Applying LADM for Brazilian Rural Cadastre – a prototype and partial results

Thiago MARRA, Kilder BARBOSA, Eduardo OLIVEIRA, Deusimar FREITAS, Oscar OLIVEIRA, Selma PADINHA, Marcio COSTA, Brazil

Key words: Cadastre, LADM, Informal Rights, Crowdsourcing, Land Administration, Brazil, Fit for Purpose

SUMMARY

Brazil has vast natural resources and is a global leader in farming, yet its land administration system still has significant room for development. Since 2013, the georeferenced rural cadastre (SIGEF), which integrates with the Land Registry, has made significant progress. However, this system focuses primarily on formal property rights, failing to capture Brazil's complex agrarian landscape, which is marked by diverse possessory rights, high levels of informality, and rapid changes in land use and tenure. This article presents a project underway to enhance this existing platform by implementing the Land Administration Domain Model (LADM) – ISO 19152:2012. The LADM-based model is designed to represent a wide variety of tenure situations, both formal and informal, including individual properties and traditional collective territories. Furthermore, the model addresses an ambiguity in Brazilian law between the "property unit" (from the Land Registry) and the agrarian concept of the "Rural Immovable" (based on possession and land use). By using LADM's three fundamental elements — parties (Party), rights (RRR), and parcels (Spatial Unit) — the project tries to configure rural immovables by linking adjacent parcels of the same party, considering both formal and informal rights that result in direct possession. Pilot studies were conducted in four distinct municipalities. Data were collected from three main sources: SIGEF (Georeferenced Cadastre System), CAR (Rural Environmental Cadastre) and SNCR (National Rural Cadastre System). The final goal is to develop an accessible and functional prototype that allows users to resolve ambiguities, clearly identifying formal components of an immovable alongside informal parcels and traditional occupations. This solution aims to pave the way for the implementation of a comprehensive cadastre for Brazil, which will support conflict resolution, sustainable land use, economic development, and social equity with environmental control.

Applying LADM for Brazilian Rural Cadastre- a prototype and partial results

Thiago MARRA, Kilder BARBOSA, Eduardo OLIVEIRA, Deusimar FREITAS, Oscar OLIVEIRA, Selma PADINHA, Marcio COSTA, Brazil

1. INTRODUCTION

Despite significant advances made in recent years, Brazil still faces major challenges in the field of Land Administration, including the need for more efficient expansion of rural registry coverage and the isolation between information systems used in the sector.
This article will address the ongoing work that aims to replace tools currently used to produce registration data. Current tools deal with the distinct aspects of the earth, with different concepts and forms of representation, with redundancies and, at the same time, gaps in representation. This scenario, coupled with a tradition of Land Administration "in silos", bring considerable limitations to Land Management in Brazil.
The new cadastral tool is being developed with the following capabilities:

- Representation of formal and informal situations;
- Reception of data obtained with different survey methods, from the most rigorous and standardized to simple sketches or drawings, incorporating the concept of Fit For Purpose (Enemark et al., 2014);
- Possibility of editing proposals from access to the web system with an on-screen editing tool (collaborative mode);
- Allow interaction with other internal (INCRA) and external systems for complementary information, avoiding data redundancy;
- Enable the visualization of geographic information in several layers to support more accurate analyses for various purposes, according to the need for the application of public policies.

As a resource to support the work, given the need to deal with data from different legacy systems, the data model has been worked on from the LADM, ISO19152 (Lemmen, 2015), given its ability to deal with informal and formal relationships, in addition to enabling various forms of spatial representation, at inclusive levels. Given the complexity of the task, the development of a functional prototype was used as a resource, covering real data from four municipalities in the country.

2. BRIEF HISTORY AND CHARACTERISTICS OF LAND ADMINISTRATION IN BRAZIL

For contextualization, we will make a short history with a succinct characterization of the main elements of land administration in Brazil.

The country has a division between rural and urban cadastres: urban under the responsibility of the municipalities, and rural[1] under the responsibility of the federal land agency (INCRA, created in 1970 to implement the policies of colonization and agrarian reform).
In the same period of INCRA's creation, two important legal changes were made: in 1972 a national rural registry system (SNCR) was created, responsible for maintaining information on rural properties and taxation; the operating regime of the property registry was changed, from transcription ("transcrições") to registration ("matrícula"), which would be the equivalent of the transition from a system of *deeds* to a system of *titles* (considering all the caveats raised by Zevenbergen, 2002).
However, in the implementation of the SNCR, map information was not incorporated. Thus, the Real Estate Registry remained functioning without a spatial base to which to reference the registrations.
Only in 2001 was a new legal change made that instituted the figure of the georeferenced survey as a requirement for updates in the Registry. Thus, only from there, a georeferenced database was created capable of systematically connecting to the properties that are the object of ownership. The so-called "georeferenced cadastre" was created.
The inputs would be given sporadically, required to update the Land Registry. The survey must be done by a qualified professional, with formal authorization, and the result of the work analysed by INCRA to later be taken to the Registry. It could be said that this process configures the Brazilian approach to AAA cadastral data (Williamson et al., 2012).
Implementing this process was not easy. It was based on analogue processes, which caused long queues and a lot of waiting time to process each request. Only the result of the process, represented by a polygon, was entered into a database.
As expected, the queues grew. Only in 2013 was implemented the digital transformation of the process (Marra et al, 2015). From then on, the data prepared by the professionals were submitted directly, online, with fully automated validation.
Despite difficulties in implementation and maintenance, the Sistema de Gestão Fundiária[2] - Sigef allowed the demand to be met. The database grew from about 70 thousand areas certified in 2013 to more than 2 million parcels validated in 2025, also allowing a minimum connection with the real estate registry (via web interface).
In this same period, however, the demands of the Land Administration could not wait. The growing deforestation in the Amazon in the mid-2000s and the immense demand for environmental licensing of agricultural activities in the country led to legal changes in 2012 that created another land cadastre, specifically aimed at these activities. The tool created did not have any connection with the data produced by the georeferenced cadastre (which connects with the Registry). Its input methods were based on crowdsourcing.
As expected, nowadays the use of data from these different sources generates more uncertainty than security, since divergence is very often. Also, the data usage from the georeferenced cadastre as a reference for Land Administration in general is still limited.
To overcome this situation, in 2016 a working group was initiated in INCRA to propose an evolution of the land information systems in use. The project foresees the replacement of two

[1] In Brazil, it is difficult to make this statement because the role of a territorial registry of reference is not widely understood. There is also the understanding that different registrations can coexist, each with its own purpose, without complementarity.
[2] Free translation: Tenure Management System.

land information systems used within the scope of INCRA, with the rationalization of its data models and processes. The proposal was formalized through a vision document in 2018. This proposal has been presented in several forums (Marra et al, 2017, 2022). Since then, means have been sought for the effective implementation of the solution.
Finally, in 2025, development work began. The proposed path, given the complexity of the task, was to start with a functional prototype that would allow:

- Apply the concepts and data models;
- Test the import and processing of legacy data;
- Test and present the new processes for entering and updating cadastral data;
- Demonstrate the ability to interoperate with land Registry and other Land Administration organizations.

3. OBJECTIVES

In this work, we will cover two fundamental stages for the development of the Cadastro Territorial Rural – CTR (Rural Land Cadastre in free translation):

- Introduce the Data Modelling
  - Fundamental concepts represented
  - Application of LADM
  - Current view of the class diagram, towards LADM_BR
- Development of the Functional Prototype
  - Actual data import results
  - Data model evaluation
  - Presentation of key features
  - Evaluation of partial results

4. METHOD

The method will be divided into two major stages. The first involves modelling the data, the second covers the application of the model through a functional prototype, using real data from existing systems. Both are part of the larger project, which aims to implement a new application to operate the CTR in Brazil, covering normative, organizational and operational revisions.
This work focuses on the results obtained with the data model and the development of the functional prototype application. The methodological steps include:

- Data modelling
  - Study of ISO 19152, LADM
  - Study of relevant legislation and standards
  - Study of relevant land information systems
  - Case studies, with elaboration of object diagrams
  - Generic conceptual modelling, with elaboration of class diagram
- Development of the functional prototype
  - Data processing

    - Choice of data sources and study area
    - Materialization of the model in a database
    - Definition of import and discrepancy resolution rules
    - Data Import
    - Evaluation of the results
- Application development
    - Definition of functionalities and business rules
    - Application development
    - Testing and approval

5. THE CTR AND ITS PROTOTYPE

5.1 Modelling

5.1.1 Key Concepts

In the scope of the project, the concepts necessary to meet the requirement of a multipurpose rural cadastre were identified. Below, we address in more detail the main ones: real estate property, informal possession and rural immovable. These were considered the main ones because they represent the most common and comprehensive in terms of coverage. It is from possessions and properties that it is possible to determine the configuration of the rural immovable, which is the object, for example, of taxation and environmental management in Brazil. It is important to mention, though, that the CTR Prototype covers other relationships, like traditional possessions.

5.1.1.1 Possession and Property

According to the Brazilian Civil Code, possession and ownership are rights that people can have over land. Property refers to the formal situation of freehold (Real Right), while possession refers to the factual situation, in which the holder acts as owner, regardless of formal title. It happens that the two can coincide, when the situation in fact corresponds to the formal situation, or they can diverge, when these situations concur, either in time or space.
In the following cases (Figure 1), we will illustrate situations in which possession is dissociated from property, which we can also call simple possession. In these cases, one situation has no legal relationship with the other, but spatially they can be associated:

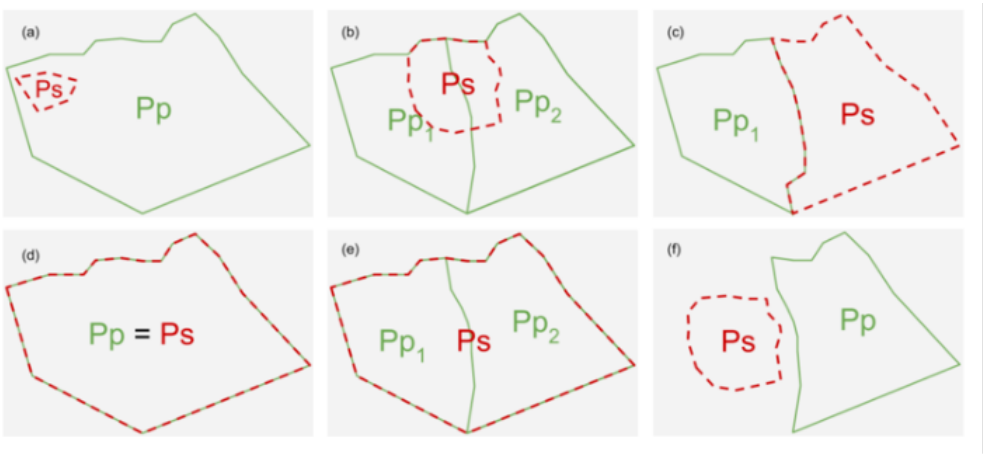
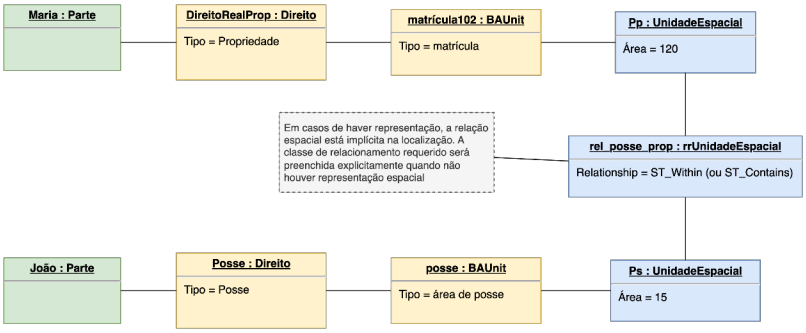


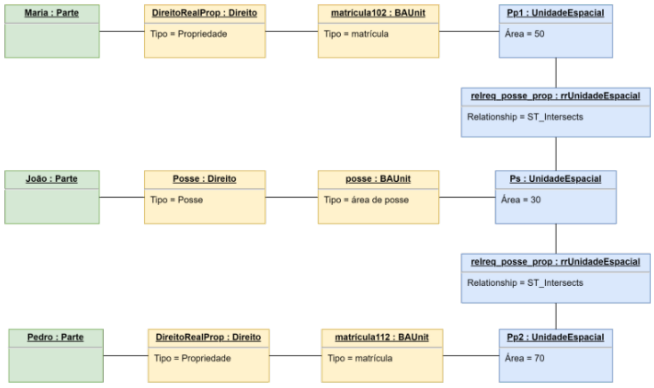
Figura 1. Examples of the situations in which possession is dissociated from property.

For each of the six hypothetical cases illustrated in the previous figure, a corresponding object diagram was generated[3].

a) Simple Possession within the Property

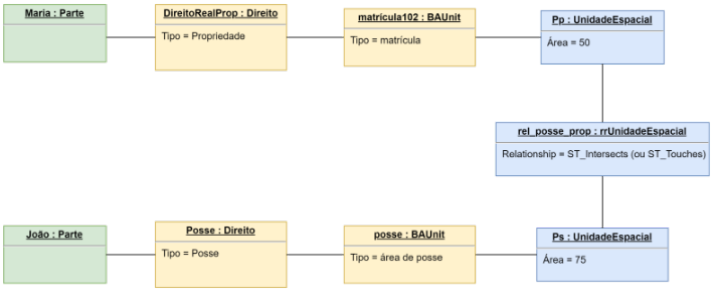


b) Simple Possession intersects two Properties

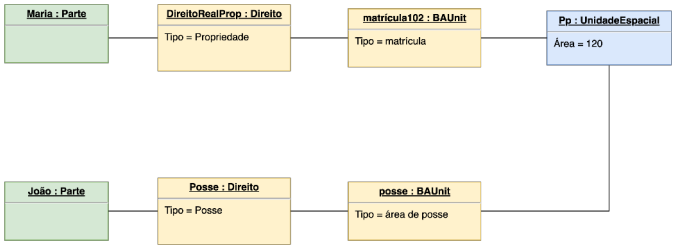


c) Simple Possession touches Property

[3] The required relationship class (LA_RequiredRelationshipSpatialUnit) was used in the diagrams only to explain the spatial relationship between the plots and was not implemented in the prototype. For search cases, data retrieval occurs by explicit topological relationship of the level topology itself or by search between levels.

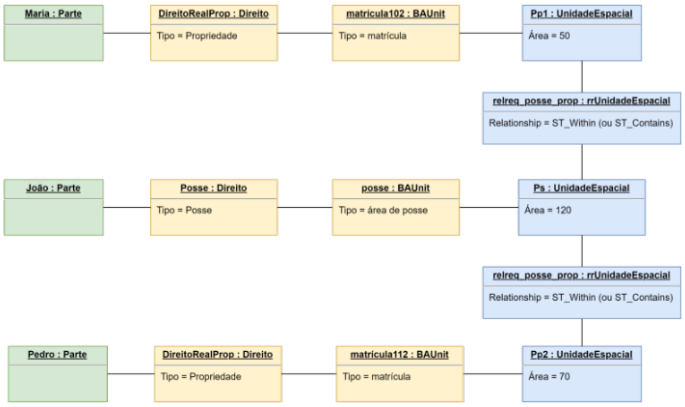


d) Simple Possession is equal to Property



This case illustrates the situation in which the administrative units of possession and property are associated with the same parcel. This reinforces the definition present in LADM that a parcel can only associate at one level, avoiding replications.

e) Simple Possession contains Properties



f) Simple Possession has no spatial relationship with Property

It is observed that in none of these cases a relationship is established between the BAUnits in question. This illustrates the definition of Brazilian legislation, in which simple possession is constituted in a totally autonomous way in relation to property. On the other hand, spatial relationships can be established between the parcels, showing situations that are currently invisible to Land Administration in Brazil.

These cases are not well represented in the tools used in Brazil. Only situations of occupation on public lands have a more coherent representation, including their parcels, for regularization purposes. Simple possessions incident in private areas do not have this type of representation.

5.1.1.2 Rural Immovable

In addition to the cases of possession and property illustrated, another situation present in Brazilian Law deals with the concept of rural immovable. Here is an important observation: there are cases in which the legislation uses the same term, "imóvel rural" (that we translated here to rural immovable), to deal with different objects.
The rural immovable of the Civil Code refers to the property, also called "basic property unit": the area registered in the Real Estate Registry or Land Registry. The rural immovable present in agrarian Law deals with the "prédio rustico" (the same as in portuguese Law), the continuous area under direct possession of the same holders, one or more, the factual situation. Therefore, it can encompass one or more formal properties and also areas of informal possession. We agree to treat the first case as "real estate property", or just property, and the second as "rural immovable", or just immovable. In the following figure (Figure 2), we illustrate a hypothetical situation that contemplates this understanding.

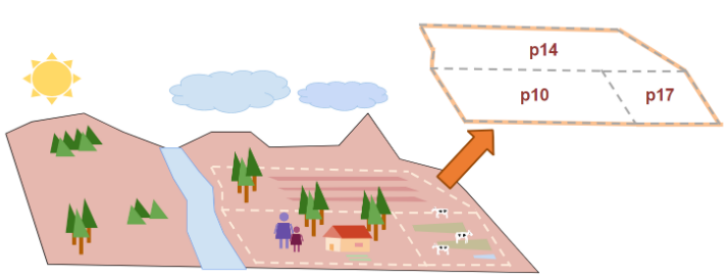


Figure 2. hypothetical situation.

In the schematic picture, parcels p10 and p14 refer to Real Estate Properties (formal) and p17 to a simple (informal) possession of the same person (Maria). According to the concept of agrarian legislation, the area corresponding to p10 + p14 + p17 constitutes a rural immovable. Maria uses the area continuously to produce and, in practice, no longer distinguishes the delimitation of the parcels. To illustrate the case supported by LADM, the following is an object diagram with the situation (Figure 3).

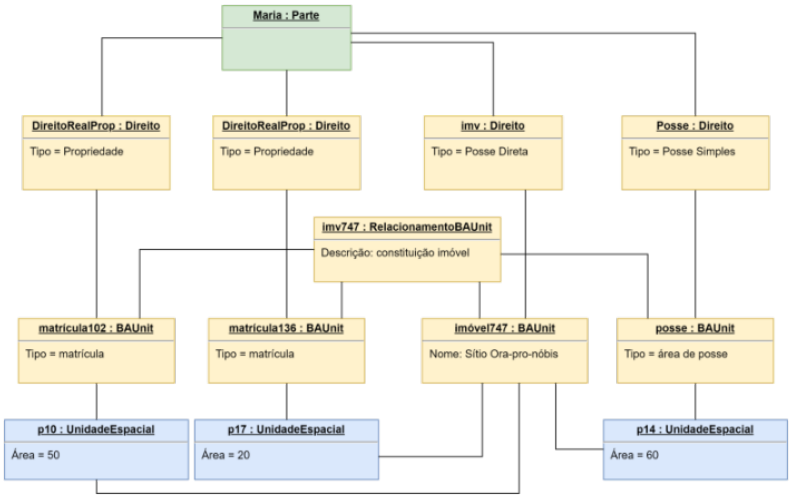


Figure 3. Object diagram to hypothetical situation.

The class of relationship required between BAUnits is used to represent the link between informal possession and properties, which indirectly refers to the parcels, as the spatialization criterion must be considered in the composition of the property (the immovable must be continuous).
For context, this case is also not treated in a systematic way in Brazilian Land Administration tools currently in use. The case of coherent representation of the rural property is particularly important because it is the BAUnit considered for various purposes, including land taxation and environmental control.

5.1.2 Quality Classes and Levels - LA_Level

The application of LADM LA_Level (Lemmen, 2015) was particularly important for a coherent representation of the situations discussed and exemplified. As is clear in the case of possession and property, which are legally independent, parcels of possession and property must be at different levels. In the hypothetical cases studied, at least three levels were proposed for different legal relationships.
Regarding spatial representation, it is proposed to explore the possibility of generating parcels with different classes of representation quality, expanding the application of Fit For Purpose concept in Brazilian georeferenced cadastre. The concept of quality classes is the result of the combination of the method of production of the data and authorship. Thus, a technically qualified professional can still produce a given AAA standard, with technical responsibility required by law, to update a parcel of property in the Real Estate Registry. This case has been called "Class A" data. The same professional or any other citizen could use non-standardized methods, such as a sketch on an image, without associated technical responsibility, to produce data so called "Class C". The concepts are represented in the Figure 4.

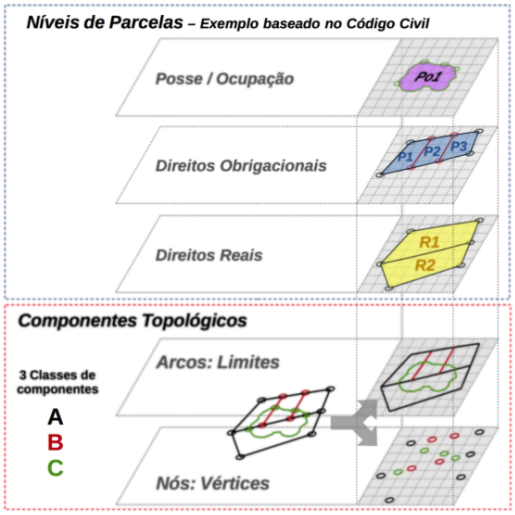
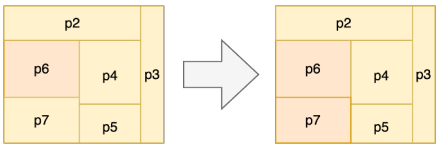


Figure 4. levels of parcels.

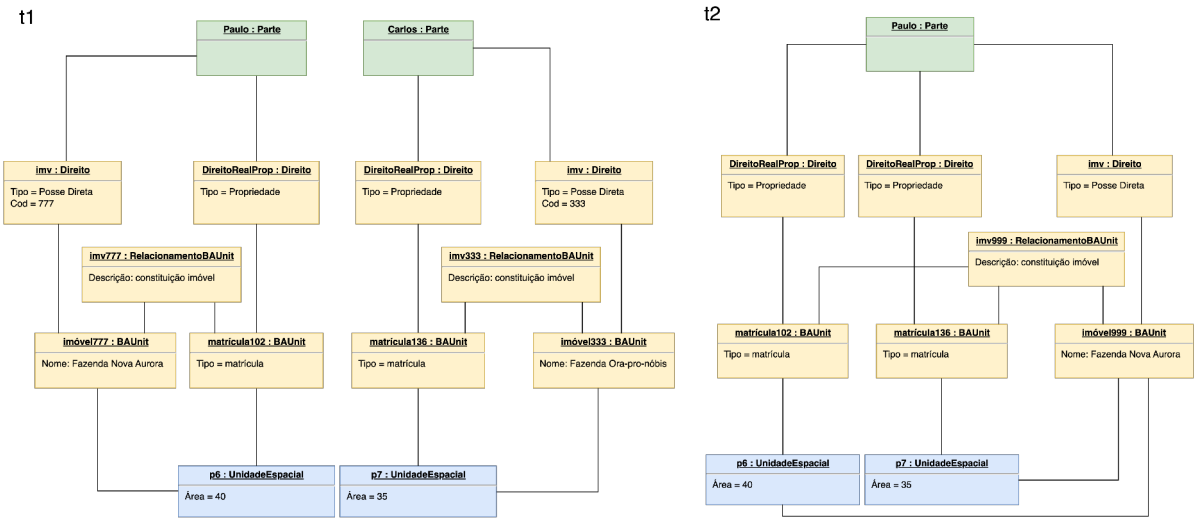
In the case illustrated schematically, there are three levels: one for Real Rights, one for Obligatory or Personal Rights (contracts) and one for Possession Rights (informal). Therefore, depending on customizable rules, different methods could be used to generate spatial representations regarding the three quality classes.

5.1.3 Object Models

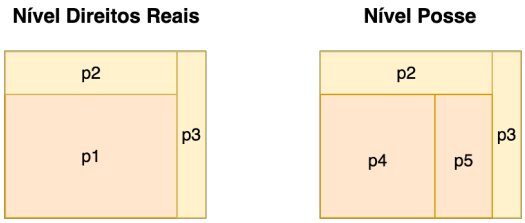
From the initial conceptual view, study of the LADM and the requirements (representation of the main legal relationships), the phase of elaboration of object diagrams began.
As inputs, the basic classes of the LADM were used, with special attention to the object diagrams present in Annex C (ISO, 2012) and relevant publications (such as Lemmen et al, 2010). In addition, the pertinent Brazilian laws and standards were considered. Part of the cases represented were generic, to indicate the most typical situations in our context. Another part of the studies was based on real documented situations. Among the dozens of cases studied, we bring two examples.
The first is the typical case of reconfiguration of rural property by transfer of ownership, without change of parcel (subdivision).



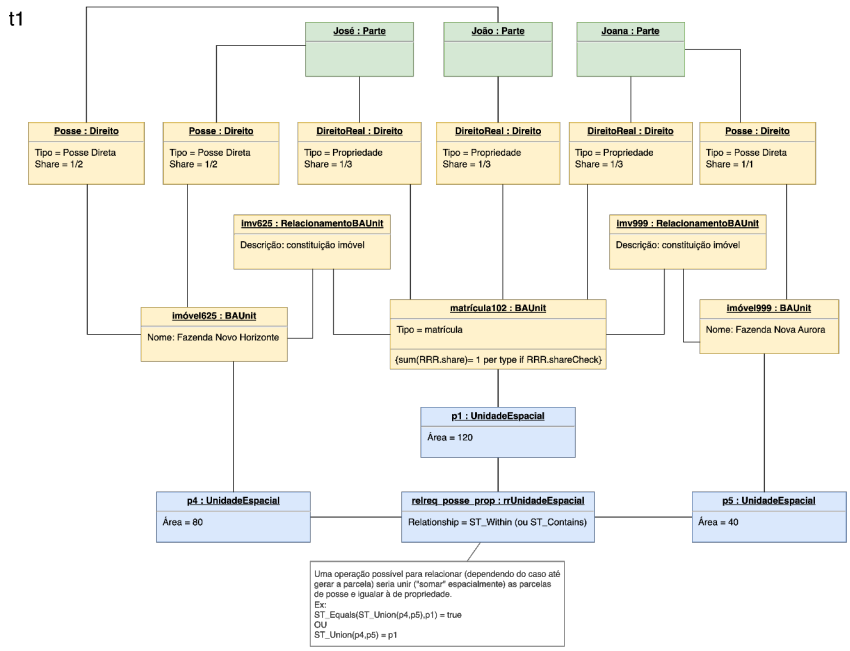
The following diagram is the representation of the objects in two moments. At time t1, Paulo owns p6 and Carlos owns p7. At t2, Paulo acquires Carlos' property and his rural immovable now corresponds to p6 and p7 together (check out BAUnit's associations).



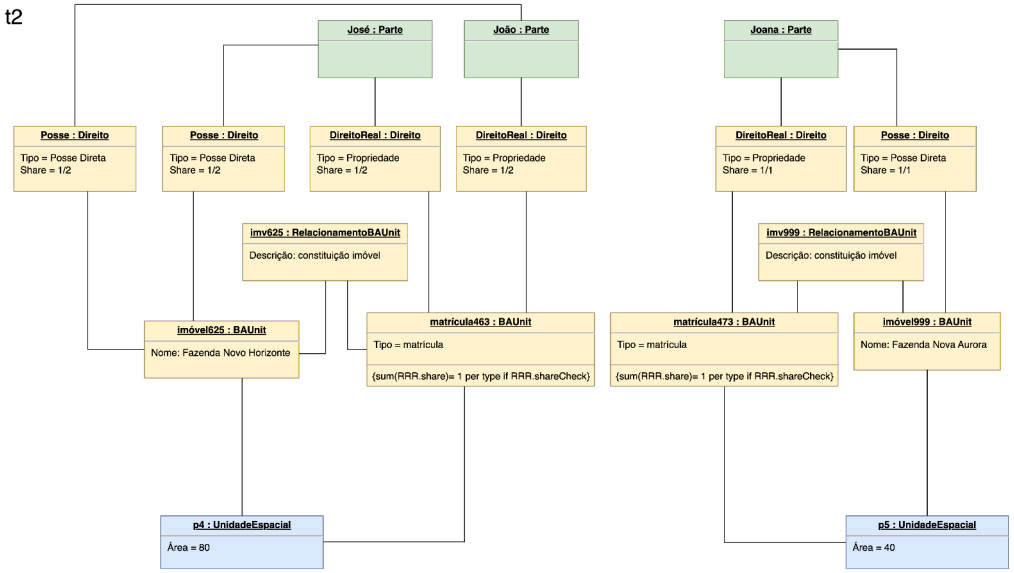
In the second case, we illustrate the situation in which the formal spatial configuration of property ("Nível Direitos Reais") is not reflected in the de facto situation of possession ("Nível Posse"). At first, there is the identification of the area of possession of one of the holders, but in terms of real rights, the right is distributed just by ideal fractions.



The parcel of property at the level of real rights has three owners in common: José, João and Joana. At the possession level, Joana's possession is individualized (p5). José and João are co-owners of parcel p4 (1/2 for each).



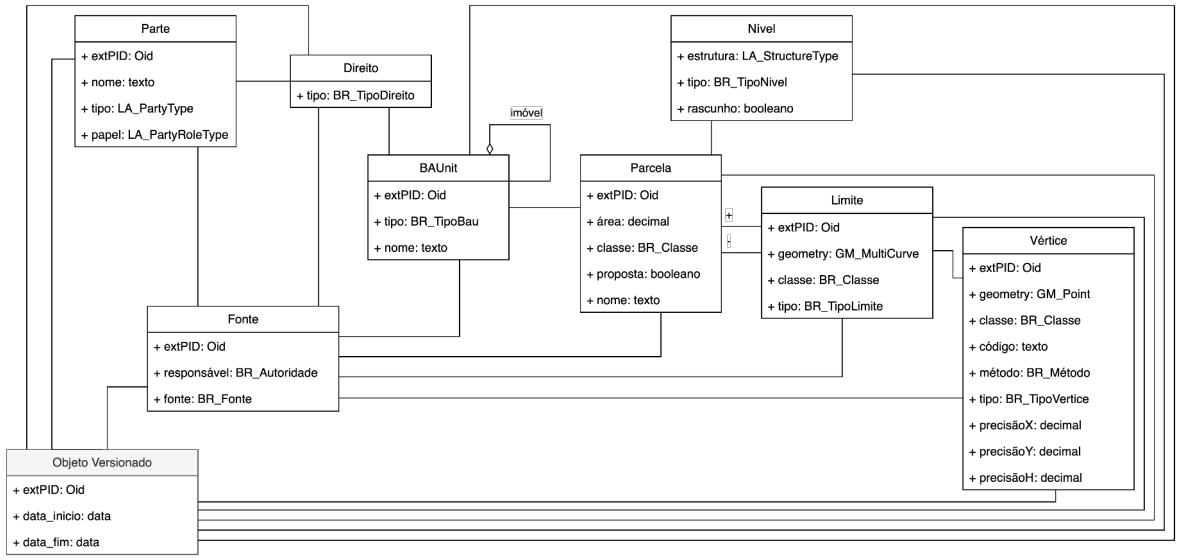
At moment t2 (below), there is a subdivision of parcel p1 at the real right level that is now associated with a new property, formally linked to Joana as owner. This example illustrates the transposition of a factual situation, represented at the level of possession, to the formal level of real right.

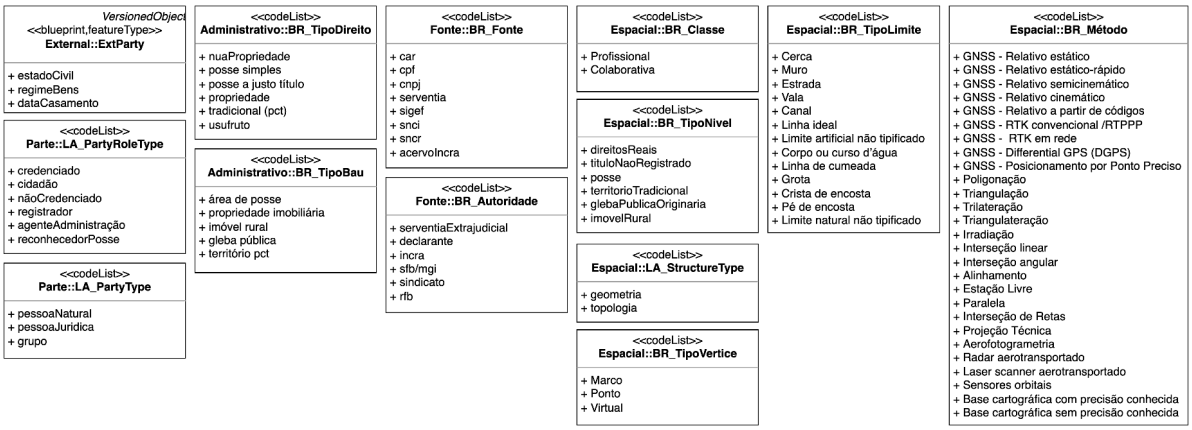


5.1.4 Proposed model

With the accumulation of cases studied, a reference model was consolidated. In the end, no class specialization was required to meet the needs of representation. Only the code lists have

been expanded. As next step, the development of a functional prototype with real data was proposed for testing the model and features envisioned for CTR implementation.
The class model used, represented below, contains the basic elements of the imported legacy data, in addition to representing the main concepts mentioned before. Therefore, it represents a cut in relation to the most complete model, which is being prepared for application in production. For example, the study for the CTR listed dozens of real and possessory rights, present in Brazilian legislation. The CTR prototype, in turn, considers (full) ownership, bare ownership, usufruct, simple possessions (informal), possession derived from title (not yet registered) and traditional possession (customary use).
Another example of a cut made for testing in the prototype was the number of levels. For the prototype, the following levels were defined: Real Rights, Unregistered Titles, Possession, Traditional Occupations, Original Public Lands and Real Estate. The selection was made based on the content of the data cut in the source systems (SIGEF, SNCI, SNCR, PCT and CAR).
As discussed, the conceptual model of the prototype was developed based on ISO 19152 – Land Administration Domain Model (LADM), contemplating a subset of classes of the standard, selected according to the needs of the CTR.
The Party class was used to represent individuals and legal entities linked to the territorial units, adopting the CPF (id adopted as citizen identification number) and CNPJ (Brazilian corporate identification number) codes as identifiers, respectively.
The BAUnit (Basic Administrative Unit) class was implemented to cover the main forms of legal and administrative entities, like real estate property, possession and rural immovable.





In the set of classes related to rights, restrictions and responsibilities (RRR), the prototype considered only the relations of rights, limiting itself to the modalities of ownership, usufruct, simple possession, and customary, as they are the most directly associated with tenure situations observed in the rural environment.

Finally, in the Spatial Unit class, the parcel entity was used as the minimum unit of spatial representation, enabling the link for geometries, its geospatial attributes to the respective administrative units.

This selection of classes allowed the implementation of a simplified model that was coherent with the conceptual framework of LADM, ensuring semantic compatibility and interoperability with other Land Administration Systems and organizations.

After this modelling stage, with the definition of the classes necessary for the development of the project, it was a matter of starting the construction of the prototype that would allow the evaluation of the model and related functionalities, under a real data extraction.

5.2 The CTR Prototype

5.2.1 General Features

In the development of the prototype of the Cadastro Territorial Rural (CTR), it was sought to structure a registration governance model based on unified authentication, differentiated user profiles and document validation flows that provide reliability and security to the registered information.

5.2.1.1 User authentication

User authentication occurs exclusively through GOV.BR login, which guarantees a unique digital identity, eliminates the need for system credentials, and ensures greater reliability in the access process. After authentication, each CPF is linked to a profile previously defined in the prototype's administrative environment.

5.2.1.2 Registration of Representatives

The prototype contemplates the possibility for the user to register representatives who can act on their behalf. In this release, to simplify the demonstration, it is not possible to select which properties the representative will have access to, nor which actions the representative can perform.
Although simplified, this approach allows the visualization in an approximate way how the functionality will be made available in the complete solution, where there will be greater detail and control over the links between users, properties and performance profiles.

5.2.1.3 User profiles

Four main profiles were defined:

Professional – user with legal attribution to perform georeferencing services for rural properties, holder of accreditation with INCRA for certification of polygons. This profile can insert data classified as professional, that is, geospatial information produced according to the Technical Standard for Georeferencing of Rural Properties of INCRA, ensuring technical rigor and cartographic reliability.

Collaborative – user who can have a direct link with the property (owner or possessor) or act as a representative but does not have a professional attribution for certification. The geospatial information inserted by this profile is considered collaborative, declaratory in nature and without the requirement of the normative technical rigor applicable to professional data.

Validator – institutional agent responsible for consolidating and validating the declared information, giving it definitive character. The validator corresponds to the actor who, by legal competence, can issue documents that legitimize the person's legal relationship with the land (example: the real estate registry officer in the case of ownership). The prototype provides two ways of acting for this profile:

- Individual validation: case-by-case analysis and validation of each request received;
- Batch validation: possibility of uploading structured files containing multiple validations, files that can even be automatically generated by the validator's internal systems. This functionality is designed to emulate future interoperability via API between the CTR and the validators' systems.

- *Analyst* – user with the competence to act in a similar way to the validator, but covering all requests in the system, and not just those intended for your institution or your specific scope of documents. The analyst, therefore, plays a transversal support role, allowing greater flexibility in the administrative examination and ensuring the continuous flow of processing of demands during the prototype.

5.2.1.4 Information flow

The process begins with the completion of a request by users of the professional or collaborative profiles, who submit data from parties (owners, possessors, etc.), documents and geospatial information. These data are initially classified as proposed, since they still need to be analysed by a competent authority.
An integral part of the request is the indication of the issuer of the document and the type of document on which the intended update is based. This information allows the automatic

forwarding of the request to the eligible validators, according to the documents that each one is authorized to issue.
In the prototype, the management of user profiles, institutional ties and types of documents remains centralized in an administrative environment, without a dedicated public interface. In this administration, it is possible to assign to each CPF not only the profile that is acting on the application, but also, in the case of validators, the documents they can issue and the institution to which they are linked.

5.2.1.5 Proposed data versus validated data

Only after validation by a user with a Validator profile (or Analyst, within the scope of the prototype), the data is no longer considered proposed and becomes validated in the system. This distinction ensures the traceability of all stages of the informational cycle, from the initial proposition by an authenticated user to the formal consolidation by a competent authority.
This model, in addition to providing legal certainty to registration information, introduces future interoperability mechanisms, through the provision of batch validation and integration via APIs, allowing the system to adapt to the technological reality of the different validators and enabling a more agile and automated data flow.

5.2.2 Data Import

In the implementation phase, it was planned to import data from relevant databases, which would allow testing the ability of the data model to conform and consistently represent the predicted situations.

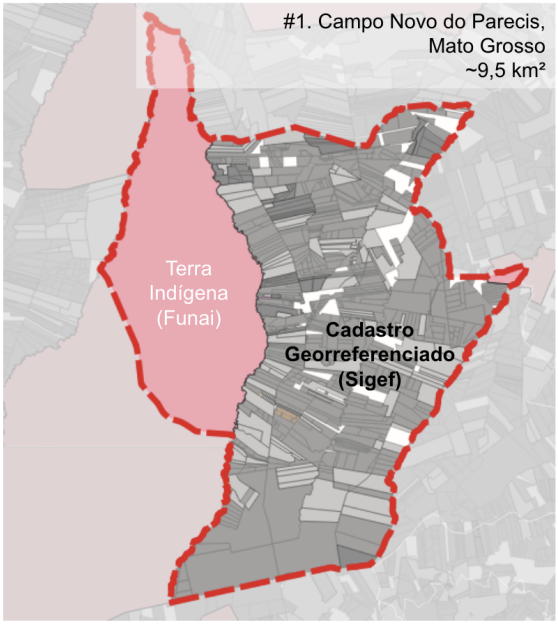
5.2.2.1 Data sources and area of study

The definition of the study area was based on criteria that contemplated the greatest diversity of legal situations such as possession, property, traditional possession (customary tenure), overlapping of polygons and quality classes (according to surveying methods).
Based on these criteria, the municipalities selected were:

- Campo Novo do Parecis – MT
- Itabira – MG
- Anajatuba – MA
- Itapecuru Mirim – MA
- Data extractions from these municipalities were obtained from the following sources:
- Sistema de Gestão Fundiária - SIGEF (free translated to Land Management System)
- Sistema Nacional de Cadastro Rural – SNCR (free translated to National Rural Cadastre System)
- Cadastro Territorial Rural – CAR (free translated to Rural Environmental Cadastre)

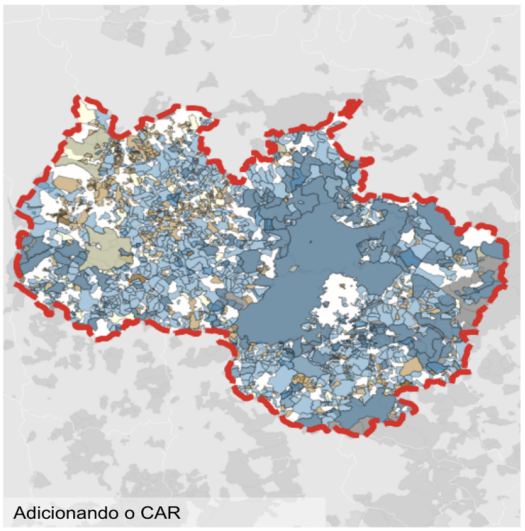
– Sistema Nacional de Certificação de Imóveis - SNCI[4] (free translated to National System of Real Estate Certifications)

The following figures show the input data from the systems described above for Campo Novo do Parecis - MT, which has strong agricultural activities and with a large portion of the municipality already present in georeferenced cadastre (in grey).

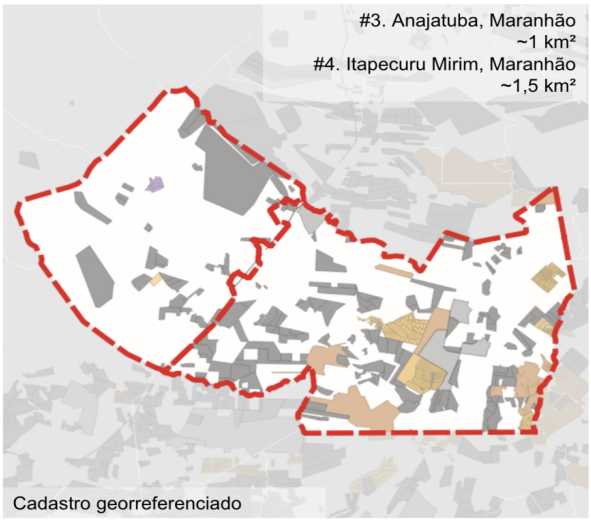


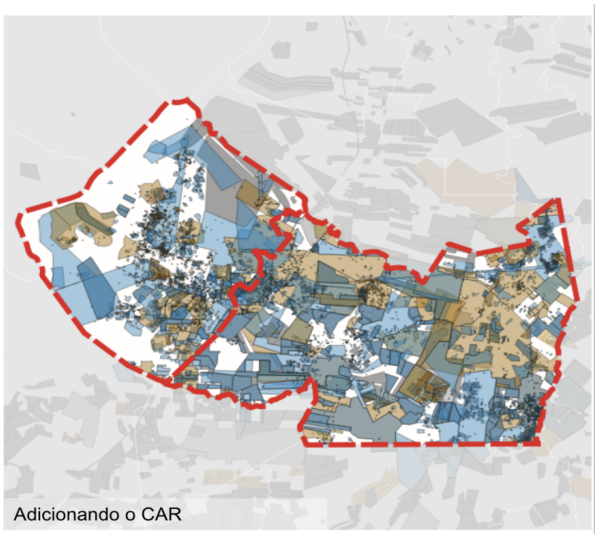
Excerpt from the municipality of Itabira (below). The immovable data from the Rural Environmental Cadastre (CAR) is shown as an added layer in the figure on the right.

[4] A system that was used by INCRA for the certification of polygons of rural properties before SIGEF. The system currently does not process new certifications, but still has in its database certified polygons that have not been migrated to SIGEF.



Cut of the northeast region of the country, municipalities of Anajatuba and Itapecuru Mirim, where there is a high rate of informality. The data from CAR is, again, shown on the right. In this case, with notable overlappings.





The data import process was divided into two stages, the import of geospatial data and later the import of party, basic administrative units and legal relationships (RRR) data.
The geospatial data was stored with topological structure, for each of the levels defined for the prototype scope:

- Real Rights (Properties)
- Titles eligible for registration
- Possession Areas
- Traditional Territories
- Original Public Lands

- Rural Property

5.2.3 Updating Features

To meet the different needs for updating cadastral information, the prototype will have the following functionalities:

- Add immovable: it allows the inclusion of a new immovable, or one that is not represented in the current SNCR database.
- Add parcel: it enables the inclusion of geospatial information of one or more parcels that is part of an immovable already existing at the databases, but which does not yet have all of its parcels spatially represented.
- Change party: used when there is a need to update only the owners or possessors of a certain property, without changing the BAUnit data or the associated parcels.
- Add document: it enables the insertion of document information (deed, title or possession) in cases of immovables that do not have it or whose information is inconsistent.
- Split parcel: it allows the geospatial division of a parcel, resulting in two or more new parcels.
- Merge parcels: it allows the merger of two or more parcels, giving rise to a new parcel.
- Rectify Parcel: used to adjust the limits of the cartographic representation of a parcel, without changing the object in the real world. Example: adjustment of a boundary represented by a sinuous watercourse whose current geometry at the base does not adequately reflect the existing configuration in the field.
- Cancel parcel: applied in cases where the geospatial data in cadastre does not correspond to a portion that exists in the real world.

5.3 **Discussion of Results**

5.3.1 Import

5.3.1.1 Importing geospatial data

It was possible to import 100% of the data from the SIGEF database regarding the study area, totalling 1,922 parcels, 1,494 at the level of real rights and 389 at the level of possession. 12 were public original lands and 27 were included in the level of unregistered titles.
The RDMS used is PostgreSQL with PostGIS extension. The embedded topology resource was used to convert geometric data to the topological model. The tolerance was 0.5m. It was identified that, depending on the function and the order of import, the adherence of the limit in relation to the vertex behaves differently. With adjustments in the process, the parcels were correctly imported with the maintenance of the consistency of the neighbourhoods within the established tolerance.
The data from the SNCI required processing to correct overlaps generated by updating problems. As it is a legacy system, these problems were expected. Of the 128 polygons, 13 were discarded.

For the CAR, which had the largest volume of data, but also a high number of inconsistencies, the numbers were: 27,725 candidate polygons, 2,121 imported. The criterion used was discarding if there was an overlap with:

- Data already imported from the previous databases; or
- Data from the CAR itself.

Additionally, the legal relationship indicated in the data was considered. Thus, possessions with overlap with properties were accepted, considering the modelling discussed above.

5.3.1.2 Importing BAUnit, RRR, and Party data

The import of data referring to administrative units, right relationships and parties was considerably more costly due to the absence of data from the Real Estate Registry. As it was not possible to obtain the primary data, several additional operations were performed to try to compensate, via secondary sources. For example, the property (RRR) and party data was obtained from Sigef if the feedback from the Registry in the system was more recent than in the SNCR (case of data redundancy). In most situations, however, the data used came from the SNCR.

As a last resource, through individual queries in scanned photocopies of documents, which is the only option available for accessing registration data at the moment, it was possible to identify that there were discrepancies even for the data in which it was informed by the registry itself that the data had been updated.

'Impossible' situations were also identified according to the model, such as the same property being part of more than one immovable. This and other situations arise from the well-known outdated information on legal relationships and its parties, once again, as a result of the lack of access to structured data from the Real Estate Registry. This highlights the basic need for integration between Registration and Cadastre, so that the information of both domains is shared between them. Today, this flow happens only in the direction from Cadastre to Registration, not the other way around.

The cases were identified and flagged pending for treatment in the next stage of prototype development, which provides the functionalities for editing the data according to the new data model.

5.3.2 Features

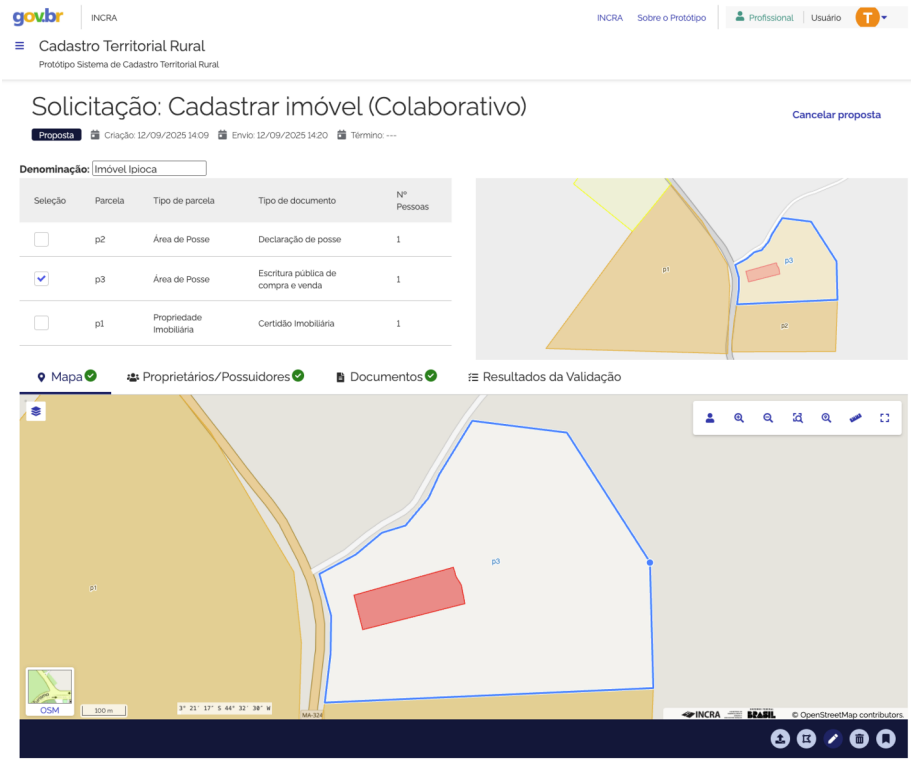
In addition to importing the data, the CTR prototype should also demonstrate the ability to deal with editing to adapt the data to the new model, as well as regular cadastral updates: change of ownership, change of legal relationships (formal and informal), editing, subdivision and merger of parcels.

One of the capabilities explored was the possibility of entering spatial data in **a collaborative way**, based on the Fit for Purpose concept, enabling its integration with "AAA" data, with standardized precision and accuracy, linked to technical responsibility. Additionally, from this data, generate the representation of the rural immovable defined by Brazilian legislation.

With this functional capacity, it would then be possible to update the immovables based on transactions involving possessions and properties. Today, this information is precariously collected by different systems, with representations that often do not converge.
The prototype includes a registration update request form that maintains the same structure for the different types of updates, according to the functionalities described in item 5.2.3.
At the top of the interface, the form presents a summary table with the basic information of each parcel involved in the application, accompanied by a miniature map that graphically represents the parcels and their immediate surroundings. The summary table allows the individual or multiple selection of plots, and this selection automatically triggers the adjustment of the framing (zoom) in the main map tab, facilitating the spatial visualization of the selected elements.
The main form sits just below, organized in four tabs:

- Map: gathers geospatial data and cartographic interaction tools with the parcels;
- Owner/Possessors: allows the registration and binding of holders (owners, possessors or legal representatives) to the respective parcels;
- Documents: it is intended for uploading and registering the data of the documents proving possession and/or ownership;
- Validation Results: presents a summary of the automatic checks performed by the system throughout the filling of the information, highlighting any inconsistencies or pending issues detected in the filling of the data, including those related to the overlaps detected.

This modular structure aims to ensure standardization, usability, and functional coherence between the different modalities of cadastral updating, promoting a uniform user experience and facilitating the integration of cadastral and geospatial information into the system.
In the following figure, we can visualize the case of a rural property according to the agrarian concept, composed of three parcels with different legal situations: a possession derived from a real property right (p1), a possession derived from a transaction contract (p3) and a simple informal possession (p2). It is the first experience in which this representation is possible. The areas in red indicate overlaps identified with other preexisting parcels in the database. The panel with the enlarged map is the editing environment, with the dot in blue indicating the vertex that can be dragged. The upper table has the summary of the data of the parcels entered for the property (p3 is highlighted).



By itself, the capacity demonstrated by the application already denotes a success of the prototype. In addition, the application allows to represent parcels using simple methods, applying the concept of quality classes. Thus, it is possible to take advantage of data already present in the georeferenced cadastre, made by a professional, which is formally linked to the Registry, and complement it with information provided directly by the citizen, with the on-screen snap features that help the input of topologically consistent data and minimize representation conflicts.

6. CONCLUSION

The results obtained so far with the development of the prototype of the CTR are considered a success case, mainly due to the feasibility of applying the proposed concepts from legacy data, through a model based on ISO 19152 (LADM).

Regarding the modelling, LADM proved to be a valuable resource to meet the representation needs foreseen for CTR, as it allowed dealing with formal and informal situations (RRR) in addition to AAA standard geospatial data combined with collaborative data (*crowdsourcing*), following a Fit for Purpose approach.

Database structures and routines for importing data from current systems were successfully implemented based on the modelling, covering four selected Brazilian municipalities. In these routines, data precedence rules were implemented, including treating the overlaps for each case, also organizing parcels into levels.

Regarding the processes and functionalities of the CTR Prototype, cadastral updating tools were also developed considering the variety of the imported data. Adding and moving nodes, boundaries, making parcels and associating tenure and personal data in one screen on the web turned out to be possible. Beyond that, it enabled the spatial representation of the Brazilian definition of rural immovable from the parcels, regardless of quality classes applied.
This creates a possibility of, in the future, obtain the immovables configurations directly from the transactions regarding properties and possessions. This feature would radically simplify dozens of processes used today in Brazilian Land Administration.
However, there is still a long way to go. The complexity of the arrangement of geospatial data into levels, with different quality classes, and the necessary validations using the tested tools is still a challenge, especially considering the scale and performance requirements expected to perform these operations. The availability of highly qualified IT professionals with experience to deal with such technologies is also a concern.
The organizational environment represents a challenge too. For example, INCRA must deal with an institutional culture that does not understand geospatial data as a basic component of the cadastre. Externally, the inaccessibility of the Real Estate Registry's structured data is one of the factors that can considerably limit the project's potential. Finally, one cannot disregard the need to implement, in fact, interoperability among the different systems that operate Land Administration in Brazil, in its multiple purposes, what requires a deeper involvement from these stakeholders.

REFERENCES

Carneiro, A.F.T., 2003. Real Estate Registry and Real Estate Registry. Real Estate Registry Institute of Brazil - IRIB, Porto Alegre-RS.

Enemark, S., Bell, K. C., Lemmen, C., & McLaren, R., 2014. Fit-for-purpose land administration. International Federation of Surveyors.

ISO/TC211. 2012. ISO 19152:2012 Geographic Information — Land Administration Domain Model (LADM). ISO Standards. ISO. 117 pages.

Kaufmann, J., Steudler, D., 1998. Cadastre 2014: A vision for a future cadastral system.

Lemmen, C., 2010. The Social Tenure Domain Model: A Pro-poor Land Tool. Fig Publ. 1–21

Lemmen, C., Augustinus, C., Plessis, J.D.U., Laarakker, P., Zeeuw, K.D.E., Saers, P., Molendijk, M., 2015. The Operationalisation of the “Continuum of Land Rights” at Country Level. The World Bank, Washington.

Lemmen, C., Augustinus, C., van Oosterom, P., Molen, P. Van Der, 2007. The Social Tenure Domain Model – Design of a First Draft Model. FIG Work. Week 2007, Hong Kong SAR, China 13–17.

Lemmen, C., van Oosterom, P., Bennett, R., 2015b. The Land Administration Domain Model. Land use policy 49, 535–545. doi:10.1016/j.landusepol.2015.01.014

Lemmen, C., van Oosterom, P., Eisenhut, C., Uitermark, H., 2010. The Modelling of Rights Restrictions and Responsibilities (RRR) in the Land Administration Domain Model (LADM), in: FIG Congress 2010 - Facing the Challenges – Building the Capacity. FIG, Sydney, Australia, p. 40.

Metaferia, M. T., Bennett, R. M., Alemie, B. K., & Koeva, M., 2022. Fit-for-purpose land administration and the framework for effective land administration: synthesis of contemporary experiences. Land, 12(1), 58.

Marra, T. B., Barbosa, K.J., Oliveira, E.A., 2015. Brazil Towards an Effective Cadastre with Sigef. Proceedings: Conference on Land and Poverty, Washington-DC, USA. World Bank, 2015.

Marra, T. B., Barbosa, K. J., Oliveira, O. O., Oliveira, E. A., 2017. Improving Land Administration in Brazil: reengineering cadastre using LADM, in: Proceedings of the Annual World Bank Conference on Land and Poverty; Responsible Land Governance: Towards an Evidence Based Approach. World Bank, Washington DC.

Paasch, J., 2011. Standardization of Real Property Rights and Public Regulations: A Terminological Approach.

Paasch, J., van Oosterom, P., Lemmen, C., Paulsson, J., 2015. Further modelling of LADM's rights, restrictions and responsibilities (RRRs). Land use policy 49, 680–689. doi:10.1016/j.landusepol.2014.12.013

Williamson, I., Rajabifard, A., Kalantari, M., & Wallace, J., 2012. AAA Land information: accurate, assured and authoritative. In Proceedings of 8th FIG Regional Conference, Montevideo, Uruguay (pp. 26-29)

UN-HABITAT, G. L. T. N., 2008. Secure land rights for all. Retrieved June, 11, 2018.

UNECE, 1996. Land Administration Guidelines - With Special Reference to Countries in Transition. United Nations, Geneva.

Williamson, I., Enemark, S., Wallace, J., 2010a. Land Administration for Sustainable Development, in: FIG Congress 2010 - Facing the Challenges – Building the Capacity. Sydney, Australia, p. 16.

Zevenbergen, J., 2002. Systems of Land Registration, Aspects and Effects. Geodesy. Technical University of Delft.

BIOGRAPHICAL NOTES

Thiago Batista Marra is Geographer, Federal University of Uberlândia. MSc in Geography, University of Brasília. Analyst in Agricultural Development and Reform on INCRA since 2006.

Eduardo Aguilar de Oliveira is a System Analyst graduated at Federal University of Maranhão, Land Georeferencing specialist and Project Manager from Getulio Vargas Foundation (FGV). Has been working in the land regularization and cadastre sectors at Incra since 2008.

Kilder Jose Barbosa is Surveying Engineer from University of Viçosa. Analyst in Agricultural Development and Reform, on INCRA since 2006.

Oscar Oséias de Oliveira is Surveying Engineer from University of Viçosa, Specialist in Notarial and Registration Law and Master's Degree in Geotechnics/Geoprocessing. Analyst in Agricultural Development and Reform, on INCRA since 2006.

Selma Helena Cirne Padinha graduated in Architecture and Urbanism from Federal University of Rio de Janeiro and Land Georeferencing specialist; graduate in law from FAESA and specialist in Notarial and Registration Law, on INCRA since 2005.

CONTACTS

Thiago Batista Marra
National Institute of Colonization and Agrarian Reform
SBN Qd. 01 Block D - Development Palace Building, 8th floor, room 805.
Brasilia, DF
BRAZIL
Phone: +55 61 34117618
thiago.marra@incra.gov.br