Revista Brasileira de Cartografia
ISSN 1808-0936 | https://doi.org/10.14393/revbrascartogr
Sociedade Brasileira de Cartografia, Geodésia, Fotogrametria e Sensoriamento Remoto

Semantic Interoperability in Topographic Mapping: Qualitative Analysis of Land Use and Land Cover Classes Using Discursive Textual

Interoperabilidade Semântica no Mapeamento Topográfico: Análise Qualitativa de Classes de Uso e Cobertura da Terra Utilizando Análise Textual Discursiva

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Received: 07.2025 | Accepted: 01.2026

Abstract: The growing demand for geospatial data integration in Brazil intensifies the challenges of interoperability between cartographic sources, especially for Land Use and Land Cover (LULC) classes in national topographic mapping. This study investigates how conceptual and structural characteristics of the topographic model influence its compatibility with official thematic mappings, with an emphasis on IBGE products. Technical interviews were conducted with 12 experts, including analysts from public institutions responsible for mapping these categories and researchers in the field. The corpus was analysed using Discursive Textual Analysis (DTA), with support from IRaMuTeQ, combining discourse segmentation, lexicometric analyses, and interpretative synthesis by questionnaire dimensions. Based on the findings, a proposal was developed to adapt the conceptual model, represented in OMT-G, with a view to supporting the integration of topographic and thematic products at a scale of 1:25,000. The results indicate semantic divergences, classification gaps and limitations in the multiscale representation of environmental phenomena, with recommendations for adjustments in classes such as ‘Forest,’ ‘Campinarana,’ ‘Exposed Soil’ and ‘Savannah,’ as well as scale-dependent guidelines for humid environments and exposed features. As a contribution, the article systematises recommendations derived from institutional technical knowledge and proposes guidelines for conceptual restructuring aligned with classification clarity, semantic compatibility, and usability in digital contexts. As a follow-up, it is recommended to validate the proposal through pilot application and testing with users and institutions in data integration flows.
Keywords: Data interoperability. Topographic map. Land use and land cover. Conceptual modelling.

Resumo: A crescente demanda por integração de dados geoespaciais no Brasil intensifica os desafios de interoperabilidade entre fontes cartográficas, especialmente para as classes de Uso e Cobertura da Terra (UCT) no mapeamento topográfico nacional. Este estudo investiga como características conceituais e estruturais do modelo topográfico influenciam sua compatibilidade com mapeamentos temáticos oficiais, com ênfase nos produtos do IBGE. Foram realizadas entrevistas técnicas com 12 especialistas, entre analistas de instituições públicas responsáveis pelo mapeamento destas categorias e pesquisadores da área. O corpus foi analisado por meio de Análise Textual Discursiva (ATD), com apoio do IRaMuTeQ, combinando a segmentação do discurso, análises lexicométricas e a síntese interpretativa por dimensões do questionário. A partir dos achados, elaborou-se uma proposta de adaptação do modelo conceitual, representada em OMT-G, visando apoiar a integração entre produtos topográficos e temáticos em escala 1:25.000. Os resultados indicam divergências semânticas, lacunas classificatórias e limitações na representação multiescalar de fenômenos ambientais, com recomendações de ajustes em classes como “Floresta”, “Campinarana”, “Solo Exposto” e “Savana”, além de diretrizes dependentes de escala para ambientes úmidos e feições expostas. Como contribuição, o artigo sistematiza recomendações derivadas de conhecimento técnico institucional e propõe diretrizes de reestruturação conceitual alinhadas à clareza classificatória, à compatibilidade semântica e à usabilidade em contextos digitais. Como desdobramento, recomenda-se validar a proposta por meio de aplicação piloto e testes com usuários e instituições em fluxos de integração de dados.
Palavras-chave: Interoperabilidade de dados. Mapa Topográfico. Uso e Cobertura da Terra. Modelagem conceitual.

 DOI: http://dx.doi.org/10.14393/rbcv78n0a-82717

1 INTRODUCTION

The growing demand for integrating, reusing, and updating spatial data has intensified debates about interoperability in geospatial databases, especially when the data are produced by different institutions with different purposes, scales, and user profiles (Kokla & Guilbert, 2020; Troumpoukis et al., 2022). In Brazil, this challenge is evident in the context of national topographic mapping, whose official vector databases are structured according to the Technical Specifications for Structuring and Acquiring Vector Geospatial Data — ET-EDGV and ET-ADGV (CONCAR, 2017; 2018). However, the literature indicates that these databases still face limitations in representing dynamic environmental phenomena, such as Land Use and Land Cover (LUC), and also partly reflect legacies of processes and products originating in analogue cartography (Sluter et al., 2018; Silva & Camboim, 2020).

The literature has highlighted that geospatial interoperability does not depend only on geometric or structural compatibility, but mainly on conceptual coherence, that is, on alignment between the meanings and classifications adopted in the data models (Reitsma & Bittner, 2003; Yu et al., 2018; Machado & Camboim, 2024). This aspect is particularly critical in thematic categories of high complexity and semantic variability — such as vegetation and UCT — whose definitions and classification criteria may differ due to technical traditions, institutional decisions, and regional specificities (Bravo, 2014; Brown et al., 2022). In practice, national cartographic products with different objectives may adopt different conceptual approaches for similar phenomena, which hinders the integration and consistent reuse of information (IBGE, 2012; Silva & Camboim, 2020).

The absence of conceptual alignment tends to compromise the internal consistency, reliability, and applicability of cartographic products, especially when this data is consumed in digital, interactive, and user-oriented environments (Ballatore et al., 2013; Robinson et al., 2017). In addition, the low frequency of updating Brazilian topographic mapping, in contrast to the speed of territorial transformations observed in different biomes, reinforces the need for strategies that favour the integration between sources and the adaptation of data models to contemporary scenarios (Silva & Camboim, 2020).

Advances in textual analysis, natural language processing, and artificial intelligence have been shown to be promising to support tasks of semantic harmonization and identification of conceptual discrepancies between models (Doan & Halevy, 2005; Real et al., 2020; Souza et al., 2025). However, in the realm of official cartography, these approaches still depend on specialized knowledge and consolidated technical criteria, since mapped objects are defined by conventions, norms, and modelling decisions that are strongly context-dependent and hardly captured by formal descriptions alone (Kokla & Guilbert, 2020; Sluter et al., 2018). Thus, a relevant strategy is to understand how data producers conceive and operationalize classes and criteria of UCT in different national products, in order to subsidize modelling guidelines compatible with the reference model adopted in the country.

In this study, the focus is on the interoperability between the topographic model, standardized within the scope of INDE, and national thematic products produced by the IBGE, with emphasis on the classes of UCT and vegetation. In particular, Land Use and Land Cover Mapping (MUTC) and Vegetation Mapping (MV) are considered, whose classifications and conceptual definitions are documented in technical manuals and are widely used in territorial and environmental analyses (IBGE, 2012; 2013). Particularly, the data classes addressed present complexities in the modelling, in the conceptualization of the mapped entities and in the dynamics of this information in space (Agarwal et al., 2002; Anderson et al., 1976).

From the cartographic point of view, structured topographic maps constitute an important basis for the derivation and synthesis of thematic maps, as they provide spatial units and reference content for thematic-spatial analyses (Gunst et al., 2000). In database-oriented approaches, this relationship is often discussed based on the distinction between "Digital Landscape Model" (DLM), which describe geographic content, and models focused on the final cartographic product (Digital Cartographic Model – DCM), in which generalization and symbology decisions directly impact the classification and representation of phenomena (Buckley et al., 2005).

In terms of integration, the literature also records initiatives to harmonize topographic and thematic bases within the scope of national spatial data infrastructures, proposing dictionaries and common conceptual models for shared classes (e.g., experiences reported in Colombia and in the national SDI of Poland) (Rocha Salamanca & Caro Arias, 1995; Olszewski et al., 2005). In addition, the typologies of cartographic products distinguish general maps (such as topographic) and thematic maps by purpose and content, reinforcing the need for conceptual compatibility when it is intended to integrate products with different functions (Petkov & Bandrova, 2020).

Despite these advances, there are still few studies that investigate in an integrated way the conceptual and classificatory incompatibilities between topographic and thematic bases at the national level, especially at the 1:25,000 scale, in which greater granularity tends to increase sensitivity to differences in definition, generalization, and class criteria. In the Brazilian context, although there are official specifications for the structuring of topographic data, the systematic articulation between these specifications and national thematic models is still limited, especially for the classes of UCT/vegetation at the scale of 1:25,000 (CONCAR, 2017; CONCAR, 2018; Silva & Camboim, 2020).

Given this scenario, the research question that guides this article is: how can Land Use and Land Cover data from the National Topographic Map (1:25,000) be modelled in order to contemplate the particularities of the Brazilian territory and, at the same time, promote interoperability with national thematic models produced by different institutions? It is based on the hypothesis that the identification and characterization of the main incompatibilities between the national topographic model and the national thematic models, supported by interviews with producers of these data, allow the derivation of modelling and adaptability guidelines applicable to the improvement of interoperability.

For this, the study uses qualitative material obtained from experts and analysed through Discursive Textual Analysis (DTA), seeking to extract recurrent patterns, divergences and recommendations, directly anchored in the practical knowledge of producers. DTA is characterized by allowing a consistent, rigorous and sensitive understanding of discourses, being a powerful tool for studies that seek to interpret meanings and represent the complexity of phenomena (Camargo & Justo, 2013; Martins et al., 2022; Marcelino & da Silva, 2025).

The overall objective of this paper is to identify features of semantic formalization, classification and modelling that influence interoperability between national topographic mapping and national thematic products related to UCT, with a view to proposing interoperability-adapted modelling at the scale of 1:25,000. As specific objectives, it is sought:

(i) plan and execute the collection of qualitative data with specialists involved in the production and/or use of the models;
(ii) analyze the material collected through Discursive Textual Analysis;
(iii) identify patterns, divergences and suggestions regarding the classes, symbologies and conceptual structures associated with UCT; and
(iv) propose a model adapted to interoperability for the UCT classes, compatible with the reference model adopted in the context of INDE.

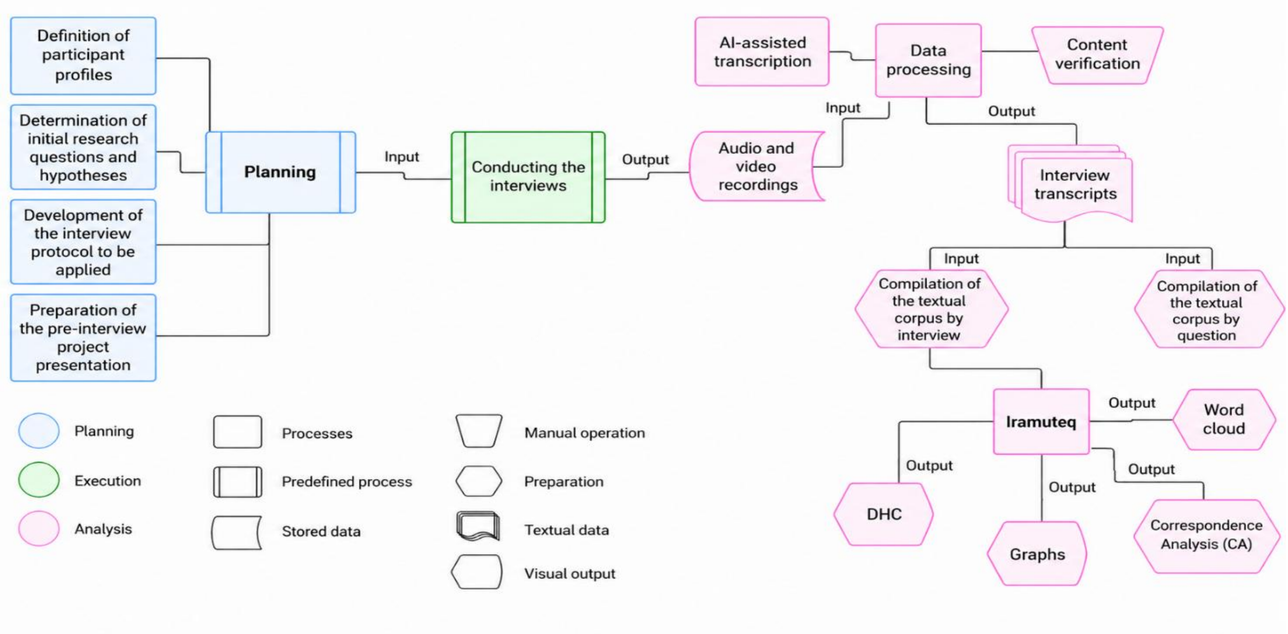
The main contribution of the work lies in the systematization of semantic and classificatory divergences between national topographic and thematic models, as well as in the proposition of conceptual adjustments guided by semantic clarity, adequacy to scale and requirements of use in digital environments, in dialogue with international initiatives for harmonization and conceptual modeling of geospatial data (Dumont et al., 2020; Al-Yadumi et al., 2021).

In the end, it is expected to offer subsidies for the improvement of the Brazilian reference mapping and for a more consistent integration between the national cartographic products aimed at territorial analysis. Although the dimension of cartographic representation and symbology emerged in the interviews as a relevant component for interoperability, this article focuses on the conceptual modeling and classificatory alignment that underlie the proposal. The detailed analysis of symbology and the proposition of new symbols are presented in a complementary work (Araujo et al., 2025).

2 METHODOLOGICAL PROCEDURES

This study adopted a qualitative approach, structured as a case study, and was organized in three stages: (i) planning of data collection; (ii) execution with application of interviews and storage of material; and (iii) data analysis, considering the structure of the collection, the content and the discourse of the participants. The three steps are represented schematically in Figure 1 and detailed in subsequent sections. This study was submitted to and approved by the Human and Social Sciences Research Ethics Committee – CEP/CHS of the Federal University of Paraná via Plataforma Brasil, under the Certificate of Presentation for Ethical Appreciation (CAAE) No. 79306724.9.0000.0214.

Figure 1 – Methodological Fluxogram.



Source: The authors (2025).

2.1 Interviews as a data collection method – planning and application

The technical interviews were chosen because they allow access to operational criteria, classification decisions and conceptual interpretations employed by producers of topographic and thematic data. Individual interviews were conducted with 12 professionals working in institutions linked to cartography and environmental monitoring in Brazil, selected based on a previously defined profile. The selection criteria included: training in Geosciences or related areas; current or previous performance related to UCT mapping; institutional experience with topographic, UCT or vegetation mapping; and familiarity with relevant standards and technical specifications.

Contact with the participants took place via institutional emails and the interviews were conducted remotely, by video calls. The script was structured in three parts: (1) contextualization of the study and presentation of the objectives, followed by characterization of the participant (attributions and experience); (2) and (3) application of a questionnaire with approximately 13 open questions, focused on potential interoperability conflicts, with emphasis on classification, modeling and design of elements by scale. The analysis of the cartographic representations adopted for specific thematic classes was also requested. Each interview lasted an average of 35 minutes.

The complete script of the interviews is available for downloading in the indicated repository through the link. As a synthesis of the characterization of the participants, Chart 1 was elaborated, which presents the characterization grouped by themes: academic training and teaching performance; experience in the various stages of cartographic production and institutional functions; and professional experience associated with the geographic regions of Brazil in which they worked.

The projects in which the participants reported experience are varied, covering mappings in different spheres — federal, state and municipal — and in different thematic natures, including topographic, land use and land cover (UCT) and vegetation mappings.

Chart 1 – Summary of the Characterization of the Participants.

Interviewees who work in the institutions	**Institution**	**Interviewees with this level of education**	**Education level**	**Interviewees with this academic background**	**Academic background**	**Interviewees who produced on this scale**	**Project Scales Executed**
1	CONDER	12	Undergraduate studies	1	Computer Science	9	1: 250.000
1	Petrobras	3	Postgraduate studies	6	Cartographic Engineering	9	1: 100.000
2	INEMA	10	Master's degree	1	Forestry Engineering	10	1: 50.000
3	IBGE	5	Doctorate	3	Biology	12	1: 25.000
2	DSG	4	Teaching	1	Geography	5	1: 10.000
1	INPE	-	-	-	-	4	1: 5.000
2	Private Initiatives	-	-	-	-	4	1: 1.000

Source: The authors (2025).

Chart 2 – General Information of the participants.

GENERAL INFORMATION	
Experiences consolidated by the interviewees	
Map. Stage	Database; Processing; Production; Acquisition; Reambulation; Update.
Administrative	Coordination; Inspection; Technical Section; Technical Chamber; Cartography Center
Teaching	UFBA; TUIUTI; IME; UFRGS
Work Region Mapped by State	
North	Amazonas; Amapá; Pará.
Northeast	Bahia; Ceará
Midwest	Goiás; Mato Grosso.
Southeast	Rio de Janeiro; São Paulo; Minas Gerais
South	Paraná; Rio Grande do Sul.

Source: The authors (2025).

The second and third parts of the interviews focused on issues related to the current classification by scale, the interoperability of the data and the presentation of the thematic classes. Chart 3 presents a summary of the questions applied, accompanied by the criteria that guided the analysis of the experts' answers and the possible analytical approaches resulting from them. For the questions involving the visual analysis of the representations by the interviewees, the images were presented during the interview, through screen sharing. In addition, the link to access the representation manuals was shared. All images and maps had an approximate scale of 1:25000 and a resolution of 300 dpi. The structure adopted for the table aims to ensure clarity in the correspondence between the research objectives, the questions formulated and the elements identified in the interviews, allowing traceability and transparency in the interpretation process.

Chart 3 – Questions applied to the experts via questionnaire (continued).

Question Applied	**Guiding Criteria**	**Analytical Routing**
1) With the current classes on the topographic map, is it possible to represent the national territory reliably? Are any changes suggested by scale?	If the current data classes are sufficient at all scales, then no recommendations will be made.	Recommending changes to scaling or data structure, if necessary.
2) The image and vectors of the same region illustrate a border area between the cerrado and caatinga classes, is this classification recommended? If so, do you indicate the subclassification, on which scales? Is it possible to integrate data from other maps?	If there is a recommendation for subclassification on larger scales and integration, then it is possible to identify the main variables to promote interoperability of the analysed classes.	Recommendations (or not) for subclassification according to the scale, justifying the response and the recommendation or not for integration.
3) Regarding the classes of wetland and marsh or marsh, what characteristics can differentiate them spatially and at what scales is it recommended to map them?	If the concepts have characteristics that differentiate them in the scope of the phenomena, then they must be represented on the recommended scale with the respective variables.	Assessment of the characteristics of the analysed classes and recommendation for presentation scale.
4) What is your opinion about the T34-700 manual and what adaptations to the symbols can be made considering the functionality and usability of current maps?	If there are modern criteria for evaluating and elaborating symbols that must be considered in addition to consolidated information, then the suggested adaptations must be highlighted.	Opinion, suggestion for adaptation and consolidation of current symbols considering the user and modern products.

Chart 3 – Questions applied to the experts via questionnaire (conclusion).

Question Applied	Guiding Criteria	Analytical Routing
5) After presenting an official mapping represented on screen, the question was asked about how difficult it was to interpret the classes and symbols?	If the symbols and classes are capable of transmitting information clearly and objectively, it would not be necessary to use captions.	Difficulties in reading and interpreting classes by experts, as well as suggestions for adaptation.
6) How important is it to represent all the attributes of the Cerrado, Caatinga and Campo classes differently on a 1:25,000 scale? (With presentation of subclass symbols in legend format).	If there is a suggestion to use subclasses, according to the mapping scale, then there is evidence for adapting current classes.	Main functionalities and meanings attributed to symbols at scale 1:25,000.
7) What is your opinion on the representation of the wetland class? Could this be considered an attribute of other classes?	If the classes and representation are clear and objective, considering the importance of representing them, then they will be read correctly without adaptations due to scale.	Analysis of symbols and classes of Wetland and Swamp or Swamp by scale.
8) Is there any class of data for the 1:25,000 scale that is not covered by EDGV 3.0 that can be integrated into this mapping?	If the data classes are insufficient for this scale, then new data classes will be suggested.	Reflection on currently available classes and any gaps.
9) Is the Campinarana class sufficiently differentiated from other plant formations on a 1:25000 scale? Are there other sufficiently differentiated formations such as Campinarana that are not foreseen in EDGV 3.0?	If the “campinarana” class is a unique plant formation, then it will be analysed by scale of representation and scope of the phenomenon. If equivalent training exists, it is expected that they will be indicated.	Analysis of the representation of the “Campinarana” class on different scales. and possible unmapped classes.
10) What is your opinion about the importance of representing the exposed soil class in topographic mapping?	If the “exposed soil” class is significant in scope across all scales, then its representation should be suggested on standard scales.	Analysis of the suitability of the “exposed soil” class at different scales.

Source: The authors (2025).

2.2 Preparation of empirical material

The data considered in the analysis included: answers to the questionnaire applied, interviewer's notes, video and audio records of the interviews in full, and transcripts. The transcripts were generated using the *Whisper* library, developed in Python language by OpenAI., followed by manual verification for quality control and correction of textual content. For the analysis stage, two distinct corpora were elaborated.

The first structure the data by set of questions, grouping all the answers to the same question, regardless of the interviewee. The second corpus, on the other hand, organizes the data by individual interviews, fully analyzing the transcribed content of each participant, focusing on their trajectory, repertoire and arguments. This allows us to observe trends, repetitions and thematic divergences in relation to each dimension of the questionnaire. Sequential procedures based on the textual corpus have been discussed by several authors, such as Camargo and Justo (2013), Flick (2008) and Martins et al. (2022). According to the specific guidelines of Camargo and Justo (2013), the files were saved in UTF-8 format, and the texts were organized in lines. In addition, the procedures indicated by Camargo and Justo (2013) guide the adoption of some fundamental practices for the proper preparation of textual data in IRaMuTeQ: a) review and correction of the file, with special attention to typing errors; b) standardization of acronyms; c) use of underscore to join compound words; d) no use of bold or italics; e) maintenance of numbers in digit format; and f) removal of special characters.

2.3 Discursive textual analysis and computational support

The analysis of the material was conducted through Discursive Textual Analysis (ATD), with the support of *IRaMuTeQ* (Interface of R pour les Analyses Multidimension Texts at Questionnaires), a free software that integrates resources from the R and Python languages and is widely used in the analysis of qualitative data. The *IRaMuTeQ* was used to support the stages of organization and exploration of the corpus, through routines such as Descending Hierarchical Classification (CHD) and Correspondence Factor Analysis (AFC), useful to identify lexical patterns and relationships between textual segments and variables, without replacing the researcher's interpretation.

After the execution of the routines in the *IRaMuTeQ*, the analytical outputs (lexical classes, associations and projections) were used as evidence to support the interpretative stage of the ATD, articulating textual patterns with the content of the answers and with the interviewer's notes, with a view to deriving modeling and adaptability guidelines related to interoperability between models.

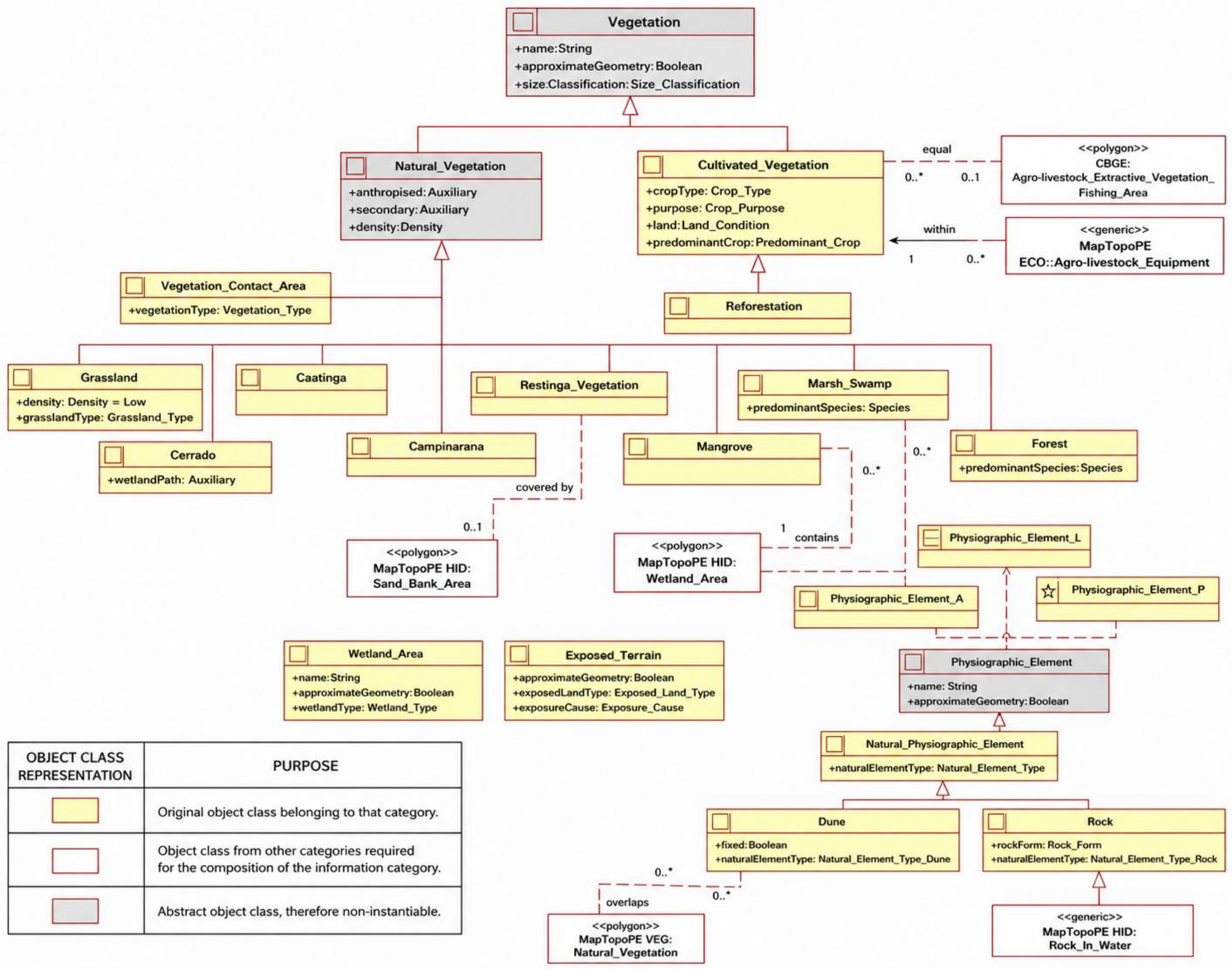
2.4 Conceptual modelling and scoping of the analyzed classes

Conceptual modelling of geographic objects defines the structure and parameters for data abstraction, simplifying reality without compromising its applicability. In the Brazilian context, ET-EDGV (CONCAR, 2017), a reference in the structuring of topographic data, adopts OMT-G as a formalism of conceptual modelling. Thus, OMT-G was used in this study to ensure adherence and compatibility with the reference model used in INDE (Borges et al., 2001; CONCAR, 2017).

OMT-G uses Class Diagrams to represent classes and relationships, which can be geospatial or conventional in nature, organized by category of information. In addition, it employs Domain Lists to define the allowed values of attributes. This structure favours the interoperability of geographic data, by supporting the sharing of information between different sectors in a consistent and standardized way (Borges et al., 2001). Based on this, conceptual modelling was adopted to guide the adaptation of the current data model, based on the interviews conducted.

In the proposed model, a distinction is made between georeferenced classes — which have spatial representation — and conventional classes, which do not have geometry, but maintain relationships with the other classes. Relationships between classes can be spatial (e.g., topological) or non-spatial (e.g., semantic associations) and are represented by dotted or continuous lines, respectively. The model also contemplates inheritance relations, allowing the generalization and specialization of classes, with support for multiple inheritance and the distinction between instantiable and abstract classes. The latter do not directly represent features in the database, but they are important for organizing common attributes. Mainly classes of the Vegetation category (VEG), in addition to three classes of the Relief category (REL) — Rock, Dune and Exposed Land — and one class of the Hydrography category (HID) — Wetland. Next, the results obtained from the software analyses are presented, complemented by the interviewer's notes and the discursive and rhetorical interpretation of the participants' statements.

Figure 2 – ET-EDGV classes analysed.



Source: Adapted from CONCAR (2017).

3 RESULTS

3.1 Lexicometric results of the corpus by question (CHD/AFC)

To specifically analyse the question "Which characteristics of data can promote interoperability?", a corpus was constructed per question, gathering the answers of all respondents for this dimension of the questionnaire. From this corpus, the Descending Hierarchical Classification (DHC) and the Correspondence Factor Analysis (CFA) were applied, with the objective of identifying lexical groupings and visualizing proximity relationships between classes and characteristic terms.

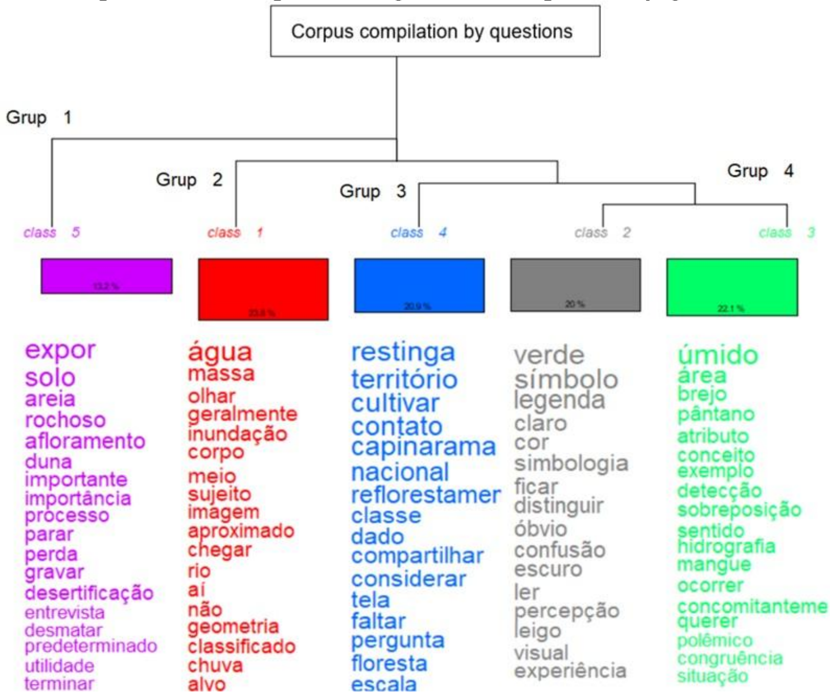
The DHC resulted in five lexical classes, with relatively balanced percentages (Figure 3): Class 1 (red, 23.8%), Class 2 (gray, 20.0%), Class 3 (green, 22.1%), Class 4 (blue, 20.9%), and Class 5 (purple, 13.2%). The dendrogram also shows a hierarchical organization in groups, in which Class 5 forms a more isolated branch, while Classes 2 and 3 present greater proximity, suggesting lexical affinity between segments associated with cartographic representation and humid environments and/or specific areas. The characteristic terms of each class were identified by the chi-square test (χ^2), according to the usual procedure in *IRaMuTeQ* (Camargo & Justo, 2013), adopting as a reference the critical value for df = 1 ($\chi^2 \geq 3{,}841$; $p < 0{,}05$). In all classes, the characteristic terms reported exceeded this threshold, evidencing a statistically significant term-class association.

In descriptive terms, Class 1 brings together vocabulary associated with water, water mass, flood, rainfall and related processes, indicating that hydrological aspects and flood dynamics appear as relevant dimensions when discussing interoperability. Class 2 concentrates terms linked to cartographic representation,

 DOI: http://dx.doi.org/10.14393/rbcv78n0a-82717

with recurrent mentions to symbol, legend, color, visual, and symbology, suggesting that legibility and graphic consistency are perceived as conditioning factors for the reuse and integration of products. Class 3 aggregates terms associated with humid environments and specific areas, such as humid, marsh and swamp, accompanied by supporting terms, such as attribute, concept and example, which points to the need for more explicit criteria and/or descriptive detail for these categories. Class 4 highlights terms associated with thematic classes and territorial cuts, with occurrences of restinga, campinarana, reforestation, territory, national and class, evidencing the articulation between the classification of UCT/vegetation and the territorial context of application. Finally, Class 5 concentrates terms associated with substrate and exposed features, such as soil, outcrop, rocky, dune and sand, as well as mentions of process and importance, indicating that the physical conditions of the terrain and the exposed features also emerge as aspects considered in the compatibility of bases.

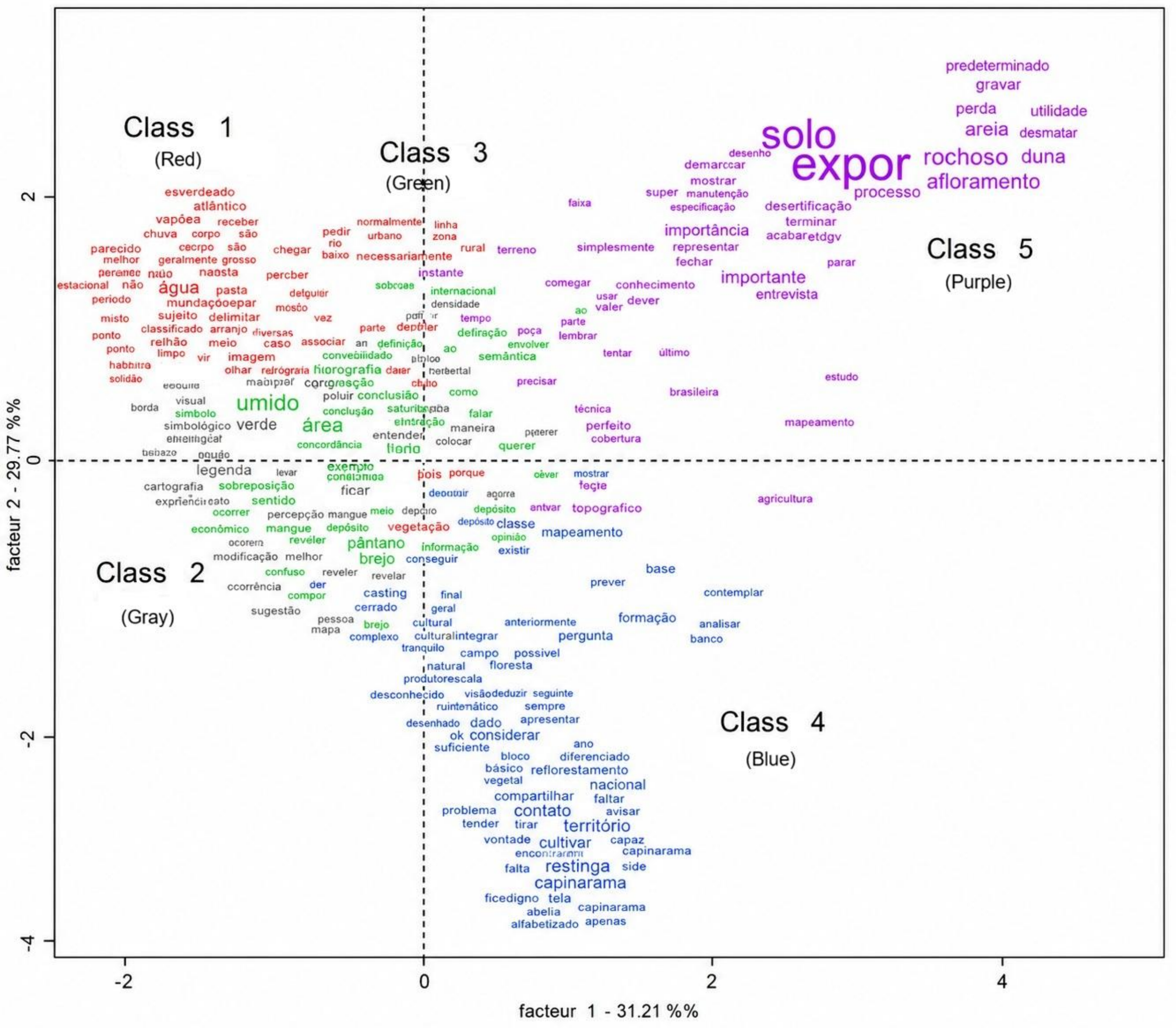
Figure 3 – Dendrogram of corpus classes organized by question.



Source: The authors (2025).

The AFC (Figure 4) complements the DHC by representing the classes in the factorial plane, indicating how the terms are distributed in axes that synthesize the lexical variability of the corpus. In the plan presented, Factor 1 explains 31.21% and Factor 2 explains 23.77% of the variance. A consistent separation between classes is observed, with Classes 4 (blue) and 5 (purple) having greater projection on the positive side of Factor 1, while Classes 2 (gray) and 3 (green) are organized closer to each other, in accordance with the grouping pattern observed in the dendrogram. Together, CHD and AFC indicate that the question on interoperability mobilizes, in a structured way, dimensions related to cartographic representation, scale dependence, and the conceptual specificity of environmental classes and UCT/vegetation.

Figure 4 – Factor analysis by correspondence, by individual corpus.



Source: The authors (2025).

For better visualization and traceability of the relationships between terms, graphs of similarity of the analysis by question (graph_simi_1) are available in the supplementary materials, as well as the transcriptions of the two corpora. The graphs and complementary materials related to the corpus per individual (graph_simi_2) are also available in the same repository, as a support for the transparency and reproducibility of the analyses.

3.2 Complementary analysis by individual interview (corpus per individual)

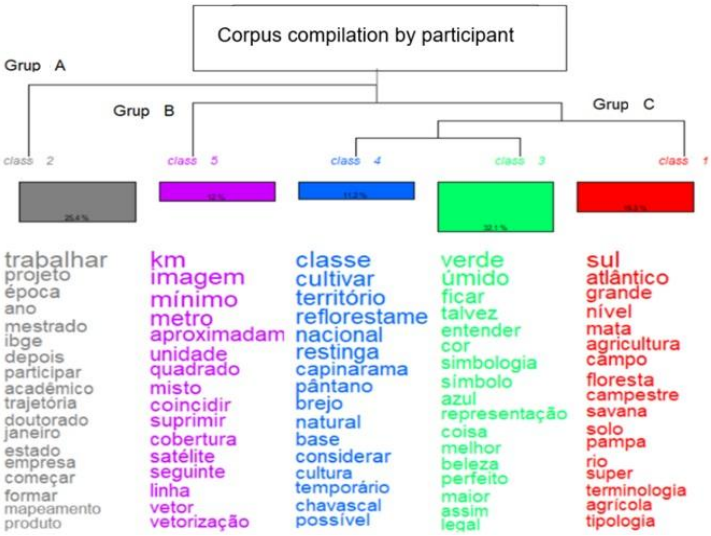
As a complementary analysis, the corpus was also organized by individual interview, with the objective of verifying the thematic stability of the set of answers and identifying lexical variations associated with the repertoire of each participant. At this stage, Descending Hierarchical Classification (DHC) and Correspondence Factor Analysis (CFA) were prioritized again, as they contribute to the unitarization and categorization procedures provided for in the DTA and allow the visualization of lexical patterns in the set of interviews.

As descriptive output of the processing, 2775 forms, 57,302 occurrences and 1672 text segments were identified in the individual corpus. The resulting dendrogram (Figure 5) organized the segments into lexical classes that, at a general level, aggregate content associated with the regional and environmental context, professional trajectory and experience, cartographic representation, UCT/vegetation categories, and technical aspects of acquisition and parameterization (such as metrics and scale). These groupings reinforce that interoperability is mobilized by the interviewees in a multifactorial way, articulating territorial and

 DOI: http://dx.doi.org/10.14393/rbcv78n0a-82717

environmental criteria with operational and institutional aspects related to the production and use of data.

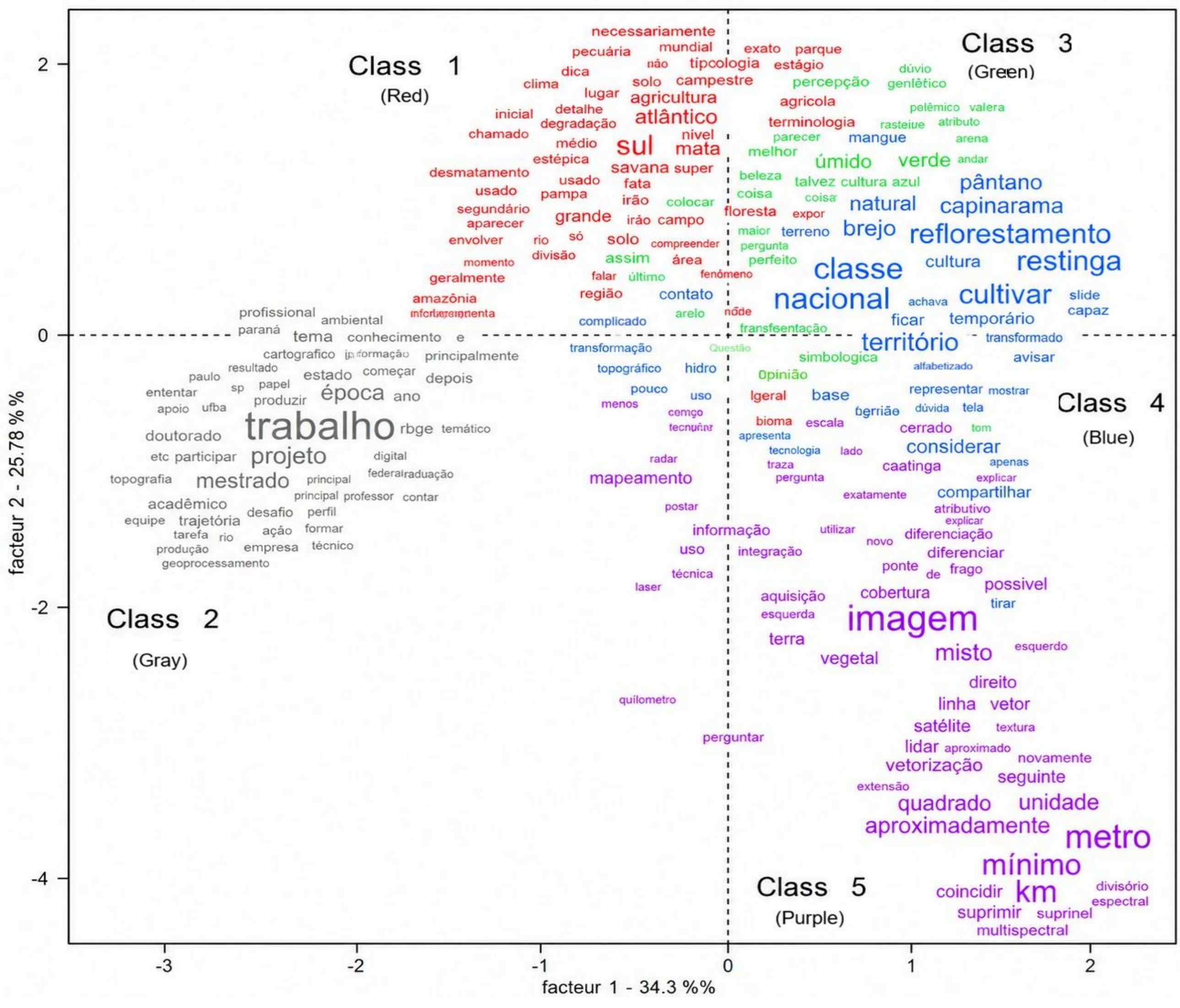
Figure 5 – Dendrogram of corpus classes organized by individual.



Source: The authors (2025).

The AFC per individual (Figure 7) was used to visualize the distribution of classes and terms in the factorial plane and to support the reading of proximities and distances between lexical sets.

Figure 7 – Factor analysis by correspondence.



Source: The authors (2025).

Thus, the analysis by individual offers a complementary verification of the thematic consistency of the corpus, while the interpretative synthesis presented below organizes, by dimension of the questionnaire, the main findings and their implications for the identification of incompatibilities and for the resulting modelling proposal.

3.3 Synthesis of findings by questionnaire size

Based on an interpretative reading of the corpus and the consolidation of responses by questionnaire dimension, an interpretative synthesis was developed (Chart 4) that organizes, by question, the recurring points and recommendations associated with interoperability. In general, the synthesis points to three predominant lines: (i) the need for conceptual and nomenclature adjustments, aligning with technical manuals and national references; (ii) recommendations for scale-dependent representation, with detailing and/or restriction of occurrence at larger scales; and (iii) the need to revise symbols and graphic standards to reduce ambiguities and improve legibility in digital contexts.

Regarding the adequacy of current classes to represent the territory, the synthesis indicates recommendations for altering the nomenclature and aligning it with the classes of the Brazilian Vegetation Technical Manual (MVB), especially at larger scales. For the situation of border areas between "cerrado" and "caatinga," there is a clear recommendation for integration with other maps and detailing by attributes, with nomenclature adjustment according to the MVB, in order to reduce conceptual ambiguity.

In the case of Wetland and Swamp/Marsh, the synthesis indicates differentiation by occurrence and scale: Wetland is recommended at all scales and Swamp/Marsh at larger scales, given the spatial scope and the need for detail. Regarding the interpretation of the T34-700 manual and the difficulties in reading classes and symbols on screen, respondents reported limitations in legibility and visual/cognitive overload, with recommendations for graphic adjustments, including changes in hatching patterns and the use of solid colours, replacing patterns considered less functional in digital environments.

The synthesis also points to recommendations for detailing by attributes at a 1:25,000 scale for classes such as "Cerrado," "Caatinga," and "Campo," emphasizing that the decision to subclassify a class tends to imply revisions in other related classes in order to maintain consistency. Finally, gaps and opportunities for expansion were identified: a recommendation for subclassification of "Forest," as well as classes related to cultivation and livestock, in addition to specific recommendations for classes such as Campinarana and Exposed Soil, whose representation was considered more adequate from larger scales, due to the occurrence and need for detail.

Chart 4 – Interpretive synthesis of respondents' answers by question (continued).

Question	Interpretive synthesis
With the current classes of topographic mapping, is it possible to represent the national territory faithfully? Is any scale adjustment recommended?	It is recommended to change the nomenclature and align it with the MVB data classes for large scales.
The image and vector captions of the same region illustrate a border area between cerrado and caatinga biomes. Is this classification recommended? If subclassification is recommended, at what scales? Is it possible to integrate data from other maps?	Data integration is highly recommended. Detailed features in data attributes. Nomenclature change according to MVB.
With regard to wetland and marsh/swamp classes, what characteristics can differentiate them spatially, and at what scales is it recommended to map them?	Recommendation: Wetland at all scales; Marsh and swamp at large scales, due to the area of occurrence of the classes.
What is your opinion on the T34-700 manual, and what adaptations to the symbols could be made, considering the functionality and usability of current maps?	Recommendations: Change the hatching patterns and use solid colours.
After the presentation of an official mapping shown on screen, the question arose as to what the difficulty was in interpreting the classes and symbols?	Difficulties in reading and interpreting the classes by specialists. Patterns and colours cognitively overload the reading process.
What is the importance of representing all the attributes of the Cerrado, Caatinga, and Campo classes differently at a 1:25,000 scale? (With subclass symbols presented in legend format).	Suggestion for detailing the data in the attributes. If this class is subclassed, it becomes necessary to subclass other classes.

Chart 4 – Interpretive synthesis of respondents' answers by question (conclusion).

Question	Interpretive synthesis
What is your opinion on the representation of the wetland class, considering the example below without a legend, and its characteristics of occurrence? Could this be considered an attribute of other classes?	It is not considered an attribute; the representation of wetland areas at all scales is important. Changes to hatching and overlays are recommended.
Are there any data classes for the 1:25,000 scale that are not covered by EDGV 3.0 and that could be integrated into this mapping?	Subclassification of forests, crops, and livestock is recommended.
Is the campinarana class sufficiently differentiated from other vegetation formations at a 1:25000 scale? Are there other sufficiently differentiated formations, like the campinarana, that are not included in EDGV 3.0?	Recommendation for the representation of this class based on large scales, due to the area and scope that differentiate it from other vegetation formations.
What is your opinion on the importance of representing the exposed soil class in topographic mapping?	Important representation; recommendation to represent this class from large scales.

Source: The authors (2025).

3.4 Conceptual and classificatory incompatibilities identified in the corpus

Based on the lexicometric results and the synthesis by dimension of the questionnaire, recurring incompatibilities were observed. First, some classes proved to be excessively general, which reduces their discriminatory power at the 1:25,000 scale. In addition, nomenclature inconsistencies emerged, especially when broad terms or terms belonging to different conceptual levels are used as classes at the same hierarchical level. Finally, the findings indicate the need to align concepts and definitions with national technical references in order to increase compatibility with thematic products frequently used together.

Among the most recurring points, the recommendation to subclassify "Forest" at larger scales to increase specificity without compromising generalization at smaller scales stands out. The need to review classes and attributes associated with cultivation and livestock farming was also recurrent, seeking greater adherence to the diversity of uses when mapping is carried out at a large scale. In general, experts emphasized that the classes represented at 1:25,000 require more explicit class criteria and/or more detailed attributes, both to reduce interpretative ambiguities and to support integration with other national products.

3.5 Aspects of scale and cartographic representation

The results also show that the interoperability discussed by the participants is not limited to the structural compatibility of the database, but involves scale and cartographic representation requirements that condition reading, reuse, and integration in digital environments. For some classes, there was an indication of representation at all scales, especially when the phenomenon was understood as structural and recurrent in the territory (for example, Wetland). For others, the recommendation was for representation from larger scales, when the phenomenon was associated with a more localized spatial occurrence and a need for greater detail (for example, Swamp/Marsh, Campinarana, and Exposed Soil).

In the graphic component, respondents pointed out difficulties in reading and interpreting the symbols, especially when viewing them on screen without immediate legend support, as well as visual overload resulting from patterns and colours. As a next step, recommendations were highlighted for reviewing the hatching patterns and for adopting more legible alternatives in digital contexts, without prejudice to the distinction between classes.

3.6 Proposed resulting model

Based on the patterns identified in the CHD/AFC analyses, the interpretative synthesis by dimension of the questionnaire, and the discursive interpretation of the corpus, a proposal for adapting the conceptual model, expressed in OMT-G, was developed to improve interoperability between topographic mapping and national thematic products. To facilitate the reading of the changes, the original ET-EDGV diagram is presented in Figure 2, and the proposed diagram (Figure 8) is presented in this section, highlighting the main structural and conceptual adjustments introduced.

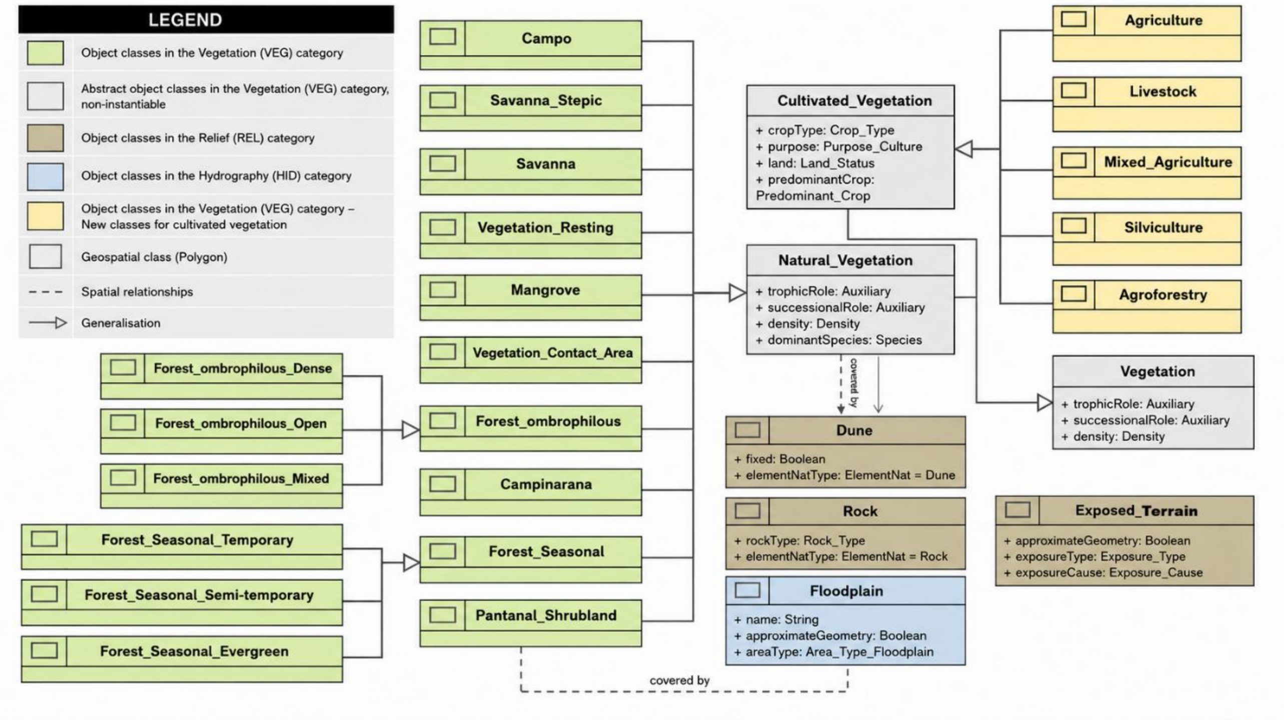
First, the proposal revises the nomenclature of classes, whose current use refers to biomes, avoiding the coexistence between them at the same hierarchical level of vegetation/phytophysiognomies classes. Thus, the classes "Cerrado" and "Caatinga" were aligned with the typologies of the IBGE phytogeographic system, adopting "Savanna" and "Savanna-Steppe", respectively.

Secondly, the “Forest” class was specialized to reflect the recurring need in the interviews for greater precision at a 1:25,000 scale. The proposal separates “Humid Forest” and “Seasonal Forest” and provides for detailed subclasses at larger scales, in line with the technical nomenclature used by IBGE for forest formations.

Finally, for anthropogenic production areas, an abstract class, Veg_Cultivada, was structured, from which subclasses such as Agriculture, Livestock, Agro-livestock, Silviculture, and Agroforestry are derived. This choice harmonizes the modelling with the terminology and scope defined in the Technical Manual for Land Use, in which silviculture encompasses reforestation and agroforestry systems.

Overall, the changes aim to reduce semantic ambiguities, improve classification consistency, and promote multiscale generalization/specialization, while preserving compatibility with the reference model adopted in the INDE and expanding its capacity for integration with national thematic mappings.

Figure 8 – Proposed class diagram (OMT-G) for Land Use and Land Cover classes in the National Topographic Map.



Source: The authors (2025).

4 DISCUSSION

4.1 Semantic interoperability: conceptual and classificatory

The results show that, in the context analysed, interoperability is understood by experts as a challenge that goes beyond geometric compatibility or mere data sharing, involving, above all, conceptual and classificatory coherence. This reading is consistent with classic discussions on semantic interoperability in GIS, which point out that differences in definition, granularity, and class criteria produce incompatibilities even when structures and formats are technically compatible (Lutz et al., 2003; Ballatore et al., 2013; Robinson et al., 2017).

The lexical groupings observed in the CHD/AFC by question (Section 3.2) reinforce this interpretation by showing that respondents systematically mobilize distinct dimensions when talking about interoperability: (i) cartographic representation (class associated with “legend”, “symbol”, “colour”); (ii) classes/themes and territoriality (class associated with “territory”, “national”, “class”, and formation terms); and (iii) specific environments and categories, such as wetlands and exposed features. This distribution suggests that the “problem” of interoperability is perceived as multifaceted: it simultaneously involves concepts, classification rules, and forms of representation.

4.2 Scale, generalization and conceptual alignment: implications for 1:25.000

A recurring point in the results is the centrality of the 1:25,000 scale as a context in which conceptual and classificatory differences become more critical, as it represents, in Brazil, a transitional scale between the scales traditionally considered small — within the scope of the National Cartographic System (Decree-Law No. 243 of 1967) — and the scales considered large. At larger scales, the expectation of detail and explicit criteria for differentiating classes increases; therefore, very broad categories or those with implicit criteria tend to generate ambiguities and incompatibilities when topographic data is combined with thematic products.

This reading aligns with both the classical tradition of cartographic generalization and its contemporary evolution. McMaster and Shea (1992) emphasize that generalization should not only preserve the geometry of objects, but also the consistency of attributes and categorization. For the authors, the retention or transformation of attributes is part of the generalization process, especially in thematic maps, such as land use and land cover maps. Using examples such as the classification system of Anderson et al. (1976), the authors demonstrate that classification is, by nature, hierarchical. This implies the need for explicit rules for the specialization and aggregation of classes when transitioning between different levels of detail, in order to preserve coherence when subclasses are generalized to their parent classes. In this sense, it is observed that the normative treatment of scales in Brazilian technical specifications (ET-EDGV and ET-ADGV) tends to privilege the notion of visibility or the occurrence of entire classes according to the mapping scale. However, these standards do not explicitly define mechanisms for hierarchical variation nor do they address semantic generalization—central aspects for the interoperability of land use and land cover classes on multiscale bases.

At the same time, contemporary literature reinforces that generalization is no longer understood solely as operations aimed at legibility, but has come to incorporate spatial and semantic contexts, as well as strategies to preserve relationships between features and support multiscale modelling and analysis (Kronenfeld et al., 2020). This change is particularly relevant for UCT classes, since what needs to be generalized is not only the geometry, but also the meaning and relationships that structure the reading of the territory. In this direction, Steiniger and Weibel (2007) argue that consistent advances depend on context-sensitive operators and the concurrent treatment of multiple classes, precisely because part of the specialist cartographic knowledge is embedded in the inter-object relationships (semantic, topological and structural) that define patterns and structures to be preserved.

The proposal presented in Section 3.6 follows this logic by making explicit mechanisms for changing the level of detail that combine specialization at larger scales and generalization at smaller scales, in a controlled manner. This is evident in the treatment of the "Forest" class, whose separation between humid and seasonal formations, with subclasses at larger scales, meets the demand for greater discrimination at 1:25,000 without hindering synthesis at smaller scales. Furthermore, the proposal reinforces the importance of coherent conceptual levels and stable terminology, aligning the classes of the reference model with widely used national references in thematic mapping, reducing ambiguities when terms from different levels are employed as classes at the same level. This guideline is materialized, for example, in the replacement of "Cerrado" and "Caatinga" with terms compatible with the IBGE's technical classification ("Savanna" and "Savanna-Steppe") and in the reorganization of "Cultivated Vegetation," with the adoption of "Silviculture" in place of "Reforestation," bringing the model closer to current land use classification practices (IBGE, 2012; 2013). In terms of multi-representation databases, this control can be understood as the need to maintain consistent links between levels of detail ("vertical" relationships between scales) and, simultaneously, preserve coherence between objects at the same level of detail ("horizontal" relationships), which is crucial for topo-thematic interoperability.

4.3 Cartographic representation as a component of interoperability in digital environments

Another relevant finding is the emphasis on legibility and consistency of representation as part of the interoperability problem. The existence of a class associated with "symbolism," "legend," "colour," and "visual" (Section 3.2) indicates that, for the respondents, interoperability also implies that products are understandable and comparable when viewed in digital environments, often with multiple layers and different styles.

This dimension is consistent with approaches that highlight that usability and visual clarity directly impact how data is interpreted and integrated into digital workflows, including affecting reliability and reuse (Robinson et al., 2017). Thus, recommendations related to the review of graphic patterns, hatching, and representation alternatives should not be interpreted as isolated stylistic decisions, but rather as requirements for communicative adequacy and visual consistency (Buckley et al., 2005). They relate to the ability of users to understand classes and distinguish features consistently, reducing ambiguities when different datasets are combined.

Although the representation dimension has emerged as a relevant component in the experts' perception, this manuscript prioritizes the implications for conceptual modelling that precede symbolization decisions. A detailed analysis of the symbol review and the proposition of cartographic representations for UCT in topographic maps was developed in complementary work (Araujo et al., 2025), which the reader can refer to for further information.

4.4 Topo-thematic integration and lessons from initiatives in FDIs

The proposed modelling also aligns with recommendations discussed in integration initiatives within the context of Spatial Data Infrastructures, which emphasize the importance of common conceptual models and harmonized dictionaries to enable integration between topographic and thematic databases (Rocha Salamanca & Caro Arias, 1995; Olszewski et al., 2005). Although the present study does not aim to build a complete formal dictionary, the proposed adjustments indicate an incremental path: establishing correspondences and refining class criteria at points where semantic misalignment tends to impede interoperability, especially in the UCT/vegetation categories and at the 1:25,000 scale.

From this perspective, the study contributes to clarifying which components (nomenclature, conceptual level, scale dependence, and representation) emerge as critical based on qualitative evidence and how such components can guide the adaptation of the reference model to increase compatibility with national thematic products.

4.5 Limitations and research agenda

This study has some important limitations. First, the analysis was conducted in an aggregated manner, prioritizing corpus patterns and syntheses by questionnaire dimension, without systematic stratification by professional profile. Second, the empirical selection prioritized classes from the Vegetation category and a limited set of classes from other categories, which requires additional steps to generalize the proposal to the full scope of the ET-EDGV. Third, the modelling proposal should be understood as an initial contribution, to be refined through complementary validations, such as consistency tests, pilot application in databases, and evaluation with new experts and institutional users.

As a future agenda, it is proposed to expand the set of classes examined to encompass categories with greater spatio-temporal variability and heterogeneous classification criteria. It is also recommended to submit the proposal to operational evaluations in databases and publishing services in order to verify the implications of implementation and integration. Also noteworthy is the need for more in-depth studies on the use of local and regional terms and their compatibility with the diversity of Brazilian biomes and their particularities, in order to refine definitions, attributes, and class criteria without compromising the standardization necessary for interoperability. Additionally, future studies could incorporate comparisons by profile variables—such as education, institutional function, and region—when sampling conditions and analytical design are compatible with this objective.

5 CONCLUSION

This research investigated which characteristics of Land Use and Land Cover (LUC) data in national topographic mapping can favour interoperability with other official sources, with an emphasis on improvements in classification and conceptual modelling. To this end, a qualitative investigation was conducted based on technical interviews with experts linked to institutions responsible for producing maps in Brazil. Their responses were analysed using textual analysis and lexicometric exploration procedures, with support from IRaMuTeQ, articulated with discourse interpretation.

The results indicate that the interoperability challenges discussed by experts are not limited to technical compatibility, but focus primarily on conceptual and classificatory coherence, especially at the 1:25,000 scale, where class criteria, detail, and generalization rules become more sensitive. The analyses by question revealed recurring dimensions mobilized by the participants — including aspects of nomenclature and definition, scale dependence, and representation requirements — that help explain why topographic and thematic databases can coexist, but still present difficulties in integration and reuse in institutional applications.

Based on these findings, an adaptation of the conceptual model was proposed, seeking to align, when pertinent, the classifications of topographic mapping with the references adopted in national technical manuals, in order to increase semantic clarity, reduce ambiguities, and support scale-dependent decisions (for example, detail at larger scales and generalization at smaller scales). The main contribution of this study lies in systematizing recommendations derived from specialized knowledge and institutional experiences, translating them into modelling guidelines that can support the evolution of the reference model and promote interoperability between national products that represent similar phenomena. From a methodological point of view, the work also explores a strategy that is still uncommon in geospatial data modelling studies: using interviews analysed by Discursive Textual Analysis, with the support of lexicometric tools, as a basis for grounding semantic propositions and bringing producers and users closer together in a more systematic way in the definition of classes, criteria, and attributes.

It is worth noting that, although the dimension of cartographic representation and symbology has emerged as a relevant component in the interviews, in-depth analysis and the proposition of new symbols are not the focus of this manuscript, being addressed in complementary work (Araujo et al., 2025). In this article, the conceptual modelling stage is prioritized, which precedes and grounds the representation decisions.

As future work, it is recommended to expand the analysis to other categories and classes of the model, in order to verify to what extent the proposed guidelines are generalized to the rest of the ET-EDGV. It is also pertinent to carry out additional validations, including consistency tests of the model and its pilot application in databases and publishing services, to assess the operational and integration implications. Finally, evaluations with users and institutions are recommended to examine the impacts on interoperability between products, especially in multi-institutional workflows and in multi-scale contexts.

Authors' Contribution

Conceptualization, V. S. A., S. P. C. e N. B. L.; Formal Analysis, V. S. A.; Investigation, V. S. A.; Methodology, V. S. A., S. P. C. e N. B. L.; Supervision, S. P. C. e N. B. L.; Validation, S. P. C. e N. B. L.; Visualization, V. S. A.; Drafting – Initial Draft, V. S. A.; Writing - Reviewing and Editing, V. S. A., S. P. C e N. B. L. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors state that there is no conflict of interest.

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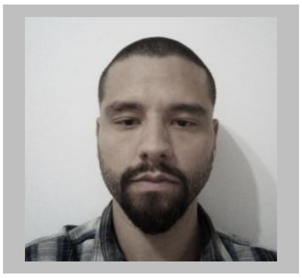
Biography of the main author



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