https://rbgeomorfologia.org.br/
ISSN 2236-5664

Revista Brasileira de Geomorfologia

v. 24, nº 4 (2023)

http://dx.doi.org/10.20502/rbg.v24i4.2401

Artigo de Pesquisa

Anthropogenic Geomorphological Mapping of the Central Sector of the João Pessoa Metropolitan Region (PB), Brazil

Mapeamento Geomorfológico Antropogênico do Setor Central da Região Metropolitana de João Pessoa (PB), Brasil

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Recebido: 29/04/2023; Aceito: 26/11/2023; Publicado: 13/12/2023

Abstract: This work presents and discusses the application of a new geomorphological mapping methodology focusing on anthropogenic landforms. The study area is the central sector of the metropolitan region of Joao Pessoa (state of Paraíba, Northeast Brazil), where there are densely urbanized areas and rural areas with high human intervention. The proposed geomorphological mapping methodology was developed based on Brazilian, English and Italian experiences and included extensive fieldwork. The final map elaborated covers from morphostructures to current anthropogenic landforms, proposing a broad and integrated legend representing all mapped taxa. The geomorphological map produced, in addition to being a synthesis of the geomorphological research developed, presents itself as an important tool for urban and environmental planning.

Keywords: Anthropogenic Geomorphology; Anthropogenic Landforms; Urban Geomorphology.

Resumo: Este trabalho apresenta e discute a aplicação de uma nova metodologia de mapeamento geomorfológico com enfoque nas formas de relevo antropogênicas. A área de estudo é o setor central da região metropolitana de Joao Pessoa (estado da Paraíba, Nordeste do Brasil), onde encontram-se áreas densamente urbanizadas e áreas rurais com elevada intervenção humana. A metodologia de mapeamento geomorfológico proposta foi desenvolvida a partir de experiências brasileiras, inglesas e italianas e contou com extensivos trabalhos de campo. O mapa final elaborado abrange desde as morfoestruturas até as formas de relevo antropogênicas atuais, propondo uma legenda ampla e integrada representando todos os táxons mapeados. O mapa geomorfológico produzido, além de ser uma síntese da pesquisa geomorfológica desenvolvida, apresenta-se como uma importante ferramenta para o planejamento urbano e ambiental.

Palavras-chave: Geomorfologia Antropogênica; Relevos Antropogênicos; Geomorfologia Urbana.

1. Introduction

Landforms have been studied over time as products of the interaction of different elements and processes, as explained by Christofoletti (1980). The main morphogenetic elements are endogenous and exogenous (CHOLLEY, 1950). However, with the advancement of technology, especially after the industrial revolution in the eighteenth century and more intensely after the second world war, human beings began to act as a profound modifier of landforms (NIR, 1983), matching and even surpassing in intensity, in certain areas of the planet earth, the endogenous and exogenous processes. Landforms generated by human activity can be called anthropogenic landforms or, as Peloggia (2005) refers, technogenic landforms.

Brazil has a wide experience in geomorphological mapping inherited from the RADAMBRASIL project in the 1970s and 1980s and can, without a doubt, be placed as a world reference in this area. In fact, Brazil has a national executive committee made up of several researchers who are working on the feasibility of a standardized relief classification system (CEN/SCBR, 2022). This places Brazil in a prominent position in the world, given that geomorphological mapping lacks a standardized system as already achieved in geological mapping. Anthropogenic geomorphology and the mapping of anthropogenic landforms has also been gaining prominence with a series of publications in Portuguese and English, such as: Peloggia (1997, 1998, 2005, 2015, 2017, 2018), Miyazaki (2014), Oliveira (2014), Silva et al. (2014), Luz and Rodrigues (2015), Paschoal et al. (2015), Barbosa et al. (2018), Barbosa et al. (2019), Barbosa and Furrier (2023), among others.

One of the great exponents of geomorphological mapping in Brazil is Professor Jurandyr Ross, who also worked for years on the RADAMBRASIL project. Ross published an article in 1992 (ROSS, 1992), where he brought a division of landforms into six hierarchical taxa, which can be used in general studies on the geomorphology of a given region. This methodology maps a variety of landforms, from the large morphostructures (geological foundation) that support the large landforms, to current landforms, produced by natural events or human activity.

Although the methodology developed by Ross (1992) is a product of the continuous evolution of the geomorphological mapping developed in the RADAMBRASIL Project, and has been widely applied in Brazil, highlighting its use in the geomorphological mapping of the state of São Paulo (ROSS; MOROZ, 1996; ROSS; GOUVEIA, 2022) and the state of Parana (SANTOS, et al., 2006), this methodology is still little applied to detail scales and in urban areas, as is the case of this work. Other authors with more recent works have brought different methodological proposals for specific geomorphological mapping of urban areas and anthropogenic landforms, among which the following can be mentioned: Rodrigues (2005), Ford et al. (2010), Peloggia et al. (2014a and 2014b), Del Monte et al. (2016), Furrier et al. (2017), Brandolini et al. (2018), Barbosa et al. (2018), Barbosa et al. (2019), Cappadonia et al. (2020), and Barbosa and Furrier (2023).

For the study of anthropogenic landforms and their consequent mapping, it is important to consider the genetic nuances existing in this type of landforms. Haigh (1978) tries to systematize anthropogenic actions and divide them into two main groups: direct and indirect anthropogenic processes. While direct anthropogenic processes are related to construction activities, excavation and changing river courses, indirect ones involve acceleration of erosion, acceleration of silting up of water bodies, subsidence of land by mining activities and even earthquakes triggered by human activities, among others. Classifications of anthropogenic landforms based on direct and indirect actions were developed by Brown (1971), Goudie (1994), Vita-Finzi (1993), Goudie and Viles (2010).

Therefore, geomorphological mapping focused on anthropogenic landforms has a series of variants to be considered that entail a higher level of complexity and detail for the researcher when compared to the task of mapping landforms of natural origin. In this sense, this work aims to analyze the anthropogenic landforms in the central sector of the Metropolitan Region of João Pessoa (Paraíba state, Northeastern Brazil) and to produce a detailed geomorphological map focusing on anthropogenic landforms applying a new methodology developed during the evolution of this research. This new methodology is based on works from Brazil, England, and Italy and brings its own methodological innovations.

2. Study area

The study area covers the three main coastal cities that are part of the metropolitan region of Joao Pessoa. The territorial extension of the three municipalities totals around 411 km². According to IBGE (2023), the largest and most populous municipality is João Pessoa with 825,796 inhabitants and 210 km², followed in area by the municipality of Conde with 171.2 km² (25,341 inhabitants) and lastly Cabedelo with 29.9 km² (69,773 inhabitants) (Figure 1).

The study area is predominantly located in the eastern sector of the Paraíba Sedimentary Basin. This marginal sedimentary basin is composed of the Beberibe, Gramame and Maria Farinha formations, the first two from the Cretaceous, and the last from the Paleocene. These formations are covered, in most of the area, by poorly consolidated sediments from the Barreiras Formation (Miocene) and by Quaternary sediments. The sediments of the Sedimentary Basin of Paraíba only outcrop in the more carved valleys of the municipalities of João Pessoa and Conde and in some sectors of the beach of Conde (BRASIL, 2002).

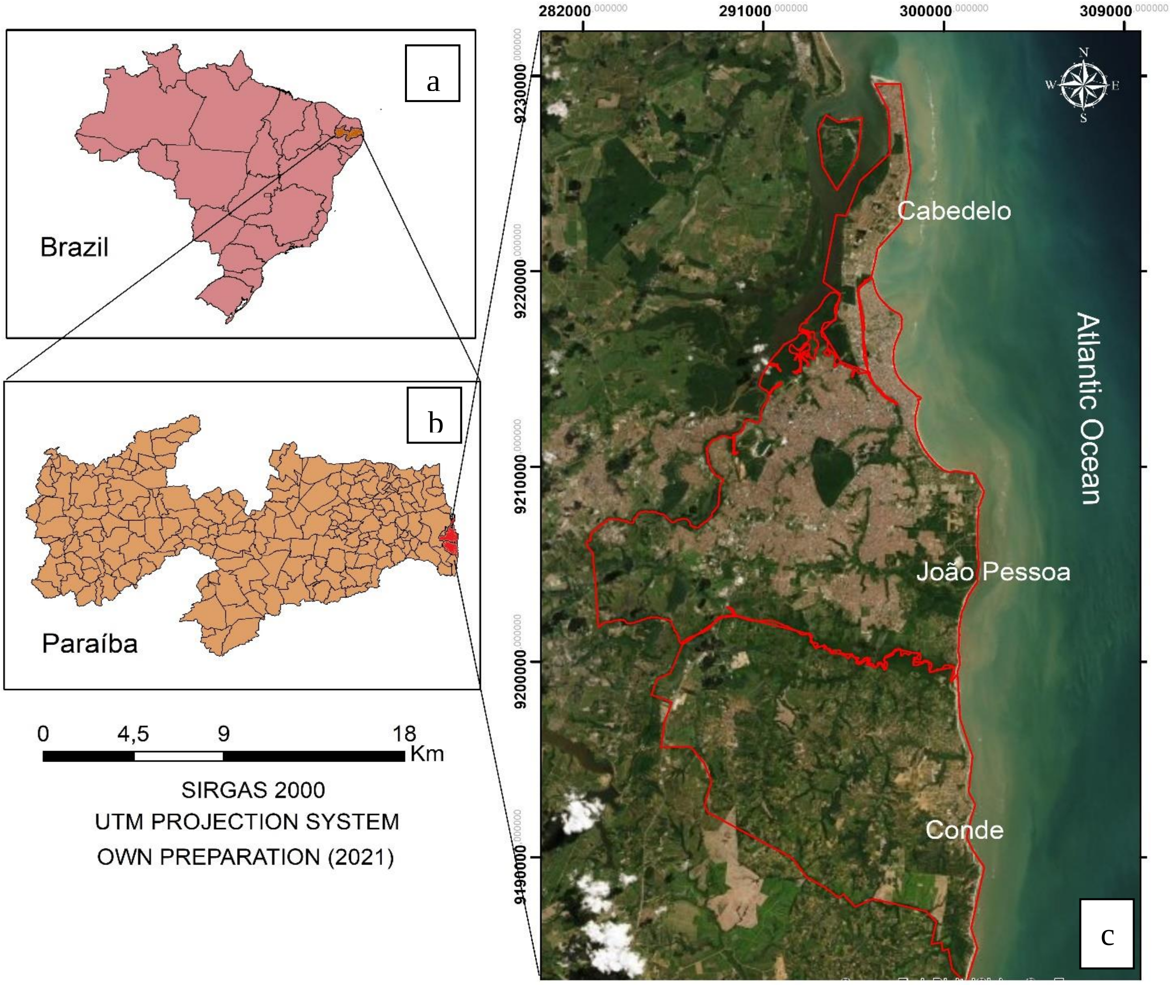

Figure 1. (a) Location map of Brazil; (b) Location map of the Paraíba state; (c) Location map of the municipalities of Cabedelo, João Pessoa and Conde. Source: Authors.

The Beberibe Formation is the basal sedimentary layer of the Paraíba Sedimentary Basin and rests, discordantly, on Precambrian crystalline basement (MABESOONE; ALHEIROS, 1988). The Gramame Formation is the first carbonate unit in the marine domain and therefore rests on the Beberibe Formation (BARBOSA, 2004). Finally, the Maria Farinha Formation represents the continuation of the limestone sequence of the Gramame Formation, differing from the previous one due to its fossil content (MABESOONE, 1994).

Covering the Paraíba Sedimentary Basin is the Barreiras Formation, a lithostratigraphic unit of Miocene age (ARAI, 2006) composed of poorly consolidated sedimentary rocks such as sandstones (predominant), mudstones and conglomerates. The outcrops of the Barreiras Formation are predominant in the study area. The exception occurs in the municipality of Cabedelo, where there are no outcrops of the Barreiras Formation, but large deposits of unconsolidated Quaternary sediments composed mainly of alluvium and coastal sediments.

Regarding the general characteristics of the local relief, the study area is basically part of two distinct geomorphological domains. The domains receive the following local names: (i) Low Coastal Plateaus, which is supported by poorly consolidated sand-clay sediments of the Barreiras Formation; and (ii) Coastal Lowland, which consist of relatively flat ground at low altitude formed by quaternary sediments of fluvial and marine origin.

In João Pessoa, the Low Coastal Plateaus are wide and are present in most of the municipality. The Coastal Lowland occupies areas close to the coastline and the estuary of the Paraíba River. The Coastal Lowland in the municipality of Joao Pessoa is wider in the neighborhoods of Manaíra, Bessa and Jardim Oceania. In the municipality of Conde, the Low Coastal Plateaus are also predominant, but they are more dissected and less wide when compared to the low plateaus of Joao Pessoa. The Coastal Lowland is present in the municipality of Conde in the coastal zone and in the estuary of the river Gramame to the north of the municipality. In the municipality of Cabedelo there is only the Coastal Lowland.

2. Technical-Operational Procedures

First, bibliographic, and cartographic surveys were carried out to serve as a basis for this research. Several theoretical sources and methodologies for geomorphological mapping (ROSS; MOROZ, 1996; SANTOS et al. 2006) and for anthropogenic geomorphological mapping (BROWN 1971; VITA-FINZI 1993; GOUDIE; VILES 2010; FORD et al. 2010; PELOGGIA et al. 2014a, 2014b; PELOGGIA, 2018; DEL MONTE et al. 2016; COOPER et al. 2018, BARBOSA et al. (2018), CAPPADONIA et al. 2020) were consulted.

As a topographic base, topographic maps printed on a 1:25,000 scale were used, with a 10 m equidistance from the contour lines, covering the entire area of the municipalities of Cabedelo, João Pessoa and Conde. These topographic maps were produced by the *Superintendência de Desenvolvimento do Nordeste* in 1974 through aerial photogrammetric surveys with terrestrial operational support (SUDENE, 1974). The accuracy of this topographic maps is excellent and in addition, it depicts the relief almost 50 years in the past. This is fundamental when the focus of the research is the mapping of anthropogenic landforms, because in these almost 50 years, many anthropogenic landforms have emerged in the study area due to the great urban expansion. These topographic maps were digitized, vectorized and their data inserted into a GIS environment (QGIS software free) where they could be handled, analyzed, and used in the final geomorphological mapping.

In order to accurately map the anthropogenic landforms, orthogonal aerial photographs taken in 1985 and 1998 were analyzed, several detailed sweeps were also made using Google Earth Pro and Google Maps, in addition to several field trips for the final check of the anthropogenic landforms and photographic captures.

The first step in the elaboration of the anthropogenic geomorphological map was the delimitation of the first four taxa following the methodology of Ross (1992). It is important to point out that, although the present work is focused on the mapping of anthropogenic landforms, a correct characterization and general geomorphological mapping is necessary, since every anthropogenic landform is situated in a morphosculpture which, in turn, is supported by a morphostructure.

In addition, on a morphosculpture they develop relief patterns that can be categorized into specific relief types. Therefore, following the methodology of Ross (1992) there is a clear hierarchy of relief, going from the broadest morphostructure (1st taxon), followed by morphosculpture (2nd taxon), relief patterns (3rd taxon), relief types (4th taxon), types of slopes (5th taxon) and natural and anthropic forms (6th taxon) (Figure 2).

Therefore, the geomorphological mapping methodology presented in this work fully incorporates Ross' (1992) methodology up to the 4th taxon, with adaptations to the predominantly tabular relief of the study area. The 5th taxon related to the types of slopes was removed, as there are no large slopes in the area, and the mapping of small slopes found in the valleys of the tabular relief would generate an excess of information that could be harmful to the reading of the map. Among the consulted bibliographies that used the methodology of Ross (1992), Santos et al. (2006), Furrier et al. (2017) and Barbosa et al. (2019) also suppressed this taxon due to the scale adopted in these works. In the last two works, the 5th taxon (types of slopes) was represented and analyzed in detailed topographic profiles and not in the elaborated maps.

The taxa according to Ross (1992) that were used in this work are the following:

- 1st taxon – morphostructures, which corresponds to the geological basement.
- 2nd taxon – morphosculptures, which is generated on the morphostructure.
- 3rd taxon – relief patterns, which are sets of smaller relief forms developed on a given morphosculpture. They can be forms of aggradation or denudation.
- 4th taxon – relief types, which are individualized forms within each relief pattern. They are distinguished by topographic roughness and are morphometrically defined according to the dissection of the relief (Frame 1). This hierarchical level can only be defined in denudational reliefs.

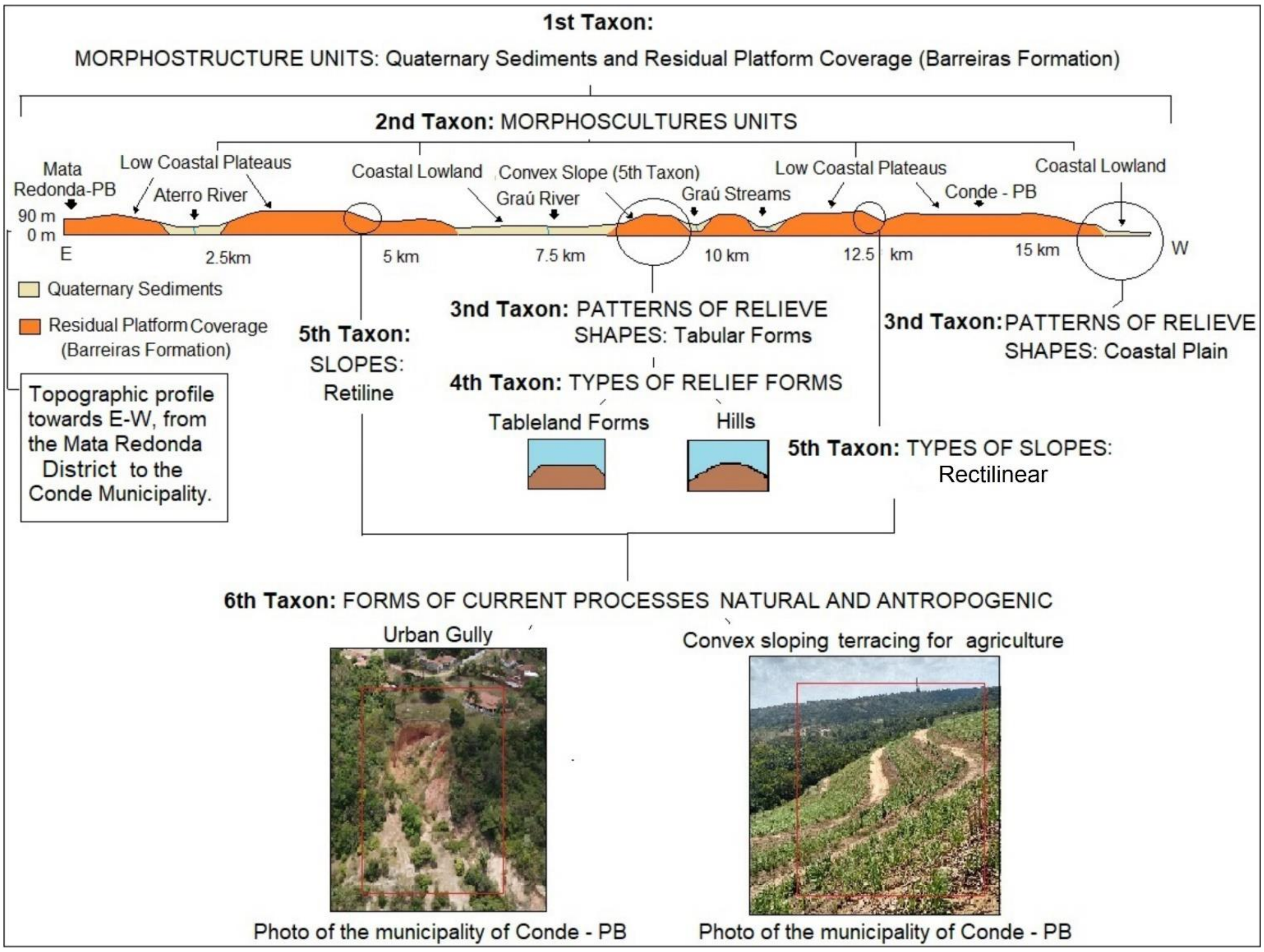

Figure 2. Relief taxonomy scheme based on the geomorphological mapping methodology proposed by Ross (1992). Source: Authors.

Frame 1. Relief dissection index matrix

Interfluvial dimension (classes) / Incision of the valleys (classes)	Very large (1) (> 1,500m)	Large (2) (1500 – 700m)	Middle (3) (700 – 300 m)	Small (4) (300 – 100 m)	Very small (5) (< 100 m)
Very low (1) (< 20m)	11	12	13	14	15
Low (2) (20 – 40m)	21	22	23	24	25
Middle (3) (40 – 80m)	31	32	33	34	35
Strong (4) (80 – 160m)	41	42	43	44	45
Very strong (5) (> 160m)	51	52	53	54	55

Source: Adapted from Ross (1992).

The relief dissection index matrix shows values in Arabic numerals that represent valleys that contain interfluvial dimension from very large (1) to very small (5) (horizontal/line) and valley notch ranging from very strong (5) to very down (1) (vertical/column). When these values are combined (horizontal/line + vertical/column), the relief dissection index is obtained, which is a morphometric way of characterizing the relief and represents the 4th taxon of the methodology proposed by Ross (1992). The way to verify the interfluvial dimension and the notching of the valleys is didactically demonstrated by Souza and Furrier (2019).

The 4th taxon of this methodology (relief types) is always grouped with the 3rd taxon (relief patterns). The relief patterns are divided into accumulation relief and dissection relief and are designated by the letters A (accumulation) and D (dissection). Grouped with the letters A (accumulation) and D (dissection) are lowercase letters that designate the specific shape of the relief, such as: Amp (Accumulation – marine plain) and Dc (Dissection – convex shape). The forms of accumulation are not accompanied by Arabic numerals, as they are not originated by dissection processes.

As an example of representation, an area mapped as **Dc 32** would consist of a dissection relief (**D**) of convex shape (**c**), with an average fluvial dissection of 40 m to 80 m (**3**) and with valleys with average interfluvial dimensions of 1,500 m to 700 m (**2**). An area mapped as **Afp** would consist of an accumulation relief (**A**) with the fluvial system as the sediment accumulation process forming a fluvial plain (**fp**). In the accumulation forms there is no representation of the 4th taxon, as they are not relief patterns originated by erosive processes of dissection.

In Ross' methodology there is also a 5th taxon, where each slope is analyzed individually and a 6th taxon, where the current natural and anthropogenic forms are mapped. These two taxa were not used in the methodology applied in this work. Instead, for mapping anthropic landforms, newly developed methodologies were incorporated, such as: Ford et al. (2010), Peloggia et al. (2014a, 2014b), Peloggia (2018), Del Monte et al. (2016), Cappadonia (2020), as well as innovative mapping techniques aimed at better representing this type of relief. A new methodology that incorporates the Ross (1992) methodology up to the fourth taxon with adaptations to the tabular relief of the study area and uses other international methodologies for mapping urban and anthropogenic relief was published by Barbosa and Furrier (2023) and was used fully in this work.

Therefore, this new methodology developed by Barbosa and Furrier (2023) was applied and tested in this work. This methodology has 5 taxa, and its main objective is to map anthropogenic landforms. It should be noted here that this new methodology is not just a compilation of other methodologies, but a methodological theoretical development on geomorphological mapping. Even having Ross' methodology (1992) as the great foundation, this new methodology proposes improvements and adaptations to Ross's methodology, as it applies it in an area of tabular relief in a very high level of detail.

To determine each anthropic relief present in the area, the methodological proposal presented by Ford et al (2010) was incorporated, with adaptations. Thus, the mapped anthropogenic forms were grouped into Class, Type and Unit, with Unit being the group corresponding to the highest level of detail and Class to the most generic level. As a practical example, we can cite, in the Class Made Ground, Type Engineered Embankment, the Engineered Embankment for Railway (Figure 3). As can be seen, this methodology also follows a hierarchy like the methodology of Ross (1992), but it is a hierarchy of anthropogenic landforms, never dealing with current natural processes such as ravines, gullies, etc. These current natural processes were incorporated into the methodology developed by Barbosa and Furrier (2023) and are part of the 5th taxon along with the anthropogenic landforms.

In order to classify the anthropogenic landforms found through the comparison of the analyzed topographic maps (SUDENE, 1974) with orbital images from different dates, we used the nomenclatures present in the work of Peloggia (2017, 2018) (Table 1). For the sake of clarity, it should be noted that Peloggia (2018) used the term technogenic ground instead of anthropogenic landforms. The nomenclatures present in Peloggia (2017, 2018) were used in the legend of the geological map produced in this work with adaptations due to the different anthropogenic landforms found in the study area.

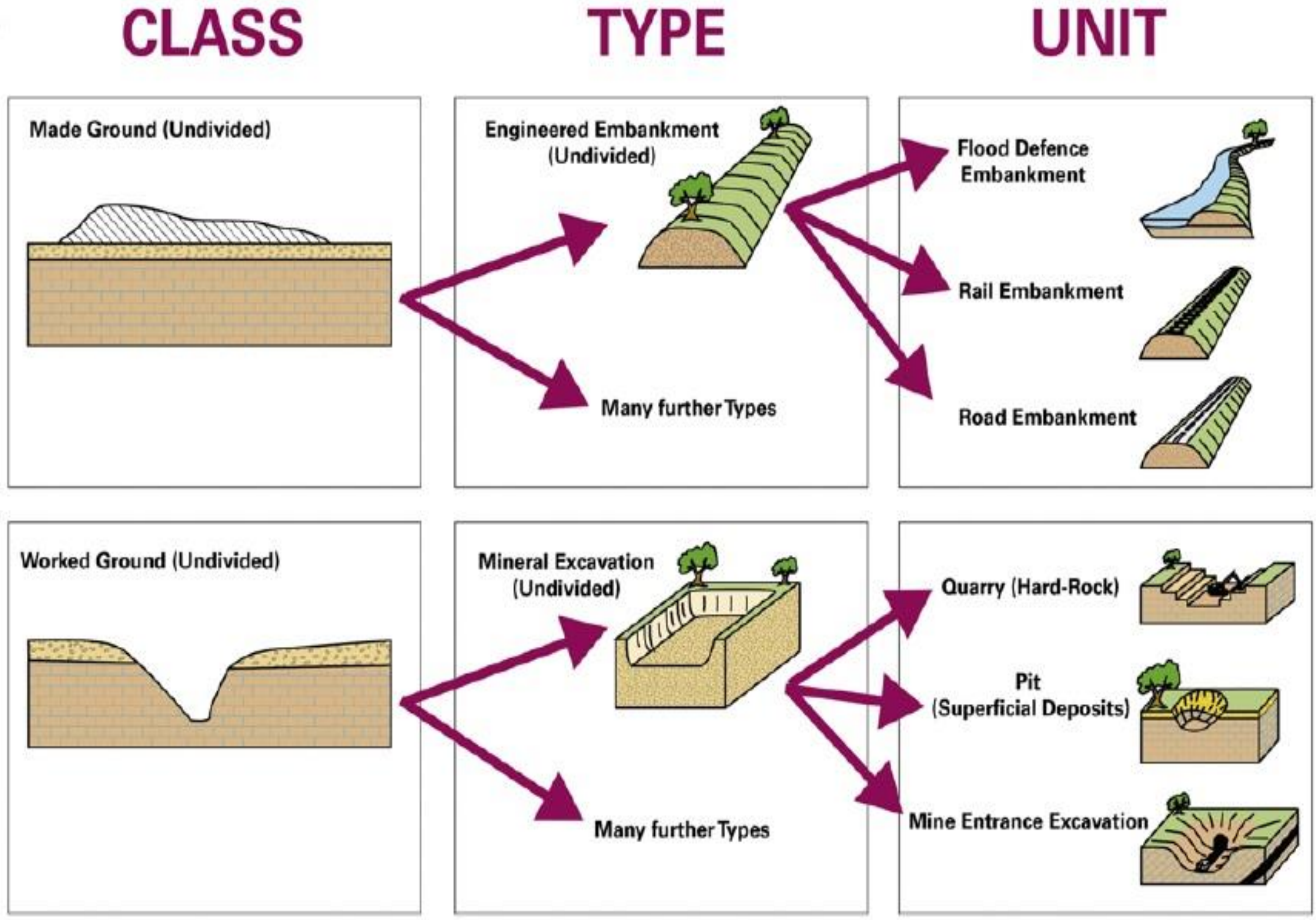

Figure 3. Examples of hierarchical classification of landforms. Source: Ford et al. (2010).

Concepts found in Peloggia et al. (2014b), dealing with anthropic deposits, were also incorporated into this work and were very useful in the geomorphological mapping carried out. These authors used unusual but extremely useful terminologies such as urbic, garbic and spolic deposits. Urbic deposits are those deposits that contain fragments of manufactured objects of modern man (commonly broken artefacts like bricks, glass, concrete, asphalt, plastic, metal alloys, crushed stone, etc.). Garbic deposits are deposits that contain organic wastes of human activity and artefacts. Spolic deposits are deposits that contain earthy (predominantly mineral) soil materials that have been moved by earth-moving equipment in surface mining, highway construction, etc.

Other nomenclatures used by Italian researchers with extensive experience in urban mapping were also incorporated with adaptations, since the study area is heavily urbanized. Del Monte et al. (2016) produced a detailed geomorphological map of central Rome. In this work, the authors used numerous historical maps that provided a richness of detail. Cappadonia et al. (2020) mapped the central part of the city of Palermo, Italy and used a series of historical maps in addition to analyzing well data for stratigraphic interpretation. It should be noted that these two works analyzed small, urbanized parts of each city and not the city completely, which differs from this work that mapped part of a metropolitan region with approximately 411 km^2. Therefore, adaptations to the work scale were inevitable. The classifications and nomenclatures used in mapping the study area of this work can be seen in Table 2.

Table 1. Classification of anthropogenic grounds for geomorphological mapping, according to Peloggia (2017).

<table>
<tr><th>Class</th><th colspan="2">Geological category</th><th colspan="2">Types</th><th>Layer or technogenic feature</th></tr>
<tr><td rowspan="8">Technogenic aggradation ground</td><td rowspan="10">Anthropogenic surface formations</td><td rowspan="8">Technogenic deposits</td><td rowspan="2">Produced ground</td><td>Embankment</td><td>Built technogenic deposits</td></tr>
<tr><td>Accumulated ground</td><td>Successively accumulated cultural technogenic layers</td></tr>
<tr><td colspan="2">Filled ground</td><td>Technogenic deposits built over excavated ground</td></tr>
<tr><td rowspan="2">Sedimentary technogenic ground</td><td>Alluvial</td><td>Valley bottom-induced technogenic deposits</td></tr>
<tr><td>Colluvial</td><td>Slope-induced technogenic deposits</td></tr>
<tr><td colspan="2">Slip technogenic ground</td><td>Induced technogenic deposits created by mass movements</td></tr>
<tr><td colspan="2">Remobilized technogenic ground</td><td>Technogenic deposits formed by the remobilization of pre-existing technogenic deposits</td></tr>
<tr><td colspan="2">Mixed technogenic ground</td><td>Technogenic deposits built, induced, or remobilized forming an undifferentiated package</td></tr>
<tr><td rowspan="2">Modified technogenic ground</td><td rowspan="2">Technogenic soils</td><td colspan="2">Altered composition ground</td><td>Natural soils with the incorporation of chemical contaminants or organic material</td></tr>
<tr><td colspan="2">Geomechanically altered ground</td><td>Compacted or turned natural soils</td></tr>
<tr><td rowspan="4">Degradation technogenic ground</td><td colspan="2" rowspan="4">Exposed or moved substrate</td><td colspan="2">Eroded ground</td><td>Erosion scars created by induced processes</td></tr>
<tr><td colspan="2">Slipped ground</td><td>Slip scars created by induced processes</td></tr>
<tr><td colspan="2">Moving or sunken ground</td><td>Subsidence depressions created by induced process</td></tr>
<tr><td colspan="2">Excavated ground</td><td>Excavation surfaces</td></tr>
</table>

Complex technogenic ground	Technogenic landscape	Complex ground	Grounds formed by the aggregation or complex overlapping of deposits or technogenic soils or substrate exposure surfaces, not differentiable in the mapping scale adopted

Source: Peloggia (2018).

Table 2. Classifications and nomenclatures for anthropogenic geomorphological mapping.

CLASS	TYPE	UNITY
Aggradation Terrain (produced, filled, alluvial or colluvial sedimentary and remobilized)	Technogenic deposits	Lithic; Sedimentary; Garbic and Urbic
Degradation Terrain (eroded, slipped, moved or excavated)	Modified slopes; Modified fluvial landforms etc.	Eorion scar; Excavation surfaces (mines); Induced gullies etc.
Modified Terrain (chemically or mechanically altered)	Chemically altered soil layers, plowed soil layers.	Leaking gas station
Mixed Terrain (overlapping or complex terrain)	Urbanized are	Not applied

Source: Adapted from Ford et al. (2010), Peloggia et al. (2014a); Del Monte et al. (2016) and Cappadonia et al. (2020).

In short, the new approach to geomorphological mapping focusing on anthropogenic landforms presented in this work takes as its starting point the first four taxa of the methodology developed by Ross (1992) while introducing a fifth and final taxon intended to map and represent anthropogenic landforms. based on the methodological assumptions of Ford et al. (2010), Peloggia et al. (2014a); Del Monte et al. (2016) and Cappadonia et al. (2020).

3 Results and discussions

The study area presents three distinct morphostructures that compose the 1st taxon of the geomorphological mapping. These morphostructures are: (i) Paraíba Sedimentary Basin, (ii) Barreiras Formation and (iii) Quaternary sediments. In the 2nd taxon, two morphosculptures were defined: Low Coastal Plateaus and Coastal Lowland. In the 3rd taxon, six different patterns of accumulation forms were mapped (intertidal plains; fluvial plains; marine plains and fluvial terraces plains; fluvial terraces and colluvium) and two patterns of denudation (tabular forms and convex forms). Due to the adopted scale, in some areas it is impossible to differentiate a fluvial terrace from a fluvial plain. In these cases, it was decided to combine the two patterns into one: fluvial terrace and plain.

Denudation forms (3rd taxon) must be grouped and mapped according to their respective morphometry, forming the 4th taxon. Accumulation forms (also 3rd taxon) are not divided into smaller units because they do not have dissection, so they are not subdivided into smaller units related to the 4th taxon.

For the results related to anthropogenic landforms mapping, referred in this work as the 5th taxon forms, it was used the hierarchical division presented by Ford et al. (2010), which divides anthropogenic landforms into

Classes, Types and Units. Classes are related to anthropogenic grounds; Types are related to the large sets of anthropogenic landforms found, and Units correspond to each individual form (Figure 3).

Out of the Classes mapped in the study area, four main ones can be outlined, which correspond to the following Grounds: Complex; Produced; Excavated and Filled. From such grounds it was also possible to determine some Types and Units.

Within the Complex Ground, the mapped Types correspond to intensely urbanized areas where the hierarchical division of anthropogenic landforms becomes impossible. In the Produced Ground tier, it was possible to identify (i) landfills related to streets, avenues, and railways (ii) garbic, urbic and lithic anthropogenic deposits (iii) beach progradation induced by anthropogenic activity; and (iv) fluvial forms of aggradation such as river embankment, and anthropogenic plains.

In the Excavated Ground, were found (i) types of mining forms with units related to surface excavation, sand extraction, or clay and limestone exploration; (ii) anthropogenic forms of coastal erosion; (iii) excavated forms related to shrimp farming; (iv) road cuts; (v) agricultural areas with anthropogenic forms linked to terracing; (vi) erosion scars and (vii) urban gullies.

Regarding the Filled Ground group, it was possible to identify anthropogenic deposit as Type, which at its turn had a mining area filled by sediments as a Unit. To conclude, other geographic attributes were mapped and inserted into the map, such as vegetation areas, hydrography, rural areas, subdivisions, active and inactive mining, along with municipal boundaries.

For a better understanding of the geomorphological characteristics of each municipality and explanation of the mapped landforms, the description of the general geomorphology, as well as the mapped anthropogenic landforms will be detailed municipality by municipality.

3.1 Cabedelo

The municipality of Cabedelo, located in the northern sector of the study area, has unique geological and geomorphological characteristics remarkably different from the other two municipalities. Its geology is composed of the Quaternary unconsolidated sediments (1st Taxon) being Coastal Lowland (2nd Taxon) its only morphosculpture. Most of the anthropogenic landforms found in the municipality of Cabedelo are accumulation forms, such as anthropogenic deposits and landfills.

Some of the deposits found in Cabedelo are closely related to coastal dynamics. In certain beaches of the municipality, it was possible to identify lithic anthropogenic deposits, used to contain beach erosion, resulting in significant local coastal dynamics change. Therefore, in some points, such deposits promote a beach progradation that constitutes an indirect anthropogenic landform (Figure 4).

The beach progradation process present at Miramar beach is directly linked to an engineering work built at the mouth of Paraíba River. This type of work is called a current guide and its purpose is to prevent the entry of sediments from the beach dynamics into the channel of Cabedelo port. In anthropogenic geomorphology studies, current guides are referred as lithic deposits, therefore an anthropogenic landform of accumulation. This structure modified the natural beach dynamics of the area, blocking the sediments coming from the south, widening the beach significantly. Miramar beach is currently the widest beach in the municipality of Cabedelo and is in process of progradation, unlike other beaches in the municipality that are in process of erosion (Figure 4).In Miramar beach, near the current guide, the sand strip is 183 m wide. Its a much larger width than the other beaches in the municipality, which attests the interference of this structure in the beach morphology, therefore producing an indirect anthropogenic landform.

Figure 4. In the foreground beach progradation at Miramar beach. In the background it is possible to observe a large part of the municipality of Cabedelo located on unconsolidated sediments of the Quaternary (1st taxon). Photo: Authors (2020) (Use of drone).

Other types of Produced Ground found in the municipality of Cabedelo are several kinds of landfills. The municipality is completely seated in unconsolidated sediments of the Quaternary; hence, landfills are extremely important and common in the construction of avenues, highways, and railway. The municipality is cut from north to south by the BR 230 highway and the commuter rail, and both structures are built on top of landfills (Figure 5).

Figure 5. Landfills for railroad and highway – Cabedelo. It is possible to visualize the unconsolidated sediments of the Quaternary between the two landfills. Photo: Authors (2020).

In addition to the forms of accumulation, some forms of Filled Ground and Excavated Ground were also verified. In former sand extraction mining areas currently, it is possible to see the formation of lakes due to the pit having reached the water table (Figure 6). That also occurs in other types of pits, such as the deposit of debris derived from civil construction and sediments generated to fill them (Figure 6).

Figure 6. Inactive sand extraction mines in Cabedelo. The mined areas are full of water due to having reached the water table, which in this area is extremely shallow. Photo: Authors (2020) (Use of drone). Photo taken from south (foreground) to north (background).

The sand extraction pits located in the Jacaré neighborhood advanced to the water table, which made it impossible to continue this activity. Figure 6 shows three inactive mines. The one in the upper part of the photo is in the process of dredging the water and filling it with rubble in its southern section, therefore ceasing to be a Worked Ground to become a Made Ground according to the classification of Ford et al. (2010). This shows how anthropogenic landforms are dynamic and need to be constantly monitored and mapped.

When the embankment process ends, probably when the local relief level is reached, this area will have geotechnical characteristics completely different from the characteristics verified in the Quaternary unconsolidated sediments in the adjoining areas. This corroborates the importance of anthropogenic geomorphological mapping and its use in urban and territorial planning.

3.2 João Pessoa

In João Pessoa municipality, that constitutes the central sector of the study area, anthropogenic landforms related to Complex, Produced and Excavated Ground were verified. The urbanized area of João Pessoa was considered as Complex Ground and covers about 80% of the total extension of the municipality.

The anthropogenic landforms present in the Produced Ground were anthropic deposits like garbic and urbics, landfills and remobilized areas, among others. These were divided into Relief Units, which are the most specific landforms, with a higher level of detail.

One of the examples of aggradational forms in João Pessoa are the lithic deposits found in the coastal zone of the municipality, mainly in its southern sector, starting at Cabo Branco beach, passing through the base of the Cabo Branco cliff, and ending after Seixas beach (Figure 7). This lithic deposit was deposited recently to contain the intense coastal erosion in this region. Due to being recent, it has not yet been possible to verify erosive or depositional processes arising from the sharp change in coastal dynamics that this lithic deposit caused. Therefore, another classic example of the need for anthropogenic geomorphological mapping to verify, in the future, landforms modified by indirect anthropic action. Lithic deposits are a classic example of direct anthropic action and the change in coastal dynamics due to this deposit will modify the beach relief, it is a classic example of indirect anthropic action.

Figure 7. Lithic deposit on Cabo Branco cliff – João Pessoa. Photo: Authors (2020) (Use of drone).

The types of anthropogenic landforms present in the Excavated Ground in the municipality of João Pessoa are mining, induced gravitational forms, erosion scar, coastal erosion accelerated by human intervention, anthropogenic cuts, and slopes. A clear example of these forms of Excavated Ground is the Timbó community, located in the Mangabeira neighborhood (Figure 8).

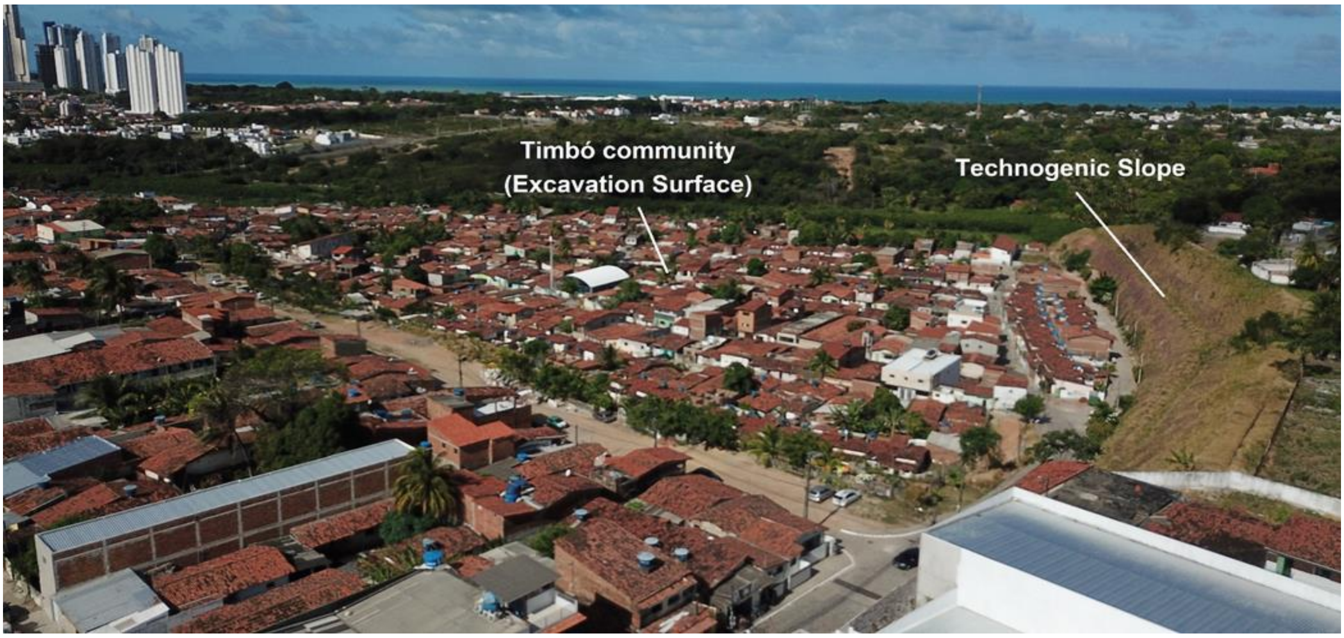

Figure 8. Excavated Ground and anthropogenic slope in the community of Timbó – João Pessoa. Photo: Authors (2020) (Use of drone).

This community is installed in an Excavated Land resulting from clay mining activity that occurred in the 1970s (Figure 8). The mined clay belongs to Barreiras Formation and was extracted to provide raw material for the construction of the Bancários neighborhood and later, for other engineering works in Joao Pessoa.

After mining ceased in the area, several workers who participated in the mining project began to settle in the site. According to Dantas (2003), based on topographic maps and aerial photographs from 1985, this community was established, delimiting itself to the south and west by anthropogenic slopes resulting from the excavation itself, which were subjected to erosion processes that caused, and still cause, constant mass movements.

Another relevant example of Excavated Land are the excavations and changes in the relief carried out in the estuary of the Paraíba River for the installation of shrimp farming. In the municipality of João Pessoa, this activity is carried out on the intertidal plain of the Paraíba River, between the course of this river and the Jaguaribe River (Figure 9).

Figure 9. Shrimp farming area seen from the Alto do Céu neighborhood – João Pessoa. Photo: authors (2020). In the upper left corner is an image from Google Earth showing the approximate location of where this photo was taken.

According to the World Bank (1998), shrimp farming consists of an activity with several possible environmental impacts in the region in which it is located, such as the degradation of fauna and flora due to the suppression of vegetation, changes in the hydrodynamics of surrounding water bodies, salinization of aquifers and soil and water degradation by the inadequate disposal of generated solid waste among others.

3.3 Conde

The geology and geomorphology of Conde municipality, which constitutes the southern sector of the study area, are similar of the municipality of Joao Pessoa. Differences between the geomorphology of the two municipalities occur from the 3rd and 4th taxon. In the municipality of Conde, the relief patterns are more dissected and less extensive than those found in Joao Pessoa, with deeper river valleys resulting in types of relief forms with a more accentuated relief dissection index. The anthropogenic landforms mapped in this municipality were: Complex Grounds, Produced Grounds and Excavated Grounds.

The Complex Ground comprises the urban nucleus of Conde located on the Coastal Tablelands carved over the Barreiras Formation and the district of Jacumã, located in the coastal zone. It is in the district of Jacumã, where urban expansion and, consequently, the formation of new anthropogenic landforms, is more visible. The landforms found in Produced Ground were landfills and anthropic deposits. In the Excavated Ground, the types of forms found were erosive forms related to agricultural areas; mining; anthropogenic cuts; anthropogenic ponds; forms of coastal erosion accelerated by anthropic action and anthropogenic slopes.

The Landfills Produced are mainly those located in fluvial plains and terraces. These embankments are built for the passage of streets, avenues and roads that cross rivers and streams and, therefore, cover part of the fluvial plains and terraces. As an example of this type of landfill, we can mention the PB 008 highway, which crosses the municipality of Conde from north to south. This highway passes through the plain of the Gramame River to the north of the municipality and through numerous streams within the municipality of Conde. Such anthropogenic landforms modify not only the natural relief, but also the fluvial dynamics (Figure 10).

Figure 10. Embankment of highway PB 008, district of Jacumã, municipality of Conde. Photo: Authors (2020).

In the Excavated Ground, the agricultural areas that are located on the Coastal Tablelands carved on the Barreiras Formation stand out. As previously explained, the relief in the municipality of Conde is more dissected than the relief found in Joao Pessoa, even though it is carved on the same geological formation. The explanation for this difference between the Joao Pessoa and Conde reliefs is due to regional tectonic issues explained mainly in the works by Furrier et al. (2006), Barbosa et al. (2013) and Barbosa and Furrier (2015). With tighter valleys and slopes with greater declivities, it is necessary to build anthropogenic terraces and slopes for greater agricultural use and reduction of erosion processes since the surface runoff is intercepted by anthropogenic terraces (Figure 11).

Terracing areas are spread across the countryside in the municipality of Conde due to this municipality having the most dissected relief with high declivities. These terracing are concentrated on the slopes of the watershed of the Salsa River, Estiva stream and Caboclo stream. Terracing is used in agriculture as a way of conserving the soil, minimize the erosion and facilitating planting in areas with high declivities. It is an old technique that helps to reduce surface water runoff and consequent erosion, increasing infiltration levels. It is based on the creation of terraces through the subdivision of leveled ramps. As seen, these are anthropogenic landforms that are quite common in the municipality of Conde. In Figure 11, slopes that exceed 2 m in height can be seen.

Figure 11. Terraces and anthropogenic slopes in an area of sugar cane cultivation. Conde. Photo: Authors (2020).

As for the anthropogenic cuts mapped in Conde, in addition to areas destined for agriculture, they are also quite common on avenues and highways that cross the municipality. As in agricultural areas, these cuts are made in the Barreiras Formation to smooth out the path through which this avenue or highway passes. The waste material from this cut is generally used for landfills in the plain's areas close to the cuts (Figure 12). These cuts were identified mainly in stretches of the BR 101 highway that crosses the municipality of do Conde from north to south in the west sector.

Figure 12. Cut in the Barreiras Formation. BR 101 Highway. Municipality of Conde. Photo: Authors (2020).

Still in the Excavated Land, other forms can be observed, such as forms of superficial excavation for the removal of material (saprolite) to be used in civil construction. These excavations, in general, are illegal and devoid of any kind of documentation, seriously impacting the local landscape and causing other environmental problems such as deforestation. In the municipality of Conde, these forms are found near the Graú and Boa Água rivers (Figure 13).

Figure 13. Surface excavation area over the Barreiras Formation, Conde. Photo: Authors (2020).

All anthropogenic landforms found in the three municipalities analyzed were plotted on the final geomorphological map according to the methodology described in this article (Figure 14). The result was an unprecedented geomorphological map rich in information from the geological foundation of the area (1st taxon) to current anthropogenic forms, such as cuts, embankments, lithic deposits, mining, etc. Another relevant point was the development of a broad and integrated legend, fundamental for understanding the geomorphological map. With this legend, professionals from related environmental areas and/or civil and environmental engineers without in-depth knowledge of geomorphology can understand and use the information on this map in other works.

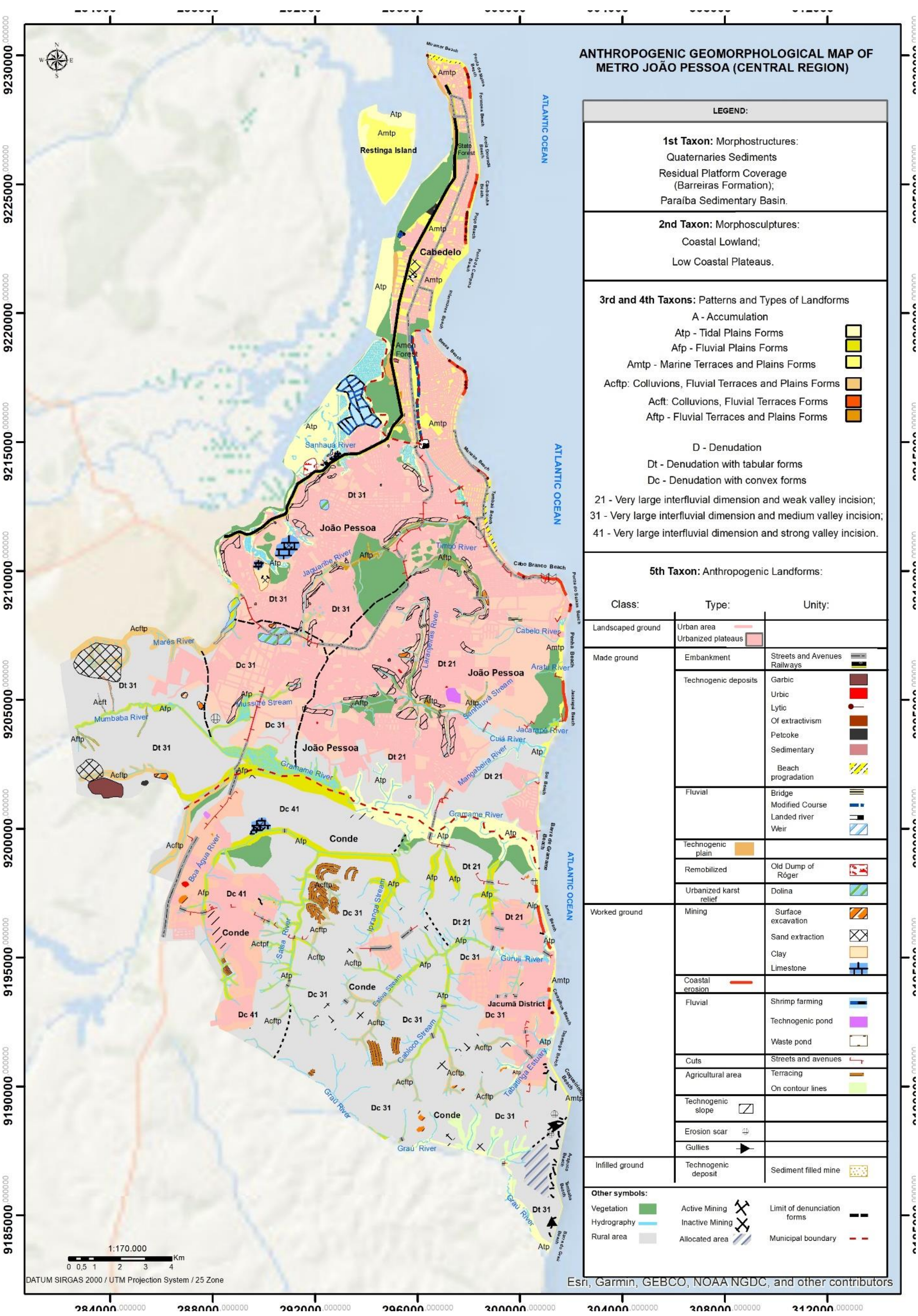

Figure 14 - Anthropogenic geomorphology map of Central Sector of João Pessoa Metropolitan Region, comprising the municipalities of João Pessoa, Cabedelo and Conde (PB), Brazil. Original map produced at 1:50,000.

4. Discussions

This work and the development of this methodology is part of a doctorate in geography already completed and defended. Both in the qualification and in the defense itself, the discussions and comments made by the panel members were fundamental for the development of this research. It should be noted that doctors in geology, physical geography and urban geography were present in this defense panel. Certainly, the main purpose of this article is to open a new methodological line on anthropogenic geomorphology and geomorphological mapping with a focus on anthropogenic landforms.

As explained in this article, Brazil is a world reference in geomorphological mapping and certainly can also be a reference in geomorphological mapping with a focus on anthropogenic landforms and geomorphological mapping applied to urban areas, given the considerable number of publications on this subject, largely cited in this article. Surely, this article and the developed methodology should be tested and applied by other researchers in other metropolitan regions with different types of landforms. Criticisms and suggestions will be very welcome, as it is clearly understood that this work is pioneering and needs greater application and validation.

It is worth noting that Ross's (1992) methodology, widely used in scientific works and articles on geomorphological mapping, lacks more careful and precise standardization. The proposal to standardize geomorphological mapping is being widely discussed by National Executive Committee of the Brazilian Relief Classification System (*Comitê Executivo Nacional do Sistema Brasileiro de Classificação do Relevo - CEN/SBCR*) and although it is a very important conceptual framework for Brazilian geomorphology, it still lacks practical application.

Another very important issue that should be further worked on and discussed is in relation to the scale adopted. There are small anthropogenic landforms and others that are very large, such as the Palm Jumeirah in Dubai or Honk Kong International Airport, which contain other anthropogenic landforms above of them. Therefore, it is necessary to think about how to map these anthropogenic landforms without compromising the graphic quality of the map. A good geomorphological map is not necessarily the one that presents the greatest amount of information, but rather the one that is most practical and readable.

Therefore, this work aims to contribute to the debate on geomorphological mapping and the importance of expanding the understanding of the mapping of anthropogenic landforms that are inserted in a larger context (mosphostructures, morphosculptures, relief patterns and relief forms) that cannot be neglected.

5. Conclusions

Despite the action of human beings on landforms is not recent, research on anthropogenic geomorphology and geomorphological mapping focusing on anthropogenic landforms remains an important topic for research and application of geomorphological knowledge. In this regard, it is necessary a robust and standardized theoretical framework, especially when it comes to urbanized areas.

As discussed in this work, the mapping of landforms, by itself, carries an inherent complexity, since processes and forms are mapped instead of concrete objects, such as vegetation, geological units, hydrography, etc. Therefore, geomorphological mapping can vary in its methodologies, representations and scales depending on the objectives of each researcher and the mapping proposal itself. These issues make standardization difficult, especially at the international level. When it comes to mapping anthropogenic landforms, this complexity deepens, as anthropogenic forms are very dynamic and complex with varied physical and temporal dimensions.

Therefore, this research sought to contribute to the construction of a comprehensive methodology strongly based on methodologies widely tested in Brazil, England, and Italy. It should be noted that this work was not based only on joining methodologies. This work made severe adaptations and proposed a methodology for geomorphological mapping of anthropogenic landforms where they are not loose in space. Anthropogenic landforms are based on a geological basement (1st taxon), on a morpho-sculptural unit (2nd taxon), on relief patterns (3rd taxon) and on relief types (4th taxon).

Although mapping anthropogenic landforms is an arduous and complex task, the final map with its integrated caption constitutes an important tool for urban, territorial, and environmental planning. The integrated legend helps understanding the map, so other professionals such as engineers and architects will be able to understand

and use this map in non-academic work. Therefore, in addition to a scientific and methodological contribution to geomorphological mapping, this work also presents a practical and applied character.

Contribuições dos Autores: Barbosa, T. S. escreveu o artigo, desenvolveu a metodologia e elaborou o mapa geomorfológico (este artigo faz parte de sua tese de doutorado). Furrier, M. Foi o orientador do doutorado, revisou o texto e traduziu para o inglês.

Financiamento: Esta pesquisa foi financiada pela Capes/Fapesq, processo no. 88887.259946/2018-00 (bolsa de doutorado)

Agradecimentos: Os autores agradecem aos dois revisores anônimos da Revista Brasileira de Geomorfologia pelas críticas e sugestões que melhoraram consideravelmente o artigo final.

Conflito de Interesse: Os autores declaram não haver conflito de interesse.

Referências

1. ARAI, M. A grande elevação Eustática do Mioceno e sua influência na origem do Grupo Barreiras. **Geologia USP Série Científica**, São Paulo, v. 6, n. 2, p. 1- 6, 2006. DOI: 10.5327/S1519-874X2006000300002.
2. BARBOSA, J. A. **Evolução da Bacia Paraíba durante o Maastrichitiano-Paleoceno – Formações Gramame e Maria Farinha, NE do Brasil**. 2004. 217f. Dissertação (Mestrado) – Centro de Tecnologia e Geociências, Universidade Federal de Pernambuco, Recife, 2004. https://repositorio.ufpe.br/handle/123456789/6564.
3. BARBOSA, M. E. F.; FURRIER, M. Caracterização geomorfológica e morfométrica para averiguação de atividade tectônica. **Mercator**, v. 14, n. 3, p. 123-149, 2015. DOI: 10.4215/RM2015.1403.0008
4. BARBOSA, M. E. F.; NOBREGA, W. R.; FURRIER, M. Geomorfologia e morfoestrutura da carta Jacumã, estado da Paraíba, Nordeste do Brasil. **Revista do Departamento de Geografia – USP**, v. 26, p. 233-251, 2013. DOI: 10.7154/RDG.2013.0026.0012
5. BARBOSA, T. S.; FURRIER, M. Methodological considerations and proposed integrated legend for anthropogenic geomorphological mapping. **Revista Brasileira de Geomorfologia**, v. 24, n. 1, e2202, 2023. DOI: 10.20502/rbg.v24i12202
6. BARBOSA, T. S.; FURRIER, M.; SOUZA, A. S. Antropogeomorfologia do município de Cabedelo - Paraíba, Brasil. **Revista de Geografia e Ordenamento do Território** (GOT), n. 13, p. 59-83, 2018. DOI: 10.17127/got/2018.13.003.
7. BARBOSA, T. S.; LIMA, V. F.; FURRIER, M. Mapeamento Geomorfológico e Geomorfologia Antropogênica do Município do Conde – Paraíba. **Revista Brasileira de Geomorfologia (Online)**, São Paulo, v. 20, n. 3, p. 525-540, 2019. DOI: 10.20502/rbg.v20i3.1571
8. BRANDOLINI, P.; FACCINI, F.; PALIAGA, G.; PIANA, P. Manmade landforms survey and mapping in an urban historical center on coastal Mediterranean environment. **Geografia Fisica e Dinamica Quaternaria**, v. 41, p. 24–34, 2018. DOI: 10.4461/GFDQ.2018.41.2
9. BRASIL. Ministério de Minas e Energia. CPRM. Geologia e recursos minerais do Estado da Paraíba. Recife: **CPRM**, 2002. 142p. il. 2 mapas. Escala 1:500.000.
10. BRASIL. Ministério do Interior. Superintendência de Desenvolvimento do Nordeste. Folhas Cabedelo, Jacumã, Conde, Nossa Senhora da Penha, Santa Rita, João Pessoa e Mata da Aldeia. Recife: **SUDENE**, Escala 1:25.000, 1974.
11. BROWN, E. H. O Homem modela a Terra. **Boletim de Geografia**, v. 30, n. 222, p. 3-18, 1971.
12. CAPPADONIA, C.; MAGGIO, C.; AGATE, M.; AGNESI, V. Geomorphology of the urban area of Palermo (Italy). **Journal of Maps**, v. 16, n. 2, p. 274-284, 2020. DOI:10.1080/17445647.2020.1739154
13. CHOLLEY, A. Morphologie Structurale et Morphologie Climatique. **Anais de Geographie**, v. 59, p. 331-335, 1950.
14. CHRISTOFOLETTI, A. **Geomorfologia**. São Paulo: Edgard Blucher, 2 ed., 1980.
15. CEN/SCBR (Comitê Executivo Nacional do Sistema Brasileiro de Classificação do Relevo). Breve estado da arte do Sistema Brasileiro de Classificação do Relevo. **Revista Brasileira de Geografia**, v. 67, n. 2, p. 212-227, 2022.
16. COOPER, A. H.; BROWN, T. J.; PRICE, S. J.; FORD, J, R.; WATERS, C. N. Humans are the most significant global geomorphological driving force of the 21st century. **The Anthropocene Review**, v. 5, n. 3, p. 222-229, 2018. DOI: 10.1177/2053019618800

17. DANTAS, M. A. C. **A comunidade do Timbó (João Pessoa – PB): análise sócioambiental e qualidade de vida.** 213 f. Dissertação (mestrado) – Universidade Federal de Pernambuco, Recife: UFPE, 2003.
18. DEL MONTE, M.; D'OREFICE, M.; LUBERTI, G. M.; MARINI, R.; PICA, A.; VERGARI, F. Geomorphological classification of urban landscapes: the case study of Rome (Italy). **Journal of Maps**, v. 12, p. 178–189, 2016. DOI: 10.1080/17445647.2016.1187977
19. FORD, J.; KESSLER, H.; COOPER, A. H.; PRICE, S. J.; HUMPAGE, A. J. An Enhanced Classification for Artificial Ground. **British Geological Survey Open Report**, v. 10, n. 36, 2010. 32p.
20. FURRIER, M.; ARAUJO, M., MENESES, L. Geomorfologia e tectônica da Formação Barreiras no estado da Paraíba. **Geologia USP – Serie Cientifica**, v. 6, n. 2, p. 61-70, 2006. DOI: 10.5327/S1519-874X2006000300008
21. FURRIER, M.; VARGAS CUERVO, G.; MONCADA, C. C. Caracterización y mapeo geomorfológico de Cartagena de Indias y adyacencias. **Boletin de Ciencias de la Tierra**, v. 41, p. 5-15, 2017. DOI: 10.15446/rbct.n41.51031
22. GOUDIE, A. **The human impact on the natural environment**. The MIT Press, Cambridge, 4 ed., 1994. 454p.
23. GOUDIE, A.; VILES, H. **Landscapes and Geomorphology**. Oxford University Press, Oxford, 2010. 137p. DOI: 10.1093/actrade/9780199565573.003.0008
24. HAIGH, M. J. **Evolution of Slopes on Artificial Landforms.** University of Chicago, Blainarch, UK. Department of Geology. 1978.
25. IBGE cidades. Disponível em: https://cidades.ibge.gov.br/ , acesso em 20 de março de 2023.
26. LUZ, R.; RODRIGUES, C. Anthropogenic changes urbanised hidromorphological systems in a humid tropical environment River Pinheiros, São Paulo, Brasil. **Zeitschrift fur Geomorphologie**. Supplementband, v. 59, 2015. DOI: 10.1127/zfg_suppl/2015/S-59207
27. MABESOONE, J. M. **Sedimentary basins of northeast Brazil**. Recife: UFPE/CT/DG. Publicação Especial n. 2, 1994. 310p.
28. MABESOONE, J. M.; ALHEIROS, M. M. Origem da bacia sedimentar costeira Pernambuco-Paraíba. **Revista Brasileira de Geociências**, v. 18, n. 4, p. 476-482, 1988.
29. MIYAZAKI, L. C. P. Depósitos tecnogênicos: uma nova perspectiva de leitura geográfica. **Quaternary and Environmental Geosciences**, n. 5, v. 2, p. 53-66, 2014. DOI: 10.5380/abequa.v5i2.33964
30. NIR, D. **Man, a geomorphological agent: an introduction to anthropic geomorphology**. Jerusalem, Ketem Pub. House, 1983.
31. OLIVEIRA, A. M. S. Antropoceno - Tecnógeno: o Brasil avança nas pesquisas (Editorial). **Quaternary and Environmental Geosciences,** v. 5, p. 1-2, 2014. DOI: 10.5380/abequa.v5i1.38012
32. PASCHOAL, L. G.; SIMON, A. L. H.; CUNHA, C. M. L. Geomorfologia antropogênica e sua inserção em pesquisas brasileiras. **Geographia Meridionalis**, v. 1, n. 1, p. 95–126, 2015. DOI: 10.15210/gm.v1i1.5691
33. PELOGGIA, A. U. G. A ação do homem enquanto ponto fundamental da geologia do Tecnógeno: proposição teórica básica e discussão acerca do caso do município de São Paulo. **Revista Brasileira de Geociências**, v. 27, n. 3, p. 257-268, 1997. DOI: 10.25249/0375-7536.1997257268
34. PELOGGIA, A. U. G. A magnitude e a frequência da ação humana representam uma ruptura na processualidade geológica na superfície terrestre? **GeoSul (UFSC),** Florianópolis, v. 14, n. 27, p. 54-60, 1998.
35. PELOGGIA, A. U. G. A cidade, as vertentes e as várzeas: a transformação do relevo pela ação do homem no município de São Paulo. **Revista do Departamento de Geografia (USP)**, São Paulo, v. 16, p. 24–31, 2005. DOI: 10.7154/RDG.2005.0016.0002
36. PELOGGIA, A.U.G. O significado arqueológico dos depósitos tecnogênico-aluviais da bacia do rio Una (Taubaté, SP). **Revista de Arqueologia Pública**, v. 9, p. 207-219, 2015. DOI: 10.20396/rap.v9i3.8641304
37. PELOGGIA, A. U. G. O que produzimos sob nossos pés? Uma revisão comparativa dos conceitos fundamentais referentes a solos e terrenos antropogênicos. **Revista UNG - Geociências**, v. 16, p. 102-127, 2017.
38. PELOGGIA, A. U. G. Geological classification and mapping of technogenic (artificial) ground: a comparative analysis. **Revista do Instituto Geológico**, v. 2, n. 39, p. 1-15, 2018. DOI: 10.5935/0100-929X.20180005
39. PELOGGIA, A. U. G.; SILVA, E. C. N.; NUNES, J. O. R. Technogenic landforms: conceptual framework and application to geomorphologic mapping of artificial ground and landscape as transformed by human geological action. **Quaternary and Environmental Geosciences**, v. 5, n. 2, p. 28-40, 2014a. DOI: 10.5380/abequa.v5i2.34811

40. PELOGGIA, A. U. G.; OLIVEIRA, A. M. S.; OLIVEIRA, A. A. SILVA, E. C. N.; NUNES, J. O. R. Technogenic geodiversity: a proposal on the classification of artificial ground. **Quaternary and Environmental Geosciences**, v. 1, n. 5, p. 28-40, 2014b. DOI: 10.5380/abequa.v5i1.34823
41. RODRIGUES, C. Morfologia original e morfologia antropogênica na definição de unidades espaciais de planejamento urbano: exemplo na metrópole paulista. **Revista do Departamento de Geografia**, v. 17, p. 101-111, 2005. DOI: 10.7154/RDG.2005.0017.0008
42. ROSS, J. L. S. O registro cartográfico dos Fatos Geomórficos e a Questão da taxonomia do Relevo. **Revista do Departamento de Geografia (USP)**, n. 6, p. 17 – 29, 1992. DOI: 10.7154/RDG.1992.0006.0002
43. ROSS, J. L. S.; GOUVEIA, I. C. M. C. A taxonomia do relevo e a cartografia geomorfológica regional. In: CARVALHO JUNIOR, O. A.; GOMES, M. C. V.; GUIMARAES, R. F.; GOMES, R. A. T. (Ed.). Revisões de Literatura da Geomorfologia Brasileira. UGB, 2022. p. 705-736. http://lsie.unb.br/ugb/livros
44. ROSS, J. L. S.; MOROZ, I. C. Mapa geomorfológico do Estado de São Paulo. São Paulo: FFLCH-USP/IPT/FAPESP, 1997. 64p. (Escala 1:500.000).
45. SANTOS, L. J. C.; FIORI, C. O.; CANALI, N. E.; FIORI, A. P.; SILVEIRA, C. T.; SILVA, J. M. F.; ROSS, J. S. Mapeamento Geomorfológico do Estado do Paraná. **Revista Brasileira de Geomorfologia**, v. 7, n. 2, p. 3–12, 2006. DOI: 10.20502/rbg.v7i2.74
46. SILVA, E. C. N.; DIAS, M. B. G.; MATHIAS, D. T. A abordagem tecnogênica: reflexões teóricas e estudos de caso. **Quaternary and Environmental Geosciences**, v. 5, n. 1, p. 1-11, 2014. DOI: 10.5380/abequa.v5i1.34521
47. 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. DOI: 10.20502/rbg.v20i1.1391
48. VITA-FINZI, C. Physiographic effects of Man. In: **The New Encyclopaedia Brittanica**, Macropaedia, v. 15, n. 20, p. 22-26, 1993.
49. WORLD BANK. **Environmental Assessment Sourcebook –** Sectoral Guidelines. Washington, D. C. 1998.