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A Cadastre proposal for Brazil

Uma proposta de Cadastro Territorial para o Brasil

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Abstract: The implementation of a cadastral system aims to meet the needs of territorial information, as well as the generation of products that meet the multi-purpose that are presented for municipal management. In Brazil, each municipality seeks to maintain a cadastre for tax purposes, with the other territorial and legal information relating to the dispersed or nonexistent parcels. In the rural area, the Federal Government has been registering with legal and regulatory procedures. For the elaboration of this proposal, premises related to legal, technical and economic aspects were listed. The arrangement regarding territorial objects and enrollments clarify and facilitate the adoption of these proposals to solve the problems faced today in the cadastres and already foreseeing the adoption of cadastral multi-purposes. The structuring of this cadastre goes through a reference network, the required accuracy, the forms of survey, the cartography registration, the products generated and who will be the federative entity responsible for conducting the system. The implementation and maintenance of the land registry are presented in the form of a flow chart clearly indicating how the system should work. It is also noteworthy that the present proposal is perfectly in line with the premises of the new versions of the Brazilian technical standards that are in the process of being revised and also seeks to enable an efficient, economical and technically safe way for implementation and maintenance to be possible data updated daily in the cadastre of Brazil.
Keywords: Cadastre. Parcel. Cadastre structure. Implementation and maintenance of the cadaster.

Resumo: A implantação de um sistema cadastral deve objetivar o atendimento das necessidades de informações territoriais organizadas, bem como possibilitar a utilização do mesmo na geração de produtos que possam atender as multifinalidades que se apresentam para uma boa gestão municipal. No Brasil cada município procura manter um cadastro para fins fiscais, sendo as demais informações territoriais e jurídicas relativas as parcelas dispersas ou inexistentes. Na área rural a União vem realizando um cadastro com um conjunto de procedimentos legais e normativos para a realização do cadastro rural. Para a elaboração desta proposta foram elencadas premissas relativas aos aspectos jurídicos, técnicos e econômicos. O arranjo relativo aos objetos territoriais e as matrículas esclarecem e facilitam a adoção destas propostas para solucionar os problemas hoje enfrentados nos cadastros e já prevendo a adoção dos multipropósitos cadastrais. A estruturação deste cadastro passa por uma rede de referência, as precisões requeridas, as formas de levantamento, a cartografia cadastral, os produtos gerados e quem será o ente federativo responsável pela condução do processo. A implantação e a manutenção do cadastro são apresentadas em forma de fluxograma indicando claramente como o sistema irá funcionar. Ainda, destaca-se que todo o escopo da presente proposta se encontra em perfeita consonância com as premissas das novas versões das normas brasileiras que estão em processo de revisão e também procura viabilizar de maneira eficiente, econômica e tecnicamente segura para que seja possível a implantação e manutenção dos dados atualizados ao dia nos cadastros do Brasil.
Palavras-chave: Cadastro. Parcela. Estrutura do cadastro. Implantação e manutenção do cadastro.

1 INTRODUCTION

The implementation of a cadastral system must aim at meeting the needs of organized territorial information, as well as enable its use in the generation of products that meet the multiple purposes that are required for a good municipal management.

Even though there is no cadastral system itself in Brazil, it is recognized that Federal Law 10.267/2001 (BRASIL, 2001), known as Georeferencing of Rural Property Law, is the major Brazilian legal landmark in terms of the Land Cadastre. In addition, the content of its articles, and later on the decrees that regulated it, was strongly inspired and supported by the cadastral principles propagated by the International Federation of Surveyors (FIG).

The future vision for the Cadastre, presented by FIG in the 1990s, was contained in the six declarations of Cadastre document of 2014, namely: i) Complete situation of the territory including rights and restrictions; ii) Integration between cartographic and registration data; iii) Replacement of cadastral cartography by data models; iv) Solutions for digital cadastral data; v) Favoring of public-private partnerships; and vi) Self-sustainable cadastre. To varying degrees, the statements guided the implementation and modernization of cadastral systems worldwide and do not seem to have lost their validity. (FIG, 1995; KAUFMANN; STEUDLER,1998).

In Brazil, this futuristic viewpoint for the Cadastre arrived in the mid-2000s, and impacted the law 10267/2001, which brought to the national scenery several cadastral concepts recommended by FIG, such as: parcel, parcel defining vertex, precision and tolerance of the defining vertex, unique parcel identifier, reference network for cadastral surveys, standardization of cadastral survey methods, cadastral completeness, cadastral execution over time, cadastral update, accreditation/certification procedures, among others. The present work shares this vision and seeks to apply it in its proposals.

This law, the regulatory decrees, the regulation, and the technical manuals that support it have some limitations. On one hand, its reach is restricted to rural properties, on the other, a set of weaknesses still need improvement (ARAÚJO et al., 2018). However, its good practices – consolidated over almost 20 years of application –, can and should be used when seeking for a conceptual adjustment, in order to define the elements of a Land Cadastre in Brazil. Two of these good practices are fundamental in this regard: the mechanism of parcel certification, and the correspondence between certified parcels and registrations.

More recently, FIG has released another vision on the Cadastre, somewhat more extensive, which recognizes the particularities of each location in relation to the degree of the maturity (or even non-existence) of the cadastral system and the legal and structural condition for its implementation and/or modernization. The principles of "fit-for-purpose land administration" are based in three axes of action: the focus on the purpose of meeting the local needs of a territorial management, a flexible spatial design for the Cadastre, and the incremental improvements of continuity and applicability (FIG, 1995; FIG, 2015; UN, 2016).

Defining the minimum and necessary elements of a Land Cadastre for Brazil is a challenging task, which goes through a conceptual review on some points, given that much has already been discussed in journal publications, dissertations, and theses on the subject. At the same time, it is necessary to look back to capture the essence of the theme, understand the current situation to ensure viability, and design ahead to ensure sustainability.

Within this context, the objective of the present research is to harmonize more than 30 years of research on Cadastre in Brazil, in compliance with FIG's cadastral principles and concepts, as well as the legal framework and national cadastral conjecture. The following chapters are arranged as follows: Chapter 2 shows the situation of Land Cadastre in Brazil; Chapter 3 lists the set of necessary technical premises that must be met when structuring a cadastral system that is appropriate to the existing technical and legal conditions, and also suggest the adoption of other measures that aim at improving and perfecting the system; Chapter 4 presents a discussion about the concepts of parcel and land objects (along with their relationship with registration), and a definition proposal for both (appropriate to our reality); Chapter 5 brings the necessity of a reference network, the need for normative updates, and suggestions for this; Chapter 6 presents the proposed arrangement and the operating flow to the cadastral system; and, finally, Chapter 7 shows the set of conclusions of the work.

2 THE LAND CADASTRE SITUATION IN BRAZIL

Ideally, every Brazilian municipality should have a Land Cadastre, covering the totality of its territory, for the purposes for which it is intended; however, there is no legal provision for this to happen. Therefore, the municipality is dependent of what its management team understands as the purposes and benefits that a minimally organized Land Cadastre will provide to its residents. In a research about land regularization in eight municipalities, Santos and Antunes (2020) indicate the lack of registration in these areas, making it difficult to carry out the work and reducing the costs involved in the process.

Each municipality seeks to maintain a cadastre for tax purposes, aiming at collecting taxes in the urban area as the main focus and objective of the system. For this, the property boundaries are raised by remote sensing; then, they receive a code – named real estate registration –, and the necessary information for the composition of equations to determine the tax amount, with other territorial and legal information relative to dispersed or nonexistent parcels.

Among the municipalities, the first situation that can be pointed out is when there is total absence of the cadastre/registration for any purpose, not even information for the collection of taxes related to the property. No spatial information is used for municipal management.

The second situation is when a part of the municipality, usually the most valued and urbanized areas, has a minimally organized cadastre, in order to fulfill fiscal functions. In these cases, it is possible to find block plans on paper, and database with sufficient information for tax collection. In other cases, rarer ones, they have an information system with cartography in digital media.

The third group of municipalities has a cadastre composing the multipurpose cadastre, with numerous information available to managers and population in general, specific sectors to update, and, in some cases, until they develop, with their information systems. Within this group, a small portion is able to integrate the various sectors that need spatial information and that also expand their reference network for cadastral surveys, not being limited to the one that was implemented when making the registration.

When thinking about Land Cadastre, another fundamental component is the land registration system, which is implemented throughout the whole country, organized in real estate districts that cover both urban and rural areas. For the purposes of registration, the property receives a number – the registration number –, and some characteristics of the properties are noted on it, which in theory should be the result of a survey carried out on the proper spot by topography. The relationship between parcel and registration number will be discussed in chapter 4.

The physical basis of the registration is the material property, that is, the delimited land area. According to Mello (2006), the registration number represents the individuality of the property, its geographical situation, and its perfect description, undergoing objective and subjective throughout registrations.

The Land Cadastre and Registry should reflect each other, which means what is registered it cadastred and vice versa. Since this does not happen, registrars have been looking for solutions to specialize enrollments by creating their own cadastre of what is enrolled. It should be reinforced that the most recent descriptive memorials have coordinates defining the limits of the properties that are taken to registration. Also, the two property identification numbers, the enrollment in the land registration and real estate registration at the city hall, which should appear in both do not always reflect the same object.

In the rural area, the Union has been making a cadastre with a set of legal and normative procedures to carry out the rural registry, through georeferencing of rural properties, but that also contains disperse and incomplete information in view of a functional and self-sustainable cadastral system. The certification system for rural properties still has its weaknesses; however, it is an example to be analyzed for what may work for registration in Brazil.

For Araújo et al. (2018) as benefits of the advancement, we can mention the agility in the certification processes, the standardization in the descriptions of the properties and parcels, besides giving the qualified professional the due responsibility of the work performed.

In addition to the rural territorial registry, the Union maintains other registers related to the territory and the areas controlled by it. The Federal Union Patrimony Secretariat of Brazil (SPU), which should be responsible for administering the assets of the Union established in article 20 of the Federal Constitution

(BRAZIL, 1998), does not have a territorial register with the information on the totality of these assets.

The SPU has been trying to demarcate and homologate two important definitions of territorial division that affect thousands of people due to their legal and positional uncertainty, which are the lines that define the Navy Land and the Midline of Ordinary Flood.

They also keep their own registers or territorial information within the scope of the Union: the National Indian Foundation (FUNAI), the Brazilian Institute of Geography and Statistics (IBGE), the Ministry of the Environment, the Federal Revenue Service, the Special Land Affairs, the National Department of Transport Infrastructure (DNIT), state-owned energy companies, among other executive branches.

The states also execute or maintain registrations through their Land Institutes, or land departments and the Secretariat for the Environment, carrying out surveys for land regularization purposes, discrimination of public lands and resolution of land conflicts and environmental registration, both in rural and urban areas.

The companies responsible for infrastructure services such as sanitation and energy keep records/registrations with the same territorial information as the city halls. They also elaborate technical rules for survey and execution of these records unilaterally, to serve only their purposes.

The reference network for cadastral surveys, the element that ensures the geometry and accuracy of the surveys and should be unique for all the purposes of the cadastre, when it exists, is carried out independently and individually by the government entities mentioned, each trying to solve their problem and ignoring the networks that are already deployed.

The unification of the basic elements of the Land Cadastre would certainly facilitate the sharing of information, reduce the costs of execution, maintenance and updating, and would also allow the expansion of the multi-purposes proposed by a modern register. While discussing collaborative, accessible 3D cadastres, municipalities are unable to perform the basic 2D Land Cadastre.

3 PREMISES FOR CADASTRE

The legal instrument that authorizes the implementation of such a Land Cadastral System in Brazilian municipalities is contemplated by item VIII, Art. 30, of the Constitution of the Federative Republic, promulgated on October 5, 1988, which makes the municipality responsible for the construction, consolidation and maintenance, which states that: “it is incumbent upon the municipalities, among other obligations, to promote, as applicable, an appropriate territorial ordering through planning and control of the use, parcelling and occupation of urban land.

The proper territorial ordering is only viable through the precise knowledge of the administered territory and the condition for this necessarily passes through a Land Cadastre perfectly integrated with the Land Registration System.

In order to guide a viable proposal for the implementation of a Land Cadastre for Brazil, some premises were listed, which must be fulfilled in order to structure a cadastral system that is adequate to the existing technical and legal conditions, as well as the adoption of other measures that aim to improve and refine the system, namely:

- Premise 1: The Register must be partial, in a common basic system that serves, exclusively, only for the identification of the territorial portion for the official proof of its limits (PHILIPS, 2004). The territorial parcel is the basic unit of the Land Cadastre (FIG, 1995).

- Premise 2: The existence of a Reference Network. Basic condition of the registration, intensified at the level of surveys of legal limits supported by a technical standard, based on the Brazilian Geodetic Network. The norm NBR 14,166 (ABNT, 1998) refers to the procedure for implanting the reference network for cadastral surveys in the municipality. Currently, this rule is being restructured, with no date for public consultation.

- Premise 3: The Land Cadastre by field measurement. The survey of the plots defining vertex must be carried out on-site by field measurement, supported by the reference network with the propagated precision, fulfilling the predicted tolerances in technical standards, as occurs in the reference countries in the area. The survey for the Land Cadastre must be by field measurement upon each vertex that defines the parcel since its legal limits are invisible and do not represent the real features (pseudo-limits usually are represented by fences and walls) existing in the field and which materialize the actual occupation of the territory.

- Premise 4: The demarcation of the property's vertexes. All vertexes must be demarcated whenever they are visible, accessible, stable and convenient. The materialization of the vertexes of the properties must be indicated in the original field surveys (sketches) and in the cadastral letter. The materialization of the vertices of the properties must meet the purpose regarding durability, as they ensure that a new verification measurement is carried out physically on the same vertex to eliminate future doubts. The vertex remaining demarcated in the field is a strong indication that the position did not change due to the reconstruction of the feature where it was materialized, such as walls, fences and buildings, for example.

- Premise 5: The forecast for multi-purposes of the Land Cadastre. The registration of territorial parcels must serve as a geometric and legal (official) basis for the other thematic registries that together form a Multipurpose Land Cadastre. Examples of thematic registrations are infrastructure, fiscal, environmental, geotechnical, public places, land occupation, among others.

- Premise 6: The integration between Property Registry and Land Cadastre. The principle of the Property Registry's specialty and the observation of the right to property are considered when, in the spatial characterization of the property involving its location and dimensions, there are no gaps or overlaps considering the entire territory. The precise spatial characterization of the property must pass through a Land Cadastre that must be interconnected with the Property Registry.

- Premise 7: The need for qualified and accredited professionals to execute the surveys. The professionals who will execute the registration must have training compatible with their qualifications established by the professional councils.

- Premise 8: The use of existing technical standards. There is currently a very significant set of laws and technical standards, both from ABNT and from regulatory entities, which are already widespread and known to professionals and which should be used to execute this proposal.

- Premise 9: The positional precision of the surveys. Defined in technical standards in order to be compatible with reality and technically supported.

- Premise 10: The use of remote sensor products, more appropriate for mass surveys, reducing costs in the elaboration of feature maps that can be used for the creation of provisional plots (non-certified plots, as will be discussed further), initial approach to a Land Cadastre,

- Premise 11: The use of municipal tax registers, which are designed considering the actual occupation of the territory and not the legal one and whose location key is the real estate registration. Remote sensor products can also be used to create provisional plots.

4 PLOT AND TERRITORIAL OBJECTS

Over the last few decades, since the topic of Cadastre has been debated in Brazil, an attempt has been made to adapt the various concepts and contents related to the Land Cadastre, in order to adopt a cadastral structure or model in our country.

Any attempt must take into account the technical assumptions already listed in the previous chapters and envision that to fulfil its purposes and be viable, the Land Cadastre for Brazil must be necessarily flexible, simple, complete and updated.

This statement does not imply discarding the internationally accepted and established concepts of Cadastre, on the contrary, the cadastral principles that guided the most developed countries in this area must be observed, studied and adjusted to our reality so that we can achieve similar results to those achieved internationally.

In order to adapt the concepts to our reality and offer the authors' position on the topic, the following definition of the plot is presented:

The plot is the unit of the Land Cadastre, it constitutes a territorial portion of continuous extension, defined by its limit vertex.

This definition is in line with and meets the international cadastral principles, in addition to being broad and flexible enough to cover the most diverse situations in which the existence of plots can be modelled (Chapter 3, Premise 1).

The spatial continuity of the parcel referred to in the definition above is a concept related to the domain

unit, the legal causes that originate it (registered or unregistered property, existence of domain titles, among others) and the political-administrative location (state, municipality), as discussed in França et. al (2018a) and Brandão (2003). In relation to the boundary vertexes that defines the plot, these must have georeferenced coordinates and the plot must receive an identification code that is unique (does not repeat in another plot), unequivocal (perfectly identifies the plot and is not confused with other types of codes) and stable (it remains linked to the plot when there is any changes in the limits, and a new code is assigned to it).

In terms of conceptual simplicity applied to the Land Cadastre, the solution given by Federal Law 10.267 / 2001 (BRAZIL, 2001) stands out, in which the concept of property (rural, in this case) is the same as the law of Public Records , Federal Law 6.015 / 1973 (BRASIL, 1973), which greatly simplified the understanding of plot and its adaptation to the territorial legislation in force in Brazil, in addition to effectively promoting the integration Cadastre Registration. The concept of law 10.267 / 2001 for plot is that it must correspond to the registration and, consequently, to the property. For the purposes foreseen by law, plot, property and registration correspond to the same object (BRASIL, 2013a).

In the INCRA registration database, which is the managing body of the rural territorial registry, there are only plots that have gone through a certification process (Figure 1). As will be discussed later, this understanding can be expanded by admitting different types of plots. However, this practice of the rural territorial cadastre has been able to promote the integration cadastre registry with a conceptual simplicity and legal adequacy and should guide the structuring of a viable cadastral model that covers both rural and urban plots.

Figure 1 – Cadastral database formed only by INCRA certified plots.

Source: INCRA (2020).

Such an understanding arising from the rural experience, supported by the legislation in force, that for the Cadastre in Brazil to become viable there must be some kind of connection between plot (element of the cadastre) and registration (element of the registration system), necessarily leads to an important particularity: plots are two-dimensional. Thus, terms such as territorial, two-dimensional and 2D must be associated with the understanding of what is a plot. Figure 2 shows a typical image of urban occupation and the respective definition of territorial plots, that is, 2D. All sorts of territorial occurrences above or below the surface, whose complexity goes beyond the two dimensions, must be modelled in the form of territorial objects, whose definition will be presented further.

Figure 2 - Example of territorial occupation (left) and corresponding territorial plots (right).

Source: The authors (2020).

The correspondence between plot and registration is a principle, which does not mean that every parcel is necessarily related to a registration and vice versa, given that there are situations in which parcels have no registration (areas of possession, public areas, roads, etc. .), as well as some registrations may refer to elements above or below the surface, not necessarily corresponding to the plot, but being linked to it (vertical condominiums, slab right, etc.). Aiming to expand and adapt these concepts, so that both plots in urban and rural areas can be covered (cadastral completeness), to fulfil the particular characteristics of rural territorial management (centralized at INCRA) and urban (spread over more than 5500 city halls), in addition to promoting the final activity of the Land Cadastre (connecting people and land), it is necessary to characterize two types of plots for the Register in Brazil: certified plots and non-certified parcels.

The certified plot is the one whose limits have been verified in loco, through measurements in the field by surveying, representing the legal limits or in order to become possible to take it to registration it when necessary, in other words, the limits of this plot correspond to the constant description in a registration and vice versa (Chapter 3, Premises 3, 4, 7 and 8). This is the common procedure applied to the plots of the rural territorial cadastre, whose process needs to be improved only. The plot should only be considered certified, after going through a process that ensures the fulfilment of two criteria: i) the non-overlap and ii) the non-existence of gaps between adjacent certified plots (currently, the certification applied to INCRA's rural registry fulfils only the first criterion, as discussed in Araújo, et. al (2018)). In order to fulfil the second criterion, there is a prior need to know which are the confronting plots, even if not yet certified.

The certified plots are the link of the Land Cadastre with the registration system (Chapter 3, Premise 6) and its purpose is the strengthening of the legal security of the titles that correspond to them (the registrations), therefore having a definitive character (in the sense of being distinct from the provisional character of the non-certified ones).

The origin of the certified plots is in the surveys required by the cadastral management bodies (INCRA for the rural, the city halls for the urban) or for the land registration with the consent of those for several processes involving legal surveying issues (Chapter 3 , Premise 7). These surveys are well used in the case of the rural cadastre, since they are standardized and are part of a system, but they are underutilized in the urban cadastre, or briefly meet a specific requirement (a building permit, an environmental license, an analysis of the feasibility of using the soil, a process of adverse possession, dismemberment, recall, etc.), to be discarded later, when they should also be used mainly to update the cadastral base. An unsophisticated yet more efficient protocol for exchanging information would make city halls and real estate registries keep each other always updated.

The non-certified plot comes from existing geospatial databases, normally delimited by methods of mass survey, or those that have not yet gone through the certification process (Chapter 3, Premise 10). The limits of the non-certified plot were not verified in loco and therefore has the reliability that the data source provides them. According to this, França et. al (2018b) lists many critical problems due to divergences in the interpretation of features that apparently define the limits of plots. In its study, flights were performed with a remotely piloted aircraft (RPA) and the restitution of features on the generated orthophoto was performed. One of the results (Figure 3) shows a set of plots with positional discrepancy and another set of plots, both not

certified, with different boundaries when compared to the restitution of features on orthophoto and the tax registration database provided by the Municipality of Florianópolis-SC. The authors indicate that the same types of discrepancy were found when comparing these data sources with the registration of the properties in question.

Figure 3 – Plots with positional discrepancy (A) and plots with different boundaries (B).

Source: França et al. (2018b).

Commonly, municipal administrations have geospatial databases of the urban territory that were raised en masse or originated from subdivision projects. These databases cover the entire length or part of the urban perimeter and were made by aerial photogrammetric restitution, satellite images, old maps, surveys for various purposes mainly to meet the fiscal objectives for the launch of territorial taxes (such as IPTU, ITBI , and others), issuing licenses, permits, among others. These are the so-called fiscal, economic, technical, real estate, tax records and a range of assigned names. Such data sources can be used to delimit non-certified plots (Chapter 3, Premise 11).

The non-certified plots are provisional in nature (which means they exist until they are succeeded by another of a definitive nature) and can be administratively altered (divided or grouped, geometrically modified, deleted or created, and so on) as already occurs in the various processes carried out in city halls on their existing geospatial databases. Progressively they must be succeeded by certified plots in a flow that will be discussed later in this work.

The study filed by França et al. (2018b) still presents a concrete example of how the progressive replacement of non-certified plots by certified plots can occur (Figure 4) which illustrates a situation in which the refund generated on the photo identified that there was only one plot (in yellow). According to the database by the Municipality of Florianópolis-SC, there were four plots occupying the same location, although with positional discrepancy in the limit vertexes. However, when the situation was confronted with the domain titles, it was discovered, from the on-site verification, that the reality was different. After the surveying process, three plots remained, each corresponding to a different registration. The coordinates of the boundary vertexes of these plots were considered, certified, and these became available to update the city hall's database and for registration. The other adjacent non-certified plots must have their vertexes adjusted to these.

Figure 4 - Example of replacing non-certified plots (left in red) by a certified one. (right in green).

Source: França et al. (2018b).

As previously mentioned, the rural cadastral base by INCRA is formed only by successively increased certified plots, but there is nothing to prevent an integration with other databases (such as the Rural Environmental Registry, for example) of non-certified plots to be modelled, as long as they are properly identified. In municipal administrations, a natural path is for the cadastral databases of the urban territory to be initially composed only of non-certified plots, so that over time they will be replaced by certified plots through the update mechanism mentioned in the previous paragraph, so that both types of plot live in harmony.

It should also be considered that there are non-certified plots that will remain so, either due to their own nature of non-correspondence as a domain, either due to the non-necessity, or due to the non-requirement to the occupant/owner of the plot by the registration management body or cadastre for certification. This does not diminishes the importance of these plots being modelled since they fulfil an important role for the collection or planning and territorial management functions with the municipal administrations.

Once the concept of plot is understood as the cadastral unit, continuous portion of the territory, delimited by vertexes, defined in 2D, certified (for purposes of registration) or not certified, we can proceed to the concept of Territorial Object. As discussed in the document "Cadastro 2014" of FIG (FIG, 1995; KAUFMANN, STEUDLER, 1998), part of the territorial reality is modelled on cadastral systems in the form of plots; this part corresponds to the basic land structure or position. Another part of the territorial reality, however, needs a concept with greater flexibility because it exists physically without corresponding to the plot itself, and because it exists legally, but also does not correspond to a plot itself. Furthermore, in both cases, although they are not plots, these territorial occurrences can occur above or below the surface, they are important and must be considered in cadastral modelling.

To make these situations equal, the FIG proposes the figure of Territorial Objects (TO) which, to suit our conceptual proposal, can be described as follows:

Territorial object is a portion of the territory in whose boundaries or location homogeneous conditions occur.

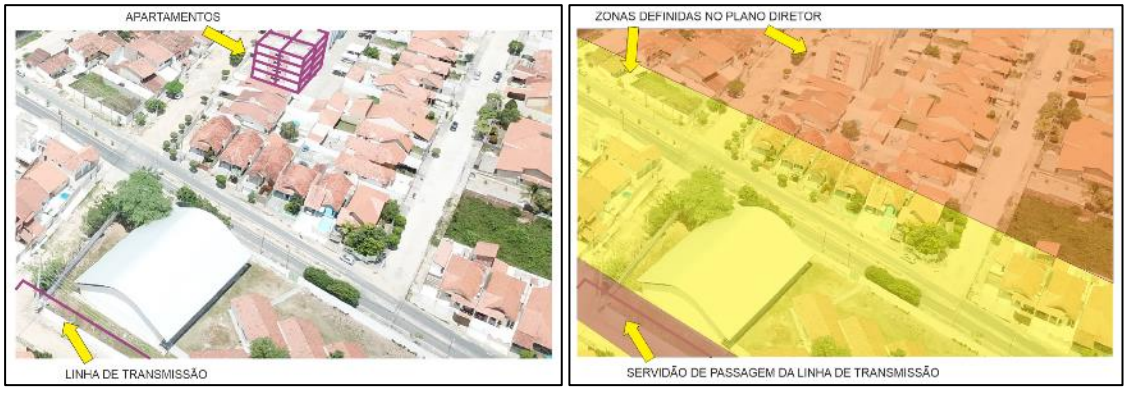
This is an even more extensive concept than that of a plot, and so it is to achieve everything related to the plot without physically corresponding to it, including in dimensions other than 2D. Therefore, Territorial Objects are n-dimensional.

Territorial Object is any natural element, artificial or existing by legal provision on, or under the topographic surface, that has homogeneous conditions within its limits. Territorial Objects can be of two different types: legal or physical (KAUFMANN and STEUDLER, 1998; SANTOS et. Al., 2013).

Legal Territorial Object (LTO) is any continuous portion that defines a right, a liability or a restriction on the territory in a homogeneous manner by legislation (RRR concept proposed by FIG). OTL does not need to be delimited in the field to exist. The permanent preservation areas (APP), zoning of municipal master plans, legal reserve, easement of passage, among others, are classified as OTL.

Physical Territorial Object (OTF) is any natural or artificial element physically existing in the territory in a homogeneous way along its extension, or location. Like OTL, OTF can exist on or under the surface. Buildings in general, vegetation, water bodies, transmission lines, among others are examples (Figure 5) of physical and legal territorial objects as OTF.

Figure 5 - Examples of Physical Territorial Objects (left) and Legal Territorial Objects (right).



Source: The Authors (2020).

This conceptual distinction of Plots and Territorial Objects corresponds to an understanding different from that proposed in Ordinance 511/2009 of the extinct Ministry of Cities, entitled Guidelines for the Multipurpose Land Cadastre (Brasil, 2009). It was proposed that each type of restriction or responsibility should be modelled in the form of a plot. However, in this way, the complexity of cadastral modelling becomes infinite and inappropriate to our reality in which the parameters of legal norms and rules are constantly changing, in addition to many of these legal restrictions not even being georeferenced. For example, by decreasing or increasing a percentage of legal reserves on real estate, by modifying the law of using and occupation of the land, by updating a master plan, natural change in the course of a river, etc., all affected plots would have to be modified, something that would make it impossible to maintain and update the registration, as well as the connection of this new reality with the registration titles.

In contrast, in the present conceptualization of the authors, changes of a legal nature such as those mentioned, concern only the affected Legal Territorial Objects, but the portions remain the same (whether they are certified or not). The conceptual complexity present in the ordinance may partly explain the non-adherence to the guidelines proposed by the Ministry of Cities, although a great effort of dissemination and training has been made with the municipal administrations.

It is highlighted that Territorial Objects, whether legal or physical, can overlap and also overlap plots, but will always be linked to a territorial plot or its portion. In this way, the application of the concept of Territorial Objects opens the way for cadastral modelling 1D, 2D, 3D, ..., nD, allowing to incorporate other elements in territorial management in addition to plots and becoming the source of countless so-called multi-purpose thematic cadastres (Chapter 3, Premise 5). Still, some Territorial Objects will also have connection/correspondence with registrations.

Finally, it should be noted that when defining that the plots have a two-dimensional nature and the OTs have n-dimensional, it is not proposed that the entire Register must necessarily be completed with 2D plots in order to move to 3D Territorial Objects or any other dimension since both concepts (plot and TO) complement each other and can be modelled and implemented in parallel in a cadastral system. What needs to be clear is that, although measurement methods and techniques have evolved rapidly on the last few decades, incorporating the third dimension in mass surveys more and more easily (digital photogrammetry, laser scanning, etc.), the product of these techniques and methods remains the same: digital surface models, which are closer to OTF (land features) than to plots (surveying processes).

Such observations aim only at defining roles and fulfilling the technical assumptions listed above in order to adequate our reality for the viability of a Registry for Brazil.

5 REFERENCE NETWORK AND SURVEY STANDARDS

One of the premises of the Land Cadastre is the existence of a Cadastral Reference Network to support the survey of the plots (Chapter 3, Premise 2). Despite this premise being widely known by the academy and professionals in the measurement area, the form of implantation and enhancement of the network has not yet been consolidated and neither the adjustment criteria and possible methods for this purpose.

Blachut et al. (1979), states that for cadastral surveys only those based on a monumental reference network are acceptable, otherwise the system is technically and economically inadequate.

With the surveying technology through satellite positioning (GNSS) and with the current solutions of real-time corrections, among others, the implantation of points of support for topographic surveys has become faster and more productive.

However, when it comes to the survey of certified parcels, with identification of limits for cadastral purposes and, consequently, the registration of real estate, with a demand for a few centimetres of precision and in which quality control must be achieved through the tolerances allowed between a plot and its borders, the difference of millimetres or a few centimetres in the support points can result in errors that do not fit the survey within the required tolerances. Therefore, technical standards must advance the concepts and parameters of a reference network.

Hasenack (2000) points out as a great difficulty in his research, which aimed to study the documentation of the originals of the Land Cadastre through field measurements, the lack of a reference

network.

Throughout the national territory, the implantation of points to support aero photogrammetric surveys is very frequent, which are generally not used for other purposes, mainly because there are no rules and legal support for the maintenance of a municipal reference network.

The reference network is not just a set of georeferenced points “spread out” across the municipality. Criteria must be defined in feasible, economical, simple, technically safe and sustainable technical standards. The current NBR14166, which deals with the procedures for the Municipal Cadastral Reference Network (RRCM), does not contemplate the needs for the implementation of the network considering such criteria, because it has not been updated since the end of the 1990s, so it is obsolete and inefficient.

Detailing the adjustment of observations, specification of terrestrial measurement methods and use of satellite positioning, added to the positional accuracy of the network's vertexes, are some of the main questions that the current standard does not answer.

As a contribution, this article brings some reflections and proposals to reach Premise 2, the existence of the Reference Network.

5.1 Deployment and Reinforcement

The reference network arrangement should basically consist of two processes: one for implantation and one for reinforcement.

The deployment process is the initial stage of the network. In this case, the municipality must plan a large area for the installation of landmarks and the measurements must be directly linked to the Brazilian Geodetic System (SGB) , that is, in its entirety, the coordinates of the vertexes of this stage are determined using GNSS satellite positioning techniques. For the deployment vertexes of the reference network, it will be given the name "Superior Vertex" (VS).

For the VS, a planning must be carried out considering the adjustment of observations on the vectors formed between the vertexes of the reference network and the SGB, and when possible, the vectors for adjustment related to the neighbouring VS must be considered.

Once the VS's are implanted, the second process is the enhancement process. This process must be carried out over time and this step must be on two levels. The first when a new vertex starts to be inserted in the network with measurements considering at least two VS or VS and SGB as a reference, in this case the nomenclature proposal is the “Main Vertex” (VP).

The VP measurements can be either via satellite positioning or terrestrial measurements using Total Station, as long as the methods used meet the requirements of adjustment.

When densifying the network, the moment will come when VS and SGB will be distant from one another and will no longer be considered neighbouring points to guarantee homogeneity in the network in a certain part of the municipal territory. For these cases, the proposal is to enhance at a second level, the level of "Support Vertices" (VA). The VA's can have their adjustment based on at least two VP's, VP combined with VS, VP combined with SGB, which means that there will always be a VP in the adjustment. In addition, it will be necessary to densify the network to the point where a VA will reference other VA's by the proximity of the vertexes.

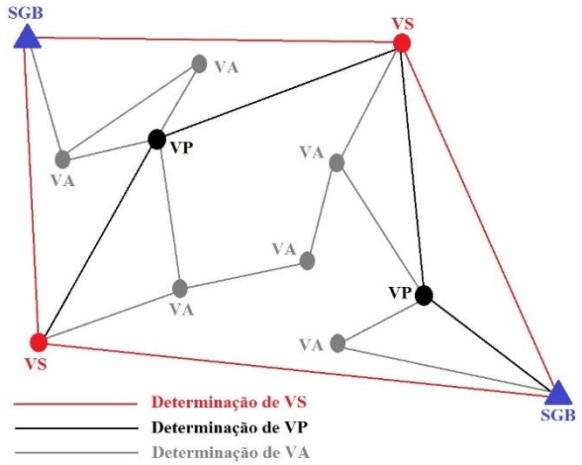
To facilitate understanding, the Table 1 shows a summary of this proposal, presenting the references for each type of vertex, name, acronym and measurement techniques. A scheme of structuring and support for the network levels is also demonstrated (Figure 6).

Table 1 - Types of vertices of RRCM.

Vertex name	**Acronym**	**References**	Techniques
Superior Vertex	VS	At least two SGB vertexes	GNSS
Main Vertex	VP	a) At least two VS b) SGB+VS	GNSS and Total Station
Support Vertex	VA	a) At least two VP b) VP+VS c) VP+VA d) VP+SBG e) VA+SGB f) VA+VA	GNSS e Estação Total

Source: The Authors (2020).

Figure 6 – Scheme suggested for the reference network hierarchy.



Fonte: Authors (2020).

In all the cases presented in Table 1, the neighbourhood principle must be considered, which makes the new vertexes to be densified by the closest vertexes, making the regions of the reference network homogeneous.

This suggestion presents a hierarchy in the context of planning and not related to the precision values of the point or classified in order. Still, it simplifies the network to only three levels instead of the current twelve levels in NBR14166 / 1998 (item 4.2) (ABNT, 1998).

5.2 Positional Accuracy

The expected positional accuracy for the vertices of the reference network establish a series of procedures that must be followed. Such accuracy must be related to the purpose of the surveys that are supported by it.

Considering the plot as the main object of the cadastral survey, the positional accuracy value of eight centimeters for its vertexes has been accepted academically and even legally (Chapter 3, Premise 9). Luz (2013) presented a study considering the concept of precision and tolerance and concludes that a suggestion of eight centimeters in planimetry would be tolerable, which the authors consider safe and technically feasible. This value also appears in Decree 9.310/2018 (BRAZIL, 2018) that regulates the REURB law, although there is a misunderstanding of text (in the writing of the decree and subsequent revision) or of concept (when confusing 2D plots with 3D territorial objects), since three-dimensional vertexes with spherical precision value (three-dimensional) were considered.

Coelho and Chaves (2005) performed a study to determine precision for the vertexes of urban properties considering the precise propagation for electronic polygonal survey and irradiated points. The

authors concluded that it is possible to achieve an accuracy better than ten centimeters for an irradiated point at a distance of up to one hundred meters starting from a vertex of the reference network with five centimeters of precision. Making an analogy to this study, the irradiated point may be the vertex of the plot.

Considering the propagation of the precision from the vertices of the SGB, especially when using survey methods by classical topography, it is impossible to achieve millimeter accuracy. Long vectors with a distance of tens or hundreds of kilometers from the base line generate precision of a few centimeters for the new points. Adjustment by polygonal and free station when used in the enhancement of the network also have an accuracy of centimeters. Klein et.al. (2017) presents results of the use of the Free Station method for network enhancement and the precision values presented in the research range from 4 to 37mm. Thus, it becomes impossible for the reference network to have a millimeter accuracy.

The proposal of this work considering the studies carried out by the aforementioned authors and aiming at real positional precision results for the vertices of the reference network, recommends the adoption of the value of 5 cm in the planimetry of the Municipal Cadastral Reference Network (RRCM)

5.3 Maintenance and Management of RRCM

The municipality must structure itself in a way that it is possible to rely on the work of professionals who operate daily with the measurement of plots and real estate (Chapter 3, Premise 7). The initial process of implementing the reference network must be the responsibility of the municipality. However, having a team to intensify the network can be an expensive and sometimes unnecessary expense.

If the VS's are implemented under the responsibility of the municipal administration and, at the same time, the rules are determined through a technical manual for the enhancement of the reference network (with standardized procedures, survey methods, adjustment guidance and results to be generated by the technicians and engineers, such as technical reports, raw files and other data necessary to maintain the network's organizational structure), the municipality will now count on the partnership of measurement work, carried out daily by several professionals, who currently operate in a non-standardized way to satisfy a specific need for a contract with various purposes.

In this case, the municipality would need a leaner technical staff to analyse the data sent by the professionals in order to approve new vertexes of the reference network, and the professionals become partners in its enhancement.

At first, this suggestion may seem inappropriate, but the fact is that since 1998, when NBR14166 was published, until today there is practically no example of how an RRCM works in Brazil. Therefore, It is necessary to seek innovative ideas since technology and the understanding of cadastral needs have advanced since then. With this proposal, the management of the reference network remains municipal, but with the participation of all the professional class in the measurement area.

6 SYSTEM ARRANGEMENT

The difficulty in consolidating a solid and efficient Land Cadastre in Brazil is partly due to the existing territorial legislation, which does not define an organizational structure and does not objectively define the flow of processes, so the various entities involved become responsible for the isolated definition, merely taking into account their need and the legislation.

The difficulty in consolidating a solid and efficient Land Cadastre in Brazil is partly due to the existing territorial legislation, which does not define an organizational structure and does not objectively define the flow of processes, so the various entities involved become responsible for the isolated definition, merely taking into account their need and the legislation. The plots of the rural territorial registry, as outlined by the articles of Law 10.267/2001, are being incorporated to the INCRA database through terms established by classes of rural properties according to their area (Federal Decrees No. 4,449/2002, No. 5,570/2005, nº 7,620/2011 and nº 9,211 / 2018) and according to the movement of processes in the interest of the owners in the real estate records. In other words, the National Institute of Colonization and Agrarian Reform - INCRA, which is the managing body of this registry, started its cadastral base from scratch, which is being progressively increased

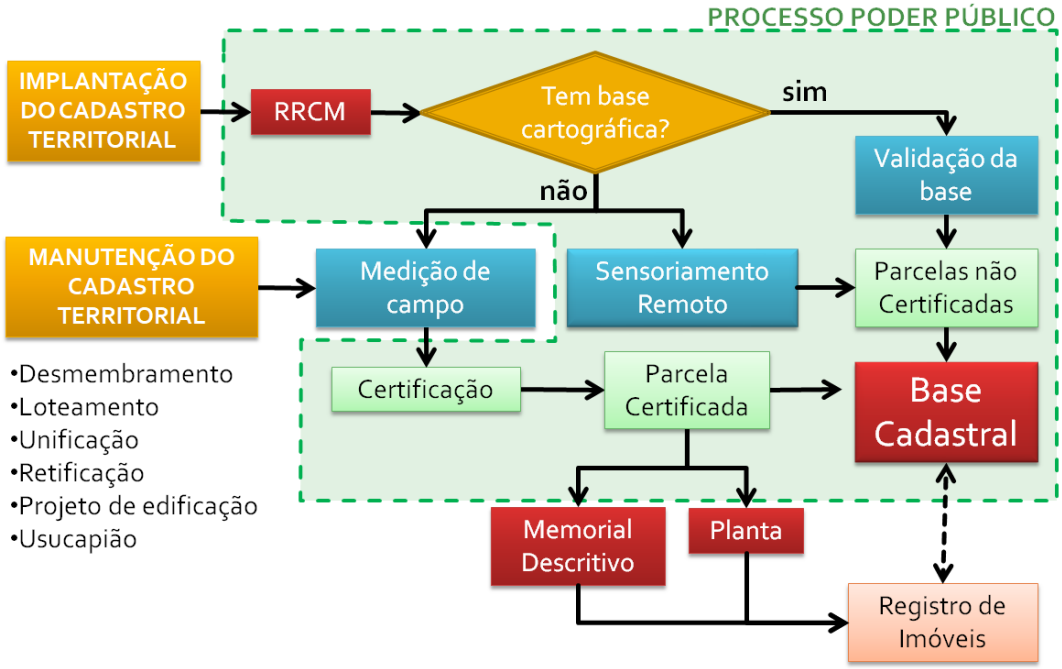
as new plots are presented and submitted to the certification process.

However, as the rural land registry is being composed (progressively increased only by certified plots), it is not feasible for the urban area due to time issues, since the number of urban properties is immensely large and the delay in the structure of the Land Cadastre, would not allow the tax collection on unknown property until the registration is complete.

A minimum public structure is necessary to allow the self-sustainable Land Cadastre to function, fulfilling its management and defining clear rules so that data is received in a structured way in order to maintain it up to date. The Land Cadastre, unlike the multipurpose cadastre, loses its efficiency if it is not updating regularly.

Therefore, a system must be defined to be adopted by the public authorities so that the Land Cadastre works in a flow of sustainable processes. Such flow was proposed by França et al. (2018) who highlights (Figure 7) that the implantation can take place from an existing cartographic base or created specifically for this purpose by remote sensing processes, such as aero photogrammetry. In both cases, non-certified plots are generated, whose geometry has not been confirmed with the field survey, and their vertexes have not yet been materialized.

Figure 7 - Land Cadastre implementation flow.



Source: Adapted by França et al. (2018).

This flow requires the government to have a minimum operating structure for the management of the Land Cadastre, initially implementing a Municipal Cadastral Reference Network (RRCM), creating the non-certified plots and maintaining the parcels that are part of the cadastral base. However, during the maintenance flow of the Land Cadastre, the owner (main interested party) is the one who pays for the onerous part (field survey) when he really needs it. To France et al. (2018) the maintenance of the cadastral base must be carried out mandatorily based on a field measurement with topography and, this is the only way that the provisional plot is properly certified and then becomes definitive.

According to França et al. (2018) regarding this flow the maintenance of the cadastral base originates from the interest of the owner, as a result of dismemberment, unification, allotment, rectification, adverse possession and any other action that requires to change or modify the plot. In addition to these, the approval of a building project in a certain plot may also stimulate the need to maintain the cadastral base, since in these cases a topographic survey is already commonly conducted.

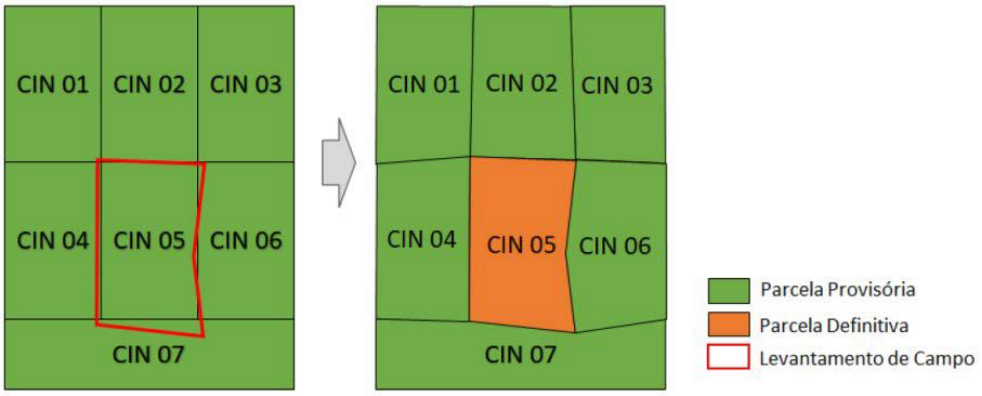
The certification mechanism created by the Law 10.267/2001 is another good practice that should be used from the experience of the rural land registry and extended to the Land Cadastre in Brazil as a whole

(rural and urban). The weaknesses of the registration system are well known, and the certification process created for rural properties, although imperfect, corresponds to a major advance in terms of legal guarantee. The certification of a rural plot corresponds to the statement of the territorial registration body (INCRA, in this case) that a given plot, when submitted by a responsible professional certified to the analysis does not overlap with another previously certified plot. Being adjacent, two certified plots must share the same vertexes of the common limit, which forces a second determination (or acceptance) of the common vertexes and consequent technical co-responsibility for the determined coordinates. At the end of the process, when there is no overlap, the plot is declared as certified and its coordinates that define limit are the ones that can go on record, being recorded in a registration (BRASIL, 2013b).

In relation to bordering provisional plots, the analysis should be regarding its geometry and confrontations. As for geometry, the comparison will not be between vertexes, but the overlap or voids between the plots, since the number of vertexes will not always be the same between the plot resulting from the field topographic survey and the bordering provisional plot or plots.

If the tolerance established in the comparison is satisfied, the registry management body must adjust the vertexes of the provisional plots to the vertexes of the definitive plot that has been certified, figure 7 shows a scheme for updating the cadastral base with the certified plot.

Figure 8 - Example of cadastral update of certified plot.



Source: França et al. (2018).

If the positioning between the plot to be certified and the bordering provisional plot is out of tolerance, the professional must initiate an administrative process with the managing body of the registry for the necessary adjustments of the provisional plots, being the managing body responsible for the geometric adjustment of the cadastral base. Only after adjustment, the plot measured in the field can be certified.

In the maintenance of the Land Cadastre, it remains for the public authorities to analyse the certification of the parcels measured in the field and update the cadastral base. Using the Land Management System (SIGEF) adopted by INCRA in the Georeferencing of Rural Properties as a reference, the management of the Land Cadastre can be automated, fulfilling to almost all the certifications without dependence on a professional who overloads the public authorities, and most of the times does not even exist on the workforce of city halls.

7 CHALLENGES AND PERSPECTIVES

The implantation of a territorial cadastral system is the greatest challenge to be faced by professionals and managers responsible for the territorial management policies, as it involves the elaboration of a legislation to provide legal security to the system, the production of technical standards applicable to the model, training professionals to work in the management, execution and maintenance of the Cadastre.

Three major obstacles are identified as inhibitors in the implementation of efficient cadastral systems and remain current, becoming challenges to be faced according to Brandão et al. (2010): The professional qualification, the lack of technological and process knowledge, and the lack of cooperation between The first

two aspects mentioned - professional qualification and lack of technological and process knowledge - reach both the training of future professionals who will work in the Cadastre and those who are currently allocated to the respective cadastral sectors of the municipal governments. The first two aspects mentioned - professional qualification and lack of technological and process knowledge - reach both the training of future professionals who will work in the Cadastre and those who are currently allocated to the respective cadastral sectors of the municipal governments. This includes the different levels of education (continuous training, technical, technological, graduate and post -graduate) in areas broadly linked to territorial management, such as: surveying, cartography, geoprocessing, geography, engineering, architecture, administration, law, among others, and goes through aspects of terminology and conceptual standardisation of the Cadastre, updating and harmonization of curriculum matrices and greater interconnection between theory and practice.

As an example, Leipelt et al. (2017) presents a comparative study of higher education in cartographic engineering and surveying in Brazil, which points to an imbalance between the respective study program. The study of the referred authors indicates that contents about Cadastre are taught in the researched institutions with workloads between 45 and 136 hours, which evidences a strong difference between graduates of higher education courses in this area, who will be the future professionals working in cadastral area. Regarding the professional qualification of public servants currently linked to the Cadastre areas in city halls, since the extinction of the Ministry of Cities in 2018, there are no reports of new courses or programs focused on Cadastre, on large-scale.

A falta de cooperação entre esferas de governo e administrações (extra e intraorganizacional) complementa o quadro de desafios e é manifestamente um dos maiores desafios à implantação de um modelo de Cadastro Territorial. Neste sentido, há uma lacuna do que se poderia chamar de "cultura cadastral" tanto de nossa sociedade quanto das organizações, que seria uma compreensão comum e disseminada, porém suficiente, da estrutura elementar e dos benefícios e vantagens do Cadastro Territorial.

Another aspect that can be pointed out as a challenge is the understanding that the Land Cadastre elaborated in accordance with the proposal presented here is the basis of all other Territorial Information Systems and Registries, ensuring legal and geometric quality, which means it is also the starting point for cadastral multi-purpose.

When it comes to the research directly related to the implementation of the Land Cadastre, the main future themes should discuss the technical aspects related to the precision and propagation of measurement variances, integration of survey methods, programs adapted to each phase of the process, correlation between the various systems , data interoperability, spatial data infrastructure for registration, forms of data access by the public and professionals involved, regulations and cadastral legislation. Among the topics mentioned, a challenging one and of great interest would be the development of a prototype system for plots certification in urban areas, which could be developed on an open platform and made available to municipal administrations.

Without further remarks on the topic, there is still a set of questions to be answered in the upcoming years: a) When will we have implemented a Land Cadastre in a way that all plots are properly identified and measured, making it possible to restore their limits at any time? b) When will we have the property rights assured using the Cadastre as a geometrical support and actions such as land regularization are only a memmory to the history? c) When will each citizen have access to the territorial information of their property in a quick and reliable way? d) When will measurement professionals have a survey standard adopted nationally? We hope to have the answers as soon as possible with the participation of everyone involved in the process, collaborating with the proposal presented here.

8 FINAL CONSIDERATIONS

The Territorial Register made by the cadastral base of plots, as well as the mapping of territorial objects, integrated with the Land Registration, are mandatory conditions for the proper territorial ordering.

A parcel of Brazilian municipalities already has geographic information systems with mapping the territory, managing the cadastral cartography of high positional and detail quality obtained by remote sensing. The procedures listed in this article aim to maintain these products as a way of acquiring non-certified parcels, which over time become certified with measurements made in the field. At first, this process may not be

pleasant considering the time issue when decades are estimated to advance the cadastral base with certified plots, but it proves to be viable, because it has the entire structure of professionals and stakeholders (measurement process applicants) so that the process does not economically burden the municipalities. No city hall of medium or large cities would be able to measure all plots in the field, this task should happen on demand and over time.

The implementation and maintenance flow of the Land Cadastre presented in this work demonstrates the possibility of integrating measurement services for various purposes that involve the measurement of properties in a municipality of any size and at any stage of cadastral or technological maturity. In this way, the proposal achieves the objective of updating daily the registration and not periodically between aerial survey contracts. Remote sensing services can and should continue, mainly because they generate broad knowledge of the territory, in addition to mapping non-certified plots.

The choice of the cadastral survey technique is a critical decision for technicians and municipal administrators. The relationship between technological advances for the production of information and management procedures does not evolve at the same pace. While there is a rapid evolution in the use of new technologies for the acquisition and processing of geographical and cadastral data, advances in management processes are much less dynamic. So that the proposed flow can work, the management processes need to be consolidated in a city hall.

Finally, it is concluded that measures such as the ones proposed in this article help to actually start the Land Cadastre recommended by the International Federation of Surveyors and similar to those observed in countries with more tradition in this area. Brazil with its territorial extension and number of municipalities has particularities that do not allow a simple copy of a European system, for example. However, with the flow of the process organized and supported by technical standards, the Cadastre can, in fact, take place in Brazil.

Authors Contribution

All the authors participated in the stages of conceptualization, methodology, writing, review and editing of this article.

Conflicts of Interest

The authors declare that there is no conflict of interest related to the preparation of the manuscript.

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