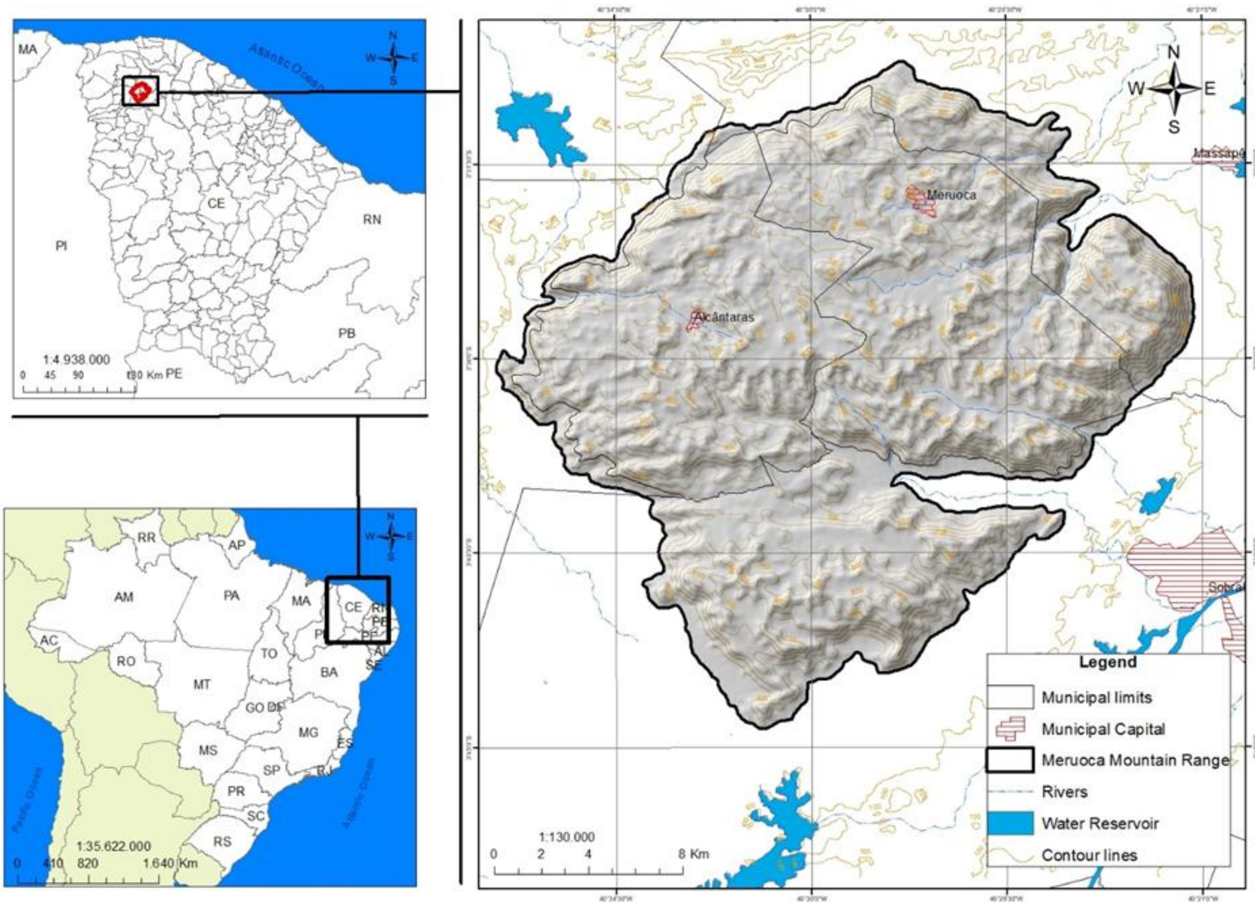

Figure 1 – Location of the Meruoca Mountain Range, northwestern state of Ceará. Source: Prepared by the authors (2025).

According to Lima et al. (2021), the Meruoca Mountain Range corresponds to a crystalline massif delimited by geological faults, presenting a shape similar to a diamond. It exhibits climatic conditions of greater humidity, which distinguish it from the semiarid conditions in which it is inserted, or from the dry hinterlands defined by Ab'Sáber (2003). Therefore, it is classified as a humid enclave, according to Falcão Sobrinho (2020).

According to Sousa and Oliveira (2006), humid enclaves correspond to true "islands" within the morphoclimatic domain of the caatingas. In these environments, the relationship among their natural components is reciprocal, with relief—through altitude, slope, and exposure—acting as the main conditioning factor of mesoclimatic characteristics.

Although the Meruoca Mountain Range may be classified among the Humid Mountains or Humid Enclaves, it is composed of distinct landscapes, reflecting the relationships among its components, such as geological structure, relief, climatic and pedological conditions, and the different types of land use and land cover. Thus, the present study sought to carry out the compartmentalization of the landscape units that compose the Meruoca Mountain Range, highlighting their formative components.

Methodological Procedures

The research was developed based on a methodological sequence structured into different stages, aiming at the compartmentalization and analysis of the landscape units of the Meruoca Mountain Range. Figure 2 summarizes the methodological procedures adopted, beginning with the delimitation of the study area. Subsequently, data processing was carried out in a GIS environment. Afterwards, secondary data were used, encompassing information related to the geoecological components. Then, the delimitation of the landscape units was performed, mainly based on relief features. Finally, an analysis of the landscape units was conducted.

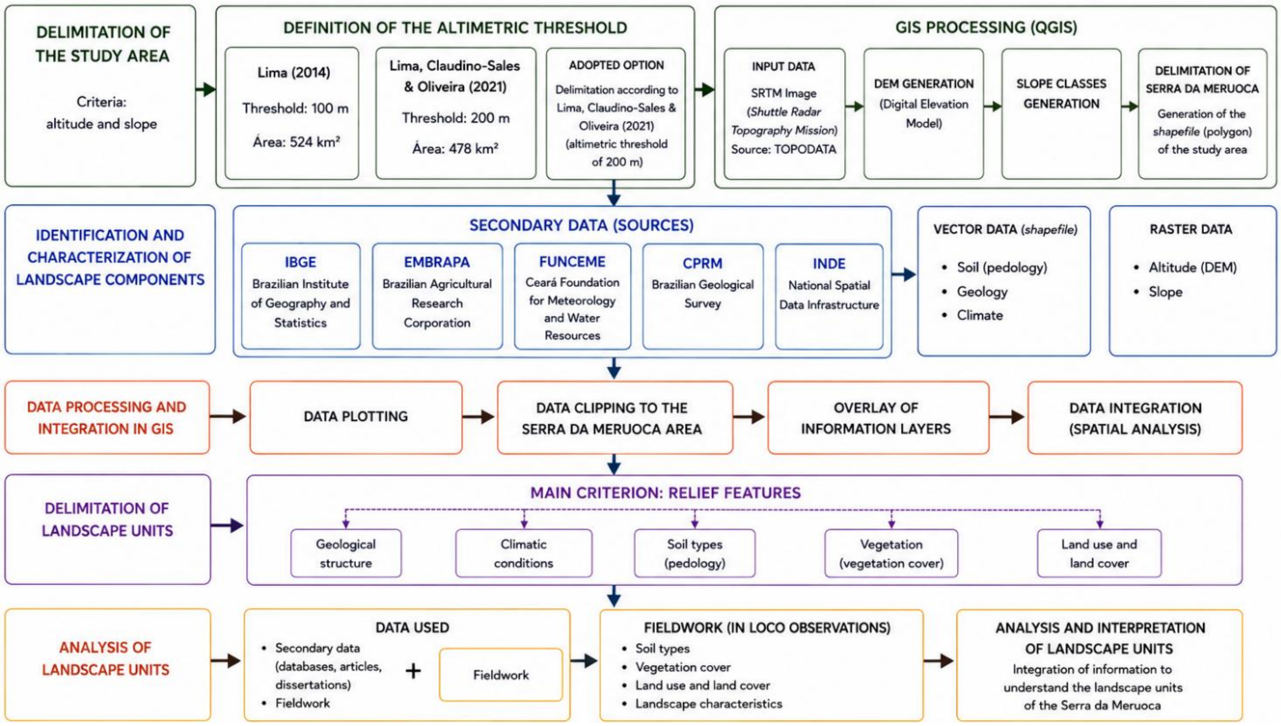

Figure 2 – Flowchart of the methodological procedures adopted in the research. Source: Prepared by the authors (2026).

As shown in Figure 2, the study area was initially delimited using altitude and slope as the main criteria. For this purpose, the methodological proposal of Lima et al. (2021) was adopted, which defines the Meruoca Mountain Range based on the 200-meter elevation contour, encompassing an approximate area of 478 km².

In the following stage, data processing was carried out within a Geographic Information System (GIS) environment using QGIS software. Shuttle Radar Topography Mission (SRTM) images obtained from the TOPODATA database were used, from which the Digital Elevation Model (DEM) and slope classes were generated. These products enabled the spatial delimitation of the Meruoca Mountain Range through the creation of vector files in shapefile format.

Subsequently, the identification and characterization of the formative components of the landscapes were conducted. For this purpose, secondary data from different public institutions were used, such as the Brazilian Institute of Geography and Statistics (IBGE), the Brazilian Agricultural Research Corporation (EMBRAPA), the Ceará Foundation for Meteorology and Water Resources (FUNCEME), the Mineral Resources Research Company (CPRM), and the National Spatial Data Infrastructure (INDE). Vector data related to pedology, geology, and climate were collected, in addition to raster data associated with altitude and slope.

After data acquisition, the information was processed and integrated within the GIS environment. At this stage, the data were plotted, clipped to the Meruoca Mountain Range area, and subsequently overlaid, allowing the integration of the different information layers through spatial analyses.

Based on this integration, the delimitation of the landscape units was carried out, adopting relief features as the main criterion. In addition, elements such as geological structure, climatic conditions, soil types, vegetation, and land use and land cover were considered, enabling the identification of the different landscape units present in the study area.

Finally, the analysis of the landscape units was conducted using both secondary data and information obtained from fieldwork. During field activities, in situ observations were carried out regarding soil types, vegetation cover, land use and land cover, and other landscape characteristics. The integration of this information enabled the analysis and interpretation of the landscape units of the Meruoca Mountain Range, contributing to the understanding of the environmental dynamics of the studied area.

Results and discussion

The results obtained in this research made it possible to understand the environmental dynamics and the organization of the landscape units of the Meruoca Mountain Range, highlighting the influence of natural factors and anthropogenic actions on the current configuration of the studied area. Thus, the Results and Discussion section presents the characterization of the geoecological components of the landscapes and the analysis of the identified landscape units, emphasizing aspects related to geomorphology, vegetation cover, soils, land use and occupation, and environmental issues.

Geoecological Components of the Landscapes of the Meruoca Mount ain Range

It is important to mention that the Meruoca Mountain Range currently corresponds to an Environmental Protection Area (APA), created in accordance with Law No. 11,891, of December 24, 2008, encompassing an area of 29,361.27 hectares. The Serra da Meruoca Environmental Protection Area presents the following delimitation: the northeastern, eastern, and southeastern slopes, starting from the 200 m (two hundred meters) elevation contour, in the municipalities of Meruoca and Massapê, and the entire area above the 600 m elevation contour, in the municipalities of Meruoca, Massapê, Alcântara, and Sobral (Lima & Freitas Filho, 2015).

According to the classification proposed by Diniz (2010), the Meruoca Mountain Range is located within the physiographic unit known as the low plateau. According to the author, this unit extends from the descent of the Ibiapaba Plateau to the coastal tablelands. It is composed of sedimentary and crystalline rocks (igneous and metamorphic), with evidence of pegmatitic intrusions, corresponding to the Meruoca area.

From a geological perspective, the Meruoca Mountain Range comprises a reddish coarse-grained granitic “stock,” formed during the Brasiliano orogeny, corresponding to continental collision events that formed the supercontinent Gondwana during the Proterozoic (2.5–541 Ma) (Lima et al., 2021).

The Meruoca-Rosário and Mucambo “stocks,” despite their spatial discontinuity caused by the rocks of the Jaibaras Group, share a set of common factors indicative of their genetic relationship and the contemporaneity of the intrusions. Both are intrusive into the Bambuí Group, which can be demonstrated by the contact metamorphism and metasomatism aureoles that, without affecting the rocks belonging to the Jaibaras Group, place them in the post-Bambuí and pre-Jaibaras period. In addition, both present generalized coarse grain size, indicating their plutonic nature, and both also display discordant behavior with the formations of the Bambuí Group (DPRM, 1973).

Thus, according to CPRM (2000), the study area is lithostratigraphically composed of the Meruoca Granitoid (eg4m), and colluvial-alluvial deposits may occur, covering valley bottoms and the bases of escarpments. According to Gorayeb and Lima (2014), the Meruoca Mountain Range corresponds to a record of the Brasiliano orogeny from the Neoproterozoic and early Paleozoic, also referred to as Neoproterozoic Brasiliano Granitoids. This suite is intrusive into rocks of the Granja Complex (PP1g) and the Martinópole (NPm) and Ubajara (NPu) groups on the northern slope, bordering the Jaibaras Basin through the Café-Ipueiras Fault (CPRM, 2003).

According to Bastos and Cordeiro (2012), the geological structure, through its chemical, physical, and mineralogical composition, is more or less resistant to exogenous processes. Thus, it constitutes the basis for landscape structuring, influencing the characteristics of the other components, especially relief and soils.

Regarding geomorphology, the Meruoca Mountain Range comprises a residual massif structured upon the Meruoca Granitoid (eg4m), delimited by Brasiliano Shear Zones (SZ), with slopes typically derived from faults, hillsides with very steep gradients and inclines, and deep valleys (Costa Falcão, 2002). Its slopes, where they come into contact with the hinterland surface, appear relatively rectilinear, demonstrating clear structural control. It also presents more pronounced erosional embayments due to the Boqueirão Stream, in the municipality of Sobral. Thus, it contains slopes, dissected plateaus, and alveolar plains (Rodrigues et al., 2024).

According to Falcão Sobrinho (2020), residual massifs, in the case of Meruoca, present hill-shaped summit tops or relief crests, indicating the preexistence of older plateau surfaces more extensive than the current ones, constituting humid highland enclaves, with steep slopes and hill-dissected summits.

Thus, in the Meruoca Mountain Range, two distinct faces can be identified. One is located to the north, with deep valleys and peaks exceeding

900 m, characterized by higher humidity and composed of ridges, hills, and semi-mamelonized forms, as highlighted by Moreira and Gato (1981). The second, located to the south, presents altimetric elevations between 600 m and 800 m, under drier conditions.

In this way, according to Lima (2016), the first face is under climatic conditions of greater humidity, with regularly distributed precipitation, such as the rainfall index recorded in the municipality of Meruoca, which reaches 1,800 mm. As emphasized by Falcão Sobrinho (2006), this area is under a more intense influence of chemical weathering, favoring the formation of deeper soils and taller vegetation cover. In contrast, on the dry slopes of the second face, there is lower humidity, higher temperatures, and poorly distributed rainfall in time and space, facilitating the occurrence of physical weathering, resulting in shallow and stony soils and shrub caatinga vegetation.

In other words, regarding climatic conditions, the area presents a higher humidity index, distinguishing itself from the semiarid conditions in which it is inserted. According to Zanella and Sales (2011), it constitutes one of the humid areas existing in the state of Ceará.

The combination of altitude and relief exposure in relation to the displacement of humid winds coming from the ocean enables the occurrence of orographic rainfall, providing high rainfall indices and configuring a humid highland environment, which represents a true humidity enclave amidst the flattened surface of the hinterland depression (Lima, 2016).

According to Sousa (2024) and IPECE (2017), the climate is classified as Mild Semiarid Tropical Hot and Tropical Hot Subhumid, with annual rainfall totals exceeding 1,000 mm and temperatures ranging from 24 °C to 26 °C. According to the Köppen classification, the climate of the Meruoca Mountain Range corresponds to Aw’, with summer rains and maximum precipitation in autumn, characterized as hot and humid, with rainfall distributed between January and June.

Furthermore, regarding surface water resources, the Meruoca Mountain Range acts as a watershed divide for the Acaraú River basin (eastern sector) and the Coreaú River basin (western sector). Thus, the best water conditions correspond to the alveolar plains with colluvial-alluvial deposits, that is, aggradational environments containing streams, enabling their use for water supply and providing better conditions for the cultivation of fruits and vegetables. It is noteworthy that the main water bodies are located in the municipality of Meruoca, such as the Flecheiras and Jenipapo reservoirs.

Regarding pedology, two predominant soil classes were identified: Red-Yellow Argisols (PVA) and Litholic Neosols (RL). The PVAs predominate on humid slopes and plateaus. According to Santos et al. (2018), they consist of mineral material with textural B horizons immediately below the A or E horizons, with high-activity clay. As for the RLs, they are predominantly found on dry slopes and are characterized by presenting lithic or fragmented lithic contact within 50 cm from the surface, with absent A or histic horizons, directly overlying the rock (Santos et al., 2018).

On the humid slopes and plateaus, where Red-Yellow Argisols (PVA) predominate, according to the classification of Fernandes (1990), Humid Forest (Perennifolious) occurs, and areas of Dry Forest (Subdeciduous) may also be found. The humid forest occurs on plateau areas above 650 m altitude and on windward slopes. On the dry slopes, where Litholic Neosols (RL) occur, Shrub Caatinga (Deciduous) was identified, that is, vegetation typically associated with semiarid conditions.

Regarding land use, livestock activities were observed, especially cattle raising. Temporary and permanent crops were also identified, such as corn, beans, banana plantations, among others. In terms of settlement, the towns of Meruoca and Alcântara stand out, as well as some districts such as Jordão, Anil, Palestina do Norte, São Francisco, Ventura, among others. This demonstrates that the Meruoca Mountain Range is significantly occupied.

Given the above, the Meruoca Mountain Range possesses its own distinctive physical-natural characteristics, including geomorphological, climatic, phytoecological, hydrological, and pedological aspects, as well as specific vegetation cover physiognomies, providing better environmental conditions and configuring it as an exceptional landscape amidst the northeastern semiarid region.

Analysis of the Landscape Units of the Meruoca Mountain Range

Some studies have already been carried out in the Meruoca Mountain Range involving landscape compartmentalization. Lima (2014) distinguished eight (8) environmental systems: dissected plateau, southern slope, western slope, humid western slope, humid northern slope, hinterland depression, alveolar plain, and fluvial plain. Lima (2016) compartmentalized five (5) geoenvironmental units: dry slopes, dry plateau, humid slope, humid plateaus, and alveolar plains.

Another compartmentalization worth mentioning is that established during the creation of the Serra da Meruoca Environmental Protection Area (APA), which was subdivided into Sector A, corresponding to the humid western slope and humid northern slope, starting from the 200 m elevation contour, and Sector B, above the 600 m elevation contour, in the municipalities of Alcântaras, Meruoca, Massapê, and Sobral.

Based on the studies mentioned above, as well as criteria of altitude, slope, and the interrelationships among landscape components, four (4) types of landscape units were compartmentalized in the Meruoca Mountain Range: dissected plateaus, dry slopes, humid slopes, and a small area characterized as foothills, corresponding to pediments (Figure 3).

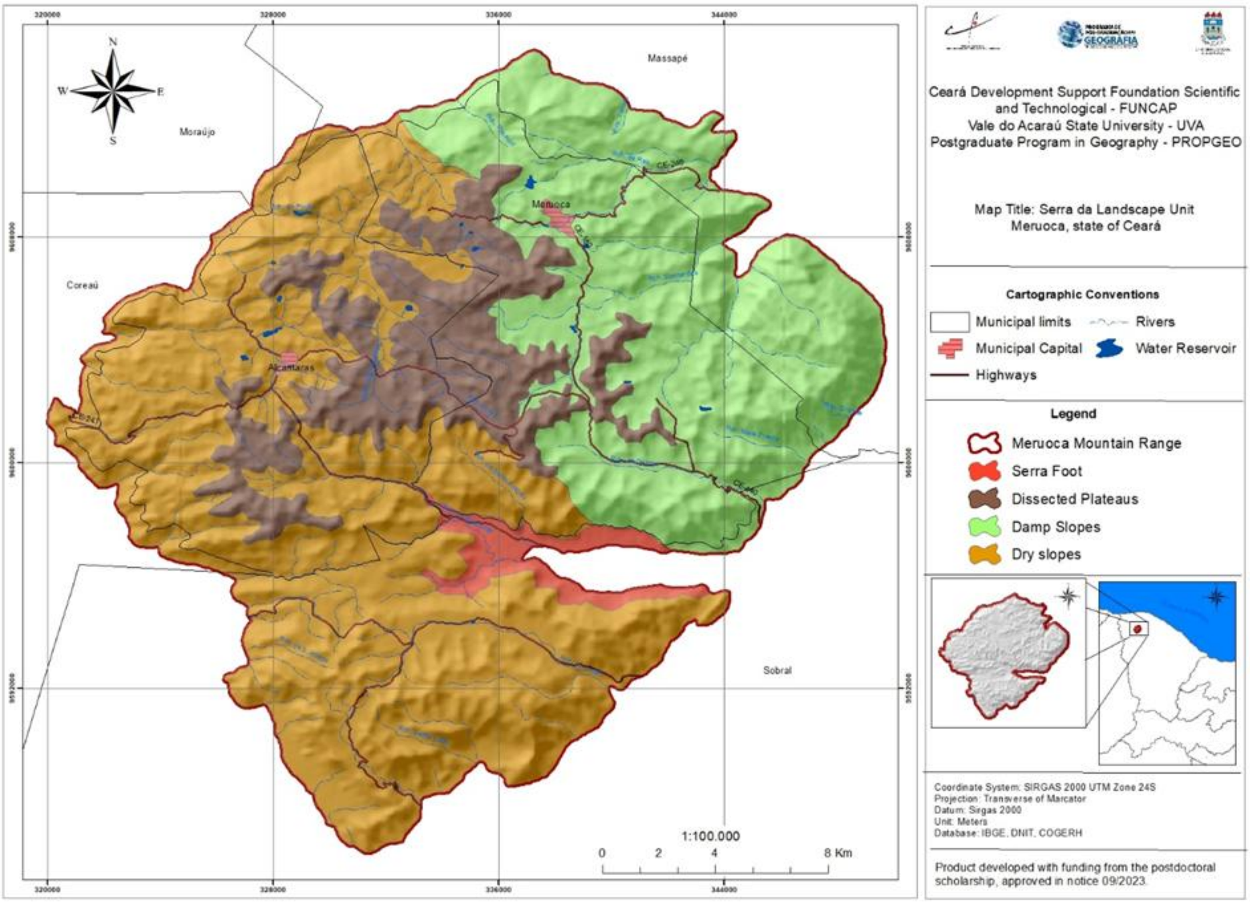

Figure 3 – Landscape Units of the Meruoca Mountain Range, State of Ceará, Brazilian semiarid region. Source: Prepared by the authors (2025).

Foothills

This landscape unit was not compartmentalized by Lima (2016), who instead delimited and classified it as Hinterland Depression. According to the author, it extends to the Meruoca Mountain Range through the valleys of the Boqueirão and Contendas rivers, presenting a flat bottom filled with alluvial and colluvial sediments.

In the present study, only the area corresponding to the Boqueirão River valley was delimited, since the delimitation differs from the previous proposal. Thus, it covers only 13 km², representing 2.8% of the researched area. It is covered by dense shrub caatinga vegetation, with Litholic Neosols (RL) soils, and altitudes not exceeding 400 m. Regarding land use, agro-pastoral activities occur, predominantly cattle raising and temporary crop cultivation, such as corn and beans. Concerning environmental problems, deforestation and burning stand out (Carneiro et al., 2018).

Therefore, foothill areas (hinterland surface) present climatic conditions similar to those of the dry slope. The area has been considerably altered due to subsistence agriculture and extensive livestock farming. This landscape unit presents environmental characteristics that allow it to be classified as environmentally fragile and, therefore, in need of conservation measures.

In addition to the pressures resulting from agro-pastoral activities, the environmental fragility of this unit is associated with the natural limitations imposed by edaphoclimatic and geomorphological conditions. Litholic Neosols (RL), due to their shallow depth and high susceptibility to erosion, become vulnerable when subjected to deforestation and inadequate soil management.

The removal of vegetation cover favors surface runoff, intensifying erosive processes and reducing the water retention capacity of the environment. Associated with this, the recurrent use of fire in agricultural practices contributes to the degradation of soil fertility and the loss of local biodiversity.

In this context, the implementation of sustainable management practices capable of reconciling the economic use of the area with environmental conservation becomes essential. Among the recommended measures are the restoration of native vegetation, the control of burning practices, the adoption of soil conservation techniques, and the encouragement of less impactful productive systems. Such actions can contribute to reducing degradation processes, ensuring greater environmental stability and a better quality of life for populations directly dependent on the natural resources of this landscape unit.

Figure 4 presents different landscapes of the foothills of the Meruoca Mountain Range. In Figure 4.a, the presence of dry and sparse herbaceous vegetation can be observed, characteristic of drought periods within the Caatinga domain. Urbanized areas and road infrastructure are also noticeable, indicating the advance of human occupation over this landscape unit.

In Figure 4.b, a foothill area can be observed with sparse and partially degraded vegetation, predominantly composed of shrub species typical of the Caatinga, in addition to the significant presence of exposed soils. This configuration indicates the occurrence of vegetation degradation processes associated with anthropogenic activities, such as burning and urban expansion.

In Figure 4.c, the presence of a paved highway can be observed, evidencing road infrastructure interventions associated with the process of urban expansion and territorial integration. Along the roadside, predominantly dry and sparse vegetation cover typical of the Caatinga can be identified.

Figure 4 – Landscapes of the Foothills of the Meruoca Mountain Range. 4.a) Foothills with the presence of the humid slope, demonstrating the advance of urbanization. 4.b) Foothill areas with the presence of exposed soils and urbanization. 4.c) Foothill area with the presence of a paved highway. Source: Authors (2025).

Humid Slopes

This landscape unit corresponds to the humid western slope and humid northern slope in the classification proposed by Lima (2014). In the geoenvironmental compartmentalization of Lima et al. (2021), it corresponds to the humid slopes. These areas cover 154 km², representing 32.2% of the total area.

They present higher average precipitation levels due to humid winds coming from the coast, which generate orographic rainfall because these slopes are located on the windward side. The greater incidence of precipitation, in turn, produces increased surface runoff (Mendes et al., 2021), determining the formation of V-shaped valleys and presenting greater altimetric amplitude, that is, greater variation between the highest point and the local base level.

Thus, the slopes are steep, exceeding 75%, with escarped relief predominating. In some sectors, due to the greater slope gradient, erosive processes are more evident, inhibiting pedogenesis and resulting in the exposure of escarped rocks and Litholic Neosols (RL). This soil type occurs on steep slopes at altimetric levels below 600 m. The steeper slopes, associated with the occurrence of shallow and stony soils, hinder the process of land use and occupation. Therefore, species of both Humid Forest and Dry Forest occur in a more preserved state, demonstrating that this is a transition area toward the Caatinga proper.

In the higher areas (above 600 m altitude) of the humid slopes, the predominance of Red-Yellow Argisols (PVA) is identified. According to Diniz (2010), these soils present medium to high fertility. Mendes et al. (2021) analyzed one Red-Yellow Argisol (PVA) profile with vegetation cover and another without vegetation cover on the humid slope of the Meruoca Mountain Range, concluding that these soils present good agricultural performance (Diniz & Diniz, 2022), although they should be conserved because they are used for the cultivation of corn, beans, and bananas.

Therefore, it can be observed that even though the area is legally protected as an Environmental Protection Area, there are small properties practicing subsistence agriculture, with permanent and temporary crops, especially mango, banana, coffee, cassava, corn, and vegetables. Vegetal extractivism was also identified, including the exploitation of babassu coconut and wood for different uses. Thus, this landscape unit should be better preserved.

Regarding environmental problems, they are related to the mobilization of weathered material from higher areas to lower areas due to the steep slopes, as well as to deforestation for agricultural development.

Thus, it is understood that humid slopes present climatic conditions of greater humidity and precipitation, as well as milder temperatures, associated with the presence of deeper soils such as

Red-Yellow Argisols (PVA), covered by humid forest vegetation. Regarding land use, permanent crops are more common, such as banana and mango plantations, among others. It is a less occupied area, with the presence of small settlements. Therefore, environmentally, it is a less fragile area; however, due to the development of socioeconomic activities, it shows signs of degradation of natural components and should therefore be preserved.

Figure 5 presents three images of the humid slopes of the Meruoca Mountain Range. The images allow the observation of the influence of climatic conditions on environmental dynamics. In image 5.a, the steep relief can be observed, with the predominance of dry forest vegetation, thus representing a transition area toward humid forest.

Image 5.b demonstrates a slope covered by humid forest, that is, relatively dense vegetation cover, suggesting the influence of microclimatic conditions of greater humidity in higher sectors.

In image 5.c, the presence of more preserved humid forest can be observed, characterized by greater vegetation density and the absence of substantial signs of socioeconomic activities. Such conditions reveal an environment with a lower level of anthropogenic intervention, favored by greater humidity conditions and the conservation of natural vegetation.

Figure 5 – Humid Slopes of the Meruoca Mountain Range. 5.a) View of the humid slope with the presence of dry forest. 5.b) View of the slope showing humid forest vegetation. 5.c) Presence of humid forest. Source: Authors (2024).

Dry Slopes

This landscape unit corresponds to the southern and western slopes in the classification proposed by Lima (2014), and to the dry slopes in the classifications of Lima et al. (2021). In the study area, it represents 50.4% of the total area, corresponding to 241 km².

This landscape unit is located on the leeward side of the Meruoca Mountain Range; therefore, it presents low rainfall indices, with the predominance of physical weathering and dissected relief, forming ridges. The predominant soil type is Litholic Neosol (RL). According to Santos et al. (2018), this type of soil presents lithic contact within up to 50 cm from the surface, with an A or histic horizon directly overlying the C or R horizon, covered by Shrub Caatinga vegetation. In the higher areas (above 500 m), Red-Yellow Argisols (PVA) occur, covered by Arboreal-Shrub Caatinga.

Regarding land use and occupation, subsistence agriculture is identified, mainly cultivating corn and beans. Extensive livestock farming was also observed, with the raising of cattle, goats, and sheep. Therefore, deforestation occurs on the steep slopes, accelerating erosive processes.

Thus, it was observed that on the Dry Slopes, the typical semiarid climatic conditions enable a more intense action of physical weathering, being associated with the predominance of shallow and young soils such as Litholic Neosols (RL), covered by arboreal caatinga (dry forest) or shrub caatinga. Regarding land use, temporary crops such as corn and beans predominate, as well as livestock farming, especially cattle raising. Therefore, these are environmentally fragile areas requiring greater conservation and preservation efforts, that is, stronger public policy actions.

Figure 6 presents the dry slopes of the Meruoca Mountain Range. In image 6.a, the predominance of Arboreal Caatinga can be observed, characterized by vegetation adapted to conditions of lower humidity, in addition to rocky outcrops distributed throughout the landscape. This configuration reveals an environment marked by the influence of semiarid conditions and the predominance of vegetation cover typical of the Caatinga.

Image 6.b demonstrates the dry slope covered by Shrub Caatinga, associated with a significant presence of rocky outcrops. In addition, the occurrence of urbanization processes can be observed, evidenced by houses distributed throughout the area, indicating greater anthropogenic intervention and human occupation within this landscape unit.

In image 6.c, Arboreal Caatinga can be observed, presenting a more preserved environmental condition. The density of the vegetation cover and the reduced presence of anthropogenic interventions indicate a more significant state of conservation.

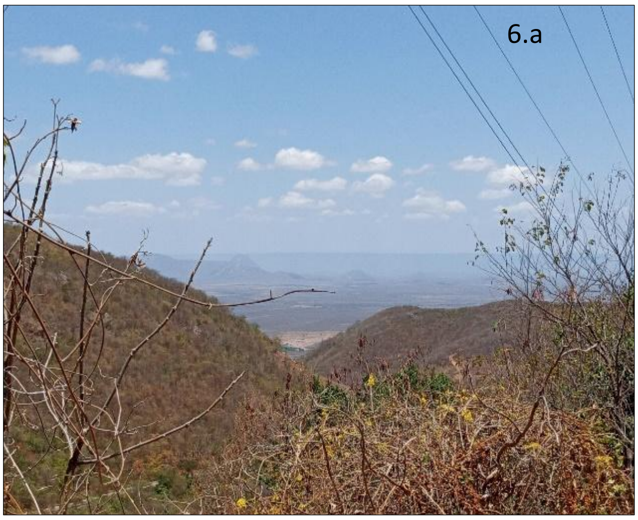

Figure 6 – Dry Slopes of the Meruoca Mountain Range. 6.a) View of the Dry Slope showing the presence of Arboreal Caatinga. 6.b) Dry Slope demonstrating the presence of Shrub Caatinga, with rocky outcrops. 6.c) Dry Slope with the presence of Arboreal Caatinga. Source: Authors (2024).

Dissected Plateaus

In the geoenvironmental compartmentalization proposal of Lima et al. (2021), this landscape unit is subdivided into humid plateau and dry plateau. In the study area, it covers 70 km², representing 14.5% of the total area.

This unit contains the areas with the highest population density, such as the town of Meruoca and the districts of Palestina do Norte and São Francisco. Regarding climatic conditions, they present characteristics similar to those of the humid slopes, constituting summit wetlands, with relief formed by hills, ridges, and rounded elevations interspersed with alveoli (Lima, 2016).

In the alveoli, where better hydrological and fertility conditions occur, occupation is more intense. It is in these sectors that urban areas are built and where land use for socioeconomic activities is more significant. In this sector, the predominant soils are Fluvic Neosols (RY), which are soils derived from alluvial sediments (Santos et al., 2018). These soils are generally used for agricultural practices.

In the higher elevation areas, Red-Yellow Argisols (PVA) occur. According to Falcão Sobrinho (2006), on the elevated plateaus these soils exceed one (1) meter in thickness and are covered by arboreal vegetation, referring to humid and dry forest. However, the humid forest is highly altered, remaining preserved only in the highest areas. The dry forest is located in the lower areas. The plateaus situated under drier climatic conditions, located in the western (W) and southwestern (SW) sectors, present shrub caatinga vegetation.

Regarding land use, both temporary agriculture (cultivation of corn, beans, tomatoes, and cassava) and permanent agriculture (cultivation of mango, papaya, and banana) can be observed, as well as livestock farming on small properties and mineral extraction. Therefore, the environmental problems are related to deforestation, urban growth, and mining activities.

Thus, the climatic conditions are similar both to those of the humid slopes and the dry slopes. In the present study area, this unit includes the alveoli, which are more densely occupied. Red-Yellow Argisols (PVA) predominate, although Fluvic Neosols (RY) also occur in the alveolar areas, with the predominance of humid forest vegetation. This landscape unit may be considered environmentally fragile and is currently highly degraded, requiring conservation measures.

Figure 7 presents the dissected plateaus of the Meruoca Mountain Range. In image 7.a, a cashew plantation can be observed in the alveoli, associated with the occurrence of exposed soils. The landscape reveals the partial replacement of natural vegetation cover by agricultural activities, resulting in alterations to the environmental characteristics of the area, especially in vegetation dynamics and the increased susceptibility of soils to erosive processes. Image 7.b exemplifies occupation within the alveoli, with the presence of residences.

Image 7.c demonstrates the humid plateau of the Meruoca Mountain Range, characterized by the presence of partially preserved humid forest. A denser vegetation cover can be observed, favored by conditions of greater humidity, although signs of anthropogenic interventions that contributed to the partial modification of the natural vegetation of the area are also evident.

Figure 7 – Dissected Plateaus of the Meruoca Mountain Range. 7.a – Alveolus with the presence of cashew plantation. 7.b – Alveoli with residential constructions. 7.c – Plateaus with partially preserved humid forest. Source: Authors (2024).

Final Considerations

Landscape geoecology, as a theoretical-methodological approach, proved to be efficient for the methodological construction of this research, enabling the analysis of the landscape units that compose the Meruoca Mountain Range. It is concluded that each unit presents its own physical-environmental characteristics, which allowed their individualization. However, these units maintain constant interaction with one another through the flows of E.M.I.

It was also observed that these units are found in different environmental states: some more preserved and others more altered. Despite this, it was verified that all of them are subjected to degradation processes resulting from the intense use and occupation of the land. This process becomes more pronounced in flatter relief areas and in sectors with greater humidity and milder temperatures, such as the humid slopes and the alveoli.

Thus, it is concluded that the Meruoca Mountain Range, in all of its landscape units, requires measures aimed at environmental preservation and conservation.

Furthermore, the importance of integrated environmental planning is highlighted as a fundamental instrument for minimizing the impacts resulting from anthropogenic activities in the mountain range. The adoption of sustainable land-use practices, associated with continuous monitoring of environmental conditions, can contribute significantly to maintaining the ecological balance of the landscape units, ensuring the conservation of natural resources and the improvement of the environmental quality of the studied area.

Finally, the research highlights the need to strengthen public policies aimed at the environmental management of the Meruoca Mountain Range, especially regarding the protection of areas most vulnerable to degradation processes. In this context, it becomes essential to promote environmental education actions among local communities, encouraging awareness of the importance of preserving natural systems and the rational use of environmental resources, aiming to ensure the sustainability of the mountain range for future generations.

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