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Global scientific production on LADM-based research: A bibliometric analysis from 2012 to 2020

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ABSTRACT

Multiple Land Administration Domain Model (LADM) related studies have been carried out in two decades. ISO 19152 LADM is an international standard and an abstract, conceptual model covering the land administration domain (including those over land and water and elements above and below the earth's surface). The LADM is considered an important component for managing and developing land administration systems worldwide. In the context of this study's, scientific publications related to LADM are examined to carry out a bibliometric analysis on LADM research from 2012 to 2020. The extent of this investigation is limited to the Scopus database for scientific publications. All databases belong to the most extensive peer-reviewed summary and citation databases. It is noted that this study is based on the same principles as the research published by Paulsson and Paasch (2015), building on existing knowledge and aiming to add value in support to the current development of Edition II of the LADM.

In this study, which covers 2012–2020, 175 LADM related scientific publications were found in the Scopus database. When the distribution of publications in journals is examined, Land Use Policy has the most published manuscripts related to ISO 19152 LADM. This analysis considers author identification, type of paper, organisational issues, and bibliometric analysis components. The analysis considered articles, books, and proceedings directly related to the LADM and included in the Scopus database or conference and workshop proceedings. For this, articles and books were selected from the Scopus database. Also, the proceedings were selected from those presented in the International Federation of Surveyors (FIG) events and workshops on LADM. Overall, this paper aims to arrange and present the global scientific production on LADM-based research.

1. Introduction

In 2012 the Land Administration Domain Model (LADM) was an ISO standard for the land administration domain (ISO, 2012). The LADM provides an internationally recognised conceptual model with four packages describing different aspects of land administration. It provides an abstract, conceptual model related to parties (people and organisations), basic administrative units, rights, responsibilities, and restrictions (ownership rights), spatial units (parcels, and the legal space of buildings and utility networks), spatial sources (surveying) and spatial representations (geometry and topology). It also provides a shared vocabulary serving as a standardised language between land administration systems worldwide, and the LADM facilitates efficient land administrations. Moreover, it can function as a land administration system (Oosterom and Lemmen, 2015).

The wide recognition and use of the current, i.e. first, edition of ISO 19152 LADM, are mainly documented through the country profiles being developed in multiple jurisdictions worldwide, resulting in a mosaic of country profiles. An overview of the LADM country profiles has been presented by Kalogianni et al. including some criteria to assess them. It is concluded that, although there is no common specific (official or unofficial) template or methodology established, there are various

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country profiles developed by countries all over the world by academia, governmental organisations, or by the industry (Polat et al., 2018; Zyoud et al., 2017).

Currently, the revision of the LADM is ongoing within ISO Technical Committee 211 (TC 211), with a substantial contribution from various international organizations, e.g. the International Federation of Surveyors (FIG). Edition II of LADM is planned to be a multipart standard addressing current and future land administration challenges, adopting a lifecycle approach, and going beyond a conceptual model. In the context of this revision, publications related to the LADM are studied. Therefore, we hope that the research presented here will be towards the analysis of the bibliography of the LADM since 2012, also providing statistical results for further research. It is a continuation of achieving the aim from the bibliography study presented in Paulsson and Paasch (2015).

The paper's content analysis is based on the same principles presented in Paulsson and Paasch (2013). Specifically, it identifies areas within LADM research that could benefit from increased attention to further development, particularly in some aspects. Among such aspects can be mentioned to organise the work. It has to be done to implement the standard in both legal and practical contexts.

The paper is structured as follows. Section 2 presents the materials and methods used for the analysis and gives an overview of the methodology in classifying the LADM topics. The bibliometric analysis results are presented in Section 3, followed by relevant illustrations and charts; Section 4 presents the results from the classification of LADM topics, while the last two sections are devoted to discussion and conclusions.

The research presented here has a three-year overlay, 2012–2015, with Paulsson and Paasch (2015). The reason is that the present research focuses on LADM-related publications published after the introduction of the LADM standard in 2012. There is no overlap between the two studies because they focus on different things and analyse more than just the classification of topics.

2. Data sources and methodology

2.1. Data sources materials

2.1.1. LADM publications indexed by Scopus

Publications are featured records of the growth of science (Mallawaarachchi et al., 2020). The publications scanned by several indexes are considered scientific. These are Science Citation Index (SCI), Science Citation Index-Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), and Arts and Humanities Citation Index (AHCI). Online databases such as Web of Science and Scopus play an essential role in delivering scientific studies to the reader. Scopus, the world's largest abstract and citation database of peer-reviewed literature, was the primary data source from which the articles analysed in this study were obtained. It provides more consistent and reliable records and better tables and graphics for Bibliometric analysis (BA) than other databases (Cobo et al., 2011; Zhang et al., 2017). The online search within Scopus was completed in 2021 by selecting "Land Administration Domain Model" and its abbreviation ''LADM'' as keywords in the Article Title, Abstract, Keywords field of the search engine to obtain the available bibliography with all the publications related to the research on the LADM published during the period from 2012 up to and including 2020. As a result of the queries made through the Scopus online database, 88 publications were retrieved, including articles, proceedings, and books focusing on the LADM (See Table 1). Data on author names, document type, publication years, country and institution, subject categories, journals, title, author keywords, and analyses have been collected.

2.1.2. LADM publications by FIG and Land world bank land and poverty conferences

According to Lisée et al. (2008) and Glänzel et al. (2006), conference papers/proceedings represent an essential part of the research area's published literature. Similarly, Goodrum, McCain, Lawrence, and Giles (2001), Visser and Moed (2005), and Butler (2008) argue that for computer-based sciences and other scientific disciplines, conference papers/proceedings are attributed even greater importance than all articles sharing knowledge.

There are conference papers/proceedings that are not registered in Scopus but contain valuable scientific information. In this scene, FIG is the leading organisation for surveying, land administration, and related disciplines, which organises international events, such as conferences and workshops, bringing together researchers working in a particular field. Besides, studies on LADM are presented at the Land and Poverty Conferences organised by the World Bank. For this reason, the studies presented in these scientific congresses and organisations are included in this study. Also, there are considerations within the scope of the bibliometric analysis (BA) of this paper. The data sources used in this analysis and the number of LADM related documents they contain are given in Table 1. Totaly, 175 documents were analsed for the BA. Eighty-

Table 1
Data sources and LADM-related documents used in the BA.

Data sources	Sub-Data sources	Document types	The number of documents analysed is directly related to LADM
Scopus	Journals, conferences and book publishing houses	Articles, proceedings and books	88
FIG Events	FIG Working Week 2020, Amsterdam, The Netherlands	Proceedings	10
	The 8th Land Administration Domain Model Workshop, 2019, Kuala Lumpur	Proceedings	16
	FIG Working Week 2019, Hanoi, Vietnam	Proceedings	6
	FIG Congress 2018, Istanbul, Turkey	Proceedings	3
	6th International Workshop on 3D Cadastres, 2018, Delft	Proceedings	6
	7th International FIG Workshop on the LADM, 2018, Zagreb	Proceedings	5
	FIG Working Week 2017, Helsinki, Finland	Proceedings	6
	5th International Workshop on 3D Cadastres, 2016, Athens	Proceedings	3
	FIG Working Week 2015, Sofia, Bulgaria	Proceedings	2
	Joint International Geoinformation Conference, 2015, Kuala Lumpur	Proceedings	3
	FIG Congress 2014, Kuala Lumpur, Malaysia	Proceedings	4
	4th International Workshop on 3D Cadastres, 2014, Dubai	Proceedings	5
	FIG Working Week 2013, Abuja, Nigeria	Proceedings	5
	5th Land Administration Domain Model Workshop, 2013, Kuala Lumpur	Proceedings	3
	FIG Working Week 2012, Rome, Italy	Proceedings	2
	3rd International Workshop on 3D Cadastres, 2012, Shenzhen	Proceedings	2
World Bank	Land and Poverty Conferences	Proceedings	6
Total			175

eight of them are articles, papers/proceedings and books scanned by the Scopus database. Seventy-seven of them are the proceedings presented in these scientific congresses and organisations events. The online search within Scopus was completed in 2021 by selecting "Land Administration Domain Model".

2.1.3. Social tenure domain model

The Social Tenure Domain Model (STDM) is an initiative to support pro-poor land administration in developing countries. It is mentioned in an informative index in the LADM (ISO, 2012, Annex I), i.e. Paulsson and Paasch (2015) included STDM publications in their LADM literature survey. However, this study has not included the STDM since the research presented here focuses on a strictly bibliometric analysis of the LADM.

2.2. Methodology

Bibliometric indicators are effective tools for analysing the research trends of a specified study area (Chiu and Ho, 2007; Goodchild and Glennon, 2010; Abejón et al., 2017; Şenel and Demir, 2018). BA includes a range of quantitative and visualisation procedures or statistics to generalise dynamics, hot issues and research trends in scientific-based publications (Polat, 2019; Li et al., 2018; Bi, 2013). This study uses quantitative BA methods and social network analysis (SNA) to determine scientific trends (Li et al., 2018; Emrouznejad and Marra, 2017; Niu et al., 2016). SNA is widely employed to visualise and analyse the relationships between various nodes in bibliometric-based studies, such as co-occurrence of keywords, academic collaborations among authors, institutions, and countries (Li et al., 2018).

This study evaluates and identifies trends in scientific research on the LADM, where a BA of documents, subject indexes in which the journal is classified, most frequently used author keywords in each subject category, and articles reviewed with the highest number of citations were taken in consideration. Keyword analysis can be considered a valuable tool for determining essential topics and research trends (Niu et al., 2016). It is aimed to identify the most frequently used keywords to identify hot topics and trends in the LADM. For this, two or more words frequently used together have been identified. The countries with the most considerable contribution and the most frequently used keywords were also identified using SNA. SNA was achieved by reporting the number of co-occurrences in the articles extracted from the bibliometric search. The network of countries, authors and keywords were represented using the VOSviewer software.

VOSviewer is a software tool for constructing and visualising bibliometric and social networks. Therefore, it is suitable to visualise co-occurrence networks of hot topics and important terms extracted from a body of scientific literature (Zhang et al., 2017). Determining research trends using bibliometric studies is receiving considerable attention, as they reveal valuable information on scientific-based research and its evolution in a specific field of study (Vain, 2007). Despite the increasing publications of research on the LADM, there are not enough bibliometric studies on the effect of LADM on land administration activities. The Paulsson and Paasch (2015) study on LADM literature is, to our knowledge, the only study ever conducted. Each publication in our study was analysed and classified according to the main classification in (Paulsson and Paasch, 2015) with legal, technical, registration and organisational categories: legal, technical, registration and organisational. In our study, all publications are analysed in terms of research topics, scientific production, collaboration among countries and authors, and most cited papers on LADM research to determine trends of LADM after standardisation.

The search in Scopus and FIG events was carried out by selecting keywords expressing ISO 19152 LADM. It aims to reach the relevant studies by searching the selected keywords in Abstract, Title and Keywords. Since the LADM was accepted as a standard by ISO in 2012, in that year the start date of the research period was selected. Besides, it is aimed to determine the direction of scientific studies related to the LADM, especially after the standardisation. The keywords were introduced together between quotations to select only articles that include those keywords in that order. Using the keywords in the correct order logically during the analysis, using them in quotations and searching in the crucial parts of the publications (such as title, summary) will provide more accurate results. Without the right keywords, it may have been difficult finding the publications that are needed.

3. Results of bibliometric analysis

3.1. Publication outputs

The annual number of scientific publications within the research period is presented in Fig. 1. A total of 175 scientific publications related to the LADM are identified and analysed. As shown in Fig. 1, scientific studies (Such as articles, proceedings, book chapters) that have been subjected to a peer-review process on the LADM are made regularly. Scopus is the largest abstract and citation database of peer-reviewed literature: scientific journals, books, and conference proceedings. Scopus indexes scientific studies that meet specific requirements (such as peer review, regular publication, original contributions). There are conference papers/proceedings not scanned by Scopus because they do not meet all the requirements but contain valuable scientific information. Those documents are from annual scientific events that are organised every year, and the LADM is commonly included in the topics presented in this context.

Furthermore, special issues in scientific journals usually follow some of the FIG events and hence, LADM publications were also prepared for this purpose. Finally, Open Geospatial Consortium (OGC) meetings, where the LADM implementation is discussed, are regularly held, and relevant publications usually follow them. All those events show that the research in the LADM is continuously progressing and is a dynamic and up-to-date research area.

Therefore, the distribution of document types was analysed, and three different document types were found among the 175 publications from 2012 to 2020. Conference papers/proceedings were the most frequently published document type comprising 49.7% of the documents (87 publications), followed by a journal article, with 86 documents (49.1%), and the last document type is book chapters, with two documents (1.3%) appearing in the selected publications (Fig. 2)

3.2. Distribution and contribution of publication sources

One hundred seventy-five studies (175) related to the LADM were presented in FIG events and twenty-three (23) different journals. Table 2 presents the distribution of the publication sources where most of the documents are published. 46.2% (81 documents) out of 175 documents

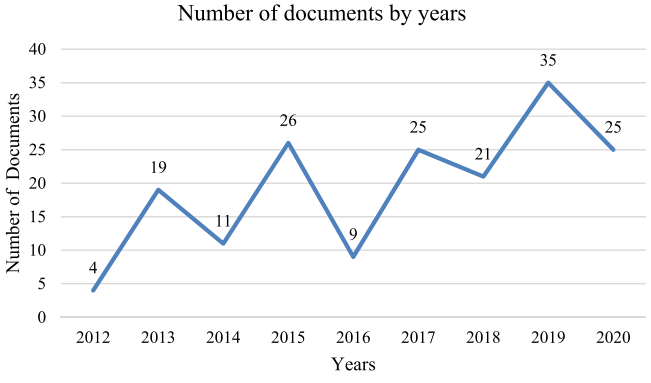

Fig. 1. Number of scientific documents published on LADM-based research by years.

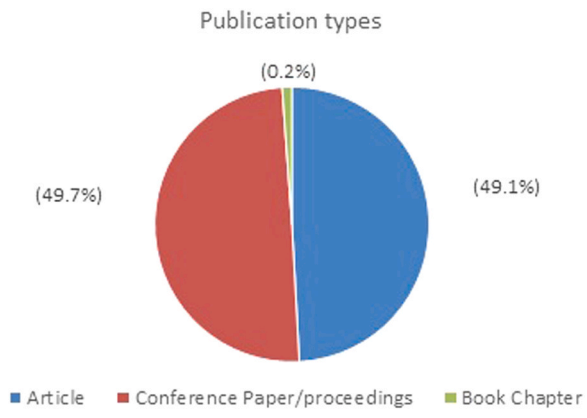

Fig. 2. Types of scientific publications published on LADM-based research.

Table 2
Publication sources that contributed the most in LADM-based research during 2012–2020.

Rank	Name of publication sources	Number and percentage of publication on LADM-based research
1	FIG events proceedings	81 (46.2%)
2	Land Use Policy	29 (16.5%)
3	ISPRS International Journal Of Geo Information	11 (6.3%)
4	Survey Review	7 (4%)
5	Lecture Notes In Geoinformation And Cartography	4 (2.3%)
6	Computers Environment And Urban Systems	4 (2.3%)
7	GIM International	4 (2.3%)
8	Other publication sources (17 pcs)	35 (20%)

were presented at FIG events in this context. In other respects, there is a high contribution related to the LADM articles from 23 different journals. According to the analysis, the scientific journal Land Use Policy published the most articles on the LADM (29 in total; i.e. the 16.5%), followed by the ISPRS International Journal of Geo-Information (11 documents; 6.3%), Survey Review (7 documents; 4%), Lecture Notes in Geoinformation and Cartography (4 documents; 2.3%, and four documents were published in GIM International, which is a magazine on geomatics with impact factor. The remaining documents were published in 17 other journals.

3.3. Author contribution and a global network of collaboration

Totally 255 authors contributed to the 175 documents in the Scopus database, FIG and World Bank events from 2012–2020. Table 3 presents the result of the author's contribution analysis. Ten authors were those that contributed the most during this period, obtaining significant achievements in LADM research. Specifically, those that contributed the most are the two editors of the first edition of ISO 19152 LADM (Table 3.).

Table 3
The authors that contribute the most to the LADM-based research.

Rank	Name of author	Number and percentage of author's publications
1	Peter Van Oosterom	61 (34.8%)
2	Christiaan Lemmen	44 (25.1%)
3	Alias Abdul Rahman	19 (10.9%)
4	Efi Dimopoulou	13 (8.2%)
5	Nur Amalina Zulkifli	11 (6.3%)
6	Jaap Zevenbergen	9 (5.1%)
7	Eftychia Kalogianni	8 (4.6%)
8	Tan Liat Choon	7 (4%)
9	Mohsen Kalantari	7 (4%)
10	Karel Janečka	5 (2.3%)

Co-authorship networks are increasingly used as valuable tools to evaluate interoperability trends and reveal leading researchers and organisations (Fonseca et al., 2016). Related to this research, five percent of 175 publications were single-author studies, and ninety-five percent of 175 studies had two or more authors. The publications show that interaction and collaboration between authors are pretty intense. Collaborations among 255 authors are depicted in Fig. 3. The size of each bubble in this figure indicates each author's number of scientific documents on LADM-related research. The bubbles are coloured based on the author's total contribution (i.e. scientific documents) in this research area. A link between two bubbles indicates a co-authorship relationship for two or more scientific documents on LADM-related research.

3.4. Institution distribution and research contribution

Research institutions and countries play a valuable role in supporting and disseminating scientific studies. Some institutions and countries support many studies to develop science and technology culture in some scientific fields. Cooperation between these leading institutions and countries with less developed countries will accelerate the development of science (Li et al., 2018; Şenel and Demir, 2018). It is crucial to determine the institutions and countries that operate intensively in some areas in this context. Table 4 presents the institutional distribution of the authors in the documents. Specifically, 187 (73.3%) out of 255 authors consist of university members and staff. Sixty-three of the authors (24.7%) who contributed to the studies are affiliated with non-academic institutions.

Table 5 shows the institution's productivity/ contribution analysis ranked by the number of publications. The top ten institution's which published more than five papers are listed below in Table 5. The institutions that contribute the most are Delft University of Technology (59 papers; 33.7%), University of Twente (32 papers; 18.2%), and Universiti Teknologi Malaysia (22 papers; 12.6%), respectively. This result confirms the result of the author's contribution, as presented above.

3.5. Country contribution and a global network of collaboration

Many studies are carried out in different countries focussing on the development, design and implementation of the LADM. Some researchers probably still need more help from researchers of contributing countries to produce research in this field. Internationally co-authored publications and cooperation can satisfy the need in the scientific area. It is imperative to identify countries that focus on developing the LADM and conducting more research in this context. In this way, countries working on the LADM can come together more, exchange ideas and work together. Twenty-eight (28) different countries contributed to the 175 publications on LADM-based research. The top ten countries are listed in Table 6. It was apparent that the countries that contributed the most are the Netherlands (70 papers, 42%), Malaysia (25 papers, 16%), Greece (21 papers, 12%), Turkey (20 papers, 11.4%), Australia (17 papers, 9.7%) and Switzerland (11 papers, 6.3%) respectively. The distribution and number of contributing countries show that the LADM gains international recognition, and contributions from worldwide are published.

Scientific production worldwide is presented in Fig. 4. The size of each bubble indicates the contribution of each country on LADM-based research. A link between two bubbles indicates the relationship between countries in scientific documents. Collaboration among countries can be observed, and four countries stand out with intense cooperation among themselves and the rest of the world: The Netherlands, Malaysia, Turkey and Greece. The intensive relationship between countries indicates that

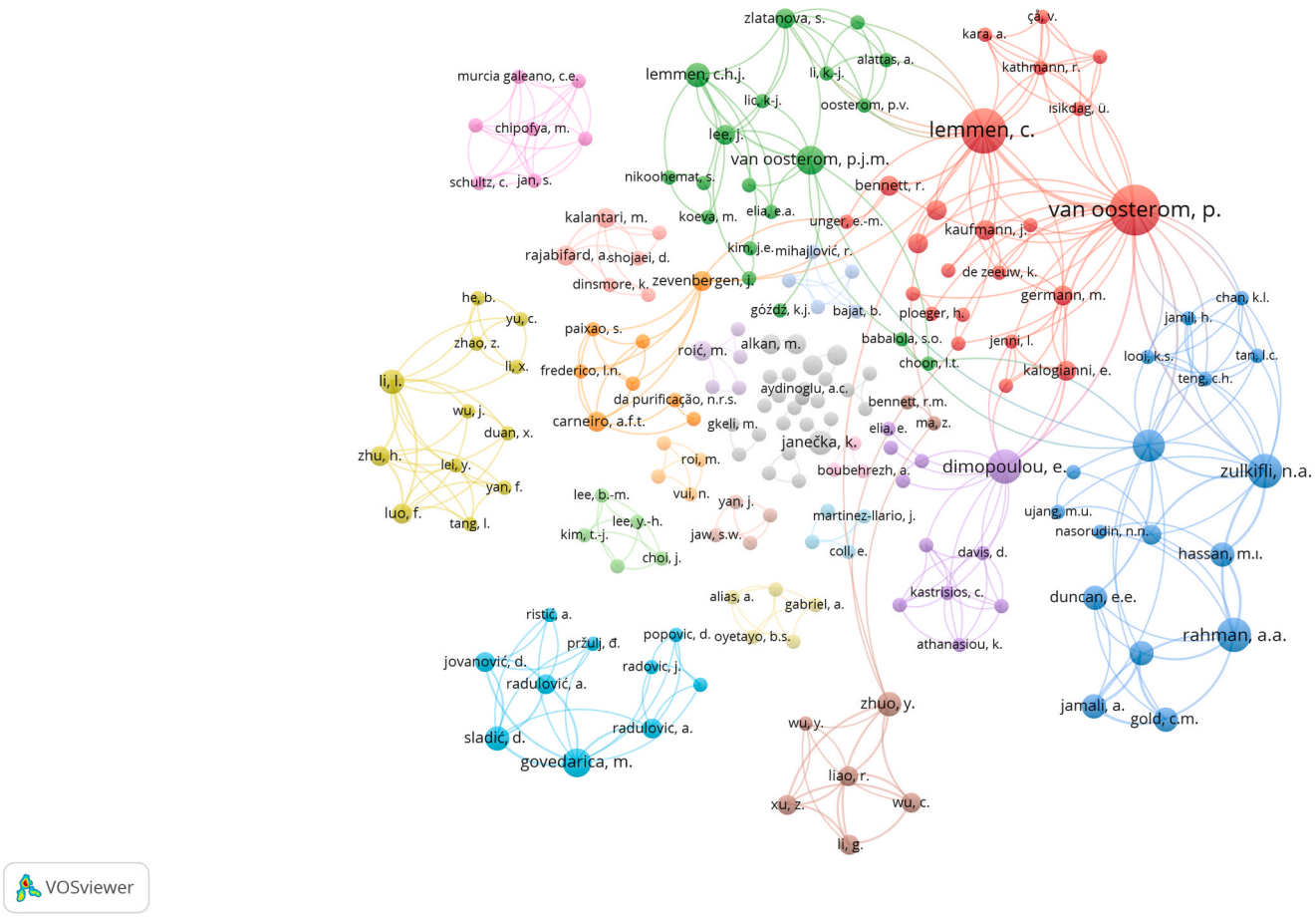

Fig. 3. Co-authorship network of authors on LADM-based research which is created using VOSviewer.

Table 4
Institution distribution of the authors.

Affiliations Distribution	Academic institutions	Non-academic institutions	Unknown	Total of authors
Frequency	187	63	5	255
Percentage	73.3%	24.7%	2%	100%

countries are working together on issues related to the LADM. This collaboration phenomenon both accelerates the acceptance and development of LADM and facilitates its implementation in more countries.

3.6. Keyword analysis and hot issues

Keywords enable authors to extend their publication's representation beyond that presented in the title and abstract to include related concepts. Keywords play a significant role in representing the content of an article. The use of 233 different keywords repeated at least twice indicates that LADM has a relationship with many fields and concepts. In this context, the five most used keywords were found to be "LADM", "3D cadastre", ''cadastre'', "land administration'', and "3D data modelling'' (and they appear n = 42, 21, 17, 11 and 7 times, respectively). This situation shows that the LADM is closely related to cadastre and data modelling, especially in land administration. As seen in the SNA of the keyword, related keywords were placed close to each other. For instance, "LADM" was the most used keyword with the highest point size and related to the same coloured keywords such as "3D cadastre", "land administration", "cadastre", "land registry", "CityGML" and "3D modelling" (Fig. 5).

Table 5
The institutions that contribute the most.

Rank	Name of Institution	Number and percentage of institution's publications	The number of institutions working together in these publications
1	Delft University of Technology	59 (33.7%)	27
2	University of Twente	32 (18.2%)	19
3	Universiti Teknologi Malaysia	22 (12.6%)	5
4	National Technical University of Athens	15 (8.6%)	7
5	Netherlands Cadastre, Land Registry and Mapping Agency	14 (8%)	5
6	Yildiz Technical University	12 (6.8%)	6
7	University of Novi Sad	7 (4.6%)	3
8	University of Melbourne	7 (4%)	3
9	University of West Bohemia	5 (2.8%)	4
10	Karadeniz Technical University	5 (2.8%)	2

3.7. Highly cited articles

Ten articles receiving more than seven citations are listed in Table 7. The most cited paper was published in 2015 by Lemmen, C., van

Table 6
The ten countries/jurisdictions that contribute the most to LADM-based research.

Rank	Country	Number and percentage of author's publications
1	The Netherlands	70 (40%)
2	Malaysia	25 (14.3%)
3	Greece	21 (12%)
4	Turkey	20 (11.4%)
5	Australia	17 (9.7%)
6	Switzerland	11(6.3%)
7	China	9 (5.1%)
8	Serbia	9 (5.1%)
9	South Korea	6 (3.4%)
10	Portugal	5 (2.9%)
11	Other countries (18 pcs)	55 (31.4%)

Oosterom, P., and Bennett, R. in Land Use Policy (n = 110). The paper's topic is "The Land Administration Domain Model" and gives an overview of the standard, presenting all the packages, the LADM requirements, and the impact and future developments. This structure and the detailed presentation of the standard form the basis for such a highly-cited reference paper.

The second most cited article (n = 76) is "The core cadastral domain model" and was published in Computers, Environment and Urban Systems in 2006 by van Oosterom P., Lemmen C., Ingvarsson T., van der Molen P., Ploeger H., Quak W., Stoter J., and Zevenbergen J. The paper proposes the core cadastral domain model in the transition to standardization in land administration. Moreover, the third most cited article (n = 54) was "Data model for the collaboration between land administration systems and agricultural land parcel identification systems" published in Journal of Environmental Management in 2010 by Inan H.I., Sagris V., Devos W., Milenov P., van Oosterom P., Zevenbergen J. The paper presents a data model for the collaboration between land administration systems and agricultural land parcel identification systems.

4. Classification of LADM topics

The LADM-related publications that are studied in this research can be classified according to their content. A publication may describe different topics, such as security of tenure, legislation, registration of rights, restrictions, and responsibilities to a greater or lesser degree. The categories used are Legal, Technical, Registration and Organizational. The legal category includes topics such as real property legislation and the legal foundations of real property rights, restrictions and responsibilities (RRRs), the security of tenure and other subtopics of the national and international legal frameworks governing the ownership, access and use of land (including legal source documents, mandates and responsibilities for organisations in a distributed environment). Land Information Infrastructure includes legal/administrative data, interoperability, update procedures, transaction processes, products and services. The registration category includes real property registration in land administration systems storing real property information, such as the content, storage, structure, database management systems, and real property information maintenance. Lastly, the organisational category includes institutional, management and capacity-building issues. Examples are organising and managing interests in land, good governance and operations, information and communication technology, and financial aspects.

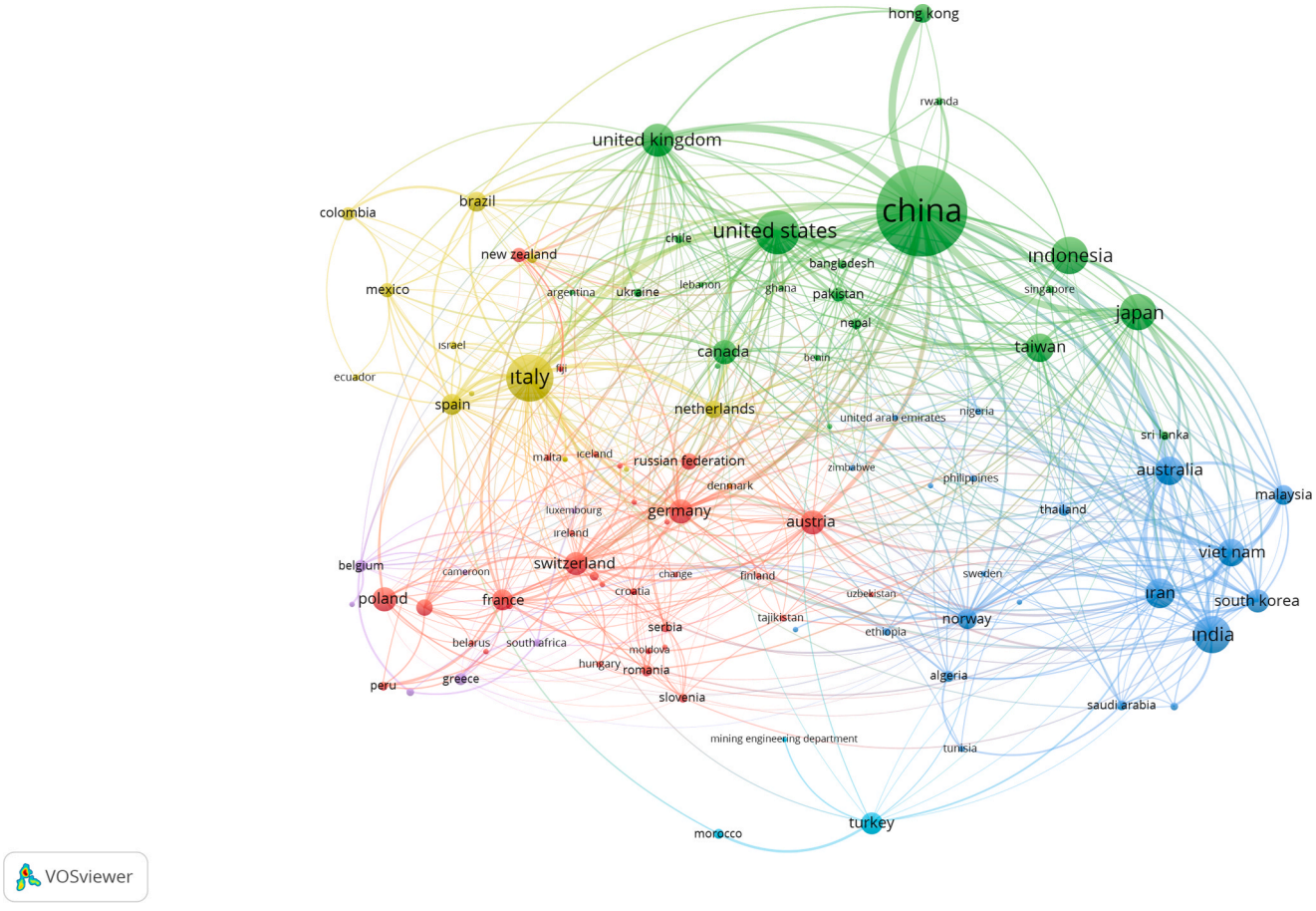

Fig. 4. Collaboration networks of countries/territories in LADM-based research during 2012–2020.

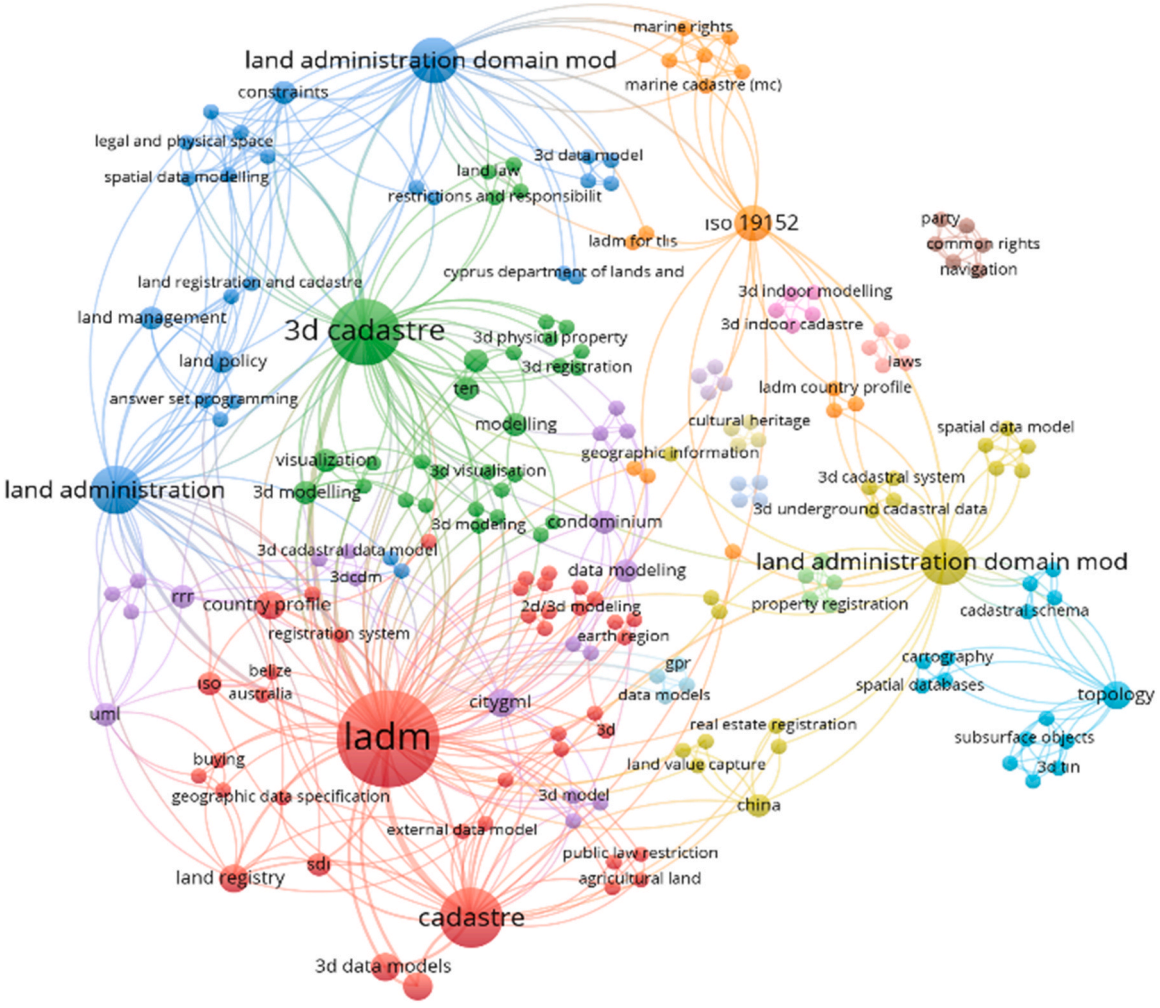

Fig. 5. Social network analyses with 233

Each publication in the study has been analysed and classified. The classification was made according to the categories described above. Only one dominant category based on the publication's content was assigned to each publication. However, assigning any publications to more than one of the four categories would have been possible since they included several different issues. It has, therefore, been a challenge to make a precise classification in several cases. For example, legal issues are often described as an introduction or addition to technical and registration issues.

The results showed that 27 of the 171 analysed publications were placed in the legal category, 64 in the technical category, 61 in the registration category, and 19 on organisational matters. During the investigated years, there has been the most focus on technical and registration issues, such as cadastre and data modelling, with less focus on legal and organisational aspects, such as rights and management. It can be explained by the fact that the LADM is the conceptual model described in UML. Many publications refer to the modelling aspects and challenges faced while preparing LADM-based UML diagrams or investigating the registration aspects related to the existing cadastral systems and legislative framework. The LADM is divided into "four packages"; 1) Parties (people and organisations), 2) Basic administrative units, rights, responsibilities, and restrictions (ownership rights), 3) Spatial units (parcels and the legal space of buildings and utility networks), 4) Spatial sources (surveying) and spatial representations (geometry and topology) (ISO, 19152). The standard is currently under revision (ISO, 2020).

The previous LADM literature survey covering the years 2001–2015 (Paulsson and Paasch, 2015) also identified a more significant focus on technical and registration issues, which means that there has not been much development in that sense. Also, the analyses are partly overlapping since the years 2012–2015 are covered in both studies. However, publications focusing on organisational issues have increased, while focused legal publications are smaller than others. Several of the organisational publications describe the development of LADM and summarise what has been done so far. This study shows that since the LADM has been in use for more than eight years, such issues have increased. Legal issues have decreased somewhat since it can be seen as forming a foundation for further applications.

It has been possible to discern some themes that appear rather frequently during the studied period and indicate general trends in LADM research. A general description of or presenting the development of country profiles in different stages is one such theme. Focus is thus still on one country at a time and its own need for and use of the LADM, and not so many comparisons between countries or more general aspects, which can be since the researchers are more familiar with their system. Visualisation aspects seem to have grown in focus. Besides, valuation information issues seem to have become a more popular theme. More general aspects of further development of the LADM are a frequent theme. One reason for this increased interest in these topics may be the ongoing initiative to add a valuation and other topics to the next edition of the LADM, including the topics mentioned above, as well as and other topics, e.g. ISO (, 2019, 2020).

Table 7
The top 10 highly cited publications during 2012–2020.

Rank	Document title	Authors	Year	Source	Cited by
1	The Land Administration Domain Model	Lemmen, C., van Oosterom, P., Bennett, R.	2015	Land Use Policy 49, pp. 535–545	110
2	The core cadastral domain model	van Oosterom P., Lemmen C., Ingvarsson T.,van der Molen P., Ploeger H., Quak W., Stoter J., Zevenbergen J.	2006	Computers, Environment and Urban Systems 30(5), Pages 627–660	76
3	Data model for the collaboration between land administration systems and agricultural land parcel identification systems	Inan H.I., Sagris V., Devos W., Milenov P., van Oosterom P., Zevenbergen J.	2010	Journal of Environmental Management, 91(12), Pages 2440–2454	54
4	Supporting indoor navigation using access rights to spaces based on combined use of IndoorGML and LADM models	Alattas, A., Zlatanova, S., Oosterom, P. V., (.), Lemmen, C., Li, K.-J.	2017	ISPRS International Journal of Geo-Information 6(12),384	40
5	3D cadastre in the Netherlands: Developments and international applicability	Stoter J., Ploeger H., van Oosterom P.	2013	Computers, Environment and Urban Systems,40, Pages 56–67	40
6	The application of the Land Administration Domain Model in building a country profile for the Polish cadastre	Bydłosz, J.	2015	Land Use Policy 49, pp. 598–605	37
7	The Land Administration Domain Model (LADM): Motivation, standardisation, application and further development	van Oosterom, P., Lemmen, C.	2015	Land Use Policy 49, pp. 527–534	35
8	Further modelling of LADM's rights, restrictions and responsibilities (RRRs)	Paasch, J.M., van Oosterom, P., Lemmen, C., Paulsson, J.	2015	Land Use Policy 49, pp. 680–689	27
9	3D modeling of the ownership structure of condominium units	Li, L., Wu, J., Zhu, H., Duan, X., Luo, F.	2016	Computers, Environment and Urban Systems 59, pp. 50–63	25
10	A country profile of the Czech Republic based on an LADM for the development of a 3d cadastre	Janečka, K., Souček, P.	2017	ISPRS International Journal of Geo-Information 6(5),143	22

5. Discussion

The bibliometric analysis necessity has increased thanks to ummarising the research topics that primarily have many documents (Kiraz and Demir, 2020). Despite the increasing popularity of bibliometric studies, the number of studies that involve the bibliometric analysis of the LADM is somewhat limited in the literature. In this context, the only study on LADM literature belongs to Jenny Paulsson and Jesper M. Paasch. In this study, Paulsson and Paasch (2015) provide an overview of the research, as evidenced by scientific publications 2001–2015, to discuss the distribution of interest areas within LADM research. With the adoption of the LADM as a standard in 2012, many scientific studies have been presented until 2021. Our study has two main objectives: (1) to determine the impact of LADM on land administration and (2) to provide a potential guide for the future of the LADM.

The result of keyword analysis usually indicates the research interests of the LADM. An analysis of the most cited papers, title and keywords showed that LADM's integration into cadastral issues (such as 2D, 3D or 4D cadastre) was the hottest topic in LADM-based research and "3D data modelling", "cityGML" and "real estate valuation" were recent major topics of LADM-based research. Many studies are about creating a cadastral-based LADM country profile (Such as the Czech Republic, Poland, Republic of Korea, Malaysia). Other LADM country profile studies are related to "modelling the spatial data (Victoria country)", "land administration (Turkey, Serbia) "land-use planning (Colombia)", "real estate valuation (Turkey)". The number and distribution of LADM-based profile studies show that many countries have adopted the LADM.

The country distribution of authors of LADM-based research studies supports this view. A content analysis of the publications showed that the technical and registration topics are still focused on in research compared to the previous study (Paulsson and Paasch, 2015). Legal and organisational topics are still in the minority, but there has been a slight increase concerning the earlier study. It was possible to discern some new topics for research, such as visualisation and property valuation.

In 95% of the scientific studies, two or more authors showed that sharing information on the LADM among the authors is quite intense. Interoperability between authors further contributes to the development of the LADM. The universities' number of scientific documents is much higher than that of the non-academic institution (see Table 4). The institutions with the most considerable contribution in the research field for 2012–2020 are listed in Table 5. These institutions emerged as the premier institutions conducting LADM-based research as defined here. The Delft University of Technology, the University of Twente and Universiti Teknologi Malaysia play a crucial role in the development and design of the LADM.

A limitation of this study is that it did not include the WoS database because the Scopus database is more comprehensive and reliable than the WoS database. After all, it indexes the journals with a high impact factor. Besides, these kinds of studies based on BA that analyses many publications could utilise more than one database, which might cause the problem that the same publication is included in more than one analysis. This study's original value and importance are that no other literature studies have made such a comprehensive BA.

6. Conclusions

At a crucial time for the LADM, during its revision process and several scientific publications since its vote as ISO standard, this bibliometric analysis provides an interesting background for the research carried out so far. Based on existing knowledge, covering an international context and considering publications in well-recognised research sources and proceedings in international events, this analysis attempts to determine the impact of the LADM on the land administration domain between 2012 and 2020.

Several academic studies have been done concerning the LADM after

2012. The studies show that the world has adopted the LADM after standardisation. Standardisation studies on land-based issues (such as cadastre, real estate valuation, planning) have significantly changed the traditional view on land administration (Polat, 2019) and encouraged various scientific studies dealing with the LADM from different perspectives. Many of these studies are focused on creating LADM profiles (Such as Malaysia, Turkey, Poland, Czech Republic, South Korea, Saudi Arabia, Israel) of the countries. These studies show that many countries want to have LADM-based land management as soon as possible.

The abundance of studies regarding using the LADM in valuation, coastal management, cadastre etc., draws attention. It is proof that the LADM has been developed in compliance with all aspects of land management.

References

Abejón, R., Pérez-Acebo, H., Garea, A., 2017. A bibliometric analysis of research on supported ionic liquid membranes during the 1995–2015 period: Study of the main applications and trending topics. Membranes 7, 63.

Bi, H., 2013. A bibliometric investigation of research trends on sulfate removal. Deslin. Water Treat. 52 (31–33), 6040–6049. https://doi.org/10.1080/19443994.2013.812991.

Butler, L., 2008. ICT assessment: Moving beyond journal outputs. Scientometrics 74 (1), 39–55.

Cobo, M.J., López-Herrera, A.G., Herrera-Viedma, E., Herrera, F., 2011. An Approach for Detecting, Quantifying, and Visualizing the Evolution of a Research Field: A Practical Application to the Fuzzy Sets Theory Field. J. Informetr. 5 (1), 146–166.

Chiu, W.T., Ho, Y.S., 2007. Bibliometric analysis of tsunami research. Scientometrics 73, 3–17.

Emrouznejad, A., Marra, M., 2017. The state of the art development of AHP (1979–2017): a literature review with a social network analysis. Int. J. Prod. Res. 55 (22), 6653–6675. https://doi.org/10.1080/00207543.2017.1334976.

Fonseca, B.P.F., Sampaio, R.B., Fonseca, M.V.A., Zicker, F., 2016. Co-authorship network analysis in health research: method and potential use. Health Res. Policy Syst. 14, 34.

Glänzel, W., Schlemmer, B., Schubert, A., Thijs, B., 2006. Proceedings literature as additional data source for bibliometric analysis. Scientometrics 68 (3), 457–473.

Goodchild, M.F., Glennon, J.A., 2010. Crowdsourcing geographic information for disaster response: A research frontier. Int. J. Digit. Earth 3, 231–241.

Goodrum, A., McCain, K., Lawrence, S., Giles, C.L., 2001. Scholarly publication in the Internet age: A citation analysis of computer science literature. Inf. Process. Manag. 57 (2), 661–675.

ISO, 2012. ISO 19152:2012. Geographic information – Land Administration Domain Model (LADM). International Organization for Standardization (ISO),, Geneva, Switzerland.

ISO, 2019. Final report from Stage 0 project on ISO 19152 LADM. ISO/TC211/WG7 N262. 2019-07-07. International Organization for Standardization (ISO),, Geneva, Switzerland.

ISO, 2020. . Minutes of project meeting 2020-11-24. ISO/TC 211/WG 7/PT 19150-6. International Organization for Standardization (ISO),, Geneva, Switzerland.

Kiraz, M., Demir, E., 2020. A Bibliometric Analysis of Publications on Spinal Cord Injury During 1980–2018. World Neurosurg. 136, e504–e513. https://doi.org/10.1016/j.wneu.2020.01.064.

Li, N., Han, R., Lua, X., 2018. Bibliometric analysis of research trends on solid waste reuse and recycling during 1992–2016. Resour., Conserv. Recycl. 130, 109–117.

Lisée, C., Larivière, V., Archambault, É., 2008. Conference proceedings as a source of information: A bibliometric analysis. J. Am. Soc. Inf. Sci. Technol. 59 (11), 1776–1784.

Mallawaarachchi, H., Sandanayake, Y., Karunasena, G., Liu, C., 2020. Unveiling the conceptual development of industrial symbiosis: Bibliometric analysis, 10 June 2020 J. Clean. Prod. 258, 120618. https://doi.org/10.1016/j.jclepro.2020.120618.

Niu, J., Tang, W., Xu, F., Zhou, X., Song, Y., 2016. Global research on artificial intelligence from 1990–2014: Spatially-explicit bibliometric analysis. ISPRS Int. J. Geo-Inf. 5, 66.

Oosterom, P., Lemmen, C., 2015. The Land Administration Domain Model (LADM): Motivation, standardisation, application and further development. Land Use Policy 49, 527–534.

Paulsson, J., Paasch, J.M., 2013. July 2013. 3D property research from a legal perspective. Computers, Environment and Urban Systems, special issue 3D Cadastres II, 40. Elsevier,, Amsterdam, pp. 7–13. July 2013.

Paulsson, J., Paasch, J.M., 2015. Land Administration Domain Model – A literature survey. Land Use Policy 49, 546–551. https://doi.org/10.1016/j.landusepol.2015.08.008.

Polat, Z.A., 2019. Evolution and future trends in global research on cadastre: A bibliometric analysis. GeoJournal 84, 1121–1134.

Polat, Z.A., Gürsoy Sürmeneli, H., Alkan, M., 2018. Bibliometric Analysis of Articles Presented Under Commission 7: a Case of the 25th Fig Congress in Malaysİa in 2014. FIG Congress 2018,, İstanbul, Turkey.

Şenel, E., Demir, E., 2018. Bibliometric and Scientometric Analysis of the Articles Published in the Journal of Religion and Health Between 1975 and 2016. J. Relig. Health 57, 1473–1482. https://doi.org/10.1007/s10943-017-0539-1.

Vain, P., 2007. Trends in GM crop, food and feed safety literatüre. Nat. Biotechnol. 25, 624–626.

Visser, M.S., Moed, H.F., 2005. Developing bibliometric indicators of research performance in computer science. In P. Ingwersen & B. Larsen (Eds.), Proceedings of the 10th International Conference of the International Society for Scientometrics and Informetrics (pp. 275–279). Stockholm: Karolinska University Press.

Zhang, H., Huang, M., Qing, X., Li, G., Tian, C., 2017. Bibliometric analysis on global remote sensing research during 2010–2015. ISPRS Int. J. Geo-Inf. 6, 332.

Zyoud, S.H.H., Fuchs-Hanusch, D., Zyoud, S.H., Al-Rawajfeh, A.E., Shaheen, H.Q., 2017. A bibliometric-based evaluation on environmental research in the Arab world. Int. J. Environ. Sci. Technol. 14, 689–706.