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CERRADO ENCLAVE AND THE UPDATE OF THE MAPPING OF LANDSCAPE UNITS IN THE STATE OF RIO GRANDE DO NORTE

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Marco Túlio Mendonça Diniz [a*] - Ana Caroline Damasceno Souza [b] - Diogo Bernardino Santos de Medeiros [c]
Antônia Vilaneide Lopes Costa de Oliveira [d] - Sandro Damião Ribeiro da Silva [e]

(a) PhD in Geography. Professor at the Federal University of Rio Grande do Norte, Caicó (RN), Brazil.
ORCID: https://orcid.org/0000-0002-7676-4475. **LATTES:** http://lattes.cnpq.br/3075753552167640.
(b) PhD student in Geography. Professor at the Federal University of Rio Grande do Norte, Caicó (RN), Brazil.
ORCID: https://orcid.org/0000-0003-1037-5685. **LATTES:** http://lattes.cnpq.br/0331312800452529.
(c) Master in Geography. Federal University of Rio Grande do Norte, Içu (RN), Brazil.
ORCID: https://orcid.org/0000-0002-3542-0449. **LATTES:** http://lattes.cnpq.br/9934756491094172.
(d) Master in Development and Environment. Federal University of Rio Grande do Norte, Caicó (RN), Brazil.
ORCID: https://orcid.org/0000-0001-8962-0692. **LATTES:** http://lattes.cnpq.br/9379700743524442.
(e) PhD student in Geography. Professor at the Federal University of Rio Grande do Norte, Caicó (RN), Brazil.
ORCID: https://orcid.org/0000-0002-0693-7238. **LATTES:** http://lattes.cnpq.br/9098603154623804.

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(*) CORRESPONDING AUTHOR
Address: UFRN. Av. José Evaristo, s/n. Penedo, CEP: 59300000, Caicó (RN), Brazil.
Phone: (+55 84) 34214870
E-mail: tuliogeografia@gmail.com

Abstract

The mapping of landscape units is a dynamic process in which constant modifications are needed. Based on this, this article sought to update the mapping of landscape units in the state of Rio Grande do Norte. This was possible due to the combination of field activities and new methodological procedures, with analyzes and refinements of previous mappings conducted by Silva (2018), Bernardino (2019), and Souza (2020). The main result is the update of a mapping that includes the (re-) delimitation and (re-) classification of Morphoclimatic Domains, Natural Regions, and Geocomplexes in the territory of this state. A new unit was identified and inserted: a cerrado enclave, which, until then, had not been described and analyzed as such in the established literature; consequently, one more natural region and two geocomplexes were mapped and delimited. New territorial occurrences of units already identified/classified in the original work were also mapped and, therefore, there was a resizing of landscapes of different taxa, which resulted from these modifications and of the refinement of their limits, due to the greater scalar detail, with the deepening of the research.

Keywords: Keywords:Geosystem; Geoprocessing Techniques; Landscape Analysis.

Resumo / Resumen

ENCLAVE DE CERRADO E A ATUALIZAÇÃO DO MAPEAMENTO DAS UNIDADES DE PAISAGEM DO ESTADO DO RIO GRANDE DO NORTE

O mapeamento de unidades de paisagem é um processo dinâmico e necessitado de constantes modificações. Partindo dessa premissa, este artigo buscou atualizar o mapeamento de unidades de paisagens do estado do Rio Grande do Norte. Isso foi possível a partir da combinação entre atividades de campo e novos procedimentos metodológicos, com análises e refinamentos de mapeamentos anteriores efetuados por Silva (2018), Bernardino (2019) e Souza (2020). Como principal resultado apresenta-se a atualização de um mapeamento que contempla a (re-)delimitação e (re-)classificação dos Domínios Morfoclimáticos, Regiões Naturais e Geocomplexos do território do estado do Rio Grande do Norte. Foi identificada e inserida uma nova unidade: um enclave de cerrado, que, até então, não havia sido descrito e analisado como tal na literatura consagrada; a reboque, mais uma região natural e dois geocomplexos puderam ser mapeados e delimitados. Mapeou-se, também, novas ocorrências territoriais de unidades já identificadas/classificadas no trabalho original e, por conseguinte, ocorreu um redimensionamento de paisagens de diferentes táxons, também como resultado, propriamente, dessas modificações, bem como do refinamento dos limites das unidades, em função do detalhamento escalar maior, com o aprofundamento da pesquisa.

Palavras-chave: Palavras-chave:Geossistema; Técnicas de Geoprocessamento; Análise da Paisagem.

ENCLAVE DE CERRADO Y LA ACTUALIZACIÓN DEL MAPEO DE UNIDADES DE PAISAJE EN EL ESTADO DE RIO GRANDE DO NORTE

El mapeo de unidades de paisaje es un proceso dinámico y necesita modificaciones constantes. Con base en esta premisa, este artículo buscó actualizar el mapeo de unidades de paisaje en el estado de Rio Grande do Norte. Esto fue posible a través de la combinación de actividades de campo y nuevos procedimientos metodológicos, con análisis y refinamientos de mapeos previos realizados por Silva (2018), Bernardino (2019) y Souza (2020). El principal resultado es la actualización de un mapeo que contempla la (re) delimitación y (re) clasificación de Dominios Morfoclimáticos, Regiones Naturales y Geocomplejos en el estado de Rio Grande do Norte. Se identificó e insertó una nueva unidad: un enclave cerrado, que hasta entonces no había sido descrito y analizado como tal en la literatura consagrada; a continuación, se podría cartografiar y delimitar otra región natural y dos geocomplejos. También se mapearon nuevas ocurrencias territoriales de unidades ya identificadas / clasificadas en el trabajo original y, por lo tanto, hubo un redimensionamiento de paisajes de diferentes taxones, también como resultado, propiamente, de estas modificaciones, así como del refinamiento de los límites de las unidades, debido al mayor detalle escalar, con la profundización de la investigación.

Palabras-clave: Geosistema; Técnicas de Geoprocesamiento; Análisis del Paisaje.

INTRODUCTION

The systemic conception in landscape studies has offered important theoretical support for the delimitation of landscape units. In it, each unit is characterized by a certain physiognomic and functional homogeneity and can be identified by the systemic analysis of the interactive attributes that compose it. In this sense, these hierarchically organized units form a mosaic of a larger system and may be studied in a single or several distinct complexes.

Practically, the landscapes hierarchically divided into integrative units are configured as an instrument for planning and ordering the territory, endowed with techniques and theoretical support that reveal characteristics of the taxonomic levels analyzed, exposing their susceptibilities and potentialities in the face of human interventions.

In this perspective, Diniz and Oliveira (2018), taking as a reference the geosystem as a category of analysis and the geocomplex as a taxonomic unit, as pointed out by Beroutchachvili and Bertrand (1978), published a mapping of landscape units in the state of Rio Grande do Norte (RN) at three taxonomic levels: Morphoclimatic Domains, Natural Regions and Geocomplexes.

The article published by Diniz and Oliveira (2018) is part of a series of thematic mappings conducted by the Geoprocessing and Physical Geography research group (LAGGEF/CNPq). The series also includes works by Diniz and Pereira (2015) and Diniz et. al. (2017), which were the basis for this study.

In the original work (DINIZ; OLIVEIRA, 2018), two morphoclimatic domains, a transition area, eight natural regions, and twenty geocomplexes at a scale of 1:250,000 were mapped for the state of RN. This article, although recent, has already become the basis for large-scale studies, such as the Ecological-Economic Macrozoning Project of the Piranhas-Açu Basin (COBRAPE, 2020), contracted by the government of the state of RN.

With the deepening of the research, especially with the advances in fieldwork necessary for the research of Silva (2018), Bernardino (2019), and Souza (2020), who conducted the mapping of geofacies in different regions of the state of RN, on a scale of 1:50,000, it was first observed the existence of a new unit of landscape not identified in the previous mapping, a cerrado enclave, not yet reported as such, and, as a consequence, another natural region and two geocomplexes; second, new territorial occurrences of units already identified in the original work; third, new empirical facts that showed the need for a resizing of the domain units, and, with that, the suppression/reclassification of natural regions and geocomplexes in terms of their immediately superior taxon; fourth, the need for refinement in the limits of the other geocomplexes, because of the scalar detailing; and, finally, the urgency of adaptations in the conventions of cartographic representations.

Thus, the aim of this new work was to map and analyze the cerrado enclave present in the territory of the state of RN, Brazil, as well as to update/refine the map of the landscape units of the RN at a representation scale of 1:250,000.

METHODOLOGICAL PROCEDURES

The state of Rio Grande do Norte is in the extreme northeast of Brazil (Figure 1), approximately between the coordinates 4°50'S and 6°59'S, and 34°58'W and 38°34'W; it is one of the nine states in the Northeast region and is limited to the west by the state Ceará, to the south by the state Paraíba and to the north and east by the Atlantic Ocean. In 2020, the estimated population for the state was 3,534,165 inhabitants (IBGE, 2020).

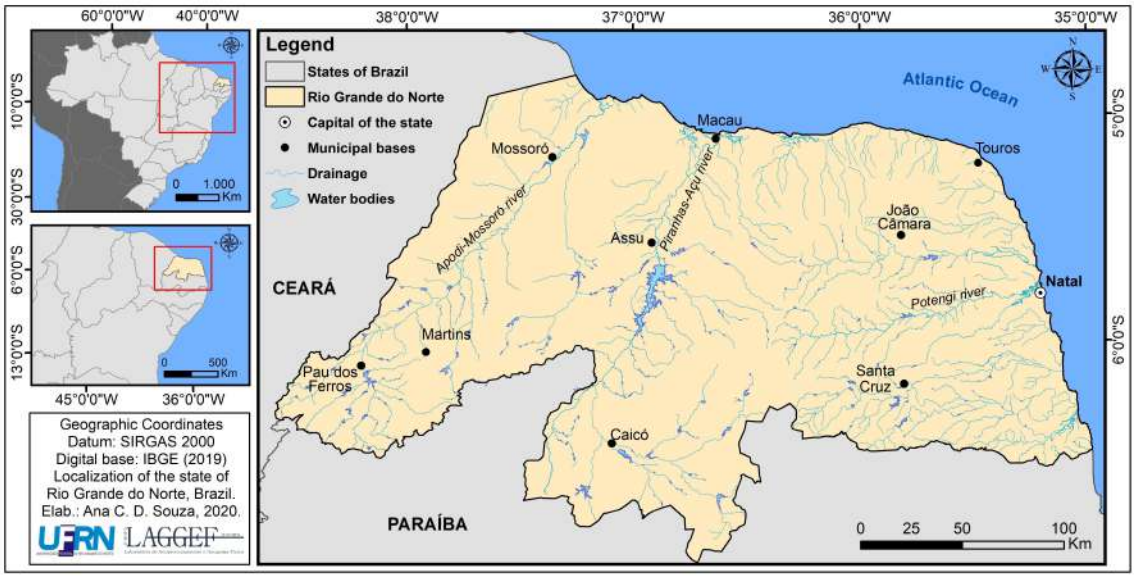


Figure 1 – Location map of the state of Rio Grande do Norte. Source: Elaborated by the authors (2020)

In this update, the same taxonomic system of the work by Diniz and Oliveira (2018) was used, now updated, which is the one proposed by Bertrand (1972), presenting the largest to the smallest landscape unit, in hierarchical order: Zone, Domain, Natural Region, Geocomplexes, Geofacies, and Geotopes. Considering the scale of the work and the existence of a single climatic zone in the area, the maps of Morphoclimatic Domains, Natural Regions, and Geocomplexes were updated, according to the refinements presented by Silva (2018), Bernardino (2019), and Souza (2020), when conducting their mapping of geofacies for different regions of the state, on a scale of 1:50,000.

The compartmentalization of the morphoclimatic domains in Brazil by Ab'Saber (2003) was used, focused on the state of RN; and the taxonomic levels of the natural region and the geocomplexes by Diniz and Oliveira (2018), on a scale of 1:250,000. In addition, the concomitant analyzes of the geologic maps of the state (ANGELIM; MEDEIROS; NESI, 2006) were used at a scale of 1:500,000; Geomorphology (DINIZ et al., 2017) at a scale of 1:250,000; Soils from the RADAMBRASIL project, Jaguaribe Natal sheet, at a scale of 1:500,000 (BRASIL, 1981); and Climatology at 1:500,000 (DINIZ; PEREIRA, 2015), which used isohyets data (SUDENE, 1990) for the change/decrease in the limits of the morphoclimatic domains of the Atlantic Forest and Agreste, considering values above 1,200mm/year.

The theoretical framework developed by Oliveira et al (2012) was used as a basis to determine the existence of a "Cerrado Enclave" in the NE portion of the state. This author conducted a floristic identification of the cerrado species in the municipality of Rio do Fogo (RN), without, however, proposing the delimitation of the occurrence of the referred unit; 94 plant species were sampled, of which, according to the bibliography surveyed, 73 are associated with this biome. Of these, 69 are also found in the caatinga, 60 in the Atlantic Forest biome, 47 in the Amazon Forest, 14 in the Pantanal, and 11 in the pampas.

To update the mapping of the area, images from the Sentinel-2A and 2B satellites, orbit 52 and 09, respectively, with the Multispectral Instrument (MSI), were used. They were acquired for free from the website of the United States Geological Survey (USGS), through https://earthexplorer.usgs.gov/. This satellite has 13 spectral bands ranging from 10 to 60 meters of spatial resolution (Table 1), of which the composition of three visible spectral bands 04, 03, and 02 (R4G3B2) were used in this research, all with a resolution of 10 meters. After the selection and acquisition of these orbital products, we composed the mosaic of five images dated from 06/30/2018 and 08/31/2018, for the East Coast and Agreste region; and four images for the Seridó Potiguar, from 12/27/2018, considered adequate due to being set between the end of the dry season and the beginning of the rainy season in the Seridó region (BERNARDINO, 2019; SOUZA, 2020).

Resolution	Band Number	Description	Central Wavelength (nanometer)	Band Combinations
10 m	B02	Blue	490	True Color RGB 04/03/02 False Color 1 and 2 RGB 08/04/03 and 04/08/03
	B03	Green	560	
	B04	Red	665	
	B08	NIR	842	
20 m	B05	Red Edge 1	705	SWIR 1 RGB 12/11/8ª
	B06	Red Edge 2	740	
	B07	Red Edge 3	783	
	B08A	Red Edge 4	865	
	B11	SWIR 1	1610	
	B12	SWIR 2	2190	
60 m	B01	Aerosol	443	–
	B09	Water Vapor	940	
	B10	Cirrus	1375	

Table 1 – Sentinel-2 satellite: spatial resolution and spectral bands. Source: USGS (2019).

These images have been popularized by the scientific community in mapping, mainly for environmental analysis and land use and cover, as they are freely available. In addition, the two satellites provide monitoring images of the area with frequent recurrence. According to the USGS (2019), the Sentinel-2 mission; which has two satellites in operation, Sentinel-2A, and Sentinel-2B; has a 10-day repetition cycle, with a sun-synchronous orbit, covering the entire terrestrial territory, to capture aspects such as vegetation, land cover, and conduct environmental monitoring due to its periodicity.

Satellite images were processed in a virtual environment of Geographic Information Systems (GIS), in the ArcGIS software (academic version), making the mosaic and its treatments, such as equalization, contrast, and brightness, to avoid abrupt transitions between the frames. Then, polygons were created for each feature and vectorized manually[1].

Besides the thematic maps used as a basis to support the classification hypotheses of each landscape unit, Google Earth Pro, version 7.3.3.2776 was used as an auxiliary support tool, to identify landscapes in a better resolution, since it provides multitemporal satellite images with a spatial resolution of up to 50 centimeters, in addition to another essential resource from the Google company: the Street View, allowing navigation in a large part of the area, covering federal and state highways and some roads. This step can be considered a preliminary validation.

In the field reconnaissance activities to identify and characterize the different landscape units, there was, first, an exploratory reconnaissance of the environment that would be mapped, and, later, the Samsung Galaxy Note 10.1 tablet was used with the previous map of the area for validating the results, with the vector files inserted in the Google Earth software.

We have also used a Global Navigation Satellite System (GNSS) device in the field, model 79CSX, of the Garmim brand; and an Unmanned Aerial Vehicle (UAV), of the Phantom 3 Advanced model, for photographic records and solving doubts regarding hard-to-reach places. After that, there was the process of finalizing, in the office, the revision of the maps and the construction of a theoretical and empirical discussion of the research results.

UPDATE OF THE MAPPING OF LANDSCAPE UNITS IN RIO GRANDE DO NORTE

With the refinement of the studies presented, to achieve the objectives of classifying and mapping the geofacies of the eastern coast and agreste of RN, Souza (2020) identified subsidies for changing the limits of morphoclimatic domains, thus having a new definition of the area, where it reduced the territorial scope of the "Domínio dos Mares de Morros Florestados" ("Domain of the Sea of Forested Hills"), or Atlantic Forest Domain.

It was observed, in the field, that the predominant characteristics in the landscapes, such as

vegetation, are responses to the climate and its elements (e.g., rainfall), and a part of the territory previously classified as the Atlantic Forest Domain does not correspond to its predominant vegetation, being part, in fact, of the "transition area (Agreste)". Thus, the Agreste has a mapping with more extensive areas in the current delimitation.

In the new mapping, a cut-off point was defined, considering values above 1,200 mm/year, for the "Atlantic Forest Domain", because only in areas with rainfall above this annual average could the ombrophilous forest, called the Atlantic Forest, be found. In the previous study, the cut-off point of this domain was of areas with rainfall greater than 1,000 mm/year. Thus, after this update, the transition area where species of the caatinga and the Atlantic Forest Domains occur, this ecotone, is delimited between the isohyets of 800 and 1,200 mm/year, in the eastern sector of RN.

Relevantly, a phytogeographic enclave was identified. Thus, an area that was previously mapped, partially inserted in the "Caatingas Domain", in the "Atlantic Forest Domain", and in the "Agreste", was now identified as the "Cerrado Enclave".

The cerrado is a morphoclimatic domain typical of Central Brazil, dominating especially terrains with heavily leached soils, especially latosols, in the Central Plateau, thus placing its occurrence in the RN under the character of an enclave. Therefore, Rio Grande do Norte has two morphoclimatic domains, a transition area, and an enclave (Figure 2). It is, however, noteworthy that these last two units are not domains (AB'SABER, 2003), but are represented on the domain map by scalar compatibility.

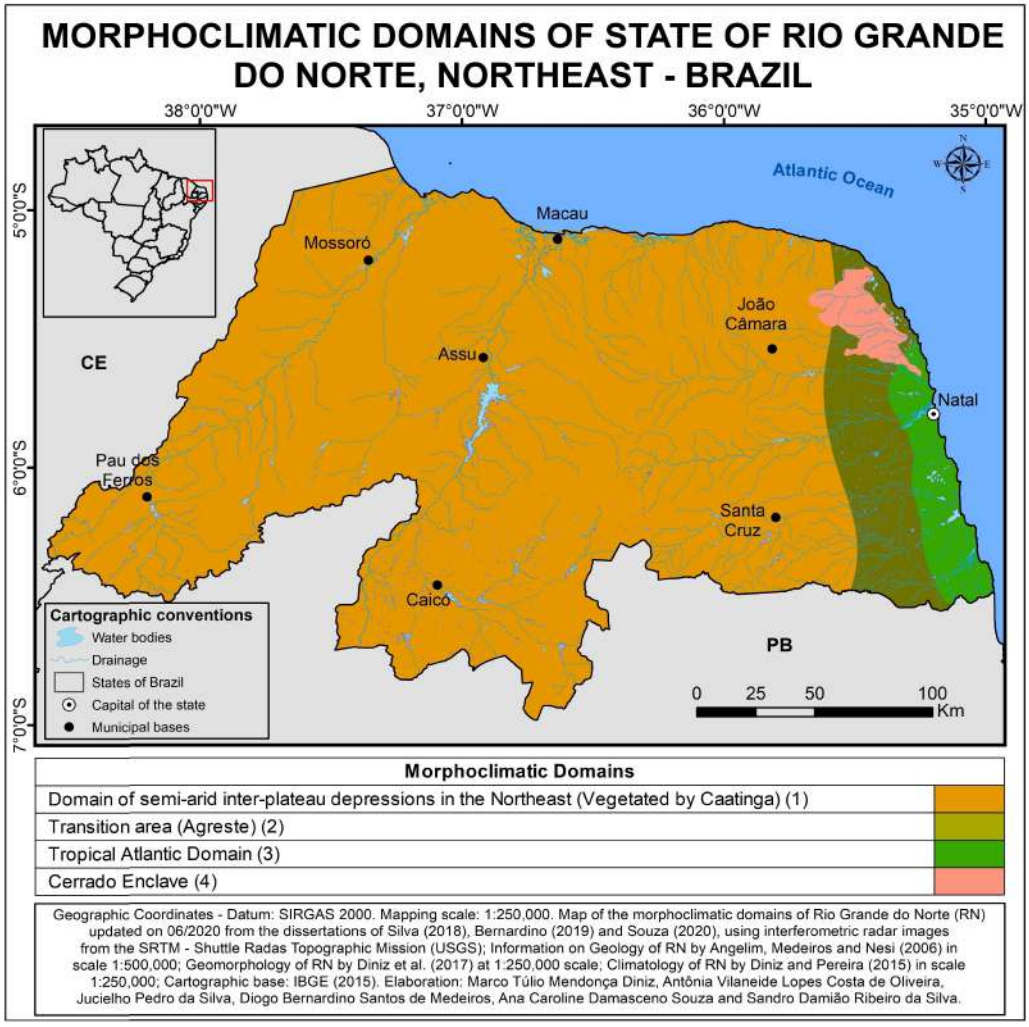


Figure 2 – Map of the Morphoclimatic Domains of the state of Rio Grande do Norte. Source: Elaborated by the authors.

The state of RN continues to have in its territory the classification of eight natural regions, even

with the updating of the mapping. With the change in the isohyet that delimits the "Agreste" and the "Atlantic Forest Domain", there was, at the same time, a decrease in the sum of natural regions, with the reclassification of the unit "Wet Depressions", which was incorporated into the "Agreste Depressions", and an addition, with the individualization of the natural region "Plains and Tablelands of the Cerrado Enclave", due to its recognition, and whose only natural region is precisely this one (Figure 3). This modification in the boundaries of the domains also caused a change in the total area of the natural region "Wet and sub-wet sedimentary plains and tablelands", since a portion of it now belongs to the "Plains and tablelands of the Agreste".

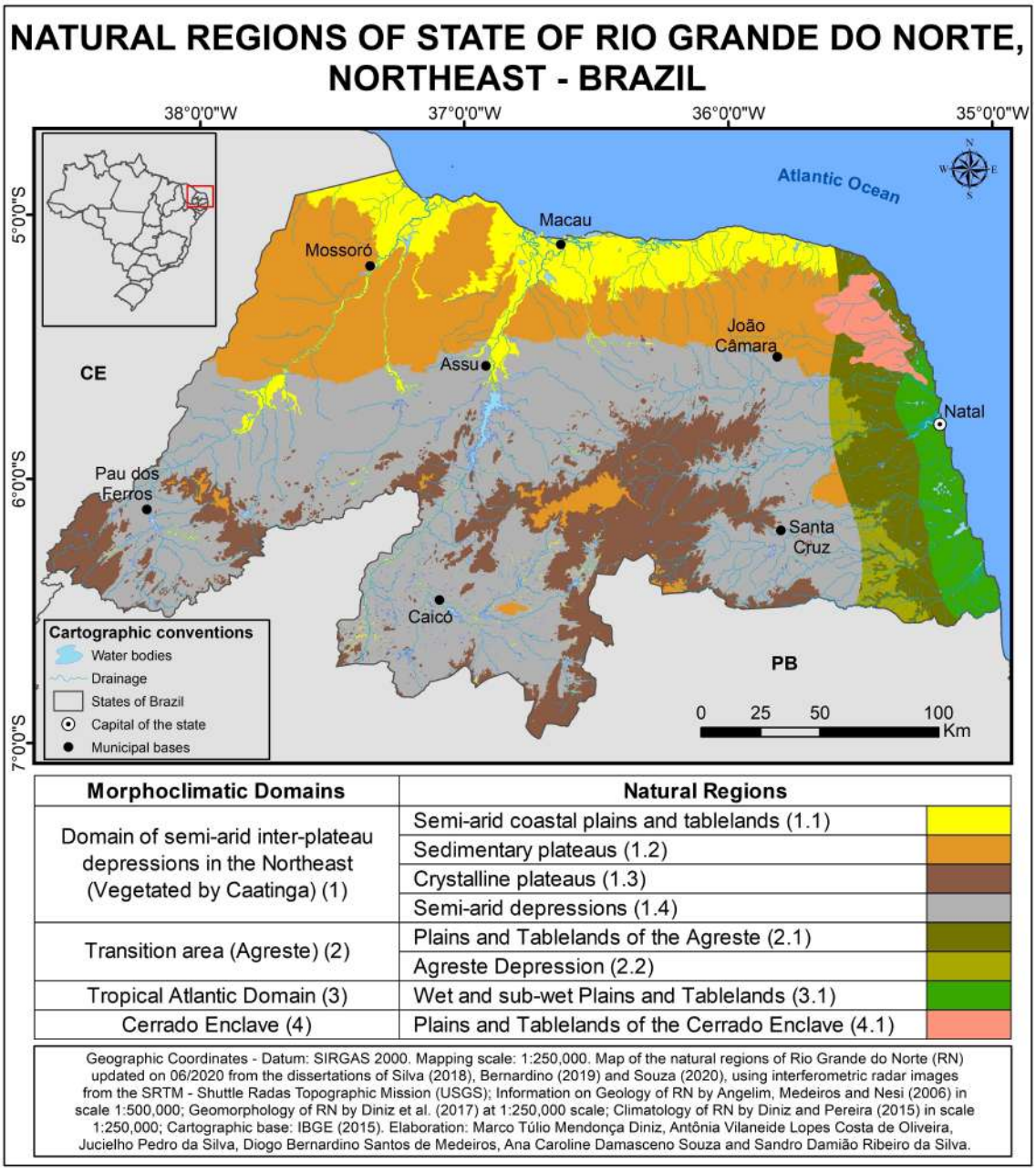


Figure 3 – Map of the Natural Regions of the state of Rio Grande do Norte. Source: Elaborated by the authors.

The mapping of the Cerrado Enclave also made this unit incorporate a small section, formerly belonging to the "Caatingas Domain", which, in the taxon of the natural region, comprised part of the unit "Sedimentary Plateaus", and, in the taxon of the geocomplexes, comprised a portion of the "Inner Tablelands"; now, they are encompassed by the natural region "Plains and Tablelands of the Cerrado

Enclave".

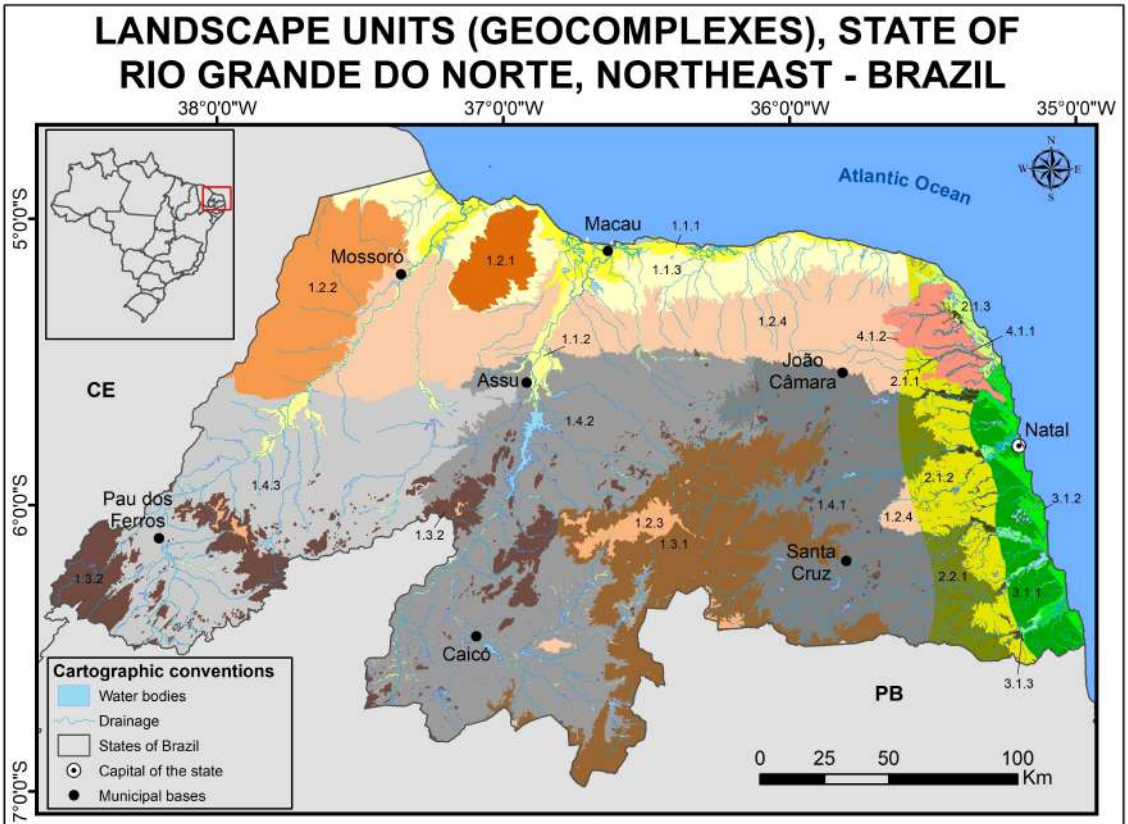
Regarding geocomplexes, in the initial mapping, twenty landscape units were identified. With the latest advances in research, the "Wet Depression" was excluded, which became part of the "Depression of the Agreste Potiguar"; and the "Floodplains of the Cerrado Enclave" and "Tablelands of the Cerrado Enclave" were inserted, which were identified as "Tablelands of the Agreste Potiguar" in the 2018 mapping. Thus, twenty-one geocomplexes were classified for the state of RN.

Table 2 presents this update of the compartments and their respective territorial areas of coverage.

Morphoclimatic Domains	Natural Regions	Geocomplexes		Area (km²)
Domain of semi-arid inter-plateau depressions in the Northeast (Vegetated by Caatinga) (1)	Semi-arid coastal plains and tablelands (1.1)	Semi-arid coastal plain	(1.1.1)	1.022,07
		Semi-arid floodplains	(1.1.2)	932,32
		Semi-arid coastal tablelands	(1.1.3)	2.853,65
	Sedimentary plateaus (1.2)	Chapada da Serra do Mel	(1.2.1)	858,19
		Chapada do Apodi	(1.2.2)	2.704,05
		Chapadas superimposed on the basement	(1.2.3)	537,71
		Inner tablelands	(1.2.4)	6.599,89
	Crystalline plateaus (1.3)	Borborema Plateau	(1.3.1)	5.025,68
		Residual and structural crystalline plateaus	(1.3.2)	2.691,59
	Semi-arid depressions (1.4)	Eastern depression	(1.4.1)	5.257,85
		Sertões do Piranhas	(1.4.2)	10.298,30
		Sertões do Apodi-Mossoró	(1.4.3)	7.288,24
Transition area (Agreste) (2)	Plains and Tablelands of the Agreste (2.1)	Floodplains of the Agreste Potiguar	(2.1.1)	273,47
		Tablelands of the Agreste Potiguar	(2.1.2)	2.001,22
		Coastal plain of the Agreste Potiguar	(2.1.3)	258,83
	Agreste Depression (2.2)	Depression of the Agreste Potiguar	(2.2.1)	1.224,26
Tropical Atlantic Domain (3)	Wet and sub-wet Plains and Tablelands (3.1)	Wet coastal tablelands	(3.1.1)	1.259,82
		Wet coastal plains	(3.1.2)	581,06
		Wet floodplains	(3.1.3)	133,13
Cerrado Enclave (4)	Plains and Tablelands of the Cerrado Enclave (4.1)	Floodplains of the Cerrado Enclave	(4.1.1)	202,13
		Tablelands of the Cerrado Enclave	(4.1.2)	647,32

Table 2 - Updated landscape units and their respective coverage areas. Source: Elaborated by the authors (2021).

Next, the new cartographic material for the delimitation of landscape units (geocomplexes) in Rio Grande do Norte is presented (Figure 4).



Morphoclimatic Domains	Natural Regions	Geocomplexes	
Domain of semi-arid inter-plateau depressions in the Northeast (Vegetated by Caatinga) (1)	Semi-arid coastal plains and tablelands (1.1)	Semi-arid coastal plain	(1.1.1)
		semi-arid river plains	(1.1.2)
		Semi-arid coastal tablelands	(1.1.3)
	Sedimentary plateaus (1.2)	Chapada da Serra do Mel	(1.2.1)
		Chapada do Apodi	(1.2.2)
		Chapadas superimposed on the basement	(1.2.3)
		Inner tablelands	(1.2.4)
	Crystalline plateaus (1.3)	Borborema Plateau	(1.3.1)
		Residual and structural crystalline plateaus	(1.3.2)
	Semi-arid depressions (1.4)	Eastern depression	(1.4.1)
		Sertões do Piranhas	(1.4.2)
		Sertões do Apodi-Mossoró	(1.4.3)
Transition area (Agreste) (2)	Plains and Tablelands of the Agreste (2.1)	Floodplains of the Agreste Potiguar	(2.1.1)
		Tablelands of the Agreste Potiguar	(2.1.2)
		Coastal Plain of Agreste Potiguar	(2.1.3)
	Agreste Depression (2.2)	Depression of the Agreste Potiguar	(2.2.1)
Tropical Atlantic Domain (3)	Wet and sub-wet Plains and Tablelands (3.1)	Wet coastal tablelands	(3.1.1)
		Wet coastal plains	(3.1.2)
		Wet floodplains	(3.1.3)
Cerrado Enclave (4)	Plains and Tablelands of the Cerrado Enclave (4.1)	Floodplains of the Cerrado Enclave	(4.1.1)
		Tablelands of the Cerrado Enclave	(4.1.2)

Geographic Coordinates - Datum: SIRGAS 2000. Mapping scale: 1:250,000. Map of the geocomplexes of Rio Grande do Norte (RN) updated on 06/2020 from the dissertations of Silva (2018), Bernardino (2019) and Souza (2020), using interferometric radar images from the SRTM - Shuttle Radas Topographic Mission (USGS); Information on Geology of RN by Angelim, Medeiros and Nesi (2006) in scale 1:500,000; Geomorphology of RN by Diniz et al. (2017) at 1:250,000 scale; Climatology of RN by Diniz and Pereira (2015) in scale 1:250,000; Cartographic base: IBGE (2015). Elaboration: Marco Túlio Mendonça Diniz, Antônia Vilaneide Lopes Costa de Oliveira, Jucielho Pedro da Silva, Diogo Bernardino Santos de Medeiros, Ana Caroline Damasceno Souza and Sandro Damião Ribeiro da Silva.

Figure 4 – Map of the Geocomplexes of the state of Rio Grande do Norte. Source: Elaborated by the authors.

The updates of the circumscriptions, new sizing, creation, and deletion of units are reviewed, below, in Table 3, as well as issues related to the cartographic representation. The dimension changes resulting from the refinement of the unit boundaries were disregarded in this table, as they represent tiny calculations (less than 100km²), even though they are updated in the most recent shapefile data and in the cartographic plot presented here. The same occurred when losing an area in the units, caused by the more detailed mapping of water bodies.

It is also important to emphasize that changes in lower units cause changes in higher ones, as well

as the opposite, as it is a hierarchical and taxonomic classification system, in which the units are formed from the junction or branch of themselves, that is, either by grouping (Upscaling or bottom-up) or by logical subdivision (Downscaling or top-down) (Cf. CORRÊA, 1986; CAVALCANTI; CORRÊA, 2013) — the methodology applied in this mapping had initially used a descending trajectory (logical division) from the differentiation of areas, and another improved upwards, in the update. Thus, in the table below, we tried not to point out the implications caused on more than one scale that were related to a single update/modification, so as not to incur redundancies.

Scale (taxon) or nature of modification	Diniz and Oliveira (2018)	Updated mapping
DOMAINS	Area of the morphoclimatic domains of the Atlantic Forest (3,540.59 km²)	(*i*) Reduction of the area covered by the morphoclimatic domains of the Atlantic Forest, now totaling 1,566.58 km².
	Transition area (Agreste) (2,931.73 km²)	(*ii*) Increase in the Agreste area, reaching 3,757.78 km², already considering the (*iii*) reductions caused by the creation of the "Cerrado Enclave" unit (~736 km²)
NATURAL REGIONS	Wet depression (297.65 km²)	(*iv*) The natural region "Wet Depression" was suppressed, with the alteration of the limits of the Atlantic Forest Domain, being incorporated into the "Agreste Depression" (with an updated area of 1,224.26km²)
	Area of the Natural Region Plains and Tablelands of the Agreste (1,625.6 km²)	(*v*) After the addition of the mapped territory in the Natural Region of the Plains and Tablelands of the Agreste Potiguar, the area now occupies 2,001.22 km², already considering (*vi*) the reductions caused by the creation of the unit "Plains and Tablelands of the Cerrado Enclave", which, in turn, occupies ~736 km².
GEOCOMPLEXES	Mapping of 20 geocomplexes in RN	(*vii*) Mapping of 21 geocomplexes in RN. Total resulting from the accounting of the balance between (*vii.1*) exclusion of the unit "Wet depression" and insertion of geocomplexes (*vii.2*) "Floodplains of the cerrado enclave" and (*vi.3*) "Tablelands in the cerrado enclave".
	Area of the geocomplex Inner tablelands 6,681.22 km²	*(viii)* Decrease in the total area (6,599.88 km²) of the "Inner tablelands" geocomplex due to the loss of sections for the new unit "Tablelands of the Cerrado Enclave", even considering the (*ix*) insertion of a new polygon of occurrence of the Inner tablelands, in the Seridó region.
	Wet depression geocomplex	(*x*) The unit "Wet Depression" has been deleted; its area was incorporated by the geocomplex "Depression of the Agreste Potiguar"
	Reduction of the areas of the geocomplexes "Tablelands of the agreste potiguar" and "Floodplains of the agreste potiguar"	(*xi*) Part of these areas were circumscribed by the geocomplexes "Tableland of the Cerrado Enclave" and "Floodplains of the Cerrado Enclave"
CARTOGRAPHIC REPRESENTATION	Color of the geocomplex Wet coastal tablelands R0G166B0	(*xii*) Color change in Wet Coastal Tablelands to a darker green R0G115B
	Color of the geocomplex Residual and structural crystalline plateaus R199G142B70	(*xiii*) Color change in the Residual and structural crystalline plateaus R114G75B67
	–	(*xiv*) Option for the following colors to represent the new units: Cerrado Enclave (R254; G148; B124); Plains and tablelands of the Cerrado Enclave (R254; G148; B124); Floodplains of the Cerrado Enclave (R255; G190; B190); Tablelands of the Cerrado Enclave (R254; G148; B124).
NOMENCLATURE	Natural region: Wet and sub-wet sedimentary plains and plateaus	(*xv*) It was changed to the term "Wet and sub-wet plains and tablelands", as it was considered more appropriate since the area does not present plateaus.

Table 3 – Synthesis of the modifications and updates proposed in the new mapping of Landscape Units in Rio Grande do Norte, concerning the original by Diniz and Oliveira (2018). Source: Elaborated by the authors (2021).

Table 3 points out that a new area of the "Inner tablelands" geocomplex was identified in the south-central part of the state. This occurs in the region popularly known as Seridó, not in sandstones of the Barreiras Series, as in the rest of the state, but in a neogenic colluvial-eluvial deposit of unconsolidated sandy sediments with an age scarcely more recent than the Barreiras (BERNARDINO, 2019). These sediments have good drainage, making surface runoff difficult and attenuating erosive processes in the area. The differential erosion between these tablelands and the surrounding crystalline areas caused the appearance of small scarps between the tableland, from flat to gently wavy relief, and the Sertões do Piranhas, that border it.

Finally, there were changes in the color palette used to represent different units in the different taxa. In short, it was decided, in agreement with the previous work (DINIZ; OLIVEIRA, 2018), that the chorochromatic scale of natural regions provides the first base of hues to be used for the representation of internal subdivisions caused by the individualization of geocomplexes. In these conventions, the geofacies would be represented strictly by the variations in the tonal value (also known as luminosity or brightness) of each color ("tone" or "hue") that symbolizes its respective geocomplex. Thus, instead of adopting a symbology with hatching, for example, a chromatic scale (gradient) was used, based on the chorochromatic palette of the geocomplexes.

However, in the works of Bernardino (2019) and Souza (2020), it was noticed that there were very similar hues/colors representing more than one geocomplex, and thus, when varying the luminosity, especially in units that had many geofacies, there were colors already similarly applied to symbolize facies of other geocomplexes, hampering the reading and interpretation of the map. Thus, in these works, changes were proposed in the color of the Wet Coastal Tablelands and Residual and Structural Crystalline Plateaus geocomplexes. They are summarized in the previous table.

In addition to these, as a new unit emerged in the domain taxon (the Cerrado Enclave), and thus, in natural regions and geocomplexes, there were increases in their color palettes, as also pointed out in Table 3.

THE CERRADO ENCLAVE OF THE STATE OF RIO GRANDE DO NORTE

The concept of enclave, defined by Ab'Saber (2003), comprises "spots of ecosystems typical of other provinces, but embedded within a domain of a totally different nature" (AB'SÁBER, 2003, p. 145). In other words, it is an area with characteristics of ecosystems from other domains of nature, such as the caatinga enclave in the "Mares de Morros" from the Southeast and the cerrado in the Amazon Forest. And now, the cerrado spot in RN was identified, between the Restinga ecosystems (in the Forested "Mares de Morros" Domain) and the caatingas from the state, this delimitation occurred because of the advances of the research by Souza (2020).

In RN, the cerrado presents itself as an enclave with visibly different features in terms of the typical vegetation of the caatingas and the Atlantic Forest (which are the two morphoclimatic domains present in the state). The enclave comprises sandy soils that are very poor in nutrients, on the terrains of paleo-dunes present in the extreme northeast of the state. In addition, it presents herbaceous and sparse vegetation (Figure 5).

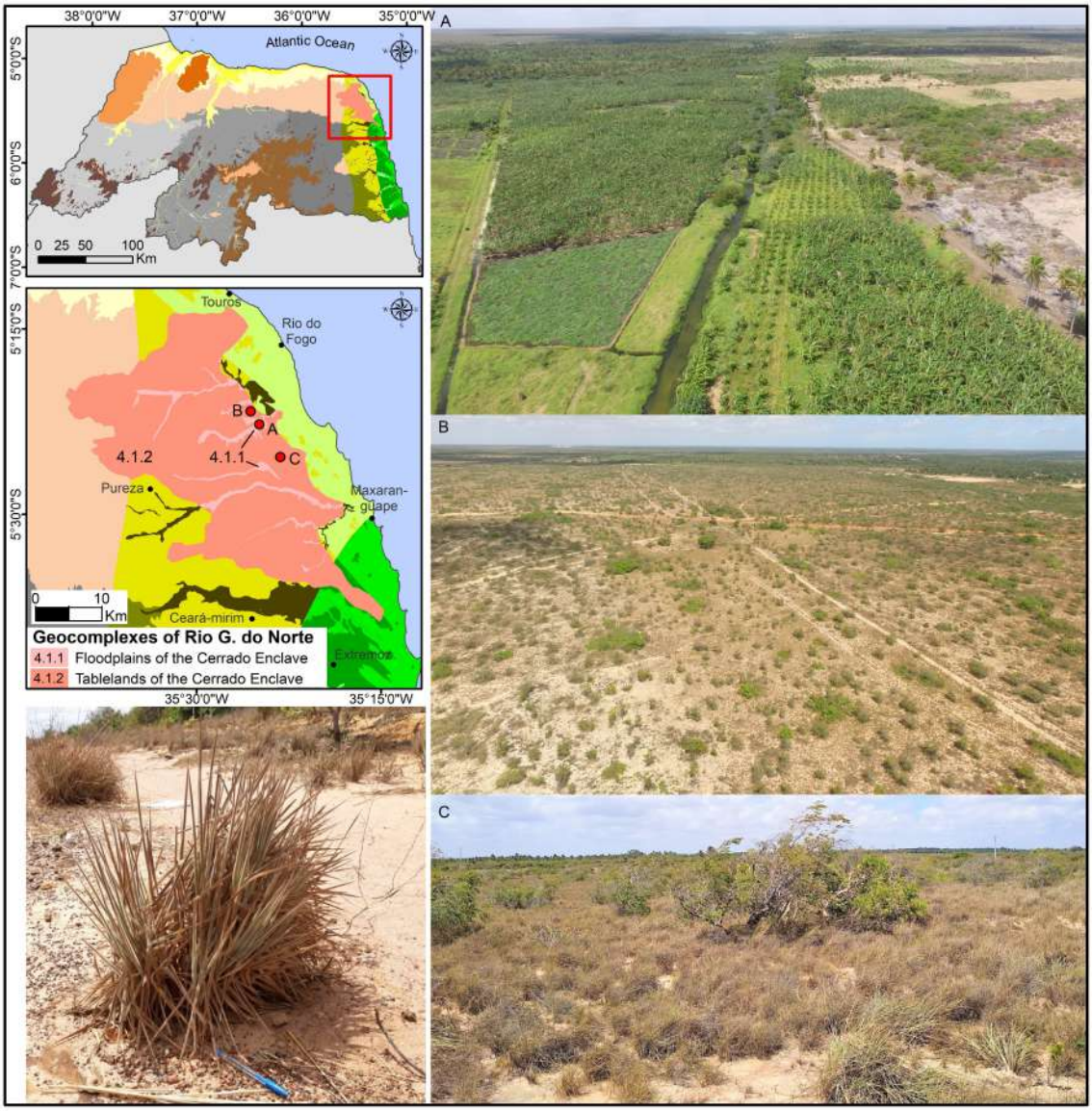


Figure 5 – Cerrado physiognomy area in the geocomplexes “Floodplains of the Cerrado Enclave” (A) and “Tablelands of the Cerrado Enclave” (B and C). Source: Elaborated by the authors (2019, 2020, and 2022).

Based on the theory by Ab'Sáber (2003), it is possible to infer that the cerrado enclave in the state of RN is the result of climatic variations during the Quaternary. At a time of drier climate, the cerrado areas would have advanced along the eastern coast of Brazil, in lands that today are occupied by the Atlantic Forest or Restingas. After the return to the current climate, the cerrados retreated, but, in this sector of leached soils from paleo-dunes in the northeast of RN, they remained as an enclave.

This enclave covers five municipalities in the state: Ceará-mirim, Maxaranguape, Rio do Fogo, Pureza, and Touros, and comprises a single natural region, called “Plains and Tablelands of the Cerrado Enclave” and two more geocomplexes: “Tablelands of the Cerrado Enclave” and “Floodplains of the Cerrado Enclave”.

The “Tablelands of the Cerrado Enclave” have a total area of 671.55 km² and a physiognomy comprising trees with twisted branches, with bushy individuals spaced apart, besides grasses (Figure 6). In a smaller area of this natural region, economic activities of permanent and temporary agriculture are present.

Figure 6 – Physiognomy of the Cerrado in the Tablelands. Source: Ana Caroline Damasceno Souza (2018).

On the tablelands, there is a wind farm with 54 wind turbines in the municipality of Ceará-Mirim. But, in general, these areas are in paleo-dune lands, with Quartzarenic Neosols that are very leached and poor in nutrients, making crops difficult, which is why these savannas of RN have extensive preserved areas.

The Floodplains of the Cerrado Enclave have an area of 63.39 km² and their main characteristics are the small rivers (Punaú and Maxaranguape) that cross this enclave through the municipalities of Touros, Pureza, Rio do Fogo, Maxaranguape, and Ceará-mirim. The recurring landscapes on its banks are used for activities of temporary agriculture, such as beans, cassava, corn, and watermelon; and for permanent agriculture, such as coconut, banana, avocado, cashew, guava, and mango.

CONCLUSION

The updating of the classification of landscape units in Rio Grande do Norte presented here was based on fieldwork, reflection on data resulting from a greater detail in the scale of analysis, and research conducted within the scope of the master's theses by Silva (2018), Bernardino (2019), and Souza (2020), which enabled scientific advancement by presenting new data in the identification and delimitation of important areas previously unknown in the field of integrated landscape studies.

Eleven points stand out, modifying the results obtained previously because of the update of the classification of these landscape units for the state of RN and we highlight the new delimitation for the taxa of the morphoclimatic domains, natural regions and geocomplexes, due to the reclassification using rainfall isohyets different from the previous mapping (from 1,000 mm to 1,200 mm) and mapping refinement; the insertion of an enclave (cerrado); in the natural regions, the area previously referred to as "Wet depressions" was incorporated into the "Depression of the Agreste Potiguar" unit, and the addition of a new unit, the "Plains and Tablelands of the Cerrado Enclave"; in the geocomplexes, there was the exclusion of the unit "Wet depressions" and the insertion of the units "Floodplains of the Cerrado

Enclave" and "Tablelands of the Cerrado Enclave", thus 21 geocomplexes were reclassified for this state; there were also changes in the colors used in two geocomplexes (Wet Coastal Tablelands and Residual and Structural Crystalline Plateaus).

It is hoped, therefore, that this mapping will be incorporated into the academic research conducted in the state, serving as a foundation for research in several areas, not being restricted to the field of geography. It is also expected that, in the coming years, advances in more specific research aimed at the Cerrado Enclave will emerge, as this area is still little known to the scientific community that tackles the "innovation" claimed by science for centuries.

NOTE

1- In the testing phase of the methodologies, the classification of Maximum Likelihood – ML was applied. However, due to the study area being quite diversified, some pixels were very similar, and the software was induced to classify some classes wrongly, such as, for example, the pixels of the urbanized area and the pixels of the different phases of the sugarcane plantation. Thus, after some tests, it was analyzed that the best technique used would be manual vectorization.

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