A Gift to the Future: LADM Modeling as a Basis for Integrating the Indigenous Theme into the Land Management System in Brazil

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SUMMARY

Environmental challenges have compelled States to seek innovative and effective solutions. At the same time, the effectiveness of ancestral knowledge has been scientifically demonstrated and is evidenced by the preservation of lands occupied by Indigenous peoples since time immemorial. In this context, this article aims to present a conceptual model for managing Brazilian Indigenous issues through the National System of Territorial Information Management (Sinter), aligned with the international Land Administration Domain Model (LADM) and the Social Tenure Domain Model (STDM). To this end, a structured framework is proposed that encompasses Indigenous issues in their territorial, legal, administrative–financial–budgetary, socioeconomic, and temporal dimensions. The proposal seeks both to incorporate Indigenous cosmology into land management systems and to integrate territorial data with the Indigenous Individual Registry, based on knowledge obtained through fieldwork in Indigenous lands and in technical–institutional contexts. The Object Modeling Technique for Geographic Applications (OMT-G), an extension of object-oriented modeling, was employed for the proposed integration with LADM classes and attributes. It is expected that the model will contribute to strengthening the guarantee of fundamental rights for Indigenous peoples and to disseminating the understanding that ancestral cosmovision broadens the socio-environmental perspective in land regulation. The article concludes that the LADM model needs to evolve to consider relationships with land in which it constitutes an inseparable part of the inhabitants' identity, and to reforest the technical-scientific thinking that underpins the epistemological foundations of territorial management systems.

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1. CONTEXTUALIZATION

Indigenous issues are characterized as the set of matters encompassing policies for the protection, promotion, and guarantee of rights for native peoples and their lands, which in Brazil are deliberated by various governmental institutions and organized civil society. Within the normative–institutional framework, these institutions converge significantly on fundamental points such as respect for the autonomy of Indigenous peoples, recognition of their cultural and linguistic diversity, and observance of their social, historical, and environmental specificities. There is also convergence regarding the participation of Indigenous representatives and the National Foundation of Indigenous Peoples (Funai) in institutional activities relevant to them.
Despite this, the systemic inefficiency of the apparatus managing Indigenous issues is evident in three critical aspects: the chronic vulnerability to which a large portion of native communities is subjected; the systematic degradation of their lands and territories (a concept that incorporates the cultural and spiritual dimensions of their relationship with the land); and the perpetuation of land conflicts, aggravated by more than three decades of non-compliance with the constitutional deadline for concluding demarcations, as established in Article 67 of Brazil's Federal Constitution. In addition, there has been an increase in the Indigenous population living in precarious urban conditions—according to data from the Brazilian Institute of Geography and Statistics (IBGE, 2022)—which highlights the challenge of fulfilling constitutional duties and international commitments assumed by the Brazilian State.
Furthermore, although the serious adversities affecting Indigenous peoples are widely known, there is no record of prominent cases in which public officials—whether individuals or legal entities—have been held accountable for administrative misconduct, either by action or omission in fulfilling their protective duties. Thus, despite their evident expropriatory intent, various violations have been passively witnessed by rulers and by much of Brazilian society as depersonalized and unaccountable collective organisms. Paradoxically, the ancestral ecological knowledge of traditional populations has gained increasing recognition internationally as an indispensable element for territorial and environmental management and for preserving planetary biodiversity, as confirmed by studies such as Hanspach et al. (2020), Turner (2021), Nitah (2021), and Levis et al. (2024).
Within this panorama, States have been compelled to jointly pursue innovative solutions that ensure the sustainability of life on Earth, and Brazil, in particular, is expected to fulfill the commitments it has undertaken before the international community. From these considerations, it becomes evident that in Brazilian territory—and perhaps on the planet—the protection of nature and Indigenous issues are intertwined within the same web of life, since much of the forest that still breathes does so because its autochthonous inhabitants (re)exist. It is therefore the responsibility of governments to connect the vertices of this socio-environmental geometry, where each point represents a people and each angle, an ancestral right that reverberates across

all aspects of human continuity. In other words, the permanence of these peoples in their lands and territories not only reconstitutes the basis of social justice in the country but also constitutes a crucial factor for biodiversity preservation and global climate balance.

When considering possible alternatives for interoperable management of Indigenous issues, it is clear that the Brazilian federal government already possesses a technological framework with adequate potential, requiring only direction or optimization for the intended purpose. This framework is the National System of Territorial Information Management (Sinter), which integrates cadastral, geospatial, fiscal, and legal data related to real estate, including Indigenous Lands (ILs). Administered by the Federal Revenue of Brazil, Sinter is regulated by Decree No. 11,208 of September 26, 2022, and stands as a strategic technological resource, given that it is already developed, implemented, and normatively compatible, and further provides the appropriate architecture to incorporate a thematic layer that promotes interoperability and accountability concerning aspects surrounding Indigenous issues.

In addition to Sinter, the Federal Revenue Service (RFB) also manages the Individual Taxpayer Registry (CPF), a registry established as sufficient to identify Brazilian citizens across public service databases, under Law No. 14,534 of January 11, 2023. The CPF is also the main attribute of the Citizen Base Registry, instituted by Decree No. 10,046 of October 9, 2019, with the purpose of improving public policy management and enabling the cross-referencing of official cadastral databases to enhance governance, among other objectives.

By managing these systems, the RFB positions itself as a central actor in the construction of a modern and inclusive land administration model responsive to emerging socio-environmental challenges. This is because, by integrating cadastral, geospatial, and legal data within Sinter and establishing the CPF as a unique identifier, the agency has the necessary structure to harmonize territorial and sociodemographic information, aligning with the LADM standard and its extension, the STDM. Consequently, the cross-referencing of CPF data with territorial information from Sinter provides ideal conditions to strengthen land governance, promote interoperability, and reinforce accountability—essential strategies in a context as sensitive as Indigenous issues.

This approach can also enhance the informational visibility of Indigenous peoples, since their absence in official records reflects a historical pattern dating back to Brazil's earliest population surveys (Oliveira, 1997) and persisting today, as indicated by recent research from the Institute of Applied Economic Research (IPEA) (Silva, Lunelli, & Souto, 2024). This omission is also reproduced in the development of public policies and national legislation, as in the General Data Protection Law (LGPD—Law No. 13,709 of August 14, 2018). By categorizing ethnic origin as sensitive information, the LGPD failed to recognize it as a fundamental identity marker of Indigenous peoples, disregarding their longstanding claim to the right to express their ethnic identity in their surname and potentially perpetuating their invisibility in governmental information systems.

From a perspective essential to this work, the correspondence between Indigenous peoples and their lands reflects a central aspect of their cosmology: the understanding of land and beings as inseparable elements. This pertinence is captured in the reflection of Indigenous leader Ailton Krenak (Krenak, 2020), who, by conceiving the human body as part of the Earth's body, reveals the persistence of a relational ontology that integrates nature and humanity into a living fabric of reciprocities. This vision, far from being a mere philosophical abstraction, materializes in the daily practices of territorial management that have ensured, over millennia, the preservation

of the most biodiverse, healthy, and intact lands and waters that remain on the planet, as documented by the studies previously cited. The history of this safeguarding reveals, however, that these people–territory communities have sacrificed their own lives in defense of their groups and ecosystems, a crucial contribution to the protection of the natural heritage now recognized globally.

In light of these arguments, this article aims to present a conceptual model for managing Brazilian Indigenous issues through the National System of Territorial Information Management (Sinter), aligned with the international standards of the Land Administration Domain Model (LADM) and the Social Tenure Domain Model (STDM). To this end, a structured framework is proposed that enables the representation and integration of territorial and cadastral data of Indigenous peoples, drawing upon knowledge obtained both from fieldwork with native communities and from technical–institutional contexts. The proposal seeks to contribute to the improvement of public policies and the guarantee of fundamental rights for Indigenous peoples, as well as to strengthen land management systems in ways that support the preservation of their places of origin, including as a mechanism for maintaining ecological and socio-environmental balance.

2. METHODOLOGY

Having established the thematic focus of this work, the methodological procedures were structured in four stages: (i) a bibliographic review to ground the key concepts related to Indigenous issues and to deepen the authors' understanding of land administration, particularly the innovations introduced by ISO 19152-1:2024; (ii) characterization of Indigenous issues with the identification of the main agencies and entities responsible for addressing them, which, at the federal level, are linked to the Ministry of Health (MS), Ministry of Education (MEC), Ministry of the Environment and Climate Change (MMA), Federal Public Prosecutor's Office (MPF), Ministry of Agrarian Development and Family Agriculture (MDA), Ministry of Social Development and Assistance, Family and Fight Against Hunger (MDS), Ministry of Justice and Public Security (MJSP), and Ministry of Indigenous Peoples (MPI); (iii) analysis of the regulations related to the Individual Taxpayer Registry (CPF), the National System of Territorial Information Management (Sinter), and the cadastral data extracted from the CPF management system, maintained in the RFB database; and (iv) definition of the classes and basic elements that will enable the integration of geospatial and socio-environmental data, followed by the adaptation of the classes and their respective attributes to support a modeling simultaneously anchored in Indigenous cosmology and the LADM standard, in line with the descriptive character of this model, as defended by Lemmen (2012).

For the development of the final stages, a conceptual map was elaborated to represent the political–administrative structure of Brazil, the institutional relationships that impact Indigenous peoples' rights, and the connections that should inevitably be integrated into the modeling (Figure 1). To design the class diagram of the conceptual model of the Indigenous thematic layer, the web tool OMT-G Designer (available at http://aqui.io/omtg/#) was employed to describe the classes, relationships, and cardinalities related to Indigenous Lands, villages, and Indigenous citizens. This tool enables the application of the Object Modeling Technique for Geographic Applications (OMT-G), an extension of object-oriented modeling

adapted to Geographic Information Systems. Based on UML, OMT-G provides a formal conceptual structure for representing geographic entities, organized into two types of classes: conventional (non-spatial objects) and georeferenced (objects with location and shape in geographic space). Developed by Borges (1997), OMT-G has become one of the most widely used methods for spatial data modeling in Brazil and was applied by the National Cartography Commission (Concar) in modeling the Brazilian National Spatial Data Infrastructure (INDE), established by Decree No. 6,666 of November 27, 2008. In addition, OMT-G is compatible with the classes and relationships defined in ISO 19152-1.

3. MODELING THE INTERFACES BETWEEN BRAZILIAN FEDERALISM, INDIGENOUS THEME AND LADM/STDM

Understanding, even minimally, the Brazilian political-administrative structure is fundamental to analyzing how the rights of Indigenous peoples are (or should be) recognized, guaranteed, and implemented in the country. In this regard, it is pointed out that, according to the Constitution of the Federative Republic of Brazil of 1988 (CRFB/1988), the Federative Republic of Brazil is the legal entity of public external law composed of the Union, the States, the Municipalities, and the Federal District. The Union is the central entity and, although it has exclusive competence to represent Brazil in its international relations, it is not to be confused with the Federal State, since it is merely a member of internal public law, as are the other federated entities.

On the international plane, the Brazilian State committed to recognizing the identity and the individual, collective, and territorial rights of Indigenous peoples by internalizing Convention No. 169 of the International Labor Organization (ILO) in 2002, later promulgated by Decree No. 5,051 of April 19, 2004. It is emphasized, however, that in the domestic domain, the CRFB/1988 had already established a specific legal regime for Indigenous lands, qualifying them as property of the Union over which Indigenous peoples have the right to exclusive and permanent usufruct, and obliging the Union to "demarcate them, protect them, and enforce all their assets" (CRFB/1988, art. 231). This article also recognized for Indigenous peoples "their social organization, customs, languages, beliefs and traditions, and the original rights over the lands they traditionally occupy."

It is from these two institutes, ILO Convention No. 169 and the CRFB/1988, that the duty of the other federative entities to protect Indigenous rights originates, which are exercised within the scope of their constitutional competences. Thus, in the exercise of its attributions, the Union delegates its competence to deal with Indigenous issues to the ministries mentioned in the methodology section, specializing it in sectors (health, education, etc.); while the States, Municipalities, and the Federal District fulfill their obligations through their respective specialized secretariats. In this structuring, the institutional responsibility of civil society also arises, resulting from its own initiative and the establishment of partnerships with public institutions of the federated entities, as occurs with Non-Governmental Organizations (NGOs), associations, and other entities, generally non-profit.

3.1 The Inseparability between Indigenous Lands (ILs) and their peoples in the model

The integrative modeling of Indigenous issues in Sinter, aligned with the LADM/STDM standard, proved challenging due to the complex Brazilian political-administrative structure and its effects on the competences of the entities responsible for managing the Indigenous issue. In the comparison between the configuration of the governance of the Indigenous theme and the "Party" package, it was observed that, as federated entities, the States, Municipalities, and the Federal District have constitutional responsibilities over the lands and autochthonous peoples, without, however, holding domain rights over the ILs—since these constitute assets of the Union. It was also verified that, in the LADM/STDM conception, the overlap between the Union's property right and the collective possession right of Indigenous peoples (ethnic groups) establishes a legal relationship in which the Union and Indigenous peoples figure, respectively, as distinct parties of the territorial relationship with the ILs. Despite the conceptual adequacy of this verification, it was identified that the inclusion of Indigenous persons as member-party of the "Ethnicity" class would violate the semantics of the model, as it would result in attributing responsibility of one party over another party—since the Union, States, Municipalities, and the Federal District are responsible for guaranteeing ethnic rights to Indigenous persons.
The solution (in LADM/STDM) for this conflict translates the primordial and inseparable relationship that Indigenous peoples maintain with the land, synthesized in the premise that "Indigenous lands do not exist without Indigenous people." In the modeling, this relationship was represented by the verb "composes" (are integral to), evidencing the inseparability between Indigenous peoples and their ancestral lands, of which they constitute territorial elements as intrinsic as the physical components of the landscape and as specific as the endemic species that exclusively inhabit that territory. The following conceptual map (Figure 1) presents the described relationships, integrating them into the proposed model (Figure 2), commented on below.

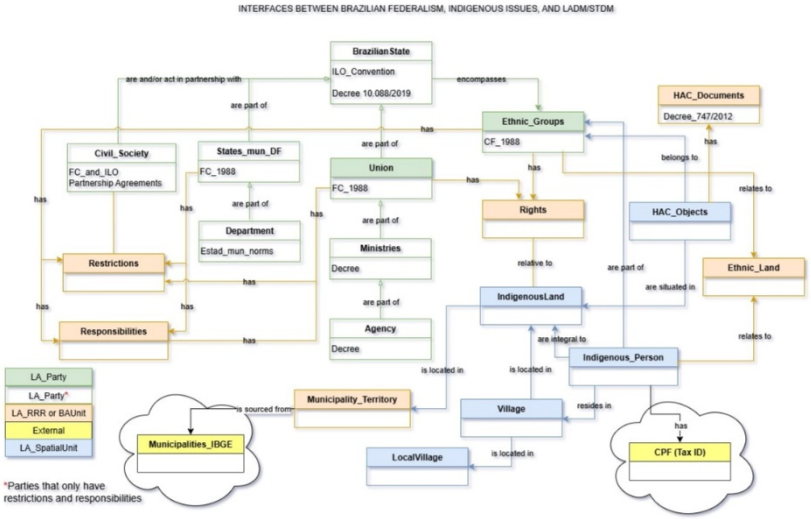

Figure 1. Conceptual map of federalism in Brazil and the integration of modeling with LADM/STDM. Source: prepared by the authors.

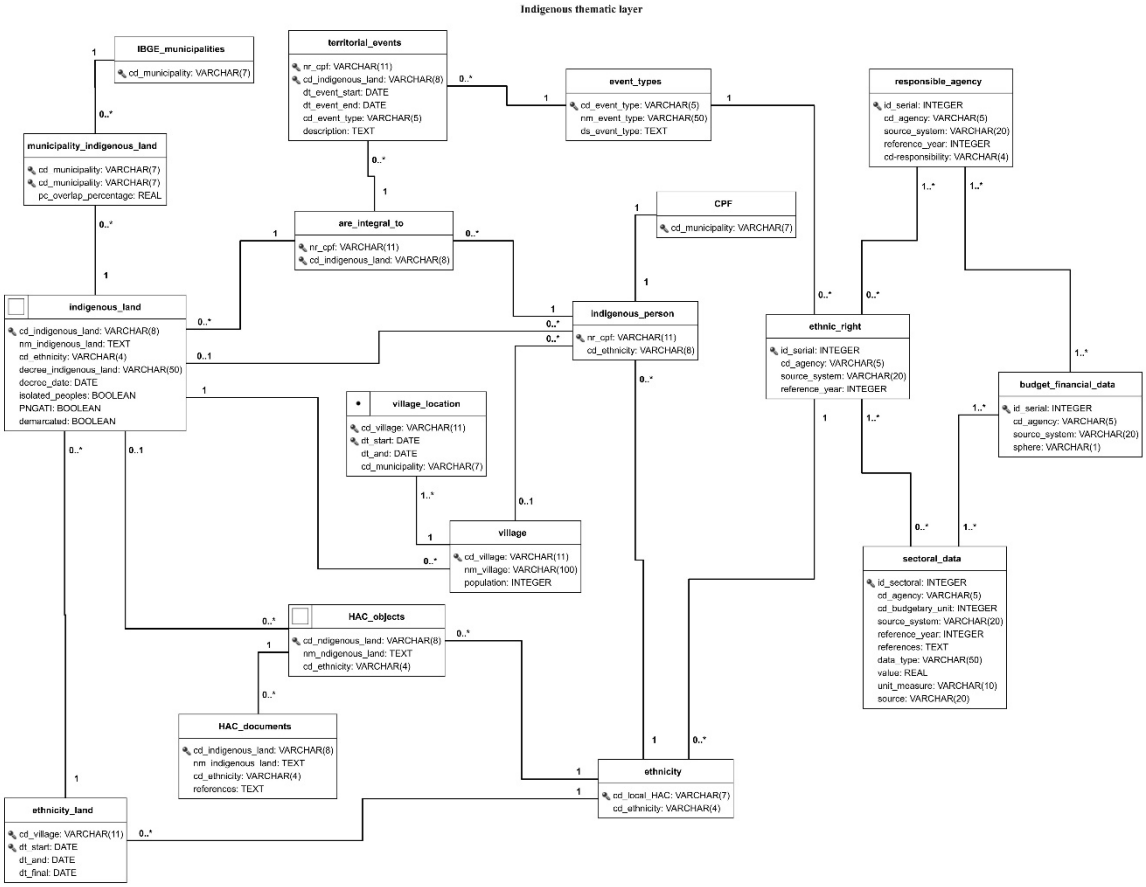

Figure 2. Conceptual modeling of the Indigenous thematic layer. Source: prepared by the authors.

With the objective of strengthening governmental interoperability in the management of Indigenous issues and offering consistent support for both the administration and the development of Indigenous policies, the proposed modeling encompasses five essential dimensions: territorial, legal, administrative–financial–budgetary, socioeconomic, and temporal.

The territorial dimension comprises the geographic representation of the boundary polygons of Indigenous lands, of HAC objects (explained later); of points related to the location of villages; and the indication that the area of ILs can occupy territorial portions of several municipalities —a relevant theme in territorial planning and the management of other Indigenous issues. In the legal aspect, it establishes correlations between ethnic rights and the applicable national (and international) normative framework. In the administrative–financial–budgetary aspect, it connects ethnic rights with the bodies responsible for guaranteeing them and with the financial–budgetary information that allows monitoring the execution of public resources destined for Indigenous policies, promoting greater transparency and efficiency in the application of investments. The socioeconomic dimension integrates sectoral information from consolidated management and transparency systems, such as Educacenso (education census) and e-SUS (Unified Health System), enabling the integration of diverse sectoral data, such as education, health, demography, and other sectors, and informing multidimensional analyses on the

socioeconomic conditions of Indigenous communities. Finally, the temporal dimension enhances the historical traceability of territorial and legal events by recording relevant chronological milestones that include dates of changes in the geographical location of villages; of official recognition of rights and responsibilities; and periods of validity of legal instruments that delegate competence to entities.

Within the scope of physical–spatial and ethnocultural particularities, it is highlighted that individuals can be multi-ethnic; that the same ethnicity can inhabit more than one Indigenous Land (IL); and that an IL may not have inhabitants with a CPF. This last hypothesis reflects the situation of isolated peoples, who may both share the area of an IL with other ethnicities or occupy an area especially designated for them. The Massaco IL, destined for the permanent possession of the isolated Indigenous people who traditionally occupy it, was the case considered to illustrate this particularity (ratified by Decree without number, of December 11, 1988). The modeling also signals the possibility of nomadism or territorial mobility of some peoples with a history of the location of villages (with start and end dates), a practice that materializes ecological sustainability by allowing the regeneration of the previously occupied area (Aparicio 2021, J. Silva 2022). In some cases, this itinerancy requires previous and subsequent actions, such as the construction of shelters, the anticipatory cultivation of food, and the reforestation of the unoccupied place, as observed in fieldwork in the Waimiri-Atroari IL and reported about the Yanomami peoples (EMIRI, 2020); and various others, such as some of those who inhabit the Javari Valley IL, many of recent contact or isolated (Braga, L. V., Cangussu, D., & Furquim, L. P. 2022).

In order to integrate Indigenous cosmology—perspectives incorporated in the National Policy for Territorial and Environmental Management of Indigenous Lands (PNGATI, Decree No. 7,747 of June 5, 2012)—the class "Objects_HAC" was inserted, with the objective of representing the Historical, Affective, and Cosmological (HAC) territorial objects, defined as specific territorial portions that have historical, affective, or cosmological symbolism for ethnic or cultural groups. These spaces are geolocated and delimited, and may or may not be associated with formal relations of possession or conventional property, which, for Indigenous peoples, are expressed as a bond of territorial belonging. Thus, they are not just geographical points, but living places that harbor spirits, memories, origin stories, rituals, and relationships with nature. Their essence transcends the legal dimension, situated in the scope of the symbolic and identity connections that human groups establish with the territory.

Due to their uniqueness, "HAC objects" are not linked to isolated individuals, but to cultural or ethnic groups with which the relationship is community-based and perennial, reflecting bonds that persist through generations and consolidate as an integral part of the group identity. Because of this, the description of the relationship between the group and the HACs is complex, demanding anthropological approaches that consider collective memory, cultural practices, and the belief system that attributes sacred characteristics to the space. Consequently, the attributes associated with HACs should not have rigid value domains, in order to allow the inclusion of texts and documents of an anthropological and geographical nature. For example, a sacred place for an Indigenous people would be freely registered as HAC with descriptive attributes of the practice (periodicity, associated mythical narratives) and links to ethnographic studies.

In short, the modeling articulates these elements through a hierarchical structure that connects, in territoriality, Indigenous people to the villages where they reside, the villages to the Indigenous lands where they are located, and these to the municipalities in whose territories

they are situated. Simultaneously, it links such elements to the bodies and entities responsible for ensuring the individual and collective rights of Indigenous peoples. This relational architecture allows both specific analyses of each level and cross-sectional studies that contemplate from individual impacts to implications of Indigenous policies, also fostering transparency and social control of public investments directed to this theme. However, its primary purpose must be to instrumentalize environmental protection as a mechanism to face growing climate challenges. The logical basis of this perspective is in the scientific evidence that indicates the concentration of most of the preserved biodiversity in ILs, which allows concluding that the permanence of Indigenous peoples in their lands and territories represents one of the most effective strategies for environmental preservation and, consequently, for the continuity of life on the planet.

In view of the above, it is concluded that, as an international standard, LADM can support the development of land administration system applications that integrate the premises that: socio-environmental factors have profoundly influenced the current panorama of land management; the protection of Indigenous lands is paramount for ecological preservation; and Indigenous peoples constitute the very reason for being of their lands. For this, semantic adaptations are necessary that understand that "the Earth is the mother of everything that lives, of everything that is, a bond of kinship that unites man to everything that surrounds him [...]. The mountain, the valley, the forest are not simply a frame, an 'exterior,' even if familiar. They are man himself" (Dardel, 2011, p. 49).

4. CONSIDERATIONS

Challenges such as climate change, pressure on natural resources, and social inequalities impose on land management a perspective that incorporates different ways of relating to the land. In the same context, LADM offers a conceptual model aimed at delimiting and controlling geographic spaces based on spatial regulation, that is, the formalization of rights, restrictions, and responsibilities (RRR) that affect the territory and its geospatial components. However, even with its flexibility and its STDM extension, which encompasses unorthodox forms of property, the model has not yet been expanded to represent perspectives of relationship with the land in which it is an inseparable part of the inhabitants' identity—whose presence qualifies it as "Indigenous land."

The semantics of this relationship are especially relevant in the proposed modeling for contexts such as Brazil, in which the deliberation of Indigenous issues is fragmented among various governmental and civil society institutions. In addition to conferring conceptual integrity on the model, representing the relationship with the land according to Indigenous cosmology represents an opportunity for the inclusion and/or decolonization of native peoples in land management systems. This approach can assist in the protection of Indigenous rights, enhancing the preservation of natural spaces that have maintained their ecological balance only due to the protagonism of peoples who often sacrificed their own lives for the continuity of their territory and their people.

With the potential to be implemented in Brazil and other countries, the presented model aims to strengthen interoperability among state agents, supporting the monitoring and development of more effective institutional protection mechanisms for Indigenous issues. For this, it is

emphasized that combining socio-environmental factors with the globally conventional technical standard requires integrated approaches sensitive to the complexity of these relationships and to the effects that may arise from their recognition. From this perspective, it is assumed that incorporating Indigenous cosmology into land management systems has the potential to reforest the technical–scientific thinking that underlies them, making their epistemological foundation more diverse and inclusive.

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BIOGRAPHICAL NOTES

Ednez Gomes Tavares holds a Bachelor's degree in Tourism from the Fluminense Federal University (UFF) and postgraduate specializations in Municipal Public Management (UFF) and Tax Law and Society Relations (University of Brasília – UnB). She is currently pursuing a Master's degree in Territorial Management at the Federal University of Santa Catarina (UFSC), developing the research project "Indigenous Peoples: the Third Included in Territorial Management Systems", which integrates environmental taxation, Indigenous policies, and the Territorial Management System (Sinter) under a transdisciplinary perspective. Her professional experience includes more than 10 years at the Brazilian Federal Revenue Service, where she works in taxpayer management and assistance. This trajectory allows her to combine knowledge in public policy, territorial planning, and tax law with a critical socio-environmental perspective. Born on Marajó Island (PA), her riverside sociocultural background strengthens her commitment to equity in access to social, tax, and territorial rights, especially for Indigenous peoples and traditional communities.

Liane Ramos da Silva is a professor in the Department of Civil Engineering at UFSC (Federal University of Santa Catarina) and a professor in the PPGTG (Graduate Program in Transport Engineering and Territorial Management). She develops research and extension projects in the areas of Multipurpose Land Cadastre, Land Administration, and Geotechnologies.

Marco Aurélio Barbiero holds a degree in Computer Science from the University of Passo Fundo (UPF) and is currently pursuing a Master's degree in Transport Engineering and Territorial Management at the Federal University of Santa Catarina (UFSC). A Tax Auditor at the Brazilian Federal Revenue Service (RFB) since 1992, he has explored the field of LADM and has sought to specialize in the modeling of unidentified territorial objects, such as "HAC objects." He is also the author of books and chronicles that address everyday events in a critical

and humorous way, proving that a tax auditor can indeed combine technical expertise with a sense of humor—even if some taxpayers still doubt the latter.

Everton da Silva holds a degree in Surveying Engineering from União das Faculdades de Criciúma, a Master's degree in Multipurpose Cadastre, and a Ph.D. in Production Engineering from the Federal University of Santa Catarina (UFSC). He has coordinated cadastral surveys and mass property appraisal projects for tax purposes in several Brazilian municipalities. He is a Professor at the Federal University of Santa Catarina in the Department of Geosciences and in the Graduate Program in Transport Engineering and Territorial Management, where he works in the research line of Multipurpose Land Cadastre. He was also an Associate Professor at the Lincoln Institute of Land Policy, where he contributed to both online and in-person courses. He leads the Grupo de Observação de Transformação do Território – GOTT (Territory Transformation Observation Group) (https://gott.ufsc.br).

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