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ORIGINAL ARTICLE

Characterisation of stakeholders' roles in a thematic SDI: a study on the environmental SDI of NGI - ICMBio Antonina -GUARAQUEÇABA - PR

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Abstract:

In 2008 the International Cartographic Association (ICA) proposed a reference model to describe Spatial Data Infrastructures (SDI) based on the Reference Model of Open Distributed Processing (RM-ODP), which has been adapted and validated by several research projects. This paper details the experience of applying the extended ICA Model to an Academic SDI of environmental character and collaborative functions, such as the description of stakeholders' roles, functions, and responsibilities, called IDE-AMB (acronym in Portuguese). The intent is to transform the IDE-AMB into a database composed of information from several institutions and academic research. The stakeholders were described based on previously established literature and their needs for access, use, production, and sharing of geospatial data from different sources for the Integrated Management Center (NGI, acronym in Portuguese) ICMBio Antonina-Guaraqueçaba, located on the northern coast of the state of Paraná. We concluded that the ICA Model presents robustness; however, it still lacks conceptual reviews and needs to be adapted to the new realities and complexities of emerging SDI.

Keywords: Spatial Data Infrastructures (SDI); Thematic SDI; Local SDI; Conservation Unit; Stakeholders.

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1. Introduction

This paper describes stakeholders for implementing a Spatial Data Infrastructure (SDI) in NGI (Integrated Management Center, acronym in Portuguese) ICMBio Antonina-Guaraqueçaba, located on the state's northern coast of Paraná. This area corresponds to an organisational arrangement of a federal conservation unit that contains the largest continuous remnant of the Brazilian coastal Atlantic Forest.

The purposes of a Conservation Unit are to preserve native areas and promote scientific research, environmental education, and leisure. For these purposes to be achieved, it is necessary to implement planning and management systems that involve territory administration, including identifying knowledge gaps and priorities regarding the conservation and sustainable use of natural resources. The creation of environmental policies requires a substantial amount of geospatial information, from varied scientific data to the perspective and experience of the End User. Scientists continuously collect data, perform analyses, and generate useful information and recommendations for policymakers.

Geographic Information Systems (GIS) are commonly used to manage environmental information. However, the mere existence of geospatial data does not guarantee their availability since they are spread among various public and private entities. While GIS is employed for spatial production and analysis to support decision-making, SDIs privilege the exchange and sharing of data and services (Alonso, 2015). In this sense, SDIs have been used on several scales (regional, national, state, local, and corporate) to cover various objectives, such as territory management and academic research, and in different contexts, such as governmental and environmental ones (Nakamura, 2010; Ortiz, 2012; Fronza, 2016; Borba, 2017).

In the academic context, geospatial data available in Academic SDI have contributed to developing new research (articles, dissertations and theses), fostering technological development and new conceptual approaches (Brito et al., 2014; Machado, 2016; Coetzee et al., 2017). Moreover, in this type of SDI, data have a greater frequency of updating and added value than those produced by official sources, subsidising the action and decision-making by public managers (Brito et al.,2014).

In 2008, in the face of the emergence of SDIs for the most varied goals and purposes, in order to reduce the differences and ensure interoperability between them, the Spatial Data Standards Commission of the International Cartographic Association (ICA) proposed a Reference Model to describe several specific points of view of an SDI independent of technologies and implementations (Hjelmager et al.,2008). This model has been applied and evaluated by different researchers, mainly for the description of stakeholders in different implementation contexts (Cooper et al.,2011; Sinvula et al.,2013; Coetzee et al.,2017). However, in the last twenty-four years, proposals to improve the ICA model are still emerging, given the technological advancement and approaches that allow identifying the requirements of an SDI from its stakeholders.

In this scenario, this work presents the first application of the ICA Conceptual Model in Brazil to describe the stakeholders of a thematic SDI Environmental local and collaborative context. To this end, adaptations and extensions of the original model were carried out. Our work added to the ICA proposition a responsibility matrix for identifying and detailing the roles of stakeholders by mapping their needs. Thus, the proposed extended model can serve as a reference for other themes, such as municipal and regional SDIs.

2. ICA Reference Model for SDI

Stakeholders define the scope, objectives, and policies of an SDI, as well as the form of exchange of goods and/or services offered by the platform. However, stakeholders may have different views on the objectives and benefits of the SDI, depending on their position and level of participation.

Thus, several forms of SDIs for various sectors of society are developed by the geospatial community, based on conceptual models such as the Reference Architecture Model proposed by the International Organization for Standardization (ISO) TC 211, the Open Geospatial Consortium (OGC) Reference Model (ORM), and the Federal Geographic Data Committee Geospatial Reference Interoperability Model (GIRM). All these models are based on the ISO/IEC RM-ODP -Reference Model for Open Distributed Processing (ISO/IEC, 2008), which allows for the description of complex distributed systems and provides a reference overview to organise the constituent parts of an SDI, enabling the description without the need for implementation, regardless of technologies and policies (Béjar *et al.*, 2012; Oliveira and Lisboa-Filho, 2017).

In order to obtain a multi-perspective description of an SDI, the ICA Commission on SDI and Standards adopted the RM-ODP using the Unified Modeling Language (UML) to propose its own SDI reference model (Hjelmager *et al.*, 2008). The choice of modelling an SDI from RM-ODP concepts was motivated by the fact that the latter is an international standard, as it provides tools for the conceptual understanding an SDI from five perspectives: business, information, computing, engineering, and technology (Hjelmager *et al.*, 2008).

Six roles for the stakeholders of the ICA Model are described through the information perspective, which a UML use case diagram can represent. This model has been used to describe the constituent parts of an SDI and how they interact with each other at a high level of abstraction (Hjelmager *et al.*, 2008; Cooper *et al.*, 2011).

With the increase in spatial data availability and the possibility of integrating voluntary geographic information (VGI) into an SDI, stakeholders' roles were reviewed, and the Reference Model was extended through functions called "subtypes" and "sub-subtypes" by Cooper *et al.* (2011). From this perspective, Béjar *et al.* (2012) extended this model by considering the relationships between the SDI and the interactions affected by the policies and the adoption of the UML4ODP profile to describe the model from an enterprise viewpoint. Based on these extensions and adaptations, Oliveira and Lisboa-Filho (2017) proposed a new version with seven main roles that the actor can assume and interact within a corporate SDI.

When applying the ICA Model, Owusu-Banahene *et al.* (2013) and Sinvula *et al.* (2013; 2017) outlined the stakeholders of National SDI (NSDI) in Ghana, Namibia, and South Africa and identified their different roles and specific characteristics. Their studies emphasise the need to understand stakeholders' roles and motivations for implementing NSDI in developing countries.

Macharis and Crompvoets (2014) applied a method based on multi-criteria analysis to evaluate different alternatives for developing SDI, combining different alternatives to satisfy all stakeholders. However, as seen in this section, the ICA Model is the primary reference for conceptual modelling of an SDI since it includes all the steps for its implementation.

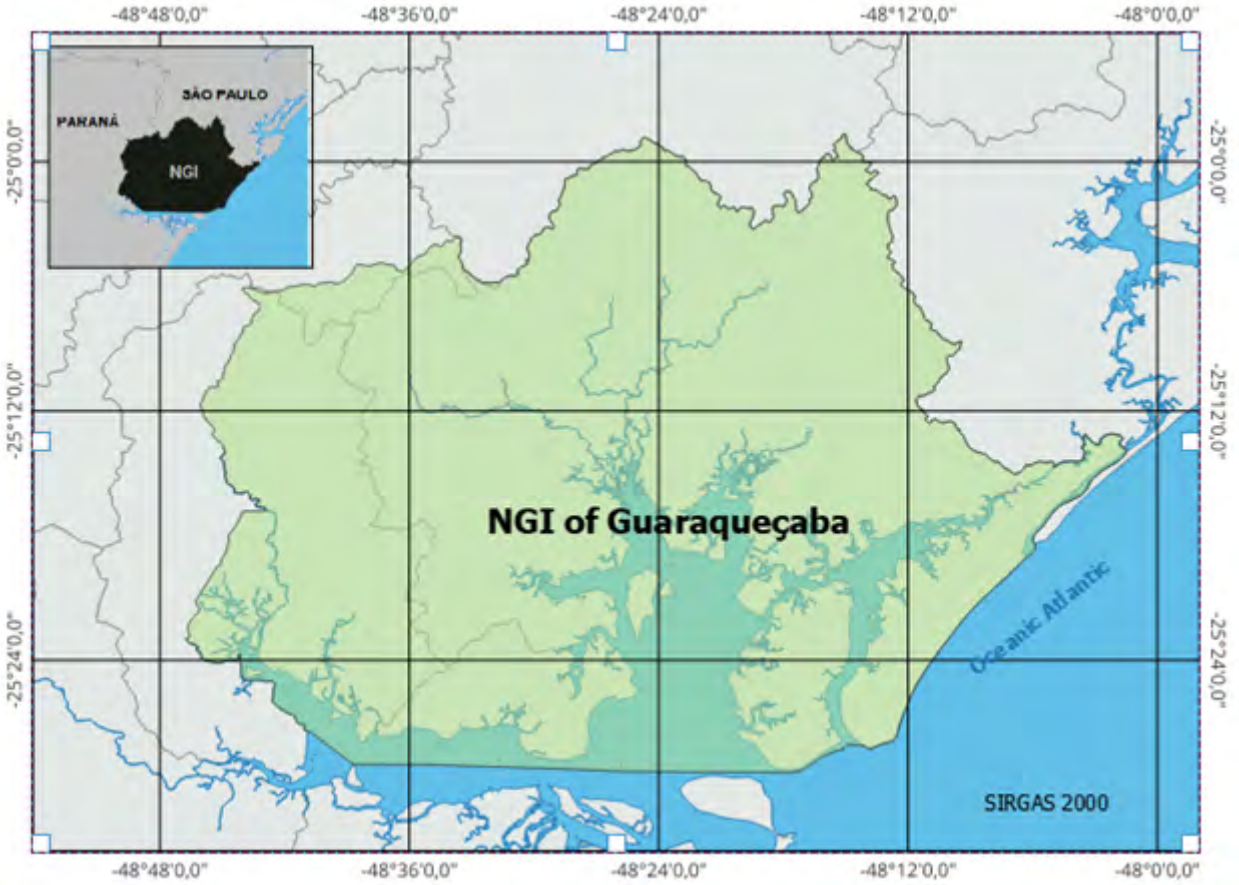
3. Methodology

3.1 Study Area

A Work Plan titled "Support and Technical Support Actions for the Planning and Management of the Federal Conservation Units of the Northern Coast of the State of Paraná" was designed based on the experience of the activities developed within the scope of the Practices in Environmental Planning and Management (GB130) unit offered at UFPR's Department of Geography, as well as the Environmental Management of the Territory (GB736) unit at UFPR's Graduate Program in Geography. The Work Plan was signed under the Technical Cooperation Agreement between UFPR and ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade). This cooperation mainly

focuses on scientific, didactic, educational, and cultural exchanges related to research projects, technological development, technology transfer, and environmental education.

Among the specific objectives of this agreement is the construction of an environmental geographic database called BDG-AMB (acronym in Portuguese), intended to integrate the geospatial information of the NGI - ICMBio Antonina-Guaraqueçaba (Figure 1) and the subsidising of decision-making processes in the management of Federal Conservation Units.



Source: The authors (2022)

Figure 1: NGI - ICMBio Antonina-Guaraqueçaba, north coast of the state of Paraná.

Initially, the BDG-AMB database aimed to integrate the environmental data provided by government agencies, research institutes, and scientific publications. The main issue, however, was the acquisition of data in different formats, with topological inconsistencies and an absence of metadata (Paula *et al.*, 2017).

Since its design in 2014, the BDG-AMB has advanced substantially due to the recognition of the importance of an information system for integrating scientists, policymakers, and citizens as a decisive contribution to the sharing, distribution, reception, and interoperability of data. Thus, in 2017, an SDI, called IDE-AMB was planned to standardise and share geospatial data and metadata to meet the new demands of the UFPR-ICMBio cooperation.

Therefore, the modelling proposal described in this paper was essential, as the purpose of the IDE-AMB is to provide geospatial technical grants for territorial planning. Furthermore, it also aims to promote collaborative discussions regarding environmental problems and data integration and exchange among the various actors of the region.

3.2 Approach for the conceptual modelling of the IDE-AMB

Figure 2 illustrates the flow of this work to build a conceptual reference model for an IDE-AMB.

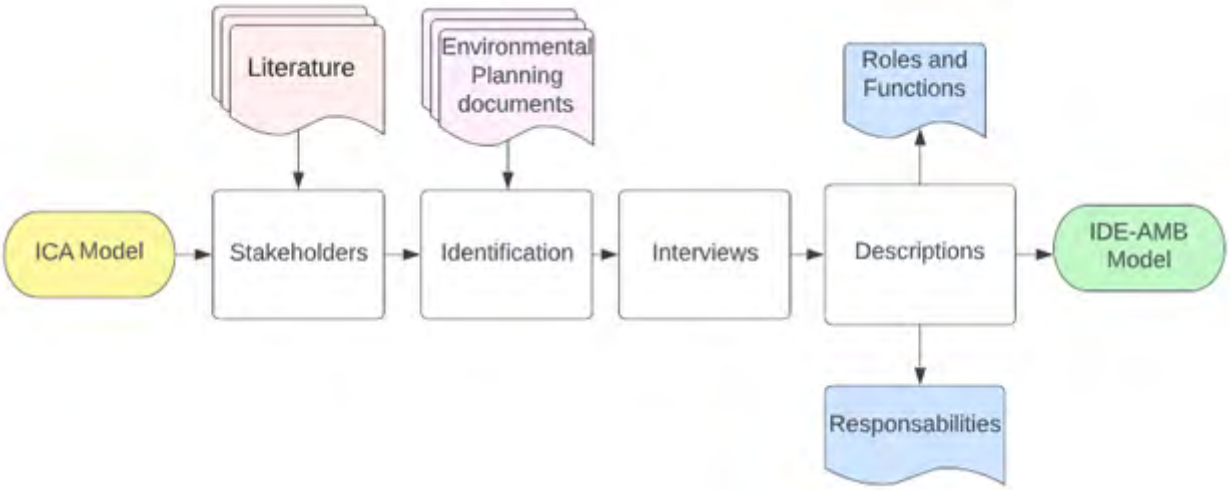


Figure 2: Steps for IDE-AMB Model

The first step for describing the stakeholders consisted of surveying all the actors that use and produce geospatial information, as well as those who generate non-spatial data and have the potential to contribute to the BDG-AMB and, consequently, to the IDE-AMB. The survey was conducted to review existing primary and secondary data sources, such as scientific publications, newsletters, workshops, seminars, conference materials, and technical meetings.

The description of the stakeholders focused on assessing their needs regarding access, use, production, and sharing of geospatial data. The identification of stakeholders, in turn, was based on the following environmental planning instruments: Integrated Development Plan for Sustainable Tourism (2017), Sustainable Development Plan for the Coast of Paraná (2018), Coastal Ecological Economic Zoning (2016), and Management Plans for the Conservation Units located in the Coast of Paraná.

The research was complemented by interviews with environmental managers, researchers, and professionals working in the region, seeking to identify the following aspects:

a) the geospatial data produced and their application to territorial planning and biodiversity conservation;

b) how official and unofficial geospatial data are made available and shared, as well as the existing conditions and platforms for that;

c) the researchers, professionals, groups, and institutions that work in the region.

The second step consisted of grouping and describing the stakeholders according to their area of interest. Finally, in the third step, the stakeholders were described using the ICA Model (2008), considering the proposals of Cooper *et al.* (2011), Béjar *et al.* (2012), and Oliveira and Lisboa-Filho (2017). Firstly, general roles were described by a use case diagram; then, a class diagram was used to represent their extended functions, considering each stakeholder's state, motivation, role, and ability.

Although extended, the ICA Model lacks a way to represent stakeholders' responsibilities schematically. Therefore, it was adapted to a Responsibility Assignment Matrix (RAM). The responsibilities described below are

adaptations made to the matrix presented by Sabbag (2013) for the IDE-AMB, with stakeholders (as individuals or groups) that are actively involved in the study area of NGI - ICMBio Antonina-Guaraqueçaba.

R (Responsible): is fully responsible for a function or activity;

A (Active): has active participation in a function or activity;

P (Passive): has passive participation in a function or activity, i.e., only consumes or provides data and services;

V (Versatile): their assignment can change or be adapted; they possess skills within a specific or general area.

4. Results

4.1 IDE-AMB Stakeholders' roles

The use case diagram below (Figure 3) illustrates the stakeholders' initial and general roles and the reorganisation applied according to their needs. The conceptual model allows an individual or an organisation to have more than one role and shows that their functions can be transferred to or overlap with others. For example, the IDE-AMB proposal is that a stakeholder can be assigned a consumer, producer, and user data provider role. In this sense, the Value-Added Reseller (VAR) role — in red in Figure 3 — was suppressed since its aggregator function can be performed by Providers, Producers, and Users (in black).

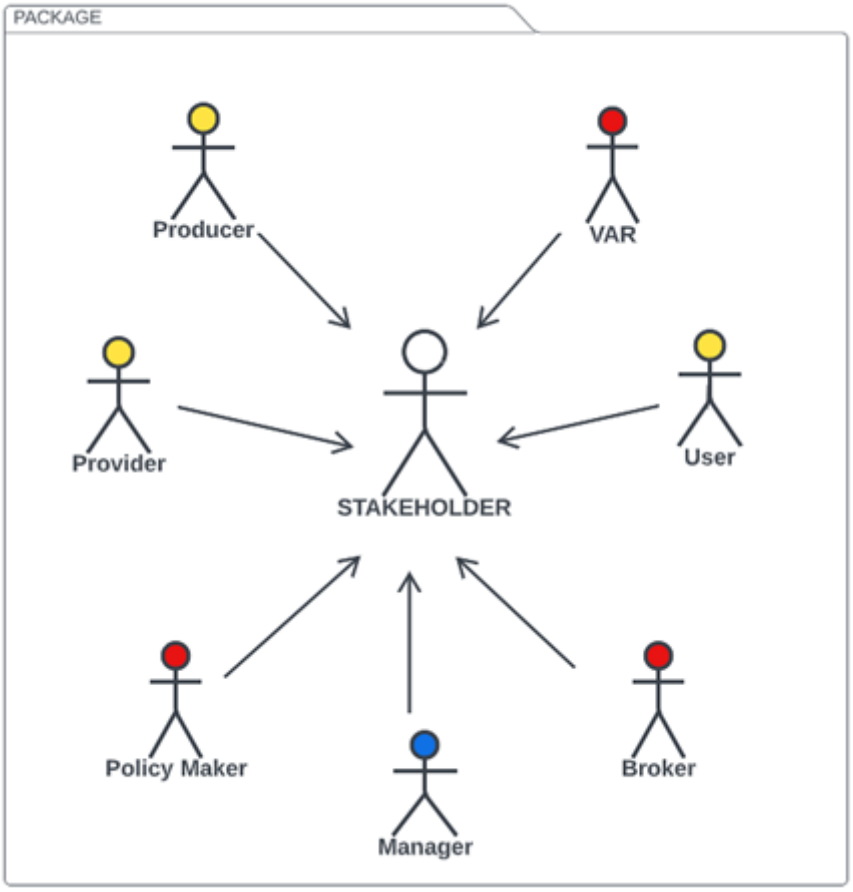


Figure 3: Use Case Diagram of IDE-AMB, adapted from Hjelmager et al. (2008)

The Policy Maker and Broker roles (in red) were suppressed, and their functions were transferred to a new role called Manager (in blue). The Broker's main function in the ICA Model is to review data and metadata. In this IDE-AMB model, the Broker's function can be attributed to all existing roles, emphasising the level of responsibility and technological solution used.

4.2 IDE-AMB Stakeholders' Functions

For the conceptual model of the IDE-AMB, the ICA Model was reorganised, and new extended functions were added to it, allowing the stakeholders to be assigned more than one role and, respectively, more functions.

The class diagram below (Figure 4) illustrates the hierarchy that can be assigned to the main stakeholder class (in purple). The subclass (in blue) defines the role assigned to the stakeholder in the conceptual model of the IDE-AMB. The "Function" subclass (in yellow) represents the different tasks that can be assigned to each role.

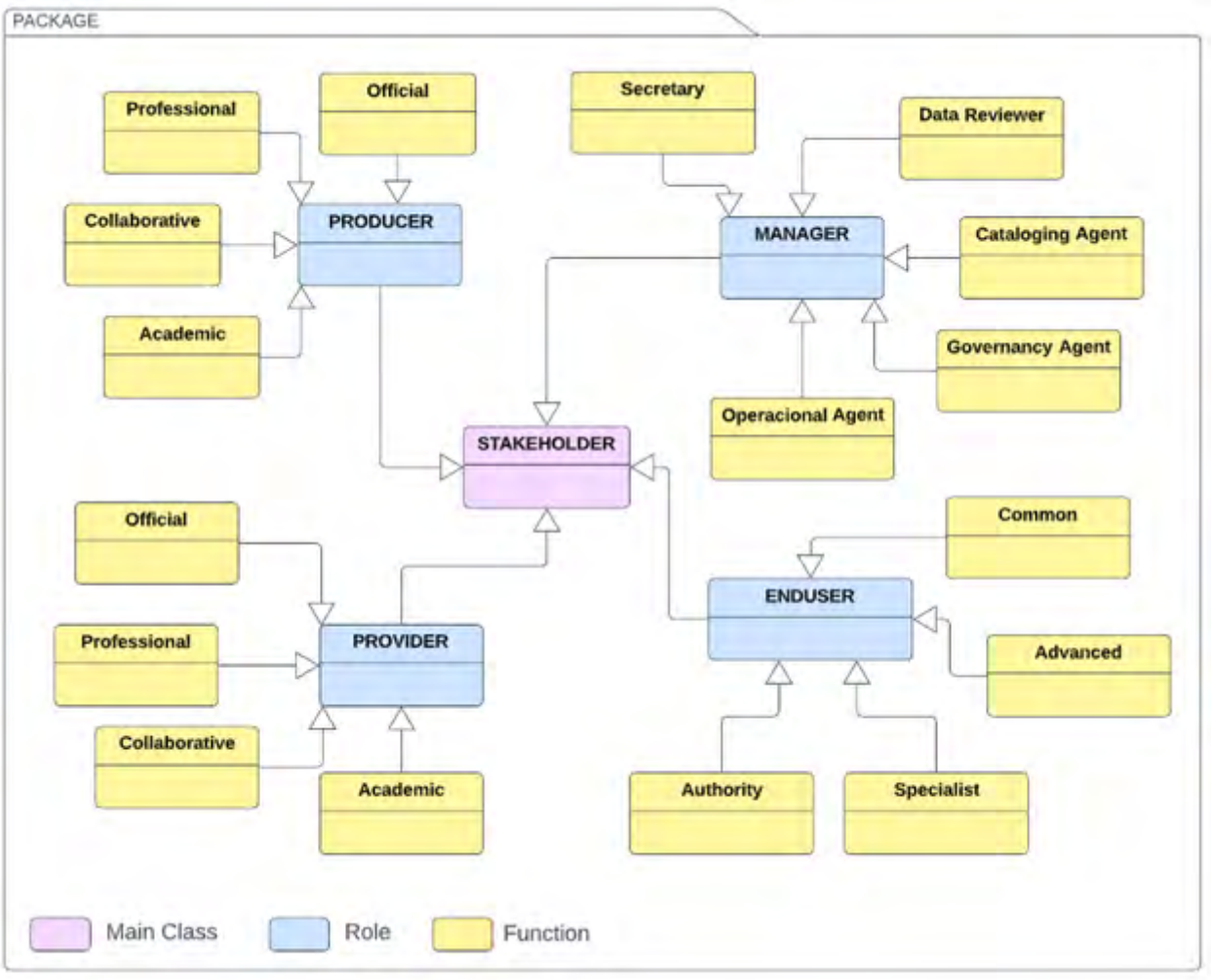


Figure 4: UML Class Diagram in the formal model, adapted from Coetzee *et al.* (2017) and extended for the IDE-AMB

The general and detailed roles of stakeholders for the conceptual model of the IDE-AMB are described below:

• USER

In this model, the user is the actor that uses the SDI for different purposes, exploring the functionalities of visualisation, manipulation, and transformation of data to be applied in other products and formats with different purposes, such as mapping and spatial analysis. In this way, the user consumes the data and services provided by the SDI to achieve their goals. Citizens in general, professional technicians, researchers, government officials, consultants, and private companies are examples of end users, all of which can have different levels of knowledge and skill, being classified as either a layman or an experienced professional in the use of geospatial data. Concerning the use of geospatial data, the users for the IDE-AMB were defined as:

Common: not a GIS software user, but has limited ability to use geospatial information. This user does not have the required technical knowledge to determine the quality and use of geospatial data and services.

Advanced: has the ability to operate GIS software and use geospatial information. Has limited technical knowledge to determine the quality and use of geospatial data and services.

Specialist: has technical/professional training in geosciences and related areas, proficiently using GIS software and geospatial information. Has technical knowledge to determine the quality and use of geospatial data and services.

Authority: uses GIS software and geospatial information, being recognised as an expert by the academic, governmental, or private sector. Has technical knowledge to determine the quality and use of geospatial data and services.

• PRODUCER

The role of adding new products (data and services) is attributed to the producer, who may be an individual, a group, or an institution. Differently from the ICA Model, the functions of the producers were reorganised and simplified for the IDE-AMB model as follows:

Official: an organisation with the budget, resources, and legal attribution to execute and produce geospatial data in one or more areas of interest, for instance: topographical, cadastral data, hydrography, meteorological, geological, and others. This organisation may be public or private, as long as it is hired for this purpose.

Professional: an individual or a nonprofit organisation that produces data and products as part of their activities.

Collaborative: a legal entity, group, or person that produces reference and/or thematic geospatial data, with or without official data support, for different purposes of public or private use. This function includes VGI (Volunteered Geographic Information) platforms and other geographic crowdsourced data initiatives, where non-specialised users create geospatial data. For this profile, there is a need to check the quality of the information provided to eliminate false or malicious contributions, such as the collaborative platform *OpenStreetMap*, which uses a technological solution to assess the reputation of its users.

Academic: a legal entity, group or person that produces reference and/or thematic geospatial data for academic purposes, such as teaching, research, and community outreach, with or without official data support from primary or secondary sources to provide environmental, social, and economic information and/or descriptions.

• PROVIDER

Providers can act as both a producer and a distributor of data. They can consume their own datasets and make them available to producers and end users. Typically, they are institutions that provide location and web mapping services and make their data available through formal requests, via electronic form, email, or through websites and geo-portals. Services are available through geoservices such as Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS).

• **MANAGER**

In this model, the Manager role replaces the roles of Policy Maker and Broker. Its extended functions are related to the IDE-AMB administration, operationalisation, quality control, policies, standards, and technical and process coordination. This actor can be an individual, a group, a committee, and/or an organisation taking over some or all of the different roles described below:

Operational Agent: responsible for ensuring the technical operation of the SDI. This role can contain four specialisations: technical support, system administration, database administration, and user management.

Data Reviewer: responsible for ensuring the quality of geospatial data. This actor was adapted from the Broker role of the ICA Model.

Cataloguing Agent: responsible for ensuring the quality of geospatial metadata, this actor incorporates the activities performed by the Broker of the extended ICA Model.

Governance Agent: the actor who defines the existence of the IDE, the policies to be applied, the data quality criteria, the restrictions etc. It is essential for them to understand geospatial data and its applications. Therefore, the term "Lawmaker" used by Cooper *et al.* (2011) has been changed to "Governance Agent".

Secretary: has the function of technical, financial, and general coordination of an SDI. They have the attribution to follow and apply policies, norms, and standards. Moreover, they have the prerogative to facilitate communication among stakeholders and ensure the proper functioning of the processes.

4.3 IDE-AMB Stakeholders

The stakeholders were grouped according to the general criteria of access, query, consumption, and geospatial data and metadata production. In addition, aspects of frequency, involvement, and data provision, as well as services with a direct or indirect relationship to official data, professionals, and collaborative academics, were also considered, as described below:

Government: corresponds to the various public institutions that compose the federal, state, and municipal governments and are not part of the academic and utility groups. The three levels of government may have similar goals but different priorities. Institutions and government authorities may have different profiles regarding their objectives concerning the use and availability of geospatial data. Regarding the IDE-AMB, for example, ICMBio can act as a provider of geospatial data while also using data produced by other sources.

Academic: consists of public or private Universities and Research and Development Centers. These organisations are recognised as major consumers and producers of geospatial data, which they do to support scientific research and for various environmental, social and economic purposes. The main needs of this group are the use of data, metadata, and services for production, analysis, and processing purposes. The capacity for carrying out scientific research in the NGI region of Antonina-Guaraqueçaba is closely related to adequate data availability and metadata documentation. Besides advancing technological innovation, academics can also act as advisors in policy-making and standardisation processes.

NGO/MP: Non-Governmental Organisations (NGO) and the Federal Public Prosecutor's Offices (MP, acronym in Portuguese) were grouped in this category. They usually consume geospatial data in order to subsidise public interest actions. In addition, they use spatial information regarding conservational aspects to analyse environmental indicators and act mainly as official data aggregators. Noticeably, NGOs usually provide geospatial data with little compliance with existing standards.

Private: corresponds to independent contractors and private companies in the geotechnology and territorial planning fields. They are large consumers of public data, as well as primary and secondary data providers. Their relationship with nature conservation is closely linked to preparing environmental impact reports for public construction and installations of large enterprises.

Utility: refers to the utilities sector. They produce a significant amount of geospatial data but with sharing restrictions. They use geospatial data to plan and distribute services, aiming to reduce operational and maintenance costs. These groups have special interests and produce geospatial data for their own consumption.

Society: corresponds to society in general. All users who potentially use geospatial information are in this group and those that have not yet been categorised.

4.4 Expansion of the conceptual model for the IDE-AMB

For the proposed conceptual model for the IDE-AMB, each stakeholder was assigned responsibility through a RAM (Table 1), which presents the role, function, and responsibility that can be assigned to each stakeholder in a detailed and systematised way. There were cases, however, in which it was impossible to assign responsibility directly.

The horizontal axis shows the different stakeholders organised in common groups, as described in the previous section, according to their needs for access, use, production, and provision of geospatial data, as well as their involvement with the management of the IDE-AMB.

The vertical axis presents the stakeholders' roles in the proposed conceptual model, subdivided into functions for the IDE-AMB. Through the intersection between columns and rows, responsibilities are assigned to each group, them being R (Responsible), A (Active), P (Passive), and V (Versatile).

Table 1: Summary of stakeholders' roles, functions, and responsibilities

Role	Function	Stakeholder					
		Government	Academic	ONG/MP	Private	Utility	Society
User	Common	A	A	A	A	A	A
	Advanced	A	A	A	A	A	A
	Specialist	A	A	A	A	A	A
	Authority	A	A	-	-	V	-
Producer	Official	R	A	-	V		-
	Professional	-		A	R	V	A
	Collaborative	P	A	A	-	V	A
	Academic	P	R	V	-	-	-
Provider	Official	R	A	-	V	P	
	Professional	P	V	-	V	P	P
	Collaborative	P	-	P	-	-	P
	Academic	P	A	P	-	-	P
Manager	Operating	A	A	-	-	A	-
	Cataloguer	R	R	A	-		A
	Statutory data	V	V	V	P	P	P
	Governance	V	V	V	P	A	V
	Secretary	A	R	-	-	-	-

Legend: R (Responsible), A (Active), P (Passive), and V (Versatile).

The letter R indicates that the group holds responsibility regarding access, production, provision, or management. For instance, the Government group is responsible for the production of geospatial data; however, it has passive (P) participation in collaborative data, being, in this case, limited to using VGI data only.

The intersection corresponding to the letter A indicates that a particular group has an active relationship. For example, an academic group can act as a producer of academic and collaborative data; however, it does not participate in the production of official data.

In the intersection represented by the letter V, the actor may or may not perform a particular function. For example, a group of private companies, which can be producers of official data, may be hired for this purpose.

The RAM allows for multiple combinations between different roles and stakeholders. It is worth noting that each IDE-AMB has a different dynamic, depending largely on the objectives and involvement of stakeholders.

5. Conclusion

This study presented the migration process from a BDG to a proposal of a Local Thematic Academic SDI (IDE-AMB) proposal for the NGI – ICMBio Antonina-Guaraqueçaba. Migration to an SDI enabled sharing and technical-scientific advancement for the UFPR-ICMBio cooperation. As the IDE-AMB is under development, it has been useful to apply the extended ICA Model to describe the stakeholders within a specific context, i.e., management and geospatial data intended for biodiversity conservation by various official and unofficial sources, especially coming from scientific research. The interested community is relatively small but with a high degree of knowledge and

needs regarding the consumption and sharing of geospatial data.

Stakeholders were described from the requirements obtained through literature review, scientific publications, workshops, seminars, conferences, technical meetings, and interviews with managers and researchers.

The incompatibilities of the model's application resulted in a new template version that was adapted and extended. The reorganisation of roles, functions, and attribution of responsibilities allowed the proposition of a more simplified model with reduced subjectivity based on the ICA Model. The strengths of collaborative data are the enrichment of outdated or incomplete official information, whereas their weak points are heterogeneity and lower reliability, both of which are considered gaps that need further research.

In general, the conceptual model recognises stakeholders by providing subsidies for their functions and responsibilities, which need to be more thoroughly studied. It should also be noted that other unpredicted combinations may be contemplated in future modelling. In this sense, the adopted model presents robustness since it admits flexibility and further adaptations according to one's objectives, context, and new interactions. At this stage of the research, no semantic problems were discussed.

The use of the RAM proved effective and offered a starting point for including stakeholders' responsibilities in the ICA Model. Although the RAM is not described in the UML, its adoption is valid as it details the stakeholders, positively identifies minor problems and avoids the repetition of errors, thus minimising conflicts created by incorrect assignments. This RAM also provides subsidies for the review of policies, norms, and standards, saving time and resources. It is expected that the reduction of roles and the adaptations presented in this paper will lead to advances and refinements of the ICA Reference Model.

Several challenges must be considered concerning the importance of using the ICA Model for stakeholder description, particularly regarding the emergence of new SDI proposals addressing various issues. In this paper, the discussion regarding the management of Conservation Units was pertinent since it addresses the need for involvement and coordination of governmental, non-governmental, and academic agents. Future works should describe the stakeholders in more detail and apply the other four points of view proposed by the RM-ODP for the IDE-AMB.

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AUTHOR'S CONTRIBUTION

All authors contributed equally.

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