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

Revista Brasileira de Geomorfologia

v. 24, nº 3 (2023)

http://dx.doi.org/10.20502/rbg.v24i3.2377

Artigo de Revisão

Detailed and Semi-detailed Geomorphological Maps: A review of relief representation in thesis by the São Paulo state's geography postgraduate programs by the beginning of the 21st century (2001-2018)

Mapas Geomorfológicos Detalhados e Semi-detalhados: uma revisão da representação do relevo em teses de programas de pós-graduação em Geografia do estado de São Paulo no início do século XXI (2001-2018)

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Recebido: 10/03/2023; Aceito: 14/07/2023; Publicado: 04/09/2023

Abstract: This study investigates the semi-detailed and detailed geomorphological mapping produced by researchers in the State of São Paulo in the beginning of the 21st century, considering its diversity of methods and symbology. 22 academic productions were analyzed. Criteria for selection were: year of publication, scale, possibility of downloadability, legibility and description of procedures. Scales ranged from 1:60.000 to 1:5.000. Different objectives were verified and grouped into 4 main categories: 1) Urban and/or Environmental Planning; 2) (Geo) Enviromental Zoning; 3) Environmental Vulnerability or Fragility; and 4) Geomorphological and/or Enviromental Analysis. References most cited were Tricart (1965), Verstappen & Zuidam (1975) and Ab'Saber (1969). Most research employed adaptations from two or more references. Most publications belonged to IGCE-UNESP program. We concluded that diversity of legends is mainly related to 8 factors corroborating the literature: 1) three-dimensionality of the terrain and bi-dimensionality of the map; 2) great number of the nature of represented attributes; 3) representation of both qualitative and quantitative data; 4) employment of three types of plotting information; 5) contradictions between legibility and academic interests; 6) time-space scales; 7) different types of landscapes; and 8) different objectives of research.

Keywords: Geomorphological Mapping; Relief Classification; São Paulo, Brazil.

Resumo: Este estudo investiga o mapeamento geomorfológico semi-detalhado e detalhado produzido por pesquisadores do Estado de São Paulo no início do século XXI, considerando sua diversidade de métodos e simbologias. Foram analisadas 22 produções acadêmicas. Os critérios de seleção foram: ano de publicação, escala, possibilidade de download, legibilidade e descrição dos procedimentos. As escalas variaram de 1:60.000 a 1:5.000. Diferentes objetivos foram verificados e agrupados em 4 categorias principais: 1) Planejamento Urbano e/ou Ambiental; 2) Zoneamento (Geo) Ambiental; 3) Vulnerabilidade ou Fragilidade Ambiental; e 4) Análise Geomorfológica e/ou Ambiental. As referências mais citadas foram Tricart (1965), Verstappen & Zuidam (1975) e Ab'Saber (1969). A maioria das pesquisas empregou adaptações de duas ou mais referências. A maioria das publicações pertencia ao programa IGCE-UNESP. Concluímos que a diversidade de legendas está relacionada principalmente a 8 fatores que corroboram a literatura: 1) tridimensionalidade do terreno e bidimensionalidade do mapa; 2) grande número da natureza dos atributos representados; 3) representação de dados qualitativos e quantitativos; 4) emprego de três tipos de informações de plotagem; 5) contradições entre legibilidade e interesses acadêmicos; 6) escalas espaço-temporais; 7) diferentes tipos de paisagens; e 8) diferentes objetivos de pesquisa.

Palavras-chave: Mapeamento Geomorfológico; Classificação do Relevo; São Paulo, Brasil

1. Introduction

Geomorphological maps are means of graphic and spatial representation used as instruments of analysis and synthesis of geomorphological phenomena (FLORENZANO, 2011) as they provide descriptive information about the terrain, identify its geomorphological nature, and date their forms (ROSS, 2007). Because of the representation of both qualitative and quantitative data, the employment of the three modes of information plotting (punctual, linear, and zonal) in the same map, and the difficulties of representing a three-dimensional object (relief) in a bi-dimensional document, Geomorphological maps are considered complex thematic maps (CUNHA, 2011).

Regarding the strategies for elaborating these maps, many methodologies have been developed and proposed throughout time in different countries (VERSTAPPEN, 2011). At least since 1960, efforts to elaborate a unified methodology and legends for geomorphological maps were made. However, a unified international and a national (in Brazil's case) pattern of geomorphological mapping was still nonexistent by the beginning of the 21st century (FLORENZANO, 2011; ARGENTO, 2009).

According to Marques Neto and Ferraro (2018), the lack of consensus and methodological standardization for geomorphological mapping among Brazilian geomorphologists has been the subject of long debates, and the difficulties of integrating morphological, morphogenetic, morphometric, morphodynamical, morpho-structural, and morpho-chronological data are well-known by researchers.

More recent reviews carried out by Botelho & Pelech (2019), IBGE (2020), and Marques Neto (2020), have shown interesting results on geomorphological maps elaborated in recent decades. According to IBGE (2020) and Botelho & Pelech (2019), in most articles, original methodologies were elaborated for mapping terrain, and a great part of the studies included adaptations of methodologies from IBGE/RADAMBRASIL (NUNES et al., 1995; IBGE, 2009) and Ross (1992).

On the other hand, a review carried out by Marques Neto (2020) considers the significant influence of Ross (1992) and RADAMBRASIL Project (NUNES et al., 1995; IBGE, 2009) methodologies in most maps, despite few direct quotes of them. Regarding non-Brazilian methodologies, the author (2020) recognizes the greater influence of French (TRICART, 1965) and Dutch (VERSTAPPEN; ZUIDAM, 1975) methodologies in geomorphological cartography in Brazil.

Verstappen (2011) considers that, except for the elaboration of map series at the national or international level, it is appropriate to apply general concepts with certain flexibility so that the mapping process is adequate for research purposes and specific characteristics of the mapped area. However, in this discussion, a few emerging questions still need to be better explored, such as: How do those adaptations differ from each other? Why choose one procedure over another? What are the factors influencing those decisions?

To approach an answer to these questions, this research has the objective of analyzing the cartographic representation and the theoretical-methodological frameworks adopted by master and doctorate theses elaborated within four of the São Paulo state postgraduate programs of Geography. Maps selected were limited to Detailed and Semi-Detailed scales (Detailed understood as those more detailed than 1:50.000 and Semi-Detailed as those more detailed than 1:100.000 scale, but less detailed or equal to 1:50.000, according to IBGE (2009) criteria) and to those published in the first two decades of the 21st century, as they are usually made in the context of elaborating and/or adapting methodologies when compared to regional or national scales.

Although these publications do not represent the whole national production, an approach of these geomorphological maps might not only indicate some tendencies and collaborate to debate new methodological proposals, but also help understand adaptations or new proposals and factors affecting the geomorphological mapping decisions on procedures, technologies, and techniques employed as well.

The hypotheses defended in this paper are that differences in geomorphological maps legends and methodology and their respective adaptations adopted in research might be mainly influenced by the following variables: theoretical-methodological frameworks of researchers and their supervisors, purposes of the research, available data and equipment, scale, and specific characteristics of the mapped landscape.

2. The complexity of Geomorphological Mapping: a brief overview

In resolutions adopted by the Sub-commission on Geomorphological Mapping in the 1960s decade, detailed geomorphological maps had the purpose of providing a complete representation of terrain, considering its characteristics, evolutionary history, and future development, informing distribution and relation between relief forms and their dimensions, appearance, origin and known ages, and including the Morphographic, Morphometric, Morphogenetic, and Morpho-chronological data (KLIMASZEWSKI; TRICART, 1964).

As mentioned, the principles and methods of cartographic representation of these elements are not a consensus among geomorphologists. A few important examples might be mentioned. In Tricart's (1965) methodology, for example, there are three principles for elaborating the geomorphological map: 1) the background of the geomorphological map should present topography, photo-plane, or a mosaic of aerial photographs; 2) structural data that influence geomorphology should be represented; and 3) process-forms and age should be combined, with chronology being represented by colors and forms by drawn symbols. It is also worth mentioning that this methodology, according to Pinheiro & Ferreira (2020), had a great influence on Brazilian geomorphological maps production in the 1970s decade.

In ITC's methodology, published by Verstappen and Zuidam (1975), on the other hand, relief units are delineated, and smaller forms are plotted along with a geomorphological development analysis, including past and current environmental conditions that influence these forms. Then, morphometric and morpho-graphic information must be complemented by the genesis and age of forms and lithology because they influence processes and forms developed (VERSTAPPEN; ZUIDAM, 1975).

A national example of methodology is presented by IBGE (2009). In this methodology, geomorphological data are divided into four taxa, which are: 1) Morpho-structural Domains; 2) Geomorphological Regions; 3) Geomorphological Unities; and 4) Types of Morphology. As stated by Marques Neto (2020), in IBGE's methodology, Morpho-structural domains are represented by basic colors, Geomorphological Regions are grouped by color families, Geomorphological unities are represented by the same color, with differentiation of hachure tones, and Types of Morphology are represented by letter-symbols, that indicate the type and their specific characteristics, and, for the dissection types of morphology, a combination of alphanumeric symbols are employed. These alphanumeric symbols indicate the form of the tops and the dissection index, which is defined by the Matrix of Relief Dissection Index, which includes the drainage density (first digit) and the depth of incisions (second digit) (IBGE, 2009).

There are quite a few problems with representing geomorphological elements in geomorphological maps. Gustavsson et al. (2006) consider that these maps might present two problems: emphasizing some specific attributes, regardless of others, or having too extensive legends, reducing their legibility. About legibility issues, Griffiths and Abraham (2008) state that these documents, when applied to different fields, such as environmental and urban planning, present difficulties to be well-read and interpreted by other professionals beyond geomorphologists. For this reason, the authors (2008) defended the elaboration of simplified and more legible maps for that purpose. In the discussion of this topic, Paron and Claessens (2011) mention a few of the main end users of geomorphological maps (i.e., agronomists, archeologists, pedologists, ecologists, environmentalists, etc.) and the fact of a considerable distance between map makers and their end users.

Cartographic and Geographic scales are related to the complexity of the geomorphological mapping procedures and representation as well. For Tricart (1965) maps of small scale are oriented to morpho-structural phenomena and maps of big scale are oriented to morphogenetic processes and their resultant forms, along with a more rigorous chronologic classification. This proposal also states these classifications correspond to a specific order of spatial-temporal magnitude of geomorphological facts, proposed by Tricart and Cailleux (1956) and Tricart (1965).

Radambrasil and IBGE's (BARBOSA et al., 1984; Nunes et al., 1995; IBGE, 2009) and Ross' methodologies both are based on taxonomic approaches to spatial-temporal scales of relief and, for IBGE (2009), cartographic scales are divided into three main categories: 1) Wall Maps (scales less detailed than 1:1.000.000); 2) Basic Maps, that are subdivided into Regional Maps (scales less detailed or equal to 1:250.000 and more detailed than 1:1.000.000), Reconnaissance Maps (scales less detailed than 1:100.000 and more detailed than 1:250.000) and Semi Detailed

Maps (scale less detailed than 1:50.000 and more detailed than 1:100.000); and 3) Detailed Maps, which are more detailed than 1:50.000.

Another proposal for map scale is presented in ITC's methodology (VERSTAPPEN; ZUIDAM, 1975), which divides maps into two main categories: 1) Large and Medium Scale Maps and 2) Small Scale Maps. The authors argue that these scales influence cartographic generalization, extrapolation, and field checking of information, as more detailed maps, have their information completely checked on field research and as less generalization as possible.

In a revision carried out by Verstappen (2011), the author classified geomorphological maps into four categories according to the use of colored areas to represent: 1. Morphogenesis - as proposed by Klimaszewski (1956), in Poland, and by Joly, in France; 2. Chronological sequences of relief form development, as proposed by Gellert & Scholz (1960), in old East Germany; 3. Lithology, as proposed by Tricart (1955, 1969, 1972), and also applied by the Center for Applied Geomorphology, in France; 4. Types of relief according to its Morphogenesis, as proposed by Pesci et al. (1962) and Pesci (1964) in Hungary.

3. Methods

The population of the study included thesis and dissertations produced in four of the Postgraduate Programs in Geography within public universities in the state of São Paulo, Brazil. Criteria for selection of those studies were: 1) being published between the years of 2001 and 2018; 2) having elaborated a detailed or semi-detailed geomorphological map; 3) both the thesis or dissertation and their respective geomorphological map should be available and downloadable in the repository or digital library of thesis and dissertations of their respective universities; 4) geomorphological map should have a good resolution so it could be readable; 5) Methodological procedures for geomorphological mapping should be described in the Method section.

The state of São Paulo was chosen for three main reasons: 1) it concentrates four of the main (Physical) Geography Postgraduate programs; 2) data has shown a concentration of publications on geomorphological mapping by the group of researchers at the IGCE-UNESP Program (MARQUES NETO, 2020); 3) the production from this state has a great influence upon national publications. However, it is important to mention that, in recent years, researchers from other states have greatly contributed to geomorphological mappings, such as Minas Gerais, Espírito Santo, Rio de Janeiro, Bahia, Paraná, Rio Grande do Norte (MARQUES NETO, 2020), etc.

To acquire the necessary information, Sucupira online Platform was accessed. In this Platform, the Geography Postgraduate programs in the state of São Paulo that were both currently functioning and contemplated Physical Geography lines of research were consulted. Then, supervisors of those programs had their names and Lattes public curriculum checked. Professors that have supervised theses or dissertations that corresponded to our mentioned criteria were selected.

Among the results, at least four thesis and dissertations of each supervisor were selected, and one article and one supervisor's thesis were included to complement legend and methodology comprehension. Thus, the number of analyzed publications was 7 for IGCE-UNESP Geography Postgraduate Program, 6 for FCT-UNESP Geography Postgraduate Program (including the article and the thesis added), 4 for USP Physical Geography Postgraduate Program, and 5 for UNICAMP Geography Postgraduate Program.

First, information was collected, and transcript information of each publication referring to Author's name; Supervisor; Postgraduate Program; Year of Publication; Mapped area; Mapping scale; Objectives of Research; Main bibliographical references for geomorphological mapping; Sources of data and software used.

Then, summaries and notes were elaborated. Objectives and method sections were emphasized, concerning issues like What are the purposes for geomorphological mapping in this research? What are the sources of data? What publications were used as references for methodology and legend elaboration? Does it adopt any pre-existent methodology? Which of them?

After that, Geomorphological Maps were analyzed, having the Graphic Semiology cartography's paradigm (BERTIN, 2010) as a reference. Concepts of graphic plotting (point, line, and area) and visual variables (size, value, texture, color, orientation, and shape) were used to classify symbols. It is also worth mentioning that a few of the analyzed maps have also used a combination of alphanumeric digits for representing genesis and relief dissection indexes and tables for indicating both organizing legends through taxonomic levels and including additional environmental information.

4. Results

There were 23 analyzed publications, one article, twelve master dissertations, and ten doctorate theses. Among these publications, 6 of them belonged to the FCT-UNESP Geography Postgraduate Program, 8 to the IGCE-UNESP Geography Postgraduate Program, 5 to UNICAMP Geography Postgraduate Program, and 4 to USP Physical Geography Postgraduate Program (Figure 1).

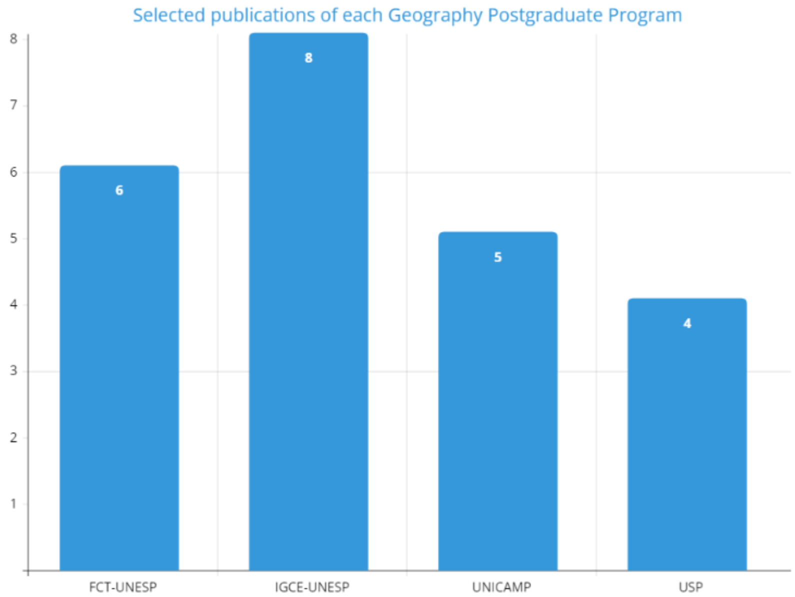


Figure 1. The number of publications selected from each Geography Postgraduate Program. Elaborated by the authors (2022).

Geomorphological maps had different scales: 1:60.000, 1:50.000, 1:40.000, 1:30.000, 1:25.000, 1:20.000, 1:10.000 and 1:5.000 (Figure 2). The distribution of these scales can be seen in the chart in Figure 2. The scale of 1:50.000 was predominant in analyzed maps, having 1 of them belonging to the FCT-UNESP Program, 4 to the IGCE-UNESP Program, 4 to the UNICAMP Program, and 1 to the USP Program. These 10 maps along with one 1:60.000 scale map are the semi-detailed maps of the sample, and the other 12 maps are the detailed maps of the sample (Figure 2).

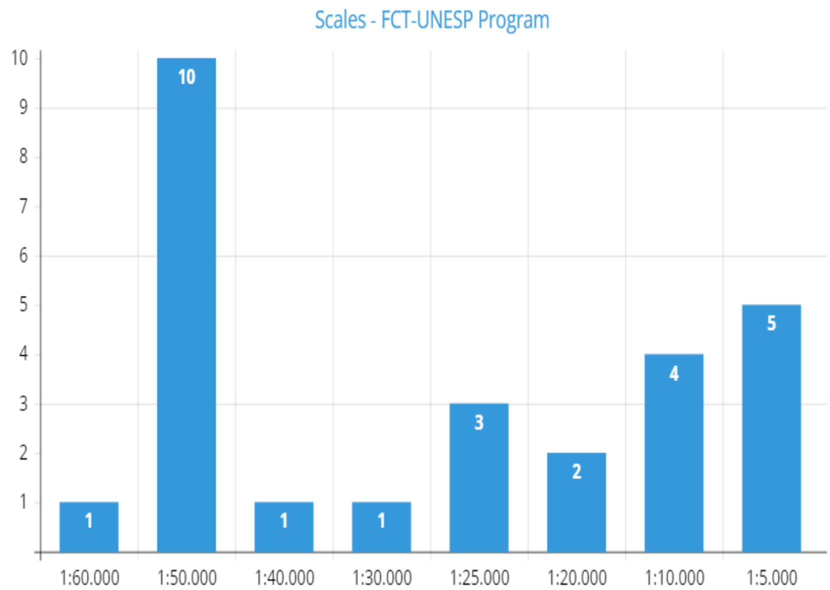


Figure 2. The number of Geomorphological Maps selected according to their cartographical scale. Elaborated by the authors (2022).

Notions of taxonomy, order of magnitude, and/or levels of approaching were harder to identify because these notions were not explicitly mentioned in the research, except for those referencing taxonomy defined by Ross (1985, 1992) and levels of approaching defined by Ab'Sáber (1969b). Visual interpretation of aerial photographs and high-resolution satellite images using stereoscopy was one of the most used procedures for interpreting and mapping terrain, especially for morpho-graphic elements.

The general objectives of the publications are worth mentioning: establishing criteria and procedures to choose areas for constructing landfill; comprehending landscape morpho-dynamics and elaborating environmental vulnerability maps to gully erosions; analyzing relief to contribute to environmental planning; supporting urban environmental planning and management; analyzing changes imposed by land use on environmental systems; estimating natural potential to erosion and soil loss; environmental and GeoEnvironmental zoning; proposing guidelines for urban planning; analyzing geomorphological dynamics in a coastal area; GeoEnvironmental delimitation and characterization; geomorphological study; comprehension of models of environmental fragility in relief-soil relations; analyzing environmental impacts; correlating environmental fragility and social vulnerability, and analyzing active geomorphological processes and the relief-rock-soil relation.

These objectives can be grouped into four main categories: 1) Urban and/or Environmental Planning; 2) (Geo) Environmental Zoning; 3) Environmental Vulnerability or Fragility; and 4) Geomorphological and/or Environmental Analysis. These categories are not necessarily mutually exclusive and might be correlated. However, they might indicate the main purpose of the research. Although "Planning" could be seen as a common and general purpose for most of the analyzed documents, in this category, were included only the research which explicitly mentioned it and couldn't fit into the other three categories.

The distribution of the frequency and their respective main methodological references can be seen in the graph of Figure 3. As we can see, Tricart (1965) has been the most cited reference among analyzed dissertations and theses. However, it is important to state that there are adaptations that are associated with other references, the most frequently mentioned references are Verstappen & Zuidam (1975) and Ab'Saber (1969a).

Documents that included adaptations associating Tricart (1965) to Verstappen & Zuidam (1975) belong to the categories of Environmental and/or Geomorphological Analysis and (Geo) Environmental Zoning. Associations between Tricart (1965) and Verstappen & Zuidam (1975) are part of the documents that had the objectives from the categories of Urban and/or Environmental Planning and Environmental Vulnerability or Fragility.

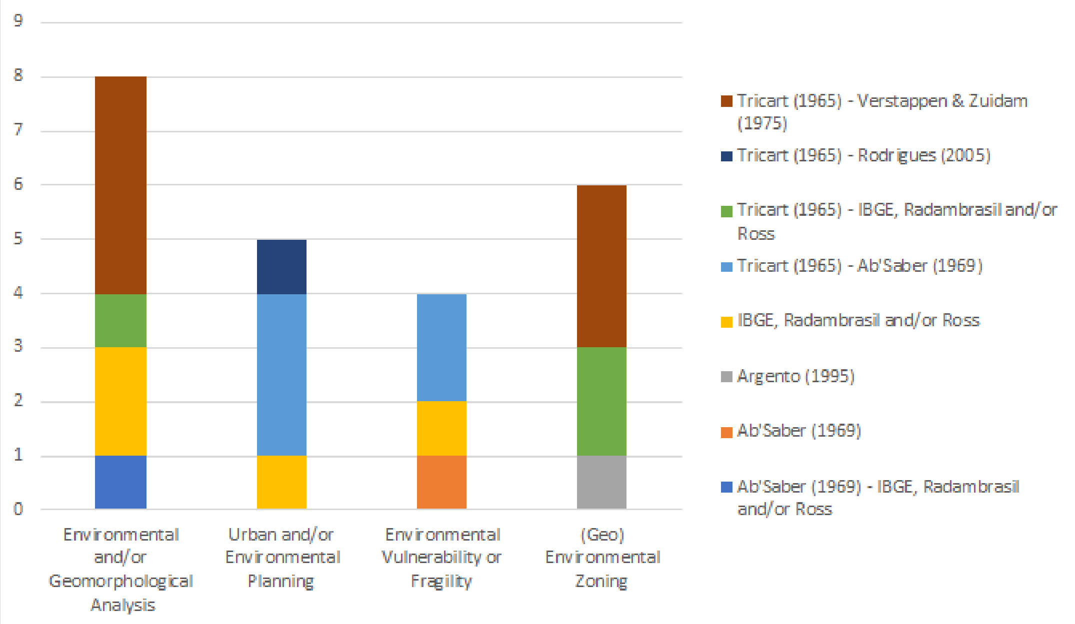


Figure 3. The number of productions from each category of objectives and main references employed. Elaborated by the authors (2023).

About the FCT-UNESP publications, detailed maps (1:25.000 and 1:20.000) were predominant. Even though methodological references were diverse, two main influences are verified: Tricart (1965) and Ab'Saber (1969b). Legends of the maps were mostly based on original legends elaborated by Nunes (2002) and Nunes et al. (2006).

This symbology emphasizes relief compartments (influenced by Ab'Sáber, 1969b), using colored areas to represent them, and geomorphological features, represented by linear and punctual symbols. As seen in Figure 4, relief compartments represented are undulating and convex hilltops, slope domains, and alluvial plains, and the forms of slopes are differentiated by the shape of linear symbols. It is also important to state that, except for the map elaborated by Silva (2012), all the geomorphological maps analyzed in this program represented the Western Highland of São Paulo state, which is characterized by wide and medium hills (PONÇANO et al., 1981).

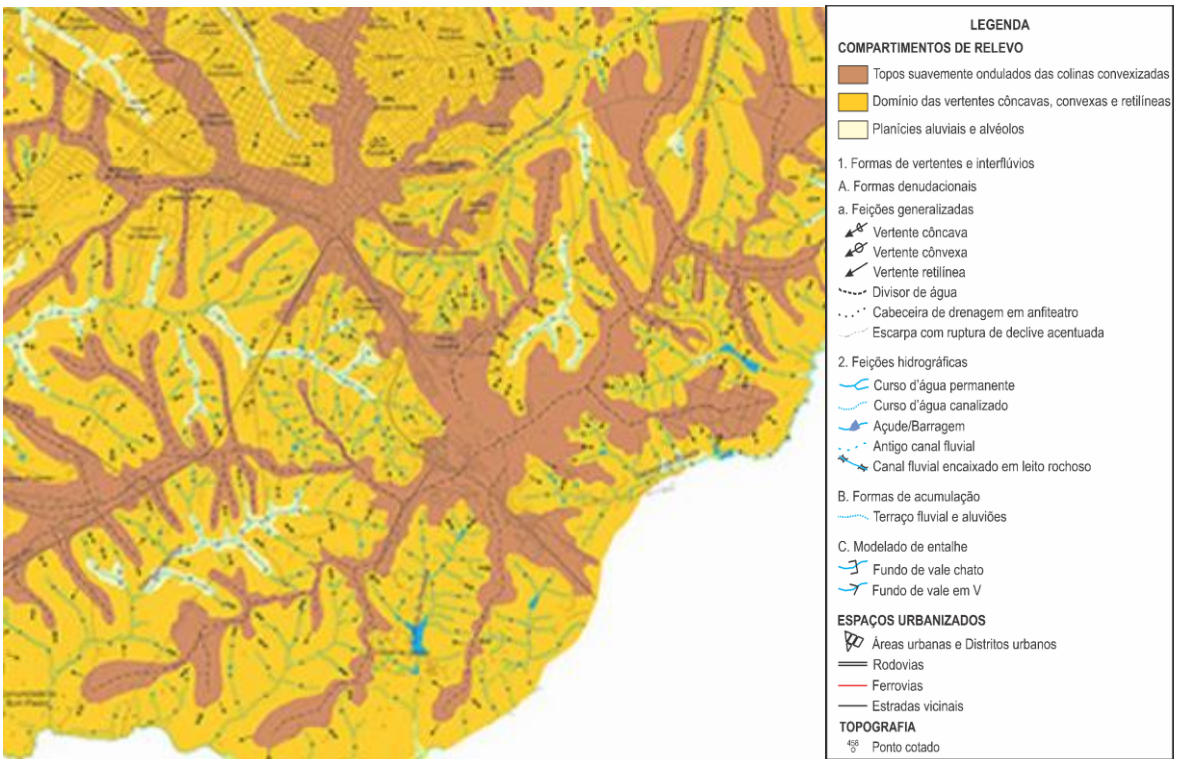


Figure 4. (a) Fragment extracted from Geomorphological Map of Presidente Prudente, 1:25.000, (b) Legend extracted from Geomorphological Map of Presidente Prudente. Source: FUSHIMI (2012).

Concerning the IGCE-UNESP program's publications, half of the maps were semi-detailed (1:50.000). Detailed maps included scales of 1:40.000, 1:30.000, 1:10.000, and 1:5.000 (Figure 5). Most methods were based on Tricart (1965) but also included adaptations based on Verstappen & Zuidam (1975). However, even though there were different symbology, it was verified that colored areas mostly corresponded to lithology, and linear and punctual symbols generally corresponded to relief features, which allows seeing Tricart's (1965) influence. Differences between maps may occur because of differences in scales, objectives, and mapped areas, as both littoral and continental areas, were studied in these publications.

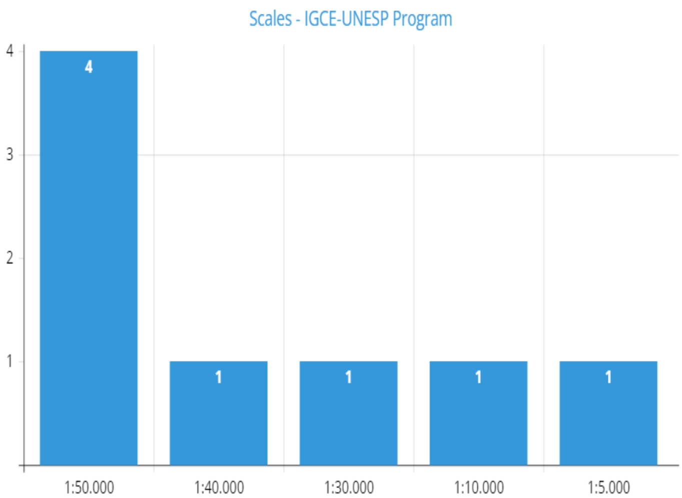


Figure 5. The number of Geomorphological Maps selected according to their cartographical scale in the IGCE-UNESP

Program. Elaborated by the authors (2022)

In the UNICAMP program, most publications had a semi-detailed map (1:50.000) and one had a detailed map (1:10.000) (Figure 6). Concerning methodological references, there were few differences between each publication. Tricart (1965) was the most mentioned reference, but others were included, such as IBGE (2006), IBGE (2009), BARBOSA et al. (1984), Ross & Moroz (1996), and Argento (1995). Just as in the IGCE-UNESP program, differences in symbology might be related to differences between littoral and continent geomorphological mapping, and objectives and scale as well.

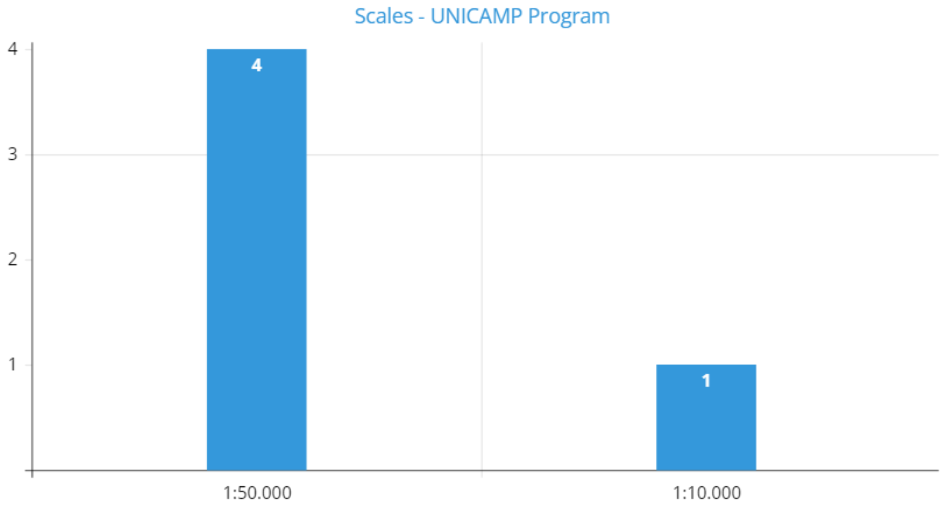


Figure 6. The number of Geomorphological Maps selected according to their cartographical scale in the UNICAMP Program. Elaborated by the authors (2022).

About the USP program, most analyzed publications had detailed maps (1:10.000 and 1:20.000) and one had a semi-detailed map (Figure 7). The great influence of Ross (1992) was verified, especially using an integrated legend, which is organized into a table, presenting the taxonomic organization and including textual information of each taxon and complementary information, such as pedological, morphometric, and geological data, for example.

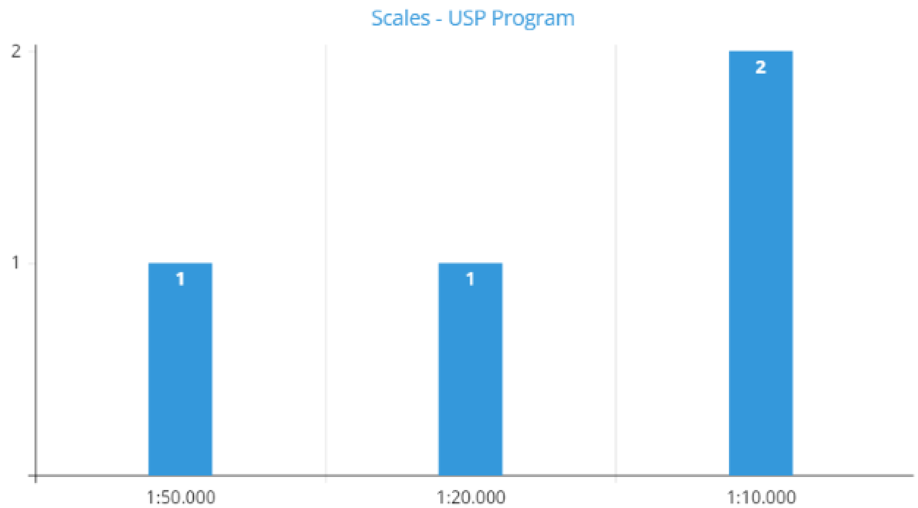


Figure 7. The number of Geomorphological Maps selected according to their cartographical scale in the USP Program. Elaborated by the authors (2022).

Inspired by Verstappen's (2011) proposal on categorizing geomorphological maps by the use of colored areas, it was possible to categorize analyzed maps in this research according to 1. Relief Compartments; 2. Lithology; 3.

Forms of Relief associated with Morphogenesis and Morphometry; and 4. Lithology and Forms of Relief overlapping, in which one of them is colored and the other one is hachured.

The use of colored areas to represent Relief Compartments was used in most of the FCT-UNESP program publications, as discussed above, but also in the UNICAMP program, having different symbologies when compared to each other. In the Geomorphological Maps elaborated by Souza (2014), for example, three different scenarios were represented (1962, 1981, 2011-2012). Relief compartments were divided into four types of accumulation forms, classified according to their genesis. The differences between these maps and those from FCT-UNESP might be explained by its objectives, which were analyzing changes in geomorphological dynamics, by their references, and especially by differences between the continental and the coastal environments.

The usage of colored areas to identify Lithology was mostly present in geomorphological maps by the IGCE-UNESP Program. A few differences in their symbology were verified, such as the usage of hachures indicating rock's resistance to weathering, the nature of sedimentary deposits and anthropic forms (SIMON, 2007), adding colored areas to indicate accumulating forms and their morphogenesis (PINHEIRO, 2008; SOUZA, 2010; PASCHOAL, 2014) (Figure 8).

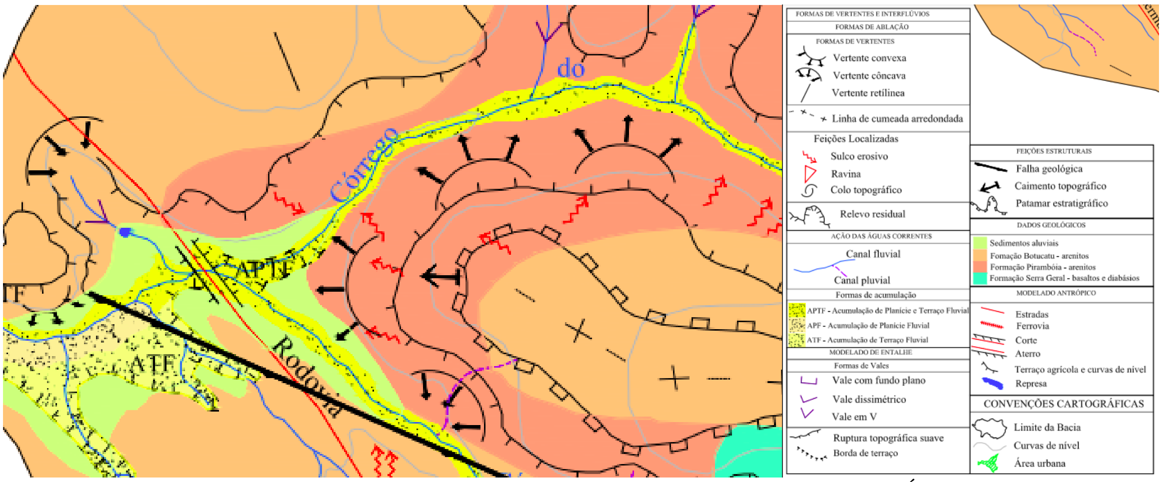
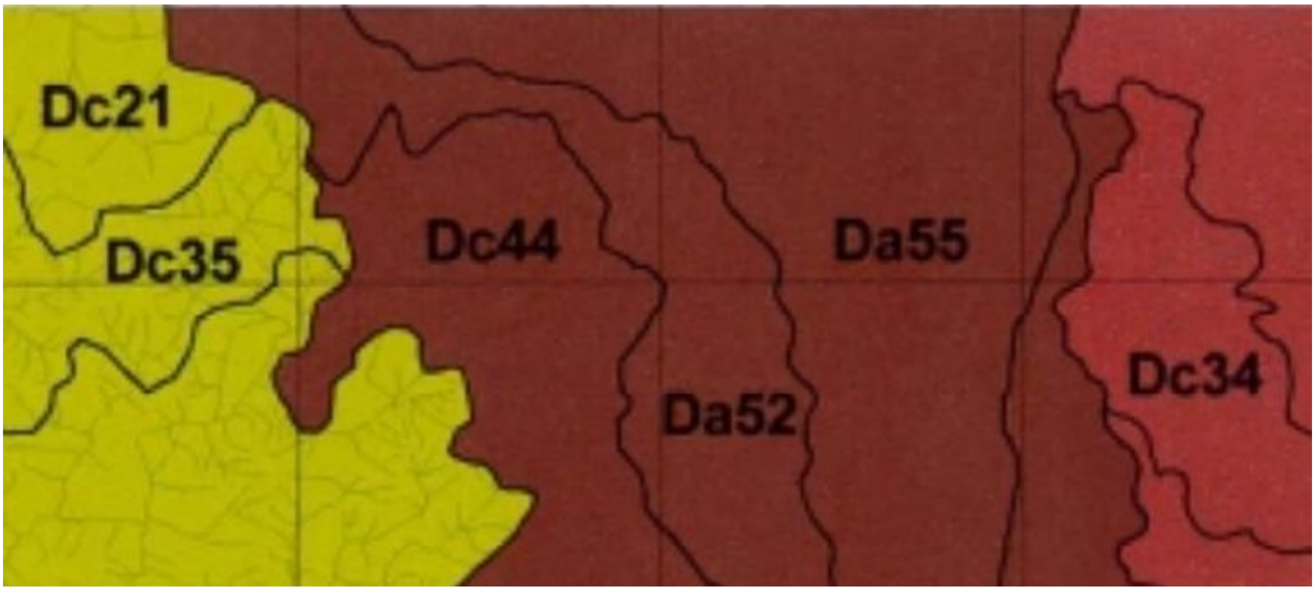


Figure 8. (a) Fragment extracted from Geomorphological Map of Basin of Córrego da Água Branca, 1:30.000, (b) Legend extracted from Geomorphological Map of Basin of Córrego da Água Branca. Source: PINHEIRO (2008).

Representation of terrain forms associated with Morphogenesis and Morphometry using colored areas with alphanumeric digits was present in two of the maps elaborated by the USP Program and in one of the maps elaborated by the FCT-UNESP Program. There have been at least two ways of doing so. One of them, used by Spörl (2001) (Figure 9) and by Silva (2012), was based upon the dissection index, which was first developed and proposed by Radambrasil Project (NUNES et al., 1995; IBGE, 2009) and by Ross (1992) and was related to the fourth taxon of Ross (1992) taxonomic proposal, that corresponds to patterns of forms. The other one, used by Gayoso (2014) (Figure 10), was related to the fifth taxon and referred to different levels of inclination of slopes, convex plateaus, and convex hilltops.



MORFO-ESTRUTURA		MORFO-ESCULTURA	MORFOLOGIA – MODELADO	MORFOMETRIA – ALT. (m)	MORFOMETRIA – DECLIV.	LITOLOGIA	SOLOS
1- ESTRUTURA CIRCULAR INTRUSIVA DE POÇOS DE CALDAS		1.1.Pl. de Poços de Caldas 1.1.1.	-Dc31 - Colinas amplas de topos convexos e vales profundos	1250 a 1450	3 a 12% >12%	Fonolitos, traquitos e tinguaitos	Cambissolo álico-textura argilosa, argila de atividade baixa
		1.1.2.	-Dc34 - Colinas de topos convexos e vales profundos	1250 a 1550	6 a 20% >20%	Fonolitos, traquitos e tinguaitos	Cambissolo álico-textura argilosa, argila de atividade baixa
		1.2. Serras da Borda do Maciço Intrusivo de Poços de Caldas 1.2.1. Serra do Monte Belo	-Da54 - Morros com topos aguçados com vales muito entalhados e com vertentes com altas declividades	950 a 1450	20 a 50% >50%	Tufos e rochas piroclásticas, fenitos, sienitos e pulaskitos	Associação de terra bruna estruturada eutrófica- muito argilosa com material litólico (pedregoso)
		1.2.2. Serra do Marinho	-Da55 - Morros com topos aguçados com vales de entalhamento médio	850 a 1600	12 a 30% >30%	Tufos e rochas piroclásticas, fenitos, sienitos e pulaskitos	Associação de terra bruna estruturada eutrófica- muito argilosa com material litólico (pedregoso)
		1.2.3. Serra do Chapadão	-Da55 - Morros com topos convexos com vales de entalhamento médio e com vertentes com altas declividades	950 a 1350	20 a 50%	Tufos e rochas piroclásticas, fenitos, sienitos e pulaskitos	Associação de terra bruna estruturada eutrófica- muito argilosa com material litólico (pedregoso)
		1.2.4. Serra do Gavião	-Da52 - Morros de topos aguçados com vales fortemente entalhados e com vertentes com altas declividades	950 a 1620	20 a 50% >50%	Tufos e rochas piroclásticas, fenitos, sienitos e pulaskitos	Associação de terra bruna estruturada eutrófica- muito argilosa com material litólico (pedregoso)
		1.2.5. Serra do Mirante/ do Deus-Me-Livre/ da Fartura	-Da33 - Morros com topos aguçados com vales de entalhamento médio e com vertentes com altas declividades	850 a 1250	20 a 50%	Tufos e rochas piroclásticas, fenitos, sienitos e pulaskitos	Associação de terra bruna estruturada eutrófica- muito argilosa com material litólico (pedregoso)
		1.2.6. Serra Paulista	-Da52 - Morros com topos aguçados com vales de entalhamento médio	850 a 1600	12 a 30% >30%	Tufos e rochas piroclásticas, fenitos, sienitos e pulaskitos	Associação de terra bruna estruturada eutrófica- muito argilosa com material litólico (pedregoso)
		1.2.7. Serra do Rio Claro	-Dc44 - Morros com topos convexos com vales de entalhamento médio	750 a 1450	12 a 30% >30%	Tufos e rochas piroclásticas, fenitos, sienitos e pulaskitos	Associação de terra bruna estruturada eutrófica- muito argilosa com material litólico (pedregoso)
2. FAIXA DE DOBRAMENTOS DO CINTURÃO OROGÊNICO DO ATLÂNTICO		2.1. Planalto de São João da Boa Vista e Águas da Prata 2.1.1.	-Dc21 - Colinas amplas de topos convexos, vales pouco entalhados e vertentes com baixas declividades	850 a 950	6 a 12%	Rochas gnaisses, gnaisses migmatizados, gnaisses facoidais, lentes de metabásicas	Podzólico vermelho amarelo distrófico-textura médio-argiloso à muito argiloso
		2.1.2.	-Dc35 - Colinas baixas com topos convexos, vales pouco entalhados e vertentes com pouca declividade	680 a 950	12 a 30% >30%	Rochas gnaisses, gnaisses migmatizados, gnaisses facoidais, lentes de metabásicas	Podzólico vermelho amarelo distrófico-textura médio-argiloso à muito argiloso
		2.1.3.	-Dc23 - Colinas baixas com topos convexos, vales pouco entalhados e vertentes com pouca declividade	680 a 950	3 a 12% >12%	Rochas gnaisses, gnaisses migmatizados, gnaisses facoidais, lentes de metabásicas	Podzólico vermelho amarelo distrófico-textura médio-argiloso à muito argiloso
		2.1.4.	-Dc44 - Morros com topos convexos, com vales de entalhamento médio e vertentes com altas declividades	950 a 1350	6 a 20% >20%	Rochas gnaisses, gnaisses migmatizados, gnaisses facoidais, lentes de metabásicas	Podzólico vermelho amarelo distrófico-textura médio-argiloso à muito argiloso

Figure 9. (a) Fragment extracted from Geomorphological Map of Altas Bacias do Rio Jaguari-Mirim, Ribeirão do Quartel and Ribeirão da Prata, 1:50.000, (b) Legend extracted from Altas Bacias do Rio Jaguari-Mirim, Ribeirão do Quartel and Ribeirão da Prata. Source: SPÖRL (2001).

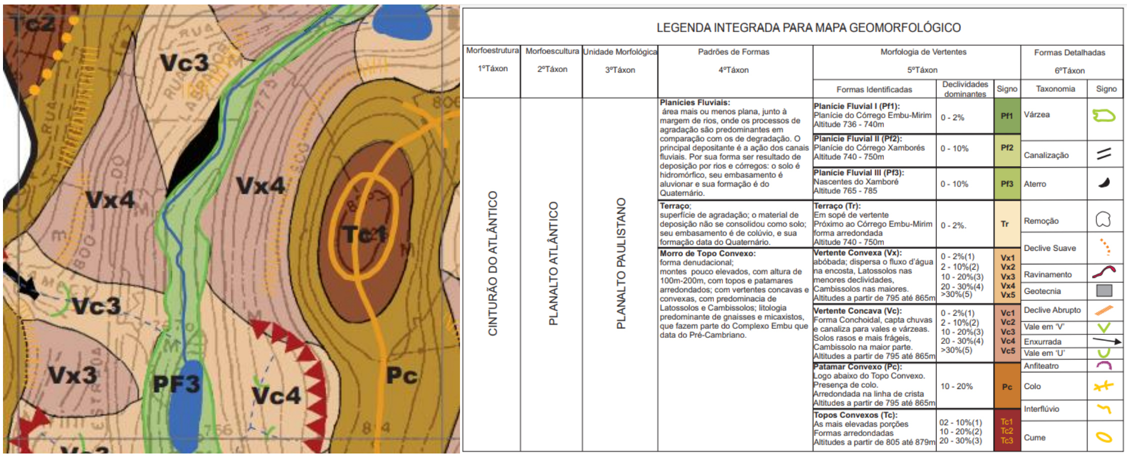


Figure 10. (a) Fragment extracted from Geomorphological Map of Basin in Jardim Ângela (São Paulo, SP), 1:10.000, (b) Legend extracted from Geomorphological Map of Basin in Jardim Ângela (São Paulo, SP). Source: Gayoso (2014).

5. Discussion

Throughout this research, it was verified that different factors might have influenced diversity among detailed and semi-detailed geomorphological maps. In the bibliographical review, it was possible to state seven main factors: 1. Three-dimensional nature of terrain and bi-dimensionality of the map (CUNHA, 2011); 2. The great number of attributes of different natures represented (GUSTAVSSON, 2006; NETO; FERRARO, 2006); 3. Cartographic representation of both qualitative and quantitative data (CUNHA, 2011); 4. Employment of three types of plotting information (punctual, linear, and zonal) in the same map (CUNHA, 2011); 5. Possible contradictions between legibility by end-users and academic interests (GRIFFITHS; ABRAHAM, 2008; PARON; CLAESSENS, 2011); 6. Issues about time-space scales complexity (TRICART, 1965; KLIMASZEWSKI; TRICART, 1964); 7. Differences in types of landscape (AB'SÁBER, 1969a; MARQUES NETO, 2020); 8. Different proposals of research (VERSTAPPEN, 2011).

Regarding diversity, data collected throughout the research corroborated Botelho and Pelech's (2019) statement about obstacles upon comparing different areas, the junction of maps in contiguous areas, and the construction of a national information bank. It is also stated that there is a demand for systematic research, especially in intermediary and detailed scales. These issues have led to contemporary efforts on the construction of a national classification system of relief (Sistema Brasileiro de Classificação do Relevo – SBSR).

On the other hand, these data could also corroborate Verstappen (2011), which affirms that standardization would only be required when producing a series of maps and otherwise it would be appropriate to apply general concepts and adequations to the research's proposal and specific characteristics of the mapped area.

The author also points out that other researchers in environmental issues and planners gradually have seen more interest in geomorphological maps and that not every piece of information included in analytical geomorphological maps is necessary for applied research, which demands flexibility in both map's legend and content and good comprehension of the problem (VERSTAPPEN, 2011). These considerations remain important as most general objectives of the thesis and articles analyzed in this paper concerned specific purposes, such as environmental planning and management and evaluation of environmental impacts by anthropic action, and represented detailed and semi-detailed scales.

In Marques Neto's (2020) discussion about types of landscape, the author mentions six of them approached in geomorphological maps, which were: "(1) coastal landscapes; (2) mountainous landscapes; (3) semi-arid landscapes; (4) urbanized landscapes; (5) landscapes influenced by farming; (6) mined landscapes" (MARQUES NETO, 2020). In this paper, results interestingly showed that specific symbols were used to represent accumulation forms in coastal landscapes from marine and fluvial-marine origin and different types of anthropic forms.

As shown in Figures 11 and 12, there were different types of mapped landscapes in different regions of Brazil. These areas included coastal, urbanized, and mined landscapes and landscapes influenced by farming. However mountainous and semi-arid landscapes were not identified. It is also worth noting that the identified types of landscape are not necessarily mutually exclusive. Coastal landscapes can also be urbanized and/or influenced by farming, for example. Such contexts might require different adaptations in symbology.

The most frequently mapped type of landscape was the coastal one. In most of the maps which represented these environments, symbology was adapted from Tricart (1965), usually associated with Verstappen & Zuidam (1975). However, some included Radambrasil (1987), Ross (1992), IBGE (2009), and Ab'Saber (1969a). The least frequently mapped landscape was the mined landscape. In its respective map, symbology representing anthropic relief forms was included.

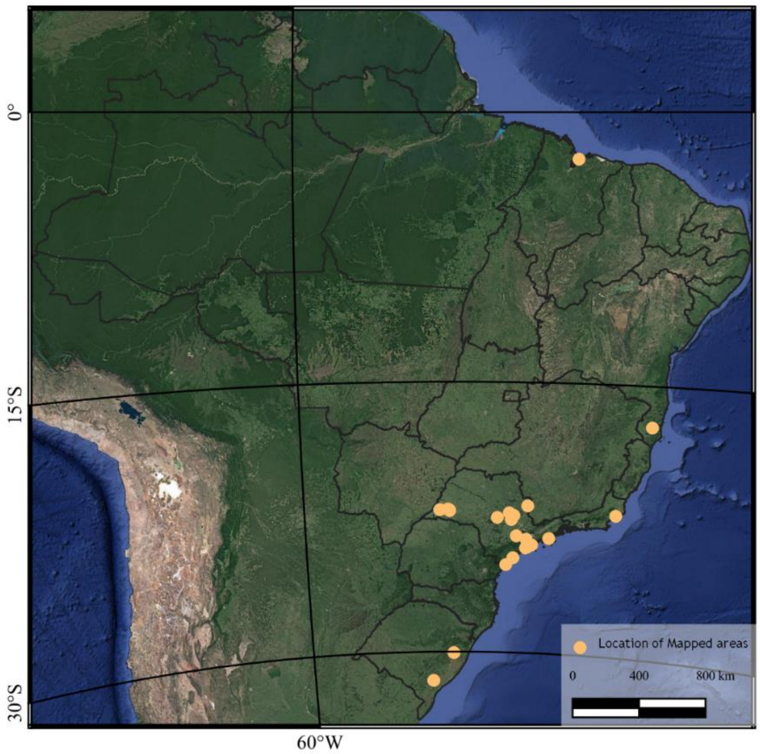


Figure 11. Map of the location of mapped areas. Source of image: Google Satellite (2023). Elaborated by the authors (2023).

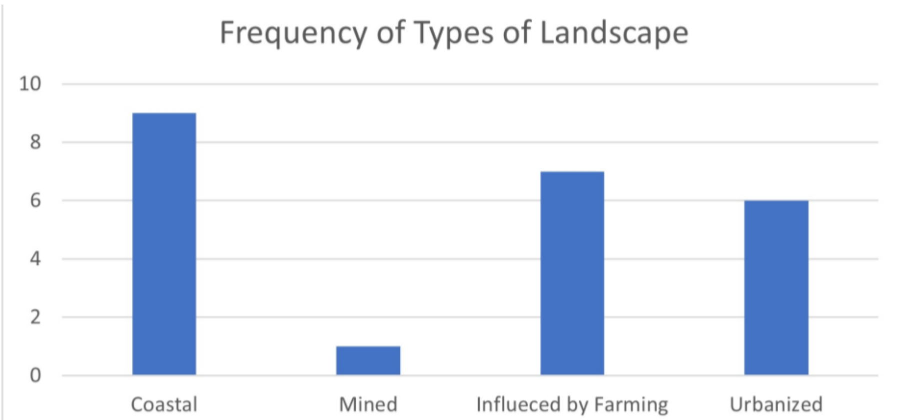


Figure 12. The number of maps according to the Types of Landscape of each mapped area. Elaborated by the authors (2023).

Classifying and grouping detailed geomorphological data might be a complex task since selecting a single criterion for it might be insufficient. Concerning this issue, a mind map (Figure 13) approaches keywords and concepts for understanding the complexity of Geomorphological Mapping, considering which were more likely related to decisions upon methodological procedures and representations of landforms.

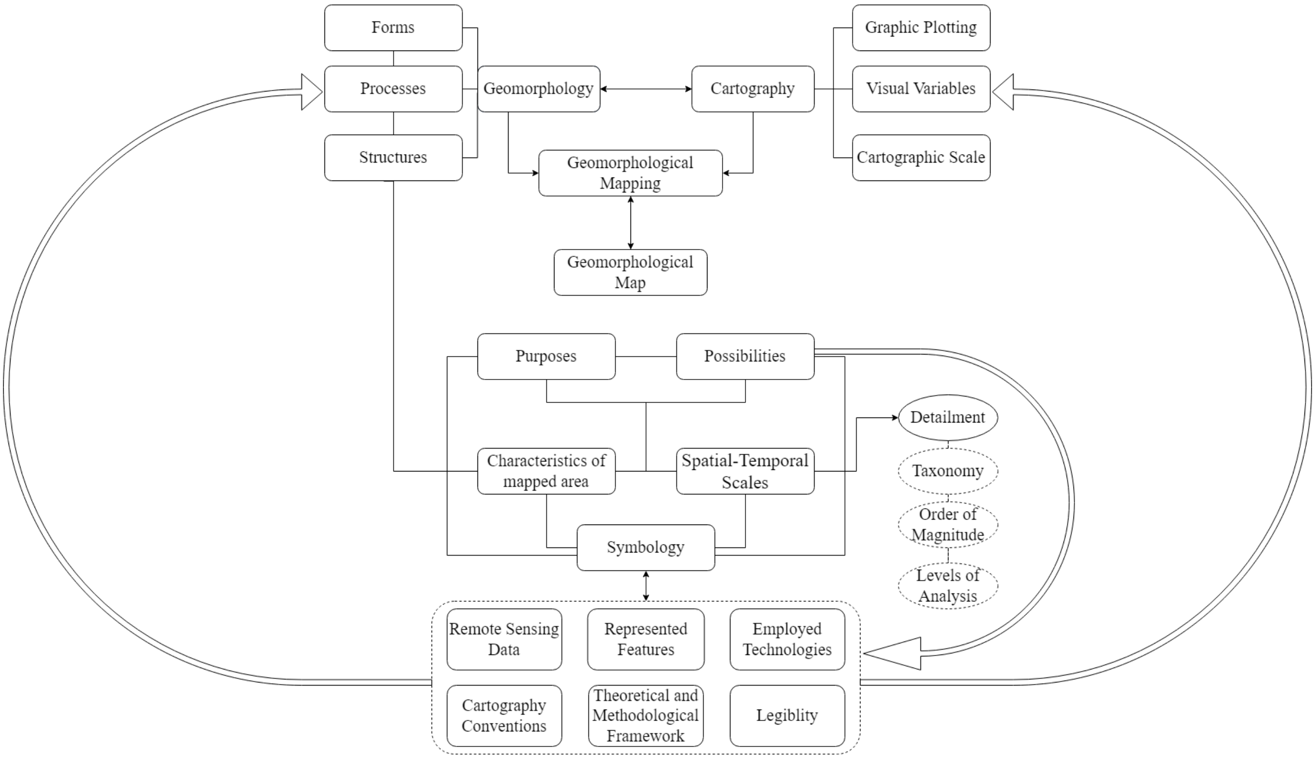


Figure 13. Mind map including keywords and concepts possibly related to decisions upon procedures and representation of relief in detailed and semi-detailed geomorphological maps. Elaborated by the authors (2022).

In this interpretation, Geomorphological Mapping is comprehended as a shared area between Geomorphology and Cartography, as argued by Marques Neto (2020). Purposes refer to purposes of both mapping and researching. Possibilities include both graphical and data acquirement possibilities, as discussed by Marques Neto; Ferraro (2018), and are related to Remote Sensing Data, Represented Features, Employed Technologies, Cartographic Conventions, Represented Features, Theoretical and Methodological Framework and Legibility of the map (which depends upon both the end-users previous knowledge and the adequate use of symbology).

Spatial-Temporal scales are related to levels of detail and generalization, which might change how relief is interpreted and represented and the purposes of mapping as well. It is also worth mentioning that the scale depends upon the availability of adequate remote sensing data, such as aerial photographs and satellite images as well. Since this availability is not uniform for every area, it might influence decisions upon procedures as well. Different frameworks may approach spatial and temporal scales using different concepts such as Taxonomy (ROSS, 1992), Order of Magnitude (TRICART, 1965), or Levels of Analysis (AB'SÁBER, 1969b), or might not explicitly mention these concepts.

6. Conclusion

Diversity of methodologies and representations of relief has been the subject of long debates in both national and international geomorphologists communities. The differences in detailed and semi-detailed geomorphological maps in the state of São Paulo was related to eight main factors: 1) three-dimensionality of the terrain and bi-dimensionality of the map; 2) great number of the nature of represented attributes; 3) representation of both qualitative and quantitative data; 4) employment of three types of plotting information; 5) contradictions between legibility and academic interests; 6) time-space scales; 7) different types of landscapes; and 8) different objectives of research.

The absence of standardization might make the comparison between maps difficult. On the other hand, diversity may have led to the advantage of approaching relief in a best-suited way for each respective research purpose and environmental characteristics of the mapped areas in semi-detailed and detailed scales. It is worth mentioning that having the factors in mind might be useful for reading, analyzing, and producing new geomorphological maps. Future research may approach this issue relating to the influence of different debates and paradigms in both Geomorphology and Cartography, identifying possible end-users of geomorphological maps in Brazil and their possible relation to the legibility and symbology of these maps.

As mentioned in the Method sections, the productions from São Paulo state might be of great influence on the national state of the art. Data have shown that even in a single state, diversity of methods and legends are present. Further research is needed, in order to explore the productions of detailed and semi-detailed geomorphological mapping in other regions of Brazil, concerning their specific environmental and geomorphological characteristics, social-environmental demands and theoretical-methodological frameworks diversity.

Contribuição dos autores: Concepção, G. V. Firmino e J. O. R. Nunes; metodologia: G. V. Firmino; validação, G. V. Firmino e J. O. R. Nunes; análise formal G. V. Firmino; pesquisa, G. V. Firmino; recursos, G. V. Firmino; preparação de dados, G. V. Firmino e J. O. R. Nunes; escrita do artigo, G. V. Firmino; revisão, G. V. Firmino e J. O. R. Nunes; supervisão, J. O. R. Nunes;

Agradecimentos: O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001.

Conflitos de interesse: Os autores declaram não haver conflito de interesse. Os financiadores não tiveram interferência no desenvolvimento do estudo; na coleta, análise ou interpretação dos dados; na redação do manuscrito, ou na decisão de publicar os resultados.

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