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Article

Mobile Cadastral Application with Open-Source Software in Colombia

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Abstract: This article presents social research, conducted through interviews with experts involved in land administration in Colombia, on the possibility of using the Fit-For-Purpose methodology, combined with indirect methods, to accelerate the capture of cadastral data. The experts were asked about the design of a data capture system, using a mobile application, to acquire data on properties and their approximate coordinates, as well as the data of their owners, where the owners themselves are the ones who declare these data. A functional prototype has also been developed and tested in Spain. Results: The design is well received, understood as a declaration by owners, especially in rural areas; further processing of the information by technicians of the competent authority is necessary; involving the population has a positive impact on the perception that owners have regarding cadastral processes; some technical and training challenges must be taken into account, to ensure consistency and quality in the data collected; and the prototype tests demonstrate, due to the low GPS accuracy of mobile phones, that the identification of boundaries over a base map is possible in properties of one hectare or more.

Keywords: cadastre; land administration; fit for purpose; free software; app; crowdsourcing; social research; LADM

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1. Introduction

Land ownership in Latin America has been a decisive issue of inequality and conflict throughout history, with a global rise in land tenure insecurity [1]. In the context of countries experiencing prolonged internal strife, Colombia has played a significant historical role with the signing of the 2016 "Acuerdo de Paz" [2], which ended more than five decades of armed conflict. This agreement has improved stability and reduced violence in rural areas. Some studies [3] examine how significantly the agreement influenced the restoration of basic services and the implementation of transitional justice in these regions.

One key aspect of this restoration is its impact on land ownership, as the agreement recognises land redistribution as a crucial measure to reduce agrarian tensions that fuelled the conflict for so many years. Among the measures implemented, there were mechanisms for the formalisation of land ownership in rural areas, a pressing issue affecting millions of people lacking legal titles [4,5]. However, this implementation has faced several challenges, such as disputes over land control and a lack of resources to execute the measures effectively [6].

Recent research [7,8] on the formalisation of rural property in Colombia highlights the importance of addressing the high percentage of lack of land tenure formalisation, which in 2019 reached 52% of rural areas in the country. This lack of formal titles has limited access to credit, reduced agricultural investment, and perpetuated rural poverty. Although significant efforts have been made in terms of regulations, the implementation of the legal models applied in the formalisation of land that has not been awarded to any private individual and belongs to the state has been limited due to several obstacles. Some of these obstacles are the lack of resources, the precariousness of the services associated with the cadastre and land registration, the low demand for titles by land holders, and conflicts related to ownership [8].

Land formalisation is crucial to addressing land tenure in areas where the majority of the rural population lacks ownership titles [4,5,9]. Processes such as the one discussed in Colombia have occurred in other parts of the world [10]. One such process [11] has occurred in Indonesia with the PaLaR (PaRticipatory Land Administration Registration) method. This method takes a participatory approach to land titling. It actively involves locals in the collection of spatial data, and associated legal data, using mobile applications and simplified systems. Its main advantage lies in its ability to adapt to local conditions and its low cost. Another participatory process is taking place in Greece, where the implementation of the Hellenic Cadastre incorporates the initial phase of data collection with the aim of making it faster, more efficient, and more complete with the help of open-source software [12–15]. This is also the case in the Republic of Benin in West Africa, where a few parcels have been registered. To remedy this anomaly, a land information system based on the Land Administration Domain Model (LADM) is designed to include and track cadastral parcels [16]. In the case of the Republic of South Africa, there is a huge amount of land occupation without land tenure, and proposals for land regularisation are being formulated [17], similar to Malaysia, where the Department of Surveying and Mapping is developing an interactive portal (SmartKadaster) to provide a platform to manage cadastral topographic information [18].

In this specific case of Colombia, with the idea of speeding up and improving the process of formalisation and restitution of rural land, the research carried out with the MetaTierras project [19] is proposed for this study as a cooperation initiative between the Universitat Politècnica de València (UPV) [20] and the non-profit organisation Fundación Forjando Futuros (FFF) [21]. The aim is a methodological proposal for the diagnosis and design of tools for land management in Colombia. After a bibliographic and normative study of the situation in the country, and in view of the existing needs, the main objective of this study is to design a tool capable of helping to resolve the possible difficulties in the process. One part of the design, a mobile application, is developed. The app allows the collection of cadastral data, such as boundaries and coordinates of the properties, as well as information on owners and documents related to the land. This is the starting material for the delimitation and registration of land by citizens, with subsequent processing by the competent authority. This approach aligns with the Fit-For-Purpose concept: using affordable modern technology, this is a participatory approach to identifying and incrementally augmenting the amount and accuracy of data [22]. The application must be accessible, which is why it is designed with free software. The FFP approach, and the use of open-source software technologies, has the potential to boost cadastral processes. Nevertheless, some technical and capacity-building challenges remain in ensuring consistency and quality in the collected data [23]. One of the keys of FFP is to improve the data progressively; geographic metadata are essential for this. Geographic metadata allow us to know where, when, who, how, and with what accuracy a geometry has been obtained. These metadata are necessary to know which is the best version of the geometry of a property, and whether the coordinates of this geometry are valid for a given use [24,25].

Social research methods have been applied to validate the usefulness of the MetaTierras design and propose improvements. Some other examples of social research applied to land administration can be found in [26–33].

2. Methodology

The research methodology is summarised in the following sections:

- Study of the current situation in the country, based on background information, examining existing data and collecting additional related information. Simultaneously, a bibliographic study is conducted, including national and international references, as well as a review of existing regulations in Colombia.
- Needs assessment and initial application design proposal.
- Qualitative social research, involving consultations with experts. Improvements are proposed throughout the design and development process.
- Architectural design and prototype development.
- Initial testing, with field trials conducted in Spain.
- Results and discussion.
- Conclusions.

2.1. Background—Initial Information, Collected Data, and Bibliographic Study

The research begins with a study of the current situation in the country based on background information, supported by the Fundación Forjando Futuros (FFF) [21] and the prior experience of the research team in Colombia [24,34]. Existing baseline data are analysed, and the main organisations involved in land tenure processes are identified, including the Agustín Codazzi Geographic Institute (IGAC) [35], the National Land Agency (ANT) [36], and the Superintendence of Notaries and Registries (SNR) [37]. Using this information, a brief comparative analysis is conducted between the Colombian and Spanish contexts for a better understanding of the situation [4].

A bibliographic study is carried out to explore various solutions implemented in other projects, both in Colombia [38,39]. Among the international cooperation projects in Colombia, noteworthy examples include the Netherlands' Land in Peace project [40–45] and Switzerland's SwissTierras project [46–48]. Additionally, existing regulations in Colombia are reviewed to identify applicable rules for the proposed design. Key regulations include the following:

- CONPES 3859 of 2016: policy for the adoption and implementation of a multi-purpose rural–urban cadastre [49].
- CONPES 3958 of 2019: strategy for implementing the public policy on multi-purpose cadastres [50].
- Joint Resolution SNR N° 04218 and IGAC N° 499 of 2020: adoption of the Extended Cadastre-Registry Model of LADM_COL [51].
- Decree 148 of 2020: partial regulation of Articles 79, 80, 81, and 82 of Law 1955 of 2019, and partial modification of Title 2, Part 2, Book 2 of Decree 1170 of 2015 [52].

This decree, in Article 2.2.2.2.6, outlines permitted methodologies for collecting information on cadastral processes. These include direct, indirect, declarative, and collaborative methods, providing a wide range of possibilities for data capture.

Following this initial background study, two important concepts emerge in the international context, which are closely linked to the collaborative initiative being undertaken:

- Crowdsourcing: Crowdsourcing [53] refers to the practice of obtaining ideas, services, or work through the collaboration of a large group of people, often via the Internet [11,12]. This methodology is widely used across various fields, particularly in government and citizen participation functions, where websites or applications are employed to engage citizens in the creation of public policies, or the resolution of social problems [54,55]. Today, crowdsourcing has become a key tool in numerous sectors, leveraging collective knowledge and community skills to solve problems, innovate, or create [14].

- Fit-for-Purpose (FFP): The Fit-for-Purpose concept is used across various fields to describe systems or solutions, designed or adapted specifically to meet their intended purpose effectively [56]. In engineering, a Fit-for-Purpose system, or product, meets necessary requirements without excessive complexity or cost, maintaining a balance between quality, efficiency, and price [57–60]. In legislation, it refers to rules or regulations tailored to specific circumstances to achieve objectives without unnecessary restrictions. In project management, it denotes whether projects meet their objectives in terms of quality, timelines, and resources [18]. Specifically, in land administration and territorial planning, Fit-for-Purpose refers to systems that are efficient, accessible, and suitable for local needs, even if they do not meet advanced technical standards [61–63]. This approach is widely adopted in developing countries to formalise land ownership quickly and affordably [9,11,12,16,17,28,57,64].

The MetaTierras project [65] is based on these two concepts as a cooperation initiative. It seeks to involve individuals in land formalisation processes while developing a simple, low-cost, and accessible mobile application to collect cadastral data. These data serve as the basis for property registration by the competent authority.

2.2. Needs Assesment and Design Proposal

Colombia has exhaustive land registry regulations. However, a previous study revealed that there are few accessible tools for citizens, even for technicians, to capture cadastral data and speed up land regularisation processes. Added to this is the difficulty of access to many areas due to orography and security.

To try to speed up data capture, after several meetings with technicians from the FFF [65], it was considered that the fastest way to obtain the geometries of rural properties, while complying with official metric quality requirements for cadastral surveys, was to do so by indirect methods, i.e., by digitising sufficiently precise cartography, for example, by means of orthophotos obtained with drones [66]. But for this to happen, it is necessary for the landowners to declare the boundaries of their land. For this statement, the idea was to create a mobile app, by means of which it would be easy for owners to walk along the boundaries of their plots, capturing the GPS coordinates and forming an approximate polygon of the property. Once the technicians have received the data of the property and its owners, they can locate the boundaries on sufficiently precise cartography, digitise them, and then initiate the regularisation file. With respect to the methodology permitted for the collection of information on cadastral processes in Colombia, this design is permitted; however, to corroborate its usefulness in the Colombian context, social research was subsequently applied, which will be discussed in the following Section 2.3.

It should be noted that, to make the declaration of boundaries accessible by means of field measurement by landowners in an economical, fast, and generalised way, there is a price to pay, which is the low accuracy of the GPS of smartphones or tablets. Current Colombian regulations do not allow such low precision, but the objective is not to delimit with the GPS of the mobile phone, but to identify the boundaries with a declarative and collaborative method. If the identification of boundaries on a precise base map is not possible, because the GPS offers a very low precision, there is too much vegetation that hides them, or there is no visible division on the ground, other means must be used to obtain the coordinates of the boundary adequately. Private companies offer a professional GPS antenna that can be attached to smartphones. These antennas can receive RTX corrections transmitted by satellite. This system can improve smartphone accuracy in Colombia by allowing it to be below 0.5 m. The antenna cost is about USD2700, and the RTX satellite correction service costs about USD700 per year. This solution can be used occasionally when the native smartphone accuracy is not enough to identify the property boundaries.

The objective of the system is twofold: on the one hand, to increase the speed of data acquisition, avoiding field visits, and on the other hand, to involve the community in the delimitation of their properties.

2.3. Qualitative Social Research

In order to validate the usefulness of a free mobile app for the collection of declarative boundary data by citizens, as well as owners and property data, qualitative social research is carried out. This research is based on several semi-structured interviews and a focus group. The interviews were conducted during the month of July 2024, and were carried out with the aim of capturing the perspective and opinion of professional experts in the administration of the Colombian territory in a cartographic environment. Some other studies, related to territorial administration, and where the interview technique has been used, are [28,32]. Respondents were asked about the feasibility, benefits, and challenges of implementing new technologies and innovative methodologies for the formalisation of land tenure in Colombia. They were also asked about the design of the MetaTierras project's proposal for data acquisition on rural properties using smartphones. Based on this information, a detailed report has been produced in Spanish, which can be found attached as Supplementary Material and on the CCASAT website.

The interviews were designed to capture the experts' perspective on 4 main questions, divided into two parts, called A and B, with 7 questions each. Part A asks general questions about the implementation of methodologies based on the FFP concept, the use of technologies based on free software solutions, and the regulatory feasibility of adopting data collection tools. Part B asks about the feasibility, in particular, of the design of the proposed technological tool.

The selection of participants for this activity was made in such a way as to ensure the relevance and depth of the responses obtained, with inclusion and exclusion criteria, such as professional experience, thematic relevance, and sectoral variety in a cartographic environment. The group includes professionals of different academic levels with proven experience in land administration-related work. The respondents have basic legal, economic, topographic, cadastral, and informatics knowledge, each one being an expert in their own discipline. The respondents also belong to the private, educational, and public sectors. This variety of profiles makes it possible to address technical, social, political, and environmental aspects.

The interviews were conducted online via the Teams platform for about 90 min. All of the participants were contacted beforehand to agree on a date and time, as well as to provide further details about the interview. The full information submitted can be found in the Supplementary Material. The data, arguments, and discussions are compiled and analysed using the technique of thematic content analysis to find patterns and recurring arguments in the responses. The publication of the results is anonymous; however, as shown in Table 1, a list of the corresponding names, positions, and experience of the participants is included.

Table 1. List of interviewees, in alphabetical order by name. Source: own elaboration.

Name	Surname	Position	LA Experience in Colombia (Years)
Adriana Marcela	Muñoz Vásquez	National Land Environment Commissioner	24
Diego	Carrero Barón	IGAC Deputy Director General	9
Gerardo	Vega	Land Claim Defender	32
Jaime Alberto	Duarte Castro	Coordinator of the Aqueduct and Sewage Cadastre of Panama	20
José Agustín	Wilches Gómez	President of the Colombian Chamber of Topography, and Entrepreneur	30
Leonardo	Cardona	Colombian Consulting and Engineering (Company)	7
Luz Angela	Rocha	Researcher and lecturer in the Universidad Distrital Francisco José de Caldas [67]	22
Oscar	Mahecha	Legal representative of the Oversight Office of the Colombian Chamber of Topography	30
Ruth Elena	Acuña	President of the Permanent Technical Commission of Geomatics of the Colombian Society of Engineers	30
Wilson	Pérez	National Land Environment Commissioner	12

Socio-Demographic Characteristics, Previous Experiences, and Knowledge

Considering the objective of the research, and the target population of the interviews, a suitable number of interviews was between five and ten. In the case of focus group research, the number of participants should be between four and eight people. In this case, the saturation of information was also taken into account. The group of interviewees included a total of 10 persons, approached in 2 different ways: 5 were interviewed individually, and 5 were interviewed in focus group mode. The focus group discussion specifically involved five technical cartography specialists. The participants are professionals in the field of land administration (LA) and cadastral management systems in Colombia, ranging in age from 35 to 67 years, with an average age of 56.3 years, and a gender distribution of 7 men and 3 women.

In terms of educational level, all participants are university graduates, 1 in law, 3 in cadastral engineering and geodesy, 5 in topographic engineering, and 1 in economics. At the postgraduate level, 6 have completed master's degrees, and 1 has a PhD in Geography. The interviewees have extensive experience in land administration and cadastral management systems, ranging from 7 to 32 years, with an average of 21.6 years in the Colombian context (Table 2). All are familiar with the concept of FFP methodologies, and have been involved to some extent in processes of surveying and collecting geographic data, and land formalisation.

Table 2. Socio-demographic analysis of respondents. Source: own elaboration.

Total Participants	Age Range	Average Age	Gender Distribution		Educational Level		Average Experience
			Men	Women	Master's Degree	Ph.D.	
10	35–67	56.3	7	3	6	1	21.6

2.4. Developed Prototype—Architecture

Once the experts' opinions on the silver design had been gathered, a prototype was developed with free software. The most important functions of the initial design were implemented: the capture of data on the properties and owners and the perimeters of the properties with GPS. The system consists of an app that can be installed on Android devices, which stores the data on the device offline and sends them to a server when there is an internet connection. The server forwards the data to the technicians in charge of the review. The prototype has a client–server architecture, where the clients are a website and an app, and the server is an internet-connected Ubuntu server that stores and serves the data (Figure 1).

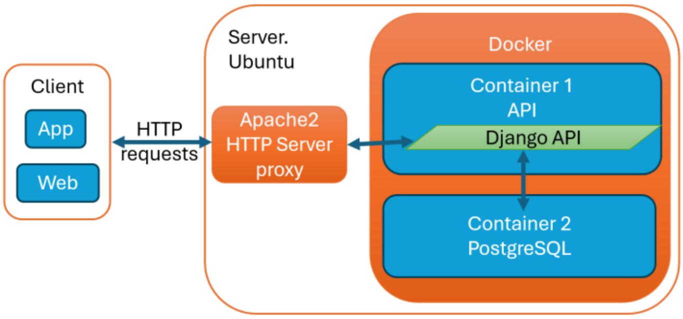

Figure 1. MetaTierras prototype architecture. Source: own elaboration.

The app is available for download at [68], and is responsible for taking data in the field and sending them to the database. The website, also available at [68], is used to allow users to register, consult, and download the data they have uploaded. Before sending data with the app, it is necessary to be registered and accepted.

The client–server architecture has the advantage that it avoids users having to install software components, such as a databases, geographic information systems, libraries, or dependencies. In addition, it avoids the configurations needed to connect the different parts of the system, such as access ports, credentials, etc. The installation of technical software is a very important barrier to a system being used. In a client–server architecture, everything is installed and configured centrally, and users always have the latest versions of the software, and data, without any special action. Software updates are carried out at a single point, and users only need to replace the app when there is a new version.

The data are stored in the PostgreSQL + PostGIS database. The Django framework takes care of the communication with the database and the data analysis algorithms. The server operating system is Ubuntu 22.04. Docker is used to build two containers, one for the database and the other for the Django (Application Programming Interface) API. Currently, the system has a Two-tier Architecture, but thanks to Docker, the system can easily be scaled up and converted to an N-tier Architecture [69]. Both the web and the mobile application were developed with the Angular framework. In the case of the mobile application, Capacitor has been used to access the resources of the mobile device on Android. The app uses an SQLite database to store the data on the device.

All technologies used are Free Libre Open-Source Software (FLOSS), or free. Many users have adopted FLOSS as part of their business in many ways. The independence from software companies, adaptability, and no cost push companies to its use. Support uncertainty and low knowledge are the bigger drawbacks [70–72]. The source code of the web as well as the app can be found in [73], and [74], respectively. The source code of the API is not a public repository for security reasons.

Description of the Use of the Developed Prototype

The first step is to apply to be a user on the website. All you need is an email address, and justify why you want to use the app. The administrators receive an email alert, study the case, and accept the user. The system notifies the user of their change in status. Once the user has been accepted, they must enter the app and log in. The session data are valid for a configurable period of time. From that moment on, as long as a connection is available, data can be sent from the device when Internet is available.

The data managed by the app follow the Cadastral Survey model LADM-COL V2, which manages the following data: property data, stakeholder data, property polygon, and boundary points. For each point, a different description and GPS accuracy are stored. Figure 2 shows the app's main screens.

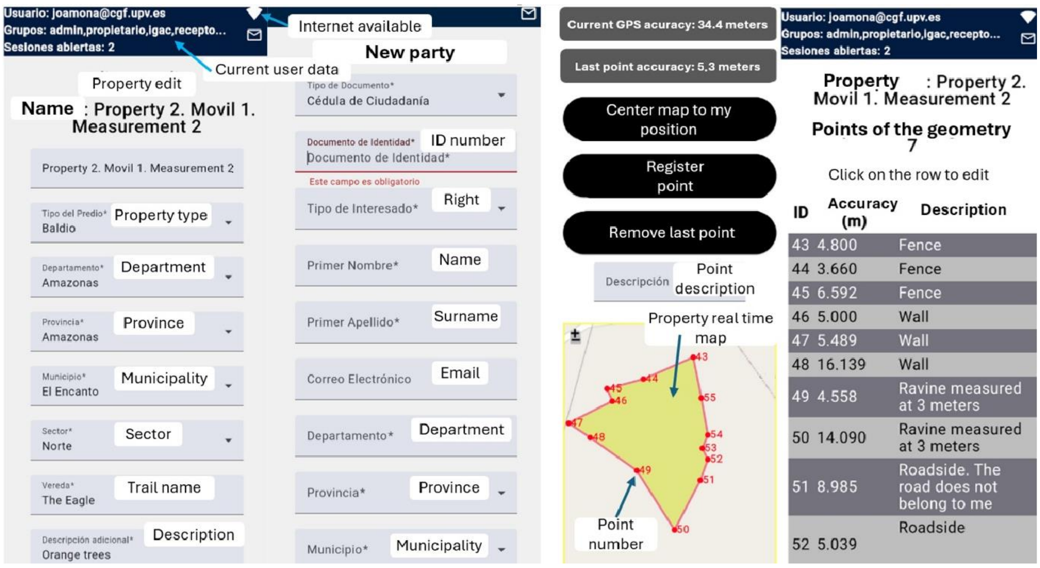

Figure 2. App main screens. Asterisks means the field is required. Source: own elaboration.

When sending the data, several text files are sent for each property, compressed in a zip file: the descriptive data of the property and the owners are sent in json files. The points, and the polygons formed with the points, are sent in geojson files. A field of the polygons stores the worst accuracy of the perimeter points. On receiving the zip file, the server sends an email, with a link to download the zip file, to the user who has just sent it, and to the technicians responsible for initiating the file. This link does not require authentication; anyone who has it can download the data, so the owner is free to share it with other technicians. Users have access to the uploaded data from the website, and can always download them again.

2.5. Developed Prototype Tests in Spain

After the development of the prototype, the application was tested on mobile phones, with Android versions 10, 11, 12, 13, and 14, in two plots in Spain. The new versions of Android are backwards-compatible, so newer versions will also support the app. Two adjacent plots were measured with four different mobile phones, but the same model, Xiaomi Red Mi 12 Note (Figure 3).

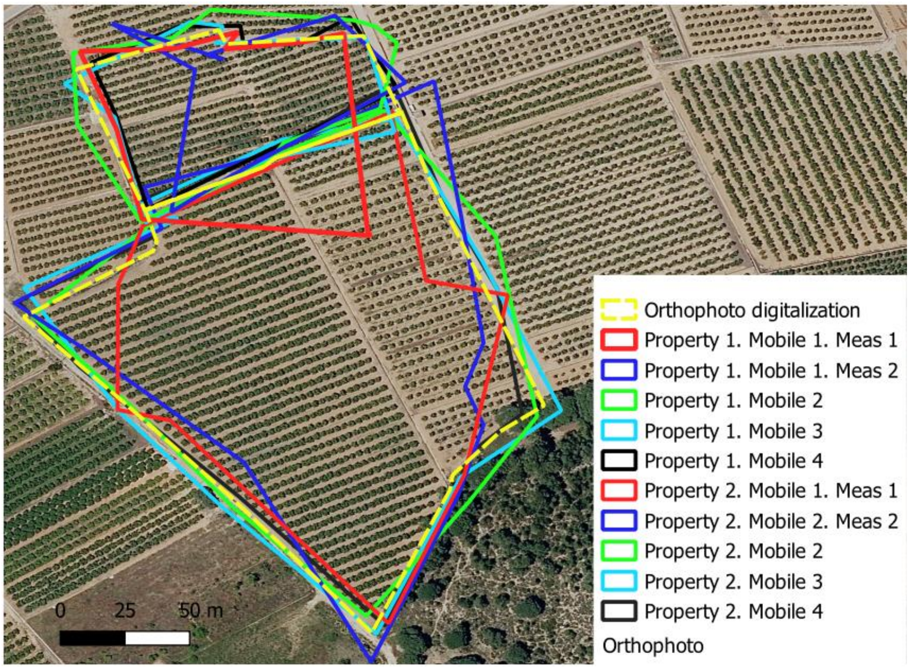

Figure 3. App tests in Spain. Measurement of two properties with 4 different smartphones. Source: own elaboration.

The area selected for the measurement is located in the town of Alginet, an area in the Ribera Alta region, Valencia, Spain; it is a flat, fairly clear area with orange tree plantations (typical fruit of the region). After various measurements, the information from the measurements was overlapped with the PNOA orthophoto [75], as can be seen in Figure 3.

The app shows the real -time accuracy of the GPS. An accuracy better than 20 m was always waited for before the points were registered. As can be seen in Figure 3, three mobiles out of four (mobile numbers 2, 3, and 4) measured with sufficient accuracy to identify the boundaries of the properties in the base map, which is the intended objective. The base map is an orthophoto, scale 1/5000, with a theoretical accuracy of 1 m. One of the mobiles, mobile 1, in the first measurement (red colour in Figure 3) gave very poor results. For this reason, the two properties were measured again with mobile 1, changing some settings. Battery saving was removed in the app, because GPS takes a considerable, and variable, time after powering up before it delivers a good position measurement, to obtain the best accuracies as soon as possible [76]. The option to use precise location was also enabled, which uses other data, such as WiFi networks, mobile phone antennas, gyroscopes, and accelerometers, to increase the accuracy obtained with GPS. The result was just as poor as in the first measurement (the blue line in Figure 3). Throughout, GPS accuracy was very erratic on this mobile, with no explanation found.

3. Results and Discussion

With regarding to the study of the situation of the country with respect to cadastre and land administration, based on background, bibliographic studies, and regulations, it is important to highlight the wide existence of projects, references, and regulations that have been applied in Colombia for years. For decades, various projects have been carried out with the support of international organisations such as the World Bank or the Inter-American Development Bank, or in cooperation with other countries such as the Netherlands, Switzerland, and currently also Germany. The most important result of these projects and international support has been the cadastral models and regulations about the conditions of cadastral data. FFP projects have also been carried out in Colombia to try to capture data faster, and the main conclusion has been that they perform well, mainly because the socialisation of the cadastral data acquisition helps agreements between neighbours. Regulations are necessary, and the findings about FFP collaborative advantages are important, but the results regarding cadastral cover are still poor. Due to this, this research proposes a design to allow any owner with a smartphone to declare approximately where their properties are and who the owners are, and, in the future, to also attach ground and document images. This information can allow technicians to obtain accurate data faster and cheaper.

The previous legislature of the Colombian government, after the peace agreements, initiated efforts to obtain cadastral data. These efforts continue in the current legislature, reaffirming the relevance of the multipurpose cadastre as a catalyst for the transition to a Land Administration System, and for the establishment of agrarian reform. This can be seen in the National Development Plan 2022–2026 [77].

With the previous information gathered [5] and based on the needs study, the initial objectives of the project were modified according to the priorities found, which finally led to the proposal of the design of an app with free software to be used by citizens as a method for the declaration of boundaries. This information is the basis for initialising the files of regularisation and acts as a declaration of boundary location to remotely digitise the correct boundaries, avoiding as much as possible expensive survey fieldwork.

As for the qualitative social research, an analysis of the responses collected is carried out, and the results are presented in a report in Spanish on the most relevant aspects. This report can be found in full as Supplementary Material to this article. It is also available in the MetaTierras Colombia project section of the CCASAT website. The following is a summary of the report.

Interviewees expressed mixed views on the implementation of the FFP approach in Colombia. Some highlighted its support of community participation, the speed it brings to cadastral production processes, and the accessibility it promotes in municipalities with low budgets. Others noted challenges in terms of accuracy margins, and the difficulty of adopting new technologies and their maintenance. In general, there was interest in the potential that this methodology can offer, especially if there is a lack of cadastral data, or difficulty in accessing them. As these methodologies involve the participation of the local community where they are developed, there was consensus that implementing these methodologies empowers the population, and involving them can have a positive impact on their perspective of the cadastre, as well as increasing their confidence in the production process.

The participants of the activity agreed that the use of technology for the collection of geographic information, based on free software solutions, is beneficial if it is supported by trained technicians and its maintenance is guaranteed.

In general, they respond that at the legal level there is no need for regulatory changes, since the provisions of the standards do not mention anything against the use of open software.

Most of them consider that the design proposed in this project is useful in the Colombian context, especially in rural areas with a lack of data and low budgets. The interviewees highlight the need to ensure interoperability, a clear definition of the IT infrastructure for data management, and that it can be updated with re-registration of historical data.

This information has been summarised schematically in Table 3.

Table 3. Social research main results. Source: own elaboration.

	FFP Implementation	MetaTierras Project Design
Advantages	- Facilitates local involvement - Streamlines cadastral processes - Positive impact on the population's perception of the cadastre - Increasing confidence in cadastral processes	- Interest in learning and testing the tool - Ability to integrate with existing processes
Challenges	- Training of users and technicians - Providing greater confidence and rigour	- Improve the accuracy with which it operates
Implications	- Technical: Integration with existing processes - Educational: Staff training - Political: Long-term cadastral planning - Social: Outreach strategies	
Recommendations	- Test in different contexts - Technical capacity building in communities	

As for the architecture used in the design of the MetaTierras system, it has important advantages over desktop applications, but the main one is that user installations are reduced to a minimum. Only a browser is needed to query the data, and the app needs to be installed to collect the data. This feature is essential if non-technical users are to capture data, as is the case here. Moreover, users in general are accustomed to the use of browsers and mobile apps. More technical users may be able to install GIS software such as QGIS, PostgreSQL, etc., but software installations are still a barrier [31]. Another great advantage of client–server applications is that all data are centralised, and only one version of the data is available, so that all users always use up-to-date data. Thanks to the virtualisation of the server services with Docker technology, it is possible to expand the server resources on demand, cloning Docker containers (virtual machines that offer the services) to distribute the workload when there are many requests.

The app has been designed to be as simple as possible. Nevertheless, information and training are recommended to manage user experience, expectations, and proper use of the system. Training videos are already available, and courses to inform and train are expected to be run in the areas where MetaTierras will be applied.

From the tests carried out in Spain, it can be concluded that the boundaries declared by field measurement with the GPS of mobile phones can serve, in many cases, to indicate the boundaries on a base image. The low accuracy of mobile phone GPS means that, to recognise the boundaries, the parcels must be at least one hectare in size. This can be seen in Figure 3, where the size of the smallest plot is about that size. For smaller plots, the captured polygons may overlap too much. In this case, the usefulness of the system lies in knowing the details of the property, the people who are claiming it, and the approximate location of the property.

4. Conclusions

The findings suggest that the FFP approach, and the use of open-source software technologies, have the potential to boost cadastral processes. The FFP methodology offers a number of advantages in terms of cost reduction, speed, and community participation, which are perceived as very positive, but it also presents challenges in terms of accuracy and adaptability. Interviewees agree that involving the population has a positive impact on landowners' perceptions of cadastral processes, and increases confidence in the procedures used. Community participation in data acquisition, even if less accurate, can help to ensure that land regularisation is seen as an asset, rather than a mere form of tax collection.

The participants in this study show an interest in articulating FFP methodologies, as they offer more speed, compared to those currently being implemented, which are also perceived to be more rigorous. Regarding the proposed design, the interviewees show interest and recognise its potential in terms of practicality and capacity for integration in cadastral processes carried out in rural areas.

New research is starting, with the first field tests in Colombia. Pilot projects are planned in different territories to adjust the tool to different contexts, where social, cultural, and physical conditions can vary. Inappropriate and unscrupulous use of the system can also occur, so efforts must be made to detect and mitigate possible frauds. Other future actions include developing community technical capacities to participate actively in data collection and verification processes.

New developments are also being considered. Next, the app will enable the capture of field images and images of documents justifying land tenure. Each landowner will be able to visualise their properties with field images, which will be georeferenced in a geoportal. These field images will also help technicians to identify boundaries and land use.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ijgi14030096/s1, Additional supporting information can be downloaded at https://github.com/joamona/metatierrascol-web (accessed on 18 November 2024). https://github.com/joamona/metatierrascol-app (accessed on 18 November 2024).

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