

Bibliometric Analysis of the Use of UAVs in Urban Area Cadastre

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Keywords: Remotely piloted aircraft, unmanned aerial vehicle, multipurpose cadastre, bibliometric review.

SUMMARY

With the technological advancement of Unmanned Aerial Vehicle (UAV), new applications are being incorporated into municipal dynamics for territorial management. Uses such as monitoring irregular settlements and inspecting construction sites have become commonplace for bodies responsible for territorial management. However, the utility of UAVs for planning and cadastral updating purposes is increasingly significant. The multipurpose cadastre is the official record of a municipality's land parcels, requiring periodic updates of parcel boundaries, primarily for fiscal purposes, to ensure fair tax collection. Given the growing interest in UAVs applications and the constant need for updated territorial information, this study conducts a systematic bibliometric review to better understand the relationship and contributions of UAVs to the qualification of the territorial cadastre. The Scopus database was used as the primary data source, and bibliometric analysis was performed using VOSviewer and Bibliometrix software. The search, conducted in April 2025, targeted documents until 2024. The bibliometric analysis of 140 results demonstrates a significant increase in publications over the last decade, with 2023 and 2024 having the highest number (18 and 22, respectively). China (21), Germany (13), the USA (10), the Netherlands (9), and Italy (9) were the most productive countries. A qualitative analysis of 13 key publications highlights the evolution from technical validation and accuracy comparisons with traditional methods towards practical applications in land rights registration, disaster response, tax inspection, and 3D cadastre. While most academic works recognize the relationship between UAV use and cadastral improvement, few delve into the challenges of integrating this data with pre-existing legal systems, the long-term sustainability of UAV-based programs, or the direct benefits for territorial governance and local populations.

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1. INTRODUCTION

Land management faces challenges associated with urban growth and informal settlements, demanding agile and effective measures from decision-makers. Technological advancements related to the use of Unmanned Aerial Vehicle (UAV) bring new application possibilities that can be integrated into municipal organization.

Maintaining an updated territorial information base is a minimum requirement for public administration. The multipurpose cadastre is the primary instrument supporting land management and planning, defined as the official and systematic inventory of municipal parcels (Silva, Erba and Silva, 2023). The spatial representation of land parcels is fundamental for establishing the multipurpose nature of the cadastre. Consolidating this information into a geospatial database allows managers to implement resource management practices and serves as a basis for financing public policies. Its "multipurpose" character stems from combining data from various sources linked to the parcel base, forming thematic cadastres. This approach aligns with the guidelines established by Brazilian Ordinance No. 3.242/2022, which directs the structuring of the multipurpose cadastre (Brasil, 2022).

Using UAVs for cadastral surveys offers technical and economic advantages over traditional methods, such as manned surveys and orbital imagery (Antunes and Hollatz, 2015). An UAV can cover urban areas in a short period, making the cadastral update process more agile. In terms of accuracy, when produced with ground control points, they can achieve centimetric precision, suitable for generating cadastral maps at larger scales. Furthermore, the operational flexibility of UAVs allows for the mapping of hard-to-access areas, such as informal settlements or risk areas (Neckel et al., 2021). Given this context, it is important to investigate how the scientific community has been addressing this theme. Therefore, this study adopts bibliometric analysis as its method.

Bibliometrics is a method that uses quantitative and statistical techniques to measure scientific production in a field of knowledge. Ball (2017) defines it as a methodology used to quantify scientific production through statistical techniques. This analysis allows for mapping the structure and evolution of a research field through objective indicators such as identifying research trends, mapping collaboration networks, analyzing publications through citations, and identifying the most relevant journals (Ferreira; Valdati, 2023). Thus, the objective of this work is to conduct a bibliometric analysis of the scientific production on the use of Unmanned Aerial Vehicles applied to the cadastre of urban areas, to identify its temporal evolution.

2. MATERIALS AND METHODS

This study uses bibliometric analysis as a methodological procedure for an exploratory and descriptive analysis with a quantitative approach. The Scopus database was selected as the primary source for collecting bibliographic data. This choice is justified by its broad coverage of peer-reviewed scientific literature across various fields of knowledge, as well as its metadata export functionalities, which are compatible with bibliometric analysis software.

The search was conducted in April 2025, with a temporal cutoff defined until the year 2024. The search strategy was designed to encompass publications containing terms related to unmanned aerial vehicles and urban cadastres in the title, abstract, and keyword fields (TITLE-ABS-KEY). The search expression used was:

TITLE-ABS-KEY ((cadast* OR regist*) AND (urban)) AND (uav OR rpa) AND
PUBYEAR < 2025

The terms UAV (Unmanned Aerial Vehicle) and RPA (Remotely Piloted Aircraft) were selected to represent the technology used for the cadastre. The terms "cadast" and "regist", using the asterisk "*", were used to include variations of words related to the theme (e.g., cadaster, cadastre, cadastral, register, registral), combined with the term "urban". The Boolean operators AND and OR were employed to refine and delimit the search results.

This Scopus search resulted in an initial set of 140 documents. For each of these documents, complete bibliographic records were exported, containing information such as title, authors, institutional affiliations, abstract, keywords, year of publication, and cited references. The data were exported in a format compatible with the analysis software (BibTeX and CSV), with no additional filters applied for document type, words, or languages, to obtain a comprehensive overview of scientific production.

Data analysis was structured along two main fronts: performance analysis and science mapping. Performance analysis focused on measuring scientific production through indicators such as the number of publications per year, the productivity of authors, countries, and institutions, and the identification of the most cited articles. Science mapping, in turn, aimed to visualize the intellectual structure of the research field by creating maps of co-authorship networks, keyword co-occurrence, and citations (Freire; Da Silva; Espíndola, 2022).

To perform the analyses and generate graphical visualizations, the software VOSviewer and the bibliometrix package in RStudio were used. These software tools are employed in bibliometric studies for their ability to process large volumes of data and generate visual representations.

3. RESULTS

The results cover the period from 2004 to 2024, with an average annual growth rate of 16.71%. There was a small variation in the number of publications between 2004 and 2012; only in 2013 did the number of works exceed five publications. From 2014 onwards, the number began to

increase significantly and has maintained continuous growth since 2021 (Fig. 1). Among the 140 publications, there are 64 Conference Papers, 51 Articles, 21 Conference Reviews, 2 Book Chapters, 1 Editorial, and 1 Review. Conference papers are the most numerous in this search subset (45.7%), while journal articles rank second, with 36.4% of publications.

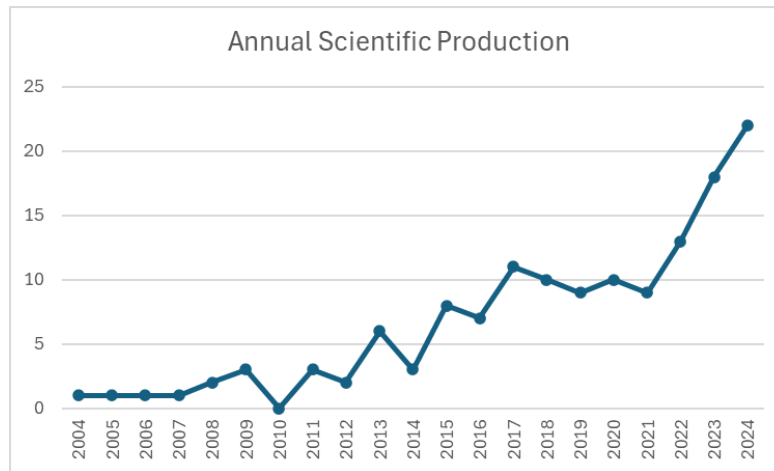


Figure 1. Number of publications per year

Publications are distributed across 16 different areas according to the Scopus classification. The main ones are: Computer Science (77 publications, 24.1%), Engineering (53 publications, 16.6%), Earth and Planetary Sciences (39 publications, 12.2%), Social Sciences (32 publications, 10%), and Physics and Astronomy (28 publications, 8.8%). Environmental Science, Materials Science, and Mathematics presented less significant numbers. It is noteworthy that each document can be listed in more than one area (Fig. 2).

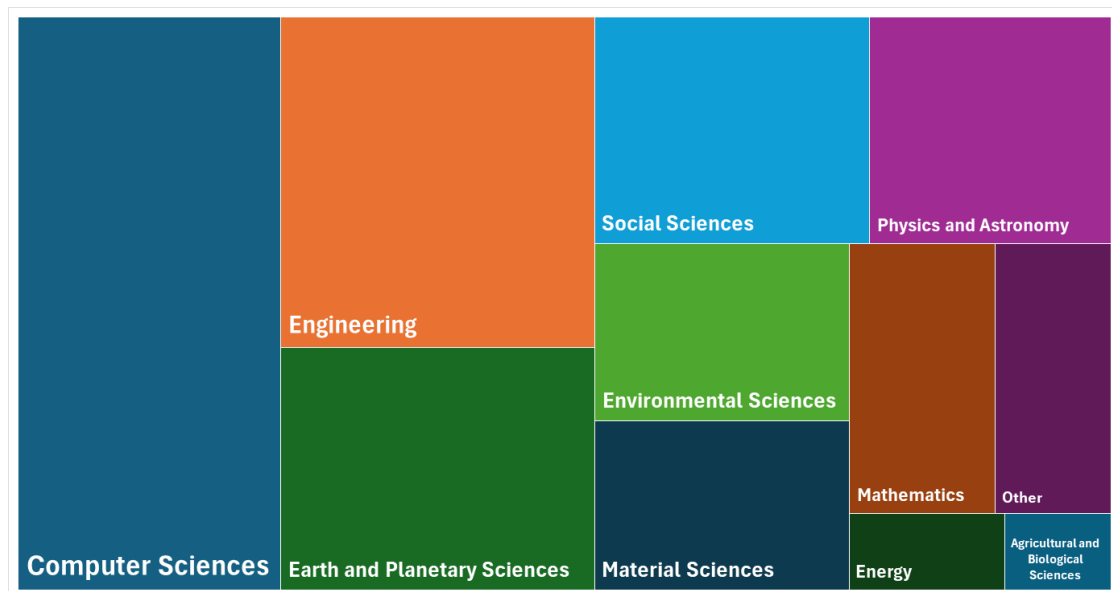


Figure 2. Publications per area.

These publications are associated with 63 different sources. The *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives* stands out with the highest number of publications (20 documents). Others include *Proceedings of SPIE - The International Society for Optical Engineering* with 12 publications, *Remote Sensing* with 11 publications, and *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences* with 5 publications. *Advances in Science, Technology and Innovation* and *IOP Conference Series: Earth and Environmental Science* each have 4 publications. The main sources are proceedings or archives, such as those related to *Photogrammetry, Remote Sensing and Spatial Information Sciences*, which contain a large number of papers and expanded abstracts from various events on the theme.

The document set has a total of 452 authors from 46 different nationalities (Fig. 3). The top five nationalities are Chinese, German, and Italian. In contrast, the analysis of academic production by affiliation reveals a distribution among various research institutions and universities that does not directly correspond to the authors' origins (Fig. 4). The most prominent is *Sofia University St. Kliment Ohridski* (Bulgaria) with 11 publications, followed by the *Fraunhofer Institute for Optronics* (Germany) with 9 documents. Institutions such as the *University of Calgary* (Canada) and the *University of Twente* (Netherlands) also feature, both with 8 publications.

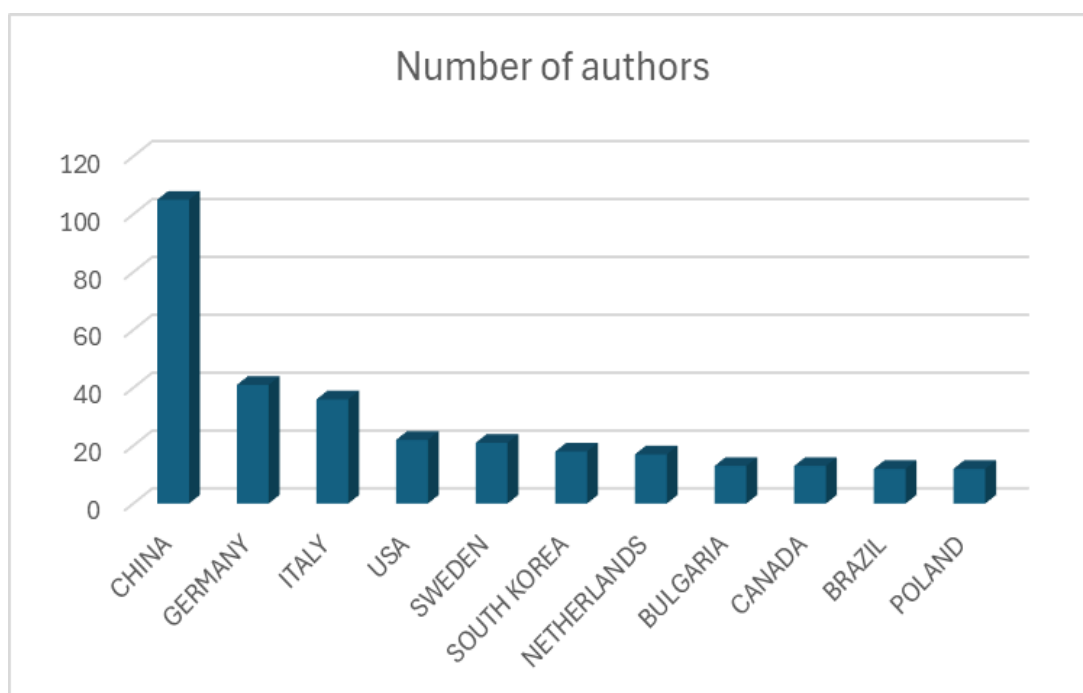


Figure 3. Number of authors by country.

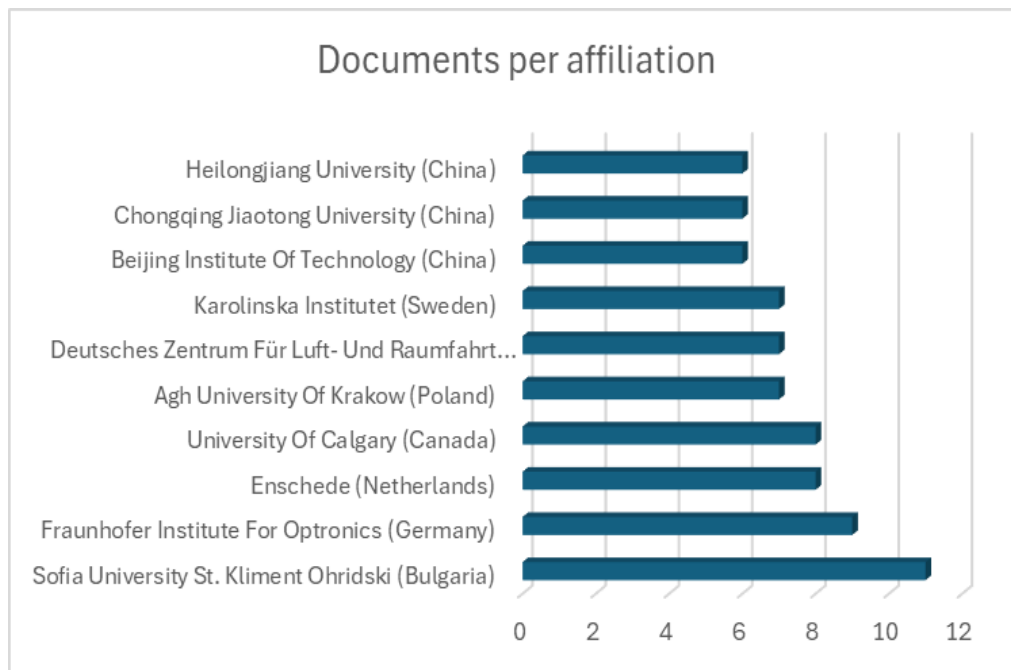


Figure 4. Number of publications by institution and country.

The most cited publications globally are: "Multi-Temporal Remote Sensing Image Registration Using Deep Convolutional Features" (Yang; Dan; Yang, 2018) and "Benchmark For Multi-Platform Photogrammetry" (Nex et al., 2015). The first is a journal article and the second a conference paper, both with over 150 citations. There are 8 documents with more than 50 citations globally (Fig. 5), all published from 2014 onwards. However, at the local level (within the dataset), there are no reciprocal citations, meaning the works do not cite each other.

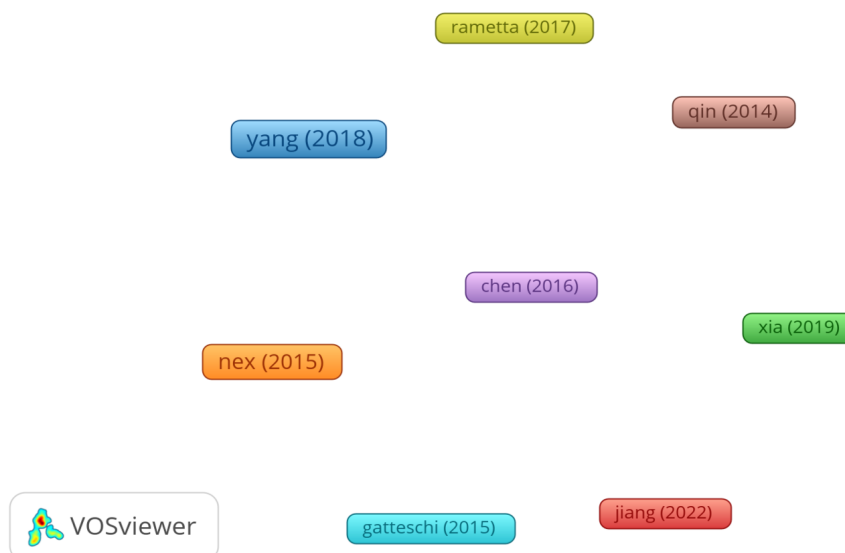


Figure 5. Most globally cited publications in the Scopus database.

Meanwhile, the most cited references locally are "A Method For Registration Of 3-D Shapes" (Besl; McKay, 1992); "Speeded-Up Robust Features (SURF)" (Bay et al., 2008) and "Random Sample Consensus: A Paradigm For Model Fitting With Applications To Image Analysis And Automated Cartography" (Fischler; Bolles, 1981). These articles are also prominent in co-citation, especially the first one, which is the central point dividing the two clusters (Fig. 6).

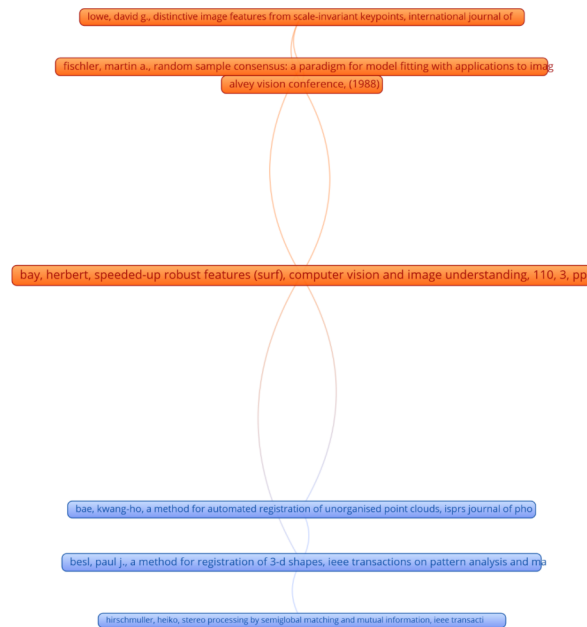


Figure 6. Bibliographic coupling.

The keyword map of the results highlights the recurrence of some terms associated with 4 clusters (Fig. 7). The term "unmanned aerial vehicles (UAV)" is the central term with 94 occurrences and is linked to all clusters, demonstrating that UAV technology is indeed connected to the entire set of publications. The term "antennas" (37 occurrences) appears second, linked to research on communication and data transmission and the use of UAVs.

The terms "remote sensing" (28 occurrences) and "photogrammetry" (27 occurrences) show the strong integration of unmanned aerial platforms with remote sensing and photogrammetry techniques, fundamental for acquiring and processing spatial data. Also notable are "mapping" (22 occurrences) and "image registration" (17 occurrences), indicating the relevance of cartographic applications and image alignment for spatial analyses. Other important terms are "three dimensional computer graphics" and "urban planning", each with 13 occurrences, suggesting a connection between the use of UAVs, 3D modeling, and urban planning.

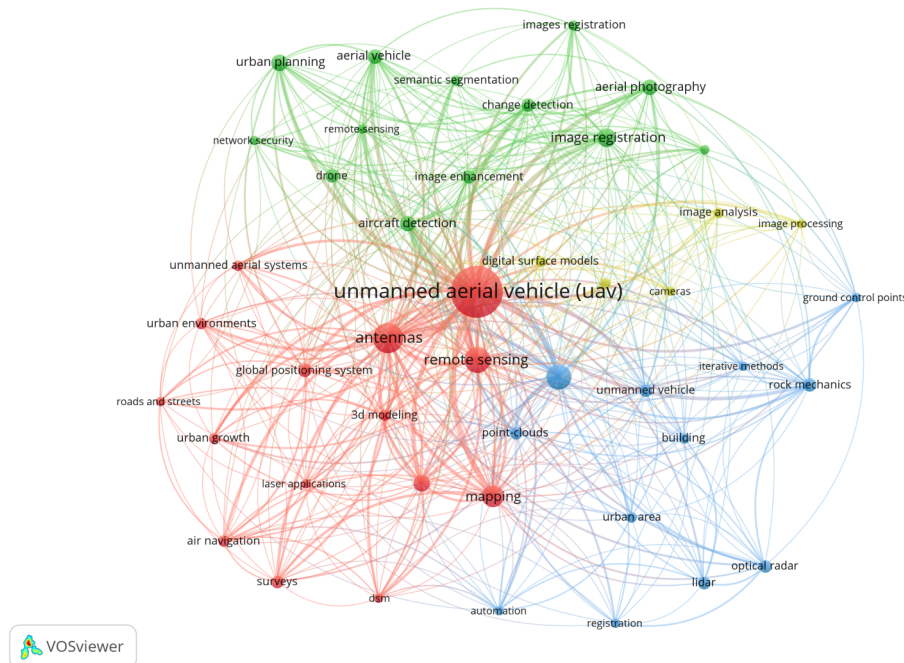


Figure 7. All keywords map

There are 45 words on the map (Fig. 7) with 5 occurrences or more. In this context, the terms "urban cadastre" or "urban registration" are not highlighted, although terms like "urban growth," "urban environments," "urban planning," and "urban area" do occur. The term "registration" (blue cluster) has 15 connections but is mainly linked to photogrammetry and associated equipment. In general, the works with the highest number of citations in the research have a technical focus, geared towards comparing methodologies and applications using high-resolution images from UAVs. Twenty-two publications had an emphasis on cadastre. Their abstracts were reviewed, and 13 that were more prominent on the theme were selected. These works are concentrated between 2016 and 2024, and a brief qualitative analysis is conducted below.

Chandrarathne (2016) is one of the first works aiming to compare cadastral surveys done with high-resolution UAV images and those done with a total station, produced in Sri Lanka. The comparison showed good potential for use in cadastral surveying. For this, various attributes derived from the parcels, such as area and position, were produced. The comparisons show that about 70% of parcel boundaries can be derived with acceptable accuracy and precision, meeting cadastral survey standards. The author indicates that using data from UAVs results in a faster update of cadastral maps in a more economical and convenient manner.

Márquez and Soto (2017) emphasize the importance of the level of detail found in aerial surveys with UAVs and present an application of stereoscopic restitution at a 1/1000 scale carried out in an urban/rural locality in southern Chile. This work used a fixed-wing UAV (Mavinci Sirius Pro, Topcon) aiming to produce cadastral plans, applying additional terrain pattern recognition algorithms.

Also in 2017, the work "*Towards innovative geospatial tools for fit-for-purpose land rights mapping*" by Koeva *et al.* (2017) was published in the *ISPRS Geospatial Week 2017* archives. The expanded abstract deals with a case study, mapping a large area of Sub-Saharan Africa with the objective of recognizing land rights using innovative technologies, part of the *its4land* project, from the European Commission's Horizon 2020 program. This project aims to develop tools inspired by the *continuum* of land rights and land management. The innovation process incorporates emerging geospatial technologies, such as smart sketches, UAVs, automated feature extraction, as well as geocloud services.

In this same line of cadastral surveying, Viñuales, Sleive, and Chalabe (2019) have a case study and the results achieved in an urban area in the Quebrada de Humahuaca, Argentina. A site certified as a UNESCO World Heritage Site, which was affected by a landslide and floods in January 2017. Precise and rapid action was needed to start reconstruction works of houses that had to be demolished due to a high degree of degradation. For this, a general update of the Cadastral Records of the city was necessary, which were analyzed individually based on the information collected for the elaboration of the Cadastral Map. The work describes each phase of the survey and application using a UAV.

Barbosa *et al.* (2020) present the application of using UAVs and terrestrial surveys to capture spherical images to obtain information about building facades, road conditions, signage, and public lighting assets, among others, in a neighborhood of the municipality of Monte Carmelo, state of Minas Gerais, southeastern Brazil. From orthophotos, the lots and buildings were vectorized, and then, with the integration of position and orientation data from the mobile mapping system, the facade photos were georeferenced to the respective lots. This procedure allowed the municipality to update the cartographic base and also for the inspection of the property tax.

Koeva, Bennett, and Persello (2022) list studies that integrate updated methods of land administration in cadastre and land registration, aiming for management aligned with the United Nations (UN) objectives of ensuring land tenure. They highlight advances in remote sensing and geoinformation, especially with UAVs, satellites, and LiDAR, to provide high-resolution data. Techniques of Artificial Intelligence, spatial statistics, and machine learning are examples of methods for change detection and automatic feature extraction, applied in projects in the field of land administration.

Works such as Tan *et al.* (2022), Tian *et al.* (2023), Naimaee, Saadatseresht and Omidalizarandi (2023) and Chu *et al.* (2023) demonstrate the current focus of UAV survey technologies on 3D Cadastre and point cloud classification, denoting an advancement of the application of the aircraft from the two-dimensional to the three-dimensional level.

Applications in the territorial cadastre are still being developed based not only on traditional orthoimages but also on oblique photos. The case of Oniga *et al.* (2023) evaluates the performance of a low-cost UAV system (DJI Phantom 4 Pro v2) equipped with a PPK GNSS module for cadastral purposes, where two types of flight were used, oblique and nadiral, over a

residential area with about 100 ground control points to calculate accuracy and Root Mean Square Error (RMSE). Comparisons were made between the process assisted by GNSS with PPK processing and the indirect georeferencing process. The comparison was based on a point cloud from a mobile laser scanner (MLS) and the UAV point clouds with manually digitized features. According to the authors, both surveys proved effective, but the aerial survey was more effective for reaching points with sighting restrictions.

Chiciudean *et al.* (2024) propose an automated method for detecting changes in maps at the building level by integrating cadastral maps with low-altitude aerial images to identify discrepancies between reference maps and captured images using images obtained by UAVs and OpenStreetMap cadastral maps. Using automatic analytical techniques, the results achieved high localization accuracy, both in terms of position and camera orientation.

Finally, Taiwo *et al.* (2024) use UAVs for a study that examines the factors influencing the adoption of UAVs for land administration in Nigeria, mapping seven rural, peri-urban, and urban sites with orthomosaics. The research demonstrated effectiveness in surveying and that physical demarcations facilitated cadastral mapping. The main implications include promoting awareness of settlement typology and addressing the regulatory challenges of UAVs.

4. DISCUSSION

The territorial cadastre aims to provide information capable of contributing to land management. Its applications range from understanding the inhabited space to municipal cartography, taxation, and spatial planning (Silva, Erba and Silva, 2023). Therefore, having data integrated with different themes, such as urban properties, green areas, tax data, and public spaces, among others, contributes to the knowledge of the municipality and, especially, where there is a need for intervention by public managers. In this context, UAVs become important data collection tools for the analysis, planning, and management of urban space.

The works found in this search reflect the popularization of UAVs, which was driven by the availability of affordable equipment for the technology market. According to Colomina and Molina (2014), their application expanded beyond the military field. For example, DJI (Da-Jiang Innovations Science and Technology), a Chinese company founded in 2006, revolutionized access to quadcopter flight equipment and has consolidated itself as the global sales leader for commercial and recreational UAVs to this day. The graphical analysis of the number of publications indicates growth in works using the term UAV from 2013 and 2014 onwards, which may be associated with the creation of the first "Ready to Fly" UAV, the DJI Phantom 1, a remotely piloted aircraft that, from a radio control and a camera, was capable of flying up to 300m away and had a flight autonomy of up to 10 minutes.

Prior to the creation of domestic UAVs, flights for aerial surveys were done using manned aircraft embarked with technicians and large image capture sensors, which meant high operational costs and long-term planning. Currently, professional UAVs have an autonomy of more than 1 hour of flight, are ready within minutes to start a survey that can be done from a

control base more than 10 km away, with good coverage and with autonomous or remote control options, depending on the work execution needs.

In the search, the Scopus database records the first publication in 2004, and they generally increase from 2014. However, analysis of the specific publications shows that the use of UAVs in urban cadastre grows from 2016. Applications of UAVs were observed in the sense of innovation in the territorial cadastre or land registration, and in this period from 2016 to 2024, the advancement of equipment in the cadastre is evident, with the use of PPK GNSS, and the inclusion of new techniques, such as 3D Cadastre and Artificial Intelligence.

Furthermore, most specific works are case studies and partial results of projects in less developed countries, where there is a need for cartographic material for cadastre and management, especially for urban areas. Therefore, UAVs become low-cost solutions with the potential to be applied in different contexts.

5. CONCLUSION

The analysis of the 140 documents from the Scopus database confirms that the theme of UAVs in urban cadastre is still growing. The publication period of the works reflects a timeframe coinciding with the popularization of low-cost UAVs, which increased access to the technology. The most recent publications still express the continuous advancement and inclusion of new technologies. The analysis of keywords and articles reveals a trend towards point cloud cadastre and the automation of processes through Artificial Intelligence and Machine Learning. This places UAVs as a central tool in workflows and land management.

Initially, the works were focused on technical validation and accuracy comparison with traditional methods, such as total stations, aiming to approve the feasibility of UAVs as a cadastral tool. Research advanced to practical applications, addressing themes such as land rights registration, response to natural disasters, tax inspection (property tax), and urban planning in different contexts, including developing countries.

Despite the advancement, the analysis also points to a geographical concentration of scientific production, with China and European countries leading the publications. In this sense, encouraging experiments and research in different contexts is important for enriching the discussion of the potential and limitations of using UAVs for cadastre. This research used a single database, Scopus, and future analyses could encompass other databases, where it may be possible to find new case studies.

It is concluded, therefore, that UAVs have established themselves as tools for the modernization of territorial cadastres. Future directions point towards a more dynamic, three-dimensional, and automated cadastre, in which UAVs, integrated with other geospatial technologies, will play an important role in promoting efficient urban management.

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BIOGRAPHICAL NOTES

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