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GEOMORPHOLOGY OF THE MUNDAÚ-MANGUABA LAGUNAR ESTUARINE COMPLEX (CELMM), ALAGOAS, NORTHEAST OF BRAZIL

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Abstract

Mappings are recurrent topics in Geomorphology, having its potentiality and specifications for understanding environmental dynamics. Therefore, the present study discussed the relief of the Mundaú-Manguaba Lagoon Estuarine Complex (CELMM) and its surroundings, using Geoprocessing and Photointerpretation techniques to measure the relief dissection and maping its units, using methodological guidelines of renowned studies in Brazil. Various dissection patterns were identified, however, 90% of the Complex has weak dissection. Two morpho structural units, 7 morpho-sculptural units and 21 morpho-sculptural subunits were sectorized, with origins related to denudational, processes in interaction with tectonic movements and variations in the average sea level throughout the Quaternary. The methodology proved to be very promising, enabling the confection of thematic maps and databases, documents that can contribute to planning and decision-making.

Keywords: Relief; Geomorphological Cartography; Dissection Index.

GEOMORFOLOGIA DO COMPLEXO ESTUARINO LAGUNAR MUNDAÚ-MANGUABA (CELMM), ALAGOAS, NORDESTE BRASIL

Resumo

Mapeamentos são temáticas recorrentes na Geomorfologia, com suas potencialidades e especificações na compreensão das dinâmicas ambientais. Nesse sentido, o presente estudo discutiu o relevo do Complexo Estuarino Lagunar Mundaú-Manguaba (CELMM) e seu entorno, utilizando técnicas de Geoprocessamento e Fotointerpretação, na aferição da dissecação do relevo e mapeamento de suas unidades taxonômicas, utilizando orientações metodológicas recorrente em estudos consagrados no Brasil. Identificou-se variados padrões de dissecação, entretanto, 90% do Complexo apresenta dissecação fraca. Foram setorizadas 2 unidades morfoestruturais, 7 unidades morfoesculturais e 21 subunidades morfoesculturais, com origens relacionadas a processos denudacionais, em interação com movimentos tectônicos e variações do nível médio dos mares ao longo do Quaternário. A metodologia mostrou-se bastante promissora, possibilitando a confecção dos mapas temáticos, bases de dados e documentos que podem contribuir com planejamento e tomada de decisões na área.

Palavras-chave: Relevo; Cartografia Geomorfológica; Índice de Dissecação.

GEOMORFOLOGÍA DEL COMPLEXO ESTUARINO LAGUNAR MUNDAÚ-MANGUABA (CELMM), ALAGOAS, NORESTE DE BRASIL

Resumen

Los mapeos son temas recurrentes en Geomorfología, con su potencial y especificaciones para comprender la dinámica ambiental. En este sentido, el presente estudio discutió el relieve del Complexo Estuarino Lagunar Mundaú-Manguaba (CELMM) y su entorno, utilizando técnicas de Geoprocesamiento y Fotointerpretación, en la valoración de la disección del relieve y cartografía de sus unidades taxonómicas, utilizando lineamientos metodológicos recurrentes en estudios consagrados en Brasil. Se identificaron varios patrones de disección, sin embargo, el 90% del Complexo tiene una disección débil. Se sectorizaron dos unidades morfoestructurales, 7 unidades morfoesculturales y 21 subunidades morfoesculturales, con orígenes relacionados con procesos denudacionales, en interacción con movimientos tectónicos y variaciones del nivel medio del mar a lo largo del Cuaternario. La metodología resultó ser muy prometedora, ya que permitió la elaboración de mapas temáticos, bases de datos y documentos que pueden contribuir a la planificación y toma de decisiones en el área.

Palabras-clave: Relieve; Cartografía geomorfológica; Índice de disección.

1. INTRODUCTION

The Cartography, as a science, seeks to build real graphic representations of spatialized objects, mapping their characteristics and describing their specificities, in order to describe their functionality in data that are transposed into maps, facilitating their understanding through a document endowed with a series of information (SOUZA et al., 2004). Geography, even before its institutionalization in academic and professional spaces, already appropriated the cartographic instruments and technologies to analyze the organizations and spatial dynamics. Examples of these uses are the ancient city maps of the Roman Empire and, more recently, the exploratory maps of classical naturalists like Alexander Von Humboldt, in the 18th and 19th centuries (CAVALCANTI, 2010).

The use of cartographic tools, when applied to the representation of spatial organizations of physical systems in Geography, allows the realization of several measurements on current and past energy processes in various landscapes, enabling the making of representative maps of the description and understanding about the cyclicality of natural processes (FERREIRA, 2014; DINIZ et al., 2017).

Applied to Geomorphology, the making of maps represents an important tool in the spatialization, classification and hierarchization of the various geomorphological facts, allowing not only the representation of the modeled but also discuss their chronology, structure and processes, current and past, as well as their general dynamics, taking into account, in addition to their particularities over time, also their relationships and landscape contexts (CASSETI, 2005; SANTOS et al, 2016), since the landform constitutes one of the main substrates of landscapes, by controlling the horizontal flows of energy and matter (CAVALCANTI and CORRÊA, 2017).

In geomorphological studies, the act of "mapping" the landform and sets is not only about identification and delimitation, but also about the description of its environmental and paleoenvironmental context. In this sense, it is correct to state that studies on the modelados have as their focus their description as elements of landscapes and their transformations over time, in a systemic perspective (LIMA, 2016).

Widely applied since the ninth century, geomorphological cartography has been advancing and specialized, following the technological developments over time (SOUZA and FURRIER, 2019). These advances are quite expressive in their diffusion with Geography, adding new methods and techniques of analysis to the concepts and methodologies widely discussed and applied by classical theorists (FLORENZANO, 2016).

By adhering, continuously, to technological apparatuses, increasingly advanced, Geomorphology assumes a high degree of specialization in their studies. With the emergence and development of Geoprocessing and Remote Sensing, geomorphological analyses, classifications and representations have gained many contributions. The example of the Shuttle Radar Topography Mission (SRTM) data in the early 2000s, more recently with the Unmanned Aerial Vehicles (UAVs) and the Optical Remote Sensing Technologies (LIDAR), which made the acquisition and processing of data more precise and less subjective (SILVA and RODRIGUEZ, 2010; NEX and REMONDINO, 2013).

Over the past decades, even in the face of considerable technological development experienced by geomorphological cartography, it still has a high degree of subjectivity in the understanding and interpretation of morphological systems, this is due to the very complexity of the object and possibilities of representation. In this sense, some premises should guide the thinking of those who decide to map, as Demek (1972) presents, by stating that one must have a certain chain of information and interpretations, related to structural, topographic and photogrammetric factors, combined with data surveys and measurements performed in the field when performing landform mapping.

In a scenario of technological advances and search for the application of a geomorphologic cartography of Alagoas, the present study sought to spatialize, rank and analyze the morphological sets present in the Estuarine Lagoon Complex Mundaú-Manguaba (CELMM), located in the central southern portion of the Alagoas coast. An effort to contribute to the discussion about the landform of the State, as well as to provide information that can help in the application of future environmental planning strategies.

The mapped area was chosen for two reasons: 1 - to be very representative of the region's geomorphology, commonly involved in environmental conservation and management strategies, which contrasts with the absence of more detailed systematic mapping; 2 - is linked to the historical and cultural value that the morphological sets represented and represent for the occupation and emancipation process of Alagoas, with its rich historical sites and emergence of Maceió as the state capital.

2. METHODOLOGY

2.1. Study Area

The CELMM constitutes a large set of lagoons, islands and marine fluvial channels, distributed in the south central coast of Alagoas (Figure 1), where it occupies fractions of the municipalities of Maceió, Marechal Deodoro, Rio Largo, Satuba, Pilar, Coqueiro Seco and Santa Luzia do Norte. It comprises the largest estuarine complex in the state and the fifth largest in Brazil (LIMA, 1998), serving as a regional base level, where the basins of the rivers Paraíba do Meio and Mundaú flow, both draining the elevated compartments of the southeastern facade of the Borborema Plateau in Alagoas and Pernambuco.

The CELMM has its morphological set structured in lithologies of the Alagoas sub-basin, modeled on consolidated and unconsolidated lithological packages of various ages, developed in a transitional environment in the ocean-continent interaction (ARAÚJO et al., 2006). Its landform encompasses several denudational and agradational morphologies, in various patterns and evolutionary process stages. Structurally, the formation history of this large estuarine lagoon complex is not yet

effectively identified, but the possibility of sinking, by late accommodation, structuring into half-granules, resulting from the separation between Brazil and Africa, and its possible more recent accommodation, should not be discarded (LIMA, 2004).

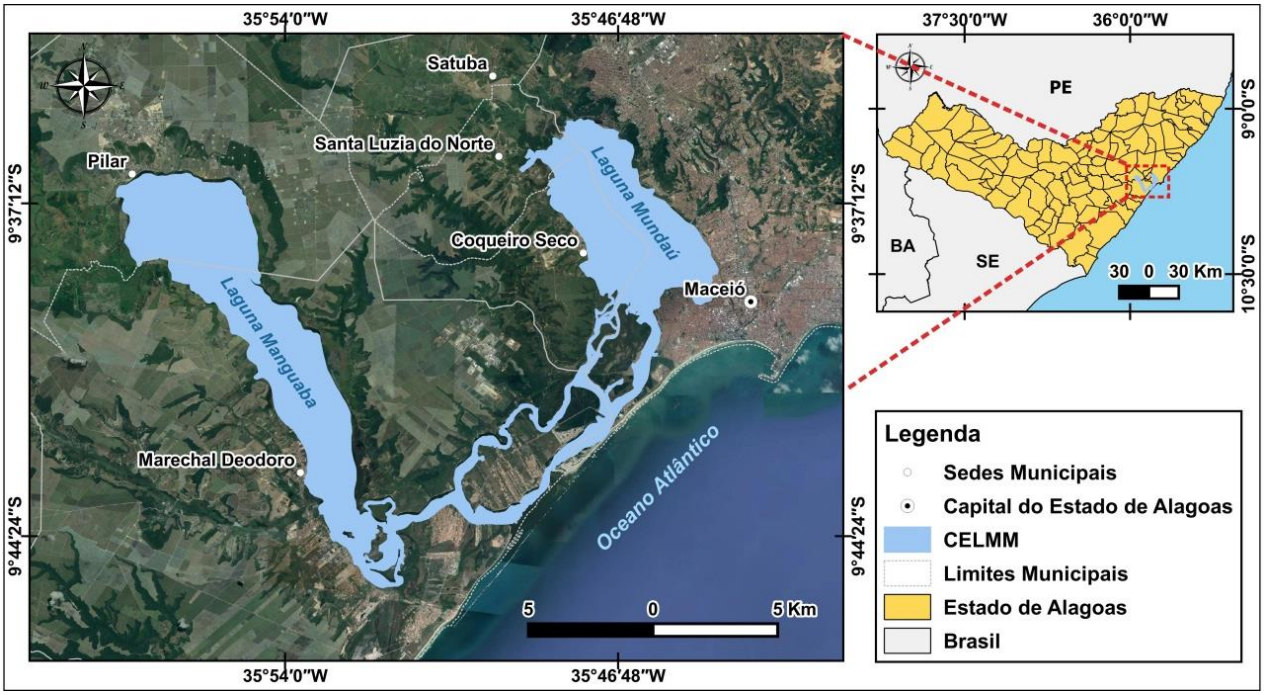

Figure 1 - CELMM location map. Source: Prepared by the authors with data from IBGE (2019).

2.2. Methodological Processes

The elaboration of this study was divided into a methodological sequence of 7 stages, which are: general definitions of the study; mapping structure; bibliographic and cartographic surveys; data processing; quantification of landform dissection; establishment of landform taxonomic units and textual construction. Each one of them, because they represent consequent phases, were executed separately, and the specificities of each one will be presented below.

The choice of the study area occurred in front of the need for the identification/construction of primary detail data for an area with geomorphology strongly linked to the cultural and historical formation of Alagoas (FERREIRA, et al., 2019), so that these can be used both by the Public Power, in zoning and decision-making activities, and by the private sector, in environmental licensing processes. To this end, it was decided to choose an accessible and widely used methodology, more aligned with the desired contributions. For this, the proposal by Ross (1992, 1994) was chosen, initially aimed at contributing to decision making.

Ross (1992, 1994) proposes a hierarchical model based on taxa for geomorphological mapping. The author developed his model by adapting the methodological proposal used by the RADAMBRASIL project (1983) in the geomorphological mapping of part of the Brazilian territory, whose methodology was proposed by the geomorphologist Teresa Cardozo da Silva. Radam Brasil sought to perform integrated readings of the landform, joining information related to the taxonomic hierarchization of the landform to the concepts of morphostructures and morphosculptures by Gerasimov (1963) and Mescerjacov (1968). In general, Ross' proposal has been widely applied throughout the Brazilian territory at various scales since its publication.

After selecting the area of interest and the method to be used, bibliographic data on the evolutionary dynamics of the CELMM were collected, in order to support discussions about its transformations over time, since in order to understand a certain morphology, one must be aware of its current and past dynamics. Cartographic bases were also surveyed in public domain portals, such as the Brazilian Geological Service - CPRM, the Brazilian Institute of Geography and Statistics - IBGE, and the Alagoas State Department of Planning and Management - SEPLAG-AL, to facilitate the mappings.

For the general processes of mapping and quantification of landform parameters, Alos Palsar data of 12.5 m spatial resolution were used (ASF, 2020). Although they represent large-scale data, they are not exactly new data, but rather re-samples of 30 m SRTM data. Thus, its use must be done with accuracy, so as not to represent exaggerated or illusory results, however, for the purpose of the study, with proper field verification, it showed promise.

The study scale chosen respected the limits of average error in mapping for data of 12.5 meters, where the maximum scale of detail allowed is 1:62,500, and for this study the scale was admitted as 1:120,000. According to Ross (1994), mappings at these scales are possible representations up to the fourth taxon, a

level equivalent to the landform types or morphological units identified. In this, we mapped up to the fourth taxon admitting the existence of morphosculptural subunits, as mapped in other regions by Santos et al. (2006); Ferreira (2014) and Diniz et al. (2017).

The calculation of the landform dissection index was performed in an automated way, following the proposal of Guimarães et al. (2017), where the calculation of the index is performed by summing the matrices of the average interfluvial dimension to the valley notch, both extracted from the digital elevation model - MDE. The authors also proposed three alternative suggestions to the dissection matrix proposed by Ross (1994), stating that they are not as effective for flat or gently undulating landforms.

Virtually all models were well suited to the study area, however, among the proposals recommended by Guimarães et al. (2017), the number 1 obtained the best results, in this sense it was used by this work for better representing the degree of dissection in the context of structured modeling in sedimentary areas (Figure 2).

For the establishment of the hierarchical and taxonomic landform units, correlations were made between: geological data, through the Geological Map of Alagoas State in 1:50.000, PETROBRAS/DNPM (1975), Maceió, Rio Largo and Marechal Deodoro sheets; Alos Palsar topographic data joined to the topographic chart 1:50. 000 of IBGE, Maceió, Rio Largo and Marechal Deodoro sheets (1985), Satellite images and aerial photographs (Google Earth Pro images with scale of 2.5m) and the field surveys that helped in the correction and refinement of the mappings.

		Dimensão Interfluvial Média				
		Muito Grande (4000m)	Grande (2750 m)	Média (1250 m)	Pequena (500 m)	Muito Pequena (125 m)
Grau de Entalhamento dos Vales	Muito Fraco (10 m)	11	12	13	14	15
	Fraco (30 m)	21	22	23	24	25
	Médio (60 m)	31	32	33	34	35
	Forte (120 m)	41	42	43	44	45
	Muito Forte (200m)	51	52	53	54	55

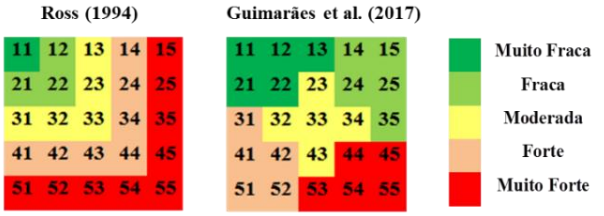

Figure 2 - Parameters of landform dissection analysis and their interpretation matrices. Source: Adapted from Guimarães et al. (2017.)

All the processing and mapping were performed with open sourcer software, Quantum Gis 3.10.4 (Long term version), being the processes performed through automated routines in the model builder. The layout of the maps was also performed in the same software, using the color palette of the Technical Manual of Geomorphology of the IGBE (2009), making use of green colors for landforms in consolidated sedimentary lithologies and yellow tones for unconsolidated sedimentary deposits. With this database and the execution of procedures, the construction and textual argumentation of the present study was carried out, uniting two variables, processes and forms, key parameters in geomorphology studies.

3. RESULTS AND DISCUSSION

The CELMM and its surroundings present well distributed patterns and classes of dissection among its sectors, segmented into two macro-compartments (Figure 3): one tabular, broad and more elongated with east-west main axis, composed of denudational morphologies, the easternmost portion of the coastal sedimentary low plateaus; the second comprises a set of recent sedimentary morphologies, predominantly flat and structured in islands, entanglements and sandy-clay bars of fluvial-marine origin.

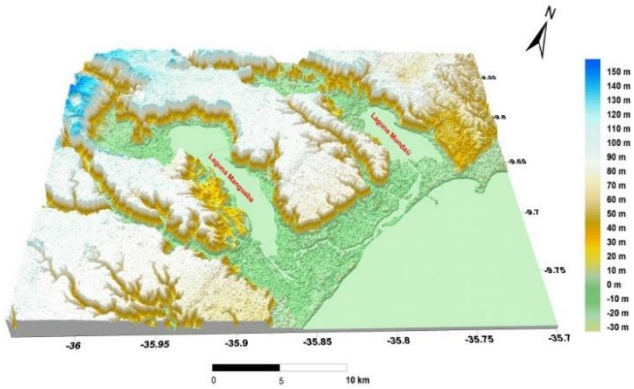

Figure 3 - Digital elevation model with well sectored altimetric compartments of the CELMM. Source: Prepared by the authors (2021).

3.1. Landform dissection of the CELMM

The indices of landform dissection have several purposes in geomorphological studies, however, when it comes to geomorphological cartography, it helps in the identification and spatial distribution of morphogenetic processes and their factors of change, enabling the sectoring, not only of morphological units, but also sectors of the landscape with similar functional dynamics, and allows the correlation of the balance between morphogenesis and pedogenesis (ROSS, 2000). Based on this, it was observed that the landform of CELMM, for being seated on consolidated sedimentary context, presented, in 80% of its area, contexts of average interfluvial dimension and valley carving, quite similar, both strongly influenced by the current fluvial systems, composed of two large hydrographic basins, Mundaú and Paraíba do Meio, besides small drainages embedded in sediments of the Barreiras formation.

The average interfluvial dimension of the area is sectored between 0-750 meters, classified as very small, when located on

the tops of the tabular forms with low gravitational influence, with the predominance of infiltration in front of the runoff, in extensive eluvial fans, comprise areas with small interfluvial dimensions, related to small basins of ephemeral surface runoff (Figure 4).

Strongly influenced by a configuration of humid climates and dense vegetation cover, the valleys of the CELMM presented varied degrees of notching, however, with predominance of those with dimensions between 0-20 meters, classified as very weakly notched, far from reaching the regional base level, the Mundaú and Manguaba lagoons. The largest drainages are in wider valleys, in humid areas or cutting perpendicularly the steep slopes of the tableland edges, with notches ranging from 20 to 80 meters, classified as weak and medium. In the interior portions of the Complex, these valleys present dimensions between 80-160 meters, classified with strong notching and arriving close to the base level.

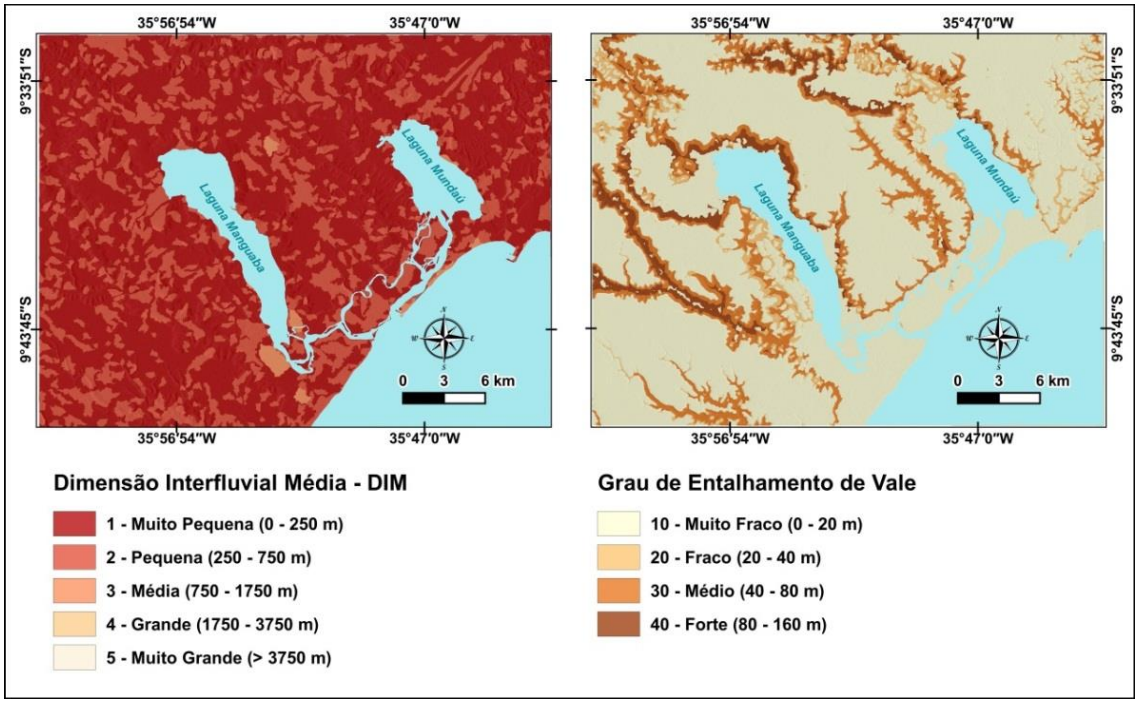

Figure 4 - Distribution of mean interfluvial dimension and valley notch grades in the CELMM. Source: Prepared by the authors (2021).

Analyzing the identified notching classes, it can be seen that there is an increasing increase in the degree of notching, advancing from east to west, in larger drainages. In part, this configuration suggests a probable relation with the sea level variations throughout the Late Quaternary that, due to the more intense hydrological regime, by the drowning of the valleys in moments of marine progradation, changes in the regional base level, ended up reworking laterally the valley slopes in a differentiated way. In opposition, at times of marine retrogradation, the base level lowered, leading to a deepening and widening of the river channels, diminishing the differences in the morphometric width x depth relationship.

By summing the matrices of valley notch degree and average interfluvial dimension, it was possible to obtain the regional patterns or units of landform dissection (Figure 5). The results show almost homogeneous patterns of dissection, with influence of planar, tabular and pluriconvex landforms, allowing not only quantifying the dissection but also tracing relations and sectorizations among its morphological compartments.

By plotting the data in the landform classification matrix proposed by Guimarães et al. (2017), it is observed that the dissection of the CELMM landform is predominantly weak; in approximately 90% of the area. Especially in the areas of tablelands and hills, edges of the Complex, while in some portions further west, appears with very strong dissection pattern. These two portions together represent about 6% of the area. The other smaller and more sparse localities represented no more than 4% and were related to flat-bottomed valley areas, due to sedimentary entrapment by lateral fluvial overflow (Figure 6).

From the measurement of the dissection units and their consequent classes, it was possible to sectorize the morphosculptural units and the morphosculptural subunits, in addition to the morphological units of the landform, which enabled the elaboration of the geomorphological compartmentalization proposal presented below.

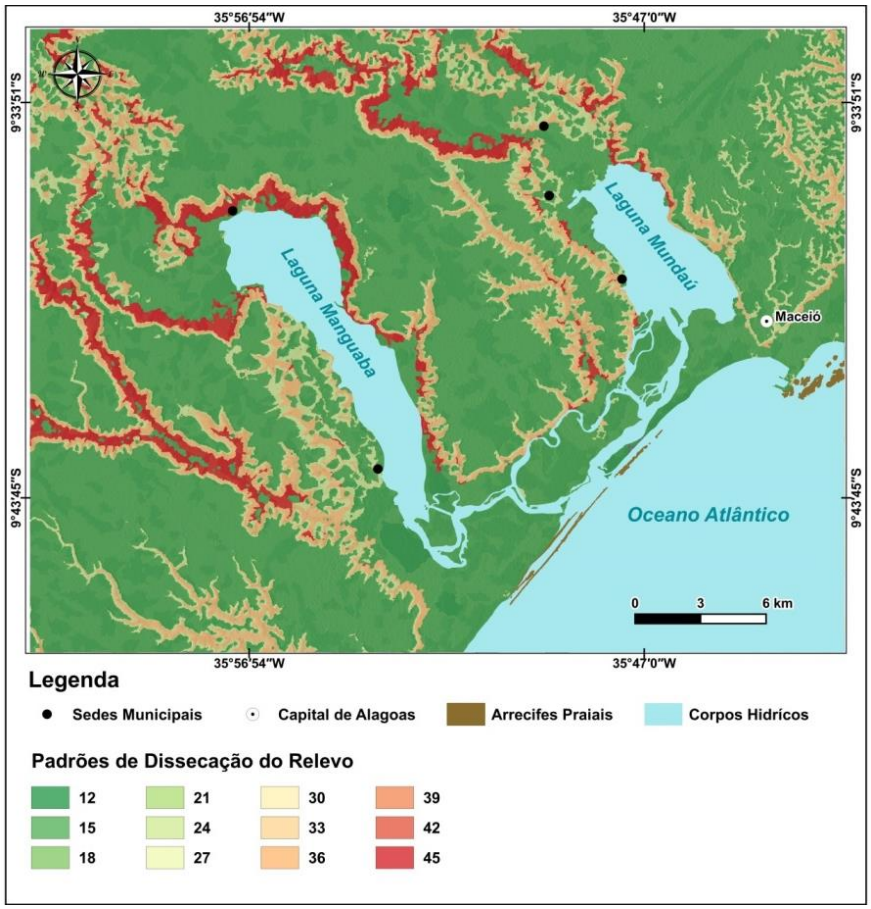

Figure 5 - Patterns of landform dissection in the CELMM. Source: Prepared by the authors (2021).

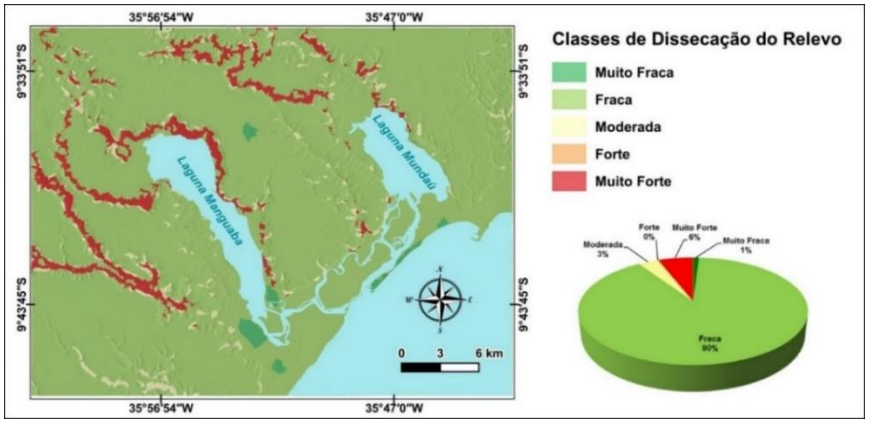

Figure 6 - Classes of landform dissection. Source: Prepared by the authors (2021).

3.2. Geomorphological Compartmentation of the CELMM

Structured on sedimentary lithologies, the landform of the area is inserted in a transitional strip between the coastal environment and continental portions. Its compartmentation is distributed in two morphostructural units: the Alagoas Sub-Basin (Figure 7B) and the Quaternary Sedimentary Coverings (Figure 7A), both in the Sergipe-Alagoas sedimentary basin (PETROBRÁS, 1979). We propose a sectoring in two genetically differentiated plateaus, one higher, where denudation processes predominate, the Lower Coastal Sedimentary Plateaus and the other lower and flatter, where pleation processes predominate, the

Coastal Plains, marine and fluvial-marine. Over these structures a series of subunits have developed, that under differentiated geomorphological regime, are sectored in smaller units that represent the morphological units, controlled by local process dynamics throughout time (Figure 8 and Table 1).

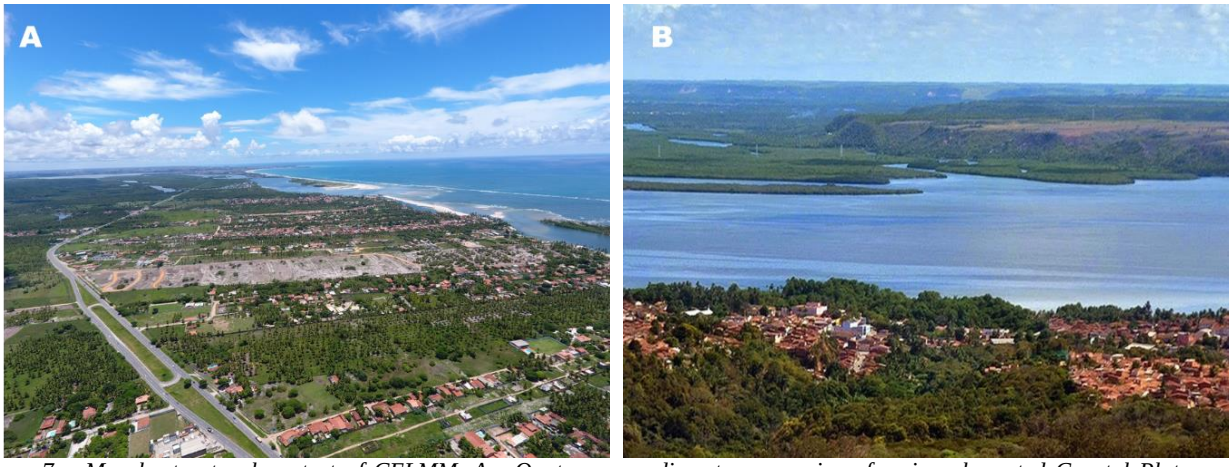

Figure 7 – Morphostructural context of CELMM. A - Quaternary sedimentary coverings forming elongated Coastal Plateau; B - Outcrops of the Alagoas sub-basin forming Coastal Tablelands bordering the Mundaú lagoon. Source: Collection of the authors (2017 and 2021).

3.3. Alagoas Sedimentary Basin

As discussed by Lima (1990) and Lima (1998), the marginal sedimentary basins are configured in sets of blocks staggering, with genesis related to the separation of Supercontinent Gondwana, initiated in the Cretaceous. This event gave rise to successive aborted rifts, forming a series of basins along the Brazilian continental margin (MATOS, 2000). As from the Cenozoic, these large basins were filled by sediments coming from the exhumation and dissection of crystalline lithologies from interior portions of the continent, which, with the consequent consolidation of the sediments and the occurrence of small tectonic pulses and glacio-eustatic variations, resulted in the elaboration of morphologies structured in extensive tabular forms (COSTA and WANDERLAY, 1994).

This Morphostructural Unit, as a whole, presents partially flattened and undulated landforms (Figure 9), settled predominantly on the areno-conglomeratic deposits of the Barreiras Formation, of plio-plastic age, and the sandstones of the Maceió, Coqueiro Seco and Poção Formations, dated from the Aptian (CPRM, 2014). This unit was divided into four morphosculptural sets related to distinct denudation processes: Conserved Coastal Tablelands; Dissected Coastal Tablelands; Dissected Hillside Tablelands and the Intraplanal Depressions.

The Conserved Coastal Plateaus present relatively flat modeling, forming large tabular surfaces with weak dissection, with small altimetric variations, compartmentalized in three individual subunits in topographic levels of distinct altitudes grouped in: between 10 and 50 meters (2.1.1); 50 to 100 meters (2.1.2) and; 100 to 150 meters (2.1.3). This topographic variation is well marked in two directions, one from the edge towards the center of the tubular areas, as the altimetry increases. The second is in an east-west direction, when the innermost morphologies present higher altitude as can be observed in profiles D-C and F-E of Figure 10.

The Dissected Coastal Plateaus correspond to areas that are very much carved by the fluvial network and bordered by large drainage headwaters. The retreat of the slopes leads to partial processes of mamelonization, generating partially tabular forms, controlled by a more intense fluvial regime, imposing moderate dissection processes. They present quite narrow valleys, resulting from reworking with the increase of the fluvial notch level, due to their low degree of inflection in the longitudinal profile of the channels as can be observed in the final portion of the H-G profile. This unit is compartmentalized into two plateaus with topography varying from 10 to 50 meters (2.2.1) and 50 to 100 meters respectively (2.2.2).

The Dissected Plateaus in Hills, predominantly composed of hills and low hills with rounded to semi-rounded tops and moderate dissection of sedimentary layers, present high stages of mamelonization, with the elaboration of convex forms. Their modeling is probably related to intense hydrological regimes during the Neogene-Quaternary transition, which reworked the slopes laterally, removing, in some portions, part of the sedimentary capping of the Barreiras formation to more clayey, more impermeable levels. This unit was sectored in three levels: hills with average altitudes between 10 to 20 meters (2.3.1), 20 to 50 meters (2.3.2) and 50 to 100 meters (2.3.3). Some of these features can be observed in profile A-B when near the lagoons.

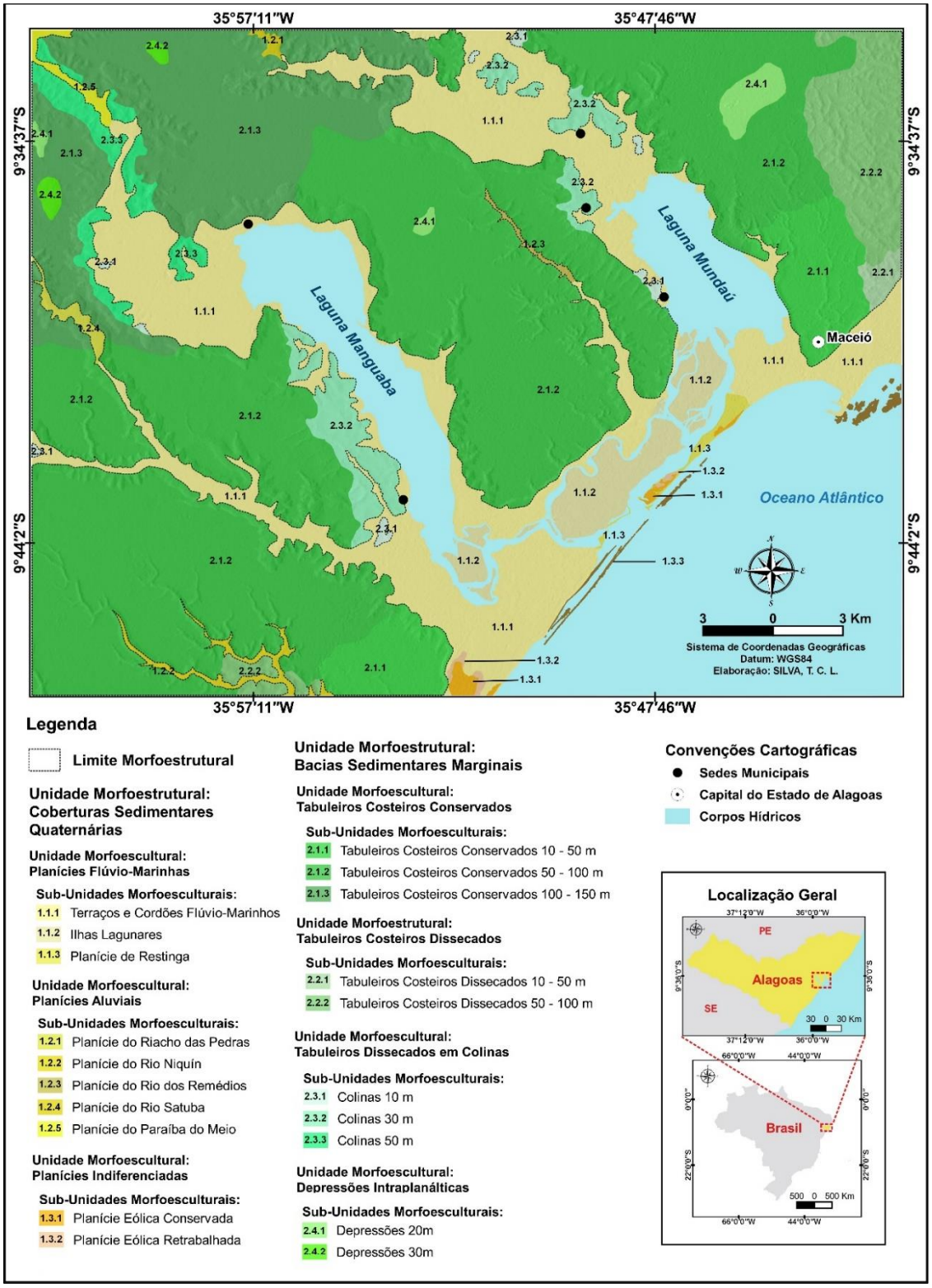

Figure 8 - Geomorphological compartments of the CELMM. Source: Prepared by the authors (2020).

Table 1 – Section of identified geomorphological units, their elevations and gradients. Source: Prepared by the author (2021).

Morphostructural Units	Morphosculptural Units	Morphosculptural Sub-Units	Elevation			
			Max	Med	Min	Grad.
1. Quaternary Sedimentary Cover	1.1. Fluvio-Marine Plains	1.1.1. Fluvial-Marine Terraces and Sand Cords	10 m	5 m	1 m	9 m
		1.1.2. Lagoon Islands	6 m	4 m	1 m	5 m
		1.1.3. Sandbar Plains	13 m	8 m	1 m	12 m
	1.2. Fluvial Plains	1.2.1. Plains of the Riacho das Pedras	69 m	52 m	30 m	39 m
		1.2.2. Plains of the Rio Niquín	29 m	12 m	6 m	23 m
		1.2.3. Plains of the Rio dos Remédios	35 m	26 m	20 m	15 m
		1.2.4. Plains of the Rio Satuba	40 m	22 m	18 m	22 m
		1.2.5. Plains of the Rio Paraíba do Meio	60 m	42 m	35 m	25 m
	1.3. Eolian Plains	1.3.1. Conserved Aeolian Plain	4 m	2 m	1 m	3 m
		1.3.2. Reworked Aeolian Plain	20 m	14 m	10 m	10
2. Alagoas Sedimentary Basin	2.1. Conserved Coastal Plateaus	2.1.1. Conserved Coastal Plateaus 10 – 50 m	51 m	32 m	9 m	42 m
		2.1.2. Conserved Coastal Plateaus 50 –100 m	102 m	73 m	51 m	51 m
		2.1.3. Conserved Coastal Plateaus 100 – 150 m	152 m	76 m	101 m	51 m
	2.2. Dissected Coastal Plateaus	2.2.1. Dissected Coastal Plateaus 10 – 50 m	52 m	23 m	11 m	41 m
		2.2.2. Dissected Coastal Plateaus 50 – 100 m	101 m	63 m	49 m	52 m
	2.3. Dissected Plateaus in Hills	2.3.1. Hills 10 m	29 m	11 m	5 m	24 m
		2.3.2. Hills 30 m	58 m	29 m	10 m	48 m
		2.3.3. Hills 50 m	115 m	52 m	38 m	77 m
	2.4. Intraplanal Depressions	2.4.1. Depressions 20 m	92 m	74 m	69 m	23 m
		2.4.2. Depressions 30 m	149 m	124 m	115 m	34 m

	Morphostructure	Morfoescultura	Morphosculptural Sub-Units
Total	2	7	20

Figure 9 – Aerial image of the Coastal Tablelands in Coqueiro Seco. In detail it can be seen a clear contact between preserved tablelands (deforested area) and some dissected portions (green area). Source: Collection of the authors (2021).

The Intraplanal depressions are closed depressed areas, wide topographic irregularities, derived from tectonic accommodation or subsidence of blocks, in the middle of the plateaus with a wedge shape, usually associated with endorheic basins. Their existence may be associated with less resistant portions of the terrain or even incidences of neotectonics as evidenced by Santos, et al. (2004). The depressions were sectored in two units according to depth gradients, presenting about 20 meters (2.4.1) when close to the coast and 30 meters (2.4.2) in more inland portions.

3.4. Quaternary Sedimentary Cover

The Quaternary Sedimentary Cover of the area was widely studied by Lima (2004) and Barbosa (1985). They are mostly composed of sandy, clayey and gravelly sediments, resulting from the deposition of materials eroded inland, as a response to the erosive cycles during the Quaternary. In these units the weathering processes overlap the denudational processes, filling the lower part of the terrain, forming the sandy cape landform. Its origins are polygenetic, being the result of fluvial, marine and eolic processes and their interactions, resulting in the origin of wide plains with altimetric variations between 20 meters and the high tide level. The Quaternary Sedimentary Coverings were grouped into three morphoscapes, the fluvio-marine, fluvial and undifferentiated plains.

The fluvio-marine plains are units that result from the entanglement and, consequently, overlapping of fluvial and marine sediments, they have genesis related to the processes of sea level variations during the Quaternary, that according to Costa and Wanderley (1994) and Lima (1998), allowed their modeling and remodeling during the transgressive and regressive cycles, sea level variations during the Late Quaternary. These units were divided into lagoon islands (1.1.2), seated on extensive muddy deposits; fluvial-marine terraces and sand cords (1.1.1), formed by sandy-clay deposits, extending to the inner portions of the Complex; and sandbar plains (1.1.3) resulting from coastal entanglement, that is, a balance between marine and lagoon processes. In the Complex these features are quite representative Figure 11.

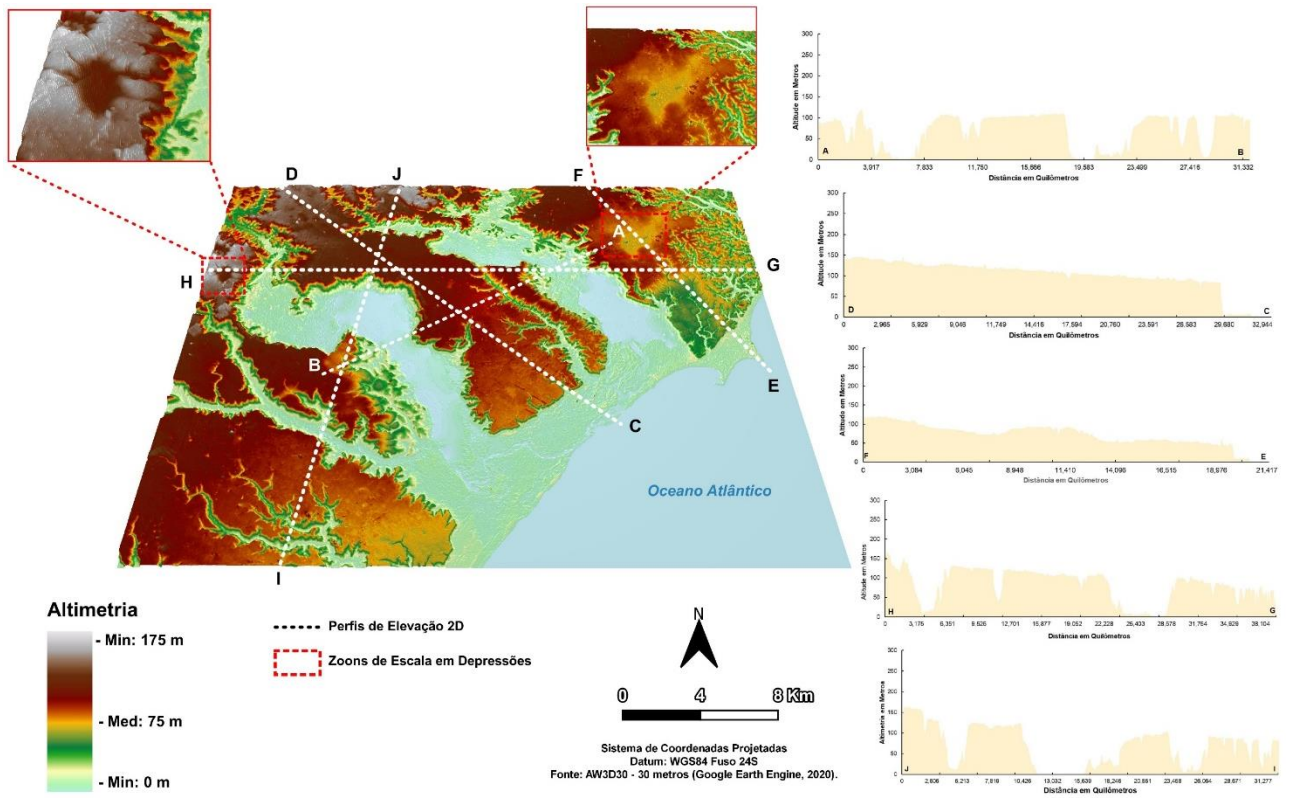

Figure 10 – Elevation context of the complex, in detail the elevation profiles and scale zoons. Source: Prepared by the authors (2021).

Figure 11 – Aerial image over Santa Rita Island. In detail several fluvial-marine islands controlled by meandering lagoon channels with well-defined sandbank plain in the upper portion of the image. Source: Authors' collection (2021).

The Fluvial Plains are the result of intensive sediment stacking flow by the fluvial network and coastal dynamics, resulting in broad plains and terraces. The plains of the Pedras creek (1.2.1), Niquim river (1.2.2), Remédios (1.2.3), Satuba (1.2.4) and Paraíba do Meio (1.2.5) were delimited, with distinct dimensions and configurations. These units are partially inserted in the mapped areas and correspond to portions, for the most part, of the lower reaches of the homonymous rivers. The various plains mapped present floodplain configurations, with very well marked topographies (Figure 12).

The Polygenetic Plains represent small sedimentary units, related to differentiated processes, of eolic origin, formed by the reworking of marine terraces and sandy strands, with reworking of sand sheets and paleodunes, and marine, through carbonate cementation processes lithifying sandy packages with a strong presence of bioclastics.

The eolian plains have their probable origin related to a drier regime than the present one, with long intervals of incipient precipitation or absence of rainfall, allowing the formation of parabolic dunes. These dune buildings still have clear morphology and form a small dune field in the central-eastern portion of the area. At present, they represent partially dissected morphologies, with traces inserted in the sandbank of Pontal da Barra, in the form of paleodunes in the northern portion and small frontal and Nebka dunes in the southern portion. In the southern part of the Complex, in Marechal Deodoro, there is a large paleodune field amalgamated in a small eolic plain dissected into a sand sheet with dissipated swell, strongly altered by successive flooding processes. This subunit has been divided into: Conserved Aeolian Plain (1.3.1), represented by dunes and paleodunes, and Reworked Aeolian Plain (1.3.2), represented by Sand Sheets reworked by successive flooding.

Figura 12 – River floodplain in the Mundaú Plain Source: Collection of the authors (2021).

4. CONCLUDING REMARKS

This study sought to contribute to the characterization and sectorization of morphogenetic processes and geomorphological compartments of the CELMM and its surroundings, drawing attention to the importance of discussing the landform of the area, aiming to contribute to planning strategies and territorial management by building databases on a detailed scale about a region so closely linked to the history of occupation and cultural construction of Alagoas.

The methodology was supported by the use of open source geoprocessing and remote sensing tools, enabling the identification of regional processes of landform modeling, in addition to the delimitation of local units sectored through the genesis-processes relationship. The application of a geomorphological hierarchization, widely tested and analyzed in several regions of Brazil, proved to be very promising in the area studied.

The mapping carried out allowed the measurement of the contexts of landform dissection of the CELMM, identifying that in 90% of the area there is a predominance of weak dissection, sectored in the tops of the tableland, while areas with strong and very strong values were identified in the hills and lagoon slopes. The determination of the current superficial processes together with the supporting bibliography allowed the sectoring of two morphostructural sets, 7 morphosculptural and 21 morphosculptural sub-units. This reveals the complexity of the landform of the CELMM, strongly related to Neo-Cenozoic sedimentary lithologies and tectonics, with strong contribution of the relative sea level variations in the Quaternary.

In general, the data produced by this study aim to contribute with information and maps that can, when used, contribute to planning and decision making by the Public Power, in an area of great historical, cultural and environmental interest. The products generated can be integrated into planning and management strategies, which would enable a better understanding of the environmental dynamics of the area.

5. REFERENCES

ARAÚJO, T. C. M.; SANTOS, R. C. A. L.; SEONE, J. C. S.; MANSO, V. A.V. Erosão e Progradação no litoral de Alagoas. In: MUEHE, D. *Erosão e Progradação no Litoral Brasileiro*. Brasília: Minitério do Meio Ambiente do Brasil, 2006.

BARBOSA, L. M. *Quaternário Costeiro no Estado de Alagoas: Influência das Variações do Nível do Mar*. 1985, 90f. Dissertação (Mestrado em Geologia) - Departamento de Geologia, Universidade Federal do Ceará, 1985.

CASSETI, V. *Elementos de Geomorfologia*. [S.I.]. 2005. Disponível em:< https://geografiaambiental.files.wordpress.com/2010/12/geomorfologia.pdf>. Acesso em: 31/01/2020.

CAVALCANTI, L. C. S. *Geossistemas no Estado de Alagoas uma contribuição aos estudos da Natureza em Geografia*, 2010, 134f. Dissertação (Mestrado em Geografia) - Universidade Federal de Pernambuco, Departamento de Ciências Geográficas, 2010.

CAVALCANTI, L. C. S. & CORRÊA, A. C. B. Geossistemas e geografia no Brasil. *Revista Brasileira de Geografia*, v. 61, n. 2, p. 3-33, 2017.

COSTA, J. A.; WANDERLAY, P. R. M. Evolução geológica-geomorfológica do Complexo Estuarino Lagunar Mundaú-Manguaba, Alagoas. *Revista de Geociências*, n°6, 1994.

CPRM, Companhia de Pesquisa de Recursos Minerais. *Mapa geológico e recursos minerais do Estado de Alagoas*. Recife, 2015.

DEMEK, J. *Manual of detailed geomorphological mapping*. 1 ed. Comm Geomorph. Surv. Mapping. IUG, Praga, 1972. 368p.

DINIZ, M. T.; OLIVEIRA, P. G.; MAIA, R. P.; FERREIRA, B. Mapeamento geomorfológico do Estado do Rio Grande do Norte. *Revista Brasileira de Geomorfologia*. v.18, n.4, 2017.

FERREIRA, B. *Geodiversidade do estado de Pernambuco*, 2014. 243f. Tese (Doutorado em Geociências) – Centro de Tecnologia e Geociência, Universidade Federal de Pernambuco, Recife, 2014.

FERREIRA, B.; SILVA, T. C. L.; SOARES, M. A.; SANTOS JÚNIOR, J. F. Patrimônio Geológico do Litoral da Região Metropolitana de Maceió – RMM, Estado de Alagoas, Nordeste do Brasil. *Revista de Geociências do Nordeste*, v.5, n.2, 2019.

FLOREZANO, T. G. *Geomorfologia*: conceitos e tecnologias atuais. 1° ed. São Paulo: Oficina de Textos, 2008.

GERASIMOV, J. *Problemas metodológicos de la ecologizacion de la ciência contemporânea*. La sociedad y el medio natural. 2° ed. Moscou: Progresso, 1963.

GUIMARÃES, F. S.; CORDEIRO, C. M.; BUENO, G. T. Uma proposta para a automatização do índice de dissecação do relevo. *Revista Brasileira de Geomorfologia*, v. 18, n°1, 155-167p, 2017.

IBGE. Instituto Brasileiro de Geografia e Estatística. *Mapa topográfico folha Maceió* (SC.25-V-C-IV-2), 1:50.000, 1985.

IBGE. Instituto Brasileiro de Geografia e Estatística. *Manual Técnico de Geomorfologia*. 2. ed. Rio de Janeiro: IBGE, 2009. 182 p.

LIMA, E. M.; CORRÊA, A. C. B. Mapeamento geomorfológico como ferramenta de caracterização ambiental do município de Garanhuns-PE. *Revista Geosul*, v.31, n. 62, p.317-336, 2016.

LIMA, I. F. *Maceió, a cidade restinga*: contribuição ao estudo geomorfológico do litoral alagoano. 2° ed. Maceió: EDUFAL, 1990.

LIMA, R. C. A. *Estudo sedimentológico e geoambiental no sistema lagunar Mundaú – Alagoas*, 1998, 120f. Dissertação (Mestrado em Geociência) - Centro de Tecnologia e Geociência, Universidade Federal de Pernambuco, Recife, 1998.

LIMA, R. C. A. *Evolução da Linha de Costa a Médio e Curto Prazo Associada ao Grau de Desenvolvimento Urbano e aos Aspectos Geoambientais na Planície Costeira de Maceió-Alagoas*. 2004, 176f. Tese (Doutorado em Geociência) - Centro de Tecnologia e Geociência, Universidade Federal de Pernambuco, Recife, 2004.

MATOS, R. M. D. Tectonic evolution of the equatorial south atlantic. In: MOHRIAK, W. U.; TALWANI, M. (Eds.). *Atlantic Rift in Continental Margins*. Washington, DC: American Geophysical Union, p.331-351, 2000.

MESCERJAKOV, J. P. Lês concepts de morphostructure et de morphosculture: un nouvel instrument de l'analyse géomorphologique. *Annales de Geographie*, v.77, n. 423, p. 539-552, 1968.

NEX, F.; REMONDINO, F. UAV for 3D mapping applications: a review. *Applied Geomatics*, v. 6, p. 1–15, 2013.

PETROBRAS/DNPM. *Mapa geológico folha Maceió* (SC.25-V-IV-2), 1:50.000. 1976.

ROSS, J. L. S. O registro cartográfico dos fatos geomórficos e a questão da taxonomia do relevo. *Revista do Departamento de Geografia*. n. 6, p. 17-29, 1992.

ROSS, J. L. S. Análise empírica da fragilidade dos ambientes naturais antropizados. *Revista do Departamento de Geografia*, v. 8, p. 63-74, 1994.

ROSS, J. L. S. *Geomorfologia*: ambiente e planejamento. 1° ed. Editora Contexto: São Paulo, 2000. 90p.

SANTOS, L. J. C.; OKA-FIORI, C.; CANALI, N. E.; FIORI, A. P.; SILVEIRA, C. T.; SILVA, J. M. F.; ROSS, J. L. S. Mapeamento Geomorfológico do estado do Paraná. *Revista Brasileira de Geomorfologia*, São Paulo, v. 7, n. 2, p. 03-12, 2006.

SANTOS, R. J. Q.; LIMA, R. C. A.; FERREIRA-NETO, J. V. A geomorfologia do tabuleiro como consequência do neotectonismo. In: ARAÚJO, L. M. *Geografia*: espaço, tempo e planejamento. Edufal, Maceió-AL, p. 225-290, 2004.

SILVA, T. I.; RODRIGUES, S. C. A utilização de SIGs e técnicas de Geoprocessamento a partir de imagens da SRTM para a Compartimentação Geomorfológica da Bacia do Médio-Baixo Curso do Rio Araguari/MG. *Caderno de Geografia*, v.20, n.34, p.58-73, 2010.

SOUZA, L. H. F.; FERREIRA, I. L.; RODRIGUES, S. C. Cartografia digital aplicada ao mapeamento geomorfológico. *Sociedade & Natureza*, v. 30, n. 16, p.133-144, 2004.

SOUZA, A. S.; FURRIER, M. Técnicas de mapeamento geomorfológico aplicadas em escala de detalhe. *Revista Brasileira de Geomorfologia*, v. 20, n. 1, p.89-103, 2019.

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