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

Evolution and trends in research on land administration and cadastre

Evolução e tendências nas pesquisas em administração territorial e cadastro

Andrea Flávia Tenório Carneiro [1] e Camila Ribeiro Miranda [2]

1 Universidade Federal de Pernambuco - UFPE, Departamento de Engenharia Cartográfica, Recife-PE, Brasil. E-mail: andrea.carneiro@ufpe.br
ORCID: http://orcid.org/0000-0002-2445-2330
2 Universidade Federal de Pernambuco - UFPE, Departamento de Engenharia Cartográfica, Recife-PE, Brasil. E-mail: caamilarm@hotmail.com
ORCID https://orcid.org/0000-0002-1200-7408

Received: 08.2020 | Accepted: 11.2020

Abstract: Over time, the relationship between people and land, the primary function of the cadastre, began to require new demands, enabling countries to structure land administration systems not only technical-organizational, but also directed to meet other needs of society, such as reducing social inequality and environmental monitoring. The theory of modern land administration has had its importance recognized, from the point of view of socioeconomic-environmental development, but its scientific nature is still discussed. Involving social aspects (history, culture, economy, environment) and information and technology systems, the studies on the themes require the understanding of concepts that need to be consolidated and well understood. In this sense, this study aimed to expose and discuss the essential concepts that need to be considered for the development of research projects in this area. It also presents researchers' questions about the scientific character of land administration, based on the indicators used in determining areas of scientific knowledge. In addition, the results of research on methodologies applied in cadastre and land administration research projects, as well as the trends identified in current research, are important for the development of future projects. Finally, based on these studies, a review of research carried out in Brazil was conducted to present an overview of what has been the object of scientific production in this area. It is hoped that this study will bring contributions for future research in the area of land administration.
Keywords: Land Administration. Cadastre. Land Management. Brazilian Cadastre.

Resumo: Ao longo do tempo, as relações entre pessoas e terra, função primordial do cadastro, passaram a exigir novas demandas, fazendo com que os países estruturassem sistemas de administração territorial de cunho não somente técnico-organizacional, mas também voltados para atender a outras necessidades da sociedade, como a redução da desigualdade social e o monitoramento ambiental. A teoria da moderna administração territorial tem tido a sua importância reconhecida, do ponto de vista do desenvolvimento sócio-econômico-ambiental, porém a sua natureza científica ainda é discutida. Envolvendo aspectos sociais (história, cultura, economia, meio-ambiente) e de sistemas de informação e tecnologia, as pesquisas sobre os temas exigem a compreensão de conceitos que precisam ser consolidados e bem compreendidos. Nesse sentido, esse trabalho teve como objetivo expor e discutir os conceitos essenciais que precisam ser considerados para o desenvolvimento de projetos de pesquisa nessa área. Também apresenta os questionamentos de pesquisadores sobre o caráter científico da administração territorial, com base nos indicadores utilizados na determinação das áreas de conhecimento científico. Além disso, os resultados de pesquisas sobre metodologias aplicadas em projetos de pesquisa em cadastro e administração territorial, bem como as tendências identificadas nas pesquisas atuais são importantes para a elaboração de futuros projetos. Por fim, com base nesses estudos, foi realizado um levantamento das pesquisas realizadas no Brasil, para apresentação de um panorama geral do que tem sido objeto de produção científica nessa área. Espera-se, assim, que esse trabalho traga contribuições para pesquisas futuras na área da administração territorial.
Palavras-chave: Administração Territorial. Cadastro. Gestão Territorial. Cadastro brasileiro.

1 INTRODUCTION

Land administration is a relatively recent term, first published in UNECE (1996). The cadastre is considered a fundamental part of the Land Information Systems, which are essentially constituted by cadastres and land registries. The concept of land administration has as its fundamental pillars the four functions relevant

to land management and sustainable development: the land's tenure, value, use and development. Over time, the relations between people and land, a primary function of the cadastre, began to demand new requirements, causing countries to structure land administration systems not only of a technical and organizational nature, but also aimed at meeting other needs of the society, such as the reduction of social inequality and environmental monitoring.

With the challenge of identifying how cadastral systems were being established in different countries, and thus contribute to the advancement of developing countries and support sustainability policies, the International Federation of Surveyors (FIG) stands out for its support of research in the area land administration and cadastre, with publications that serve as reference for researchers and international organizations. From the well-known Statement on the Cadastre (FIG, 1995) to the important Cadastre 2014 (KAUFMANN; STEUDLER, 1998), technology has been gaining space and brings new possibilities for representing geospatial features. In 2012 the ISO 19.152 was published, a Land Administration Domain Model (LADM) that proposes the description of cadastral systems through basic classes that represent the relations between people and land through their rights, restrictions and responsibilities.

More recent research studies at the international level indicate a paradigm shift in the more traditional concepts of the cadastre, aiming at the flexibility of precision requirements, for the structuring of preliminary systems that can help especially in cases where it has not been possible to structure a minimum system. There is an urgent need to make it possible for cadastres to represent territorial dynamics in a clear, simple way and to be flexible and adaptable to each reality. The so-called fit-for-purpose cadastre, seeks to guarantee, especially for developing countries and those in need of well-defined cadastral systems, technically applicable and economically viable solutions. Finally, the UN Agenda 2030 presents the 17 objectives for sustainable development, making it clear that in order to achieve these objectives it is essential to have good organization of the land administration systems. Such systems, therefore, are presented as fundamental instruments for achieving the millennium goals. Moreover, in 2019 a document was published by the United Nations Committee of Experts on Global Geospacial Information Management (UN-GGIM,2019) that guides the structuring of an efficient land information system, considering legal and administrative reforms, as well as the absorption of technological possibilities for this purpose.

With recognized importance from the point of view of socio-economic-environmental development, the theory of modern land administration is still discussed with regard to its scientific nature. As it involves social aspects (history, culture, economy, environment) as well as of information and technology systems, it involves the comprehension of many concepts that need to be consolidated and well understood.

The objective of this study was to present and discuss the essential concepts that the authors consider necessary to be understood for the development of research projects in this area. It also presents the questions of researchers about the scientific character of land administration, based on the indicators used to determine the areas of scientific knowledge. In addition, the results of research on methodologies applied to research projects about cadastral and land administration, as well as the trends identified in current research, are important for the elaboration of future projects. Finally, based on these studies, a survey of research studies carried out in Brazil was performed, to present an overview of what has been object of scientific production in this area.

2 A CONCEPTUAL BASE FOR RESEARCH ON LAND ADMINISTRATION AND CADASTRE

An analysis of land administration as an area of knowledge requires the presentation of the most widely used concepts, since the authors who dedicated themselves to this type of research point out the conceptual bases as one of the critical factors in the consolidation of the area as a branch of scientific knowledge.

Relations between people and land vary according to the cultural, socioeconomic and political realities of each country. They also vary over time, according to the demands for land and the complexity of its occupation. Thus, it is important to present the essential elements involved in the structuring of systems that aim to support policies for accessing land and monitoring its use.

2.1 Land management, land administration and cadastre

Land is a finite resource and since ancient times it has been recognized as a patrimony and synonymous with power and wealth. The growing demand generated by the increase in the urban population, and the consequent increase in needs for food and water, shows that its use and occupation must be well managed, for the benefit of the collective society. The principles of sustainable development are based on the search for a balance between social, economic and environmental issues related to the use of the planet's resources.

International organizations have been mobilizing to guide and support countries in order to develop updated and reliable land information systems, which serve as the basis for increasingly more efficient land management initiatives, aiming to achieve the objectives of sustainable development, to end poverty and inequality, and to address the consequences of climate change.

Land management involves the implementation of fundamental political decisions about the nature and extent of investments in land. Thus, it involves routine operational decisions made by land administrators, such as land surveyors, appraisers and property registry officers. From an institutional point of view, land management includes the formulation of land policy, the legal structure, resource management, land administration arrangements and land information management. It involves both government and private initiatives. Land governance is concerned with the policies, processes and institutions responsible for land management, including property and natural resources. Good land governance requires a regulatory framework and adequate operational processes to efficiently implement land policies, taking into account the principles of sustainable development. Land administration is part of the infrastructure that supports good land management (UNECE, 1996; UNECE, 2005; WILLIAMSON et al., 2010).

The term land administration was established by the United Nations Economic Commission for Europe (UNECE) in the document Land Administration Guidelines (UNECE, 1996), and refers to the processes of determining, registering and disseminating information on property, value and use of land and its associated resources. Such processes, updated in the UNECE (2005), include the determination (adjudication or formalization) of property rights and other attributes of the land, related to its value and use, the evaluation of its limits and its graphic description, in addition to detailed documentation and the availability of relevant information for the real estate markets.

It is important to consider that this definition was established based on the experience and needs of European countries, and does not always apply to cases in developing countries, which usually have, in addition to property, a wide range of land tenure regimes, as observed by UN-GGIM (2015). In this case, according to UN-GGIM (2015), the definition presented by FAO (2002) seems more appropriate: the way in which the rules of land tenure are applied and operationalized. **Land Administration**, formal or informal, thus comprises a wide variety of systems and processes to manage:

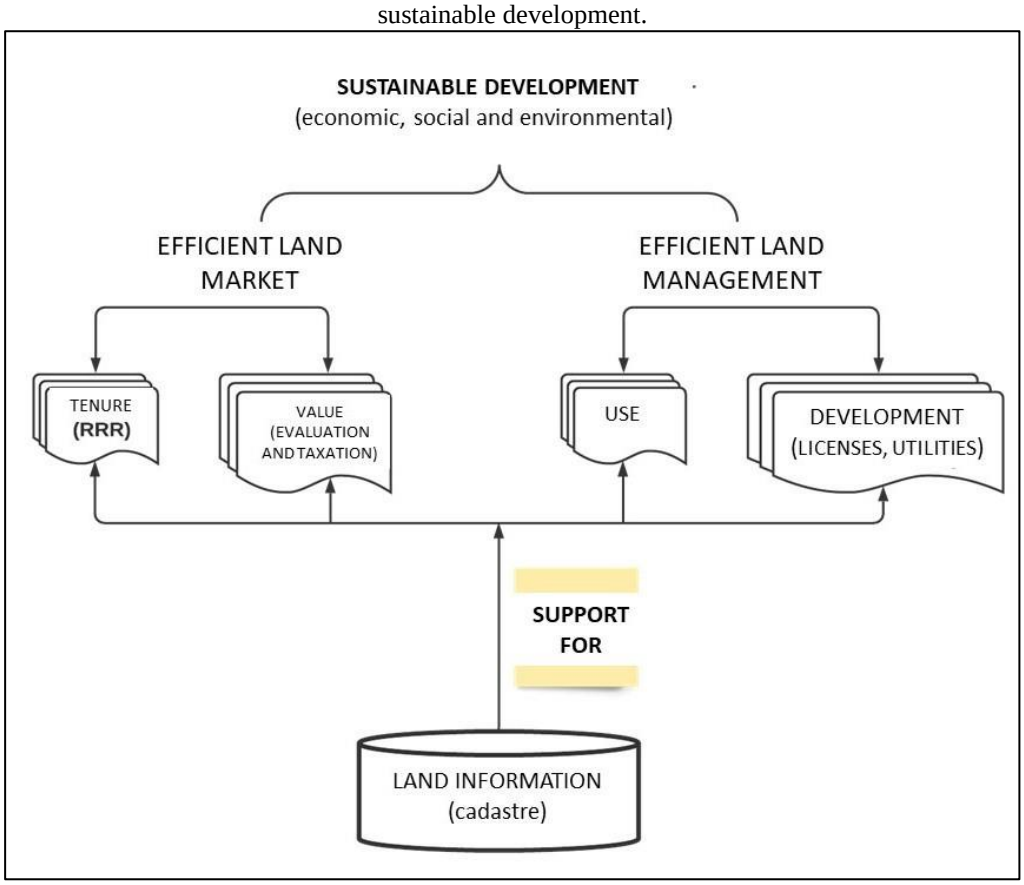
a) Land rights: the granting of land rights; the delimitation of the limits of the parcels to which the rights are attributed; the transfer from one party to another through sale, lease, loan, gift or inheritance; and the judgment of doubts and disputes about rights and limits of the parcels;
b) Regulation of land use: planning and application of regulations and judgment of conflicts regarding land use;
c) Land assessment and taxation: revenue collection through land assessment and taxation methods and resolution of disputes regarding land assessment and taxation.

Land administration systems involve a set of principles that guide the collection, processing, storage and use of data on land ownership, its use, quality, location and change over time. It also refers to databases structured to support decision-making based on these principles (AUC-ECA-AfDB Consortium, 2010).

Emerging as support systems for real estate taxation, land administration systems have been recognized in the last decades, as having a much stronger role in providing a country with an infrastructure for the implementation of land management policies and strategies in support of sustainable development – as stated in documents that bring the justifications and importance of implementing and improving such systems,

such as the Bathurst Declaration of FIG (FIG, 1999), UN-GGIM (2015) and UN-GGIM (2019). FIG (2009) points out that it is crucial to understand that a land administration system can never be an end in itself; its nature is to serve society, whatever the current situation of that society. The document UN-GGIM (2019) also reinforces that the land administration system relates people and land and informs how, what, who, when and where, regarding the main functions of land management: land tenure, its use, value and development. Figure 1 shows in a schematic manner this relation between land information systems and land management, aiming to meet the objectives of sustainable development.

Figure 1 - Land information system as a basis for efficient land management and meeting the objectives of sustainable development.



Source: Williamson et al (2010).

According to FIG (2014), an effective land administration system must be fit-for-purpose, appropriate and adequate, interoperable and sustainable, flexible and inclusive, and be able to accelerate efforts to document, register and recognize the relations between people and land in all its forms. It should help to guarantee humanity better access to land and the security of its rights, capable of mitigating issues related to land as a cause of conflict, and not leave anyone behind, a general principle of the 2030 Agenda.

For many countries this is definitely a break with the past, because elements considered essential to the land administration system, such as the cadastre and land registration, have historically been considered an instrument of colonial powers or another form of government to guarantee their own land rights. Sustainable land administration systems are, therefore, systems that serve society well, by providing sets of products and services that are now fully inclusive, to meet current and future demand. This includes the poor who in many countries are currently excluded from participating (FAO, 2002).

Just as the understanding about land administration evolved according to the needs of society, so did the understanding about the cadastre. For Williamson et. al. (2010), the land management paradigm makes a national cadastre the engine of the land administration system, supporting a country's ability to achieve sustainable development goals.

2.2 The evolution of the concept of cadastre

Enemark (2012) emphatically expresses the importance of the cadastre, when he states that the impact of a well-structured cadastre can hardly be estimated, and that a well-designed cadastral system acts as the backbone of a society. On the other hand, the author emphasizes the difficulty of proposing a concept that can be applied to any case, since a cadastre can be designed and implemented in several ways, depending on the origin, history and cultural development of the country or region. Basically, he defines the cadastre as a registration that identifies land parcels.

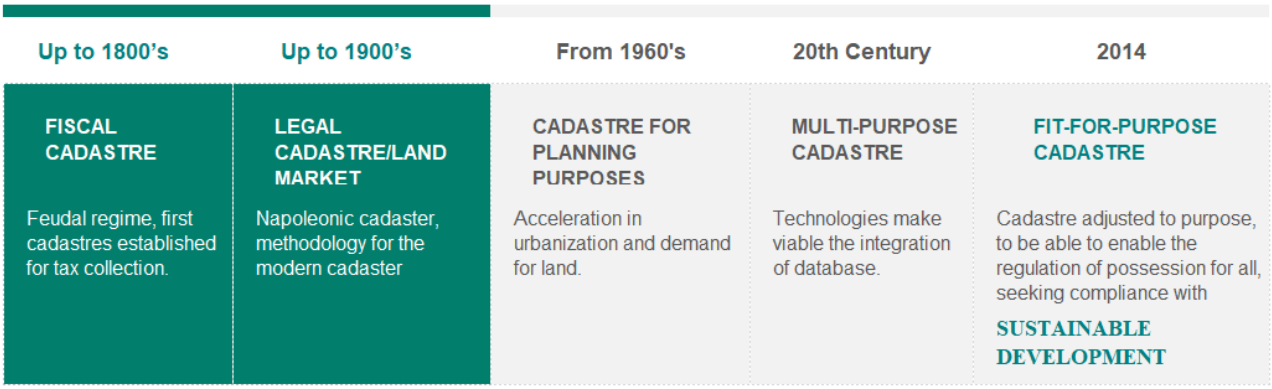
The traditionally accepted concept of cadastre says that it is an updated land information system, based on parcels, containing a record of interests over land (eg, rights, restrictions and responsibilities). It generally includes a geometric description of land parcels linked to other records that describe the nature of the interests, the ownership or control of those interests, and often, the value of the parcel and its improvements. It can be established for fiscal, legal purposes, to support land management and land use, and to support sustainable development and environmental protection. This is the concept proposed in FIG (1995), which has been adopted by several other institutions and authors, such as FIG (1999), UNECE (1996), UNECE (2005), Williamson et al. (2010), among others.

Silva and Stubkjær (2002) highlight the spatial component of the cadastre, agreeing with Dale and McLaughlin (1989) and Larsson (1991), who define the cadastre as a systematic and official description of land parcels, including a single identifier for each parcel. In addition, the cadastre includes descriptive data containing attributes of the parcels, and the representation of the limits of each parcel on large-scale maps.

The expansion of the understanding of the cadastre, from its function as an instrument for the collection of taxes to its recognition as a fundamental part of an administration system aimed at sustainable development, is strongly related to the development of information technologies, which allow the integration of systems from different sources. Despite these potentialities, the development of cadastres does not occur satisfactorily in all countries, because the structuring of such systems does not depend only on technological development, and even if it were so, not everyone has access to these technologies.

To illustrate this evolution of cadastres, Figure 2 presents in a very simplified manner the main milestones of change. However, Williamson et. al. (2010) present a detailed analysis of the relation between this evolution of the cadastre and important historical aspects. A document that deserves to be highlighted is the Cadastre 2014 (KAUFMANN; STEUDLER, 1998), which brought essential points for the cadastre of the next twenty years and represented an important orientation in the cadastral reforms that followed.

Figure 2 - Understanding the cadastre over time, based on Williamson et al. (2010).



Source: The authors (2020).

For FIG (2014), the difficulty of land administration services for most countries that have failed to implement such systems, is the use of traditional and high-precision survey techniques, which are consequently more expensive. UN-GGIM (2015) also recognizes that, in developing countries, conventional ways of managing and administering land have a history of failures in fulfilling their functions, since conventional technical solutions are very expensive, which makes them financially unsustainable. At the same time, the

need for viable systems to manage and administer land is now greater than ever, with new challenges being added to the problems that already existed.

Thus, the ideal proposal is to implement a fit-for-purpose cadastre, which must be flexible and focused on the needs of citizens (such as providing security of tenure and control of land use), instead of requiring sophisticated technical solutions and highly accurate surveys. FIG (2014) proposes that the characteristics of these cadastres be:

a) Flexible: in spatial data capture methods, according to the conditions of land use and occupation;
b) Inclusive: in the sense of covering all forms of possession and all lands;
c) Participatory: with community support in the capture and use of data;
d) Accessible: for institutional use and for society in general;
e) Reliable: in terms of information that is reliable and up-to-date;
f) Feasible: in relation to the implementation of the system in the planned time and within the resources available;
g) Upgradeable: with regard to improvement and modernization in response to social and legal needs and to economic opportunities.

3 LAND ADMINISTRATION AS AN AREA OF SCIENTIFIC KNOWLEDGE

As explained in the previous item, the first time land administration appeared as an area of knowledge was in the UNECE document (UNECE, 1996), although Williamson et al. (2010) emphasized that the intellectual roots of the discipline in the management of relations between people and land and the specialized survey tools are much older. Modern survey methods, as an activity that involves collecting land information through precise determination of limits and identification of the parcel, have a history of hundreds of years. Enemark (2004) mentions that land administration is an intersectoral and multidisciplinary area. In addition, the relation between people and land varies within and between countries and regions, and an adequate response to the formation of competencies must reflect this basic characteristic.

Researchers have been dedicated to analyzing this question of land administration as an area of scientific knowledge, and some approaches will be presented below, with indications of references for those who would like to deepen their study on the matter.

3.1 Investigating land administration as an area of knowledge

According to Groenendijk et. al (2012), land administration emerged from and is still strongly based on the cadastre and land registry and related disciplines. The concepts involved in the subject, however, have been expanded, as discussed in the previous section, and the new perspectives in the area of land administration knowledge point in different directions and different areas. In other words, land administration is characterized by multiple perspectives and is based on several disciplines, such as: surveying, economics, law, administration, engineering, statistics and the social sciences. Williamson et. al (2010) evaluate that the application of scientific methodologies to the theory of land administration has its main focus on the design, construction and monitoring of systems to achieve articulated objectives. This, in turn, gave land administration a practical approach to find solutions and absorb and learn from failed efforts, as long as the flaws were clearly apparent.

The tradition of trying to improve systems and methods has helped to produce a body of literature in which large-scale administrative system projects are discussed vigorously, and project evaluation is openly discussed. The combination of critical evaluations and applied scientific methods, or the engineering approach, is present in the theory and practice of modern land administration. When the land administration approach enters the implementation phase, it focuses on **how** to build multipurpose cadastres, rather than **why** they should be built.

Groenendijk et al. (2012) noted, however, that the status of land administration as an area of knowledge defended by Williamson et al. (2010) was not sufficiently clear, and that there is no single understanding of it by all the main researchers, a fact that is not uncommon, since the term land administration is relatively new in education and research. From this observation, they carried out a research study with the objective of answering a question: what is the nature of land administration as an area of knowledge? For that, they used the methodology applied by Scholl (2008), who investigated e-governance as an area of knowledge. According to Scholl (2008), the areas of knowledge are determined by academic communities who define which problems should be studied, develop certain central concepts and organization theories, adopt certain research methods, organize forums to share research and insights, and offer career opportunities for academics. A knowledge area is a particular branch of learning or body of knowledge whose defining elements - that is, phenomena, assumptions, epistemology, concepts, theories and methods - distinguish it from other knowledge formations. This understanding is in accordance with the definition used by CAPES (2020): "Area of Knowledge (Basic Area): set of interrelated knowledge, collectively constructed, gathered according to the nature of the object of investigation for the purposes of teaching, research and practical applications."

To try to qualify e-governance as an area of knowledge, Scholl (2008) used the following indicators and dimensions: 1) existence of a formal definition; 2) a common knowledge base; 3) a specific set of research problems; 4) converging theories; 5) admitted research procedures and methods, and 6) a shared view of the importance of the study domain. In addition to these indicators, the author included: 7) structural elements at the university level (departments, colleges, universities), 8) graduate programs and students, 9) a worldwide research community, 10) academic and professional associations, 11) recurring journals and conferences, 12) self-identification of the researcher with the discipline, 13) leaders, that is, prominent and visible scholars, 14) textbooks, 15) loyalty to the area of knowledge, expressed by accepted facts and rules, 16) specific terminology of subjects in the area, and 17) strong interaction between the area of knowledge and its field of action.

This set of indicators was used by Groenendijk et al. (2012) to assess the scientific nature of land administration, through research in diverse publications, websites and other sources. Although the authors do not consider the results as definitive, deserving to be deepened in some questions, they conclude that land administration represents a discipline still in formation, which can be considered an emerging area of interdisciplinary study, based mainly on the traditional areas of cadastre (surveying/geodesy/cartography) and land registry. A summary of the results is presented in Table 1, and the details of the research can be consulted in the cited publication (GROENENDIJK et al., 2012).

Table 1 - Evaluation of the scientific nature of land administration.

CRITÉRIUM	STATUS	CRITÉRIUM	STATUS
A formal definition	Yes	Scientific and professional association	Sim
Common knowledge base	No/partial	Journals and conferences	No/partial
Specific set of research problems	No/partial	Researchers identified with the area	Partial
Unifying theories	No	Leaders/researchers with visibility	Partial
Research procedures and methods	No	Textbooks	Yes
Shared vision	No	Loyalty to the area expressed by accepted facts and rules	Partial
Structural elements at the university level	Yes	Specific terminology	Partial
Graduate programs and students	Yes	Strong interaction between research and professional practice	Yes
A community of researchers distributed in the international community	No		

Source: Groenendijk et al. (2012).

Cagdas and Stubkjær (2009) were also dedicated to the analysis of land administration and cadastre from the scientific point of view. The authors published two articles papers, Cagdas and Stubkjær (2009) and Cagdas and Stubkjær (2011), in which methodologies used in 10 and 5 doctoral theses respectively were analyzed. In Cagdas and Stubkjær (2009), they affirm that despite important contributions that have been developed, it is still not possible to identify a universal and coherent cadastral theory, until the time of publication of the research. The authors point out that theories are constructed with concepts, which have to be clear, precise and with agreed goals, and that in the study ambiguities were still observed in the definitions and uses of the concepts.

In addition to the complexity of the proposition or adoption of a concept that is universal with regard to the cadastral general area, it is also necessary to highlight issues related to terminology. Silva and Stubkjær (2002) point out, for example, the use of the terms **cadastres** and **cadastral systems**, where the term cadastral

systems has been used in a very vague manner, sometimes as a synonym for cadastre. According to Bogaerts (1999) apud Silva and Stubkjær (2002), a cadastral system is a combination of cadastre and land registry, and therefore the two terms cannot be used interchangeably. This understanding is the same as that of Enemark (2012), who states that it makes sense to talk about cadastral systems or cadastral infrastructures, instead of cadastre, when these systems or infrastructures include the interaction between the identification of land parcels, the registration of rights, the evaluation and taxation, and control of current and possible future land use. For the author, a multi-purpose and mature cadastral system can in fact be considered a land administration system. Table 2 presents a summary of these understandings.

Table 2 - Distinction of terminologies, based on Silva and Stubkjær (2002) and Enemark (2012).

CADASTRE	CADASTRAL SYSTEM	MULTI-PURPOSE CADASTRE (Land Administration Systems ?)
• systematic and official description of parcels • descriptive data (atributes) • representation of limits of each parcel in maps	CADASTRE + LAND REGISTRY	CADASTRE + REAL ESTATE REGISTRY + THEME CADASTRES (use of land, value, environmental data, etc...)

Source: The authors (2020).

Still with respect to terminology, many countries use the term cadastre with the meaning used in this study, without the need for a specification: *cadaster* or *cadastre*, *catastro*, *kataster*, *catasto*. However, in some countries the term cadastre has other meanings, thus the use of '*cadastro predial*' (in Portugal and former Portuguese colonies) and '*catastro territorial*' (in Latin American countries). In Brazil, where the term cadastre also has a broader meaning, several terminologies have been used: real estate cadastre, municipal cadastre, fiscal cadastre, urban cadastre or rural cadastre, multipurpose cadastre. Since 2009, with the disclosure of Ordinance 511 (BRASIL, 2009), from the Ministry of Cities, an effort has been made to consolidate the term 'land cadastre' (*cadastro territorial*).

3.2 The methods used in research studies on land administration and cadastres

Cagdas and Stubkjær (2009) and Cagdas and Stubkjær (2011) analyzed the different approaches used in the research on land administration, and more specifically, cadastre. Their conclusions corroborate with the research by Groenendijk et. al. (2012), with regard to the need to consolidate terminologies and concepts that may contribute to the construction of new theories within the cadastral domain. The authors classified research on cadastral topics into two major groups:

a) **in the field of social sciences**: from an anthropological, economic, geographical, historical, legal, organizational, and political point of view;

b) **in the field of information science**: this may be behavioral research, aiming to identify organizational problems of the human-computer relationship, or a project research, seeking to develop information technology mechanisms to solve such problems.

In Cagdas and Stubkjær (2009), the methodological and theoretical aspects of ten doctoral theses developed **in the field of social sciences** were analyzed. The article presents a detailed comparison of the methods used in the research, covering collection techniques and data analysis, as well as the procedures that specify how the research was carried out. The authors highlight the widespread use of qualitative methods, especially in the case studies.

Silva and Stubkjær (2002) and Cagdas and Stubkjær (2009) note that cadastral and land administration systems depend on social, economic and cultural factors that need to be understood, and that the case study method allows the identification and description of these factors and their relations, favoring the understanding of existing systems, before proposing a new system or solution.

Cagdas and Stubkjær (2011) analyzed the methods used in five doctoral theses developed **in the field**

of information science. In this regard, the authors explain that the behavioral science paradigm seeks to develop and verify theories to understand or predict human and organizational behavior, aiming to establish a set of concepts that can be used in the elaboration of laws, models and theories. On the other hand, the design research paradigm seeks to develop and evaluate mechanisms to solve the identified organizational problems.

Table 3 presents a synthesis of the research methods used in the field research of the social sciences (CAGDAS; STUBKJÆR, 2009) and in the field of the information sciences, of the design research type (CAGDAS; STUBKJÆR, 2011).

Table 3 - Methodologies used in research studies in the area of cadastre and land administration, based on Cagdas and Stubkjær (2009) and Cagdas and Stubkjær (2011).

	Research in the field of social sciences	**Research in the field of information sciences**
Approach	Geography; Institutional factors (history, cultural and legal structure, including norms for formal and informal situations, social relations of societies); Actors or interested parties (real estate registry, cadastre and other governmental organizations, among others); Procedures (adjudication, real estate transfers, installments); Technology (survey and cartography methods, information systems).	Design and development of models to evaluate or improve the components of cadastral systems, Geographic Information Systems and Spatial Data Infrastructures. Some of these models serve the business community, applying technological innovations to improve the effectiveness of an organization and its services; others serve the academic community by bringing new visions to better understand a phenomenon.
Methodology	Revision of the literature Research design with choice of: • research method, including the theoretical basis • data collection techniques • data analysis method • case study (or population) • research development • presentation of results (complaints and validation) • discussion of results and recommendations for further studies	• Problem identification and motivation • Defining the objectives for a solution • Design and development (of conceptual constructions, models, methods, instances or new properties of technical, social and/or information resources) • Demonstration (experiment, simulation, case study, among others) • Evaluation • Communication

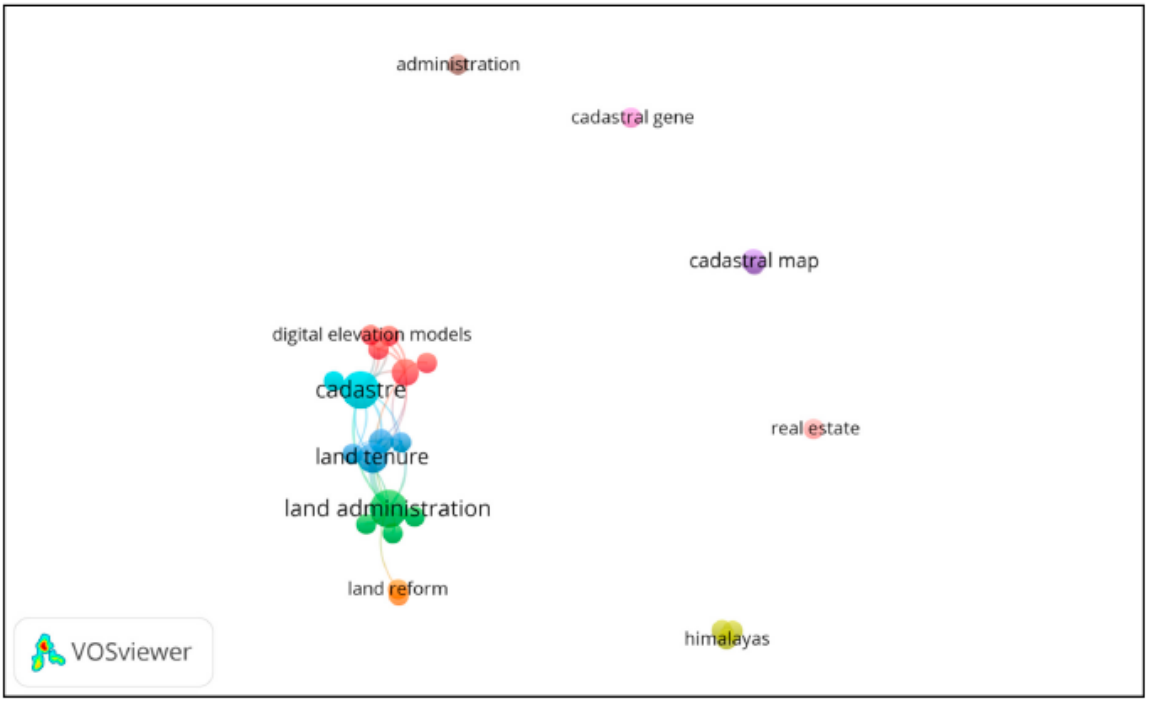
Source: The authors (2020).

3.3 Trends in research on land administration and cadastre

Pimenta et al. (2017) explain that bibliometric research is based on quantitative and statistical methods, and evolved in the 21st century thanks to the creation of computer programs for bibliometric techniques, which has gradually achieved greater popularity, quality and quantity of published studies, helping to understanding researchers' intellectual performance. Bibliometric research studies have been carried out in the area of geospatial information, such as GIS and remote sensing (LIU et al., 2016; ZHANG et Al., 2017; POLAT, 2019; CHOI, 2020).

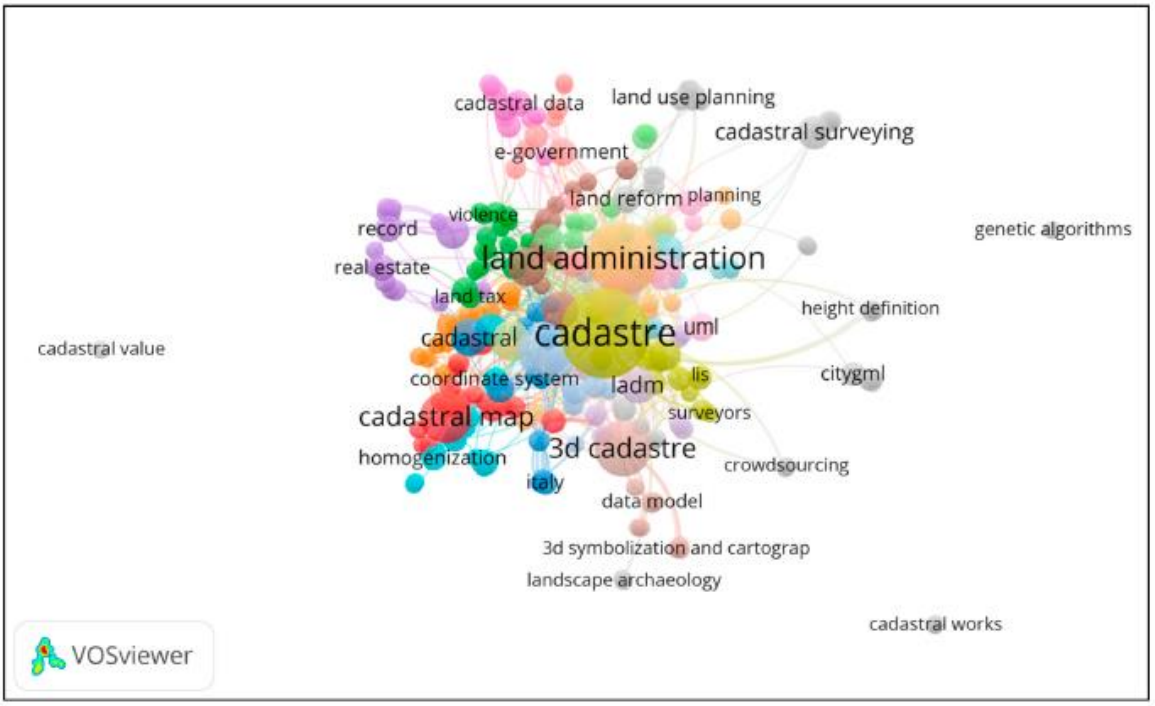
Choi (2020) conducted a bibliometric study in the field of cadastral research, involving publications from 1987 to 2019. The study combined the research methods of semantic analysis and keyword network, as well as determined the characteristics of each group, analyzed the groups' networks and extracted the centrality and density indices. This analysis provided qualitative and quantitative evidence of the evolutionary process of the topics of cadastral research, and clearly showed the expansion of the subjects covered, in accordance with the expansion of the understanding of the cadastre presented previously. Figure 3 shows the keywords and their interconnections, referring to the period from 1987 to 2001 and Figure 4 shows the period from 2008 to 2014, where you can see the words related to technology in the second period.

Figure 3 - Keyword networks of the publications on cadastres, referring to the period from 1987 to 2001.



Source: Choi (2020).

Figure 4 - Keyword networks of the publications on cadastres, referring to the period from 2008 to 2014.



Source: Choi (2020).

The results illustrate the progress in the application of technological innovations in the cadastres, as highlighted in the combination of relevant keywords, primarily related to the technology of spatial information and citizen participation in the production of cadastral maps, through Voluntary Geographic Information (VGI). The trend confirmed that open data methods appear as new possibilities in the use of spatial data, and these aspects of innovation are integrated with social issues. Choi (2020) also points out that research on the standardization of cadastral spatial data is a challenge, as well as the articulation with other research areas. 3D and 4D cadastres provide information about rights above and below the surface, and their evolution over time (STOTER et al.; 2004; Van OOSTEROM, 2018; Van OOSTEROM et al., 2006; CARNEIRO; ERBA;

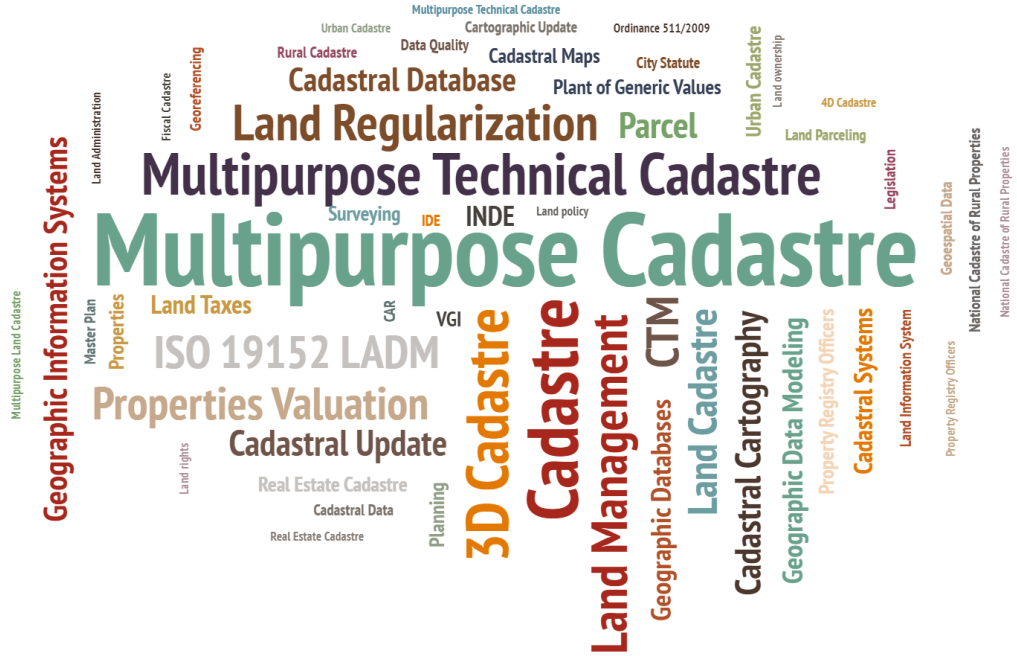
ARRUDA, 2012). The study was also able to identify that the role of cadastres in providing legal bases for land ownership rights and land use planning must continue. What changes are the methods used by cadastres, which must also be continually updated to have an intelligent land management policy. Therefore, the results reinforce the need for a solid understanding of the concepts involved in the scope of research on cadastral topics, so that technological innovations can be applied for the benefit of an ever more efficient cadastre.

4 AN OVERVIEW OF RESEARCH ON LAND ADMINISTRATION AND CADASTRE IN BRAZIL

After addressing the concepts and nature of land administration and cadastre as an area of scientific knowledge, an investigation was carried out on scientific research in Brazil, with regard to the theoretical and practical aspects of land administration systems and cadastres. As a result, an inventory consisting of 132 scientific productions was obtained, including: articles published in the *Boletim de Ciências Geodésicas* - BCG, in *Revista Brasileira de Cartografia* - RBC and in international journals, in addition to theses and dissertations carried out at the Federal University of Pernambuco (UFPE), Federal University of Santa Catarina (UFSC), Federal University of Paraná (UFPR), State University of São Paulo - Campus Presidente Prudente (UNESP-PP), University of São Paulo (USP) and Federal University of São Carlos (UFSCar).

To understand the trend of the main topics addressed, a semantic analysis of the keywords used in the publications was performed and synthesized in a word cloud, which made it possible to represent the frequency with which the terms appeared in the research studies over the years. A word cloud, as well as histograms and graphs, works as a tool that hierarchizes the words according to their occurrence and relevance, but with a visual and direct language, where the size of the word in the cloud is directly proportional to the frequency. 394 keywords were identified and the terminology problem mentioned in item 3.1 is highlighted, with more than one term corresponding to the same concept. Thus, to ensure that the word cloud had the clearest and most objective presentation possible, 51 words were chosen that presented the most representative frequencies of the researched universe, and that corresponded to different concepts. The result is shown in Figure 5.

Figure 5 - Word Cloud of the most significant keywords of the research in the area of land administration and cadastre.



Source: The authors (2020).

As observed in the studies presented in the previous items, academic interest on the topic in Brazil is strongly connected with changes in land legislation, either due to the need to identify and solve problems, or to foster theoretical and conceptual discussions, establishing a symbiotic relationship. Thus, consequently, the

advents of Law 10.267, responsible for the creation of the National Cadastre of Rural Properties (CNIR), Ordinance 511/2009 of the Ministry of Cities, Decree 6.666 / 2008 and ISO 19152: 2012 LADM (ISO, 2012; LEMMEN; OOSTEROM; BENNETT, 2015), echoed in the publications of scientific articles, dissertations and theses, which constituted the research analyzed in the present work. With the publication of Decree 8764/2016, which instituted the National Land Information Management System - SINTER, an integrating system of urban, rural and land registries, this topic is expected to be frequent in research published in the coming years.

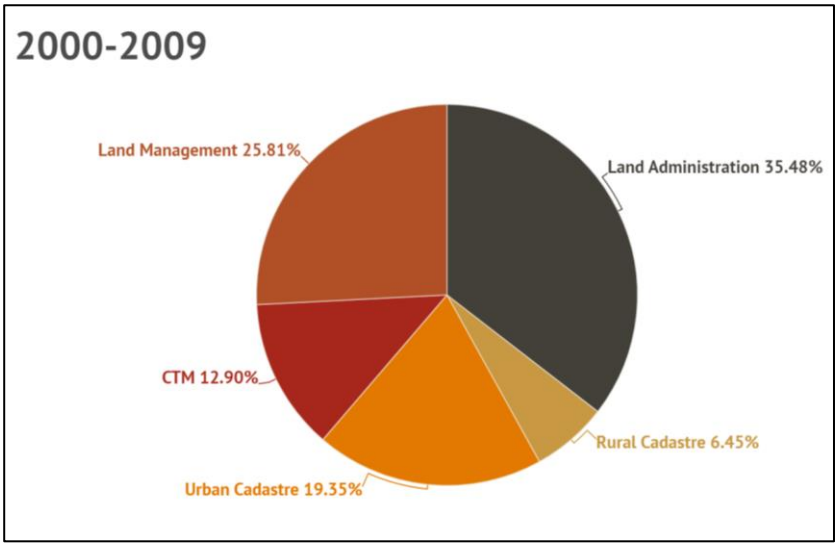
4.1 Temporal evolution of the topics covered in the research studies

After identifying the general behavior of the research studies through the main keywords used, the evolution of the science of land administration was investigated more specifically during the three intervals: until 1999, from 2000 to 2009 and from 2010 to 2020. For that, it was necessary to summarize the keywords and thematic areas into six categories, based on the evaluation of the methods, techniques and theoretical foundation of the research. The categories were: Land Administration, Land Management, CTM (corresponding to Multipurpose Technical Cadastre or Multipurpose Land Cadastre), Urban Cadastre, Rural Cadastre and 3D Cadastre.

In the period up to 1999, ten (10) research studies were identified, the first being the dissertation developed in 1979 by Prof. Tarcísio Ferreira da Silva, which proposed a metropolitan cadastral model. In 1991, the area of concentration in Multipurpose Technical Cadastre was created at the Postgraduate Program in Civil Engineering at UFSC, and in 1994 the I Congress of Multipurpose Technical Cadastre and Land Management - COBRAC was held by the same group of researchers. Although this research has used as database only publications in journals and theses and dissertations, it is important to highlight the importance of COBRAC for the dissemination of technical-scientific research in the area

In the period from 2000 to 2009, some actions led to the improvement of the land administration system and cadastres in Brazil. The rural cadastre prospered with Law 10.267/2001, considered a landmark for the country's land management in general, even if only applicable to rural properties. In the urban context, Ordinance 511/2009 proposed guidelines for the implementation of the Multipurpose Cadastre in Brazilian municipalities. An important contribution of this regulation was the proposal to adopt a concept of cadastre in line with the concept of FIG. According to BRASIL (2009), “The Multipurpose Land Cadastre (MLC), when adopted by the Brazilian Municipalities, will be the official and systematic land inventory of the municipality and will be based on the survey of the limits of each parcel, which will receive an unequivocal numerical identification." In 2008, the National Spatial Data Infrastructure - INDE was instituted, through Decree 6.666/2008, with the objective of promoting the ordering, storage and dissemination of geospatial data. As a result of these advances, these regulations have helped in some way to increase interest and demand for the improvement of the cadastres, and motivated the development of more research on related topics. Thus, from the inventory of 132 research studies, 27% were published in that period from 2000 to 2009, distributed in the topics represented in the graph in Figure 6. This was a period with more consistent scientific discussions, accompanied by rules and guidelines.

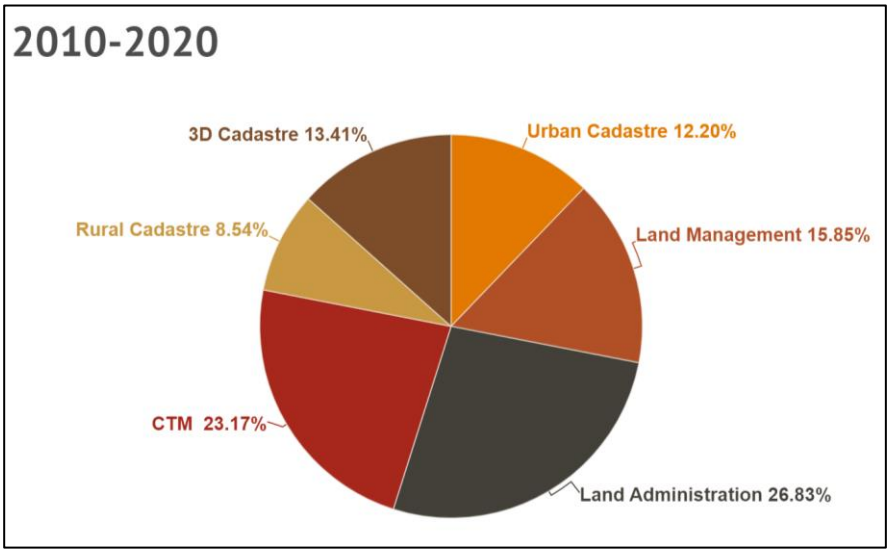
Figure 6 – Research topics published from 2000 to 2009.



Source: The authors (2020).

Most research was carried out in the last decade, between 2010 and 2020, representing about 70% of the inventory. The concepts and methods related to land administration have been consolidating and collaborating to awaken cadastral awareness in the country. When ISO 19152: 2012 – LADM (ISO, 2012) proposed the description of the cadastres from packages, sub-packages and all the relations involved between the agents of the land cadastre, as well as the rights, restrictions and responsibilities, some researchers, such as Paixão et al. (2015) and Purificação, Carneiro and Julião (2019), began investigating the applicability of the model, exploring its potential for the most diverse Brazilian cadastres. It is also important to highlight the presence of the 3D cadastre, which did not appear among the most frequent in the previous period. Another important fact was that the interest in understanding the existing land dynamics in urban centers made the urban cadastre and its application to land regularization subject to studies and publications. Figure 7 illustrates the themes covered in this period.

Figure 7 – Research topics published from 2010 to 2020.



Source: The authors (2020).

With this brief overview of research in the area of land administration and cadastre in Brazil, we can observe that researchers have sought to align themselves with international scientific developments, considering local specificities. The increase in scientific production is a trend that should continue, due to the expansion of cartographic engineering and surveying courses, and the growing interest in multidisciplinary research, as is the case in this area of research.

5 FINAL CONSIDERATIONS

This study presented relevant and current theoretical questions for research on land administration and cadastre. The questioning regarding the nature of land administration as an area of scientific knowledge and the consequent indications of the need to consolidate concepts and terminologies, point to the direction that needs to be followed to strengthen this emerging area of knowledge. Analyses of the latest research trends show that a consistent theory is still fundamental for the proposal of models that are appropriate to the realities of each country, as well as for exploring geospatial technologies, information systems and for manipulating large databases to perfect cadastres.

It also sought to present an overview of research carried out in Brazil, concluding that it has contributed to the definition and improvement of the current regulatory framework, as well as to the investigation of the application of new technologies and the development of models for the improvement of systems. In this sense, it is likely that in this decade that is starting, efforts will be directed to analyze land cadastres as a basis for land regularization projects, in compliance with Law 13.465/2017, and to contribute to the structuring of SINTER, due to its importance in the integration of the various Brazilian cadastres. Ongoing research studies also point to the study of the possibilities of using voluntary information in structuring more simplified systems, which may serve as preliminary information for meeting the goals of the UN's Agenda 2030.

Although the present study has not delved into the concepts and methods that have been used in Brazilian research, the analysis of the keywords point to the same conceptual and terminological weaknesses indicated in international studies.

The intention of this study was to contribute to future research in the area of land administration, which has been considered increasingly relevant to the planet, as evidenced by international studies. The documents of international organizations and FIG publications have served as a safe guide for researchers, showing relevant topics of scientific interest to be further explored, and hence it is recommended that interested parties try to keep up dated in this regard.

6 FUTURE CHALLENGES AND PERSPECTIVES

One of the challenges identified in the research studies is the need to consolidate a consistent theoretical framework for the training of new researchers, as well as technical professionals in cadastre. With this in mind, further studies can be produced to continue to develop the topics that appear as relevant in the results of this research study.

As perspectives for future developments, we recommend further investigation in the following issues:

a) Regarding the multidisciplinary nature of the topics related to cadastres and land management, how to intensify the relation between technological questions and aspects of the social sciences in Brazil?

b) As for the technical aspects, how to consider and integrate the possibilities arising from technologies accessible to citizens, such as voluntary information, and the needs for reliability and quality of cadastral data?

c) Regarding the contributions to the establishment of land administration systems aligned with the objectives of development for the millennium, what are the strategies for the viability of such systems, so that they are continuously improved?

Acknowledgments

The authors thank CAPES - Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Coordination for the Improvement of Higher Education Personnel) for the master's grant.

Contributions from the Authors

Conceptualization and supervision under the responsibility of Andrea F.T. Carneiro. Research by Camila Ribeiro Miranda and Andrea F.T Carneiro. Methodology and writing (draft, review and editing) by Andrea F.T. Carneiro and Camila Ribeiro Miranda.

Conflit of Interest

The authors declare that there is no conflict of interest.

References

AUC-ECA-AfDB CONSORTIUM. **Framework and Guidelines on Land Policy in Africa - Land Policy in Africa: A Framework to Strengthen Land Rights, Enhance Productivity and Secure Livelihoods.** Addis Ababa: AUC-ECA-AfDB Consortium**,** 2010. Disponível em: https://www.uneca.org/sites/default/files/ PublicationFiles/ fg_on_land_policy_eng.pdf. Acesso em 31 jul. 2020.

BRASIL. Ministério das Cidades. Portaria n.º 511 de 07 de dezembro de 2009. Diretrizes para a criação, instituição e atualização do Cadastro Territorial Multifinalitário (CTM) nos municípios brasileiros. Diário Oficial da República Federativa do Brasil, Poder Executivo, Brasília, DF, 08 dez. 2009. Seção 1, p.75.

ENEMARK, S. Building Land Information Policies, 2004. Proceedings of UN/FIG Special Forum on Building Land Information Policies in the Americas, Aguascalientes, Mexico, 26-27 out. 2004.

ENEMARK, S. From Cadastre to Land Governance**.** FIG WORKING WEEK, 2012, Rome. **Proceedings of the FIG Working Week**. Copenhagen: International Federation of Surveyors (FIG), 2012. 1-21. Disponível em: http://fig.net/resources/proceedings/figproceedings/fig2012/papers/ss06/SS06_ enemark_0000.pdf. Acesso em 03 ago. 2020.

CAGDAS, V.; STUBKJÆR, E.. Doctoral research on cadastral development. **Land Use Policy**, 26,4, 869-889, 2009. https://doi.org/10.1016/j.landusepol.2008.10.012. Disponível em: https://www.researchgate.net publication/222547643_Doctoral_research_on_cadastral_development. Acesso em: 17 jul. 2020.

CAGDAS, V.; STUBKJÆR, E. Design research for cadastral systems. **Computers, Environment and Urban Systems**, 35, 77–87, 2011. DOI. :10.1016/j.compenvurbsys.2010.07.003.

COORDENAÇÃO DE APERFEIÇOAMENTO DE PESSOAL DE NÍVEL SUPERIOR (CAPES). Tabelas de áreas de conhecimento/avaliação. Disponível em: https://www.capes.gov.br/acessoainformacao/informacoes-classificadas/91-conteudo-estatico/avaliacao-capes/6831-tabela-de-areas-de-conhecimentoavaliacao. Acesso em 03 ago. 2020.

CARNEIRO, A.F.T; ERBA, D.A.; ARRUDA, E.A.A. Cadastro Multifinalitário 3D: Conceitos e perspectivas de implantação no Brasil. **Revista Brasileira de Cartografia**, v. 64, n. 2, 11. 2012. Disponível em: http://www.seer.ufu.br/index.php/revistabrasileiracartografia/article/view/43791. Acesso em: 26 out. 2020.

CHOI, H.O. An Evolutionary Approach to Technology Innovation of Cadastre for Smart Land Management Policy. **Land,** 9, 50, 1-19, 2020. https://doi.org/10.3390/land9020050. Disponível em: https://www.mdpi. com /2073-445X/9/2/50. Acesso em 02 ago. 2020.

DALE, P.; MCLAUGHLIN, J. **Land information management: an introduction with special reference to cadastral problems in Third World countries**. Oxford: Oxford University Press, 1989.

FOOD AND AGRICULTURE ORGANIZATION (FAO). **Land tenure and rural development**. FAO Land Tenure Studies. Rome: FAO, 2002. Disponível em: http://www.fao.org/3/y4307e/y4307e00.htm. Acesso em 01 ago. 2020.

FÉDÉRATION INTERNATIONALE DES GÉOMÈTRES (FIG). **Fit-For-Purpose Land Administration**. FIG publications n.60. Copenhagen: International Federation of Surveyors (FIG), 2014. Disponível em:

https://www.fig.net/resources/publications/figpub/ pub60/Figpub60.pdf. Acesso em 01 ago. 2020.

FÉDÉRATION INTERNATIONALE DES GÉOMÈTRES (FIG). **Land Governance in Support of The Millennium Development Goals.** FIG publications n.45. Copenhagen: International Federation of Surveyors (FIG), 2009. Disponível em: https://www.fig.net/ resources/publications/ figpub/pub45/figpub45.pdf. Acesso em 28 jul. 2020.

FÉDÉRATION INTERNATIONALE DES GÉOMÈTRES (FIG). **Statement on the Cadastre**. FIG publications n.11. Copenhagen: International Federation of Surveyors (FIG), 1995. Disponível em: https://www.fig.net/resources/publications/figpub/pub11/figpub11.asp. Acesso em 26 jul. 2020.

FÉDÉRATION INTERNATIONALE DES GÉOMÈTRES (FIG). **The Bathurst Declaration on Land Administration for Sustainable Development.** Copenhagen: International Federation of Surveyors (FIG), 1999. Disponível em: https://www.fig.net/resources/ publications/figpub/pub21/figpub21.asp. Acesso em 28 jul. 2020.

GROENENDIJK, L. et. al. Land administration as an academic discipline: to be, or not to be. FIG WORKING WEEK, 2012, Rome. **Proceedings of the FIG Working Week**. Copenhagen: International Federation of Surveyors (FIG), 2012. Disponível em: https://www.oicrf.org/-/land-administration-as-an-academic-discipline-to-be-or-not-to--1. Acesso em 25 jul. 2020.

KAUFMANN, J.; STEUDLER, D. **Cadastre 2014 - A Vision for a Future Cadastral System**. Rüdlingen: International Federation of Surveyors (FIG), 1998. Disponível em: https://www.fig.net/resources/publications/ figpub/cadastre2014/translation/c2014-english.pdf. Acesso em 29 jul. 2020.

LARSSON, G. **Land registration and cadastral systems**. Essex: Longman Scientific and Technical, 1991.

LEMMEN, C.; Van OOSTEROM, P.; BENNETT, R. The Land Administration Domain Model. Land Use Policy, v.49, p535-545, 2015. Disponível em: https://www.sciencedirect.com/science/article/pii/S0264837715000174. Acesso em: 26 out. 2020.

LIU, F. LIN, A.; WANG, H.; PENG, Y.; HONG, S. Global Research Trends fo Geographical Information System from 1961 to 2010: A bibliometric analysis. **Scientometrics**, 106, 751-768, 2016.

PAIXÃO, S. K.; HESPANHA, J.; GHAWANA, T.; CARNEIRO, A. F. T; ZEVENBERGEN, J.; FREDERICO, L.N. Modeling indigenous tribes' land rights with ISO 19152 LADM: A case from Brazil. **Land Use Policy**, v.49, 587-597, 2015. Disponível em: https://www.sciencedirect.com/science/article/abs/pii/S0264837714002725. Acesso em: 26 out. 2020.

PIMENTA, A. A.; PORTELA, A. R. M. R.; OLIVEIRA, C. B.; RIBEIRO, R. M. A Bibliometria nas Pesquisas Acadêmicas. **SCIENTIA**: Revista de Ensino, Pesquisa e Extensão, v. 4, n. 7, p. 1-13, 2017. Disponível em: https://flucianofeijao.com.br/novo/wp-content/uploads/2017/12/EDUCAR_PARA_A_CIDADANIA FINANCEIRA.pdf. Acesso em 02 ago. 2020.

POLAT, Z. A. Evolution and future trends in global research on cadastre: a bibliometric analysis. **Geojournal**, 84, 1121-1134, 2019.

PURIFICAÇÃO, N.R.S.; CARNEIRO, A.F.T.; JULIÃO, R.P. A proposal for modeling and implementing an integrated system for brazilian cadastres according to iso 19152:2012 Land Administration Domain Model. **Bol. Ciênc. Geod.**, Curitiba , v. 25, n. 4, 2019; DOI.: 10.1590/s1982-21702019000400026.

SCHOLL, H. J. Discipline or Interdisciplinary Study Domain? Challenges and Promises in Electronic Government Research. In: CHEN H. et al. (eds) **Digital Government. Integrated Series In Information Systems**, v. 17. Boston: Springer, 2008. p.22-41. DOI.: 10.1007/978-0-387-71611-4_2.

SILVA, M.A.; STUBKJÆR, E. A review of methodologies used in research on cadastral development. **Computers, Environment and Urban Systems**, 26, 403–423, 2002. DOI.: 10.1016/S0198-9715(02)00011-X.

STOTER, J. E.; van OOSTEROM, P. J. M.; PLOEGER, H. D.; AALDERS, H. J. G. L. Conceptual 3D Cadastral Model applied in several countries. In: Proceedings of the FIG Working Week. Atenas, 2004. Disponível em: <http://www.gdmc.nl/publications/2004/3D_cadastral_model.pdf>. Acesso em 26 out. 2020.

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE (UNECE). **Land Administration in the UNECE Region: Development, Trends and Main Principles.** New York and Geneva: United Nations Publications, 2005. Disponível em: http://www.unece.org/fileadmin/DAM/hlm/documents/Publications/landadmin.devt.trends.e.pdf. Acesso em 28 jul. 2020.

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE (UNECE). **Land Administration Guidelines with Special Reference to Countries in Transition**. New York and Geneva: United Nations Publications, 1996. Disponível em: http://www.unece.org/fileadmin/DAM/hlm/documents/Publications/land.administration.guidelines.e.pdf. Acesso em 28 jul. 2020.

UNITED NATIONS COMMITTEE OF EXPERTS ON GLOBAL GEOSPATIAL INFORMATION MANAGEMENT (UN-GGIM). **The Application of Geospatial Information – Land Administration and Management**. United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), 2015. Disponível em: http://ggim.un.org/meetings/GGIM-committee/documents/GGIM5/and%20admin%20and% 20mngnt%20background%20paper%203.2%20final.pdf. Acesso em: 27 ago. 2020.

UNITED NATIONS COMMITTEE OF EXPERTS ON GLOBAL GEOSPATIAL INFORMATION MANAGEMENT (UN-GGIM). **Framework for Effective Land Administration: A reference for developing, reforming, renewing, strengthening or modernizing land administration and management systems**. United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), 2019. Disponível em: https://ggim.un.org/meetings/GGIM-committee/9th-Session/documents/ E_C.20_2020_10_Add_1_LAM_ background.pdf. Acesso em 01 ago. 2020

Van OOSTEROM, P (ed.). Best practices 3D Cadastres – Extended Version. FIG Publication, 2018. Disponível em: http://www.gdmc.nl/3DCadastres/FIG_3DCad.pdf. Acesso em: 26 out. 2020.

Van OOSTEROM, P., PLOEGER, H., STOTER, J., THOMPSON, R., LEMMEN, C. Aspects of a 4D Cadastre: A First Exploration. In: Proceedings of the XXIII FIG Congress. Munique, 2006. Disponível em: http://www.gdmc.nl/publications/2006/Aspects_of_4D_Cadastre.pdf. Acesso em: 26 ago. 2020.

WILLIAMSON, I. et. al. **Land administration for sustainable development**. Redlands: ESRI Press, 2010.

ZHANG, H. et. al. Bibliometric analysis of global remote sensing research during 2010-2015. (Open Access). **ISPRS International Journal of Geo-Information**, , 6, 332, 1-19, 2017. DOI.:10.3390/ijgi6110332.

Biographies of the authors

Andrea Flávia Tenorio Carneiro, Arcoverde-PE-Brazil, 1966. Cartographer Engineer from the Federal University of Pernambuco – UFPE in 1989. Master in geodetic sciences from the Federal University of Paraná - UFPR in 1993 and PhD in production engineering from the Federal University of Santa Catarina - UFSC in 2000. She did postdoctoral training at Universidade Nova de Lisboa - UNL in 2018. Teacher of the Department of Cartographic Engineering at UFPE since 1994, in Recife-PE. Works in teaching and research in the areas of cadastre and land management in the courses of cartographic engineering and surveying and post-graduation in geodetic sciences and geoinformation technologies.

Camila Ribeiro Miranda, Salvador-BA-Brazil, 1994. Surveyor Engineer from the Federal University of Alagoas - UFAL in 2018. She did a sandwich graduation at the University of Colorado Boulder in 2014. Master's student in Geodetic Sciences and Geoinformation Technologies at the Federal University of Pernambuco. She has experience in the field of geosciences, with emphasis on territorial cadaster, geoprocessing, mapping of risk areas and urban territorial planning.