NATIONAL TECHNICAL UNIVERSITY OF ATHENS
SCHOOL OF SCHOOL OF RURAL, SURVEYING AND GEOINFORMATICS ENGINEERING

DEPARTMENT OF TOPOGRAPHY

AREA OF CADASTRE

Introducing New Tools and Institutional Procedures into Cadastral Surveying

DOCTORAL DISSERTATION

for the title of Doctor of Philosophy in Engineering submitted in

the School of Rural, Surveying and Geoinformatics Engineering,
National Technical University of Athens

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Diploma in Rural, Surveying and Geoinformatics Engineering NTUA

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June 2024

ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ
ΣΧΟΛΗ ΑΓΡΟΝΟΜΩΝ ΚΑΙ ΤΟΠΟΓΡΑΦΩΝ ΜΗΧΑΝΙΚΩΝ
- ΜΗΧΑΝΙΚΩΝ ΓΕΩΠΛΗΡΟΦΟΡΙΚΗΣ

ΤΟΜΕΑΣ ΤΟΠΟΓΡΑΦΙΑΣ

ΓΝΩΣΤΙΚΗ ΠΕΡΙΟΧΗ ΚΤΗΜΑΤΟΛΟΓΙΟΥ

Διερεύνηση νέων τεχνικών και θεσμικών διαδικασιών για ενα σύγχρονο μοντέλο Κτηματογράφησης

ΔΙΔΑΚΤΟΡΙΚΗ ΔΙΑΤΡΙΒΗ

για τον Επιστημονικό Τίτλο του Διδάκτορα Μηχανικού υποβληθείσα στη Σχολή Αγρονόμων και Τοπογράφων Μηχανικών - Μηχανικών Γεωπληροφορικής του Εθνικού Μετσόβιου Πολυτεχνείου

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Ιούνιος 2024

«Η έγκριση της διδακτορικής διατριβής από την Ανώτατη Σχολή Αγρονόμων και Τοπογράφων Μηχανικών - Μηχανικών Γεωπληροφορικής του Ε.Μ. Πολυτεχνείου δεν υποδηλώνει αποδοχή των γνωμών του συγγραφέα (Ν.5343/1932, Άρθρο 202)».

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Καθηγητής ΠΑΔΑ

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The research was funded by a scholarship awarded by
the Eugenides Foundation scholarship program.

Only the educated are free.

Epictetus

Acknowledgments

This thesis marks the culmination of a long period of my studies in the School of Rural, Surveying and Geoinformatics Engineering in the National Technical University of Athens. This period started in 2005, when I initially enrolled for my graduate studies and continued with my postgraduate studies in the Masters Programme in Geoinformatics. The pursuit of a doctoral degree in NTUA commenced in 2017, affording me the chance to engage in in-depth scientific research. Additionally, it provided me with the privilege of forming meaningful friendships and partnerships with distinguished researchers. Within this segment, I wish to convey my heartfelt appreciation to all those individuals who, in various capacities, contributed to the successful completion of this research endeavour.

Professor Chryssy Potsiou, for her unwavering support and comprehensive assistance at every stage of this dissertation. I heartfully thank her for her continuous scientific guidance and the genuine trust she showed me in every aspect of our long-standing collaboration. I appreciate the invaluable opportunities she provided me in the fields of research and teaching, as well as the freedom and respect she demonstrated toward my research choices. Above all, I thank her truly for the unique research environment, for her selfless support and tireless and diverse assistance throughout my research activities, for her exceptional willingness, boundless enthusiasm, truly endless time, inexhaustible patience, and unparalleled ability for dialogical contemplation, study, and in-depth and incisive critique even of the most complex scientific, research, and academic subjects.

Professor Charalabos Ioannidis for his profound trust in my research and his enthusiastic embrace of my ideas within an emerging academic domain. His continuous technical and scientific assistance throughout the years of this academic journey has been invaluable. Additionally, I extend my heartfelt appreciation for his methodical supervision, unwavering academic and professional guidance, and his insightful recommendations and feedback on all publications. These contributions not only have provided vital technical and scientific support that has greatly enriched this research but also have enriched my personality.

Professor Marinos Kavouras, for his collaboration, encouragement and helpful advice during the course of my research. His depth of knowledge and enthusiasm have been a driving force behind my academic journey.

My appreciation to the members of the examination committee for their keen interest in my research and their willingness to assess this thesis.

The Eugenides Foundation scholarship program and the Thomaideio Foundation for the financial support I received for my research work, whose support is gratefully acknowledged.

The dedicated team of anonymous volunteers participated in the practical experiments for this doctoral dissertation. Their invaluable contributions and unwavering commitment have been instrumental in the success of this research. I am deeply thankful for their time, expertise, and trust in this project, even while remaining anonymous. Their support has been truly impactful, and I am honored to have worked alongside such dedicated individuals.

I would also like to express my gratitude to my friends for their belief in me and my work, as well as for their encouragement and unwavering support.

In conclusion, I wish to extend my special gratitude and love to my family and especially my parents for the provisions and support they have provided me. I am truly grateful for their unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this dissertation.

Konstantinos Apostolopoulos
Athens, June 2024

Publications

This doctoral dissertation has been published in scientific journals and presented at international conferences after blind peer review processes in order to publicize and disseminate this research. Presented below are the publications that hold the greatest prominence and significance:

Peer-reviewed journals

Potsiou, C., Ioannidis, C., Soile, S, Boutsi, A-M., Chliverou, R, **Apostolopoulos, K.**, Gkeli, M., 2023. Geospatial Tool Development for the Management of Historical Hiking Trails - The Case of the Holy Site of Meteora. Land. 2023; 12(8):1530. https://doi.org/10.3390/land12081530

Apostolopoulos, K., Potsiou, C. 2022. How to Improve Quality of Crowdsourced Cadastral Surveys. Land 2022, 11, 1642. https://doi.org/10.3390/land11101642.

Theodosopoulou, Z., Kourtis, I.M.; Bellos, V., **Apostolopoulos, K.**, Potsiou, C., Tsihrintzis, V.A. 2022. A Fast Data-Driven Tool for Flood Risk Assessment in Urban Areas. Hydrology 2022, 9, 147. https://doi.org/10.3390/hydrology9080147

Bakogiannis, E., Potsiou, C., **Apostolopoulos, K.**, Kyriakidis, C. 2021. Crowdsourced Geospatial Infrastructure for Coastal Man-agement and Planning for Emerging Post COVID-19 Tourism Demand. Tour. Hosp. 2021, 2, 261–276. https://doi.org/10.3390/tourhosp 2020016

Apostolopoulos, K., Potsiou, C. 2021. Consideration on how to introduce gamification tools to enhance citizen engagement in crowdsourced cadastral surveys. Survey Review. 1(1).

Potsiou, C., Paunescu, C., Ioannidis, C.; **Apostolopoulos, K.**, 2020. Nache, F. Reliable 2D Crowdsourced Cadastral Surveys: Case Studies from Greece and Romania. ISPRS Int. J. Geo-Inf., 9, 89.

Apostolopoulos, K., Geli, M., Petrelli, P., Potsiou, C. and Ioannidis, C. 2015. "A new model for Cadastral Surveying using Crowdsourcing," Survey Review, SRE 809.

Mourafetis, G., **Apostolopoulos, K.**, Potsiou, C. and Ioannidis, C. 2015. "Enhancing Cadastral Survey by Facilitating Owners' Participation," Survey Review 47(344), 316 -324.

Peer-reviewed conference papers

Potsiou, C., Ioannidis, C., Vlastos, T., Soile, S, **Apostolopoulos, K.**, Boutsi, A-M., Gkeli, M., 2023. ''A Geospatial Integrated Tool for Historic Walking Trails in the Holy Site of Meteora'', FGI Working Week 2023, Orlando, 28 May – 1 June, 2023

Apostolopoulos, K., Mittas, G., Retsas, K., Ioannidis, C. Potsiou, C. 2017. "Assessment of the Legalization Framework of Informal Development in Greece", GeoPreVi 2017, Bucharest, 14 -16 September 2017

Gkeli, M., **Apostolopoulos, K.**, Mourafetis, G. Potsiou, C., Ioannidis, C. 2016. "A new model for Cadastral Surveying using Crowdsourcing". Proc. SPIE 9688, Fourth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2016), August 12, 2016

Others

Apostolopoulos, K., Potsiou, C. 2022. ''Time to discuss improving the quality of crowdsourced cadastral surveys''. Workshop Joint FIG Commissions 3 and 8. Athens, December 13 -14.

Apostolopoulos, K., Retsas, J., Potsiou, C. 2021. ''An open source application for Gamification in Cadastral Surveying''. FIG e-Working Week 2021. Amsterdam, June 20 – 25.

Apostolopoulos, K., Kanta, E., Potsiou, C. 2019. "Development of an Open Source Software for Reliable 2D Crowdsourced Cadastral Surveys". Romanian Surveying Week, Cluj - Napoca, September 23 – 28 2019.

Apostolopoulos, K., Potsiou, C. 2019. "Participatory Procedures & Consideration for Introducing Gamification tools in the Hellenic Cadastral Project''. Cluj - Napoca, September 23 – 28 2019.

Apostolopoulos, K., Potsiou, C. 2018. ''Reliable 2D Cadastral Surveys with Citizen Participation: Case Studies in Greece and Romania. 27th Panhellenic ArcGIS Users Meeting, Athens, May 30 -31.

Potsiou, C., Paunescu, C., Ioannidis, C., **Apostolopoulos, K.**, Nache, F. 2018. "A Proposed Procedure for Reliable 2D Crowdsourced Cadastral Surveys: Case Studies from Greece and Romania". FIG Commission 3 Workshop and Annual Meeting 2018, Naples, December 3-6 2018.

Apostolopoulos, K., Mittas, G., Retsas, K., Ioannidis, C. Potsiou, C. 2017. "Assessment of the Legalization Framework of Informal Development in Greece", GeoPreVi 2017, Bucharest, 14 -16 September 2017.

Apostolopoulos, K., Ioannidis, C., Nache, F., Paunescu, C., Potsiou, C. 2017. "A Proposal for Flexible, Affordable and Reliable Systematic Cadastres: Examples from Greece and Romania". FIG Working Week 2017, Helsinki, May 29 – June 2 2017.

Apostolopoulos, K., Ioannidis, C., Potsiou, C. 2016. "A proposal for fast, flexible, low-cost and reliable Cadastral Surveys". FIG Commission 3 Workshop and Annual Meeting 2016 joint to International Symposium GEOMAT and EGoS General Assembly, Iasi, November 3-7 2016.

Gkeli, M., **Apostolopoulos, K.**, Mourafetis, G. Potsiou, C., Ioannidis, C. 2016. "A new model for Cadastral Surveying using Crowdsourcing". Fourth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2016), April 4-8, 2016.

Apostolopoulos, K., Geli, M., Petrelli, P., Potsiou, C. and Ioannidis, C. 2015. "A new model for Cadastral Surveying using Crowdsourcing", Joint Workshop FIG Commission 3 & Commission 7 on Crowdsourcing of Land Information, Malta, November 16-20, 2015.

Mourafetis, G., **Apostolopoulos, K.**, Potsiou, C. and Ioannidis, C. 2014. "Enhancing Cadastral Survey by Facilitating Owners' Participation", Geospatial Crowdsourcing and VGI: Establishment of SDI & SIM, FIG Commission 3 Workshop and Annual Meeting, Bologna, November 3-7, 2014.

Potsiou, C., Basiouka, S., Mourafetis, G., **Apostolopoulos, K.** 2014. "New Technologies in Land Administration", The Social Tenure Domain Model - Training of Trainers, Kuala Lumpur, June 13-16, 2014.

Abstract

The primary aim of this study is to present an innovative crowdsourced cadastral model with worldwide applicability. This model's feasibility is thoroughly examined through a combination of theoretical analysis and practical experimentation. The research involves the implementation of diverse methodologies and the engagement of volunteers from various regions of interest. Notably, the research selects the Hellenic and Romanian Cadastral projects, both of considerable national significance, as case studies to serve as prototypes for this investigation. The overarching goal of this research is to introduce a Fit-For-Purpose (FFP) crowdsourced cadastral model that is characterized by its simplicity and efficiency compared to previous models. This approach is anticipated to enhance processes, reduce associated costs, and actively involve citizens in the cadastral data compilation and management.

The first chapter introduces the dissertation's foundational elements, presenting the research topic and the broader contextual landscape. It delineates the chosen research methodology, emphasizing its interdisciplinary nature, and lays out the primary objectives, motivations, and innovations driving this investigation.

A thorough examination of the current state of research is undertaken in the following chapter. A historical review of Sustainable Development and the Agenda 2030 initiative sets the stage for a critical analysis of the pivotal role played by cadastre and geospatial data in the pursuit of Agenda 2030 goals. The chapter further focuses on the evolving landscape of citizen participation and gamification tools within government projects, highlighting their potential contributions. A specific focus is placed on the integration of citizen e-participation in cadastral mapping and land administration, underpinned by best practices and real-world collaboration examples from the Hellenic Cadastre project. Additionally, the chapter presents the evolution of the Fit-For-Purpose (FFP) Land Administration Approach, with particular attention to its core component, the FFP spatial framework. National case studies are presented to showcase best practices in its implementation.

The research also provides a comprehensive overview of cadastral methods in Greece and Romania. Legal, institutional, and technical aspects of surveying, mapping, and data management are dissected to offer a thorough understanding of cadastral frameworks in these countries. The chapter also explores the meticulous methodology applied to ensure quality assurance and quality control (QA/QC) in the Hellenic Cadastral Project, encompassing various measures designed to ensure strict compliance with the General Project Quality Program.

Based on this investigation, a novel Fit-for-Purpose (FFP) cadastral model is introduced. This model is designed to address the multifaceted challenges inherent in establishing modern cadastral systems. It presents an incremental and pragmatic approach, drawing upon existing knowledge and practical examples presented in earlier chapters. The primary goal of this model is to optimize data collection efficiency and quality by integrating cutting-edge IT tools and fostering increased citizen engagement. The model's flexibility is highlighted, demonstrating its applicability to diverse cadastral projects, thereby promoting reliable and flexible cadastres at both local and national levels.

The proposed cadastral model undergoes rigorous testing in diverse contexts, including urban, rural, and suburban areas. It also evaluates its performance when integrated with modern IT tools and explores the impact of citizen engagement through gamification in cadastral mapping. A comprehensive analysis of the FFP cadastral model's potential benefits and challenges is

presented, providing valuable insights into its capacity to improve the efficiency, inclusivity, and accuracy of crowdsourced cadastral systems.

The research concludes by addressing its primary objectives, highlighting the overarching, technological, and societal results, and suggesting unexplored areas for future research. The key insights, conclusions, and contributions derived within the scope of this extensive research project are highlighted and categorized into three main sections: the first section offers a detailed discussion of the research's implications and significance; the second section extracts valuable lessons from successful aspects of the study, providing practical lessons; and the final section provides a concise overview of potential directions for future research, underscoring emerging trends and opportunities within the fields of cadastral systems and land administration.

Keywords

Land Administration, Cadastre, Cadastral Surveying, FFP Cadastre, Crowdsourcing, Citizen Participation, Citizen Engagement, Gamification, VGI, Quality Controls

Περίληψη

Ο κύριος στόχος της παρούσας διδακτορικής διατριβής είναι να παρουσιάσει μια νέα μοντελοποιημένη διαδικασία κτηματογράφησης, η οποία θα παρέχει γρήγορες και αξιόπιστες λύσεις για την ολοκλήρωση και τη λειτουργία του Κτηματολογίου σε επίπεδο χώρας, αξιόπιστα και οικονομικά, με την συμμετοχή των πολιτών, των εφαρμογών κινητής τηλεφωνίας και UAVs, και την χρήση σύγχρονων εργαλείων πληροφορικής για την καταγραφή των ιδιοκτησιακών δικαιωμάτων και την απόκτηση Κτηματολογικών δεδομένων. Οι προτεινόμενες εφαρμογές που θα χρησιμοποιηθούν για την ολοκλήρωση της Κτηματογράφησης, υποστηρίζονται από την σύγχρονη τάση του crowdsourcing και της συμμετοχής των πολιτών καθώς και τις mobile κυβερνητικές υπηρεσίες (m-gov).

Η εφικτότητα αυτού του μοντέλου εξετάζεται εκτενώς μέσω της συνδυασμένης θεωρητικής και τεχνικής τεκμηρίωσης και σε ευρήματα μέσα από μια σειρά πρακτικών πειραμάτων. Η έρευνα περιλαμβάνει τη συμμετοχή εθελοντών και την εφαρμογή διαφορετικών μεθοδολογιών από διάφορες περιοχές ενδιαφέροντος. Σημαντικό για τη διαμόρφωση της μοντελοποιημένης διαδικασίας είναι ότι η έρευνα επιλέγει τις διαδικασίες Κτηματογράφησης της Ελλάδας και της Ρουμανίας, ως περιπτώσεις μελέτης προτύπου. Ο γενικός στόχος αυτής της έρευνας είναι να εισάγει ένα μοντέλο κτηματολογικής καταγραφής που είναι προσαρμόσιμο στις ανάγκες κάθε χώρας και θα χαρακτηρίζεται από την ευελιξία και την αποδοτικότητα του σε σύγκριση με προηγούμενα μοντέλα. Αναμένεται ότι αυτή η προσέγγιση θα βελτιώσει τις κτηματολογικές διαδικασίες, θα μειώσει τα συνοδευτικά κόστη και θα ενεργοποιήσει τους πολίτες στη συλλογή και τη διαχείριση των κτηματολογικών δεδομένων.

Το πρώτο κεφάλαιο παρουσιάζει τα θεμελιώδη στοιχεία της διδακτορικής διατριβής, παρουσιάζοντας το θέμα της έρευνας και το ευρύτερο πλαίσιο στο οποίο αναπτύσσεται. Περιγράφει την επιλεγείσα μεθοδολογία της έρευνας, τονίζοντας το διεπιστημονικό της χαρακτήρα, και καθορίζει τους κύριους στόχους, τα κίνητρα και τις καινοτομίες που καθοδηγούν αυτήν την έρευνα.

Στο επόμενο κεφάλαιο πραγματοποιείται λεπτομερής εξέταση της τρέχουσας κατάστασης της έρευνας στο πεδίο του Κτηματολογίου και της Διοίκησης της Γης. Μια ιστορική ανασκόπηση της Αειφόρου Ανάπτυξης και της Agenda 2030 των Ηνωμένων Εθνών θέτει το πλαίσιο για μια κριτική ανάλυση του καθοριστικού ρόλου που διαδραματίζει το κτηματολόγιο και τα γεωχωρικά δεδομένα στην επίτευξη των στόχων της Ατζέντα 2030. Το κεφάλαιο επικεντρώνεται, επίσης, στην εξέλιξη της τάσης του πληθοπορισμού, της συμμετοχής των πολιτών και των εργαλείων παιχνιδοποίησης σε κυβερνητικά έργα, τονίζοντας τις δυνητικές συνεισφορές τους. Δίνεται έμφαση στην ένταξη της διαδικτυακής συμμετοχής των πολιτών στις κτηματολογικές διαδικασίες και στη διοίκηση της γης, υποστηριζόμενη από τις καλύτερες πρακτικές και πραγματικά παραδείγματα συνεργασίας, που έχουν προκύψει από το έργο του Ελληνικού Κτηματολογίου. Επιπλέον, παρουσιάζεται η εξέλιξη της Fit-For-Purpose (FFP) προσέγγισης στη διοίκηση της γης, με ειδική έμφαση στο χωρικό της πλαίσιο. Επίσης, παρουσιάζονται περιπτώσεις μελέτης σε εθνικό επίπεδο για την ανάδειξη των βέλτιστων πρακτικών στην εφαρμογή του.

Στο επόμενο κεφάλαιο, η διδακτορική διατριβή διερευνά τις επίσημες κτηματολογικές μεθόδους στην Ελλάδα και στη Ρουμανία. Παρουσιάζεται το νομικό, θεσμικό και τεχνικό πλαίσιο τους. Επιπρόσθετα, εξετάζεται η μεθοδολογία που εφαρμόζεται για να διασφαλιστεί ο ποιοτικός έλεγχος στο έργο του Ελληνικού Κτηματολογίου, περιλαμβάνοντας διάφορες μεθόδους και εργαλεία που σχεδιάστηκαν για να διασφαλίσουν την αυστηρή συμμόρφωση του με το Γενικό Πρόγραμμα Ποιότητας Έργου του Ελληνικού Κτηματολογίου. Επίσης, εξετάζεται ο εμπλουτισμό τους με άλλη χωρική πληροφορία, η οποία θα κριθεί χρήσιμη για την αναπτυξιακή διάσταση ενός σύγχρονου κτηματολογίου.

Με βάση αυτήν την έρευνα, παρουσιάζεται ένα σύγχρονο μοντέλο κτηματολογίου. Αυτό το μοντέλο σχεδιάζεται για να αντιμετωπίσει τις πολυδιάστατες προκλήσεις που συνοδεύουν τη δημιουργία σύγχρονων κτηματολογικών συστημάτων. Το μοντέλο περιλαμβάνει μια σταδιακή και πραγματιστική προσέγγιση, εκμεταλλευόμενο την υπάρχουσα γνώση και τα πρακτικά παραδείγματα που παρουσιάστηκαν σε προηγούμενα κεφάλαια. Ο βασικός στόχος αυτού του μοντέλου είναι να βελτιώσει την αποδοτικότητα και την ποιότητα στη συλλογή κτηματολογικών δεδομένων, ενσωματώνοντας προηγμένα εργαλεία πληροφορικής και προάγοντας τη συμμετοχή των πολιτών. Επισημαίνεται η ευελιξία του μοντέλου, καθώς δείχνει την εφαρμοσιμότητά του σε διάφορα κτηματολογικά έργα, προωθώντας έτσι αξιόπιστα και ευέλικτα κτηματολόγια τόσο σε τοπικό όσο και σε εθνικό επίπεδο.

Το προτεινόμενο κτηματολογικό μοντέλο υποβάλλεται σε αρκετές πρακτικές εφαρμογές σε διάφορα μοτίβα, συμπεριλαμβανομένων αστικών, αγροτικών και περιαστικών περιοχών. Αξιολογείται μέσω αυτών η αξιοποίηση σύγχρονων εργαλείων πληροφορικής και εξετάζεται ο αντίκτυπος της συμμετοχής των πολιτών μέσω εργαλείων παιχνιδοποίησης στις κτηματολογικές διαδικασίες. Παρουσιάζονται τα δυνητικά οφέλη και οι προκλήσεις της υλοποίησης του προτεινόμενου κτηματολογικού μοντέλου, καθώς και οι επιτυγχανόμενες ακρίβειες, οι χρόνοι και τα προβλήματα που εμφανίστηκαν.

Η έρευνα ολοκληρώνεται με τα ευρήματα σε θεωρητικό και πρακτικό επίπεδο, τονίζοντας τα γενικά, τεχνολογικά και κοινωνικά αποτελέσματα, και προτείνοντας ανεξερεύνητους τομείς για μελλοντικές έρευνες. Οι κύριες εισηγήσεις, συμπεράσματα και συνεισφορές που προκύπτουν στο πλαίσιο αυτού του εκτενούς ερευνητικού έργου τονίζονται και κατηγοριοποιούνται σε τρεις κύριες ενότητες: η πρώτη ενότητα προσφέρει μια λεπτομερή διερεύνηση των συνεπειών και της σημασίας της έρευνας, η δεύτερη ενότητα παρουσιάζει πολύτιμα διδάγματα από τις πρακτικές εφαρμογές και η τρίτη ενότητα παρέχει μια συνοπτική επισκόπηση πιθανών κατευθύνσεων για μελλοντικές έρευνες, τονίζοντας αναδυόμενες τάσεις και ευκαιρίες στους τομείς των κτηματολογικών συστημάτων και της διοίκησης της γης.

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Abbreviations

Accurate, Assured, and Authoritative cadastre	AAA cadastre
Division for Sustainable Development Goals	DSDG
European Union	EU
Fit For Purpose	FFP
Fit For Purpose Land Administration	FFP LA
Geographic Information System	GIS
Global Sustainable Development Report	GSDR
Hellenic Geodetic Reference System 1987	HGRS87
Hellenic Mapping and Cadastre Organization	HEMCO
Information and Communication Technology	ICT
International Federation of Surveyors (Fédération Internationale des Géomètres)	FIG
Land Administration System	LAS
Large Scale Orthophoto	LSO
Millennium Development Goal	MDG
Minimal Viable Product	MVP
National Cadastral and Mapping Agency	NCMA
National Spatial Data Infrastructure	NSDI
National Technical University of Athens	NTUA
Non-Governmental Organization	NGO
Organization for Economic Co-operation and Development	OECD
Quality Assurance/Quality Control	QA/QC
School of Rural, Surveying and Geoinformatics Engineering	SRSE
Spatial Data Infrastructure	SDI
Sustainable Development Goals	SDG
Sustainable Ideas Game	SIG
United Nations	UN
United Nations Department of Economic and Social Affairs	UNDESA
United Nations Economic Commission for Europe	UNECE
United Nations Economic Commission for Europe	UNECE
United Nations Regional Information Centre	UNRIC
Very Large scale Orthophoto	VLSO
Volunteer Geographic Information	VGI
World Bank	WB

1 Introduction

1.1 Motivations of the research

Most developed countries have established institutional infrastructures for land administration and legislation related to safeguarding and recording property rights on land and real estate, and their values. They also provide the necessary administrative services to ensure and guarantee these rights, the ability to use land and real estate, their development and licensing, and the ease of obtaining loans. These services support the real estate market and bolster the modern economy.

Simultaneously, in such countries, the National Spatial Data Infrastructures (NSDIs) have gradually been developed and updated over several years through the combination of land administration information prepared according to established standards and traditional procedures, with additional geospatial information managed by various administrative services, always at national coverage. Nation-wide geospatial data sets when combined with cadastral information support evidence-based decision-making for land management, aiming for good governance, both for the economy and the environment, as well as the social state.

The first revolution in cadastral surveying processes came with the introduction of photogrammetry and its use in the cadastral surveying process. The second significant revolution came with the advancement of computer technology and the introduction of automation and Geographic Information Systems (GIS) in cadastre. Old analog maps have been transformed into digital format within a modern GIS environment. Today, we are in the era of the third significant revolution (platform land administration), with the use of Internet services and applications, mobile government (m-government), leading to Cadastre 2.0, as well as sensors and the Internet of Things, Internet 4.0, which is expected to soon lead to Cadastre 4.0. Technological development offers opportunities for further improving the speed, quality, and updating of cadastral surveys, as well as reducing their costs, thereby enabling the collection of a larger volume of information in a very short time frame, opening up new avenues for the preparation of large-scale cadastral maps in countries that have not yet been fully surveyed, as well as the process of updating them.

This doctoral thesis contribution is aligned with and inspired by certain global trends, ideas and motivations such as:

- The global need to increase efficiency and Reliability of cadastral surveying: One of the primary motivations is the need to enhance the efficiency and reliability of the cadastral surveying process at the national level. This might be driven by existing inefficiencies or shortcomings in the current system, which could lead to issues like property disputes, land management problems, or delays in property registration.

- The technological advancement in the digital era: that clearly enables innovation in the cadastral domain. The existing methods and technologies were outdated, and there was a recognition that modernizing the cadastral surveying process can lead to improved outcomes.

- The global need for Cost-effective methods: By proposing a new cadastral surveying process, the research aims to find ways to complete cadastral surveys in a more economical manner. This is particularly important for all countries in need to compile cadastral mapping to meet the SDGs timely.

- The global trend for increased Citizen Participation: The increased citizen participation aims to make the cadastral surveying process more efficient, inclusive, and transparent. This could be driven by a belief in the importance of involving citizens in land and property management projects and decisions, potentially to raise awareness, reduce corruption, reduce costs and increase community engagement.

- The global trend to increase modern technology utilization: The research intends to leverage modern information technology tools. This reflects a recognition of the potential benefits of using cutting-edge technology to improve and speed up the cadastral process, which might involve automation, data analytics, and other tech-driven solutions.

- The increasing use of unmanned Aerial Vehicles (UAVs): The inclusion of UAVs in the proposal suggests an interest in using advanced technology for data collection and mapping. UAVs can provide low-cost, high-resolution aerial imagery, which can be valuable for cadastre purposes.

- The global trend of Crowdsourcing methodology: The reference to crowdsourcing indicates a desire to tap into collective intelligence and resources. This approach can lead to more reliable, comprehensive and up-to-date cadastral data, as well as increased local citizen engagement in maintaining property records.

- The increasing trend for Mobile Government Services (m-gov): The integration of mobile government services highlights a commitment to making cadastral data and services accessible through mobile devices. This could enhance convenience and accessibility for citizens and professionals involved in land and property management.

1.2 Objectives of the research and methodology

This research unfolds across multifaceted dimensions, encompassing a spectrum of research questions and objectives of investigation such as:

a) Is it possible to define a Fit-for-Purpose Cadastral Survey Model to meet SDGs in a reliable, timely, and affordable manner?
b) What are the most appropriate tools and methodologies to achieve that?
c) How should we check the suitability of each tool and methodology before using it?
d) What are the most appropriate controls to be integrated into the proposed F-F-P cadastral model to ensure the reliability of the results?
e) How can we enhance the usability of the proposed model for other geospatial data collection applications apart from cadastral surveying?

The objectives of this research are the following:

- Design and Propose a Fit-for-Purpose Cadastral Survey Model

Design and propose a modeled process for cadastral surveys that will be affordable, reliable, fast and flexible enough to utilize new tools and techniques, always applicable to the local situations, and needs, aiming to create multi-purpose land administration geospatial infrastructures. Cadastral data quality may vary according to the local situations but should be upgradable incrementally to a AAA cadastre as the local conditions improve.

This process should involve land parcel identification and parcel boundary delineation on a basemap, as well as cadastral data collection in terms of property rights and adjudication of right holders. The same methodology should support the possible enrichment of this infrastructure with additional geospatial information useful for the development of a multi-purpose land administration system.

- Conduct a Comprehensive Literature Review to identify the most appropriate tools and methodologies

This encompassing literature review spans a broad spectrum of topics, including current trends in cadastre and land administration systems, the evolving landscape of the United Nations' Agenda 2030, specifically in domains linked to cadastre and land administration, citizen engagement in the decision-making processes and in the principles of good governance. This comprehensive literature review is the bedrock upon which the research constructs its theoretical framework.

This framework is designed to propel the fast transformation of cadastre into a modernized model that aligns with the dynamic landscape of cutting-edge technological advancements. It envisions the strategic incorporation of emerging techniques, reimagines institutional processes, and adapts to the changing technological landscape, which includes the pervasive influence of smart mobile devices, the ubiquitous reach of the internet, and the transformative potential of crowdsourcing.

- Implementation of Emerging, Low-Cost Technologies and Smart Devices

Central to this investigation is the examination of how emerging, low-cost technologies and smart devices such as smartphones, UAVs, applications, tablets, crowdsourcing, cloud computing, gamification, etc., can be strategically harnessed to revolutionize the compilation of cadastres and other geospatial infrastructures. In this light, the research strives to elucidate not only the technological advances but also the theoretical aspects that have the potential to underpin modern developmental cadastral systems.

  - Introduce Crowdsourcing and Enhance Citizen Engagement in cadastre-related activities.

    In alignment with modern trends, the research underscores the deployment of crowdsourcing mechanisms and the active involvement of citizens in cadastre-related activities. This integration is not only a nod to participatory governance but also a strategic alignment with the broader global development agenda. Furthermore, the research probes the transformative potential of mobile government services (m-gov) in fostering citizen engagement in these processes.

  - Introduce Gamification elements in Cadastral surveys

    Further bibliographic research was conducted regarding the use of the crowdsourcing method in conjunction with the gamification strategy, integrating game mechanics into a non-game environment such as the cadastral survey. This technique is implemented through goals and rewards. This technique significantly encourages user engagement by satisfying their internal need for recognition of their efforts, resulting in increased dedication.

Parallel to the investigation of cutting-edge technology, this research endeavors to undertake an in-depth investigation into the present state of cadastral processes. This includes an analysis of the technologies currently deployed in cadastral surveys. The goal is to unravel the intricacies and challenges entailed in modern practices, with a specific focus on efficiency and the attainment of precision in data compilation for developmental cadastres.

- Examine the official cadastral procedures in Greece and Romania to identify lessons learned and current experience

Furthermore, this research aims to investigate the existing cadastral surveying processes in two European countries, Greece and Romania. Greece and Romania share a common goal of establishing fully functional Cadastres. This investigation serves as a touchstone to identify strengths, weaknesses, and areas ripe for enhancement in the current cadastral practices. Guided by the principles of the Fit-For-Purpose (FFP) approach, the research aims to delineate a pragmatic roadmap for the strategic integration of new technologies and innovative practices.

- Examine the suitability of each tool and methodology used prior to the compilation of the proposed model

At this step, the suitability of each tool is examined based on a comprehensive and representative assessment of the achieved results and effectiveness across diverse environments. Key parameters that are investigated include geographic diversity, socio-economic conditions, land use patterns, the existing problems arisen in the cadastral surveys and the existing state of cadastral data in Greece and Romania.

- Examine the most appropriate controls that should be integrated into the proposed model to ensure the reliability of the results

To ensure that the quality of the above-mentioned results will be achieved, a certain number of controls must be introduced in the procedure of the proposed methodology. Based on the experience gained from the assessment of the tools as well as on the study of the two methodologies already implemented in Greece and Romania, certain controls are introduced in the proposed model to ensure the quality of the results.

- Enhance the usability of the proposed model for various applications apart from cadastral surveying

The usability of the proposed F-F-P cadastral survey model is tested, by example, for additional geospatial data collection from a distance, for an application for tourism.

1.3 Innovations of this research

The primary innovations introduced by this particular research encompass a broad spectrum of technical, theoretical, practical, and sociological dimensions. These innovative aspects are detailed as follows:

- The research introduces the need for a strategic decision to design a cadastral surveying model that will support the United Nations' Agenda 2030 for Sustainable Development and will enable the timely fulfilment of several SDGs with a significant land component mentioned in their targets such as 1,2,5,11 and 15. At the time this research was initiated, the design of such nationwide cadastral surveying projects did not take into consideration this need. Today, the design of any land tool should take into consideration the SDGs and several other relevant global documents; therefore this PhD is a valuable contribution towards this direction.

- The research combines insights from global crowdsourced mapping initiatives with established protocols to create a novel approach to crowdsourced cadastral surveys, drawing from valuable lessons learned in the process. This PhD builds upon the previous research initiated by (Basiouka and Potsiou, 2011; Basiouka and Potsiou, 2012).on introducing crowdsourcing methodology into cadastral surveying, and it actually tests the options, the available technologies, and the current cadastral surveying methodologies and provides a model for crowdsourced cadastral surveys. This innovative crowdsourcing model for cadastral surveys is adaptable and flexible, making it suitable for implementation in various land administration projects. It has been meticulously developed, rigorously tested for its effectiveness and further refined based on real-world experiences and observations.

- One of the key innovations of this work is the enrichment of crowdsourced cadastral data with additional crowdsourced geospatial information. This includes enhancements such as environmental factors, land use patterns, and infrastructure data, providing a comprehensive view of land assets. Such enriched data support evidence-based decision-making for sustainable development initiatives and the implementation of the UN Sustainable Development Agenda 2030.

- The research proposes incorporating gamification elements into the cadastral surveying process. To encourage this involvement, a gamification procedure is proposed, where successful participants may be rewarded with certificates, badges, leaderboards, progress bars, fee discounts, or similar incentives. This contributes to the effort for more community engagement and allows for creating a team of committed successful volunteers that will be engaged each time there is a need for the collection of crowdsourced, georeferenced geospatial data at the cadastral mapping scale. Such geospatial crowdsourced infrastructures are valuable in facing a large number of challenges, such as disaster risk reduction and management projects.

- An additional novel aspect of this research is its emphasis on involving citizens in many phases of the cadastral surveying process. It introduces mechanisms for public participation in several phases of cadastral surveying such as (a) the compilation of a cadastral basemap, (b) enabling individuals to contribute data, edit and validate the cadastral records, thus promoting transparency and community involvement in the cadastral surveying project.

1.4 Research process

This section describes the structured methodology of the research process. It is organized into distinct phases, each contributing to the overarching goal of generating valuable insights into the study's objectives.

The initial phase is the definition of the objectives under investigation, thereby establishing the core research query. The formulation of this research query sets the direction for the study's objectives and related questions. To address these research objectives, an extensive examination of international literature was conducted.

The following phase comprises the examination of the study and entails the compilation of the proposed model that will successfully address the study's objectives and related questions. The pragmatic segment of the research comprises a series of six compelling case studies, each wielding distinct benefits and outcomes. By assessing the proposed model in diverse contexts, this phase facilitates an in-depth understanding of its adaptability, limitations, and potential for broader implementation.

The last phase revolves around composing and delivering the comprehensive findings of this research. Additionally, it offers a brief collection of possible directions for future research, alongside emerging trends and prospects.

1.5 Structure of the study

This dissertation is structured into six distinct chapters.

The present chapter marks the culmination of the initial chapter of this research. Within this chapter, the research topic, and its background context are introduced, along with an explanation of the methodology employed. Moreover, the primary objectives, motivations, and innovations of the research are presented.

The second chapter undertakes an in-depth investigation into the present state of research. A historical review of Sustainable Development and the UN Agenda 2030 is conducted. It explores the vital role of cadastre and geospatial data in achieving Agenda 2030 goals and examines the progress of citizen participation and gamification tools in government projects. Additionally, the chapter explores the integration of citizen e-participation in cadastral mapping and land administration, highlighting best practices and collaboration examples in the context of the Hellenic Cadastre project. It also presents the evolution of the Fit-For-Purpose (FFP) Land Administration Approach and its core component, the FFP spatial framework, alongside country-wide case studies demonstrating best practices in its implementation.

The third chapter provides an overview of cadastral methods in Greece and Romania, focusing on legal, institutional, and technical aspects of surveying, mapping, and data management. It also examines the methodology applied to maintain quality assurance and quality control (QA/QC) in the Hellenic Cadastral Project. This includes various measures aimed at ensuring compliance with the General Project Quality Program.

The fourth chapter presents a novel Fit-for-Purpose (FFP) cadastral model designed to address challenges in creating robust cadastral systems. It offers an incremental and pragmatic approach, drawing from existing knowledge and practical examples, presented in the previous chapters. It aims to optimize data collection efficiency and quality through the integration of IT tools and increased citizen engagement, ultimately providing a flexible method applicable to diverse projects, and fostering reliable and modern cadastres at both local and national levels.

The fifth chapter rigorously tests the proposed Fit-for-Purpose cadastral model across various contexts, assessing its adaptability and resilience in crowdsourced land administration. It examines its applicability in diverse landscapes and communities, encompassing urban, rural, and suburban areas, and evaluates its effectiveness with modern IT tools. Additionally, it explores the impact of citizen engagement through gamification elements in cadastral mapping. It also provides a comprehensive analysis of the FFP cadastral model's potential benefits and challenges, offering insights into its prospects for achieving more efficient, inclusive, and accurate cadastral systems.

The sixth and final chapter serves as a comprehensive summary of the research findings, highlighting key insights and conclusions derived within the scope of this research project. This chapter is divided into three main sections: the first section presents a detailed discussion of the research, the second section extracts valuable lessons from successful aspects of the study, and the final section provides a concise overview of potential directions for future research, highlighting emerging trends and opportunities in the field.

2 Literature review

Over the past two decades, there has been a significant revolution in the way that geographical data, information, and expertise are created and shared. The concept of using the internet to create, exchange, visualize, and user-generated geographic information and knowledge is known as "Volunteer Geographic Information" (VGI), and it was envisioned through the usage of several computing devices and platforms. The acquisition, maintenance, analysis, visualization, and ultimately application of geospatial data have all undergone radical change as a result of the Neogeography revolution. This affects common practices because it enables a more thorough and comprehensive understanding of the environment we live in on all facets of life, encompassing new services to take place, applications and processes to be developed, all of which are location-based; we now have the capability to track where and when everything is occurring - and in real-time.

The public continuously gathers and stores a sizable amount of geographic data, supported by the development of new technologies to support Citizen Science. It can make a significant contribution to the creation and upkeep of a quality, useable, and trustworthy geographic information system (GIS) and geospatial data infrastructure. The paradigm of crowdsourcing has been developed as a logical extension of the concept of volunteer geographic information. This is supported by the fact that users today have access to a variety of user-generated geographic and geo-tagged digital information data sources that have been created and are being maintained by both public and private citizens, in addition to traditional or official and authoritative geospatial and map information. As a result, the updating process for spatial data infrastructures (SDIs) and geospatial data is presently changing.

Crowdsourced data does not always follow the same pattern. The methods used to acquire the data should match the intended purpose and context, just as quality and dependability requirements should. There is a need to take into consideration the crowd's engagement as an essential component of the methodology in all crowdsourcing operations, whether they involve a small number of participants or hundreds of thousands. The recruitment, maintenance, and upkeep of the relationships with the crowdsourced project participants also require devoted resources. The methodology must take into account the individuals who will contribute to the operation and the strategy that will be used to encourage their participation, much like planned field survey works.

The method that will be utilized to capture the data and validate them must be also determined. Other important considerations include choosing the appropriate tools for data collection and recording. Several factors that will affect the data-gathering methodology and approach may be found in crowdsourcing project contexts.

The difficulty of crowdsourced cadastral projects lies in the requirement to involve a broad range of participants with varying levels of experience and knowledge, using various methodologies that take into account the particular spatial, temporal, and thematic domain of the cadastral data collection activities.

The internet revolution in the last two decades is known as a "disruptive technology" affecting National Cadastral and Mapping Agencies' (NCMAs) operations. From Web 1.0, which allowed users to view and download information from online databases and geospatial portals to Web 2.0, which encouraged user participation and the use of crowdsourcing techniques to gather data, to Web 3.0, which included data and information for computers to use, this technology offers the best platform. The way NCMAs function and work has also changed as a result of this evolution. NCMAs initially created tools and methods to share their maps and data online (Web 1.0). Nowadays, a large number of NCMAs have a geospatial portal that is functioning. Additionally, many NCMAs are looking into adopting Web 2.0 to enhance their business processes through the usage of crowdsourcing techniques.

Moreover, in order to assist countries and institutions achieve achieving their digital transformation and to bridge the geospatial digital divide in the implementation of the Agenda 2030 for Sustainable Development, it is crucial to investigate the potential for using these new technologies in the cadastral surveys, develop guidelines, and share principles and current trends in legal and policy frameworks. Governments can effectively engage their citizens by empowering them to collect and interpret geospatial data in order to improve the data's usability. The public's participation could also help the digital economy reach its full potential.

The chapter investigates the state of the art as a first step of the research. It includes a historical review of the Sustainable Development and Agenda 2030 and analyses the role of cadastre and geospatial information in fulfilling the goals of the Agenda 2030. It also investigates the progress of citizen participation and gamification tools in government projects and identifies ways to introduce VGI and gamification tools into land administration projects. A literature review is also included on the integration of citizen e-participation into cadastral mapping and land administration and the potential for the integration of gamification tools. Best practices of citizen participation and voluntarism in land management procedures in Greece were also provided as well as collaboration examples between government, the private sector, and the right holders for the Hellenic Cadastre project.

The chapter also investigates international publications to present the Fit-For-Purpose (FFP) Land Administration Approach and its development over time. One of its core components – the FFP spatial framework is presented and analyzed. Moreover, several case studies of best practices in the implementation of Fit for Purpose Land Administration are included.

2.1 Sustainable Development and Agenda 2030

2.1.1 Introduction

In 2015, at the 70th UN General Assembly, all United Nations Member States adopted the Agenda 2030 for Sustainable Development which provides a shared blueprint for peace and prosperity for people and the planet. According to the Agenda preamble (United Nations, 2015), it is a plan of action for people, planet, and prosperity that also seeks to strengthen universal peace in larger freedom, and all countries and all stakeholders, acting in collaborative partnership, will implement this plan.

It consists of 17 Sustainable Development Goals (SDGs) and 169 targets that are of a global nature and of general application with a timetable for implementation by 2030. They create implementation commitments for all developed and developing countries, taking into account different national realities, levels of development, national policies, and priorities. The Agenda 2030 promotes the integration of all three dimensions of sustainable development - social, environmental, and economic - into all sectoral policies while also promoting the interconnection and coherence of the policy and legislative frameworks on the SDGs (United Nations, 2015).

The United Nations Regional Information Centre (UNRIC) states that the achievement of the SDGs requires partnerships between governments, the private sector as well as civil society. These inclusive partnerships, which are based on principles, values, shared vision, and common goals and which place people and the planet at the center, are essential at a global, regional, national, and local level (UNRIC, 2019).

Therefore, the SDGs will not be achieved without significant public awareness and engagement. Citizens and civil society have been actively involved in the SDGs since before they existed mainly through non-governmental organizations (NGOs) and actively contributed to the drafting of the goals through the Open Working Group. Their active participation will hold governments accountable for the promises they made in 2015, so there is an urgent need to find innovative ways of raising public pressure to deliver a more just and sustainable world by 2030 (Desai, et. al, 2018).

In 2018, the UN Department of Economic and Social Affairs conducted the two-year UN E-Government Survey that assesses the e-government development status of the 193 UN Member States (United Nations, 2018) that underlined the critical role of government in ensuring that no one is left behind in implementing the Agenda 2030. It reports that: “E-participation can serve as a catalyst for citizen engagement and in achieving the objectives of the Agenda 2030. Raising awareness of information and services and promoting their use require partnerships with other actors, such as civil society and the private sector. The government is a supplier of services, but the demand for them should be promoted across sectors to overcome multiple challenges of different population segments”.

In accordance with the information provided by the United Nations (United Nations, 2019), 30% of the youth of the world population is "digitally bred" and actively used the Internet for at least five years and the number of Internet users in Africa has almost doubled over the last four years. However, there are still 4 billion people who do not use the internet today with 90% of them belonging to the developing world.

In the context of activating citizens, the United Nations has taken a number of actions such as the “SDGs in Action” application. This application is available in App Store and Google Play with which you can learn about the 17 SDGs, get news on your favorite goals, find out what you can do to achieve them, create your own events, and invite others to join you in sustainable actions and events (UN, 2019), and the action “what is your own goal” which is a Greek Campaign for the SDGs in which you can take a photo with your favorite goal and upload it to Facebook with the tag #yourGoalGreece #SDGs_Greece#theUNinGreek (UNRIC, 2019). Along with the actions, several games have been created to enhance the participation of citizens in achieving the SDGs. Two characteristic examples are the “Go Goals!” board game (United Nations, 2019) and the Sustainable Ideas Game (SIG) (Yudanto et. al, 2017) which intend to raise awareness about the SDGs, encourage personal reflection, and foster social interaction through an SDG-game.

Many of the targets and indicators outlined in the SDGs have a direct correlation with land and various other natural resources, such as SDGs 1, 2, 5, 11, and 15. Numerous cartographic bodies (Ordnance Survey 2006, USGC 2013 and Map Action 2020), alongside regional and government organizations (Antoniou et al. 2009; Haklay et al. 2014), as well as local authorities (for example, in Kibera, Nairobi, Berdou, 2011; in Canada, Begin, 2012; in Tanggamus and Grobogan, Indonesia, Aditya et al. 2020) have integrated volunteerism and citizen engagement into their geospatial initiatives. They have also explored strategies to reinforce this involvement, such as establishing dependable volunteer groups and incorporating gamification elements.

In Greece, since ancient times there has been the spirit of volunteerism and citizen participation with a recent example of the Olympic Games. It is characteristic that in the Olympic Games of 2004, 160,000 citizens participated voluntarily in their conduct (The Olympic Movement, 2004). Other characteristic examples of volunteerism in Greece are identified in the areas of blood donation (NBDR, 2019) and forest protection (GSCP, 2019).

2.1.2 Historical review

Sustainable development is a key concept in the 21st century and is a great challenge for humanity. That is why, in recent years, it has developed internationally into an important priority for the governments, the organizations, the business sector, and the civil society in general. Every sector must understand the complexity and the interdependence of the issues raised, in order to contribute to the search for the right solutions and to commit to concrete actions both at individual and collective levels.

A development that meets the demands of the present generation without compromising the capacity of future generations to meet their own needs is the primary definition of sustainable development (WCED, 1987). More than 178 nations adopted Agenda 21, a comprehensive action plan to create a worldwide partnership for sustainable development to enhance human life and environmental preservation, at the international conference in Rio de Janeiro, Brazil, in June 1992 (United Nations, 1992). At the time, the definition of sustainable development was "development that provides long-term economic, social, and environmental advantages by addressing the demands of present and future generations."

Additionally, the agreements reached at the international conferences in Maastricht in 1992 (EU, 1992) and Amsterdam in 1997 (EU, 1997), as well as the European Union's treaties, all reaffirmed the importance of sustainability. Sustainable development is a continuous process of change and adaptation, not a static situation, with the goal of meeting the needs of the present without reducing the ability of future generations to meet their own needs, through the balanced and equal pursuit of all goals. This is stated in the European Union's strategy for sustainable development, which was first adopted at the Gothenburg European Council in 2001 (EU, 2001) and developed in later relevant texts (Figure 2.1).

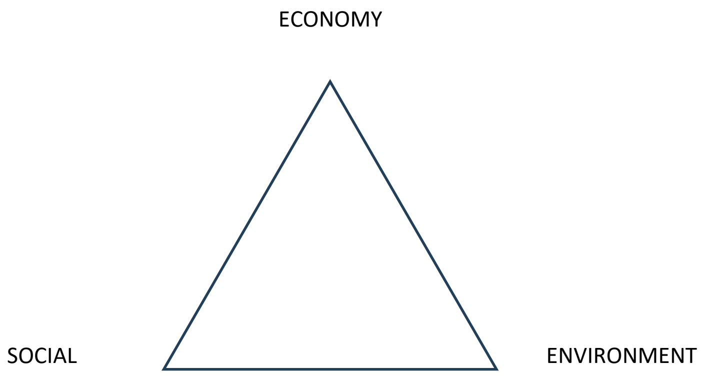


Figure 2.1 *Equilateral Triangle of Sustainable Development.*

For this cooperation to work:

- Weightings that combine a number of criteria at several levels, frequently balancing competing interests and interests that depend on the passage of time.
- Honest, informed, and constructive stakeholder conversation and consultation, which calls for the development of frameworks and the adoption of guidelines for stakeholder interaction.

At the Millennium Summit, at UN Headquarters in New York, in September 2000, all member states of the UN unanimously adopted the Millennium Declaration (United Nations, 2000). Eight

Millennium Development Goals (MDGs) were developed as a result of the summit to end extreme poverty by 2015. Ten years after Rio, the Johannesburg Declaration on Sustainable Development (WSSD, 2003), which was adopted at the South African Summit for Sustainable Development in 2002, reaffirmed the commitments of the international community to end poverty and protect the environment. It built on Agenda 21 and the Millennium Declaration and gave greater weight to global partnerships.

Member states of the United Nations endorsed the text "The Future We Want" in Rio de Janeiro, Brazil (United Nations, 2012), where they determined, among other things, to begin a process of defining new specific goals that will support the MDGs and serve as the foundation for achieving sustainable development. The Rio+20 conference's final report included a number of measures for putting sustainable development into practice, including principles for future work programs like financing the development of Small Island Developing States (isolated, remote coastal communities that are susceptible to widespread harm, destruction, or loss of ecosystems, are sensitive to climate disasters, and have scarce resources).

The UN General Assembly created a 30-member Open Working Group in 2013 to develop a proposal for these new goals (United Nations, 2013). The United Nations (United Nations, 2015) finalized these goals in September 2015. Sustainable Development Goals (SDGs), consisting of 17 primary goals, 169 targets, and 231 indicators, were chosen by 193 member countries and must be accomplished by all nations by 2030. All nations, developed and developing, have pledged to implement the Sustainable Development Goals, in contrast to the former Millennium Development Goals.

With the passage of numerous other significant accords, 2015 was a watershed year for multilateralism and global policy-making:

- The Disaster Risk Reduction Sendai Framework (United Nations, 2015)
- Addis Abeba Action Agenda on Financing for Development (ICOFFD, 2015)
- The agreement known as "Transforming our world: the 2030 Agenda for Sustainable Development," which was endorsed at the UN Summit on Sustainable Development in New York in September 2015, contains the 17 SDGs (United Nations, 2015)
- The Paris Agreement on Climate Change (United Nations, 2015), often known as the Paris Agreement.

Currently, the Division for Sustainable Development Goals (DSDG) of the United Nations Department of Economic and Social Affairs (UNDESA) strengthens nations' abilities to achieve the SDGs and their themes, including water, energy, climate, oceans, urbanization, transport, science, and technology, and provides significant support to countries. It is also tasked with producing an annual progress report on global sustainable development (Global Sustainable Development Report - GSDR). The DSDG plays a key role in assessing the progress of the implementation of the Agenda 2030 as well as in the implementation of its promotion activities to all its stakeholders.

The United Nations Agenda 2030 for Sustainable Development (United Nations, 2015) provides a shared blueprint for peace and prosperity for people and the planet. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call to action by all countries - developed and developing - on the basis of global cooperation. They recognize that ending extreme poverty and other deprivations must go hand in hand with strategies that improve health and education, reduce inequalities, and promote economic growth, while simultaneously tackling climate change and working to save our oceans and forests.

2.1.3 The Agenda 2030

The Agenda 2030's goals and targets for the years 2015 to 2030 coordinate action in areas that are crucial for people, planet, prosperity, peace, and partnerships (5 Ps). According to the UN website, '*the interlinkages and integrated nature of the Sustainable Development Goals are vital to ensure the new Agenda's purpose is delivered. If we realize our vision across the Agenda, the lives of all of us will be substantially improved and our world will be transformed for the better*' (United Nations, 2022).

The UN Charter (United Nations, 1945) serves as the foundation for the Agenda 2030. It is based on the United Nations Millennium Declaration from 2000, the Universal Declaration of Human Rights from 1948, international human rights treaties, and the World Summit Declaration from 2005. (United Nations, 2005). As a strong foundation for the creation of the new agenda, the collective conclusions of all significant UN conferences and summits were also used.

The World Summit on Sustainable Development (WSSD), the Program of Action of the International Conference on Population and Development (UN PF, 1995), the Beijing Platform for Action (BDPA, 1995), and the United Nations Conference on Sustainable Development (Rio+20) (UN, 2012) are among the most significant of these.

The outcomes of the Fourth United Nations Conference on Least Developed Countries (UN, 2011), the Second Conference on Landlocked Developing Countries (UN, 2014), the Third United Nations World Conference on Disaster Risk Reduction, and the Third International Conference on Small Island Developing States (UN, 2014) are also included (UN, 2015).

The issues and commitments discussed at the aforementioned conferences and summits are interconnected and call for all-encompassing solutions. The Agenda 2030's content contains the new strategy that is necessary to properly address them.

The agenda is expected to address, among other things, the following major global challenges:

- the eradication of poverty in all of its manifestations and dimensions;
- employment, particularly among young people;
- threats to global health;
- the fight against inequality within and between nations;
- safeguarding the planet from climate change, desertification, and drought;
- land degradation; water scarcity; loss of biodiversity;
- the depletion of natural resources;
- the most frequent and severe natural disasters;
- terrorism;
- forced population movement;
- creating sustainable communities.

However, this is a period of great potential. Significant progress had been achieved toward many development goals by the time of the epidemic, the energy crisis, and the conflict that followed.

Access to education had considerably improved for both sexes, and hundreds of millions of people had been pulled out of abject poverty. The growth of information and communication technologies, along with global connectedness, particularly during the pandemic, have shown significant promise for securing the advancements made, closing the gap between nations, and creating knowledge societies.

The adoption of the Agenda 2030 for Sustainable Development by all UN member states in September 2015, which includes the 17 Sustainable Development Goals, 169 targets, and 231 indicators, is a significant development for the global community. It marks the first time that universal goals have been established internationally and are expected to be implemented by both developed and developing nations.

For the first time, all UN member states acknowledge the importance of geospatial data and cadastre as essential instruments for achieving the 2030 Agenda's objectives. Because of this, all participating nations are upgrading, enhancing, or finishing their national systems for land administration systems (LAS) and national spatial data infrastructures (NSDI).

The 17 main goals of the Agenda 2030 are as follows (Figure 2.2):

- GOAL 1: No Poverty
- GOAL 2: Zero Hunger
- GOAL 3: Good Health and Well-being
- GOAL 4: Quality Education
- GOAL 5: Gender Equality
- GOAL 6: Clean Water and Sanitation
- GOAL 7: Affordable and Clean Energy
- GOAL 8: Decent Work and Economic Growth
- GOAL 9: Industry, Innovation and Infrastructure
- GOAL 10: Reduced Inequality
- GOAL 11: Sustainable Cities and Communities
- GOAL 12: Responsible Consumption and Production
- GOAL 13: Climate Action
- GOAL 14: Life Below Water
- GOAL 15: Life on Land
- GOAL 16: Peace and Justice Strong Institutions
- GOAL 17: Partnerships to achieve the Goal

Figure 2.2 *The 17 Sustainable Development Goals. Source: UN, 2015 – Own Elaboration*

The Agenda 2030 is the plan of action put forth by the international community to achieve sustainable development for all, which is defined as economic growth that ensures inclusive social well-being as well as the preservation of the environment and natural resources for the benefit of both the present and future generations. As a result of the interconnected nature of the SDGs, all policy areas need to adopt a far more comprehensive strategy.

The SDGs are focused on ensuring that no one is left behind and eradicating all forms of inequality, and the worldwide community is steadfastly committed to accomplishing them by the year 2030. The SDGs offer Greece an important opportunity to recover from the ten-year economic crisis and make the transition to a new development model that balances the three pillars of economic, social, and environmental concerns, according to the Ministry of Environment and Energy (Ministry of Environment & Energy, 2021). Their implementation concerns all social partners, from the public and private sectors and local government to the academic community, NGOs, and civil organizations, who should work together to achieve them. Their implementation goes beyond the bounds and responsibilities of the government and ministries.

A notable illustration of the adage "If we can measure it, we can improve it" is the adoption of 231 indicators to track and evaluate the advancement of the SDGs and their sub-goals. Despite their importance, the majority of UN or government announcements have had little effect, according to this adage (Gates, 2013). Governments can plan operations and estimate expenses in order to draw in the required investment money by tracking and recording ongoing progress through indicators.

2.1.4 The role of cadastre and geospatial information in fulfilling the goals of the Agenda 2030

Cadastre and geospatial information play a crucial role in achieving the Sustainable Development Goals (SDGs). One of the most significant contributions of cadastre and geospatial cadastral information is the provision of legal empowerment of tenants and occupants, of increased security of tenure, and their ability to provide accurate and reliable data on land tenure, land use, and land cover. This information is essential for developing and implementing policies aimed at reducing poverty and promoting sustainable development. Properties, when registered into cadastral systems, may be used as collateral and thus property owners may acquire easy access to credit.

In most developed countries, the security of tenure is taken for granted. However, a rough estimate indicates that for 70 percent of the world's population, this is not the case (McLaren, 2015). In most developing countries, people cannot register and safeguard their land rights, or it is too costly. The majority of these people are the poor and the most vulnerable in society. Therefore, over recent years, LASs have developed to also capture and include more informal and social types of tenure. This is encouraged and supported through the development of concepts such as the continuum of land rights, the social tenure domain model, and aspects of responsible governance of tenure.

Moreover, cadastre and additional geospatial information into the cadastral data sets can support the monitoring and evaluation of the progress of the achievement of SDGs by uncovering inequalities and providing reliable data on various indicators, such as land use, access to resources, and land tenure security. This information can help policymakers to identify areas where progress is lagging and take corrective measures.

Cadastre and geospatial information can also facilitate evidence-based decision-making by providing insights into land use planning, resource allocation, and disaster management. For example, accurate mapping of hazard-prone areas can help to identify vulnerable communities and support the development of effective disaster risk reduction strategies.

In addition, cadastre and geospatial information can help to improve the delivery and improvement of public services, such as health, education, and sanitation. Accurate mapping of population distribution, infrastructure, and access to services can help governments identify underserved areas and allocate resources effectively. Furthermore, cadastre and geospatial information can support the development of smart cities and promote sustainable urbanization. By providing accurate data on land use patterns, infrastructure, and mobility, geospatial information can help city planners design efficient and sustainable transportation systems, optimize land use, and improve access to public services. Finally, cadastral information can be integrated with information derived by sensors and may support the development and operation of digital twins.

Cadastre and geospatial information are also essential for ensuring transparency and accountability in land management and in developing fair land policies. By providing reliable data on land ownership and use, these tools can help prevent corruption and ensure that land is allocated fairly and equitably.

In summary, cadastre and geospatial information are critical tools for achieving the SDGs of Agenda 2030. They provide vital data and insights that are necessary for promoting sustainable development, improving public services, supporting smart cities, and ensuring transparency and accountability in land management.

The following are some of the many indicative targets supported by the existence of cadastre systems:

- *Target 1.4*: By providing accurate and up-to-date information on land use, ownership, and value, cadastre, and geospatial data can help reduce poverty and ensure equal rights to economic resources.

- *Target 2.3*: The use of cadastre and geospatial data can help increase agricultural productivity and efficiency, which in turn can contribute to reducing hunger and malnutrition.

- *Target 5.a*: By improving land administration systems and using geospatial data, it becomes easier to ensure women's equal rights to economic resources, as well as access to ownership and control over land and other forms of property.

- *Target 11.3*: Using cadastre and geospatial data can help cities and human settlements become more inclusive, safe, resilient, and sustainable.

- *Target 13.1*: Accurate and up-to-date geospatial data can help improve our understanding of climate change impacts, as well as support the development and implementation of climate adaptation and mitigation strategies.

- *Target 15.3*: The use of cadastre and geospatial data can help conserve and restore ecosystems, as well as support the sustainable management of forests, wetlands, and other natural resources.

- *Target 16.3*: Improving land administration systems and using geospatial data can help ensure equal access to justice, as well as support the rule of law and accountable and inclusive institutions.

- *Target 17.19*: Improved land administration systems can contribute to the mobilization of domestic resources through the effective taxation of land and property, and support the achievement of sustainable development.

2.2 Crowdsourcing and citizen participation in the Cadastral procedures

2.2.1 E-Government and citizen participation

Without regard to the distance between the information producer and the user, the growth and use of the Internet over the past 20 years, from Web 1.0 to Web 3.0, has made it possible for the information to be distributed and diffused easily, quickly, reliably, and affordably. In response to this change, governments started utilizing new Information and Communication Technology (ICT) capabilities, leading to the development of e-government, which is today known as m-government. Social networks, cloud computing, and mobile communication all fundamentally alter how ICT is used, how people behave online, and what citizens should expect from the government. In addition, a new generation of users with entirely distinct digital needs and physiognomies has already emerged, constituting a critical mass in both the workplace and society whose wants cannot be disregarded (Kavouras and Kokla, 2011). The international bibliographies list Government 1.0, Government 2.0, and Government 3.0 to reflect the consistent development and evolution of e-government (Figure 2.3).

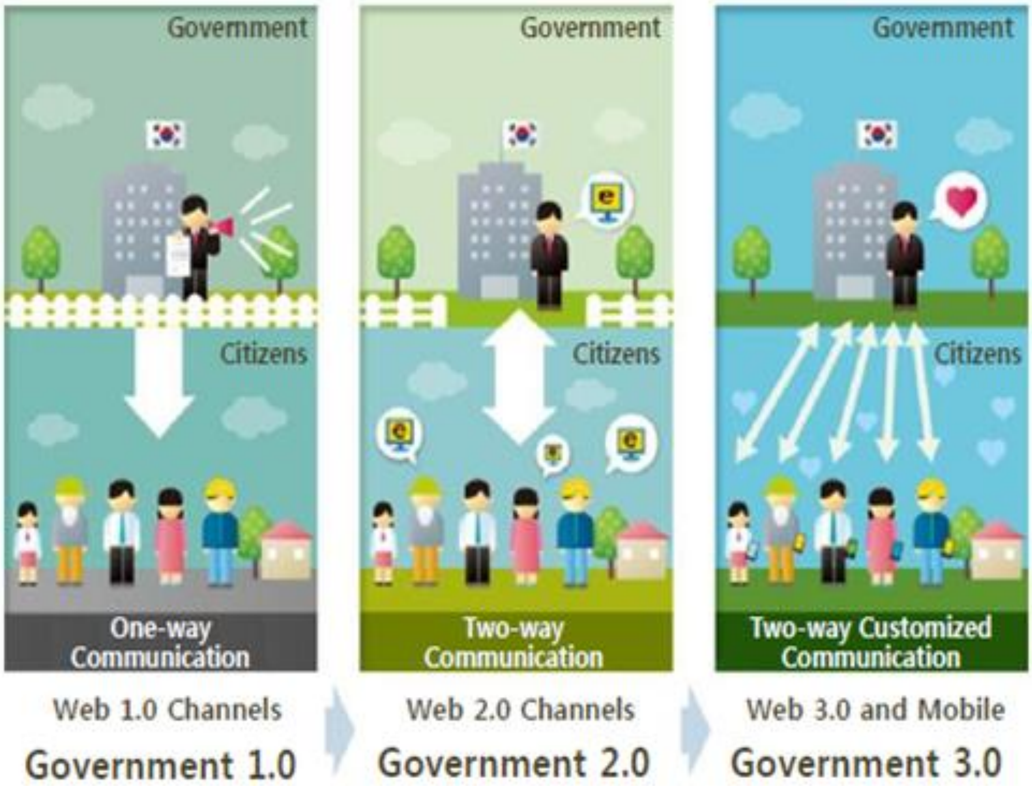


Figure 2.3 *E-government Paradigm Shift. Source: NIA, 2013.*

Tim O'Reilly introduced the phrase "Web 2.0" for the first time in 2005 (O' Reily, 2005) to refer to a revolution brought on by the internet. This was essentially a novel idea for the World Wide Web. It was more about a fundamental shift in how providers and users saw the Internet at its earlier stage, known as Web 1.0, than it was about new technological advancements. Web 1.0 has evolved from a space for mass information consumption to one that is more interactive and participative for both creators and users. According to Bruns (2006), users of Web 2.0 are not just information consumers but also producers, or "produsers," whose outputs are typically referred to as user-generated content.

Governmental operations have been impacted by the rising usage of web technology. Government 2.0 makes use of Web 2.0 technologies to socialize online services, procedures, and information (Nam, 2011). Government 2.0, in O' Reilly's opinion, looks to be an effort to use Web 2.0's benefits for social networking and integration to deliver government services to people and businesses in a more efficient manner (O' Reilly, 2005). Through online comments, live chats, and message boards, collaborative technologies enable two-way communication between citizens and governments (Nam, 2012). Currently, Government 2.0 includes a sizable number of Public Administrations from Member States of the EU and the Organization for Economic Co-operation and Development (OECD) (OECD, 2019). The term Web 3.0, which often refers to existing Web 2.0 concepts, indicates new trends. The focus of Web 3.0, according to Opsahl, is on applications that look for data on behalf of users that is likely to be of interest. Web 2.0 was about users manually contributing data and interacting with one another regarding that data (Opsahl, 2011).

The usage of the semantic web and public information infrastructure at a higher degree of integration can offer new levels of service quality in the area of e-government. E-government 3.0

aims to integrate all forms of contact with citizens, create pervasive e-government, anticipate user requirements, and build an e-infrastructure that will enable increased automation of services and their autonomy. Government 3.0, according to Nam's definition from 2013, is "a Semantic Web-based government that customizes all government services based on the circumstances and preferences of each individual" (Nam, 2013). It was further defined by Perreira in 2018 as "the use of disruptive information and communication technologies (ICTs) (such as blockchain, big data, and artificial intelligence technologies) in combination with established ICTs (distributed technologies for data storage and service delivery) and the wisdom of crowds (crowdsourcing and co-creation) towards data-driven and evidence-based decision and policy making" (Pereira et. al, 2018).

The transition from e-government to m-government, which can be seen as the new frontier of service delivery and a new way to transform the government by making public services more accessible to citizens, has been made possible by the evolution of disruptive ICTs and mobile technologies and their ability to connect to wireless networks (Trimi et al., 2008; Mengistu et. al, 2009).

Essentially, m-government has been defined 'composite approach for efficient exploitation of all wireless devices (Zalesak, 2003), with the aim of improving benefits to the parties involved in e-government' (Kushchu et. al, 2003). The main goal of m-government is to empower citizens through mobile devices in order to 'accomplish reform by encouraging transparency, eliminating distance and other divides' (Thomas et. al, 2003). The development of applications that offer new and simpler ways for citizens to organize themselves, raise issues, take action, connect with their spatially enabled society, and otherwise become "active citizens" is made possible by the growth of mobile Internet (Kavouras, 2005).

According to Conge, the act of participating as a citizen reflects a person's desire to have an impact on how their community is run (Conge, 1988). Alder stated that civic engagement and activities are ways for "an active citizen in the life of a community to improve conditions for others or to help, shape the community's future" in 2005. (Adler, 2005).

The phrase "citizen involvement" is extremely broad and is used differently depending on the domain. According to Gordon, citizen engagement is broadly defined as the collection of political and social behaviors that enable people to participate in and have an impact on public affairs outside of their immediate private sphere (Gordon, et. al, 2013). Additionally, he later revealed that there are numerous administrative goals driving the creation of civic engagement platforms and the adoption of new technology to facilitate two-way contact between the government and citizens (Gordon et. al, 2014). Moreover, Thiel stated that a person's idea of "citizen involvement" will change depending on their background (Thiel, 2016).

Civic participation, according to the World Bank in 2016, is "*the participation of private actors in the public sphere, conducted through direct and indirect interactions of civil society organizations and citizens-at-large with government, multilateral institutions, and business establishments to influence decision making or pursue common goals. Engagement of citizens and citizens' organizations in public policy debate, or in delivering public services and contributing to the management of public goods, is a critical factor in making development policy and action responsive to the needs and aspirations of the people and potentially of the poor*" (The World Bank, 2016).

The Internet, smartphones, blockchain, and sensors, among other modern and disruptive technologies, have developed quickly, opening up new opportunities for citizen participation in the digital sphere. Wide ranges of modern technologies provide ways to support general community building and civic engagement. According to Hassan and Nader (2016), these technologies allow for the development of applications for a variety of unique involvement strategies and incorporate a number of mobile device built-in sensors, such as a gyroscope, accelerometer, and microphone (Ertio, 2013).

According to a study conducted by Nielsen in 2006, participation in online communities follows the 90-9-1 rule, which states that 90% of users are merely information consumers who make no contributions, 9% make occasional or light contributions, and the remaining 1% produce the majority of the information (Nielsen 2006). Furthermore, research on e-participation has emphasized how few citizens use e-government services (Nam 2012) and how unlikely it is for them to use e-government websites and applications for participative and counselling activities (Reddick, 2011). Because the full benefits of m-participation cannot be realized until citizens really interact with full exploitation of these tools, the low level of citizen involvement and engagement is a persistent difficulty for governments adopting online platforms.

We may find a number of definitions and classifications of citizen or civic participation in the worldwide bibliography. The concepts of "participation" and "non-participation" were first articulated by Arnstein in 1969. He developed a typology of eight levels of participation in the form of a ladder, each rung correlating to the level of citizen power in deciding the outcome, from non-participation to varying degrees of tokenism to levels of citizen authority. Additionally, he divided participation into three categories: enabling, engaging, and empowering (Arnstein et. al, 1969).

Information, consultation, and cooperation are other names for these three engagement levels. Different frameworks have given different names to the third one, such as active or full engagement and collaboration. The primary distinction between those levels is the type of citizen-government contact or communication that is used. While information can be seen as a one-way channel where the government creates and provides information for the purpose of the people, consultation is a limited two-way interaction where people can give the government comments on predetermined themes but not new ones. It is based on how information was previously defined. Citizens are asked to share their ideas and opinions, but governments identify the issues for consultation, establish the questions, and oversee the process. By establishing better two-way communication with public input on issues and decision-making, cooperation is categorized. It is a partnership between the citizens and the government when the latter actively participates in defining the manner and nature of policy-making. In the third level, citizens are partners in governance. The more citizens have the ability to participate in decisions the higher the level of participation. Therefore, empowerment refers to giving citizens the chance to influence and participate in the decision-making process (Arnstein et al., 1969; Gramberger et al., 2001). (Thiel, et. al, 2015).

Munster further emphasized that there is no citizen involvement in the design process at the lower levels of citizen participation. Citizens can "identify interests and the agenda, assess the risks, and recommend solutions" at the medium levels. However, it can only be transformed into a "partnership in the ultimate choice" at the highest level of citizen participation (Munster et. al, 2017). In other words, securing three key components—the availability of technology, organizational and management reforms at the level of the public sector that can be in line with the available technology, and user adoption — is necessary to ensure the successful implementation of innovative e-government services.

Therefore, the personalization of e-government services is a method of transformation that may encourage increased citizen engagement (West, 2004; Guo and Lu, 2007). Additionally, if the goal of e-government transformation is to move toward the trend of personalizing e-services, then this transformation may be more successful if public e-services evolve from being purely functional to include some more engaging and enjoyable dimensions while maintaining their goal (Al-Yafi, et al., 2016).

2.2.2 The gamification context

The objective of gamification is to maximize motivation, create a positive user experience, and maintain user engagement. It provides a framework or guidance for designing user interactions and activities. The emergence of modern IT tools and new tools, such as mobile apps, social media, and game technology, have improved and diversified the methods used for civic engagement (Shipley and Utz 2012); they permit the integration of big data of different types (visual, textual, audio, etc.) and their presentation in user-friendly formats (Gramberger 2001; Kleinhans et al. 2015).

There are various definitions of gamification that can be found in the international bibliography. According to Deterding et al. (2011), gamification is "the use of game design components in non-game contexts," which implies that the presence of game-like characteristics in a system is a criterion for deciding if it is gamified for the purpose of enhancing user experience and engagement. In 2016, Huotari and Hamari conducted a thorough analysis of this definition.

The elements of this definition, according to their analysis, are listed as follows (Huotari and Hamari, 2016):

- *the use (rather than the extension) of*
- *design (rather than game-based technology or other game-related practices)*
- *elements (rather than full-fledged games)*
- *characteristic for games (rather than play or playfulness)*
- *in non-game contexts (regardless of specific usage intentions, contexts, or media of implementation).*

Additionally, in 2011 Schell described it as "a problem-solving environment that you enter into because you want to" and Reynolds described it as "a system where you utilize game features to try to convince people to do what they don't want to" (Schell, 2011), (Reynolds, 2011). Later on, in 2012, Huotari and Hamari defined it as "*a process of providing affordances for gameful experiences which support the customers' overall value creation*" and as a "*service packing where a core service is enhanced by a rule-based service system that provides feedback and interaction mechanism to the user with an aim to facilitate and support the users' overall value creation*" (Huotari and Hamari, 2012).

Along these, Llagostera (2012) and Burke (2014) provided additional definitions for gamification, presenting it as a system that is able to "*apply game mechanics in everyday applications and situations to boost engagement, fun, and good behavior*" and as "*a use of game mechanics and experience design to digitally engage and motivate people to achieve their goals*".

However, the majority of the earlier definitions were founded on the idea that while there isn't a well-defined set of game features, gamification mostly results from the usage of game design elements. Only a handful of them, as Huotari and Hamari have already indicated, defined gamification as *"a process of enhancing a service with motivational affordances for gameful experiences in order to support users' overall value creation"* (Huotari and Hamari, 2016). More particularly, their concept of gamification places a strong emphasis on the psychological and motivational states that are elicited in users by the motivational affordances. This suggests that the psychological effects are more important to gamification than its design and that these outcomes may serve as "mediators" for behavioral output. Figure 2.4 depicts these crucial elements: design (gamification affordances), and psychological and behavioral gamification effects.

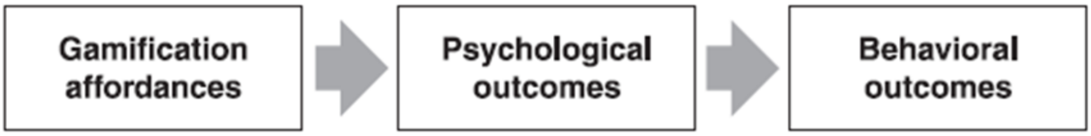


Figure 2.4 *Key aspects of gamification. Source: Huotari and Hamari, 2016.*

Regarding the above strategy, Rigby and Ryan in 2011 highlighted the significance of the psychology and motivation of the gamer at the center of the design of a gamified activity (Rigby and Ryan, 2011). Furthermore, according to Deterning's 2011 statement, gamifying any activity requires more than just adding a "layer" of game-like components; it also requires giving people the impression that they are "playing a game". Users should be able to feel engaged and in the right circumstances to make meaningful decisions depending on the obstacles they will face thanks to the gamified system (Detering et al., 2011). Morschheuser further stated that "gamification refers to design that seeks to, first, increase the motivation of users or participants to engage in an activity or behavior and, second, to increase or otherwise change a given behavior" (Morschheuser, et. al, 2017). As a result, the research community has put a lot of effort into defining and pinpointing the proper motivational factors that could increase user engagement and participation. These factors are well recognized to have several manifestations. They concentrate on discovering the motivations behind satisfying human needs, which can be done either internally (internal factors) or extrinsically (external factors). The list below includes a few of these theories of motivation.

According to Ryan and Deci's theory from 2000, users' urge to play is driven by their "innate psychological demands". They divided these demands into three categories (Ryan and Deci, 2000):

- Autonomy, which describes the willpower required to carry out an activity for one's own benefit.
- Competence, which refers to a person's drive to take on challenges and to feel effective and competent in addressing them.
- Relatedness, occurs when a person connects with others in a way that makes them feel secure.

Bartle offered yet another classification of gamers' motivations in 2004. He divided the players into three different groups. According to this hypothesis, gamer's motivation depends on their personality type (Bartle, 2004) as follows:

- Achievers, players who are motivated by in-game objectives, typically some sort of point accumulation.

- Explorers, players with a strong desire to learn everything they can about the gaming world, including its geography and game mechanics.

- Socializers, players who interact and role-play with other players while playing a game. They take advantage of the gaming environment to distress other players, and they find satisfaction in making other people feel uncomfortable and anxious.

Additionally, in 2009, Pink configured another categorization of gamer motivation related to three elements of personal satisfaction. These elements can be recognized as follows (Pink, 2009):

- Autonomy, which is the desire of individuals to control their own lives and how they do their jobs.

- Mastery, which is the desire to achieve personal satisfaction through challenges that fit the capabilities of individuals.

- Purpose, which is the sense of consistency of intrinsic needs as a way to attain personal fulfilment.

Later in 2011, Zichermann and Cunningham discussed the value of external rewards related to gamification. These incentives might increase, reinforce, and hasten a user's natural motivation. However, they emphasized that because of their negative effects on users' motivation, their incorporation in the gamification process may have irreversible effects on its operation (Zichermann and Cunningham, 2011). In addition, Hamari highlighted that various psychological and social processes, like recognition, network externalities, social comparison, and goal-oriented behavior, are connected to the gaming experience in 2013 (Hamari, 2013).

How to effectively combine the crowdsourcing technique with gamification is another crucial question for the research community. In order to positively impact citizens' behaviors (such as participation, concentration, work duration, engagement, or work quality) in crowdsourcing projects, it is essential to be able to harness their motivation (Morschheuser, et. al, 2017). Participants in these initiatives have a variety of experiences, skills, knowledge, and motivations, which are typically combined for a shared crowdsourcing objective (Barron et al, 2016).

These gamified crowdsourcing projects are supported either by one of the following four parties or by *a combination of them* (Huotari and Hamari, 2016)*:*

- the core service provider,

- a third-party service provider,

- the customer him- or herself,

- and another customer.

Over 3000 crowdsourcing-related examples are listed on crowdsourcing.org, a popular crowdsourcing website (Crowdsourcing.org, 2015). Additionally, it is anticipated that by 2015, the gamification of some processes has occurred in at least 50% of all organizations that manage innovation processes (Morschheuser et. al, 2017). Besides this, gamification has a good impact on crowdsourcing labour, either through improved motives or contributions, according to Morschheuser's research from 2017 (Morschheuser, et. al, 2017). Additionally, he created a conceptual framework for a gamified crowdsourcing system (Figure 2.5).

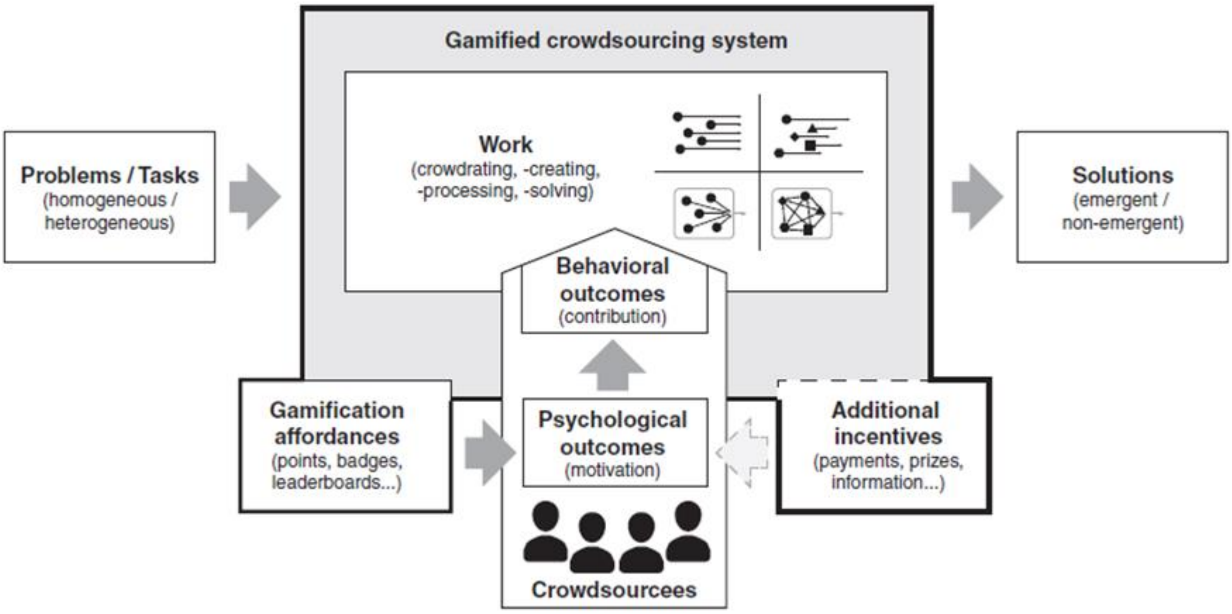


Figure 2.5 *Conceptual Framework of Gamified Crowdsourcing Systems Source: Morschheuser et al., 2017.*

Projects using gamified crowdsourcing techniques exist in a variety of fields, such as digital navigation and cartography. The creation of digital maps using crowdsourced data, the collection of location-based sensory data (Kawajiri et al., 2014; Wang et al., 2015), geospatial data (Goncalves et al., 2014), location measurements (Uzun et al., 2013), and the collection of indoor navigation data (Reinsch et al., 2013; Bockes et al., 2015) are just a few of the studies in this field that are available in the literature.

2.2.3 Best Practices of Citizen Participation and Voluntarism in Land Management Procedures in Hellas

This section investigates and focuses on two crucial aspects: (a) examples of volunteerism and citizen engagement have been incorporated in Greece, and (b) the partnership formed between the government, private sector, and civil society regarding the Hellenic cadastral project. The purpose is to gauge the accomplishments of the project and pinpoint areas that require attention to ensure its continued success. The ultimate goal is to establish a three-way alliance that will advance the Hellenic Cadastre project.

2.2.3.1 Voluntarism Examples in Greece

The Olympic spirit of volunteerism has been a longstanding characteristic of Greek culture since ancient times (The Olympic Movement, 2004). This was clearly evident during the 2004 Olympic Games when over 45,000 Greek citizens volunteered to participate in the organization of the main event, and another 15,000 volunteered for the Paralympic Games. This example illustrates the involvement of a large number of volunteers for a limited period of time, motivated by the international significance of the event and national pride.

The development of e-government has facilitated voluntarism and citizen participation in various sectors in Greece. For instance, the Municipality of Kifissia has created a reward program for citizen voluntary participation, which includes honorary awards, certifications, letters of recommendation, and appropriate clothing equipment such as gloves, hats, and boots depending on the activity (Municipality of Kifissia, 2019). This exemplifies the activation of a smaller group of volunteers for a longer period of commitment.

Furthermore, other examples of voluntarism and citizen participation include blood donation (National Blood Donation Registry, 2019), forest protection (Greek Society for the Conservation of Nature, 2019), and cleaning of the coastal zone projects. The participatory action of blood donation is supported by a unified, innovative information system for the management of the National Blood Register, with approximately 630,000 citizens registered to date. As for forest protection, the ability to enroll as a volunteer firefighter after passing an examination has been institutionalized, and incentives such as social insurance, appropriate equipment, and psychological support have been established due to the nature of the action (Greek Society for the Conservation of Nature, 2019).

2.2.3.2 Collaboration between government, private sector, and right holders for the Hellenic Cadastre project

Prior to 1995, the existing Land Registry System in Greece did not have full support from cadastral maps. This meant that cadastral surveys, which are used for a variety of purposes including city planning and land consolidation, relied heavily on a participatory process where landowners would declare their rights to their land and identify their parcels in the field or through aerial photos and/or orthophotos. This participatory culture in land administration issues has been present in Greece for a long time.

However, the weaknesses of the land registry system in Greece made it necessary to establish the Hellenic Cadastre in 1995. This project aimed to introduce a more reliable and accurate land registry system that was backed by cadastral maps. To improve the system, the adjudication of owners was planned to be a participatory, self-declaration procedure, and the surveying process was outsourced to the private sector through a tender procedure. This partnership between the cadastral agency and the private sector was established to compile the Hellenic Cadastre, which would provide a comprehensive and reliable source of land information for various purposes.

The establishment of the Hellenic Cadastre was a significant milestone in the modernization of the land administration system in Greece. It has brought greater efficiency, transparency, and accountability to the management of land-related information, and has enabled the government to better implement land policies and projects. The participatory approach to land registration has also contributed to the development of a more inclusive and democratic land governance system in Greece.

The state and other landowners are required to declare their ownership rights and identify them on aerial photos or orthophotos. The traditional method encourages property owners to participate by electronically submitting required documents and data, involving a large number of people but for a specific task and a short time. All landowners must provide necessary documents to the private surveyors (contractors) responsible for cadastral mapping.

At the same time, a scientific study was launched to assess and verify the dependability of cadastral data obtained from landowners or non-experts through crowdsourcing. The study focused primarily on the technical aspects and precision of the geometric measurements achieved using mobile apps. The research team of the Laboratory of Photogrammetry of NTUA has been studying the perspectives and participation of citizens in land administration since 2012. The potential of using crowdsourcing techniques for cadastral mapping (Basiouka and Potsiou, 2012) has been explored, as well as the motivations of citizens (Basiouka and Potsiou, 2013). In 2014, a collaboration with the Hellenic NMCA investigated the enhancement of cadastral Surveys by facilitating owners' participation (Mourafetis et al., 2015) and introduced new technology, including citizen participation and m-services/m-government (Gkeli et al., 2016). Based on the experiences from the cadastral projects in Greece and Romania, a crowdsourced cadastral surveying procedure has been developed, which was modeled, and tested (Potsiou et al., 2020). After assessing available technology and developing a methodology for crowdsourced cadastral surveys, the next step was to assess citizen participation at all phases of a project. To do so, several issues should be investigated, such as citizen engagement in the various tasks of cadastral surveying, the skills needed by volunteers for each task, the necessary size of the volunteers' group, the required time and duration of their commitment for each task, the evaluation and assessment process of their products and reliability, as well as the level of empowerment that should be given to them.

2.2.3.3 Cadastral applications in the Hellenic Cadastre project

The efficiency of the existing tools (developed by the private surveyors and the Hellenic NCMA) utilized by citizens to declare their property rights at the Hellenic cadastral project is evaluated. To assess citizen participation, a group of 25 volunteers who possessed the necessary skills and had a long commitment to the current research (Basiouka et al., 2015; Apostolopoulos et al., 2018) participated to test the tools.

The tested tools are the following:

i. the KT5-20 application;
ii. KTHMA.gr;
iii. The TeleKtima;
iv. MyKtimapoints;
v. an application using the Esri's Collector for ArcGIS;
vi. the platform developed by the Greek Cadastral Agency.

The (i), (ii), (iii), (iv), and (v) tools have been designed by the private sector (the cadastral surveyors/ contractors) to make it easier to collect cadastral data for the cadastral surveys they were in charge of. The findings of these applications' testing by the group of reliable volunteers are listed below along with a brief description of each application.

i. The KT5-20 application has been developed by a consortium of cadastral contractors for the Laconia Regional Unit of Greece. This application allows the citizens/ right holders to browse through the preliminary basemaps prepared by the contractors, locate their land parcels, and print extracts that they can attach to their formal declaration (Figure 2.6 top). The main environment of the application consists of two synchronized maps (aspects) and a table where information about the selected fields is presented (Figure 2.6 bottom).

ii. KTHMA.gr is another application that has been developed in Greece for cadastral procedures by contractors. This application can support the cadastral procedure for the Regional Units of Chalkidiki, Drama, Xanthi, Kastoria, Florina, Magnisia and Kozani. Citizens/ right holders can choose among different basemaps and can quickly and simply locate their parcel (Figure 2.7). With this application, the citizens can locate their parcel, delineate it on the basemap and print an extract with its coordinates on the Greek Grid Reference system and its calculated area. The citizens can use the printed extract to declare their parcel through the Cadastral Office or electronically through ktimatologio.gr.

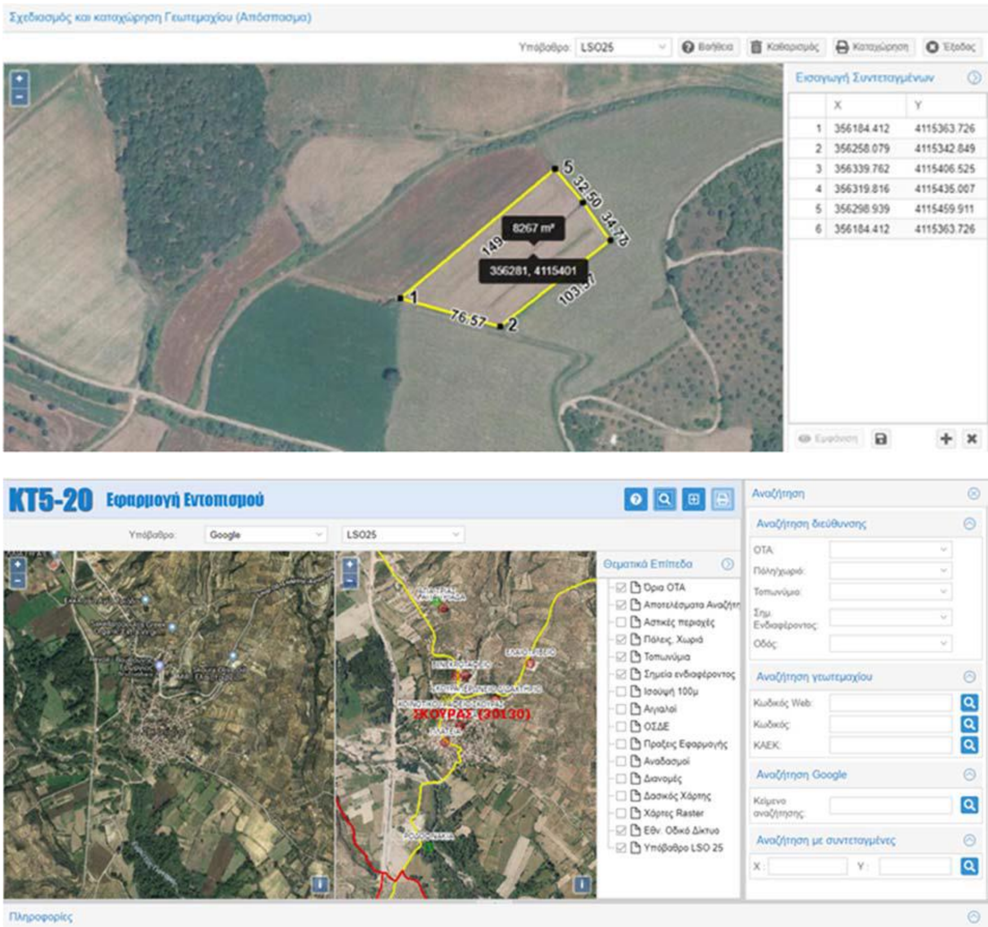


Figure 2.6 *(top) Printed extract of the identified land parcel. (bottom) KT5-20's main interface with two synchronised maps. Source: Apostolopoulos & Potsiou, 2021.*

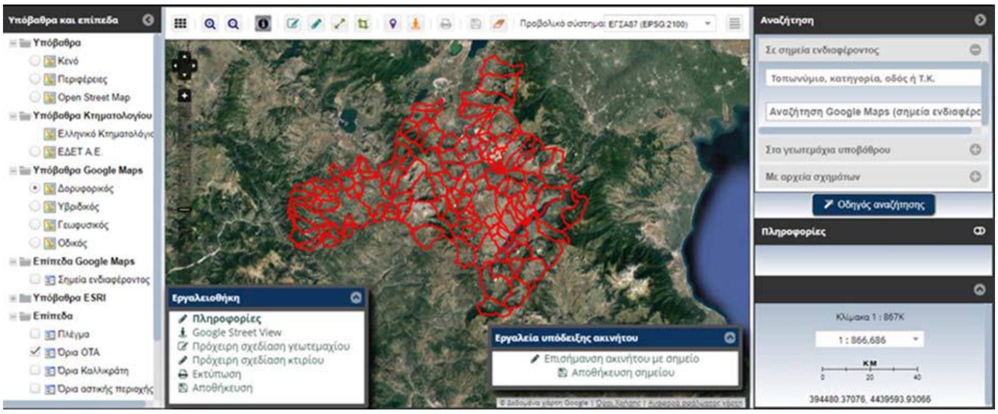


Figure 2.7 *TeleKtima's application interface. Source: Apostolopoulos & Potsiou, 2021.*

iii. The TeleKtima application is another application that was developed in Greece for cadastral surveying purposes. It is developed by the same consortium of contractors as the KTHMA.gr application that is described above and it can be used in the Regional Units of Florina and Kozani. With the Telektima, citizen/ right holders can identify and send the coordinates of their parcel boundaries to the contractor's office, who can use them at a later stage to digitally display the land parcel boundaries in the available basemaps (Figure 2.8). The land parcel's coordinates can be forwarded to the relevant recipients (e.g., Cadastral Offices) or the interested citizen with a small fee. This application is available in both desktop and mobile versions.

Figure 2.8 *KTHMA.gr application interface. Source: Apostolopoulos & Potsiou, 2021.*

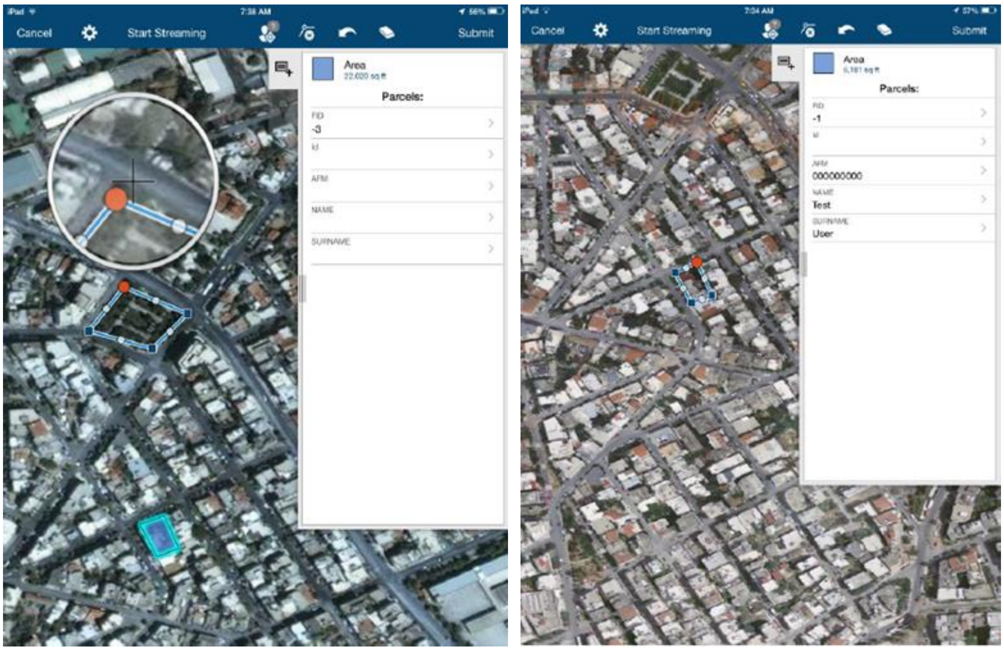
iv. MyKtimapoints is an application that has been developed by Hellenic NCMA's contractors to facilitate the cadastral surveying procedure. This application can be used to support the cadastral procedures of the Regional Unit of Lasithi in the region of Crete. With this application, citizens/ right holders can locate their land parcels on the available basemap

(Google Maps), delineate them, and save it in the application DB. Then, they can print an extract of it, including its coordinates on the Greek Grid Reference system and its calculated area, and receive a unique code number that will be stored in the system (Figure 2.9). With this printed extract and the unique code, the citizens/ right holders can complete the declaration of their rights in the Cadastral office.

Figure 2.9 *MyKtimapoints platform's printed extract. Source: Apostolopoulos and Potsiou, 2021.*

v. An application has been developed, applied, and tested (Mourafetis et al., 2015; Apostolopoulos et., al 2018; Potsiou et al., 2020) using Esri's Collector for ArcGIS as part of this research on the subject of engaging citizens in the fields of cadastral mapping and land administration. This application is a configurable version of ESRI's ArcGIS online. ESRI's ArcGIS online provides organizational accounts where groups of users can be defined with various levels of operational capabilities. These accounts may be bought from ESRI, but for the needs of this research free account for academic purposes that offers full functionality is offered.

The application provides all the necessary functionality for completing the task of declaration. Citizens/ right holders may digitize their properties (Figure 2.10 a) and complete the declaration form with their property's descriptive information, either online or offline. They may then fill in the necessary attributes as well, such as personal data and the property's descriptive information (Figure 2.10 b). In addition, the application allows attachments such as photos taken with the mobile's camera. Moreover, a video guide has been established, that sets out in detail the operation and usage of the application



(a) **(b)**

Figure 2.10 (a) *Digitizing land parcel boundaries and making refinements.* ***(b)*** *Right: Completion of property's descriptive information. Source: Apostolopoulos and Potsiou, 2021.*

vi. In 2019, a more sophisticated platform was developed and made available by the Hellenic NCMA (Mourafetis and Potsiou, 2020) for the purpose of enabling citizens/right holders to locate and digitize the boundaries of their property and submit a declaration of property rights directly to the cadastral agency without the involvement of the contractors. The use of this application is optional; alternatively, right holders may -if they wish- submit their declaration at the private cadastral offices (Hellenic Cadastre, 2019).

Through the electronic platform of the Hellenic NCMA, the citizens/right holders are enabled with the following options: (a) identify their land parcels, (b) digitize the boundaries, (c) submit their property rights and print an extract of their submission, (d) check the outcome of the cadastral survey during the public presentation of the collected cadastral data, (e) submit an objection request during the preliminary public presentation (if errors are detected) and (f) submit a correction application during the public presentation (Figure 2.11). The platform, also, includes a tool that allow spatial data validation, and an automated checking of the crowdsourced spatial data for the majority of the cases, so that all gross errors in the geospatial location of the property units will be avoided. The use of the electronic platform is free of charge and is supported by a user guide and is available both in desktop and mobile versions.

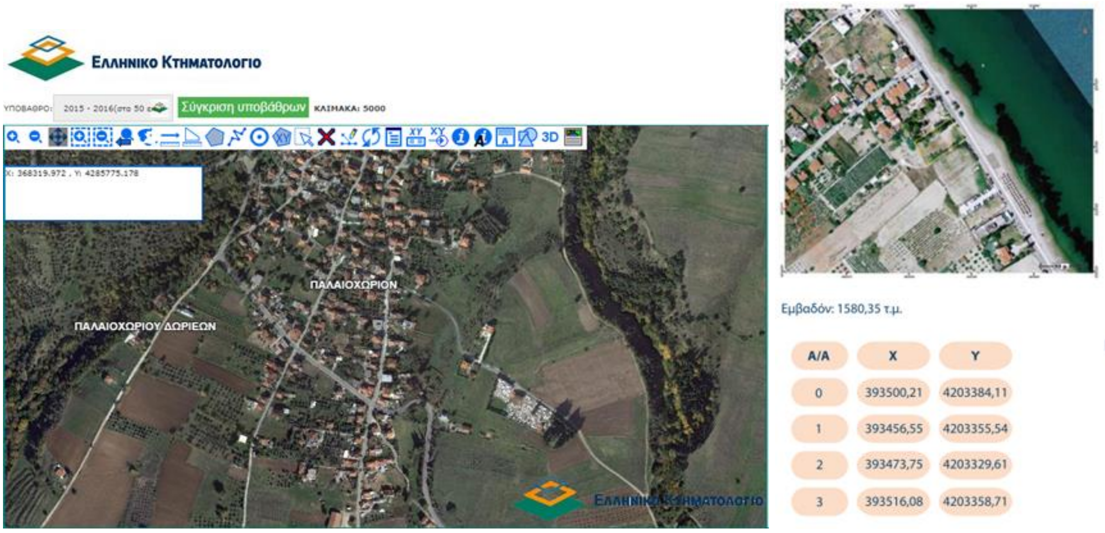


Figure 2.11 *(a) Ortho-image View Application that is free of charge, electronically available at ktimatologio.gr. (b) Printed image of the parcel declaration. Source: Apostolopoulos and Potsiou, 2021.*

The private sector had created these tools (Table 2.1) to assist the cadastral procedures during a time when the declaration phase in Greece was only carried out physically in cadastral offices with the presence of right holders. However, with the introduction of the new digital platform in 2019, these tools became obsolete as the official cadastral tool could fully support cadastral processes at all stages, including the declaration phase and addressing objections in forest areas and geometric objections.

Table 2.1 *Cadastral applications in the Hellenic Cadastral project. Source: Apostolopoulos & Potsiou, 2021.*

	User guide	**Time/ parcel (min.)**	**Price**	**Desktop / Mobile**	**Upload**	**Data save types**	**Basemaps**
Hellenic NCMA	√	20' (10' for parcel identification)	Free	Desktop/ mobile	Right holders' data, documents, drawings (AutoCAD DXF, ASCII ή GML)	Pdf + Coordinates + Area	LSO 25 (2007-09), LSO 25 for Attica and Cyclades regions (2010) Aerial photos of 1945
KT5-20	√	10'	Free + Premium features for land surveyors	Desktop	Coordinates	Pdf + Area + Unique code on the system	LSO 25 (2007-09), Google maps, Street View, OpenStreet Maps, Bing maps, aerial photos of 1945

KTHMA.gr	√	10'	Free	Desktop	ESRI Shapefile, AutoCAD or Google Earth (shp, shx, dbf, cpg, prj, dxf, dwg, kml, kmz)	Pdf + Area	LSO 25 (2007-09), Google maps, Street View,OpenStreet Maps, Esri's Basemaps
TeleKtima	√	10' (for the desktop version) Depends on the parcel (for the mobile version)	5 euros per parcel (10 euros min) + VAT	Desktop/ mobile	Partially right holders' data, mobile's GPS location	Coordinates upon request	Google maps
myKtimapoints	√	10'	Free	Desktop/ mobile	mobile's GPS location	Pdf + Coordinates + Area + Unique code on the system	Google maps
Esri's Collector for ArcGIS	√	20' (10' for parcel identification - may vary depending on the shape and extent of the land parcel)	Free account for academic purposes	Desktop/ mobile	Right holders' data, photo attachments, mobile's GPS location	ESRI Shapefile & shp, shx, dbf, cpg, prj, dxf, dwg, kml, kmz	LSO 25 (2007-09), Google maps

2.2.4 The Fit-For-Purpose (FFP) Land Administration Approach

Many developed nations have robust land institutions and regulations that safeguard peoples' relationships with their land and offer land administration services to protect and frequently guarantee land rights. These services directly assist the land markets that support modern economies. However, an often-quoted accurate estimate shows that for 70% of the world's population, this is not the case (McLaren, 2015). People are prohibited from taking part in formal land administration systems and are unable to register and protect their land rights. Since they have no level of tenure security, the majority of them are the poorest and most vulnerable members of society who live under continual threat of eviction.

An estimated four billion land units are impacted by this security of tenure gap, most of which are concentrated in areas of new and expanding urbanization, which is extremely dynamic and places great strain on land and natural resources. Conflict and land grabbing are often caused by a lack of security of tenure. The inability of residents to engage in economic progress is significantly hampered by this lack of secure tenure, which also generates enormous instability and inequities. Due to the related land risk, it also undercuts improved environmental care and discourages responsible private investment. Ineffective institutions, inappropriate laws and regulations, high costs, complexity, a lack of capacity, poor maintenance, lengthy implementation times, and a large degree of inappropriateness for the local context and conditions have all contributed to the failure of attempts to implement conventional land administration solutions to tight the security of tenure gap. To create systems that are economical, pro-poor, scalable, and sustainable, it is necessary to find new and creative ways to determine how all land is inhabited and exploited. The Fit-For-Purpose (FFP) approach to land administration has had a significant impact and offers a workable option for controlling land usage and ensuring tenure security.

The FFP approach, which does not favor the most recent technology or expensive, time-consuming field survey procedures, is directly influenced by the needs of the nation for handling present land challenges. Depending on the size of the country, it addresses all tenure types and all land that is feasible and attainable in a fair amount of time. The "Minimal Viable Product" (MVP) methodology is used to develop an entry point solution that initially meets the needs of all the stakeholders. When necessary and appropriate in view of societal development, the result can then be improved in terms of the quality and variety of the evidence of land rights information. It can be modified to meet the needs of various regions within a country. Finally, the development and maintenance of this approach are sustainable because of the network of locally educated land officers who increase the reach of the limited available worldwide land experts.

A number of adjustments to the institutional, legal, and regulatory frameworks are also made as part of the process of implementing the FFP approach to provide nationwide solutions for land administration. A typical change process would start by establishing an environment that was flexible enough to support FFP methods and would ultimately necessitate removing any obstacles and limitations.

A fit-for-purpose approach includes the following elements according to (Enemark et al., 2014):

- **Flexible** in the spatial data capture approaches to provide for varying use and occupation.
- **Inclusive** in scope to cover all tenure and all land.
- **Participatory** in approach to data acquisition and use to ensure community support.
- **Affordable** for the government to establish and operate, and for society to use.
- **Reliable** in terms of information that is authoritative and up-to-date.
- **Attainable** to establish the system within a short timeframe and within available resources.
- ***Upgradeable*** with regard to incremental improvement over time in response to social and legal needs and emerging economic opportunities.

The FFP approach's starting point is comparable to the MVP in a product development context; this is the product with the best risk-to-reward ratio. This strategy is very relevant for developing and enhancing FFP land administration solutions. The initial FFP land administration solution only needs to fulfil the goal by satisfying the minimal demands of the countries. The approach can then be improved over time through a number of actions as demand for new requirements arises. In accordance with the country-specific FFP land administration strategy, each country's starting place may change and be steadily incrementally improved.

Three key characteristics constitute the FFP approach as follows (Enemark et al., 2016):

a) Focus on the purpose

In order to implement best regulatory practice, the approach must first focus on the "what" in terms of the desired outcome before creating the "how" to be the best "fit" for achieving the purpose. The main objectives of land administration systems are typically identified as ensuring everyone has a secure tenure, but they also facilitate access to credit and investments, property valuation and taxation, planning, and control of the usage of land and natural resources, aiding in land development, and providing land information to endorse land policy decision-making. Therefore, a spatial framework is required for the systems to function. This framework should identify and delineate the ownership and use of the various land parcels. Once more, this structure should be created in accordance with the purpose. For instance, accurate boundary surveys are not necessary per se for the security of land tenure; rather, the land parcel merely has to be sufficiently identified on a basemap.

b) *Flexibility*

Being adaptable to fulfill actual needs for certain tasks and locations is a crucial component of the FFP approach. It involves being flexible with regard to the requirements for accuracy, interoperable spatial information, and the recording of a range of various tenure types, as well as with regard to modifying the legal and institutional framework to best meet societal needs. The flexibility relates to fostering this variety of land rights, whether they be de jure or de facto, that may eventually be acknowledged by a state institution like the local government or validated by a social institution. Additionally, the recording process itself necessitates flexibility not only in terms of the "what" (the tenure type), but also in terms of the "who," which can be either a citizen, as well as a family, tribe, community, village, or farmers' cooperative; and the "where," which is not always a specific land parcel or spatial unit but can change depending on where rights and social relationships apply. The FFP approach offers a conceptual solution to these land right issues in a straightforward manner.

c) Incremental improvement

The systems must be built to first satisfy society's most basic demands while also allowing for incremental improvement over time in response to social and legal requirements for economic growth, investments, and potential profit opportunities in the long run. The use of an FFP approach does not restrict expectations for a final solution, such as those in line with some cutting-edge systems employed mostly in industrial countries. Additionally, it has to do with the "minimum viable product" (MVP). Focusing on the purpose, such as ensuring everyone has a secure job, the MVP is about finding the best approach to do this by weighing the costs, accuracy, and time. For instance, it will be quite expensive to conduct quick and precise field surveys. The product can also be established rapidly and affordably using the FFP approach, but the accuracy will not be as precise as it could be. This equilibrium will alter, though, as the system of land administration keeps evolving. Therefore, more expensive and accurate procedures can be used because there is more time once everyone has registered using the fast and inexpensive way.

2.2.4.1 The development of the FFPLA method over time

"Land administration" has its origins in the cadastral and land registration systems that were initially created to provide information about land value, ownership, and land use categories (FIG, 1995). These systems were developed for different purposes in various cultures, judicial systems, and regions worldwide. The primary distinction between these systems is whether only the transaction is recorded (deed systems) or the title itself is documented and secured (title systems). The cultural and legal differences relate to whether a country's legal system is based on Roman law (deed systems) or German or Anglo common law (title systems). This variation is also evident regarding the influence of colonization's legacy.

In the past, "land administration" was a term used to describe the processes involved in identifying, recording, and disseminating information about land ownership, value, and use, which was essential in implementing land management policies (UNECE, 1996, Dale et al, 1999). However, recent years have seen a shift in focus towards designing land administration systems

(LASs) that function as infrastructure to support sustainable development by enabling the implementation of land policies and management strategies (Williamson et al. 2010). This shift in focus has resulted in changes in the type and quality of information required for LASs. The LASs comprise four operational components: land tenure, land value, land use, and land development, which ensure proper management of property rights, land use restrictions, and responsibilities concerning natural resources, including the marine environment. However, the foundation of such solutions is the land tenure component, which establishes the relationship between people and land by recording information about land parcels.

Developed countries have mature land institutions and laws that protect the relationship between people and land, ensuring the security of tenure. However, this is not the case for approximately 70% of the world's population, especially in developing countries, where people cannot register and safeguard their land rights due to cost constraints (McLaren, 2015). Typically, the poorest and most vulnerable individuals in society face the brunt of this issue. In response, LASs have evolved to include more informal and social types of tenure, such as the continuum of land rights, the social tenure domain model, and aspects of responsible governance of tenure (GLTN, 2008; FIG, 2010; FAO, 2012; Zevenbergen et al, 2016). These concepts aim to capture and integrate such tenure arrangements, which are crucial to ensuring that people have equitable access to land and resources.

The main catalyst for this transformation has been the global agenda aimed at eliminating poverty, ensuring food security, promoting gender equality, and protecting human rights, among other objectives. This agenda was established by the Millennium Development Goals (MDGs) in 2000 and was later succeeded by the Sustainable Development Goals (SDGs) in 2015. The agenda has emphasized the importance of securing land rights and has established targets and measures to monitor progress toward achieving these goals. In addition to this, technological advancement has been another driving force, as it has made it easier to access innovative mapping and surveying techniques, such as satellite and drone imagery, handheld GPS, mobile phones, and methods for managing vast datasets (World Bank, 2017).

Over the years, efforts towards providing secure land rights at a large scale have resulted in the development of the FFPLA approach in 2014 (Enemark et al. 2014; Enemark et. al, 2016). This approach is aimed at meeting the challenges of delivering secure land rights at scale within a specific jurisdiction. The approach comprises of three interconnected frameworks: the spatial, legal, and institutional frameworks, which work together to deliver the desired outcomes as depicted in Figure 2.12. The FFP approach is deemed appropriate and necessary to achieve the objective of providing secure land rights at scale within a specific jurisdiction.

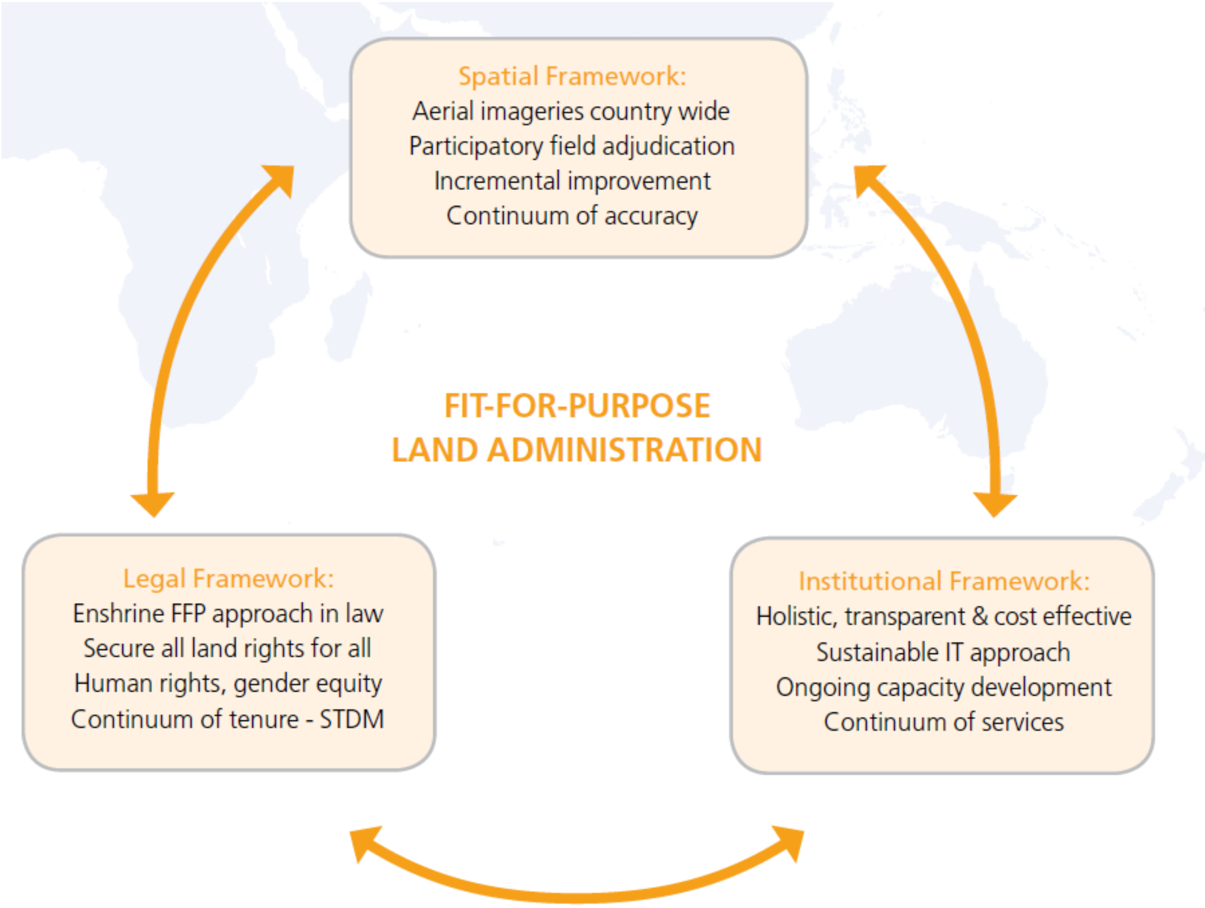


Figure 2.12 *The Fit-For-Purpose concept. Source: Enemark et al., 2016.*

For this PhD, it was decided to focus on the geospatial aspect of the FFP approach, referred to as the spatial framework. Unlike highly accurate regulations, the level of detail and accuracy in this representation is driven by the user's needs in identifying land parcels as a foundation for securing various legitimate rights and tenure forms, as outlined in the legal framework. The institutional framework, in collaboration with partnerships, manages land rights, usage, and natural resources while providing comprehensive and accessible services. (Enemark et. al, 2016). The approach is adaptable, cost-effective, participatory, and can be improved over time.

2.2.4.2 FFP Spatial Framework

The FFP approach encourages the use of a variety of scales of satellite/aerial imagery as the spatial framework to identify and record visible boundaries in order to considerably speed up the process of documenting land rights. The majority of land rights boundaries may be determined using this efficient, affordable, and highly participative method. When necessary, high-value land and properties, as well as invisible or disputed boundaries, can be the only places where high accuracy and expensive conventional field surveying techniques are used. With this approach, less experienced locals can receive training and work in the cadastral surveys. This is crucial because it enables the FFP approach to be very scalable and supports the purpose of securing land rights for everyone in much less time. To provide an entirely inclusive methodology, the FFP approach directly supports pro-poor recordation and the continuum of rights. To build a digital land administration infrastructure, aerial imagery can be used to digitize the boundaries of the spatial units. By using aerial imagery, many other land administration and management processes can make use of the spatial framework and get greater advantages. The process of creating the spatial framework is ongoing It should be improved when opportunities and needs present themselves, for instance through improved land and natural resource management and infrastructure building projects. When necessary and feasible, upgrading strategies will enable incremental developments toward a spatial framework compatible with modern, fully integrated land administration systems.

The spatial framework is a primary, large-scale map that depicts how land is divided into spatial units (such as land parcels) for particular uses and right holders. It serves as the foundation for dealing with land administration requirements like recording and managing legal and social tenure, valuing and taxing real estate, identifying and managing current land use, planning for future land use and development, delivering utility services, and managing and protecting natural resources. Depending on the area and density of the land usage, the accuracy requirements for the aforementioned land administration requirements may differ. Accurate boundary cadastral surveys are not necessary for the security of tenure. Identification of the land parcel in connection to the accompanying legal or social right is a crucial consideration. When comparing different types of land in rural areas to denser built-up urban areas, the level of accuracy needed for planning and managing land usage also differs significantly.

The spatial framework has been created in many developed regions of the world by thorough cadastral mapping over the duration of nearly two centuries, and it is maintained through accurate surveys that are carried out in accordance with established guidelines and procedures. The concepts predominantly employed in developed countries should be considered as the ultimate goal, not as the point of entry when evaluating the resources and capacities required for establishing spatial frameworks in developing countries. While applying such advanced standards for adjudication, boundary marking delineation, and field surveys in developed countries may be appropriate, doing so in developing countries is prohibitively expensive, time-consuming, and resource-demanding. In most cases, these standards are also irrelevant for creating an initial, suitable, and adequate spatial framework. Therefore, approaches that are fast, affordable, complete, and reliable should be the main focus. When necessary or appropriate, the spatial framework can then be upgraded and updated (Enemark et al., 2014; Enemark et al., 2015).

The entire implementation process starts with choosing the mapping tool and scales that will be utilized for different regions based on their terrain, land use, and building density. The visible bounds can then be determined in the field based on the actual occupancy ownership using aerial imagery. This is a collaborative process that includes all stakeholders. In order to refer to the associated legitimate rights, the results can be directly derived from the images and the land parcel numbers. The final spatial framework can then be digitally preserved and used as a basic layer in the national land information administration system. Nevertheless, the general process may change based on the specific local needs (Figure 2.13).

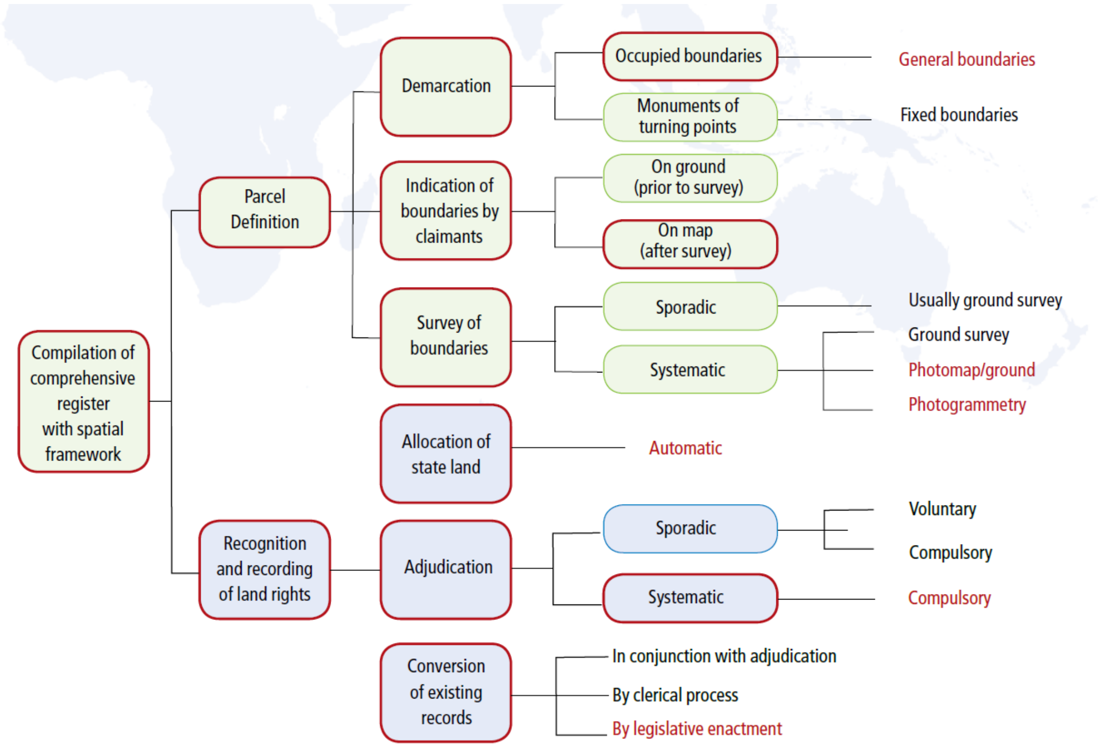


Figure 2.13 *Different approaches to initial registration of property rights. The red frames and text depict the FFP approach. Source: Enemark et al., 2016.*

2.2.4.3 FFP case studies – best practices - Crowdsourcing and Volunteered Geographic Information in cadastre

Ethiopia

The implementation of the FFP LA approach in Ethiopia has been a significant success story. Ethiopia is a country that has a long history of land tenure insecurity, with much of the land being held and used informally, and only a small percentage of the population having secure land rights. In recent years, however, the Ethiopian government has made significant efforts to address this issue through a comprehensive land administration system based on the FFP LA approach (Koeva et al., 2021).

The implementation of the FFP LA approach in Ethiopia began in 2011 with the establishment of the Federal Land Administration and Use Directorate (FLAUD), which was responsible for implementing the approach at the federal level. The approach was then implemented in different regions of the country, including Oromia, Amhara, Tigray, and Southern Nations, Nationalities, and Peoples' Region (SNNPR) (Figure 2.14) (Bennett and Alemie, 2016).

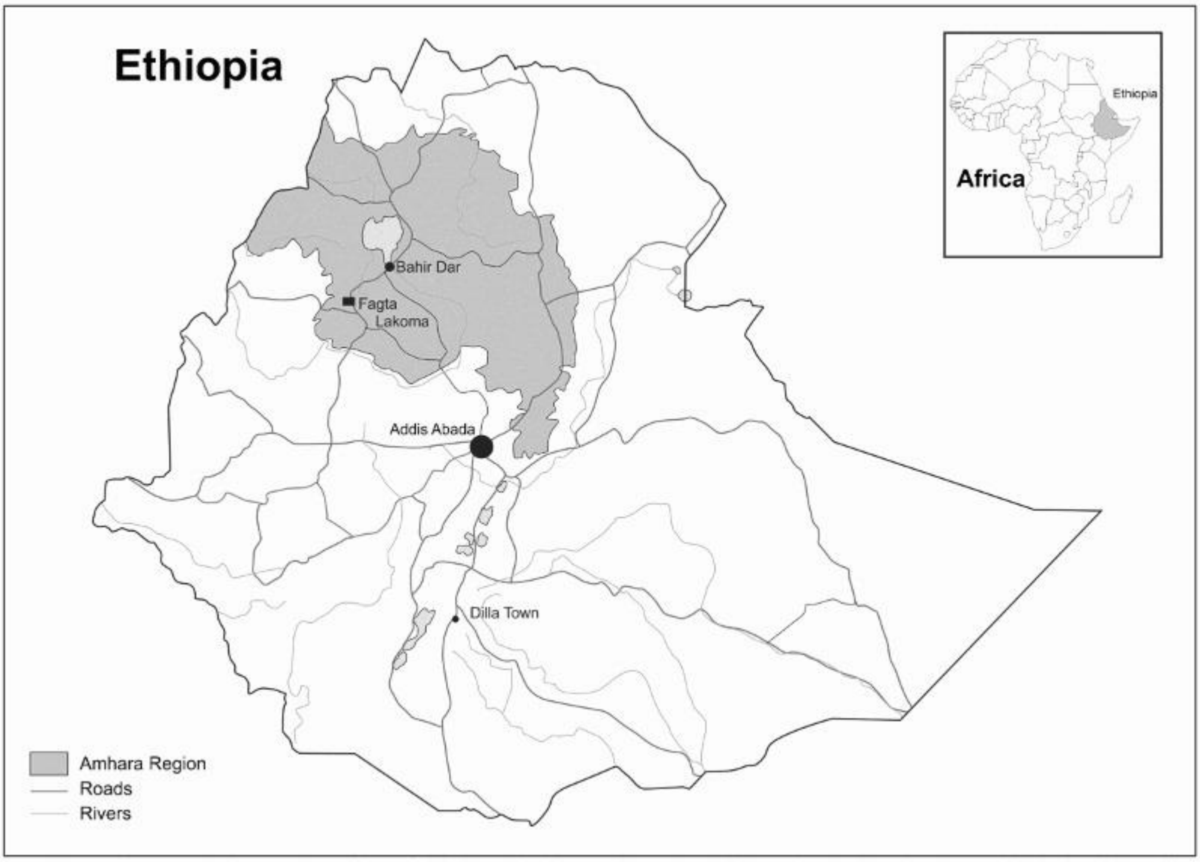


Figure 2.14 *Four case locations in Ethiopia Source: Bennet and Alemie, 2016.*

One of the notable successes of the FFP LA approach in Ethiopia has been the issuance of more than 17 million land certificates to farmers and other landholders across the country. This has provided these individuals with secure land rights, enabling them to access credit, invest in their land, and make long-term plans for their agricultural activities.

Another significant success has been the use of geospatial technology in the implementation of the FFP LA approach. Ethiopia has made significant investments in geospatial technology, including the use of satellite imagery and handheld GPS devices, to accurately map land boundaries and establish a comprehensive land registry. This has enabled the government to effectively manage land use and natural resources, as well as provide inclusive and accessible services to the population.

An example of the successful implementation of the FFP LA approach in Ethiopia is the land registration project in the Amhara region. This project aimed to register land and issue certificates to landholders in 68 districts across the region. The project used a participatory approach, involving local communities in the mapping and registration of land parcels. This approach helped to build trust and ownership among the communities and ensured that the land registration process was more inclusive and transparent.

Another example of the successful implementation of the FFP LA approach in Ethiopia is the work done in the SNNPR. In this region, the approach has been used to address the issue of land tenure insecurity among pastoral communities. The government worked with these communities to establish customary land rights and to register their land using the FFP LA approach. This has helped to secure the land tenure of pastoral communities and has enabled them to access credit and other resources needed to improve their livelihoods.

Overall, the implementation of the FFP LA approach in Ethiopia has been a significant success story. The approach has helped to address the long-standing issue of land tenure insecurity, providing millions of people with secure land rights and enabling them to access credit, invest in their land, and make long-term plans for their agricultural activities. The use of geospatial technology and participatory approaches has been key to the success of the approach, helping to ensure that the land registration process is inclusive, transparent, and accessible to all.

Rwanda

Rwanda is another African country that has adopted the FFP LA approach to address the issue of land tenure security (Musinguzi and Enemark, 2019; Koeva et al., 2021). The country has a history of conflict and displacement, which has led to complex land ownership and tenure arrangements. In response to these challenges, the government has implemented a series of land reforms since the early 2000s, which have aimed to clarify land tenure arrangements, promote land registration, and strengthen land administration systems.

One of the key components of the FFP LA approach that has been implemented in Rwanda is the use of innovative technology and data management systems to support land registration and administration. For example, the government has developed an online platform called the Rwanda Land Management and Use Authority (RLMUA) that allows citizens to register their land online and obtain official land titles (Figure 2.15). The platform also includes a public information system that provides information on land use, land values, and other land-related data. It has helped to improve the accuracy and completeness of land records and has made it easier for citizens to obtain official land titles.

In addition to these technological innovations, the FFP LA approach in Rwanda has also emphasized the importance of building strong institutional and legal frameworks to support land tenure security. The government has established a number of institutions, including the Rwanda Natural Resources Authority (RNRA) and the Rwanda Land Management and Use Authority (RLMUA), which are responsible for overseeing land administration, registration, and dispute resolution processes. The government has also enacted a series of laws and policies, including the Land Law of 2005 and the Land Use Consolidation Policy of 2009, which have provided a legal framework for land tenure security and supported the development of a more efficient and effective land market.

A notable success story of the FFP LA approach in Rwanda is the country's Community Land Trust (CLT) program, which has aimed to promote collective land ownership and secure land rights for vulnerable groups such as women, widows, and orphans. Under this program, communities are encouraged to form legal entities known as Community Land Trusts, which can then manage and govern communal land on behalf of their members. This approach has been particularly effective in areas where land fragmentation and conflict have been major issues.

Figure 2.15 *Example from Rwanda showing aerial imagery (left), from which the parcel boundaries are easily identified (right). Source: Musinguzi and Enemark, 2019.*

Colombia

In Colombia, the FFP LA approach has been implemented through a project called "Strengthening of the Property Formalization Process in Colombia" in 2018. This project was funded by the World Bank and the Colombian government and was implemented by the National Planning Department (DNP) and the National Land Agency (ANT) (Figure 2.16) (Molendijk et al., 2019; Becerra et al., 2021).

The project aimed to improve the security of land tenure for small-scale farmers and vulnerable populations, with a focus on rural areas. The project used a participatory approach to land administration and management, involving communities and local organizations in the process.

The spatial framework was implemented through the use of innovative mapping techniques, including satellite imagery and drones, to accurately map land parcels and identify land use patterns. The legal framework was strengthened by developing a land registration system that was accessible and affordable to small-scale farmers, and by developing laws and regulations that protected their land rights.

The institutional framework was strengthened through the establishment of a network of land administration offices and the development of training programs for land administrators. These offices provided services such as land registration, land titling, and dispute resolution. The project also established partnerships with local organizations, such as NGOs and community groups, to help deliver services and ensure community participation in the land administration process.

One of the successes of the project was the formalization of over 210,000 land titles for small-scale farmers and vulnerable populations, covering over 1.5 million hectares of land. This helped to improve the security of land tenure for these populations and promote inclusive economic growth. The project also helped to reduce conflict over land by providing a transparent and accessible land administration system.

Figure 2.16 *FFP LA map in Los Mandarinos, Colombia. Source: Molendijk et al., 2019*

Overall, the FFP LA approach was successful in Colombia, as it helped to improve the security of land tenure for small-scale farmers and vulnerable populations and promote inclusive economic growth. The participatory approach to land administration and management, and the use of innovative mapping techniques, were key factors in the success of the project.

2.3 Concluding remarks

To conclude, over the past two decades, there has been a significant revolution in the way that geographical data, information, and expertise are created and shared. The concept of using the internet to create, exchange, visualize, and analyze user-generated geographic information and knowledge is known as volunteer geographic information (VGI), and it was envisioned through the usage of several computing devices and platforms. The acquisition, maintenance, analysis, visualization, and ultimately application of geospatial data have all undergone radical change as a result of the neogeography revolution. This affects common practices because it enables a more thorough and comprehensive understanding of the environment we live in on all facets of life, encompassing new services to take place, applications and processes to be developed, all of which are location-based; we now have the capability to track where and when everything is occurring - and in real-time.

The public continuously gathers and stores a sizable amount of geographic data, supported by the development of new technologies to support citizen science. It can make a significant contribution to the creation and upkeep of a quality, useable, and trustworthy GIS and geospatial data infrastructure. The paradigm of crowdsourcing has been developed as a logical extension of the concept of volunteer geographic information. This is supported by the fact that users today have access to a variety of user-generated geographic and geo-tagged digital information sources that have been created and are being maintained by both public and private citizens, in addition to traditional or official and authoritative geospatial and map information. As a result, the updating process for spatial data infrastructures (SDIs) and geospatial data is presently changing.

Crowdsourcing and VGI are effective methods for acquiring spatial data that complement official and authoritative data sources. However, the methods used to acquire the data should match the intended purpose and context, just as quality and dependability requirements should. The engagement of the crowd is an essential component of the methodology in all crowdsourcing operations. The recruitment, maintenance, and upkeep of relationships with crowdsourced project participants also require dedicated resources. The methodology must take into account the individuals who will contribute to the operation and the strategy that will be used to encourage their participation, much like planned field survey works.

The difficulty of crowdsourced cadastral projects lies in the requirement to involve a broad range of participants with varying levels of experience and knowledge, using various methodologies that take into account the particular spatial, temporal, and thematic domain of the cadastral data collection activities. Governments can effectively engage their citizens by empowering them to collect and interpret geospatial data in order to improve the data's usability. The public's participation could also help the digital economy reach its full potential.

In order to assist countries and institutions in achieving their digital transformation and to bridge the geospatial digital divide in the implementation of the Agenda 2030 for Sustainable Development, it is crucial to investigate the potential for using these new technologies in cadastral surveys, develop guidelines, and share principles and current trends in legal and policy frameworks. Governments should consider adopting Web 3.0 to enhance their business processes through the usage of crowdsourcing techniques. The public's participation in land administration projects can help to bridge the gap between government and citizens.

The Fit-for-Purpose (FFP) Land Administration Approach has emerged as a cost-effective way of providing secure tenure, improving land administration, and promoting sustainable development. The FFP spatial framework is an essential component of this approach and provides a standardized, systematic, and scalable way to record, manage, and share spatial information. Best practices of citizen participation and volunteerism in land management procedures can be found in various countries, including Greece. Collaboration between government, private sector, and right holders is crucial to the success of cadastral projects.

3 Investigation of official cadastral procedures in Greece and Romania

Cadastre plays a vital role in each country, serving various purposes such as improving security of tenure, facilitating access to credit for low- and middle-income households, implementing equitable property taxation, and creating a sustainable real estate market that can attract investments and help reduce poverty and climate change impacts (UN, 2015). Despite being European Union (EU) members, both Greece and Romania lack a complete and up-to-date cadastre for their entire territories. As a result, they are simultaneously executing property registration initiatives that are closely monitored and evaluated by local and international experts (Torhonen et al., 2015; Avgerinou et al., 2018; Lamprou et al., 2018; Lawrence et al., 2018; Papakyriakopoulos et al., 2018; Zifou et al., 2018). This fact bolsters scientific confidence that these projects are being designed (always within the legal, socioeconomic, and political framework of each country) based on current international and local expertise, and are following the necessary practices to build a technically and legally reliable AAA (Accurate, Assured, and Authoritative) cadastre (Williamson et al., 2012).

The responsible National Cadastral and Mapping Agencies (NCMAs) define the technical specifications for gathering the necessary geospatial and cadastral data, and the private sector carries out cadastral surveys through a bidding process, following the formal procedure. Pilot participatory projects marked the start of both initiatives, revealing all the issues and difficulties. In these projects, landowners are asked to identify and locate their land parcels on orthophotos, declare their rights, and provide all relevant documentation. Both projects rely on photogrammetric methods and orthophotos as basemaps to capture initial cadastral data. In Greece, additional field surveys are only conducted, when necessary, as the private surveyors may choose any method, they consider adequate (which is a fit-for-purpose approach), whereas in Romania, cadastral maps are mandatory and must be compiled through field surveys.

This chapter aims to provide an overview of the cadastral methods used in Greece and Romania, with a focus on the legal, institutional, and technical aspects of cadastral surveying, mapping, and data management. The objective of this chapter is to examine the formal procedures used for cadastral data collection in both countries, to create a more adaptable and efficient model that incorporates new IT tools and enhanced citizen participation, in order to expedite the initial data collection phase while ensuring better quality and effectiveness of the process, as indicated by earlier studies (Basiouka and Potsiou, 2014; Mourafetis et al., 2015; Basiouka and Potsiou, 2016; Apostolopoulos et al., 2018). This general fit-for-purpose method can be applied to the specific circumstances of the current projects and to projects on a countrywide scale to create reliable, accurate, assured, authoritative, and modern cadastres.

3.1 The Hellenic Cadastre

3.1.1 Historical review

The establishment of the new Hellenic State in 1825 marked the beginning of efforts to implement a cadastral system for Land Administration purposes. It was not until 1836, following the publication of a Royal Decree by King Othon that the first attempt to introduce a cadastral system was made. The goal was to enhance the land market and facilitate mortgage loans.

In 1853, the French Mortgage Bureaux System, known as the "Transfers and Mortgages Registration System," was introduced in Greece. This system, which is still in use today, involves the registration of all legal rights related to land, including land ownership, leases, mortgages, charges, easements, seizures, and claims. There were 396 operational offices across the country where this information is accessible to the public, subject to specific requirements.

However, the system has some notable drawbacks. The legal information primarily relies on textual descriptions of land parcels, which often prove insufficient for accurately locating real estate. Although since 1977, all registered deeds pertaining to land parcels in urban areas are required to be accompanied by topographic diagrams that are isolated and not integrated with a cadastral map, rendering the system disconnected and incomplete in terms of spatial information.

In several instances, the information within the "Transfers and Mortgages Registration System" is not available in digital format. Additionally, access to the system is limited to searching by the owner's name, reflecting a "person-centric" model. Furthermore, it is important to note that while this system is responsible for registering deeds, it does not guarantee the accuracy or validity of the deed contents.

In 1895, a proposal for a Cadastre Law was put forth, followed by the publication of a new Law in 1910 (Greek Government Gazette, 1910), which pertained to the Hellenic Cadastre. After a devastating fire in Thessaloniki in 1917, significant efforts were made to establish a Cadastre in the city. Subsequently, in 1923, a Legislative Decree was enacted to codify cadastral surveys in urban areas.

Between 1926 and 1929, a specific cadastral system known as the Dodecanesean Cadastre was implemented on the islands of Rhodes and Kos in Southern Greece, governed by a dedicated Cadastral Regulation that remains in effect to this day. In 1932, the rural cadastre project began, focusing on registering areas involved in raisin production.

During the 1940s, two cadastral bureaux were established in the Kallithea and Paleo Faliro counties near Athens, covering a total area of 1200 hectares and continuing operations up to the present. Between 1971 and 1974, the initial phase of a new cadastre system was initiated, covering a significant portion of Greece, including Crete, Peloponnese, Central Greece, Thessaly, and parts of Thrace. However, this project was halted following political changes in 1974.

In 1976, an attempt was made to register forest land areas, and in 1983, certain cadastral data was indirectly collected as part of urban planning activities under Law 1337/83, which introduced the Urban Plan Implementation Act. In 1986, the establishment of the Hellenic Mapping and Cadastre Organization (HEMCO) took place under (Greek Government Gazette, 1986). HEMCO, belonging to the Ministry of Environment, Physical Planning, and Public Works, was responsible for mapping the country, implementing and managing the Hellenic Cadastre, and creating databases for national resources and the environment.

The Hellenic Cadastre, designed in 1994, aims to be a modern Information System that enhances the efficiency of land transactions and ensures secure land tenure (HEMCO, 1994). It serves as a vital source of information for various sectors, including land management, urban and rural planning, agricultural policy, land administration, and environmental monitoring (Economic Commission of Europe 1996).

Progress of the Hellenic Cadastre

- <u>First generation of the Hellenic cadastre (1995 - 1999)</u>

The work of the National Cadastre began with pilot studies scattered throughout the country in the mid-1990s (Greek Government Gazette, 1995; Greek Government Gazette, 1998). During the period 1995-1999, three pilot cadastral programs were assigned, focusing on the geographic distribution of selected areas and their diversity to gain experience in various cases (urban, rural, island, mountainous areas, etc.). In this phase, 340 main agricultural areas were registered, covering 6.2% of the territory. These programs were completed, and gradually, since 2003, the Cadastre has been operational for these specific areas.

- Second generation of the Hellenic cadastre (2004-2009)

With the projects implemented by the Hellenic NCMA under the Third Community Support Framework (CSF), co-financed by the European Commission, a new management approach was adopted, making extensive use of economies of scale and the capabilities offered by the most advanced technology.

This phase was the initiation of a new program that targeted 106 urban local government units (OTAs) across Greece. The cadastre process for these areas was divided into two phases, each with its own competitive procedures. The first phase, which received funding from the Third CSF, was successfully completed by the end of 2009 for all the selected areas. The assignment of contracts and the subsequent implementation of the second phase gradually progressed for these regions.

Moreover, in 2007, as a significant assessment of the project's advancement was underway, the decision was made to modernize the Hellenic NCMA in alignment with prevailing global trends. The primary objective of this enhancement was to create e-services and workflows, aiming to both reduce the need for manual labour and enhance efficiency by leveraging cutting-edge technologies and cloud computing. All contracted parties were seamlessly linked to centralized IT systems via secure networks in real-time. Property rights holders were granted the opportunity to remotely submit all necessary documents for their property rights through the Internet, conveniently from their home or office (Mourafetis and Potsiou, 2020).

- Second generation of the Hellenic cadastre – Mount Parnitha (2009)

A new program was announced concerning the cadastral works of 11 municipalities in Mount Parnitha, an environmentally sensitive area, with the aim of protecting it from potential encroachments following the recent wildfires in the region.

- Third generation of the Hellenic cadastre (2011 – 2016)

Within 2011 and in accordance with the Memorandum that called for the announcement of cadastral projects for 4,000,000 rights, the Hellenic NCMA announced two new cadastral programs that concerned:

a. 268 primarily urban municipalities for which the necessary cartographic background had already been produced for the entire area to be registered as part of the relevant project of the Third Community Support Framework (CSF) (2,575,119 rights).
b. 10 regions of the country with extensive agricultural land, including reclamation and redistribution, in which the digitized data from the implementation of the corresponding co-financed project of the Third CSF, as well as the elements of the Land Parcel Identification System (LPIS) and declarations for agricultural subsidies, are expected to be utilized (4,346,878 rights).

- Fourth generation of the Hellenic cadastre (2016 – current)

The fourth generation of cadastre involves the recording (and matching with digital backgrounds) of 16 million property rights, covering 65% of the country's territory. Almost the entire territory is now undergoing cadastral registration. Both old and new studies are ongoing, while in some areas the start of cadastral registration is still pending.

Additionally, through the approval of Law No. 4727/2020, a comprehensive and coherent legal framework was introduced for the digital governance of the nation. The central focus of this policy revolves around "open data" and the extended utilization of public data, aligned with corresponding European regulations.

The Hellenic NCMA has already begun furnishing "open data" within the main repository of public information managed by the Greek Government (Ministry of Digital Governance, 2020). It actively contributes to advancing digital governance and aligning with the European approach to further harness and exploit public data. It announces the specific datasets that will now be accessible as 'open data'.

A selection of the "open data" from the Hellenic NCMA pertains to land parcels, posted and partially approved forest maps, land coverage, and designated Natura 2000 areas (Figure 3.1). Moreover, the catalog encompasses monitoring information tracking cadastre progress, and operational aspects, as well as statistical data, budgetary allocations, and execution details.

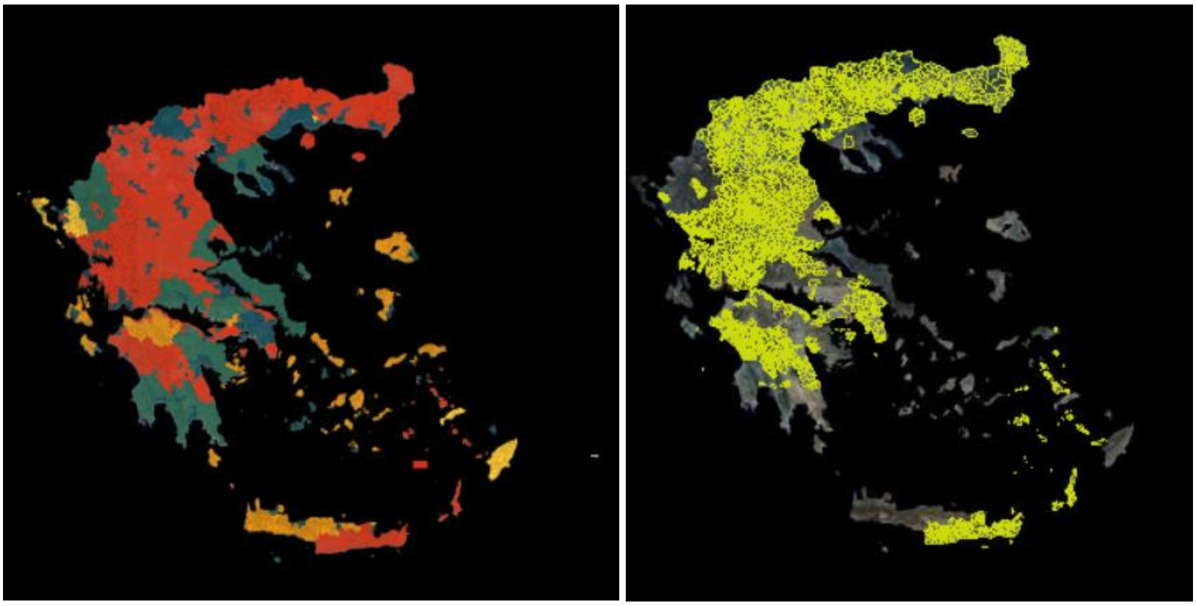


Figure 3.1 *(a) Current state of cadastral surveys in Greece (draft cadastral data (green), declaration phase (orange), initial registration phase (red), operations phase (deep blue). (b) Areas in Greece where publication of draft cadastral data has taken place. Source: Ministry of Digital Governance, 2023*

The ensuing catalogue of the available 'open data' is accessible both through the official website of the Hellenic NCMA (Hellenic Cadastre, 2020) and the Unified Digital Portal of Public Administration (Ministry of Digital Governance, 2020). It also outlines the timeline for the commencement of open data availability and it will be expanded and enriched, serving as a valuable instrument for research and developmental purposes (Figure 3.1).

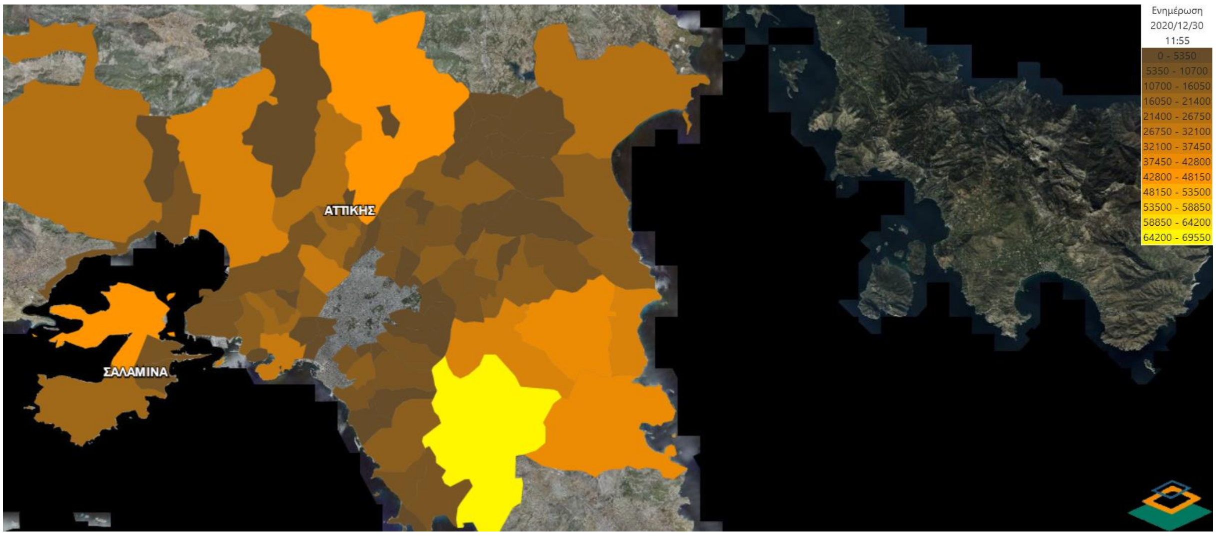


Figure 3.2 *Statistical data about the registered area under cadastral survey in Attica region. Source: Ministry of Digital Governance, 2023*

The overall progress of the Hellenic cadastral project can be summarized as follows (Figure 3.3):

- *1st and 2nd Phase*: Approximately 29% of the country's property rights, which amounts to around 11,442,000 rights, have already been registered.

- *3rd Phase*: Another 62% of the property rights, approximately 24,175,000 rights, are currently in the process of being finalized and registered.

- *4th Phase*: The remaining 7% of the country's rights, totaling 2,735,000 rights is under cadastral survey.

- Remaining registrations: Approximately 776,000 rights, accounting for 2.0% of the country's rights, still need to be registered. These mainly pertain to pre-existing specific cadastres in Athens and certain Greek islands, including the Dodecanese Cadastre, which covers Rhodes, Kos, and part of Leros Islands.

To conclude, the ongoing Hellenic cadastral project is employing a modern participatory approach, enabling individuals who are not experts or landowners to digitize land parcel boundaries using crowdsourcing methods. However, significant errors have been encountered in accurately identifying their land parcels when attempting this task remotely, rather than in the field (for example, on a basemap, often an orthophoto), leading to substantial delays and additional expenses for the cadastral project (Balla et al., 2022). In response, the Hellenic NCMA has implemented the following strategies:

i. Creation of various online services.

ii. Provision of advanced basemaps, generated by cadastral professionals, which incorporate additional geospatial data (such as points of interest and street names).

iii. Introduction of multiple automated checks, including system validations of the submitted data during the declaration process, along with the provision of an error list, all aimed at ensuring the identification and rectification of such errors in the remote data collection process, As of January 2020, over 750,000 participants have submitted their declarations online (totalling 1.1 million declarations).

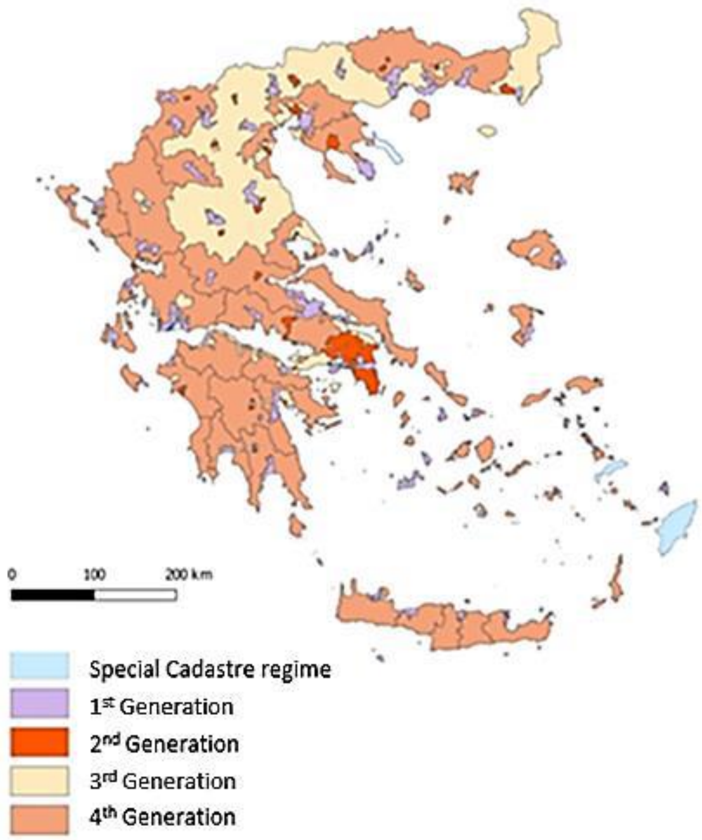


Figure 3.3 *Progress of the Hellenic Cadastre. Source: Hellenic Cadastre.*

3.1.2 Legislation

The legislation pertaining to the Hellenic cadastral surveys forms the cornerstone of a comprehensive land registration system in Greece. These laws establish the necessary guidelines and regulations to ensure the precise, transparent, and accessible recording of land information. They outline the systematic procedures for conducting cadastral surveys, collecting data, and registering properties, while also defining the roles and obligations of the involved parties. By providing a strong legal framework, these legislations aim to improve the efficiency and efficacy of cadastral operations, safeguard property rights, and foster public confidence in the Hellenic Cadastre. The most important laws of this legislation are the following:

- *Law 2308/1995*: This law introduced the concept of the unified cadastre system in Greece. It aimed to ensure the accuracy and reliability of land registration. The law defined the roles and responsibilities of various stakeholders, including the Hellenic Cadastre Agency, surveyors, and the National Cadastre and Mapping Agency (NCMA). It outlined the procedures for cadastral surveying, data collection, and the establishment of temporary local offices for the declaration collection and cadastral survey. The law emphasized the publicity of registrations but did not guarantee the legal security of registered ownership rights. It recognized the need for collaboration between public entities involved in the cadastral survey process.

- *Presidential Decree 224/1998*: This decree provided detailed regulations for the implementation of the Hellenic Cadastre. It specified the technical requirements for surveying, data collection methods, and the creation of cadastral basemaps. The decree outlined the procedures for cadastral surveying, including the use of photogrammetry and field surveys. It defined the responsibilities and obligations of cadastral surveyors (contractors) during the survey process. The decree addressed the integration of existing land reform projects' information into the cadastral basemaps. It highlighted the need for coordination between the NCMA and cadastral surveyors.

- *Law 2664/1998*: This law introduced amendments to certain provisions of Law 2308/1995. It aimed to address issues related to property rights acquisition and registration. The law emphasized the importance of cooperation between public entities involved in the cadastral survey process, including the Ministry of Agriculture, the Ministry of Environment, Physical Planning and Public Works, and the Ministry of Finance. It included provisions to protect the rights of individuals during the survey and registration procedures. The law outlined procedures for the exchange of information between different public entities involved in the cadastral survey process.

- *Law 3972/2011*: This law aimed to improve the efficiency and accuracy of the Hellenic Cadastre. It focused on the digitization of data and the integration of existing land registries. The law established the Hellenic Cadastre Agency as the central authority responsible for managing and coordinating the cadastre system. It introduced provisions for the creation of a comprehensive legal framework for land registration. The law emphasized the importance of public access to cadastral information and the establishment of user-friendly systems for data retrieval.

- *Law 4251/2014*: This law further amended and supplemented the provisions of Law 2308/1995. It addressed administrative and technical matters related to the Hellenic Cadastre. The law organized the structure and functions of the Hellenic Cadastre Agency. It outlined the rights and obligations of surveyors involved in cadastral surveying. The law introduced procedures for dispute resolution and objections, including the establishment of an independent administrative committee. It aimed to simplify the registration process and enhance public access to cadastral information through digital platforms.

- *Law 4546/2018*: This law introduced amendments to Law 2308/1995 and Law 4251/2014. It aimed to enhance the cadastral survey process and improve the organization of the Hellenic Cadastre Agency. The law introduced changes to the structure and functions of the agency, including the establishment of regional cadastre offices.

3.1.3 Main stages of the Hellenic cadastral surveys

The formal procedure for conducting Cadastral Surveys in Greece is as follows (Figure 3.4):

a) The process begins with the selection of the area to undergo cadastral survey. A call for bids is issued, and interested parties submit their proposals. The selected surveyors (contractors) are then commissioned to carry out the cadastral survey. Temporary local offices are established for the collection of declarations and the survey itself, with this responsibility falling under the jurisdiction of the Hellenic NCMA.

b) The Hellenic NCMA provides orthophotos that serve as the basis for compiling the initial cadastral basemaps. The scale of the orthophotos is 1:1000 for urban areas and 1:5000 for rural areas. The cadastral surveyors utilize photogrammetric techniques to compile the basemaps, incorporating existing information from previous land reform projects that may have generated cadastral data in the area. This includes projects related to urbanization, city planning, urban regeneration, land consolidation, land expropriation, or the demarcation of coastal boundaries. Field surveys are conducted only when necessary.

c) The next step involves the submission of declarations by the right holders, which includes personal data, address, parcel geometrical data, types of property rights, and information about the deed or title. Additional information such as existing field surveys or coordinates of boundary nodes obtained through GNSS devices may also be included. This information is then linked to the orthophotos for parcel identification. Declarations can be submitted either electronically or by visiting the temporary office.

d) The cadastral surveyor edits the submitted data to create the draft cadastral map. The contractors integrate any new changes or transactions that occur during this period, such as subdivisions or transfers, into the digital database.

e) The submitted cadastral data is validated by lawyers who review its legality, as well as by cadastral surveyors. If any gaps or problems are identified, additional field surveys may be conducted, or the right holders may be requested to provide additional information. Any new changes in the cadastral data during the survey period should be submitted by the right holders.

f) The draft cadastral maps are published, and cadastral extracts of these maps are sent to the right holders (via email) for their information.

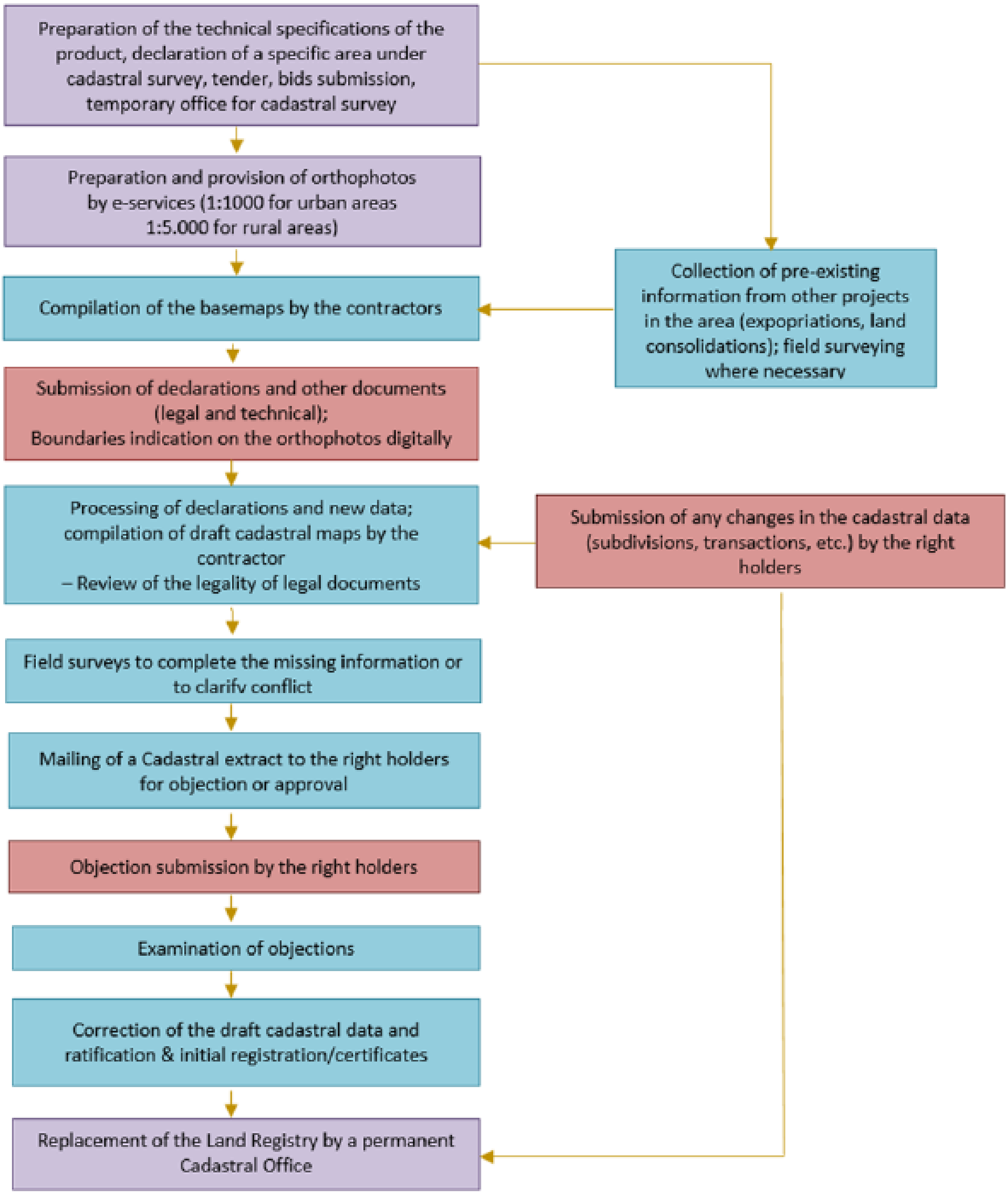


Figure 3.4 *Main stages of the official procedure of the Hellenic Cadastre Survey (stages in purple colour depict NCMA actions; stages in blue colour depict cadastral surveyors' actions; stages in pink colour depict right holders' actions). Source: Potsiou et al., 2020.*

g) Right holders have the opportunity to submit objections if they identify any errors. There are two types of errors: obvious errors that can be immediately corrected, such as spelling mistakes or incorrect registration of identity data, titles, or land rights, and errors that require further examination, such as corrections to a parcel's geometric data or requests for changes in or removal of a right holder from the cadastral records. The latter objections

are reviewed by an independent administrative committee consisting of three members, including two members from the bar association and one cadastral surveyor.
Once the objections have been addressed, the cadastral data is corrected, and the final cadastral tables and maps are prepared. These registrations are referred to as Initial Registrations, representing the first and official registration in the Hellenic Cadastre.

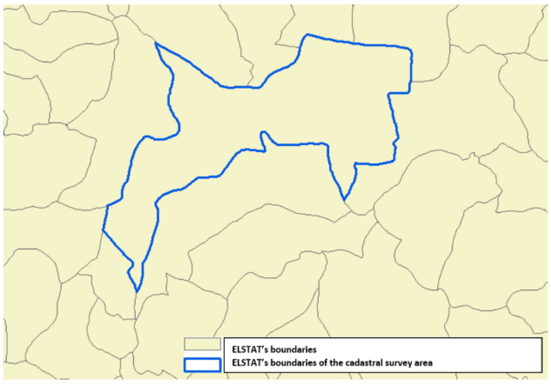
h) Subsequently, the temporary cadastral office is closed, and a permanent Cadastral Office is established to replace the existing Land Registry Office in the area.

3.1.4 Compilation procedure of the Advanced Basemap

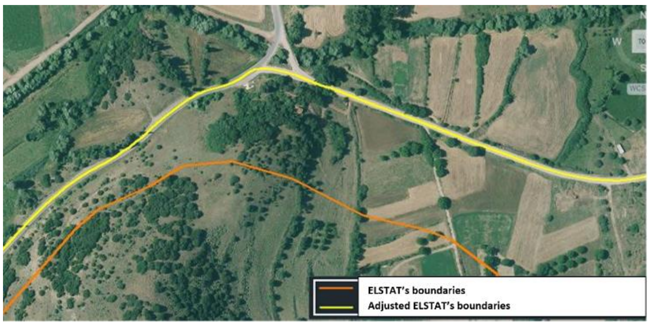
The collaboration between the cadastral agency and contractors/ cadastral surveyors facilitates the compilation of the Hellenic cadastre. During the initial phase of cadastral surveying, the contractor focuses on creating an advanced cadastral basemap. This enables right holders to accurately identify their land parcels and submit the necessary declarations. To develop the advanced cadastral basemap, the contractor utilizes the official orthophoto provided by the Hellenic Cadastre. Additionally, they incorporate any pertinent pre-existing geospatial data (e.g., land parcels and road network) obtained from past administrative acts, such as the approval of urban plans, urban regeneration projects, land expropriation projects, or the official demarcation of the coastal line, which determines the division between private and public land. The compilation of the advanced cadastral basemap adheres to specified technical requirements (Greek Government Gazette, 2007) and is submitted within a regulated timeframe to undergo verification and validation by the Hellenic NCMA.

3.1.4.1 Procedure for the delineation of all administrative boundaries in the area under Cadastral Survey

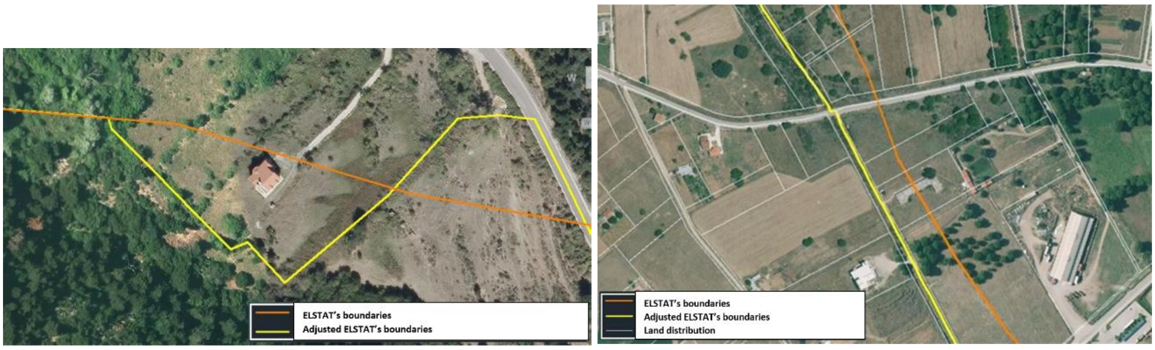
To accomplish the objective mentioned above, the contractor is responsible for processing the provided data and acquiring any missing or necessary spatial data or administrative acts. They need to define the boundaries of urban areas and accurately identify and outline the land parcels depicted in the orthophoto. If there is missing information, the contractor should be capable of conducting field surveys. Initially, the contractor establishes the boundaries of the cadastral study area and the urban settlements. This geospatial information is derived from ELSTAT (Hellenic Statistical Authority) (Figure 3.5 a). If necessary, the contractor adjusts these boundaries on the orthophoto by considering both man-made and natural features, such as rivers, road networks, land parcel boundaries, and existing administrative acts (Figure 3.5 b - d). The purpose is to generate edited boundaries for the cadastral study area (Figure 3.6).



(a)



(b)



(c) **(d)**

Figure 3.5 (a) *The boundaries of the cadastral survey area as provided by ELSTAT. The adjustment of ELSTAT's boundaries with* ***(b)*** *the road network,* ***(c)*** *the boundaries of land parcels and* ***(d)*** *the land distribution. Source: Apostolopoulos and Potsiou, 2022.*

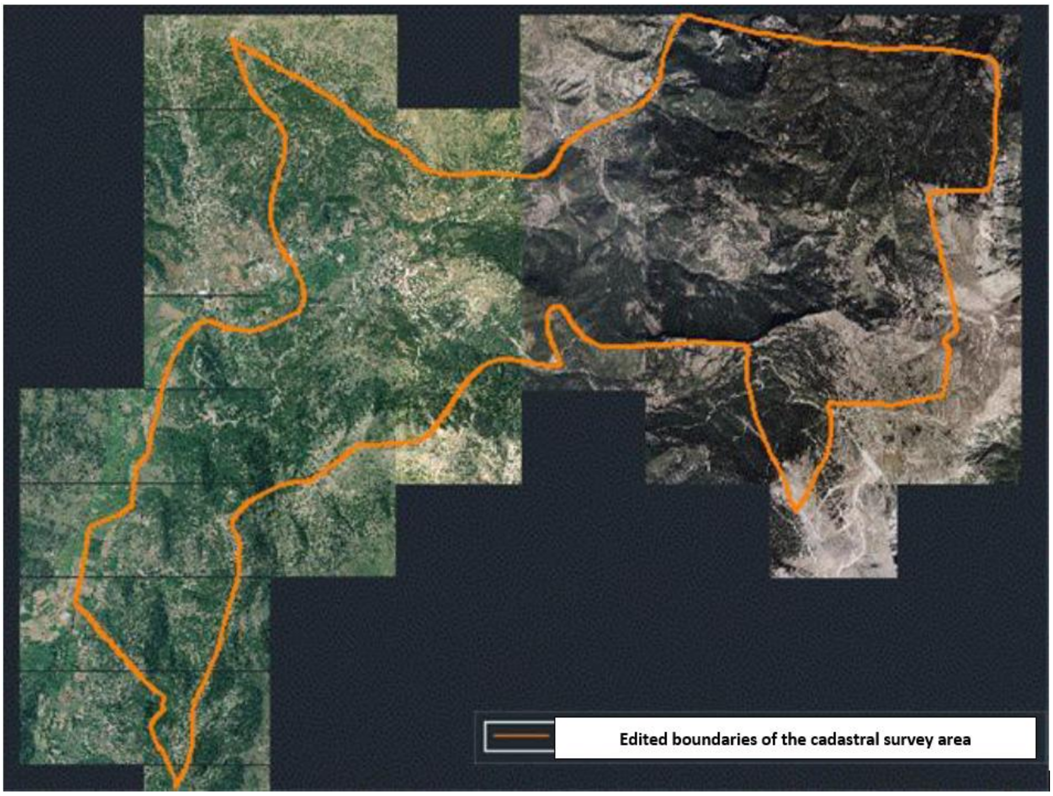


Figure 3.6 *Edited boundaries for the cadastral study area. Source: Apostolopoulos and Potsiou, 2022.*

Once the boundaries of the cadastral study area have been established, the contractor proceeds to delineate the boundaries of the urban settlements on the orthophoto. These boundaries are derived from the officially ratified city plans (Figure 3.7 a). However, it is important for the contractor to also incorporate the boundaries of unplanned settlements (Figure 3.7 b and c). Subsequently, the contractor is required to compile a technical report containing the edited boundaries and submit it to the Hellenic NCMA for thorough technical assessments and approval. Figure 3.8 presents this procedure.

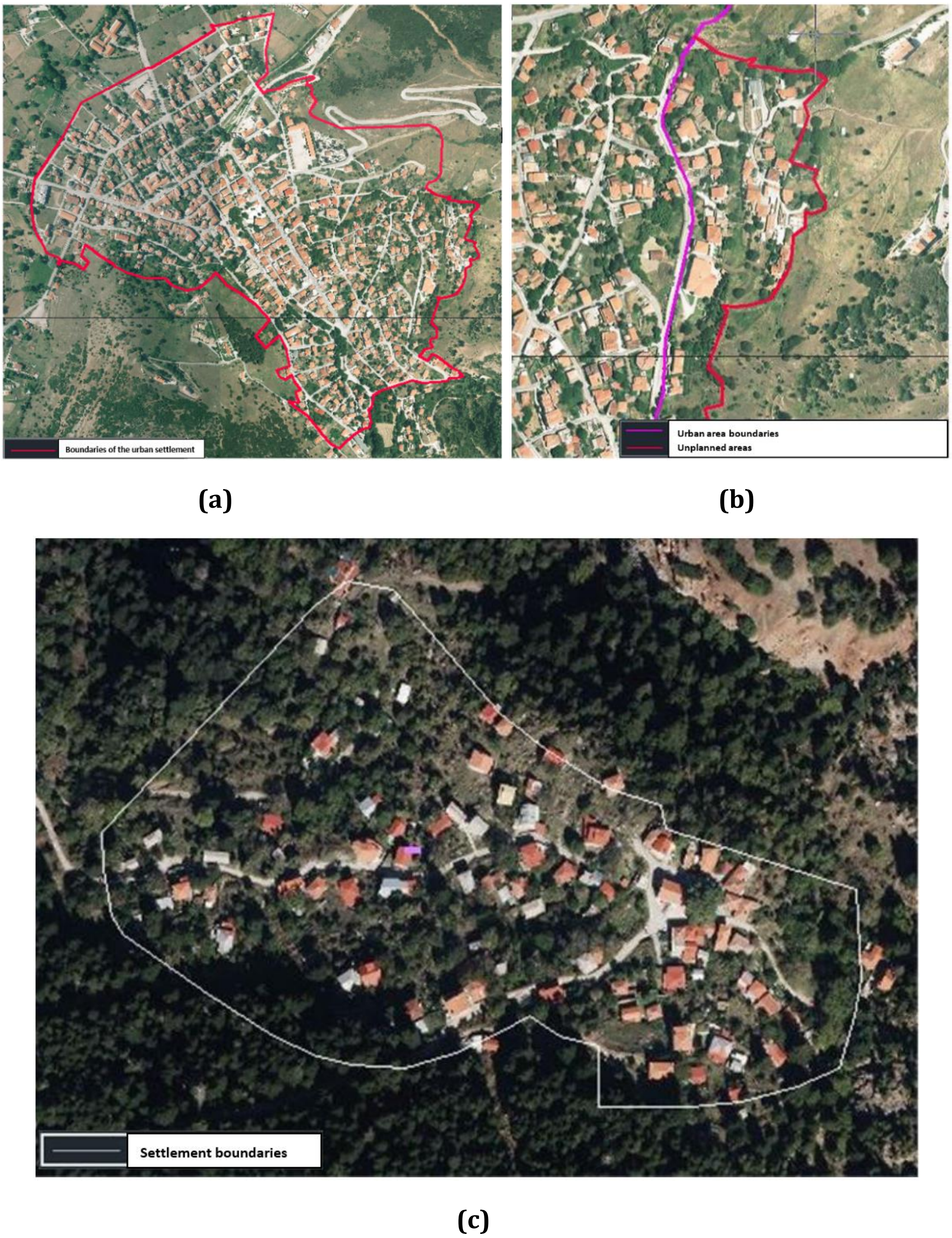


__Figure 3.7__ ***(a)*** *Digitization of city's boundaries with ratified city plan.* ***(b)*** *and* ***(c)*** *Digitization the unplanned settlements boundaries. Source: Apostolopoulos and Potsiou, 2022.*

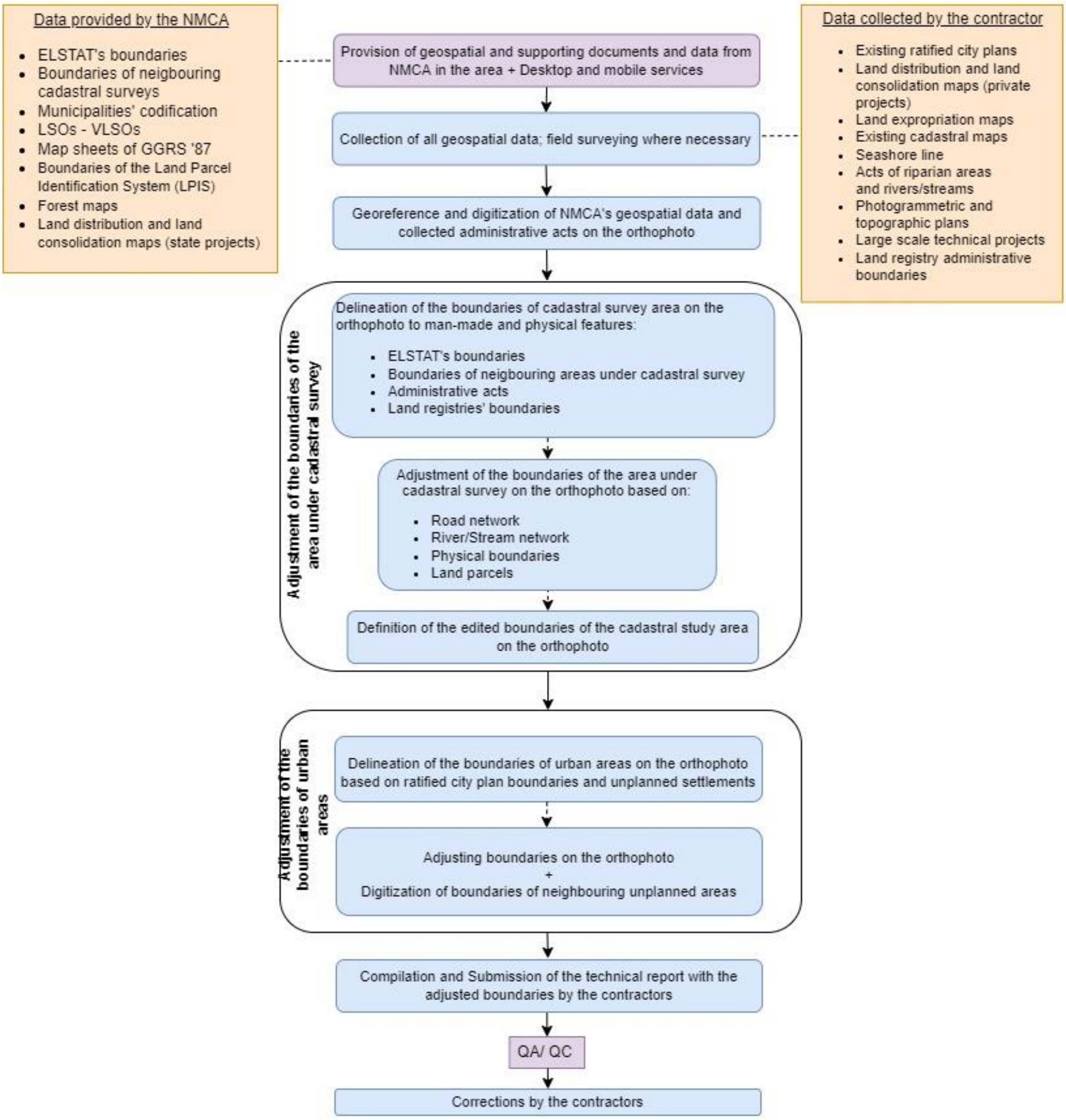
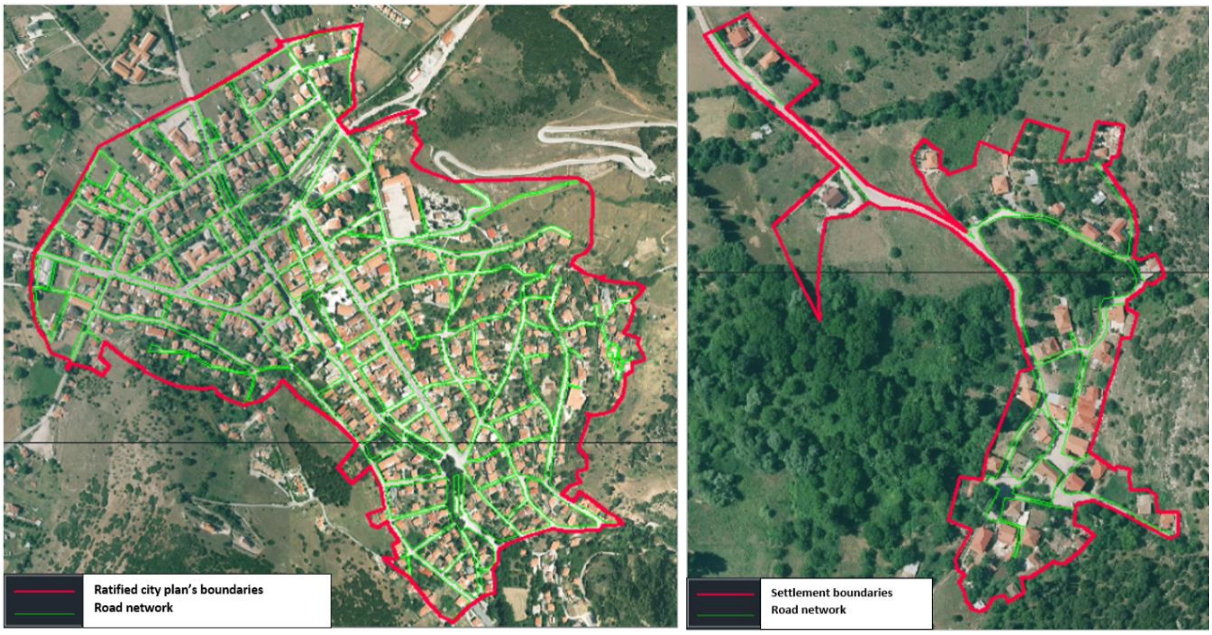


Figure 3.8 *Procedure for delineating administrative boundaries in the cadastral study area, involving NMCA (purple) and contractor (blue) actions. Source: Apostolopoulos and Potsiou, 2022*

3.1.4.2 Compilation Procedure for the Advanced Basemap in Urban and Rural Areas.

Once the Hellenic NCMA has approved the edited boundaries, the contractor responsible for preparing the advanced cadastral basemap for urban areas must carry out the following tasks:

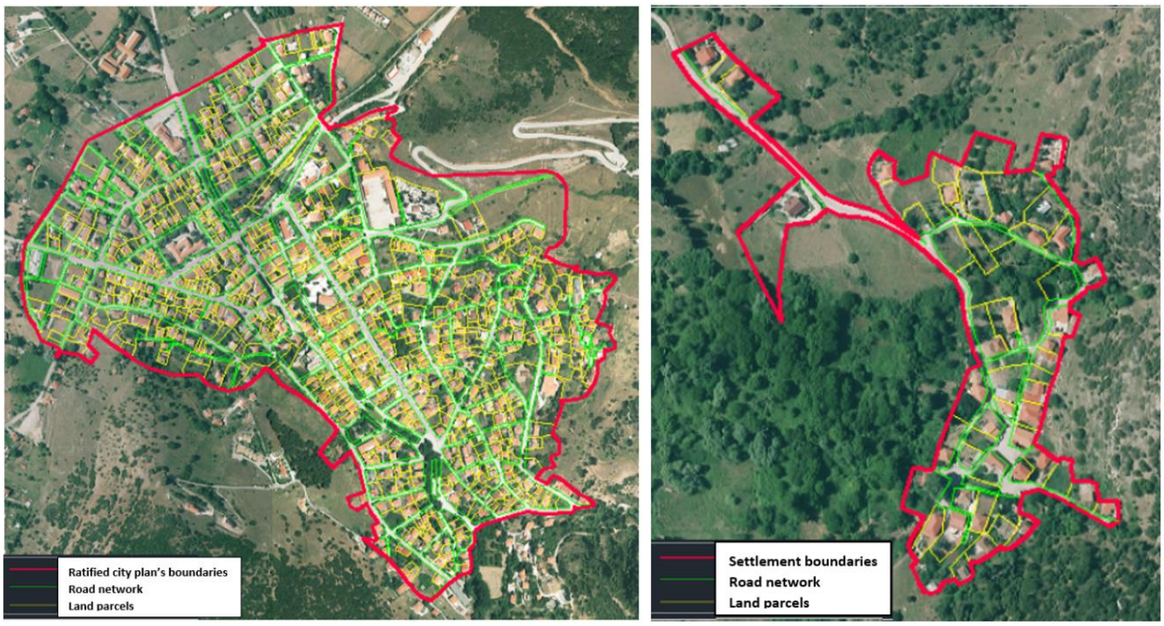
- Digitize the road network using the ratified city plans, administrative acts, and existing cadastral/topographic maps (Figure 3.9 a). In the absence of administrative acts, the road network should be digitized using photo-interpretation tools in conjunction with topographic surveys (Figure 3.9 b).



(a) **(b)**

Figure 3.9 (a) *Digitized city plan's road network on orthophoto.* ***(b)*** *Digitized road network of an unplanned settlement with photo-interpretation tools. Source: Apostolopoulos and Potsiou, 2022*

- Identify and digitize the readily identifiable preliminary land parcels on the orthophoto (Figure 3.10 a, b). If land parcel boundaries are not clearly visible on the orthophoto, the contractor should involve local citizens to assist in identifying and digitizing them. In such cases, cooperation with local authorities is necessary to engage and inform the local communities to encourage maximum participation.



(a) **(b)**

Figure 3.10 *Digitized obvious preliminary land parcels on the orthophoto (a) within a ratified city plan and (b) within an unplanned settlement. Source: Apostolopoulos and Potsiou, 2022*

- Divide the urban areas into cadastral units based on specific criteria. Each cadastral unit corresponds to a building block (excluding the surrounding streets) and is delineated by roads, irrigation canals, or other natural/man-made features. Each cadastral unit is represented by a single polygon and is assigned a unique sequential number within its respective cadastral sector. Streets, public squares, parks, and rivers are assigned separate code numbers. The codification and organization of specific areas like green areas or archaeological sites are defined in the special edition of the Hellenic Cadastre's Codification and Organization.

Figure 3.18 depicts the procedure that has been described above for the urban areas. In rural areas, the contractor responsible for preparing the cadastral basemap is required to carry out the following tasks (as also shown in Figure 3.18):

- Delineation and establishment of rural area boundaries for cadastral registration on the orthophoto. These boundaries are defined as areas outside urban areas.
- The road and river/stream networks on the orthophoto are digitized using photo-interpretation tools and topographic surveys (Figure 3.11 - 3.11).

(a) **(b)**

Figure 3.11 *Road network digitization on the orthophoto through the following methods:* ***(a)*** *Utilizing existing land distribution maps* ***(b)*** *using photo-interpretation tools. Source: Apostolopoulos and Potsiou, 2022*

Figure 3.12 *River digitization using photo-interpretation tools on the orthophoto. Source: Apostolopoulos and Potsiou, 2022*

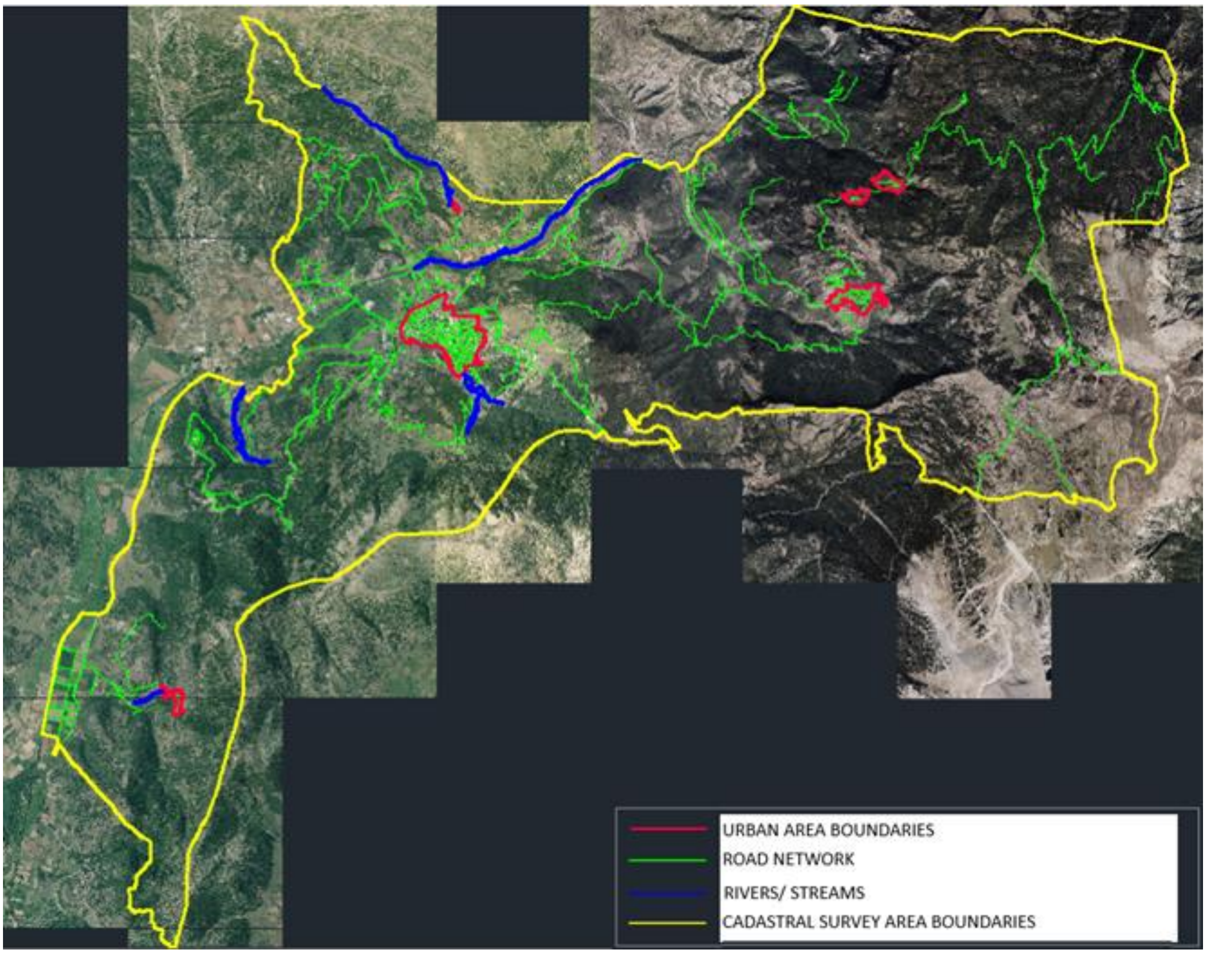


Figure 3.13 *Urban area boundaries, road and river/ stream networks in the area under cadastral survey. Source: Apostolopoulos and Potsiou, 2022*

- The forest maps, both preliminary and approved, are overlaid on the orthophoto, as shown in Figure 3.14.
- The land parcel boundaries, derived from existing administrative acts, are georeferenced and digitized on the orthophoto. If such information is not available, the contractor is responsible for digitizing the preliminary land parcels using photo-interpretation tools and the assistance of local citizens. Figure 3.15 a and Figure 3.15 b illustrate this process.

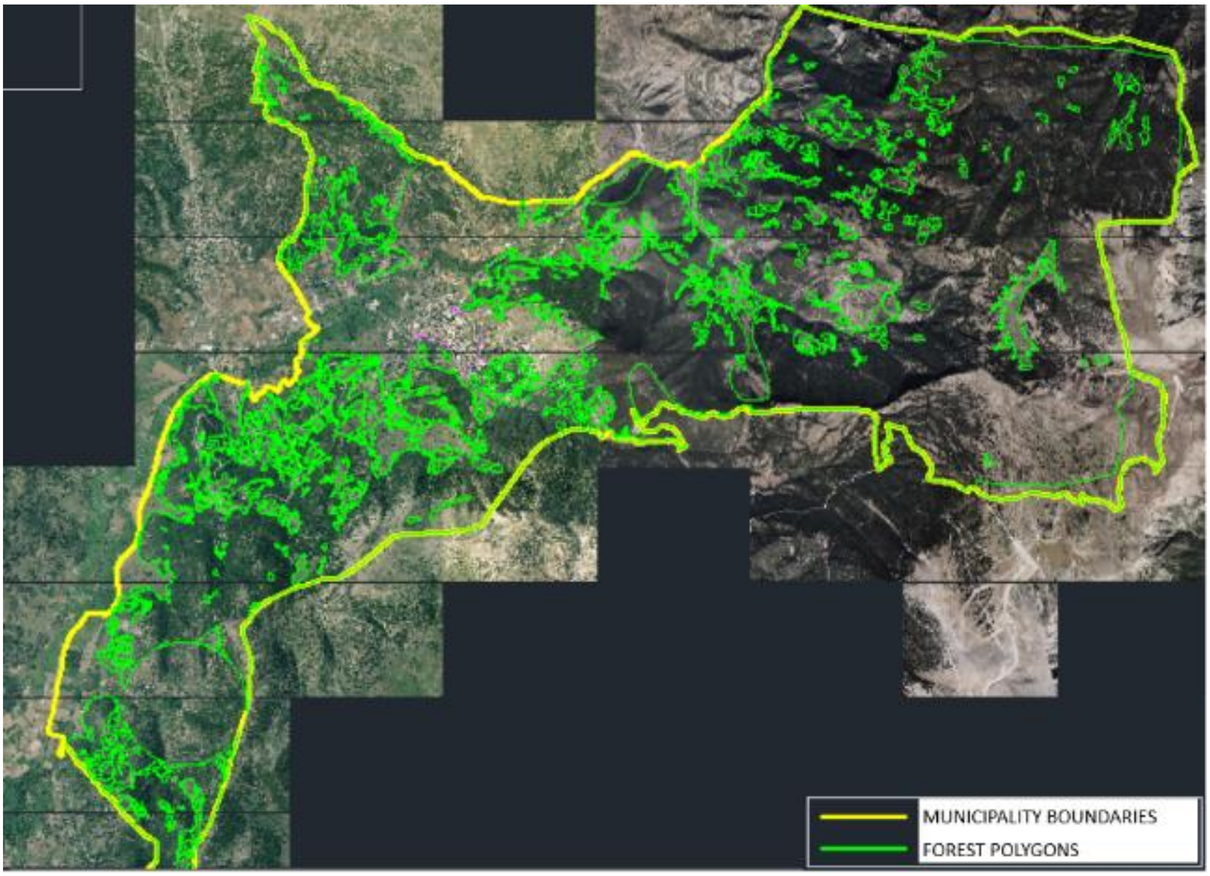


Figure 3.14 *Forest map overlay on the orthophoto. Source: Apostolopoulos and Potsiou, 2022*

(a) **(b)**

Figure 3.15 *Geo-referencing and digitization of* ***(a)*** *land distribution parcels,* ***(b)*** *along with digitization of land parcels using photo-interpretation tools. Source: Apostolopoulos and Potsiou, 2022*

- The rural areas are divided into cadastral units and cadastral sectors according to specific criteria. Cadastral units, ranging from 20 to 200 hectares (or potentially more if necessary), are enclosed by roads, rivers, or other natural or man-made features. Each cadastral unit is represented as a single polygon and assigned a unique ascending number within its respective sector, as described in the special issue of the Codification and Organization of the Hellenic Cadastre (Figure 3.16).

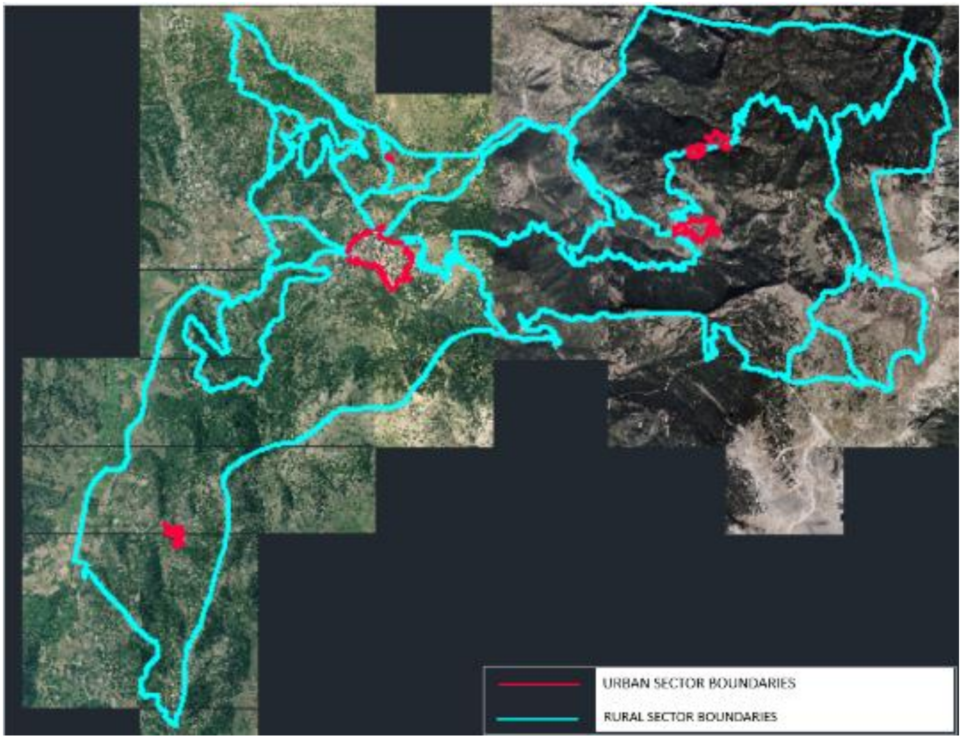


Figure 3.16 *The subdivision of the rural sector into cadastral units and cadastral sectors. Source: Apostolopoulos and Potsiou, 2022*

Figure 3.17 presents an example of an advanced basemap.

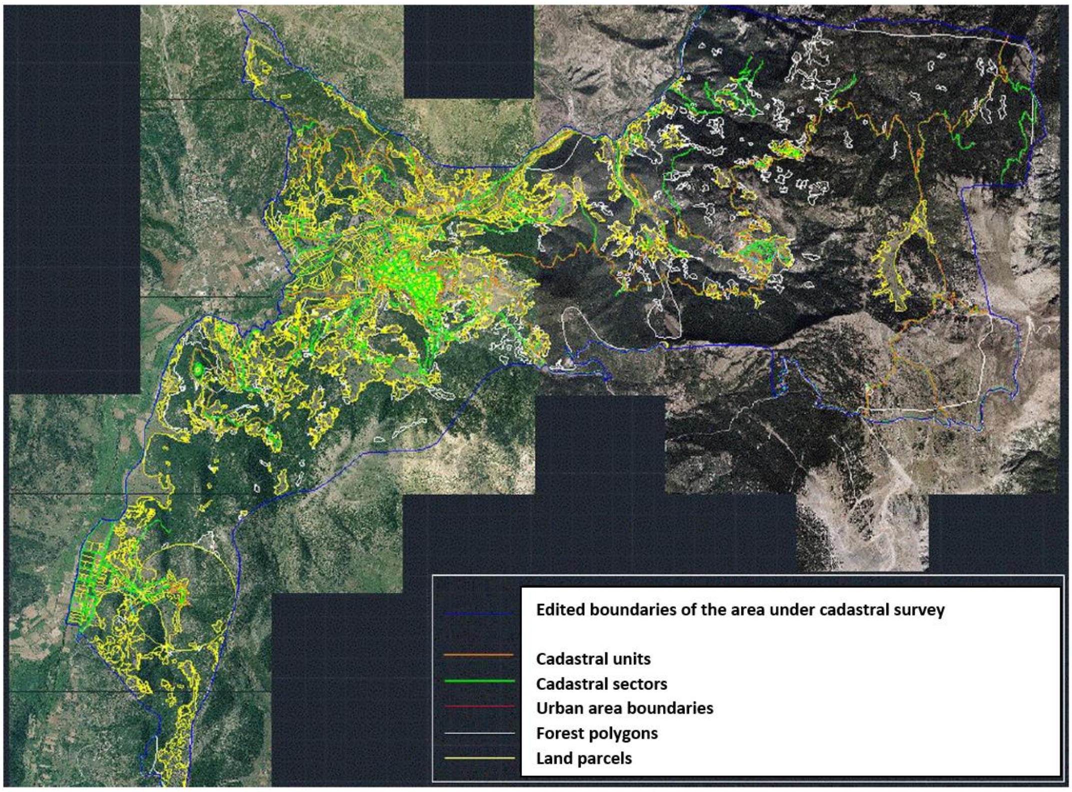


Figure 3.17 *An example of an advanced basemap. Source: Apostolopoulos and Potsiou, 2022*

Subsequently, it is the responsibility of the contractor to compile and submit the technical report of the basemaps (pertaining to both urban and rural areas) to the NCMA for thorough technical evaluation and approval. This crucial step ensures the accuracy and reliability of the basemaps before further progress is made (Figure 3.18).

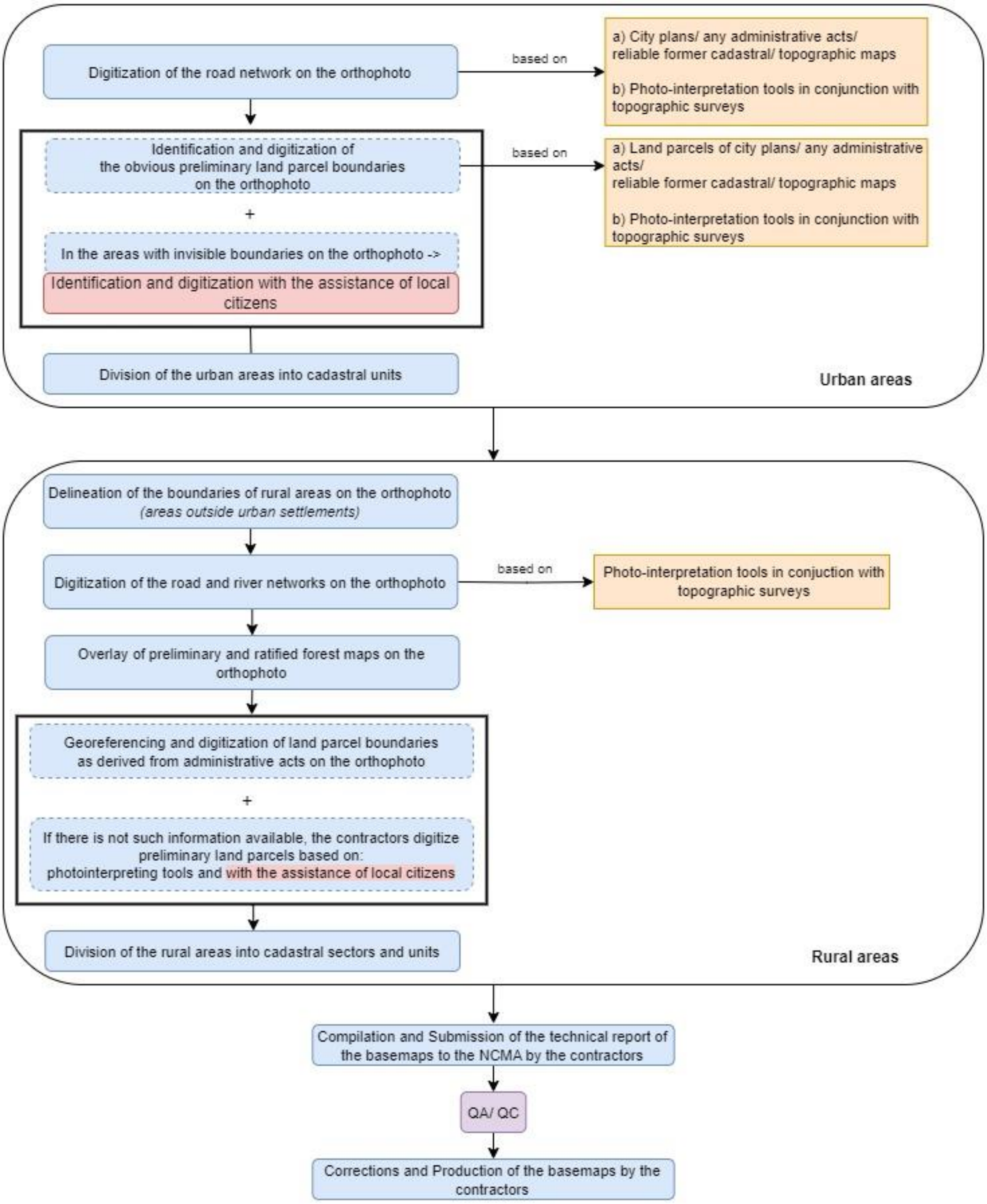


Figure 3.18 *Compilation procedure of the advanced cadastral basemap for urban and rural areas, involving NCMA (purple), contractors (blue), and volunteers (pink) actions. Source: Apostolopoulos and Potsiou, 2022*

3.1.5 Quality Assurance/Quality Control (QA/QC) Methodology

This section explores the methodology used for Quality Assurance/Quality Control (QA/QC) in the Hellenic Cadastral Project. The QA/QC methodology encompasses various controls concerning adherence to the General Project Quality Program, such as equipment, staff, services, timetable, and deliverables. Additionally, it ensures compliance with technical specifications for geospatial data.

Throughout the compilation process, as referenced in Potsiou et al. (2020), the contractors perform Quality Control (QC) assessments of their products, specifically the cadastral maps and data, prior to submitting them to the NCMA. The contractors are required to make multiple electronic submissions of the cadastral maps and data to the NCMA before advancing to the subsequent phase and receiving payments. To provide further clarity, the Hellenic NCMA receives both intermediate and final submissions of the geospatial data (digital cadastral data) as follows:

i. Submission of the preliminary cadastral database (advanced cadastral basemap),

ii. Submission of 50% of the digital cadastral database (following the declaration submission phase),

iii. Submission of the whole digital cadastral database (following the declaration submission phase),

iv. Submission of the revised cadastral database (following the objection examination phase),

v. Submission of final cadastral database (following the initial registration).

To be more precise, the interim deliverables related to the creation of the advanced cadastral basemap include the following:

- Established boundaries of the cadastral study area including (a) the digital files of the boundaries and (b) a technical report detailing the delineation of the boundaries.
- Compilation of the advanced preliminary cadastral basemap including (a) the digital files of the advanced preliminary cadastral basemap, (b) the metadata files and (c) the technical report.
- Scanned documents and maps, which consist of legal and administrative records obtained from existing relevant projects.

The deliverables of the subsequent phases consist of the following:

- The General Project Quality Program.
- Technical reports encompassing the compilation and revision of the digital cadastral database as well as the compilation of cadastral diagrams and tables.
- The digital database containing descriptive cadastral data.
- The digital database comprising spatial cadastral data.
- The quality index of the cadastral database, determined through sampling control.

- Verification of geometric accuracy through sampling control.

The detailed description of the deliverables for the aforementioned submissions, along with the required controls to be conducted by the Hellenic NCMA, can be found in the Technical Specifications Regulation (Greek Government Gazette, 2007). According to these regulations, if the controls reveal notable deviations, a revised submission must be made. As stated (Kavadas, 2018), the QA/QC methodology employed for the Hellenic cadastral project encompasses the following steps:

- Oversight and control of the Quality Plan's execution.
- Conducting audits to assess the processes and services delivered by the contractor.
- Ensuring quality control of the deliverables produced within the cadastral project.

The quality of the deliverables is determined by the following factors, as indicated by (ISO, 2002; Kavadas, 2018):

- Completeness of data, including the presence or absence of features, their attributes, and their relationships:
  - Data commission, which refers to redundancy and excessive data that do not contain necessary features and attributes.
  - Data omission, indicating data that are missing from a dataset.
- Logical consistency of data, which measures the adherence to logical rules regarding data structure, attribution, and relationships:
  - Conceptual consistency, ensuring the internal coherence of the system's structure and the alignment between user task goals and system procedures.
  - Domain consistency, verifying that attribute values adhere to specified value domains.
  - Format consistency, assessing the degree to which data is stored in alignment with the physical structure of the dataset.
  - Topological consistency, defining a set of rules that govern the relationships between neighboring points, lines, and polygons to determine how they share geometry.
- Positional accuracy of data, which assesses the accuracy of the position of features:
  - Absolute accuracy, measuring the proximity of reported coordinate values to accepted or true values.
  - Relative accuracy, evaluating the proximity of the relative positions of features in a dataset to their accepted or true relative positions.

- Gridded data position accuracy, gauging the proximity of spatial position values in gridded data to accepted or true values.

▪ Temporal accuracy of data, which relates to the quality of temporal attributes and temporal relationships of features:
    - Accuracy of time measurements, examining the closeness of reported time measurements to accepted or known true values.
    - Temporal consistency, ensuring that the discrepancy between values stored in the database of real-time systems and the actual data remains within predefined limits.
    - Temporal validity, enabling the tracking of time periods for geospatial data in terms of real-world validity.

▪ Thematic accuracy of data, which measures the difference between attribute values and true values:
    - Classification correctness, calculating the ratio of correctly classified objects to the total number of objects in the test set.
    - Non-quantitative attribute accuracy, assessing whether a non-quantitative attribute is correct or incorrect.
    - Quantitative attribute correctness, determining the proximity of a quantitative attribute value to an accepted or known true value.

There are two types of controls implemented: controls of intermediate deliverables and controls of final deliverables. The adopted quality control (QC) methodology for both intermediate and final deliverables is depicted in detail in Table 3.1.

Table 3.1 *Quality control of deliverables. Source: Kavadas, 2018.*

	Quality control of deliverables
Thematic data	Data uploading (Completeness, Logical Consistency, Temporal Accuracy)
	Legal inspection (Completeness, Thematic Accuracy, Temporal Accuracy)
	Technical inspection (Completeness, Thematic Accuracy, Temporal Accuracy)
Spatial data	Parcel boundaries correctness based on the delineated boundaries of the properties as shown on orthoimages (Completeness, Thematic Accuracy)
	Implementation correctness of topographical diagrams (Positional Accuracy)
	Implementation correctness of bounding parcels within administrative acts (Completeness, Positional Accuracy, Thematic Accuracy)
	Cadastral parcels area compatibility (area in cadastral data vs area in deeds) (Positional Accuracy, Thematic Accuracy)
	The ability to detect non-localized properties (Completeness)
	Possible errors on parcel boundaries using neighboring parcels (Positional Accuracy)
	Geometric accuracy of spatial data with field measurements (Positional Accuracy)
Thematic & Spatial data	Completeness of deliverable, structure and content correctness (Logical Consistency, Thematic Accuracy)
	Correlation of spatial data with corresponding thematic data (Completeness, Logical Consistency)
	Quality indicator of cadastral data (Completeness, Positional Accuracy, Thematic Accuracy)

Completeness · Logical Consistency · Positional Accuracy · Temporal Accuracy · Thematic Accuracy

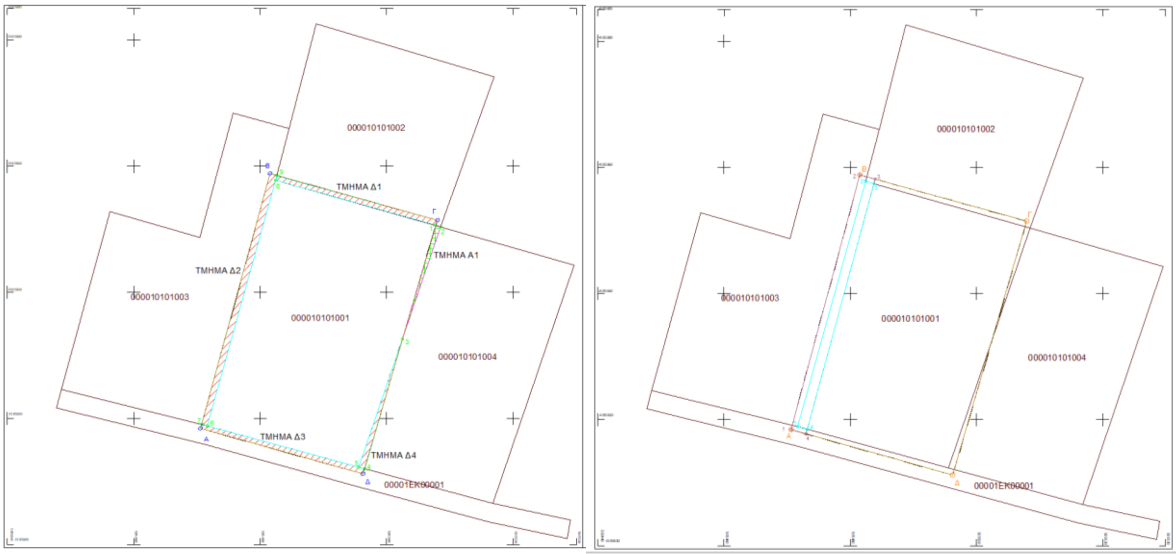
Thematic data undergo checks for completeness, logical consistency, temporal accuracy, and thematic accuracy. This includes verifying the presence of essential thematic data such as id data, addresses, land registry numbering, deed data, and more. Spatial data are examined for completeness, positional accuracy, and thematic accuracy. This involves assessing the geometric accuracy of boundary nodes, ensuring compatibility of land parcel area size on the cadastral map and on the deed, and other relevant factors.

It is noteworthy to highlight that the implementation of the intermediate QC methodology has significantly reduced the number of appeals and petitions for correction by right holders during the objection's submission phase in the Hellenic cadastral project. On average, the appeal rate is 3.4% for thematic data and less than 1.5% for spatial data.

Quality controls encompass various aspects, such as:

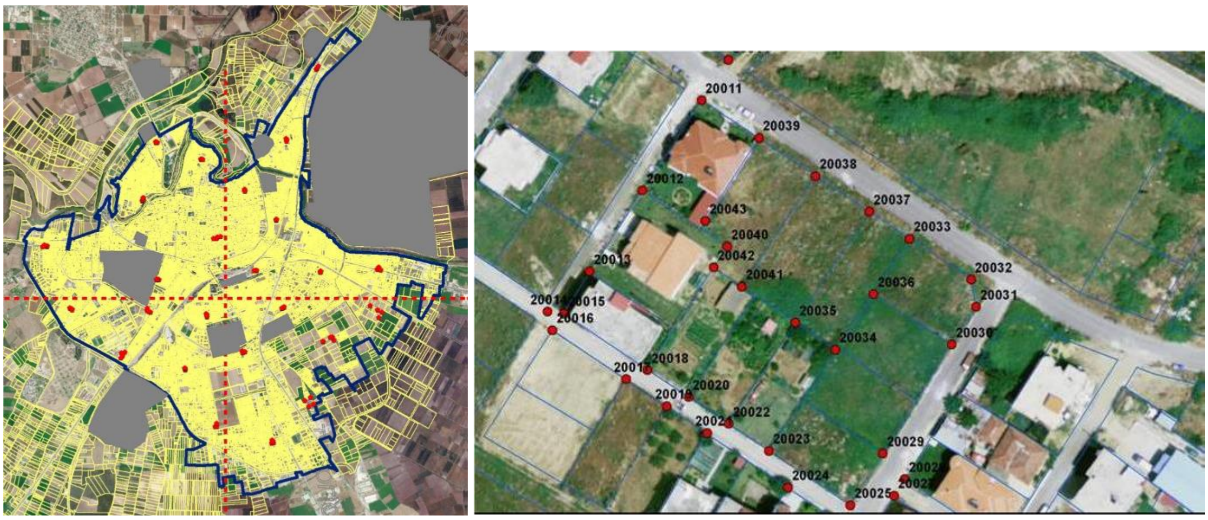
- Ensuring compliance with the required accuracy standards.
- Verifying the geo-reference of administrative acts.
- Checking completeness of titles, right holder data, land parcel area size, and other relevant factors (Figure 3.19 a, b).
- Conducting field measurements to assess compatibility with HEPOS (Hellenic Permanent GPS Network).
- Performing field measurements to validate the adjustment of administrative acts (as shown Figure 3.20 a, b).
- Carrying out field measurements and inspections to verify the boundaries of the land parcels (Figure 3.20 c).
- Assessing the completeness of the cadastral basemap in terms of required accuracies and scales.

These controls are crucial in ensuring the accuracy, integrity, and completeness of the cadastral data and administrative processes involved.

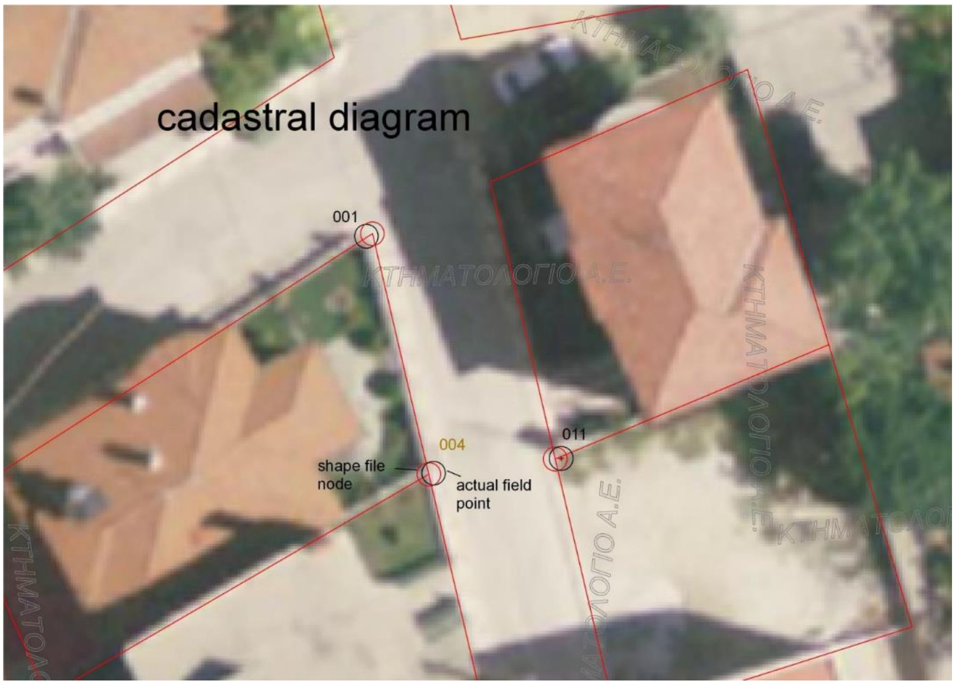


(a) **(b)**

Figure 3.19 (a) *Geometric adjustment of land parcel boundaries* ***(b)*** *and passage easement. Source: Tzanis, 2021.*



(a) **(b)**



(c)

Figure 3.20 (a) *Planning field measurements.* ***(b)*** *Conducting field measurements.* ***(c)*** *Verification of boundaries through checkpoints in cadastral basemap. Source: Kavadas, 2018.*

3.2 The Romanian Cadastre

3.2.1 Historical review

Romania is located in the southeastern region of central Europe and encompasses the Danube area, which includes the Danube Delta and the Carpathian Mountains in the south-central part of the country. It shares borders with five neighboring countries and the Black Sea, with a total length of 3,150 km. The country has a land area of 238,391 km^2 and is divided administratively into 41 counties, including the Bucharest Municipality. These counties comprise 103 municipalities, 217 cities, and 2,861 communes. In order to achieve a general cadastre throughout the country, systematic registration operations need to be carried out in 3,181 administrative units (Austrian Cultural Heritage, 2017).

Land measurements, mapping, and inventory activities in Romania date back to the late 18th century, when the country was divided into four provinces: Wallachia, Moldova, Dobrogea, and Transylvania. The first maps made by Romanian authors were the Map of Wallachia (1700, Constantin Cantacuzino) and the Map of Moldova (1737, Dimitrie Cantemir). The first cadastral and land book registration activities were conducted in Transylvania, Banat, and Bukovina in 1794 when these areas were under Austro-Hungarian jurisdiction. These works were carried out gradually over time and based on three land surveying campaigns: the Josephine land survey (1764-1785), the Franciscan land survey (1806-1869), and the Franciscan-Josephine land survey (1869-1896). These land survey methods, along with the process of creating land books, served as a model for other countries in Central Europe and the United Kingdom.

The different stages of Romania's cadastral activity can be summarized as follows:

i. Early Period of the Cadastre

ii. Period of the Cadastral Organization in Romania (1919-1933)
iii. Period of Modern Cadastre and Unification of Land Books (1933-1955)
iv. Period of Land and Cadastre Systems (1955-1990)
v. Period of Property Law Application (1991 - currently)

i. Early Period of the Cadastre

Cadastral and land registration works began at different times across the Romanian provinces during the 19th century, depending on historical circumstances. In Transylvania, Banat, and parts of Bukovina, cadastral works started following the Austro-Hungarian system in 1794 and continued after 1850, using the "Conceptual Cadastre" approach, which involved the description and delineation of the localities' borders, limits of plots, hydrographic network, and communication network of localities.

These cadastral works continued following a phased approach, which included the Josephinian land survey (1764-1785) (Figure 3.21), the Franciscan land survey (1806-1869), and the Franciscan-Josephinian land survey (1869-1896). The aim of these surveys was to establish a conceptual cadastre that involved the delimitation, description, and representation of borders, plot limits, hydrographic networks, and communication networks.

***Figure 3.21** Cadastral map of the Banat region, 1769-1772. Source: National Archives of Romania, 2023.*

In Wallachia and Moldavia, attempts were made to introduce the cadastre in 1831 and 1832, respectively, by the first border-settling engineers trained at specialized schools. The rest of the country established the cadastre after World War I, alongside land reform. However, the extent and scope of these early cadastral surveys in Wallachia and Moldova are not explicitly mentioned in the provided information.

ii. Period of the Cadastral Organization in Romania (1919-1933)

Between 1919 and 1933, Romania underwent significant developments in its cadastral surveys and land registration processes. During this period, efforts were made to establish a more organized and systematic approach to cadastral activities throughout the country.

In 1919, the establishment of the 'Directorate for Cadastre and Technical Works' focused on measuring domains and dividing land assigned to peasants after World War I. However, it is important to note that the cadastral surveys during this period faced challenges related to the lack of a uniform geodetic triangulation network. As a result, measurements were conducted using local reference systems, leading to differences in accuracy and content across different regions.

One notable advancement took place in 1930 when the stereographic projection system was adopted. This development came about through collaboration between the Directorate for Cadastre and the Geographic Institute of the Army. The stereographic projection system improved the accuracy and consistency of cadastral surveys by providing a standardized method for mapping and representation.

The period between 1919 and 1933 marked a significant stage in Romania's cadastral surveys and land registration activities. It saw the establishment of a dedicated directorate, the implementation of cadastral activities for land distribution, and advancements in mapping techniques. These efforts laid the groundwork for a more comprehensive and organized cadastral system in Romania.

iii. Period of Modern Cadastre and Unification of Land Books (1933-1955)

This period was marked by various socio-political changes and economic transformations, including the establishment of a communist regime.

In the early stages of this period, the cadastral surveys in Romania continued to focus on land measurement and parcel divisions. The "Directorate for Cadastre and Technical Works" had a central role in conducting these cadastral surveys. Efforts were made to improve the accuracy and consistency of measurements by adopting advanced surveying techniques and equipment.

Law no. 93/1933 played a pivotal role in shaping the cadastre and land registration system during this period. It introduced regulations on how to organize and prepare the national cadastre, emphasizing the establishment of unitary geodetic networks and the creation of cadastral plans and registers. Cadastral works were initially carried out in Wallachia and Dobrogea, followed by Moldavia and Oltenia. Existing surveys in Transylvania, Banat, and Bukovina were also updated, but their progress was halted due to the war. After World War II, temporary land measurement and parceling works were undertaken to allocate land to peasants. Notably, the cadastre institution lost financial support from the communist government. In 1949, agricultural collectivization was implemented, rendering the existing cadastral law and measurements obsolete within the totalitarian regime.

Due to the rise of the communist regime in Romania in the late 1940s, the approach to land ownership and management underwent significant changes. The state assumed greater control over land resources, and the land was gradually collectivized and redistributed among collective and state farms. This shift in land ownership and agricultural structure had implications for the cadastral surveys during this period.

The cadastral surveys conducted between 1933 and 1955 focused on documenting land ownership within the framework of state control and collectivization. The surveys aimed to identify and register land parcels, determine property boundaries, and record ownership information in accordance with the new socialist principles. The cadastral surveys were carried out by specialized institutions under the supervision of the Ministry of Agriculture and Food Industry, with an emphasis on central planning and state ownership of land. The data collected through these surveys served as the basis for land management, agricultural planning, and resource allocation within the collective and state farm systems.

It is important to note that during this period, the cadastral surveys were influenced by the ideological and economic changes brought about by the communist regime. The focus shifted from individual land ownership to state-controlled collective and state farms, and the surveys aimed to support land management and planning within this new framework.

Overall, the cadastral surveys in Romania between 1933 and 1955 underwent significant transformations due to the socio-political changes and economic shifts brought about by the establishment of a communist regime. The surveys focused on documenting land ownership within the context of collectivization and state control, supporting central planning and land management within the agricultural sector.

iv. <u>Period of Land and Cadastre Systems (1955-1990)</u>

During this period, the Romanian government focused on implementing a comprehensive cadastral system to ensure efficient land management and land administration. The cadastral surveys were conducted by specialized institutions under the supervision of the Ministry of Agriculture and Food Industry.

One of the main objectives during this period was to establish a unified and accurate land registry throughout the country. Cadastral surveys were carried out to measure and define land parcels, determine property boundaries, and register land ownership information. These surveys aimed to provide clear and standardized documentation of land assets across Romania. The cadastral surveys during this period were conducted using advanced surveying technologies and methods, including aerial photography, photogrammetry, and geodetic measurements. These technologies helped improve the accuracy and efficiency of the cadastral surveys and allowed for more precise mapping of land parcels.

Furthermore, the cadastral surveys played a crucial role in supporting agricultural planning and land-use management. The data collected through these surveys was utilized to assess agricultural potential, determine land suitability for various purposes, and allocate land resources for different agricultural activities. Land ownership was predominantly held by the state, individual ownership rights were limited, and land allocation was primarily based on collective and state farms. The cadastral surveys aimed to establish a clear record of land holdings within this state-owned framework.

v. Period of Property Law Application (1991 - currently)

Following the downfall of communism, the implementation of the Land Property Law no. 18/1991 aimed to facilitate the restitution of confiscated lands to their original owners. Subsequently, the Law of Cadastre and Land Registration (Law 7/1996) (Romanian Government Gazette, 1996) was introduced five years later, enabling the establishment of a modern system for registering property ownership. Additionally, it led to the creation of the National Office of Cadastre, Geodesy, and Cartography, which later transformed into the National Agency for Cadastre and Land Registration (ANCPI - NACLR) in 2004 (Savoiu et al., 2015). The ANCPI-NACLR held the responsibility of managing systematic cadastral surveying projects throughout Romania.

Since then, the National Program of Cadastre and Land Registration in Romania is regulated mainly by Law No. 7/1996. This legislation guides the organization and preparation of the cadastral works, emphasizing the establishment of unitary geodetic networks and the creation of cadastral plans and registers. The implementation of this cadastral system involves conducting cadastral works country-wide at the level of cadastral sectors.

According to the Romanian Statistical Yearbook of 2017 (Romanian Statistical Yearbook, 2017), the integrated cadastre and land register system encompasses 3,181 administrative-territorial units, consisting of 103 municipalities, 217 cities, and 2,861 communes, which further include 12,957 villages.

The ongoing National Cadastre and Land Registration Program, financed by the National Agency of Cadastre and Real Estate Advertisement, is set to be completed by 2023. This program, regulated by Law no. 7/1996 and subsequent modifications, as well as Resolution of the Government no. 294/2015, aims to achieve the free-of-charge registration of real estate in the integrated cadastre and land register system.

The systematic cadastre works are carried out either at the entire administrative-territorial unit level or selectively in specific cadastral sectors. Specialized providers follow the legislation and technical norms outlined in Law 7/2016 to execute the systematic registration of real estate in cadastral sectors. Once the registration is completed, owners or their heirs receive a certificate for registration in the land register (Hogaș and Bofu, 2018). With the financial resources allocated between 2016 and 2017 by the National Agency of Cadastre and Real Estate Advertisement, cadastral works, including systematic registration at the level of basic administrative-territorial units and cadastral sectors have been successfully concluded.

The ANCPI initiated the National Program of Systematic Land Registration in Romania (PNCCF) in 2015, intending to register all localities in the country by 2023. However, as of June 2022, only a mere 4% of localities have been successfully registered. It is evident that achieving the project's objective within the proposed timeframe is highly unlikely (Paunescu et. al., 2022). The systematic registration process had reached its final stage in 57 administrative-territorial units across 20 counties. Additionally, systematic registration works were accomplished for 1,470 cadastral sectors situated within 595 administrative units, covering 38 counties (ANCPI, 2023) (Figure 3.22). Figure 3.23 also presents the number of registered properties in Romanian cadastral surveys as of 2023.

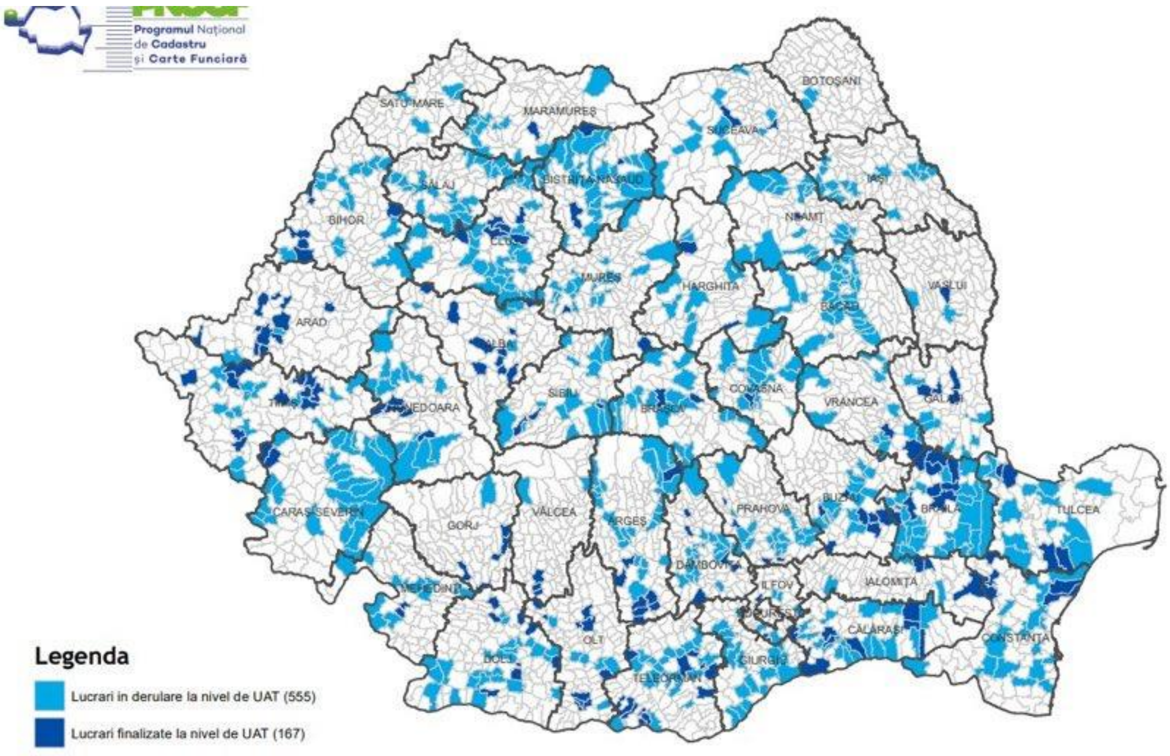


Figure 3.22 *Progress of the Romanian cadastral surveys. Source: ANCPI, 2023.*

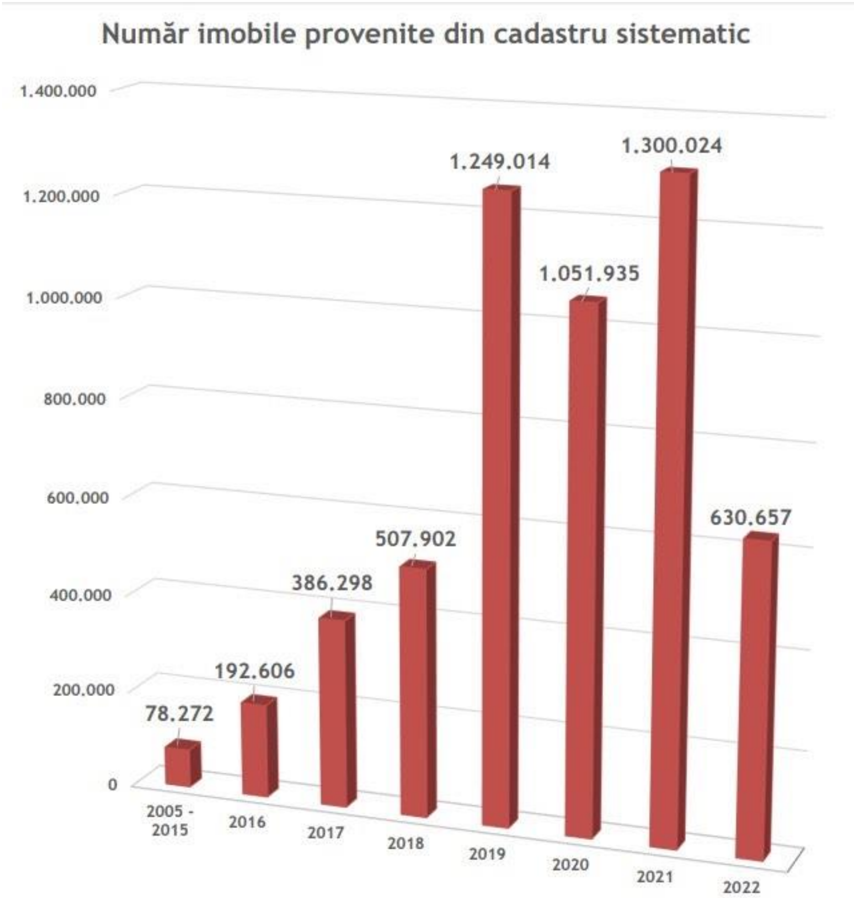


Figure 3.23 *Number of properties registered in Romanian cadastral surveys. Source: ANCPI, 2023.*

There is ongoing discussion regarding the slow progress of the Romanian land registration program. The majority of published papers on the Romanian land administration system and systematic land registration primarily focus on legislative matters (Badea et al., 2015), technical land surveying, and procedural aspects (Gresita and Grigorie, 2017; Oprea, 2017; Badescu et al., 2018; Moca et al., 2018; Koncsag and Vel tan, 2019; Pop et al., 2021), as well as alternative methodologies and emerging opportunities (Savoiu et al., 2015; Potsiou et al., 2020).

A potential solution to expedite the formal land registration process in Romania is the implementation of the fit-for-purpose approach. This approach emphasizes a participatory and innovative methodology that can be tailored to the specific context of a country (Bennet et al., 2016; Zevenbergen et al., 2015). It prioritizes purpose, offers flexibility, and allows for easy upgrades (Enemark et al., 2015). Unfortunately, the Romanian National Program of Systematic Land Registration was not originally designed in accordance with the fit-for-purpose concept. Limited flexibility in technical matters and a lack of clearly defined objectives contribute to the slow pace of registration. However, certain stages of the land registration project, such as public displays of work and complaint resolution, align with the principles of the fit-for-purpose approach.

3.2.2 Legislation

The legislation governing cadastral surveys in Romania has evolved over time, with several laws shaping the framework for land registration. These laws have played crucial roles in shaping the cadastral surveys and land registration system in Romania, promoting standardization, modernization, transparency, and efficiency in land registration processes. They have provided a legal framework for cadastral surveys, ensuring accurate and reliable data for effective land management and administration. The key laws of this legislation are provided:

- *Law no. 93/1933*: This legislation established regulations for organizing and preparing the land cadastre. It emphasized the creation of unitary geodetic networks and provided guidelines for developing cadastral plans and registers.

- *Law no. 7/1996 (amended by Law no. 351/2001)*: This law established the legal framework for the National Agency for Cadastre and Land Registration (ANCPI). It aimed to modernize and digitize cadastral data, improve the efficiency of land registration processes, and ensure the accuracy and reliability of land information.

- *Law no. 7/2006 (amended by Law no. 119/2010)*: This legislation focused on simplifying administrative procedures and reducing bureaucracy in the cadastral and land registration system. It introduced measures to expedite the process of issuing land titles, support procedures for property transfers, and improve the accessibility of cadastral information to the public.

- *Law no. 154/2012 (amended by Law no. 170/2016)*: This law aimed to simplify administrative procedures in the cadastral and land registration system, further reducing bureaucracy and enhancing efficiency. It introduced measures to accelerate the process of updating and registering cadastral data, promote transparency, and improve public access to land information.

- *Law no. 7/2016*: This legislation focused on enhancing the legal framework for land cadastre and land registration. It introduced measures to improve the accuracy and reliability of cadastral data, establish a unified system for land valuation, and facilitate the integration of geospatial information in the land registration process.

- *Law no. 203/2020***:** This law aimed to simplify administrative procedures and improve the efficiency of land registration. It introduced measures to enhance the process of registering and updating cadastral data, enhance the transparency of land transactions, and promote the use of electronic systems in land registration processes.

3.2.3 Main stages of the Romanian cadastral surveys

The systematic cadastral registration procedure in Romania follows the steps outlined below, as depicted in Figure 3.24:

a) Declaration of a specific administrative-territorial unit for the cadastral survey and issuing a call for bids. Private cadastral surveyor companies (contractors) are commissioned for the task.

b) ANCPI provides orthophotos to the cadastral surveyors for the compilation of draft cadastral basemaps. These basemaps incorporate all available data from the Cadastral Office, Town Hall, or other public institutions. An advertising campaign is organized at both national and local levels to inform property owners about the commencement of systematic registration and their associated benefits, rights, and obligations.

c) Cadastral field surveys are conducted, involving activities such as parcel identification on orthophotos by property owners, submission of declarations with property rights and owner information, on-site measurements of boundaries and building footprints, processing of declarations and new data by contractors, and validation of the legality of legal documents presented by property owners. It is mandatory for the geometrical data to be derived from these field surveys, requiring contractors to measure all identifiable properties in the field.

d) The information collected is processed by the cadastral surveyor to create the technical cadastral documentation and the draft cadastral map for the relevant administrative area. Any subsequent changes such as subdivisions or transactions that occur before finalizing the draft cadastral map must be reported and incorporated into the digital database by the contractors.

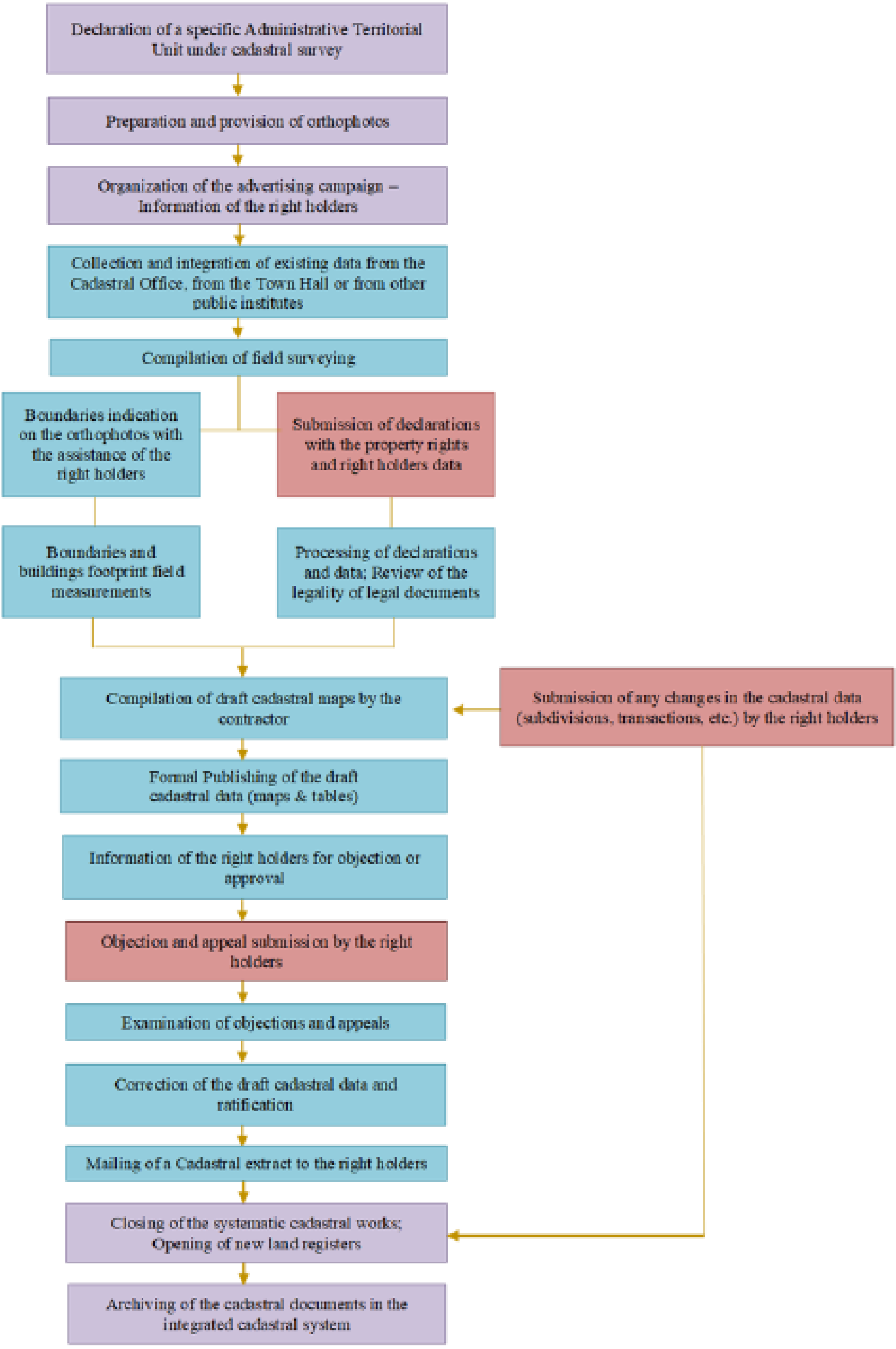


Figure 3.24 *Main stages of the Romanian Cadastre Survey (stages in purple color depict state actions; stages in blue color depict contractors' actions stages in pink color depict right holders' actions). Source: Potsiou et. al., 2022*

e) The draft cadastral data, including maps and tables, is formally published at the ANCPI's offices for a period of two months, and the affected property owners are informed.

f) Property owners have the opportunity to submit objections and appeals. An independent administrative committee, consisting of a member from ANCPI, a cadastral surveyor, and a representative from the city hall, reviews and addresses the objections.

g) The cadastral data is corrected and the technical cadastral documentation is updated based on the examination of objections. The final cadastral tables and maps are then prepared.

h) Land book extracts and extracts of the new cadastral plan are mailed to the property owners in accordance with the provisions of the law.

i) The systematic cadastral works are concluded, and the old cadastral and land registry records are closed. New land book registers are opened to reflect the updated cadastral information.

j) The cadastral documents are archived within the integrated system of cadastre and land book for long-term storage and retrieval.

3.3 Concluding remarks

In conclusion, the establishment of a comprehensive and up-to-date cadastre is of utmost importance for countries like Greece and Romania. These cadastres serve multiple purposes, including enhancing the security of land tenure, facilitating access to credit for low- and middle-income households, implementing fair property taxation, and fostering a sustainable real estate market that attracts investments and contributes to poverty reduction and mitigating climate change impacts.

Despite being members of the European Union (EU), Greece and Romania currently lack complete and up-to-date cadastres for their entire territories. To address this issue, both countries have initiated property registration projects that are closely monitored and evaluated by local and international experts. This demonstrates that these projects are being designed based on the latest international and local expertise, and are following appropriate practices within the legal, socioeconomic, and political contexts of each country. This instills scientific confidence in the efforts being made to establish technically and legally reliable cadastres that are accurate, assured, and authoritative (AAA).

The responsibility for gathering geospatial and cadastral data lies with the National Cadastral and Mapping Agencies (NCMAs), while the private sector conducts cadastral surveys through a formal bidding process. Pilot participatory projects have played a crucial role in identifying challenges and difficulties encountered during these initiatives. Landowners are actively involved in identifying and locating their land parcels, declaring their rights, and providing necessary documentation. Photogrammetric methods and orthophotos are utilized as basemaps to capture initial cadastral data. In Greece, additional field surveys are conducted when deemed necessary, allowing private surveyors to choose suitable methods based on a fit-for-purpose approach. On the other hand, Romania mandates cadastral maps to be compiled through field surveys.

This chapter has provided an overview of the cadastral methods employed in Greece and Romania, with a focus on the legal, institutional, and technical aspects of cadastral surveying, mapping, and data management. The objective has been to examine the formal procedures used for cadastral data collection in both countries and propose a more adaptable and efficient model that incorporates new IT tools and enhanced citizen participation. The aim is also to expedite the initial data collection phase while ensuring better quality and effectiveness of the process, as indicated by earlier studies.

The examination of the formal procedures used for cadastral data collection in Greece and Romania has provided valuable insights for developing a more adaptable and efficient cadastre model. The incorporation of new IT tools and enhanced citizen participation in the process aims to enhance data collection while ensuring the highest quality and effectiveness. The utilization of a fit-for-purpose approach, where the surveying methods are tailored to the specific needs and requirements of each project, allows for a pragmatic and cost-effective implementation.

While the focus of this chapter has been on Greece and Romania, the principles and approaches discussed can be extrapolated to other countries facing similar challenges in their cadastre development. The successful implementation of a modern cadastre requires collaboration, knowledge sharing, and continuous improvement. Countries can learn from one another's experiences, best practices, and innovative solutions to develop efficient and effective cadastral systems.

The establishment of a complete and up-to-date cadastre is crucial for countries worldwide. It serves as a foundation for secure land tenure, facilitates access to credit, enables equitable property taxation, and fosters a sustainable real estate market. Greece and Romania's ongoing property registration initiatives, guided by local and international experts, demonstrate a commitment to addressing the gaps in their cadastres. By adopting a fit-for-purpose approach, incorporating new IT tools, and enhancing citizen participation, countries can develop reliable, accurate, assured, authoritative, and modern cadastres. The benefits of such cadastres extend to social stability, economic growth, and sustainable development, making them indispensable components of effective land administration systems.

4 Proposed Model for a FFP Cadastral Procedure

Cadastral surveys are crucial for effective land administration, providing information on land ownership, boundaries, and land rights. However, many countries face challenges in establishing comprehensive and reliable cadastral systems due to various factors such as limited resources and personnel, complex land tenure and legal systems, and diverse geographical contexts. In response to these challenges, the concept of a fit-for-purpose methodology has emerged as a flexible and efficient approach to cadastral surveys. This chapter aims to introduce a fit-for-purpose model for cadastral surveys, drawing experience and knowledge from existing literature, the Agenda 2030, and in-depth research on the compilation procedures of the Hellenic and the Romanian cadastral systems, and a series of case studies to test the proposed methodology, as presented in chapter 5.

The proposed fit-for-purpose model emphasizes a pragmatic and incremental approach to cadastral surveys, prioritizing the specific needs and objectives of cadastral projects rather than striving for absolute accuracy from the initial phase of these projects. By tailoring survey methods and data requirements to the intended use and context, this methodology seeks to overcome barriers and expedite the implementation of cadastral systems.

To build a comprehensive understanding of the fit-for-purpose model, this chapter will draw upon the extensive literature review that explores the theoretical foundations, principles, and practical applications of this approach. It will delve into the works of experts and scholars who have contributed to the development and refinement of fit-for-purpose cadastral surveys. By synthesizing existing knowledge and insights, this chapter will lay the groundwork for the subsequent exploration of the methodology's practical implementation.

Furthermore, this chapter will examine the compilation procedures of the Hellenic and Romanian cadastres as case studies to provide empirical insights into the application of fit-for-purpose methodologies in real-world contexts. The analysis of these specific cases will shed light on the challenges encountered, the strategies employed, and the outcomes achieved.

The chapter will also highlight the significance of case studies in understanding the practical aspects of fit-for-purpose methodologies. These case studies, which will be presented in the subsequent chapter (Chapter 5), showcase the diverse contexts in which the methodology has been implemented, including varying geographical locations, patterns and socio-economic conditions. Through the analysis of these cases, readers will gain insights into the adaptability and effectiveness of fit-for-purpose approaches across different settings.

These approaches could be adopted to gather essential geospatial data without conducting detailed professional field measurements and utilizing cost-effective modern technologies and participatory techniques. They may even be used to collect geospatial data to enable a number of land management projects, such as swift planning enhancements and effective management of emergency demands by working from home using open data in a number of cases. Such cases may include the extreme situations of a lockdown (as was the case during the pandemic) and those situations that have evolved in the post-COVID-19 era using the legacy and experience of "working from home" acquired during the pandemic. Such an example is given with an application of this methodology for planning for tourism.

By incorporating findings from the literature review, insights from the compilation procedures of the Hellenic and Romanian cadastres, and the examination of these case studies, this chapter aims to provide a modern fit-for-purpose model for cadastral surveys. It sets the stage for a deeper exploration of the practical implementation, challenges, and benefits of this approach. Through this holistic approach, readers will gain a solid foundation of knowledge and understanding to navigate the complexities and opportunities associated with fit-for-purpose cadastral surveys.

In summary, this chapter introduces a proposed model for a new FFP cadastral procedure, which offers a pragmatic and incremental approach to overcome challenges in establishing comprehensive and reliable cadastral systems. By synthesizing existing knowledge and examining real-world applications, this chapter provides an overview of the fit-for-purpose methodology, setting the stage for a deeper exploration of its practical implementation and implications in subsequent chapters.

4.1 State of the art

As of 2014, the utilization of technology seemed to be a valuable asset for cadastral surveyors, both in terms of systematic record-keeping and system maintenance in all countries. It offered the potential for fast and timely delivery of reliable results while also reducing overall costs. New technological advancements such as handheld GPS devices, Wi-Fi, smartphones, and mobile applications provided the capability to greatly facilitate cadastral surveys. In traditional systematic registrations, property owners had typically been involved in the adjudication phase, where they either demonstrated their property boundaries in the field or on existing basemaps depending on availability. However, conducting field visits could be time-consuming and costly for both the owners and surveyors. An alternative approach was inviting owners to the office and showcasing their boundaries on aerial photos or other available basemaps, such as old maps. However, this method posed the risk of confusion and incorrect identification of properties, particularly if the boundaries were not clearly visible on the basemaps. Fortunately, advancements in technology could significantly enhance these procedures by providing more accurate and accessible tools. Additionally, involving non-professional groups like community leaders and local residents could also contribute to the improvement of the adjudication process (Basiouka and Potsiou, 2011).

There was a need to enhance cooperation between professionals and property owners by providing them with basic instructions and training to facilitate their direct involvement in capturing and maintaining information about their properties. This shift aimed to redirect the focus of qualified professional surveyors from the traditional role of data collection to establishing a new procedure where property owners (or other non-professional local groups) would directly undertake data collection. Subsequently, the surveyor's role would shift towards evaluating and managing the collected data. It was crucial to create incentives, build public trust, and raise awareness among property owners regarding the benefits they would gain from this approach (Basiouka and Potsiou, 2013). Additionally, it was necessary to explore whether adjustments to the policy frameworks were needed within each country's legal context to facilitate the implementation of this new procedure.

Regarding the type of cadastral information collected by property owners, it varied depending on the country's circumstances, capacity, and infrastructure availability. The information could include:

- Centroid positions or boundary markings of land parcels.
- Building outlines, characteristics, number of floors, property rights, and/or property photos.
- Data of property right holders and photos or scans of supporting documents.

It was also important to utilize various basemaps based on the availability of additional topographic information.

As analyzed in Chapter 3, Greece and Romania have provided valuable insights for developing a more adaptable and efficient cadastre model. Specifically, Greece offers a valuable case study area for examining lessons learned and sharing experiences in the field of systematic cadastral registration since 1995. The Greek project utilizes a "self-declaration" submission approach in its adjudication procedure, where property owners are required to submit their legal documents and/or surveying plans and identify their parcels on orthophotos. Despite efforts to inform all property owners in the survey areas and encourage their participation, some areas experienced low levels of participation due to owners moving to distant locations. Particularly in rural areas, even when property owners did participate, they encountered difficulties in correctly identifying their properties on the orthophotos, leading to a significant percentage of gross errors (Basiouka and Potsiou, 2011).

Consequently, after extensive efforts and careful consideration, the Greek cadastral agency concluded that re-surveying these areas was the most appropriate solution, despite the associated increase in costs. Basiouka and Potsiou (2011) conducted a pilot case study to address the challenges faced in these areas, aiming to explore the efficiency of crowdsourcing techniques in facilitating property owners, reducing errors, and expediting the formal cadastral procedure. The area of interest was mapped over a weekend using crowdsourcing techniques, with the assistance of a handheld GPS device and fifteen volunteers supervised by three surveyors. Local authorities informed landowners and other volunteers, organizing a meeting where surveyors explained the use of the handheld GPS. The volunteers collected the data, and the surveyors edited it in the office.

A comparison between the produced draft cadastral map and the official cadastral re-survey provided by the Hellenic NCMA revealed that the location and shape of all land parcels were accurately defined, and the majority of the land parcels' area sizes were within the technical requirements of the project. Conversely, in the cadastral survey delivered by the contractor, despite the use of high-accuracy surveying instruments, almost all land parcels were inaccurately located and shaped, and only 10.5% of them met the technical specifications in terms of area size. These results underscored the need for better facilitation of the owners' participation procedure in the future. Building upon this research, the first step towards building the proposed model for a new FFP cadastral procedure was to choose to utilize a case study area in Greece to further explore and test the value of mobile services and new methods in improving the adjudication procedure and enhancing owners' participation.

4.2 Investigating technology developments and citizen participation in an urban environment

The development of mobile devices and new software opened up possibilities to enhance traditional practices and achieve more precise outcomes concerning technical and operational aspects. In 2014, (Mourafetis et al., 2015) proposed a new procedure to enable the collection of cadastral data using mobile devices, like smartphones and tablets, along with existing low-cost commercial software. This allowed for the elimination of errors saved time, and reduced additional costs for re-surveying, thanks to the use of simple tools that were accessible to most citizens, even in developing countries. It also facilitated the modern participation of owners or general beneficiaries in cadastral projects.

The experiment employed ESRI's ArcGIS online application 'LADM in the Cloud' (Jones, 2013), which was accessible on both IOS and Android platforms (ESRI, 2014). The ESRI application

(Figure 4.1) was appropriately designed to collect and record cadastral information for an entire area. The implementation of this application had two components (a) the server side and (b) the client side.

Figure 4.1 *ArcGIS online application 'LADM in the Cloud' - Version of 2014. Source: Jones and Land, 2012.*

4.2.1 The Server Side - ArcGIS online

ESRI's ArcGIS online allowed the definition of organizational accounts for groups of users with various operational capabilities. Although these accounts were available for purchase from ESRI, a 30-day trial account with full functionality was utilized for this case study.

The first step of the procedure involved selecting a basemap to use. ESRI offered a range of basemaps, including imagery and vector options that could be combined. Additionally, users had the option to add external OGC WMS services. However, using arbitrary internet maps was not suitable for a formal cadastral procedure, except in cases where developing a basic cadastral system was the only choice. For this research, it was decided not to use arbitrary maps available on the internet and instead opted to use available orthophotos. These orthophotos were specifically produced in 2007 for the Greek cadastre project, utilizing well-known photogrammetric methods, aerial images, and ground control points. Such basemaps were considered reliable and appropriate for cadastral purposes, with their scale and accuracy typically defined by each country's cadastre technical specifications. This step was crucial as it distinguished the information derived from the proposed method, based on digitized information with the orthophoto's accuracy, from that obtained through crowdsourcing techniques using arbitrary internet maps, where the smartphone's positioning accuracy was a limitation.

In Greece, the responsible NCMA offered orthophotos for the entire country with an accuracy suitable for urban areas at a 1:1000 scale and for the rest of the country at a 1:5000 scale. It opted to use this orthophoto as the basemap while also exploring other basemaps provided by ESRI.

The next step involved defining the descriptive information to be collected by citizens. This process could be as simple as creating a shapefile with the necessary fields (e.g., social security number, ID number, name, and surname) and publishing it through the ArcGIS Desktop application in ArcGIS online. This implementation and deployment were relatively straightforward.

In the developed application, a map with two basemaps (one from ESRI and one WMS layer from EKXA S.A.) was created in ArcGIS Online. The layer created in ArcGIS Desktop was added on top of the basemap, enabling citizens to digitize their properties and this information was made publicly available and released in the cloud. Cloud technology facilitated the integration of various information types, offering web services accessible to various stakeholders, including governments, banks, citizens, and professionals (Figure 4.2).

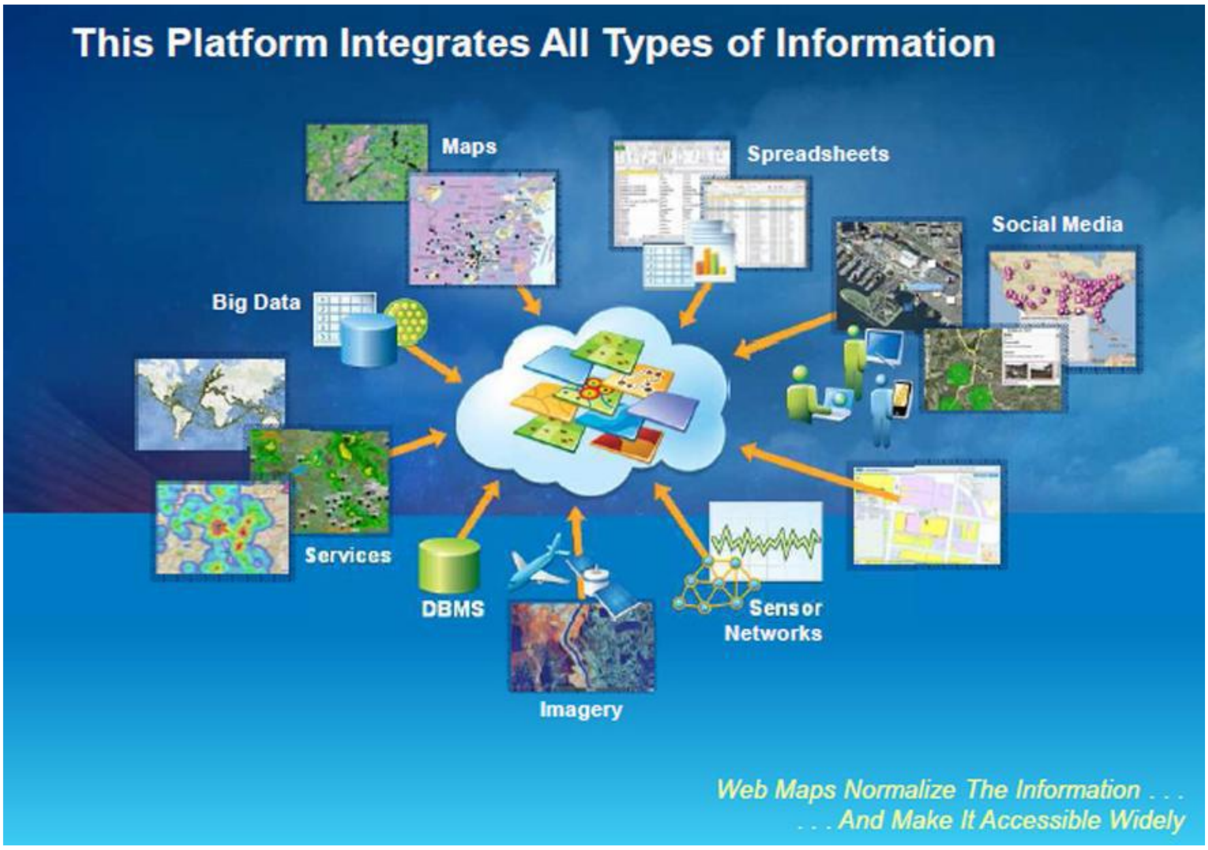
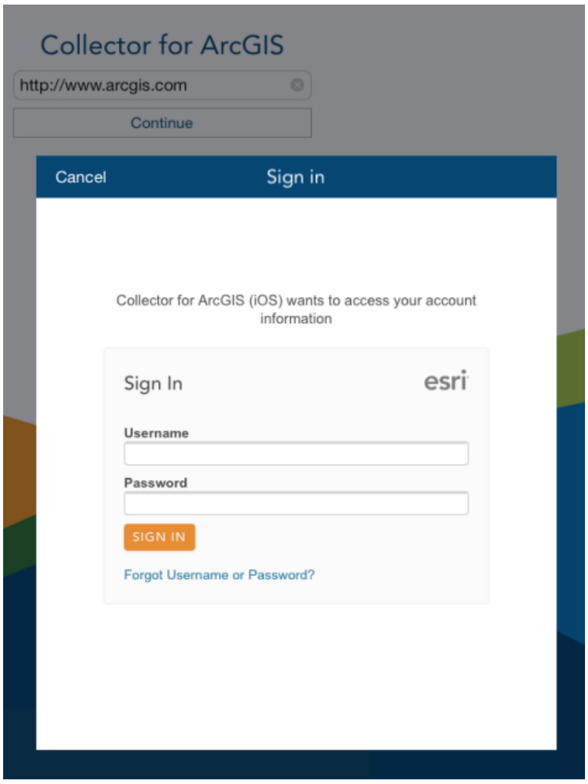


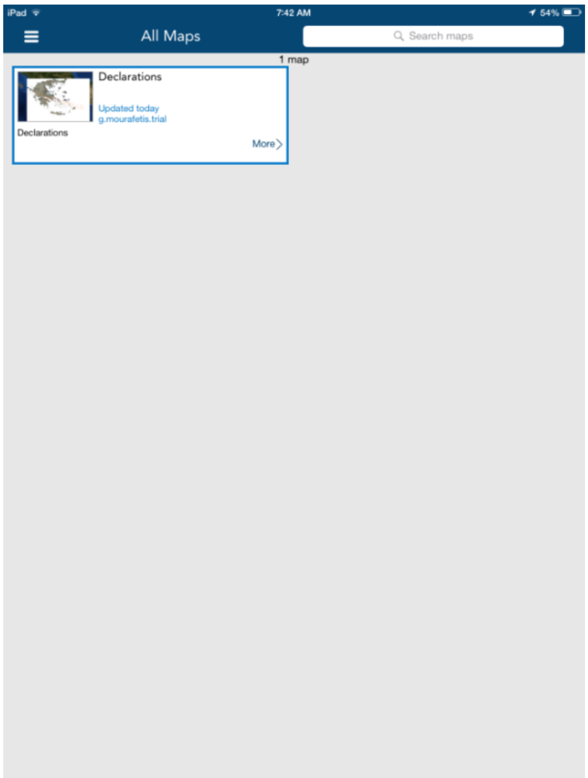
Figure 4.2 *Integration of information and web services in the cloud. Source: Jones and Land, 2012*

4.2.2 The Client Side - Collector for ArcGIS

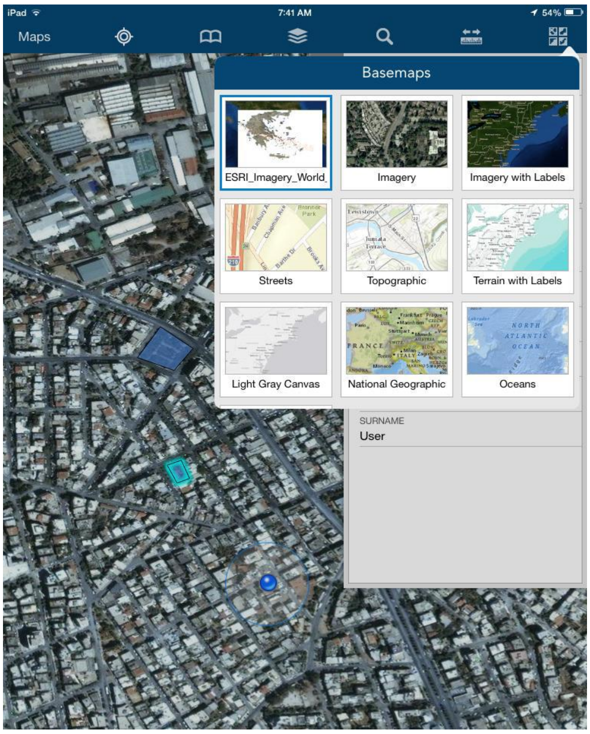
ESRI introduced a mobile application known as "Collector for ArcGIS," which could be effectively utilized alongside ArcGIS online. This application was made accessible on both IOS and Android platforms and came at no cost for users with organizational accounts. Its features encompassed all the necessary functionalities to effectively carry out the declaration task of the cadastral procedure.

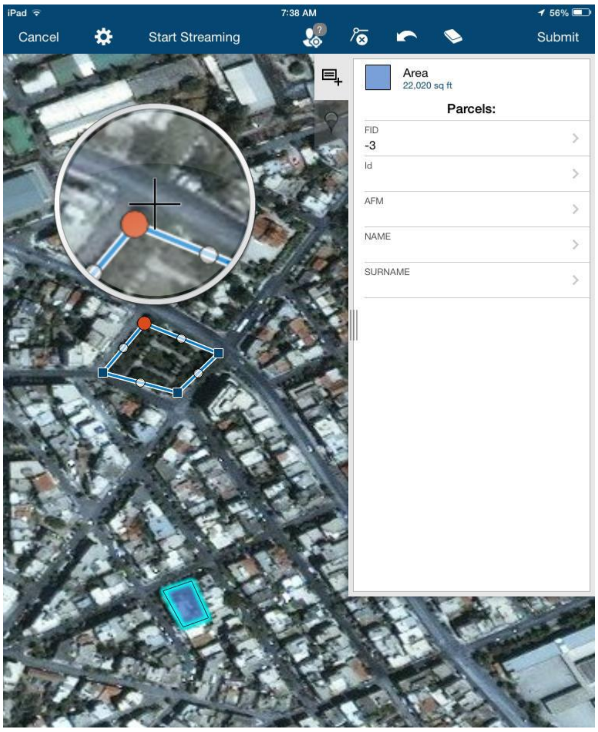
Upon logging into the application (Figure 4.3 a), users were presented with a choice between utilizing a pre-existing map (Figure 4.3 b) and opting for another map available from ESRI's repository (Figure 4.3 c). Once positioned approximately on the orthophoto, taking into account the variability of GPS accuracy ranging from 3 to 20 meters, users had the ability to digitize property boundaries either online (in cases where the boundaries were not clearly visible on the basemap) or offline. If the property boundaries were distinguishable on the orthophoto, owners could zoom in on the map, either in real-time or at a later stage, to perform necessary refinements on the orthophoto displayed on their smartphone screen. This approach proved crucial, especially when the GPS positioning accuracy was inadequate. As a result, the digitized boundary points attained the geometric precision of the basemap, achieving an impressive level of accuracy (0.25 meters in this specific experiment) attributable to the orthophoto used for urban areas, rather than being limited to the accuracy of the smartphone's GPS positioning (Figure 4.3 d).





(a) **(b)**





(c) **(d)**

__Figure 4.3 (a)__ User login __(b)__ Declaration selection __(c)__ Basemap selection (d) Boundaries digitization and adjustments. Source: Mourafetis et al., 2015.

After digitizing the property boundaries, the owner had the option to complete the required attributes, including personal data, and other relevant information. In cases where a team of volunteers was involved and a large number of parcels needed to be digitized rapidly on-site, the output could be edited offline to achieve higher accuracies on the orthophoto. These edited data could then be submitted at a later stage. Once the data was ready, it could be posted back to ArcGIS online and securely stored there.

Moreover, tests were conducted using this procedure in both urban and rural areas. Based on their results, the editing interface was found to be highly convenient, providing satisfactory accuracy within the cadastral technical specifications, especially when an accurate orthophoto was used in conjunction with a suitable touch pen.

One of the most beneficial features of the application was its versatility in adapting to varying conditions. Users could digitize parcel boundaries offline if the GPS signal and accuracy were not optimal. Alternatively, the app allowed users to rely on GPS streaming for coordinate collection when the GPS accuracy was sufficiently reliable. Additionally, the application facilitated attachments, including photos taken with the mobile's camera. This feature proved valuable in the cadastral survey process, allowing users to attach important documents, like the property title or even a photo of the property itself. Moreover, these attachments fulfilled the requirements of other public or private sector organizations.

4.2.3 Implementation in the Formal Procedure of a National Cadastre

In the past, the typical approach involved governments providing specifications for the required tasks or cadastral products and then seeking input from professionals to define the methodology, estimate project duration, and assess costs (Adlington, 2011). However, this approach has changed significantly today. Strong governments now establish strict regulations for professions and governmental agencies, outlining not only the scope of the project but also the allocated budget and, significantly, imposing strict deadlines for project completion. An example of such a case is the Hellenic Cadastre project, which has been under development for 29 years since its initiation.

ESRI's development of Collector for ArcGIS provided reliable location information for properties and their boundaries, along with effective tools for defining parcel boundaries. The application was known for its simplicity and low cost, making it accessible to anyone who wished to locate boundaries on readily available internet maps that could be uploaded on the server side. The right holders using their mobile phones could easily record georeferenced images of boundaries and buildings. The increased availability of accurate orthophotos of properties on the internet, similar to the case in Greece, proved highly beneficial.

For cadastral projects, cost and time were paramount considerations. Uncertainty about completion times could lead to delays and escalating expenses. The proposed methodology had the potential to enhance the adjudication of property owners, rights, and properties in the Greek cadastre. By fostering collaboration between cadastral surveyors, citizens, and communities and incorporating this approach into the project, data collection could be expedited, resulting in significant reductions in both costs and time, while also yielding more accurate and directly manageable information. Volunteer-created cadastral maps were verified by cadastral surveyors or the responsible NCMA, depending on each country's circumstances. Importantly, implementing this method in Greece did not require any legal amendments, as the Greek cadastral technical specifications pertaining to the final product, not the method employed for its creation, ensuring adherence to required accuracies.

In a broader context, the role of cadastral surveyors should be the training of volunteers and local communities. Local students, qualified individuals, or young surveyors with adeptness in smartphone technology could support the entire fieldwork and explain the data collection process and necessary attributes to property owners and locals familiar with the region.

As a result, a national-level network could be established, comprising responsible cadastral surveyors, volunteers (including students or qualified individuals and young surveyors), and citizens. This network, structured like a pyramid, with cadastral surveyors at the top, could provide essential expertise for the entire process, training volunteers and verifying outcomes. Volunteers then could transfer this knowledge to citizens in local communities. The procedure needs to be thoroughly legitimized and explained, with the responsible agency offering a demonstration facility and tools to regulate data access and procedures. This network-based approach held promise for expediting National Cadastre Projects while minimizing the risk of significant errors in parcel identification.

4.3 Investigating technology in an urban, suburban and rural environment and Citizen engagement with Gamification

Based on the experience derived, the next step of this research was to introduce a practical methodology supporting a contemporary approach to cadastral surveys. The fundamental aspects of this suggested approach emphasized the active involvement of property owners and the utilization of IT tools, such as smartphones or tablets, along with a blend of cost-effective commercial and open-source software. The primary goal was to enhance the traditional procedures, reducing costs and saving time, making it particularly valuable in developing regions where m-services could grant the majority of the population access to vital information. Additionally, the approach sought to enhance the reliability of collected data by mobilizing property owners, their neighbors, or other trusted locals, who could contribute through their expertise, time, money, knowledge, and experience.

To further stimulate and encourage property owners' participation, the research proposed incorporating gamification elements into the cadastral process. This method involved integrating elements commonly found in games, such as point scoring, competition, and rules, into non-gaming contexts, serving as an online marketing technique to drive engagement with products or services. The gamification strategy aims to tap into individuals' intrinsic desires for social interaction, learning, mastery, competition, achievement, status, self-expression, altruism, or closure. By employing rewards as incentives, such as points, achievement badges, levels, progress bars, or even real rewards, the methodology sought to motivate participants and foster a spirit of healthy competition among them. Ultimately, this approach held the potential to revolutionize cadastral surveys, making them more inclusive, efficient, and accurate.

The outcomes of this research revealed a comprehensive methodology aimed at modernizing cadastral surveys. The initial phase of this methodology (Figure 4.4) involved engaging property owners and local volunteers, either through direct gatherings or by providing training videos on the responsible NCMA's website. During these sessions, participants could be familiarized with the project's procedures and offered incentives, including gamification rewards, to motivate their active involvement. Information about the entire procedure and its benefits would be disseminated within the local community, fostering enthusiasm for increased participation.

Next, volunteers would receive training from expert surveyors, primarily focusing on geometry and the usage of available basemaps. Additionally, they should be educated on operating GPS mobile phones to precisely locate properties on the basemap. Subsequently, the data collection process might begin, with volunteers digitizing their property boundaries and optionally those of neighboring parcels, along with relevant information such as property rights, owners' names, and deeds. This approach should allow for cross-checking property boundaries and ensuring comprehensive data coverage.

Upon completing the boundary point collection, the responsibility for collecting and verifying the digitized data would shift to private surveying companies or the NCMA's staff, who also employed legal experts. Technical assessments could be conducted efficiently, allowing for a timely completion of the national cadastral mapping coverage, thereby facilitating well-informed decision-making.

Errors or discrepancies could also be addressed at this stage, and in case of significant inaccuracies in data collected by property owners, the collection process could be redone. Ultimately, the outcome of this procedure involved generating draft cadastral maps for the surveyed area, which, after the completion of legal controls, could form the foundation for a robust land administration system.

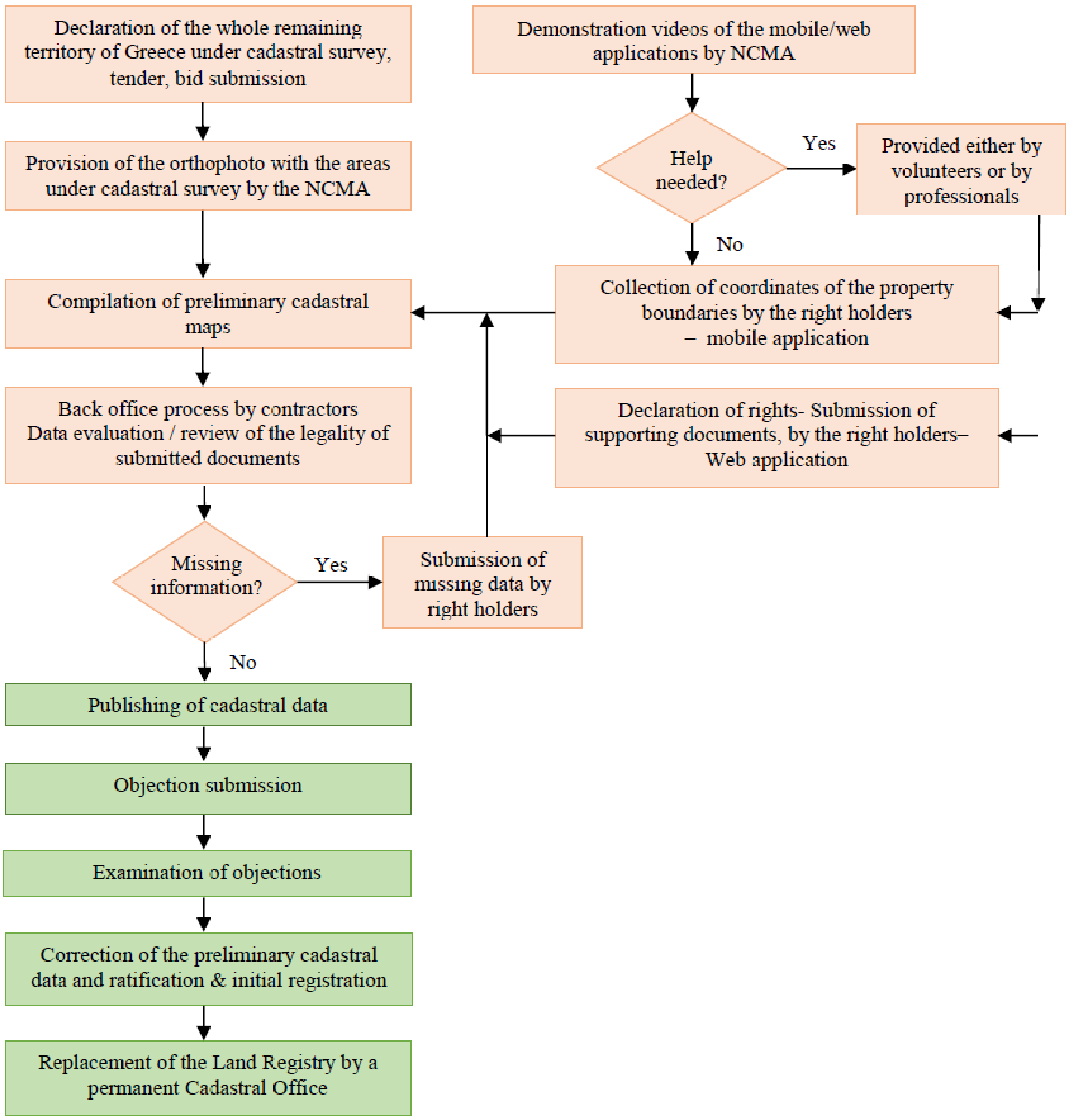


***Figure 4.4** Main phases of the proposed methodology. Source: Gkeli et al., 2016.*

The ensuing steps could focus on publicizing the draft cadastral data, maps, and tables, while successful volunteers would be rewarded with agreed bonuses, tax reductions, or registration fee discounts. The dissemination of data could be tailored to cadastral agency policies, either limited to property owners to facilitate error corrections or open to the general public while safeguarding private owner information.

The final phase encompassed a period for objection submissions, followed by a meticulous examination by surveyors and legal experts to secure the validation of cadastral maps and the issuance of titles. This comprehensive approach sought to enhance cadastral surveys, making them more participatory, efficient, and transparent, thus contributing to the development of well-organized land administration systems.

4.3.1 Utilization of commercial software applications

The proposed crowdsourcing procedure was implemented through the utilization of commercial platforms, specifically ArcGIS Online and ArcGIS for Server. By employing ArcGIS Online, individuals gained access to ESRI's secure cloud, granting them the capability to efficiently manage, create, and store data as published web layers (ESRI, 2015). The cloud's advantages included unlimited storage capacity, comprehensive backup and recovery capabilities, the convenience of accessing data from anywhere with an internet connection, and cost efficiency in terms of software updates, application management, and staff-related expenses.

The implementation utilized ArcGIS for Server software, which facilitated the dissemination of geographic information to users within the organization and potentially beyond, accessible via an internet connection. In this context, the application made use of the Portal for ArcGIS, an integral component of ArcGIS for Server Standard and Advanced editions, providing a user experience akin to that of ArcGIS Online but within the organization's own infrastructure, whether on-premises or in the cloud. With Portal for ArcGIS, individuals were empowered to share maps, applications, and other geographic information with fellow users within their organization, all conveniently delivered through a dedicated website (ESRI, 2015; Mourafetis et al., 2015).

ESRI's emphasis on cloud security ensures that ArcGIS Online maintains the confidentiality, integrity, and availability of data. As per ESRI's security policies, customers preserve their intellectual property rights for data published through ESRI cloud services. Access to organizational data is restricted to authorized users within the organization, with each entity enjoying its dedicated database for isolating stored features. Data owners maintain full control over the deletion of data, which is permanently removed without any traces in a recycle bin. The ArcGIS Online Privacy Statement boasts certification with top-notch privacy standards, including TRUSTe Certified Privacy Seal and EU Safe Harbor (US Department of Commerce). For added reassurance, ArcGIS Online leverages cloud infrastructure providers that comply with ISO 27001, FedRAMP, and SSAE 16 SOC1 Type2 regulations.

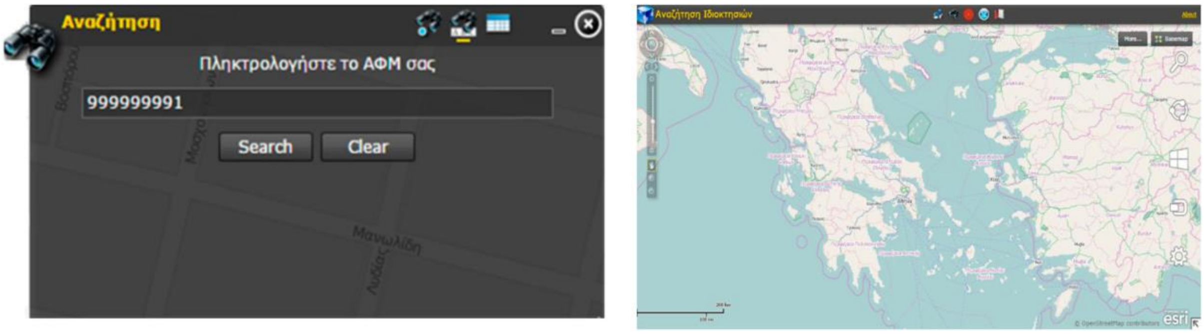
Additionally, ArcGIS for Flex, a versatile ArcGIS for Server tool, is conventionally deployed within an organization's service-oriented architecture, on-premises. Functioning as a user-friendly web application, ArcGIS for Flex empowers users to effortlessly create customized map applications without the need for programming expertise. Notably, in this particular study, ArcGIS for Flex's utility lies in introducing a gamification tool to enhance the cadastral data collection process, offering essential capabilities for measuring and validating procedure results.

For the collection and recording of cadastral information, the chosen application was ESRI's Collector for ArcGIS, designed to cater to both IOS and Android platforms. The implementation encompasses two key aspects (Mourafetis et al., 2015):

- The server side involves selecting the most suitable basemap from ESRI's extensive collection (including imagery and vector options) or incorporating external OGC WMS services, all seamlessly integrated through the ArcGIS Desktop application. Additionally, users are equipped with the necessary descriptive information, typically stored in shapefiles with the appropriate fields, and published on ArcGIS Online.

- On the client side, the focal point is the ESRI application Collector for ArcGIS, working harmoniously with ArcGIS Online. Users log in, access the chosen basemap, and embark on the task of digitizing property boundaries, whether online or offline, while diligently filling in all the required attributes. Once completed, the collected data is securely transmitted back to ArcGIS Online, ensuring its safe storage.

In support of volunteer efforts and to monitor the progress of their work, an application within ArcGIS Viewer for Flex was developed (Figure 4.5 a) and integrated five additional tools into this platform. As a result, volunteers could track the number of digitized properties and easily identify the ones they personally contributed to by entering their tax code into the Search tool (Figure 4.5 b). This functionality enabled their participation in the gamification process. The application also equipped users with tools to locate specific addresses on the map, utilize bookmarks for quick access to selected areas, print map sections, and export data in a zip file format directly to their computers (Figure 4.6).



(a) **(b)**

Figure 4.5 *ArcGIS Viewer for Flex interface:* ***(a)*** *Tax code number search* ***(b)*** *Tax code number search results on the basemap. Source: Mourafetis et al., 2015.*

To make the application accessible to users, a public IP address (Internet Protocol) was utilized, providing a unique number for device recognition in a network following the Internet Protocol standard. Within the NCMA, authorized members, acting as administrators, could have full access to the application. For volunteers, access through the search tool could be limited solely to the data they contributed. They could either add or correct the data they collected or assess their level of contribution to the gamification rewards. Implementing these customizations was straightforward through the ArcGIS Viewer for Flex by incorporating the appropriate fields into the search process settings.

(a) **(b)** **(c)**

Figure 4.6 *ArcGIS Viewer for Flex interface:* ***(a)*** *Location search tab,* ***(b)*** *Data export tab and* ***(c)*** *Bookmarks tab. Source: Mourafetis et al., 2015.*

4.3.2 Implementation in the Formal Procedure of a National Cadastre

The successful implementation of the proposed methodology within a national cadastral project hinged significantly on the motivation and active voluntary involvement of property owners and local volunteers. It remained crucial for the volunteers to undergo comprehensive training led by professional surveyors (or through e-learning tools). This training encompassed a range of important topics, such as the various advantages of the National Cadastre, utilizing the application to make simple geometric determinations for identifying unmarked boundaries on the basemap, and mastering the GPS operation on their mobile phones for digitizing property boundaries. Additionally, volunteers needed to familiarize themselves with the user-friendly menu and functions of the Collector for ArcGIS application, accessible through specific buttons on their smartphone screens. The digitization of property boundaries could be performed conveniently using these applications, either online or offline. As part of the process, the volunteers were required to store basemap layers on their mobile devices for the specific areas they aimed to digitize. Upon completion, they could input supplementary cadastral data about the property and transmit the entirety of the information via email to the assigned companies overseeing cadastral surveys in the relevant areas under the cadastral survey.

Cadastral surveyors bore the responsibility of collecting the digitized property information and conducting thorough technical assessments of the data submitted by the volunteers. In cases where significant errors were detected in the collected boundary data, cadastral surveyors could promptly execute necessary corrections, employing field surveying or photogrammetric methods as needed. Following this, they could securely forward the edited data to the responsible NCMA, with electronic signatures serving as a means of ensuring data safety through cloud services. It is worth noting that this particular step was integral to the official procedure for cadastral surveys, aligning with existing practices in Greece, where assigned companies conveyed their results to the Hellenic NCMA through secure internal cloud services, effectively addressing any security concerns that might arise from such cloud usage.

To facilitate efficient data management, the NCMA should take charge of categorizing the information into two distinct groups: personal private data (including volunteer/owner names, ID numbers, addresses, and email addresses) and parcel information (comprising the address and ID of each specific parcel). The personal data could be safely stored within the organization's cloud infrastructure (organizational account) or housed within ArcGIS for Server on the organization's own system. Draft cadastral maps, on the other hand, could be stored in the public account within the cloud, granting broad access to citizens. Subsequently, the NCMA should manage the final publication of the cadastral data, announcing a call for final objections before proceeding to issue property titles, completing the objection examination phase, and ultimately achieving an AAA cadastre.

In order to encourage volunteers to actively participate in the process, the developed application within the ArcGIS Viewer for Flex exploited the principles of gamification. This innovative application empowered officials from the NCMA to conveniently assess a volunteer's contributions by importing their tax code and reviewing the number of properties that had been successfully digitized. Depending on the level of engagement and productivity, the NCMA would then communicate the earned benefits through personalized e-mails, notifying volunteers of the discount rates applicable to property taxes or registration fees. Additionally, upon completion of the property registration process in each area under the cadastral survey, the NCMA would proudly display the names of the most proactive volunteers who had significantly contributed to the data collection process. These thoughtful incentives not only might provide volunteers with indirect economic advantages but also grant them well-deserved social recognition for their efforts.

For developing nations, the proposed methodology holds tremendous promise as a viable solution for the compilation or successful conclusion of ambitious nationwide cadastral projects. With careful consideration of the unique needs and available fundamental infrastructure in each country, suitable adjustments can be made to ensure seamless implementation and maximum effectiveness.

When faced with a lack of funds to afford commercial software, such as the ESRI's Collector for ArcGIS, alternative non-commercial applications capable of efficiently recording properties were utilized. The only drawback they had compared to the Collector for ArcGIS was their lack of support from ESRI's Cloud safety storage.

In situations where accurate basemaps (orthophotos) were unavailable in areas under cadastral survey, freely accessible global maps like OpenStreetMap, Google Earth, or Bing Maps could be used. Despite resulting in a final product of slightly lower geometric accuracy, this approach still could fulfill the purpose of creating a cadastre that could meet the urgent needs for land registration.

In case there was an insufficient number of local surveyors available or their involvement in guiding volunteers was too costly, the task could be handed over to specially trained volunteers or university students. Data storage in the cloud is proposed to be implemented to reduce expenses related to storage and maintenance. Moreover, scholarships could be provided to university students and supervisors engaged in this field, aiming to raise awareness and encourage further studies in this domain.

4.4 Implementing the proposed procedure in urban, suburban, and rural environments

The next step of this research was to apply the studied formal cadastral data collection procedures in Greece and Romania and develop a general, more FFP model. Both of the cadastral projects in these two countries underwent continuous revisions by local and international experts, but both encountered significant challenges in meeting their deadlines successfully (Basiouka and Potsiou, 2014; Torhonen et al., 2015). These particular cadastral projects were chosen for investigation to assess their methodology, experiences gained, and the challenges they faced, as there was always room for improvement and closing gaps in their processes.

Additionally, the implementation of new IT tools and enhanced citizen participation was tested, with the goal of expediting the initial cadastral data collection phase while simultaneously improving data quality and efficiency. This approach was based on previous research (Basiouka and Potsiou, 2014; Mourafetis et al., 2015; Basiouka and Potsiou, 2016; Apostolopoulos et al., 2018). The proposed fit-for-purpose method has aspired to be adaptable and relevant to the specific circumstances of ongoing projects, ultimately leading to the establishment of reliable, accurate, assured, authoritative, and modern cadastres.

The underlying concept involved investigating, designing, and testing a novel procedure where the initial cadastral data collection phase was carried out with increased involvement and responsibility of the right holders (often non-professionals). Professionals or local volunteers with appropriate training would supervise this process. Modern and cost-effective IT technology, such as tablets or smartphones, along with accurate basemaps, could be utilized to enhance the precision of the land parcel's location and reduce the likelihood of significant errors. The overall aim was to expedite the compilation time and minimize additional costs arising from substantial errors in parcel location and identification.

The objective of this step of the research was to explore and test various options for further enhancement, moving towards a more fit-for-purpose approach, and to develop, test, and propose a general crowdsourced model that is flexible, adaptable, and applicable.

4.4.1 Main Phases of the Proposed FFP Procedure

The proposed procedure (Figure 4.7) is presented and analyzed below.

Preparatory Phase*:* The preparatory phase resembles the first stages of the formal cadastral procedures of Greece and Romania (Figure 3.4 and Figure 3.24). If the responsible NCMA lacks the resources to prepare and provide new Large-Scale Orthophotos (LSO) and Very Large-Scale Orthophotos (VLSO) for the entire territory under cadastral survey, an alternative solution could be to utilize old orthophotos. Additionally, private surveyors can contribute by using Unmanned Aerial Vehicles (UAVs) to provide recent orthophotos for areas that have undergone significant development since the acquisition time of the old orthophoto.

The next phases of the cadastral procedure have undergone significant changes in the new procedure and are described as follows:

- Compilation of crowdsourced draft 2D cadastral maps and declaration of rights.

During this phase, all right holders in the cadastral surveyed area will be invited to participate by digitizing their respective parcel boundaries. They will be required to submit these digitized boundaries, along with all necessary supporting documents, declaring their rights through online platforms. As is customary in cadastral surveying, community involvement plays a pivotal role in achieving success. It is essential to empower right holders, enabling them to use the Internet and their mobile devices, such as smartphones or tablets, for data collection during the initial cadastral registration.

The new approach emphasizes the power of crowdsourcing, where the public actively contributes to the creation of draft 2D cadastral maps. This inclusion of citizens in the mapping process also fosters a sense of ownership and transparency in the cadastral system.

To facilitate this process, web applications and mobile applications, specifically tailored for this purpose, will be developed by the responsible NCMA (Apostolopoulos et al., 2018). Contractors or the responsible NCMA should provide demonstration videos and comprehensive instructions on how to utilize both applications effectively.

The digitization of property boundaries and the submission of supporting documents and additional information will be performed through a mobile application. The most recent orthophoto, incorporating pre-existing cadastral information, will serve as the basemap for this digitization process. Contractors are responsible for incorporating any relevant cadastral information derived from administrative acts, city-planning projects, urban regeneration projects, land expropriation projects, or coastal line definition projects. Such cadastral projects typically produce AAA cadastral data known for its high geometric accuracy. In instances where the responsible NCMA cannot provide a recent orthophoto of the area, contractors may utilize unmanned aerial vehicles to capture high-resolution orthophotos, ensuring accurate and up-to-date data collection.

Right holders have the option to delineate parcel boundaries using two different approaches. They could physically visit the property, utilize the basemap, and digitize the parcel polygon on the field. Alternatively, if they can identify their land parcel on the orthophoto, they may digitize the boundaries from a distance. Recent research in this domain has revealed interesting findings. Boundaries that are visible on the basemap and digitized using smartphones exhibit geometric accuracies comparable to those produced by formal surveying procedures. However, parcel boundaries that were not visible on the basemap and were digitized using the Global Navigation Satellite System (GNSS) of the smartphone exhibit significantly lower geometric accuracies (Apostolopoulos et al., 2018).

In challenging scenarios, such as when parcel boundaries are not clearly visible or recognized on the orthophoto or when there is a lack of auxiliary evidence on the basemap (e.g., surveying diagrams), various options are available for parcel identification. Right holders could use their smartphones' GNSS device to achieve an accuracy of a few meters, or they may physically walk the perimeters of their land parcels, using a GNSS antenna. For instance, Esri's Collector App utilizes a mobile Bluetooth connection to connect with devices like the Trimble R2GPS, which boasts a "quality antenna" for receiving weak GNSS signals and required correction signals, theoretically providing sub-meter accuracy for observed points (Molendijk et al., 2018). In cases where the task proves difficult, owners could assign the job to contractors, who will complete it using traditional field surveying.

Typically, neighboring land parcel owners may digitize each part of a parcel boundary multiple times, contributing to increased final digitization accuracy. If the measurement discrepancies fall within technical specifications, the contractors would select the mean measurement during the data editing process. Disputes between neighbors regarding the exact location of their borders could be resolved by the contractors, who could cross-check the submitted documents. Additionally, state-owned or municipal land parcels could undergo land registration in a similar manner.

Moreover, right holders should be asked to provide any other evidence that confirms the declaration of property boundaries. This might include existing private professional surveying diagrams of the land parcel. Such cadastral data could be used by the contractors during the later stage of back-office editing of the collected data. Right holders could be also required to upload personal data statements along with deeds or other legal information necessary to substantiate the declared rights. These actions should be carried out using the NCMA's web application.

In case a right holder faces difficulty in using the applications, assistance could be requested. Trained team leaders, volunteers, or students might manage the applications, or local private surveyors could be engaged to support the right holder.

At the end of this phase, the responsible NCMA would have a draft cadastral map. This stage might reveal the types and sizes of problems encountered, such as conflicts arising from claims by multiple right holders over certain parcels or the existence of non-claimed parcels. The number of undeclared or non-claimed parcels is of significant importance in this participatory process, necessitating further research on how to encourage right holders' participation in such projects (Basiouka and Potsiou, 2016). Various reasons could contribute to the lack of participation, such as high registration fees, fears of property tax imposition, or ignorance about the value of the cadastre and property registration, among others.

- Editing of the crowdsourced draft 2D cadastral maps by contractors

After the completion of the previous phase, contractors selected through a competitive bidding process would be entrusted with the task of creating a unified database using the collected cadastral data. Additionally, their responsibilities would involve verifying the legality of the documents submitted by the right holders, ensuring geometrical compatibility of the spatial database, and addressing any gaps in the collected cadastral data. If necessary, right holders might be contacted for clarification on specific matters. In cases where information might be missing, either the team leaders and/or the right holders would be requested to gather and provide on-site data, or the surveyor/contractor would handle the issue.

Should any discrepancies arise between the measured area size and the size recorded on a deed, particularly if it exceeds the technical specifications, the contractors could make efforts to resolve the problem, keeping the new measurements if a resolution is not feasible.

Upon completion of this phase, the responsible NCMA would receive the draft cadastral maps and tables, which would serve as the basis for publishing property rights. To ensure accuracy, the NCMA should conduct quality control on the geometric accuracy of the received cadastral maps or commission an independent private company before accepting and publishing them. The quality control process might involve periodic field surveying of point coordinates, which would then be compared to the coordinates of the land parcel boundaries in the draft cadastral map.

- Publishing of the draft cadastral data

During this phase, certain similarities to the formal procedures of Greece and Romania persist, but several enhancements were also proposed. The publishing phase could follow the formal procedures of Greece and Romania. One option is to mail the relevant cadastral data to each individual right holder separately. However, it is recommended that an open publishing approach should be adopted, as it offers greater transparency and facilitates quicker identification and rectification of any errors that might arise.

- Objections phase

This phase has been restructured in the proposed procedure. Under this procedure, right holders should be granted the opportunity to raise objections and request corrections for any data they could substantiate with evidence. For instance, if the area size of a land parcel appears to be smaller than what is documented in a deed, and the discrepancy exceeds the technical specifications, right holders could initiate the objection process. In such cases, a local professional field survey should be conducted to ascertain the final and accurate result, which might then be officially registered.

An inherent weakness that may arise during the objection procedure, as observed from past experiences in Greece, is the potential for prolonged delays in committee proceedings, particularly when multiple objections are received from various municipalities. As a suggested approach to enhance the process, consideration could be given to prioritizing properties that necessitate further judgment. Properties without objections could be finalized and subsequently moved forward to subsequent operational stages, while those with pending objections would remain on hold awaiting further judgment (Gkeli et al., 2016). This approach, however, demands more effort and attention in operations, as they would need to carefully discern the status of each individual land parcel.

- Initial registration phase

This particular phase in the proposed methodology bears resemblance to the concluding stages of the two official procedures in Greece and Romania.

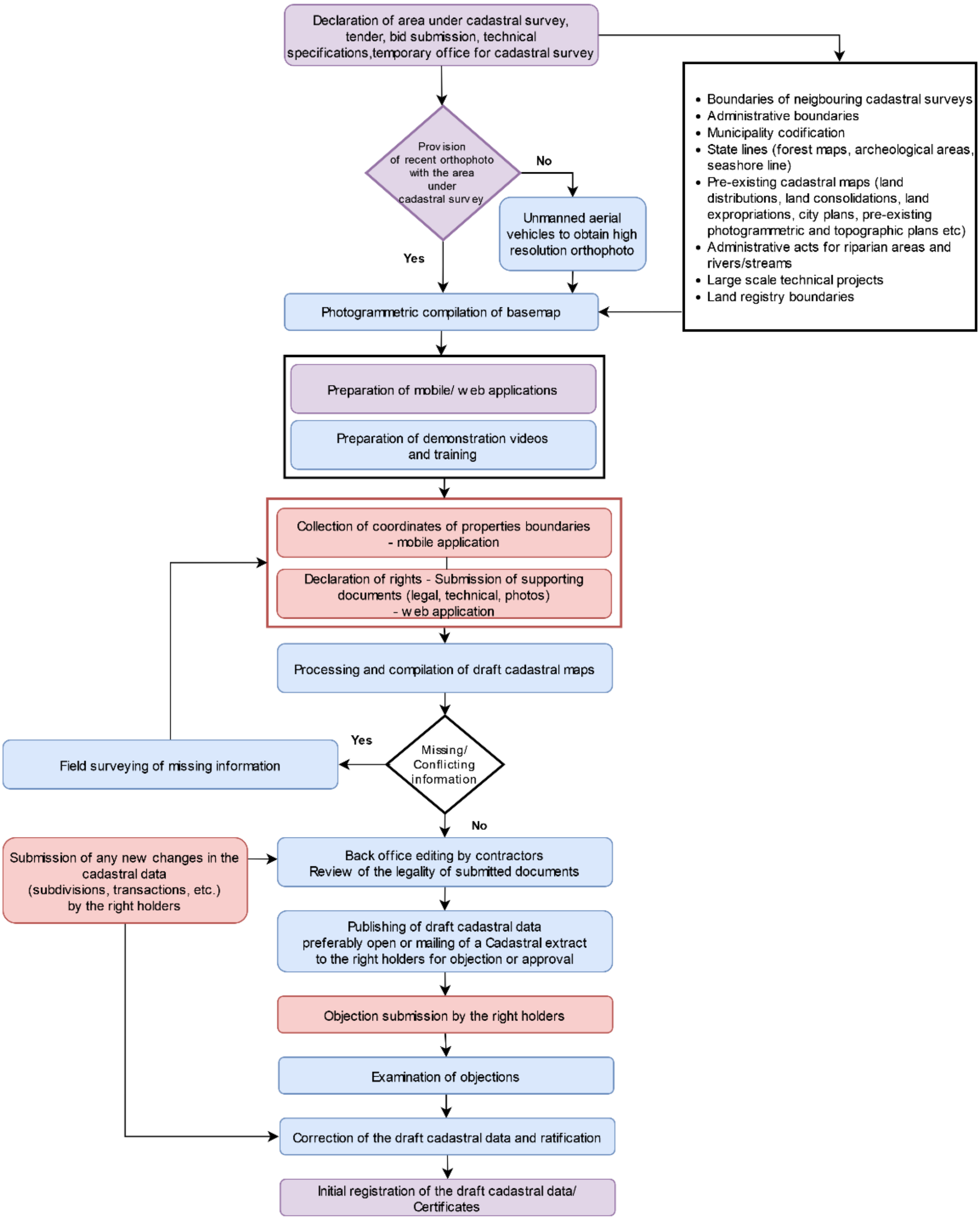


***Figure 4.7** Main phases of the proposed FFP procedure (state agency actions in purple, contractors' actions in blue, and right holders' actions in pink). Source: Potsiou et al., 2020.*

4.4.2 Supporting Video Guide

A video guide was developed to facilitate the implementation of the proposed procedure, providing comprehensive instructions on how to use the aforementioned applications. The creation of this video guide was deemed necessary as right holders were required to utilize a combination of applications effectively to actively participate in the land registration process.

In this informative video, guide (Figure 4.8), two essential applications were described: Esri's Collector for ArcGIS (a cross-platform mobile data capture application) and MapIT GIS (an open-source collector application developed by Potsiou et. al 2020. The guide offered guidance on installing these applications from Android and IOS platforms and provided insights into navigating all available menus.

Specifically, the video guide covered essential information, including the phase of the land registration process in which right holders would participate. Moreover, it outlined the IT facilities right holders should possess, preferably a smartphone or tablet with an internet connection, to ensure seamless participation.

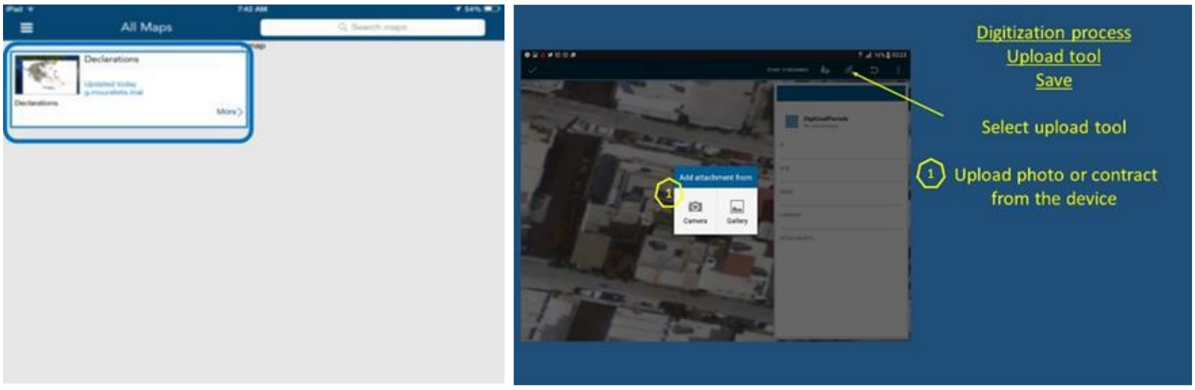


Figure 4.8 *Exemplary snapshots from the applications' video guide:* ***(a)*** *choosing the Basemap;* ***(b)*** *Digitization Process - Uploading Photos. Source: Potsiou et al., 2020.*

Additionally, the video guide presented detailed descriptions of the applications, including their menus and specifications, equipping right holders with the knowledge to confidently operate them. It also elaborated on the types of data that could be recorded, encompassing boundaries, photographs of deeds, and images of the land parcels. This comprehensive video guide could empower right holders to actively and effectively engage in the land registration process, contributing to its success and efficiency.

4.5 Development of an open-source application with gamification elements

The next step of this research was the development of an open-source mobile application enriched with gamification elements to enhance citizen engagement in the proposed procedure. The developed application (named 'PropReg') serves as a convenient tool for users to record cadastral data and related descriptive information using their mobile devices.

To build this application, the MERN stack development has been utilized. MERN represents a distinctive version within the MEAN stack (MongoDB, Express, Angular, Node), wherein the conventional use of the Angular.js front-end framework is substituted with React.js. Additional alternatives encompass MEVN (MongoDB, Express, Vue, Node), and essentially any front-end JavaScript framework is compatible with the stack.

4.5.1 Application's stack development

In order to develop a fully functional mobile application, three basic components were needed (Figure 4.9):

1. Building the mobile application (a client-side JavaScript framework) - React Native

2. A service application that will connect the mobile application with the database (the premier JavaScript web server)- NodeJS (Express)

3. A permanent storage database - MongoDB

In application development, all these components compose what is called the stack of the app and there are many different languages, frameworks and libraries one can use in order to create a production-grade mobile app, although some of the tools have gained much more popularity than others.

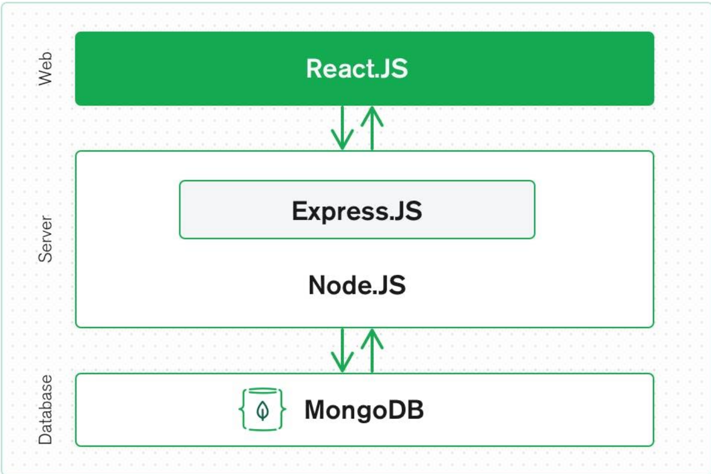


Figure 4.9 *Developed application stack development. Source: Dev community, 2023.*

For creating the mobile application, Facebook has released and is maintaining the framework called React Native (React Native, 2023), which recently gained a lot of traction. A staple in building services/back ends, like the one mentioned in the second point is a JavaScript runtime, called Node.JS (Node JS, 2023). It is built on Chrome's V8 JavaScript engine (which is used in the Google Chrome browser) allowing for server-side programming that allows users to build network applications, among others. Express.JS and Node.JS constitute the intermediary or application layer. Express.js stands as a web framework for server-side operations, while Node.js serves as the widely embraced and potent JavaScript server platform. Irrespective of the specific version opted for, ME(RVA)N represents the perfect method for handling JavaScript and JSON comprehensively. For the database, many tried and tested systems can used. One very modern but stable database is MongoDB (MongoDB, 2023) and in order to use it with the rest of the application's stack, a library implemented specifically for that reason was exploited, called Mongoose (Mongoose, 2023).

An in-depth, explanation of the stack components follows:

- Front-end Development - React Native

React Native enables the execution of Javascript code within a mobile environment. Unlike its competitors (such as Ionic, PhoneGap, and Cordova), it does not rely on web views; instead, it utilizes the actual materials provided by different platforms to create truly native UIs. This is achieved by allowing the creation of UIView instances similarly to platform-specific languages.

In contrast, other alternatives like Google's Flutter (Flutter, 2023) follow a different approach. They create an abstract syntax tree from the JavaScript code and then compile it to run on multiple devices. However, a drawback of this method is the need to create new compilers for each targeted platform, as there is no existing tool that can accept JavaScript as entry code and produce output for all desired platforms.

React Native addresses this challenge by utilizing existing compilers (Figure 4.10) designed for specific platforms. It operates within two realms: the JavaScript realm and the Native realm. Both realms can share information through a "bridge," which is a crucial component of the React Native architecture and provides significant flexibility.

Figure 4.10 *Exploitation of existing compilers by React Native. Source: Dev Community, 2023.*

The bridge handles asynchronous commands between the two realms (Figure 4.11), functioning similarly to how a message queue communicates between two services. The JavaScript realm sends asynchronous JSON messages describing the actions the Native realm should perform. For example, the JavaScript side may send information about views that need to be created by the Native side. When the Native side is ready, it will execute the requested actions accordingly.

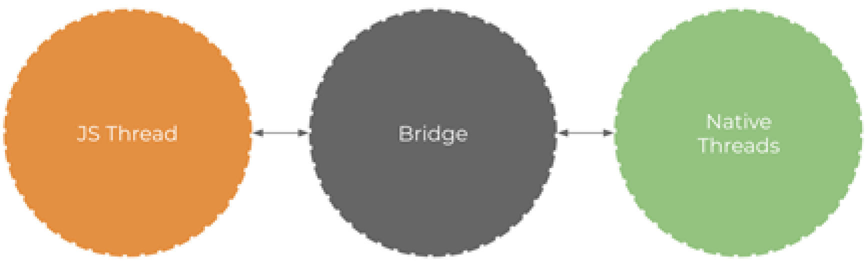


Figure 4.11 *React Native as a 'bridge' between two realms, the Javascript one and the Native one. Source: Dev Community, 2023.*

The asynchronous nature of the communication, being non-blocking, contributes to the smooth management of views on the screen. The bridge is implemented in C/C++ and can be run on multiple platforms. It incorporates the Apple JavaScriptCore framework, exposing APIs to access the capabilities of the JavaScriptCore VM. These APIs are commonly used in the Obj-C and Swift world. However, there is also a C API, with the Obj-C API being a wrapper around it. This design allows JavaScript code to be executed within a C/C++ program, enabling the injection of variables, functions, and declaration of globals to enhance existing JavaScript code. React Native leverages this capability to facilitate communication between JavaScript and the native world, thus triggering actions in the C/C++ world.

- Back-end Development - NodeJS (Express)

Regarding the back-end development of the application, the platform-specific characteristics for iOS and Android should primarily be decided. As for the iOS platform, the Obj-C, as an extension of the C language, facilitates native communication with it, resulting in seamless exchanges between the bridge and the Swift / Obj-C realm. On the Android platform, the reliance is on the Java Native Interface to enable communication with the bridge (Figure 4.12).

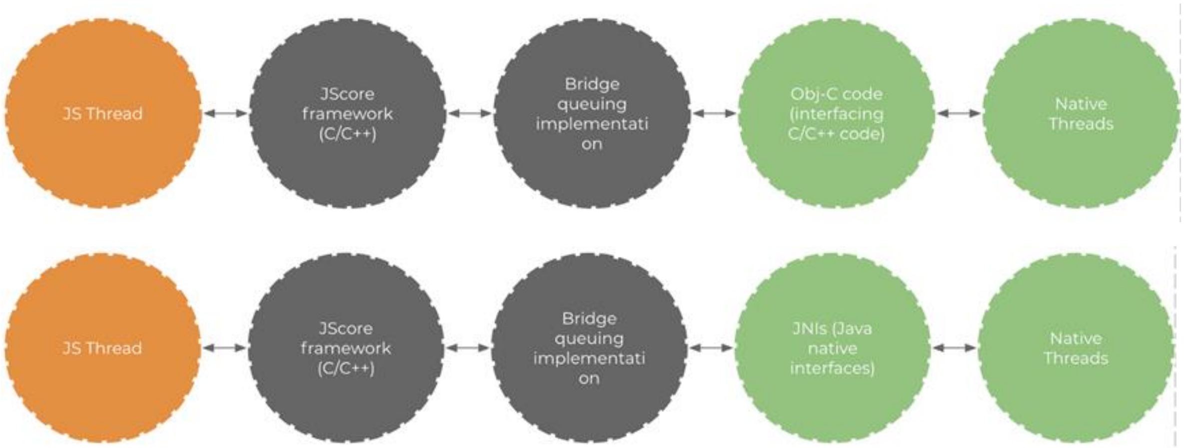


Figure 4.12 *JS interaction with iOS and Android platforms. Source: Dev community, 2023.*

Moving on to the Express Web Framework, Node.js serves as a JavaScript runtime built on Chrome's V8 JavaScript engine, specifically designed for server-side programming. This feature allows users to develop network applications with ease. One of the primary advantages of Node.js is its efficiency and provides rapid execution. Being based on Chrome's V8 JavaScript engine, it compiles JS code into highly optimized machine code, making it exceptionally fast.

Moreover, Node.js adopts an event-driven and non-blocking I/O model, contributing to its lightweight and efficient performance. The event-driven programming paradigm ensures that the control flow of the program is determined by the occurrence of events. It involves the use of event listeners, which are blocks of code assigned to detect specific events. When an event is fired, it triggers the corresponding event handler function. The Node Event Loop, an integral part of Node.js, monitors these events, facilitating the smooth execution of asynchronous operations.

The term "non-blocking" signifies those methods in Node.js are executed asynchronously. Since the Node event loop operates under a single thread, certain operations, such as reading a file, could potentially block the event loop until the entire file is read. To enhance efficiency, developers opt for the asynchronous approach, which involves calling a call-back function to read a chunk of the file and then allowing other events to run before reading another chunk.

Another notable advantage of Node.js lies in its extensive package ecosystem called NPM (Node Package Manager). NPM is recognized as the largest ecosystem of open-source libraries worldwide, offering a plethora of resources for developers. It comes bundled and automatically installed with the Node.js environment. To manage dependencies effectively, each project contains a file called package.json, which keeps track of all the modules installed via npm. By specifying the versions of each package, developers ensure the reproducibility of the application built by other team members. To install the required packages, other developers usually need to execute the command "npm install."

Regarding the Express framework, it is a lightweight and open-source Node.js web application framework that simplifies the development of websites, web apps, and APIs. With Express, developers can effectively structure web applications to handle various HTTP requests at specific URLs. In the broader context of APIs (Application Programming Interfaces), they play a crucial role in enabling programs to communicate and exchange information. Applications that expose APIs make it possible to send and receive data with other applications built using different frameworks.

- Application database - Mongoose

To build the application's database, MongoDB has been used. MongoDB is an open-source, NoSQL database management system that utilizes a document-based approach and employs BSON (Binary JSON) for high throughput data storage. Applications built on MongoDB consist of three fundamental components: connecting to a MongoDB instance, accessing and manipulating database data, and finally, closing the connection.

MongooseJS serves as an Object Document Mapper (ODM) designed to support MongoDB usage by facilitating the translation of MongoDB documents into program objects. It offers several advantages compared to using native MongoDB, such as:

- It provides an abstraction layer over MongoDB, eliminating the need to interact with named collections directly. This simplifies database interactions and enhances code maintainability.

- It introduces the concept of models, which play a crucial role in defining the structure and behavior of documents. Models handle tasks such as establishing default property values and data validation.

- It allows developers to attach functions to models, enabling seamless integration of additional functionalities. This feature promotes code reusability and enhances extensibility.

- It employs function chaining for queries, offering a more flexible and readable approach to database operations. This results in code that is easier to comprehend and maintain.

Mongoose employs schemas to model the data that an application intends to store and manipulate in MongoDB. The schema describes the attributes of the properties (fields) that the application will interact with. Key attributes defined in the schema include (a) data type (specifies the type of data the property holds, such as string or number), (b) requirement (determines whether the property is mandatory (required) or optional), and (c) uniqueness (specifies whether the property's value must be unique, allowing only one document in the database to have that particular value for the property).

To conclude, Mongoose serves as a valuable tool in the MongoDB ecosystem, offering an abstraction layer, models for structured data representation, and additional functions to enhance the application's capabilities. By utilizing Mongoose's features, the developers can achieve improved code organization, maintainability, and overall efficiency when working with MongoDB databases.

4.5.2 Application's utilities and gamification elements

'PropReg' is an innovative application poised to support the cadastral registration process and enhance citizen engagement in it. It is designed with a user-friendly interface and mapping tools that enable the submission of property declarations and caters to three distinct user roles: NCMA, land Surveyor/ team leader, and citizen/ right holder. Each user type plays a pivotal role in contributing to an accurate and up-to-date cadastral system.

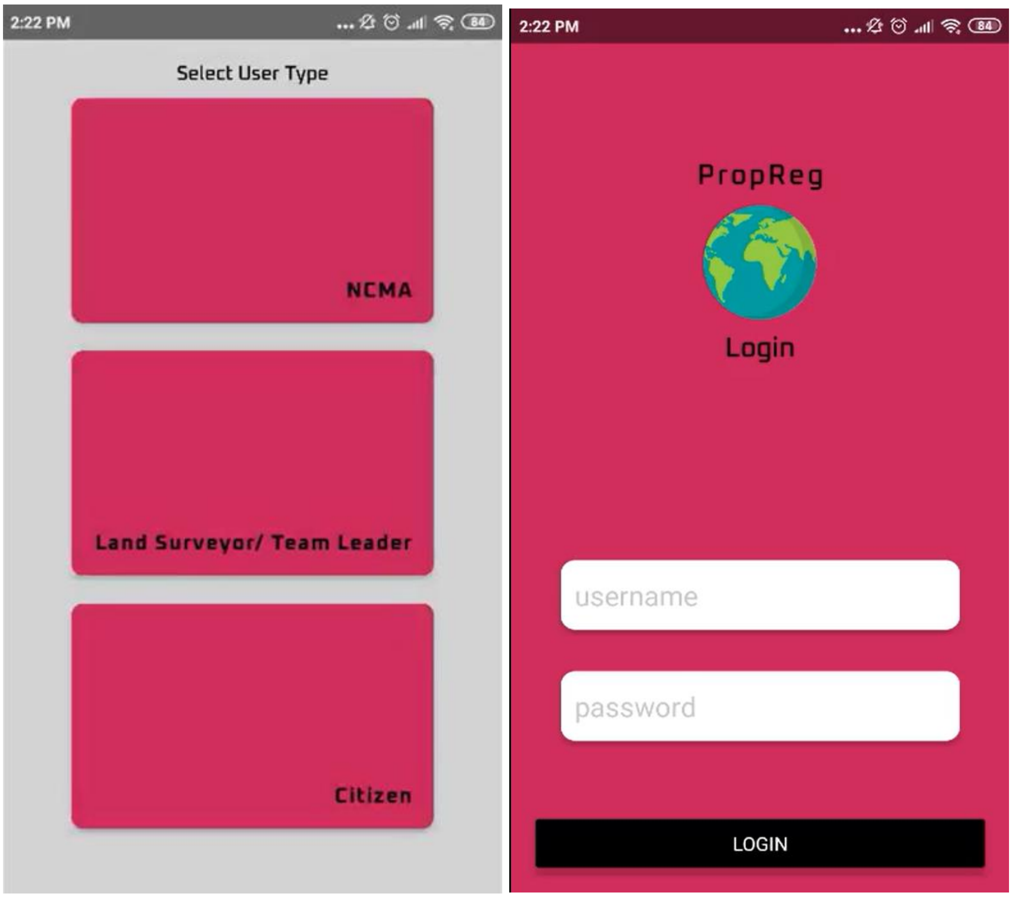
Moreover, it provides personalized profiles to the users based on their roles. These personalized profiles motivate users through earned badges, progress tracking, and possibly leaderboards, fostering an engaged and collaborative community.

The key application features as well as the gamification elements of the developed application are presented below:

- User Sign-in and Role-Based Access

'PropReg' ensures secure access through email and password authentication. During registration, users select roles as National Cadastral Mapping Agency, Land Surveyor, or Citizen, granting them tailored access and capabilities within the application (Figure 4.13).

The responsible NCMA could benefit from administrative privileges, enabling them to view users' content and team declarations, and monitoring and assess the cadastral process. For example, by monitoring vital statistics, such as the total number of registered properties and their combined area, agencies could ensure efficient land management.



(a) **(b)**

Figure 4.13 (a) *Role-Based Access and* ***(b)*** *User Sign-in.*

Land Surveyors/ team leaders utilize the application's advanced mapping features to precisely check the digitized property boundaries and uploaded legal documents. They can also see the number of declarations submitted by the right holders (Figure 4.13). Each land surveyor could be assigned a team of citizens/ right holders and supervise their progress.

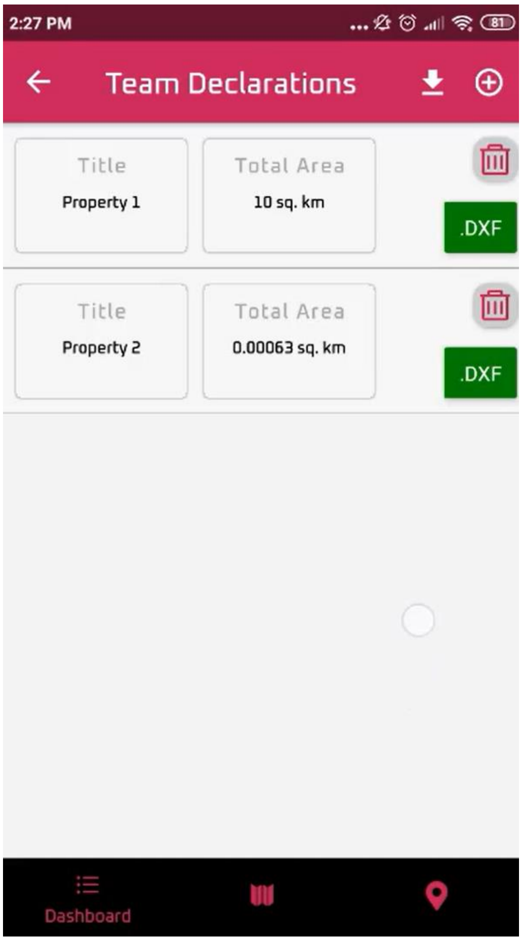


***Figure 4.14** Monitoring of team declarations in the application.*

Right holders could use the application to declare their property rights by locating their property, digitizing it, and submitting supporting documents (such as photos of the land parcel boundaries, ID documents, and deeds). They can also add points of interest in the area to support the cadastral process and help the community in the identification of the land parcels (especially in the rural areas).

- Points of interest digitization

The application provides the ability to digitize points of interest (POIs) by citizens in the area under cadastral survey. The digitization of POIs allows citizens to actively contribute to the creation and maintenance of a comprehensive and up-to-date database of locations that are of interest or significance in their community or region. The digitization process typically involves the identification of a point of interest using either the GPS technology available in their mobile devices or directly on the available basemap (recent orthophoto of NCMA, OpenStreetMap, Google Maps).

Once the POI has been digitized, citizens can input the relevant descriptive information into the application. This information may include descriptions, names, categories, and any other relevant attributes that help identify and categorize the point of interest. Points of interest can vary significantly, such as parks, historical landmarks, public facilities, art installations, local businesses, etc. Therefore, citizens may need to categorize the POIs based on predefined categories or tags to maintain an organized and easily searchable database.

They can also upload a photo of the digitized POI to provide easy visualization and analysis of the points of interest on a map (Figure 4.15).

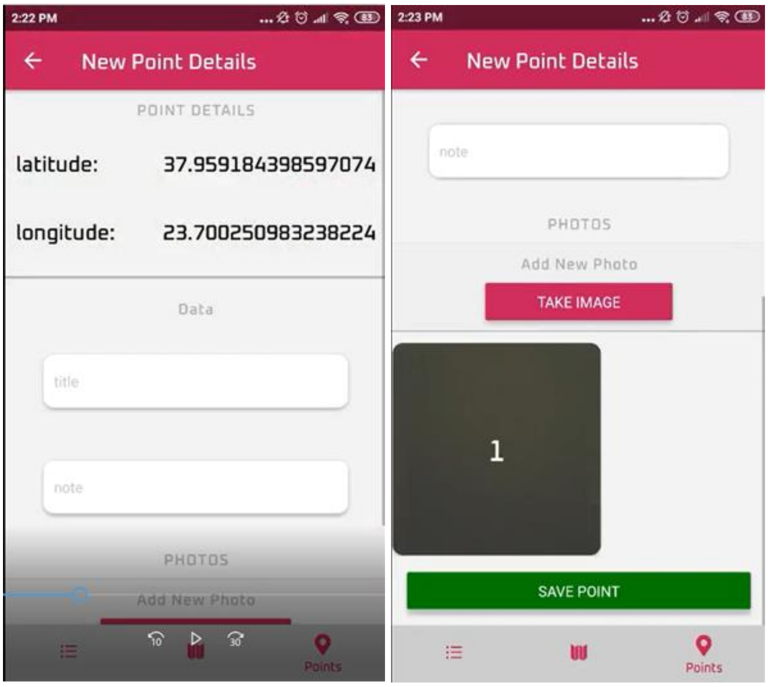


Figure 4.15 *Application's interface of POI's relevant descriptive information.*

- Submitting property declaration

'PropReg' allows citizens to submit a comprehensive declaration regarding the ownership of their property rights. Right holders could input relevant details about the property for which they are submitting the cadastral declaration. They have the option to select from various basemaps (recent orthophoto of NCMA, OpenStreetMap, and Google Maps) and easily locate and digitize their land parcel boundaries. Through this application, individuals can swiftly identify and delineate their property on the chosen basemap.

After being positioned approximately on the basemap using the GPS of the mobile phone, users are provided with the capability to digitize property boundaries. This digitization process could be carried out either online, particularly in cases where the boundaries were not easily discernible on the basemap, or offline. If the property boundaries were identifiable on the orthophoto, right holders have the option to zoom in on the map, either in real-time or at a later moment, to make essential adjustments to the orthophoto visible on their smartphone screen (Figure 4.16 a-d).

After the property boundaries were digitized, right holders could proceed to complete the required attributes, including personal data and other relevant descriptive information (Figure 4.16 e-f). This includes the street name, building or house number, city, state/province, postal code, and any other relevant location-specific details as well as the property type (e.g., residential, commercial, agricultural), area, and dimensions of the property according to the deed. The application also provides the ability to upload photos of the property boundaries. This functionality has proved to be highly beneficial during the cadastral survey procedure, enabling users to associate significant documents, such as property titles or even photographs of the property, to the relevant data.

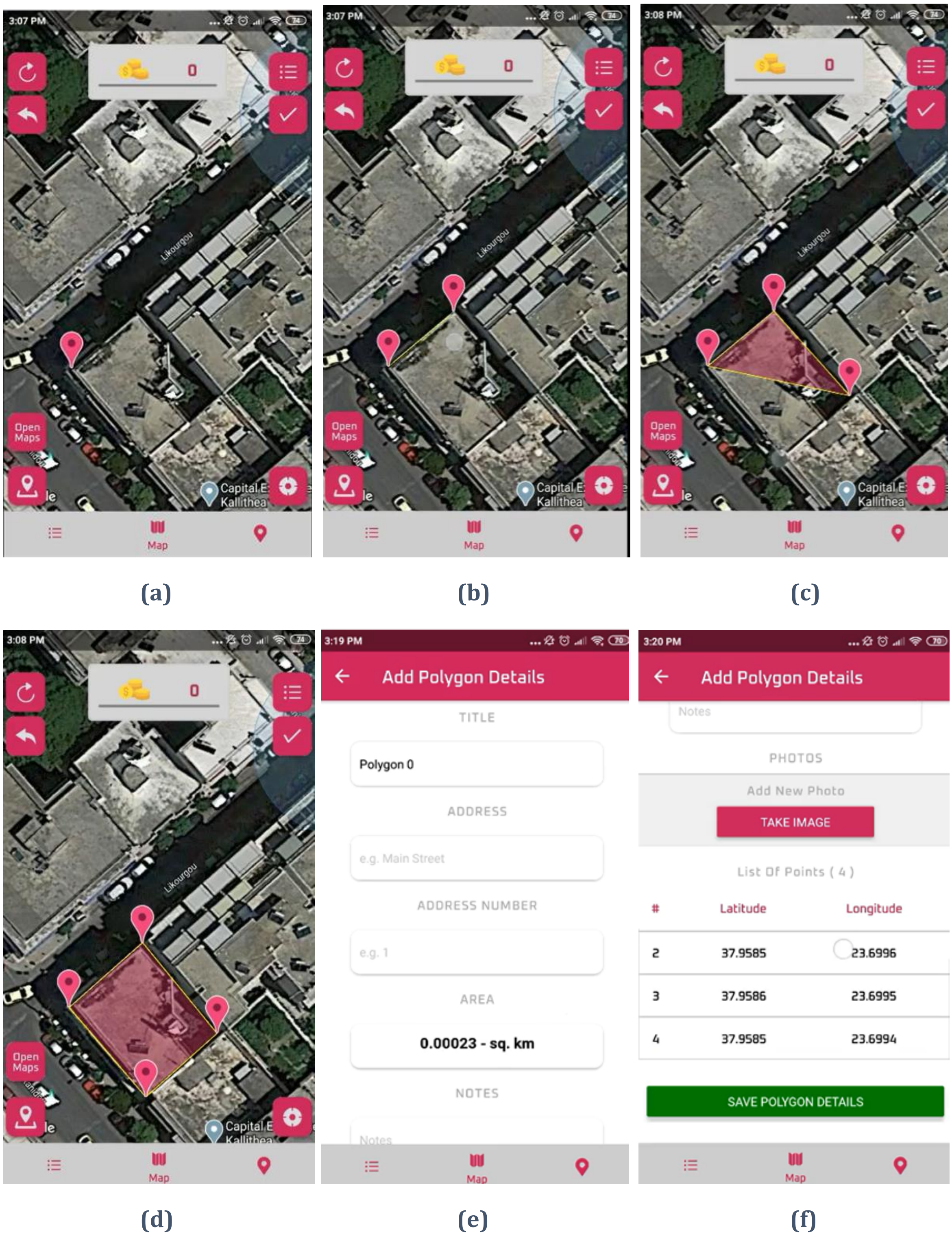


Figure 4.16) (a – d) *Step by step boundaries digitization and adjustments and* ***(e-f)*** *submission of necessary information and documents in the 'PropReg'.*

Before finalizing the submission, the right holder should carefully review all the provided information and uploaded documents to ensure accuracy and completeness.

Upon successful submission, the mobile application generates an acknowledgment confirming the receipt of the cadastral declaration. The property owner also receives a reference number or tracking code to monitor the status of their submission (Figure 4.17).

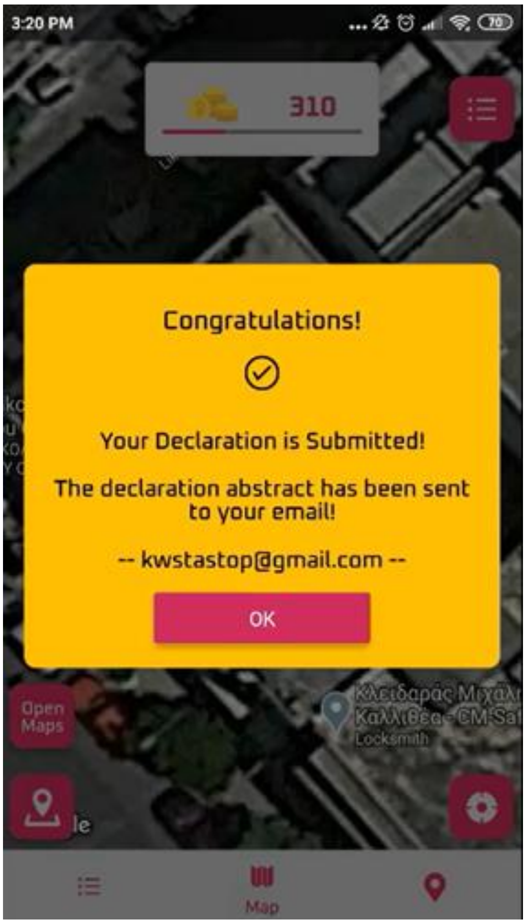


Figure 4.17 *Receipt of successful submission of property declaration.*

- Gamification elements

'PropReg' introduces an innovative blend of gamification elements strategically designed to amplify citizen participation in cadastral processes. By infusing interactive components, rewarding milestones, badges, leaderboards, progress bars, and a user-friendly interface, the application creates an engaging ecosystem that motivates citizens to actively partake in the cadastral procedures. The application's gamification elements are presented below.

Tokens of Empowerment

In 'PropReg', users are awarded tokens for completing various tasks and milestones within the application. These tokens serve as virtual currency, symbolizing the user's progress and commitment to declaring their property rights. As users accumulate tokens, they unlock new levels and features, creating a sense of accomplishment and advancement (Figure 4.18).

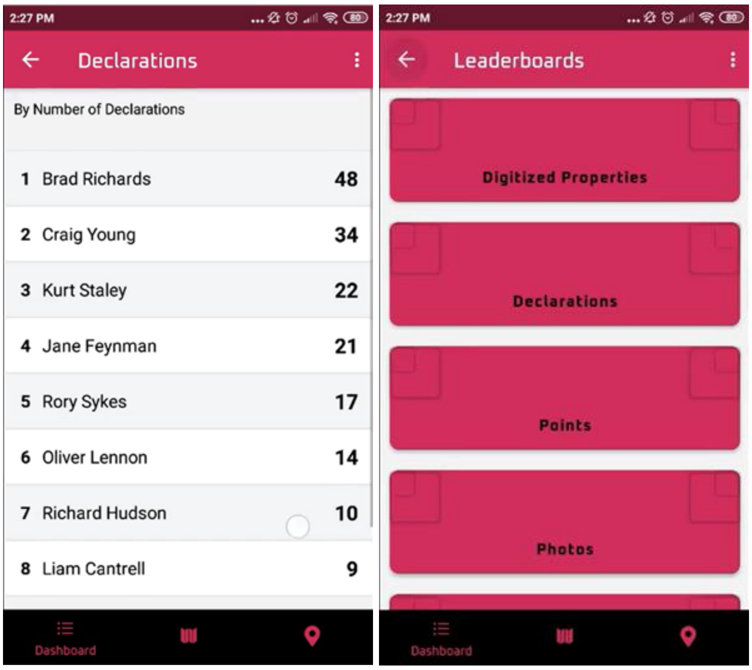
Progress Bar

To provide a clear visual representation of the cadastral declaration process, 'PropReg' incorporates a dynamic progress bar. As users input property information and complete required steps, the progress bar fills up, giving users a sense of how far they have come and what tasks remain. This feature not only ensures transparency but also motivates users to complete their property rights declaration efficiently (Figure 4.18).

Figure 4.18 *Application's tokens of empowerment.*

Leaderboards

'PropReg' fosters healthy competition among users by integrating leaderboards. Users can see how their progress compares to that of others, stimulating a sense of community and encouraging friendly rivalry. The leaderboards motivate users to strive for excellence in cadastral applications and incentivize them to climb the ranks through consistent and accurate submissions (Figure 4.19 a). The application provides a series of different leaderboards based on the number of digitized properties, the number of declarations, the digitized POIs, and the number of submitted photos (Figure 4.19 b).

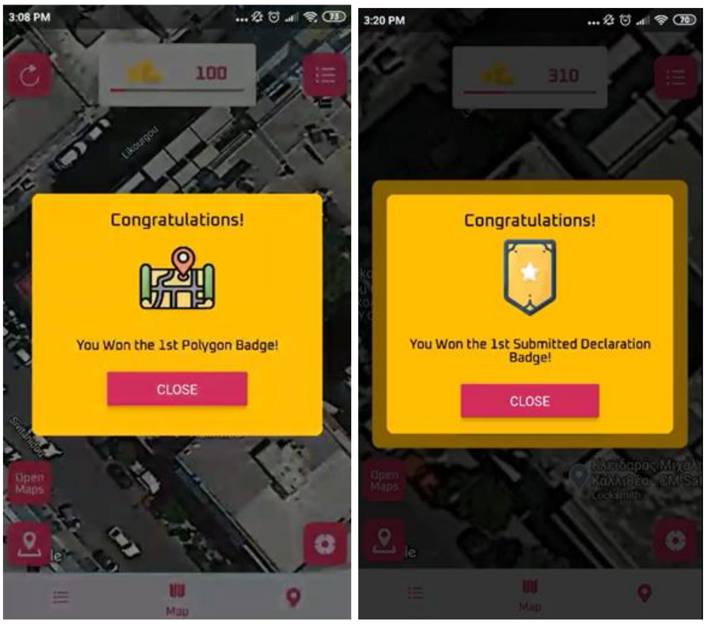


(a) (b)

Figure 4.19 a. *Leaderboard by the number of declarations.* ***b.*** *Application's different leaderboards.*

Badges

Recognizing the users' achievements and expertise, 'PropReg' incorporates a badge system. Users earn badges for completing specific cadastral steps (Figure and Figure) and mastering specific aspects of cadastral applications, such as accurately submitting property details or understanding legal documentation. These badges not only showcase a user's proficiency but also encourage them to continuously refine their knowledge and skills.



(a) (b)

Figure 4.20 *Badges for completing specific cadastral steps:* ***(a)*** *polygon digitization and* ***(b)*** *submitting the declaration.*

The user's overall progress and achievements can be seen in the profile menu as depicted in Figure 4.21. In this menu, the user can see the badges that he has earned, his progress according to the progress bar, his rank in the leaderboards and the achievements that he has earned, as well as the acquired digital tokens.

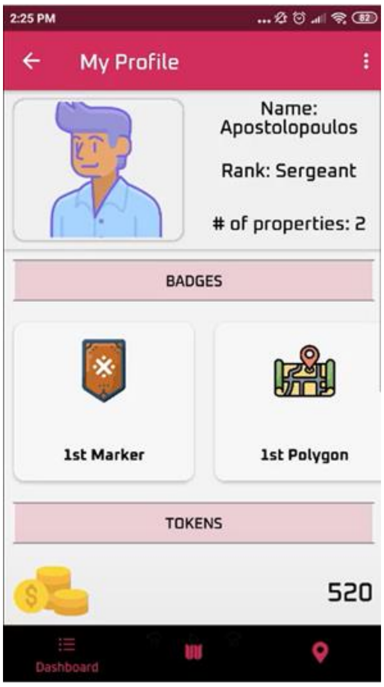


Figure 4.21 *Application's profile menu.*

4.6 Investigation of using new technologies and collection of additional geospatial information from a distance

The cadastre plays a pivotal role in supporting sustainable and well-planned development. It provides a foundation of accurate and up-to-date information necessary for effective decision-making, reducing land-related disputes, encouraging investments, and facilitating overall economic and social progress. Therefore, the next step of this research focuses on the instigation of new technologies and methodologies for remote geospatial data collection to support this role. The objective is to investigate the feasibility, accuracy, and efficiency of gathering geospatial information from a distance, by working from home using open data, with potential applications in various land management fields such as environmental monitoring, urban planning, disaster management, agriculture, and more. The study encompasses the analysis of cutting-edge technologies and open data, including satellite imagery, remote sensing, aerial drones, and advanced data analytics techniques. It is tested on a case study for devising an efficient, cost-effective, and dependable approach for coastal management in Greece, specifically tailored for tourism purposes.

In this regard, a team of skilled surveyors has crafted a proposed methodology and provided training to volunteers, enabling them to gather diverse data points of interest related to a public coastal zone. The data encompasses various aspects, such as the measurement of free and unused public space, rocky areas, parking spots (organized or unorganized), land usage patterns, built-up and green areas, municipal lighting, pedestrian crossing points, beach umbrellas, path routes, street furniture, and more.

To test the proposed methodology, a group of volunteers gathered geospatial data concerning the seashore of a portion of the Athenian Riviera. One of the topics under examination at the national level is tourism planning (Greek Government Gazette, 2020), due to the significant impact of this economic activity on the national GDP (Bakogiannis et al., 2020).

The fundamental components of this methodology encompass:

- identifying the specific types of geodata that require collection,
- determining the necessary geometric accuracies,
- pinpointing appropriate tools and available open-source data suitable for the project,
- assessing the required personnel and the number of volunteers needed,
- evaluating the qualifications and skills of both personnel and volunteers participating in the project,
- estimating the total man-hours required

The initial phase of this methodology entails defining, in a comprehensive and detailed manner, the essential geospatial data crucial to the project's objectives. These data may vary depending on the intended purposes, covering diverse fields of coastal management such as risk and disaster management (Griffith-Charles, 2021), human mobility management, real estate management, geo-conservation, historical development (Oremusová et al., 2021), geo-heritage management (Merciu et al. 2023), and geo-tourism development (Tessema et al., 2021).

Furthermore, this methodology accounts for planning emerging tourism activities in previously undeveloped regions, encompassing aspects like land use types, hotels, restaurants, bars, sports facilities, housing, schools, demographic data, etc. The datasets (Table 4.1) may include but are not limited to:

i. available public spaces,

ii. parking spaces (organized or not) and boat storage areas,

iii. structures within the coastal zone (e.g., hotels, bars, restaurants, sports facilities,

iv. cinemas/ theatres, supermarkets, malls, medical centers/ pharmacies, gasoline stations),

v. green areas and rocky regions,

vi. municipal lighting and street furniture,

vii. locations of pedestrian crossing points and underground crossings,

viii. beaches (organized or not) and facilities designed for people with special needs,

ix. beach umbrellas,

x. access points, road networks, dead ends, and path routes,

xi. transportation-related information like bus stops, ports, and taxi stations,

xii. key municipal facilities such as the authority building, police station, and citizen service center, as well as places of worship,

xiii. port authority,

xiv. rocky seafronts,

xv. residential areas,

xvi. points of interest related to cultural heritage.

***Table 4.1** Categories of geospatial data to be collected. Source: Bakogiannis et al., 2021*

Geospatial Data to Be Collected		
Free and unused public spaces	Green areas	Beaches (organized or not)
Parking spaces (organized or not)	Municipal lightning and street furniture	Beach umbrellas
Constructions on the coastal zone (e.g., hotels, bars, restaurants)	Pedestrian crossing points	Road network and path routes
Bus stops	Municipal authority building	Port authority
Rocky seafront	Residential area	Facilities for people with special needs

The subsequent phase involves establishing the required geometric precisions for the aforementioned geospatial datasets. These accuracies must align with technical standards at both national and EU levels with the Inspire legislation. As this research centres on remotely gathering all geospatial data, the precision of existing datasets for Greece is of high importance, including open cadastral maps and high-resolution orthophotos. Specifically, for urban areas, the orthophotos' RMSExy is less than 28 cm, and for rural areas, it is less than 35 cm. As for cadastral maps in urban areas, RMSx is ±0.5 m; RMSy is ±0.5 m; and RMSxy is ±0.71 m, while in rural areas, RMSx is ±1.0 m; RMSy is ±1.0 m; and RMSxy was is 1.41 m. These accuracies proved sufficient for all tasks mentioned above. For countries lacking such available basemaps, urgent cases may resort to basemaps from platforms like Google maps, OpenStreetMap, or even basic air photos.

Following the definition of necessary geospatial data types and corresponding accurate requirements, the selection of appropriate IT tools, software, and data are essential to support and exploit this crowdsourced methodology. These tools could range from commercial to open-source solutions, with the latter being preferred. Notably, there is an array of open-source tools like QGIS, OpenStreetMap, and Greece offers online datasets encompassing road and rail networks, significant locations (airports, police stations, ports, town halls, etc.), hydrographic networks, coastal lines, protected natural areas, Corine land cover, cultural heritage sites, municipal boundaries, demographic data, free Wi-Fi spots, forests, and lakes. These resources could contribute positively in terms of cost-effectiveness and adaptability for such projects.

Furthermore, ensuring the sustainability of such projects necessitates defining the appropriate personnel. Two key aspects to consider are the number of individuals involved, including both professionals and volunteers, and their essential qualifications and skills. Volunteers participating in the project must receive training from professionals, such as surveyors and planners, through a well-designed e-training course. This course should equip them with the knowledge of utilizing available IT tools and software, identifying and digitizing geospatial data on available basemaps, and avoiding errors in the process. The professionals, on the other hand, are responsible for quality control and necessary editing of the crowdsourced geospatial data, leading to a final product that meets all technical specifications. The methodology's various steps are depicted in Figure 4.22.

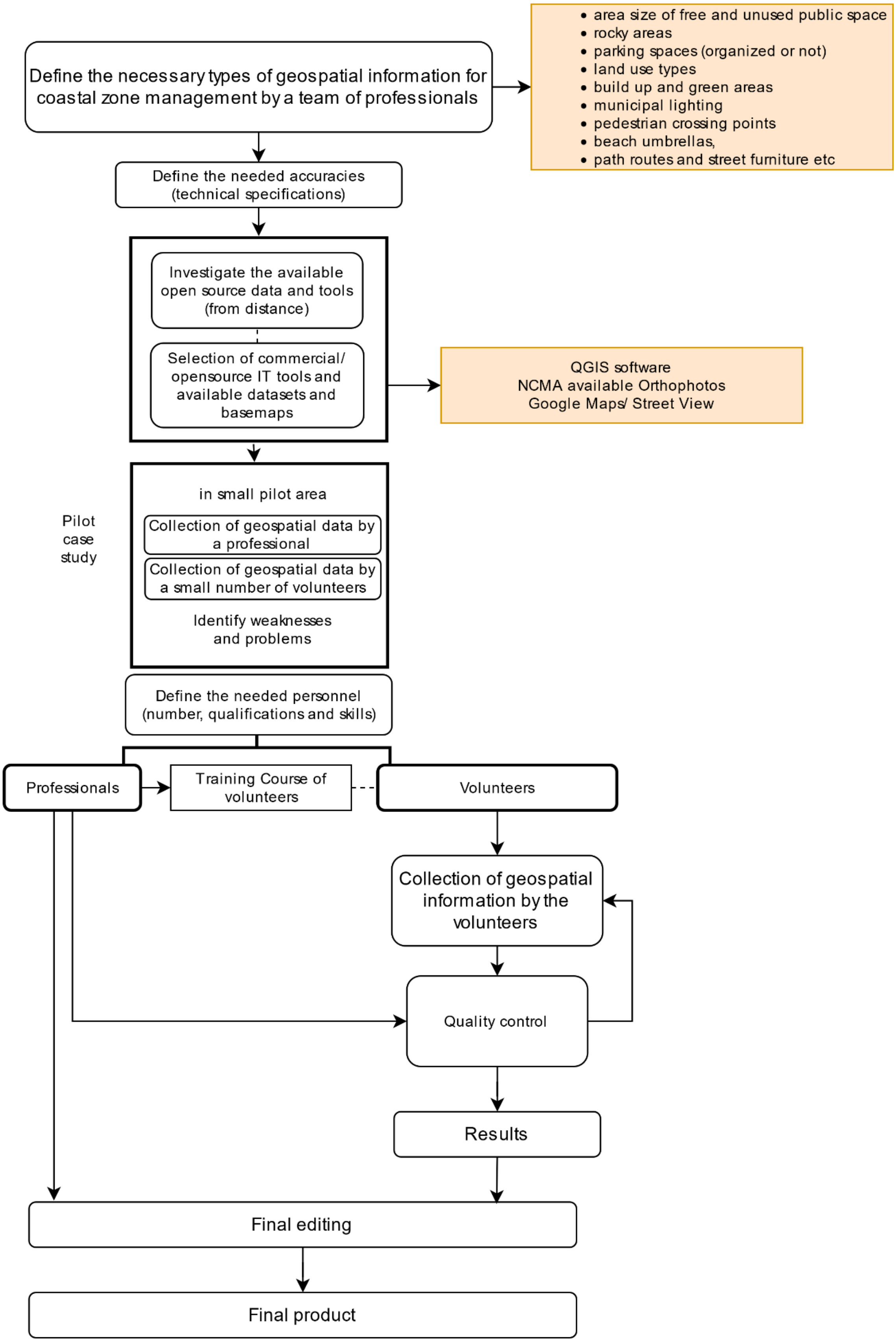


__Figure 4.22__ Proposed methodology for crowdsourced geospatial data collection from a distance to Facilitate coastal management and Planning in response to evolving tourism demand. Source: Bakogiannis et al., 2021.

4.7 Investigation on how to improve the Quality of Crowdsourced Cadastral Surveys

The primary objective for the next and final step of this research was to provide a revised version of the proposed FFP methodology that will include the essential quality controls required for ensuring the accuracy of a modern cadastre.

Enhancing the accuracy and reliability of crowdsourced cadastral surveys hinges significantly on a primary and pivotal step - the compilation and utilization of an advanced basemap. To achieve this, the engagement of trained volunteers who have received instruction from a professional surveyor/contractor is highly proposed.

Therefore, a proposed model is put forth to create an advanced basemap for crowdsourced cadastral surveys, drawing on the aforementioned investigation (Chapter 4.6). This model suggests incorporating additional geospatial information onto recent orthophotos, such as Very Large Scale Orthophotos (VLSOs) and Large Scale Orthophotos (LSOs), as depicted in Figure 4.23. In this proposed model, professionals in charge of the crowdsourced cadastral survey should handle certain aspects of their usual responsibilities for the cadastral project, such as geo-referencing, adjusting, and editing existing geospatial data. Furthermore, these professionals will supervise a team of trained volunteers to execute any further enhancements on the advanced basemap.

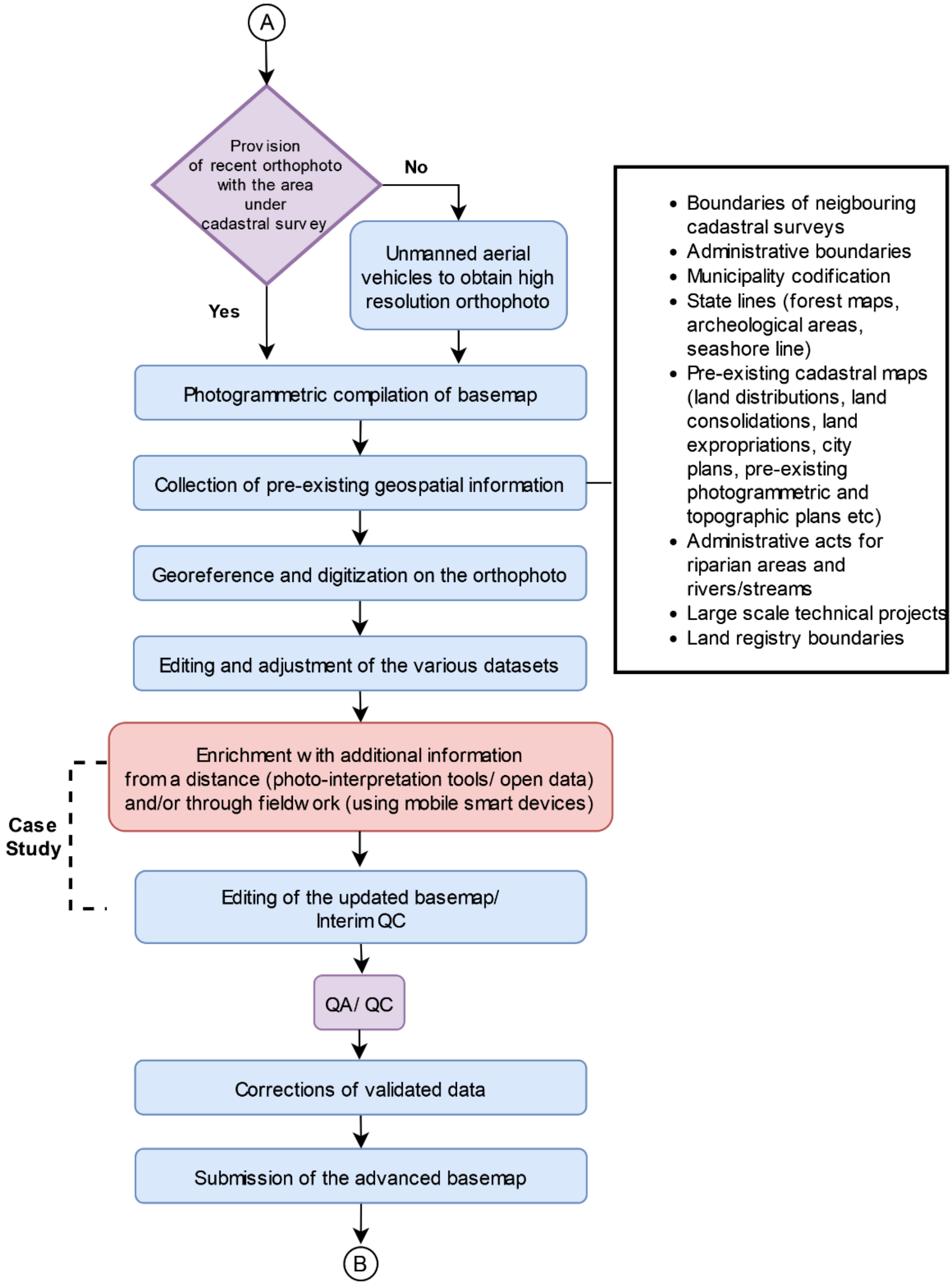


Figure 4.23 *Compilation of an advanced crowdsourced basemap – a model involving trained volunteers (pink), NCMA (purple) and Professionals (blue), and Volunteers (pink). Source: Apostolopoulos et al. 2022.*

Further enrichment may entail the inclusion of additional geographical features such as road/ river network data, names of roads and rivers, forest areas, and rural settlements. These settlements could be formal or informal and might lack detailed city plans, such as specific information about land parcels, roads, settlement names, public spaces, and settlement boundaries. Moreover, the data collection for this purpose could involve gathering information about building footprints, both formal and informal constructions, green areas, and points of interest, like stadiums, hospitals, and municipal buildings.

The volunteers should have two primary methods to collect this data. First, they can use photo-interpretation tools or access open data from a distance. Second, they can conduct fieldwork using mobile smart devices. However, it is crucial to note that creating an advanced basemap requires a significant, long-term commitment from the volunteers and specific skills. Therefore, a small number of volunteers is recommended for this specific task. Conversely, during the declaration submission phase, as mentioned earlier a large number of volunteers is more suitable (Neis and Zipf, 2012; Cetl et al., 2019).

The editing of the updated basemap, which is produced by trained volunteers, should be undertaken by professionals. Subsequently, the responsible NMCA should validate the updated basemap before making it available to the public for the declaration submission process.

For an AAA crowdsourced cadastre, it is essential to continuously improve the accuracy of the cadastral data, both thematically and geospatially. To facilitate this improvement, a General Project Quality Program is proposed to be integrated into an updated version of the proposed model. This General Project Quality Program encompasses various aspects like equipment, staff, services, timetable, deliverables, etc., and ensures compliance of geospatial data with the AAA technical specifications. By following this model, the FFP crowdsourced cadastral survey can gradually transform into an AAA cadastre.

The proposed updated model introduces three Quality Assurance/Quality Control (QA/QC) steps, as depicted in bright green color in Figure 4.24. Specifically, the first QA/QC step occurs after compiling the advanced basemap, the second QA/QC step takes place following the declaration submission phase and the third QA/QC step takes place after the objection's submission phase.

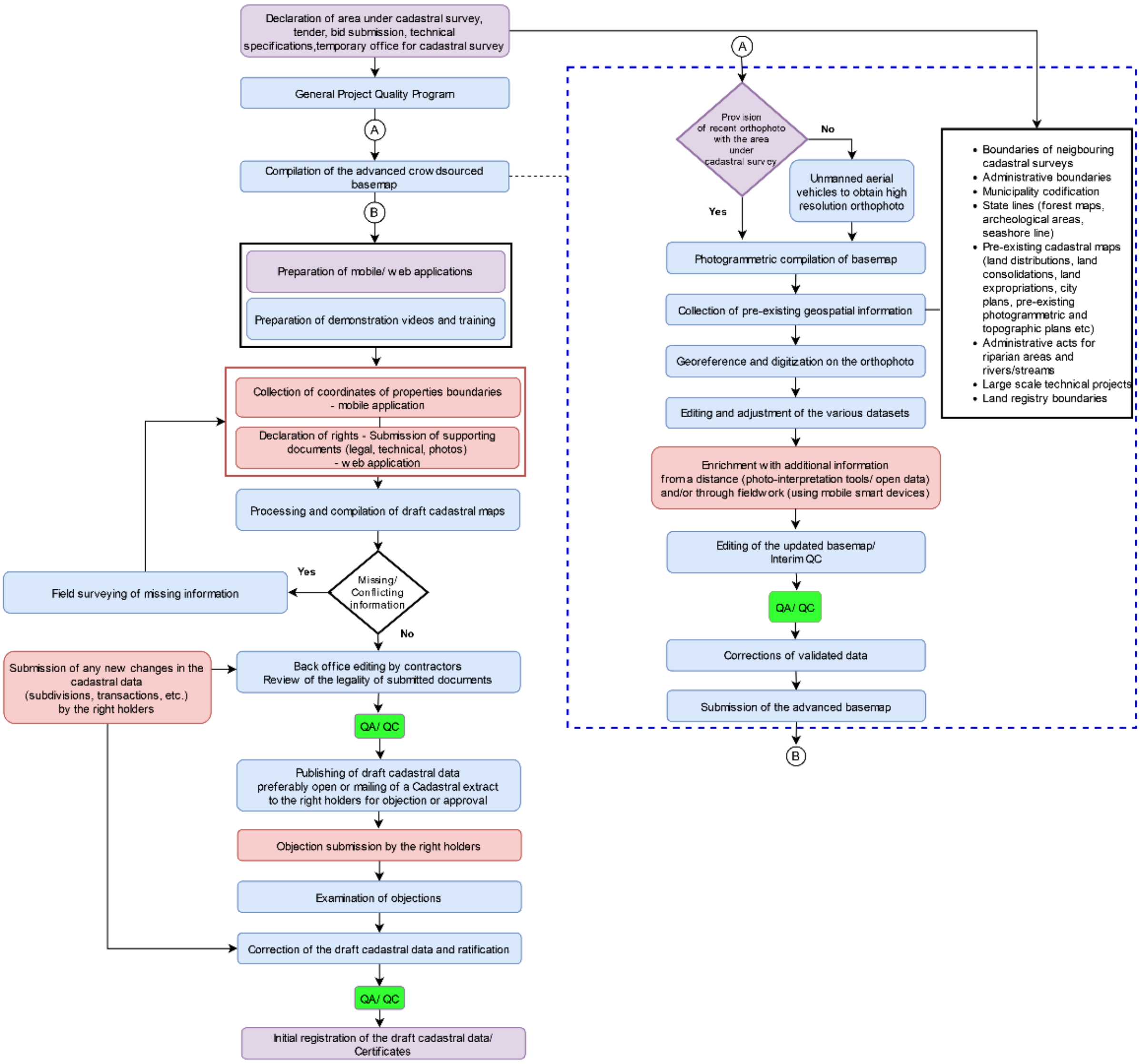


Figure 4.24 *Proposed crowdsourced model enhanced with QA/QC phases, involving non-professionals (pink), NCMA (purple), professionals (blue), and volunteers (pink). Source: Apostolopoulos et al. 2022.*

4.8 Concluding remarks

In conclusion, the proposed fit-for-purpose model presented in this chapter offers a flexible and efficient approach to cadastral surveys. It emphasizes tailoring survey methods and data requirements to the specific needs and objectives of cadastral projects, rather than striving for absolute accuracy from the outset. This pragmatic and incremental approach is designed to overcome barriers and expedite the implementation of cadastral systems.

To develop a comprehensive understanding of the fit-for-purpose model, the chapter draws from an extensive literature review exploring the theoretical foundations, principles, and practical applications of this approach. It also delves into the works of cadastral experts who have contributed to the development and refinement of fit-for-purpose cadastral surveys. This synthesis of existing knowledge lays the groundwork for the subsequent exploration of the methodology's practical implementation that will be presented in the next chapter.

The proposed fit-for-purpose model, as presented in this chapter, emphasizes a tailored and incremental strategy to overcome these challenges. Rather than aiming for absolute accuracy from the outset, the FFP approach prioritizes the specific needs and objectives of cadastral projects, thus streamlining the implementation process.

Furthermore, the chapter has offered empirical evidence through the examination of case studies, particularly the compilation procedures of the Hellenic and Romanian cadastres. These real-world applications shed light on the challenges encountered, strategies employed, and outcomes achieved, illustrating the adaptability and effectiveness of fit-for-purpose approaches across different contexts.

By synthesizing existing knowledge, insights from case studies, and lessons from literature, this chapter has contributed to the development of a modern fit-for-purpose model for cadastral surveys. This model is poised to address the challenges associated with comprehensive and reliable cadastral systems effectively. As the subsequent chapters delve deeper into practical implementation, challenges, and benefits of the fit-for-purpose approach, readers will be equipped to navigate the intricacies and opportunities that lie ahead.

To establish such a fit-for-purpose model several proposals can be considered:

- *Enhance Collaboration*: Responsible NCMAs should actively collaborate with local and international experts, fostering knowledge-sharing and experiences to ensure the successful implementation of their cadastral projects. This collaboration will help address challenges and improve the overall quality of the cadastres.

- *Foster Citizen Participation*: Active engagement of landowners and stakeholders is crucial for the success of the cadastre initiatives. NCMAs should establish mechanisms to involve citizens in the data collection process, such as user-friendly platforms for land identification, rights declaration, and document submission. This will enhance transparency, inclusivity, and ownership.

- *Embrace Technological Advancements*: NCMAs should embrace the latest IT tools and technologies to support the cadastral data collection process. This includes adopting digital mapping systems, remote sensing techniques, and data management software to improve efficiency, accuracy, and data integration.

- *Continual Monitoring and Evaluation*: Regular monitoring and evaluation of the cadastral projects are essential to ensure their effectiveness and identify areas for improvement. NCMAs should establish mechanisms to track progress, measure outcomes, and make adjustments as needed. This will ensure that the cadastres remain up-to-date, reliable, and responsive to changing needs.

- *Capacity Building*: Investing in training programs and capacity building initiatives for both the public and private sector involved in cadastral surveying and mapping is crucial. This will ensure that professionals possess the necessary skills and expertise to carry out accurate and reliable cadastral activities. Continuous professional development and knowledge exchange should be promoted.

By implementing these proposals, the countries can expedite the establishment of complete and up-to-date cadastres, benefiting their citizens and society as a whole. These cadastres will enhance security of land tenure, facilitate access to credit, ensure fair property taxation, and create a sustainable real estate market. Furthermore, they will contribute to poverty reduction efforts and help mitigate the impacts of climate change. The successful implementation of robust and reliable cadastres will serve as a foundation for future economic and social development in these countries.

In summary, the introduction of the proposed fit-for-purpose cadastral model marks a significant step forward in land administration. Its pragmatic and incremental nature, combined with insights from literature and real-world applications, promises to enhance crowdsourced cadastral surveys, making them more efficient and adaptable in diverse contexts. The chapter sets the stage for further exploration, where a comprehensive understanding of the fit-for-purpose methodology will lead to improved land management practices worldwide.

5 Testing of the New FFP Cadastral Model

5.1 Introduction

This chapter is dedicated to rigorously testing the proposed Fit-for-Purpose cadastral model in various contexts. The primary objective is to assess its adaptability, resilience, and capacity to overcome hurdles in crowdsourced land administration while catering to the unique needs of diverse landscapes and communities.

It aims to explore the proposed model's applicability across diverse contexts, in urban, rural, and suburban areas, while evaluating its effectiveness in leveraging modern information technology IT tools. Furthermore, it seeks to assess the impact of citizen engagement facilitated by the incorporation of gamification elements in the cadastral mapping process. The selection criteria for these case studies aim to ensure a comprehensive and representative assessment of the model's applicability and effectiveness across diverse environments.

The key parameters that are taken into consideration in the selection of the areas for testing the proposed cadastral survey model are the following:

a) geographic diversity and socio-economic conditions: various case studies are being held in urban, suburban, and rural areas to investigate the challenges and the geometric accuracy of the results;
b) land use patterns: various urban patterns with attached and detached buildings, rural patterns with high and low vegetation, fixed and non-fixed boundaries, and complex property shapes are examined;
c) specific problems already identified in the cadastral surveys in Greece and Romania;
d) areas with existing official cadastral data to be used for the assessment of the achieved results, in areas with no official cadastral data, professional field surveys are conducted to be used for the assessment of the achieved results.

The first case study delves into the investigation of technology implementation in an urban environment. By leveraging advanced IT tools, including smartphone technology and cloud-based platforms, citizens actively participate in mapping their neighbourhoods and digitizing property boundaries.

The second case study extends the examination of the technology implementation to suburban and rural environments, where the crowdsourced cadastral model is assessed for its adaptability and citizen engagement potential. Emphasizing user-friendly mapping applications such as ESRI's Collector for ArcGIS, this case study empowers local citizens/ right holders to actively contribute to land parcel identification and boundary delineation. In order to enhance and foster citizen engagement, the case study introduced the integration of gamification elements into the cadastral procedure.

The third case study adopts a comprehensive approach by testing the model across urban, suburban, and rural environments in Greece and Romania. Through meticulous evaluation, this study identifies the strengths and weaknesses of the crowdsourced cadastral methodology in each context, while concurrently gauging the level of citizen engagement in the cadastral process.

The fourth case study tests the developed open-source application with gamification elements in an urban environment. The focus is to examine the efficacy of the application that leverages gamification techniques to enhance citizen engagement and participation in the cadastral process. By deploying this innovative tool in an urban setting, the aim was to evaluate its impact on data accuracy, user satisfaction, and overall effectiveness in modern land administration practices.

The fifth case study examines the prospects of utilizing new technologies to remotely collect geospatial data to complement the crowdsourced cadastral model. By integrating additional geospatial information, this case study aims to enhance existing geospatial infrastructures and cadastral database comprehensiveness.

The sixth case study focuses on the improvement of crowdsourced cadastral survey quality. Through meticulous analysis of data validation processes, feedback mechanisms, and citizen training, this study identifies necessary QA/ QC to be implemented in the proposed model to enhance crowdsourced data accuracy and reliability.

In conclusion, this chapter endeavors to provide a multifaceted analysis and assessment of the proposed FFP cadastral model in land administration. The insights drawn from the diverse case studies aim to shed light on the potential benefits, challenges, and future prospects of adopting this innovative approach to achieve more efficient, inclusive, and accurate cadastral systems.

5.2 Case study No. 1 - Investigating technology in an urban environment

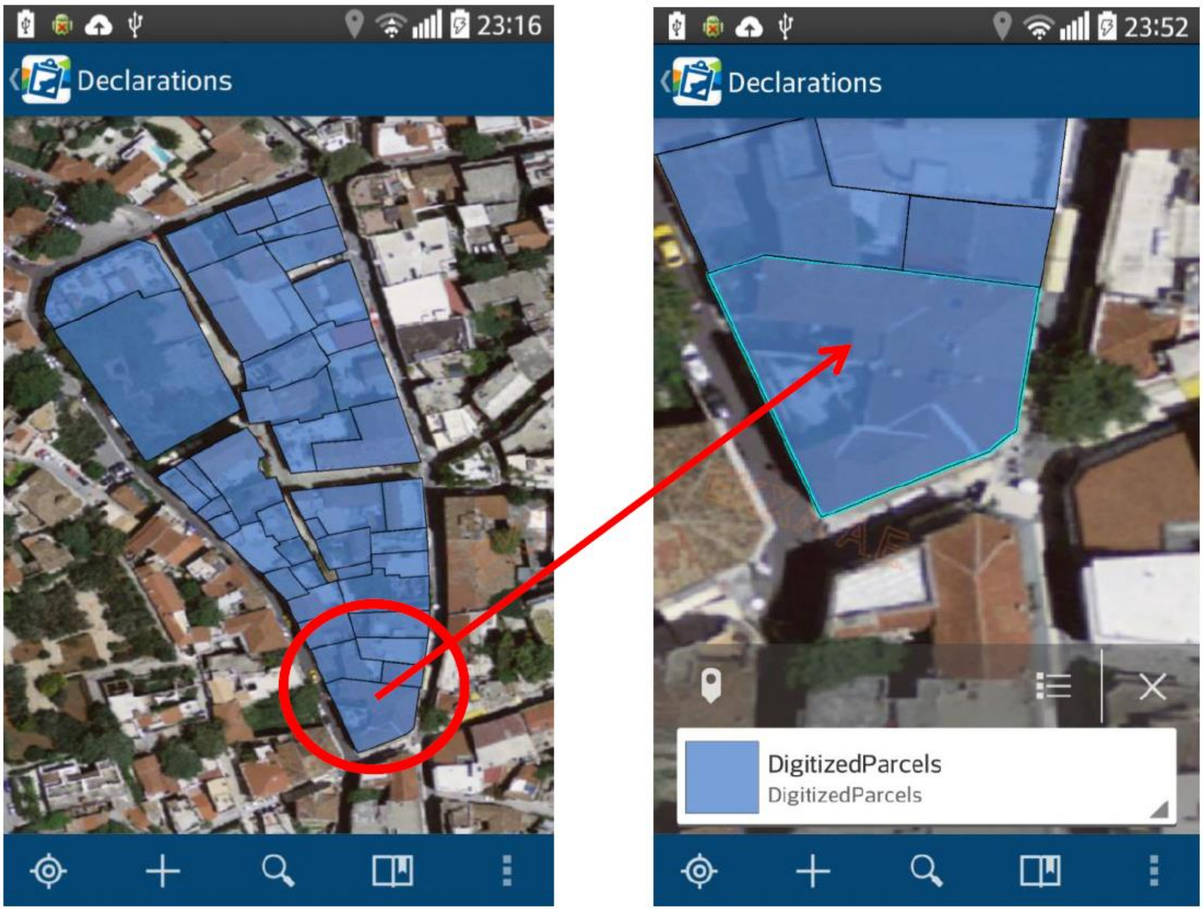
The first case study was conducted in Plaka (Figure 5.1), a historic and protected urban neighborhood in the heart of Athens, Greece, to assess the viability of the proposed methodology. Plaka, known as the "Neighbourhood of the Gods," is situated around the northern and eastern slopes of the Acropolis and features intricate streets and neoclassical architecture. It is built upon the ancient residential areas of Athens and holds numerous archaeological sites.

Figure 5.1 *Case study area – Plaka neighbourhood in the heart of Athens.*

To examine the effectiveness of the proposed approach in an urban setting, the case study employed Hellenic NCMA’s highly detailed true-orthophotos the basemap, offering an accuracy of 1:1000. Local volunteers, including non-professionals familiar with the area (not all of whom were landowners), participated in the data collection process using GPS-enabled mobile phones. They either visited the properties in person, using their mobile devices on-site or worked from home using desktops or laptops. As some parcels were inaccessible, the volunteers digitized the parcel boundaries on the basemap from their office or home locations. A land surveyor oversaw the team's efforts.

Following the completion of the measurements, the volunteers created a draft cadastral map for the Plaka area. Figure 5.2 (a) illustrates a part of this crowdsourced map. The overall accuracy of the cadastral map was deemed satisfactory. When zoomed in for a closer look (Figure 5.2 b), the map displayed greater distinguishability, owing to the high accuracy of the basemap (true orthophoto) used in the process.

Hence, it can be asserted that when it comes to accuracy, using a precise true orthophoto as a basemap is crucial in urban areas where boundaries are well-defined and visible on the orthophoto, exemplified by the Plaka area in the city center. In rural areas, where parcel boundaries are also fixed on the ground and visible on the orthophoto, the results can generally meet the specified requirements.



(a) **(b)**

Figure 5.2 *Part of the crowdsourced cadastral map in Plaka neighborhood. Source: Mourafetis et al., 2015.*

However, in remote rural regions where parcel boundaries are not fixed on the ground and, consequently, not depicted on the basemap, users are left with the option of gathering coordinates with the aid of GPS at the locations where landowners believe the boundaries exist. In such scenarios, the accuracy heavily relies on the GPS precision of the smartphone and the quality of the signal, leading to potential variations of accuracy within a range of 3 to 20 meters. To enhance the accuracy of these boundary points, additional field measurements may be conducted by a land surveyor or a trained team leader during the office editing process. Yet, no ground system for accuracy improvement is necessary. Nonetheless, in many of these cases, the boundaries are inadequately described in the deeds, making precise geometric positioning unattainable.

Smartphone positioning is achieved through a combination of the satellite GPS system and the ground antenna network of the mobile phone provider. In urban areas, such as the case study area in this research, positioning primarily relies on the ground antenna network due to dense urban construction and narrow streets, hindering a strong satellite connection. However, urban areas benefit from a highly concentrated mobile phone antenna network, designed to serve customers effectively within city limits, resulting in better and more accurate positioning, always meeting the required accuracy level for the aforementioned services.

Moreover, the application used in the study offers a practical feature allowing users to take and attach photos from the field (Figure 5.3) if necessary. This proves especially valuable during cadastral surveys, as it facilitates easier differentiation of property sizes and boundaries during the office editing phase. Furthermore, a crucial element of the application involves registering the property's attributes (Figure 5.4).

Figure 5.3 *Property's photo uploads using the ESRI's Collector for ArcGIS application. Source: Mourafetis et al., 2015.*

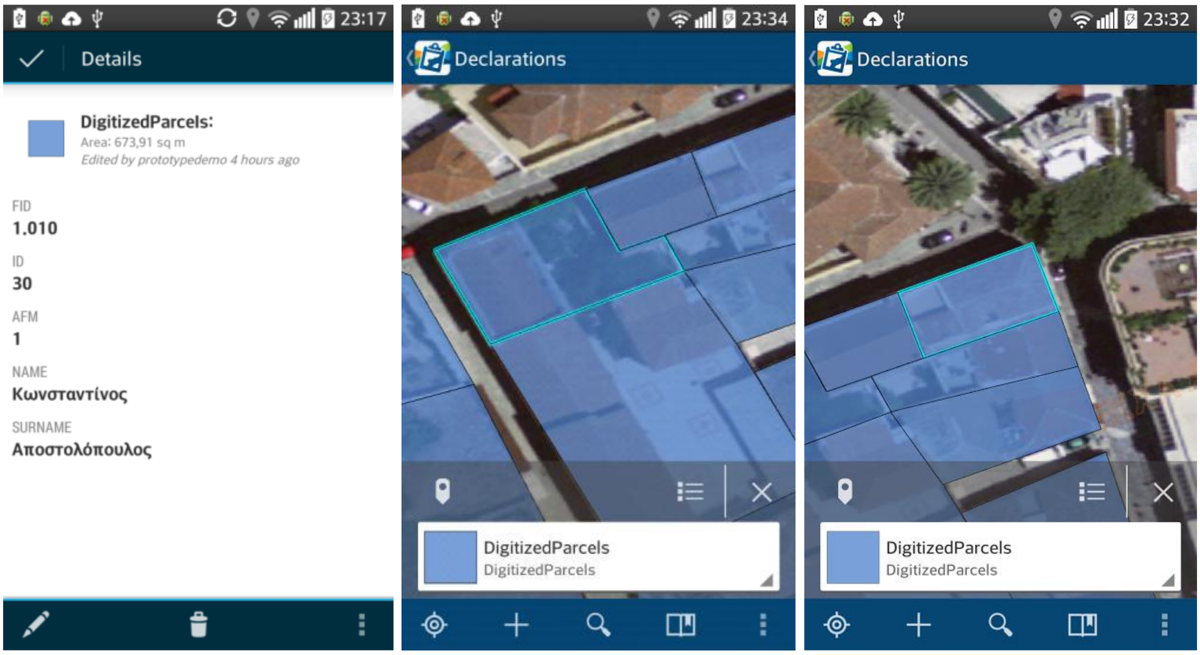


Figure 5.4 *Registration of property's attributes and boundaries using the ESRI's Collector for ArcGIS application. Source: Mourafetis et al., 2015.*

The findings obtained from the implemented case study are highly promising, particularly when applied in countries with a certain level of infrastructure, such as access to orthophotos for basemaps and a dense network of mobile phone antennas. The creation of the draft crowdsourced cadastral map was accomplished swiftly, at a minimal cost, and with a commendable average level of accuracy. This project yields several valuable insights and suggestions.

Firstly, it is crucial to note that all collected information is securely stored in the cloud, ensuring the protection of personal data. Moreover, the specific application offers the flexibility to make certain collected data accessible to the public while keeping some information protected with restricted access limited to relevant agencies. This feature proves highly advantageous in terms of safeguarding private data.

Additionally, it should be emphasized that while the achieved rough location accuracy relies on factors like the type of mobile phone used and the existing network of antennas, the proposed methodology's accuracy for the draft cadastral mapping is entirely contingent on utilizing a precise basemap. Another supporting aspect is the option to work either connected to the internet or offline in the field, which is particularly advantageous in areas with poor internet connectivity.

Furthermore, the overall procedure and maintenance costs remain low and should be fully covered by the responsible NCMA or the authorized cadastral surveyors. Citizens, on the other hand, can utilize this application free of charge. Incentives could be provided to participating citizens/property owners in the form of reduced registration fees, further encouraging engagement and cooperation in the process.

5.3 Case study No. 2 - Investigating technology in an urban, suburban and rural environment and Citizen Engagement with Gamification

The second case study includes three separate pilot studies. These studies were conducted in different areas of Greece, representing an urban location in Kaisariani, Athens, a suburban setting in Ayia Marina, Keratea, and a rural region on Panayiouda, Lesvos Island. To facilitate these studies, two software applications were utilized: ESRI's ArcGIS online application Collector for ArcGIS and a custom-made application called BoundGeometry (Apostolopoulos et al., 2018).

In these pilot studies, the collected cadastral data by volunteers encompassed crucial details such as parcel boundaries, building footprints, and descriptive information relating to property rights and the personal data of property owners.

5.3.1 Pilot study in an urban area

The first pilot study involves an urban area situated within the municipality of Kaisariani, an eastern district of Athens, located approximately 3 km east of the city center. In this study, two volunteers used the Esri's Collector for ArcGIS and Bound Geometry applications, along with high-resolution orthophotos provided by the Hellenic NCMA, as basemaps. Their primary task was to digitize the boundaries of 146 land parcels distributed across eight blocks of Kaisariani (Figure 5.5 a).

Despite the limited number of volunteers, data collection in this area was relatively straightforward. The smartphone's GPS signal was robust, thanks to the dense mobile phone antenna network in the vicinity. The GPS was used for rough positioning with an accuracy of 1–3 meters, and then further manual adjustments were made by zooming in and moving the cursor. However, the direct identification and collection of all property boundaries from the orthophotos proved challenging. In cases where boundaries were fixed in the field, such as when they coincided with building facades, but were not clearly visible on the orthophotos, the Measure tool of Collector for ArcGIS was necessary.

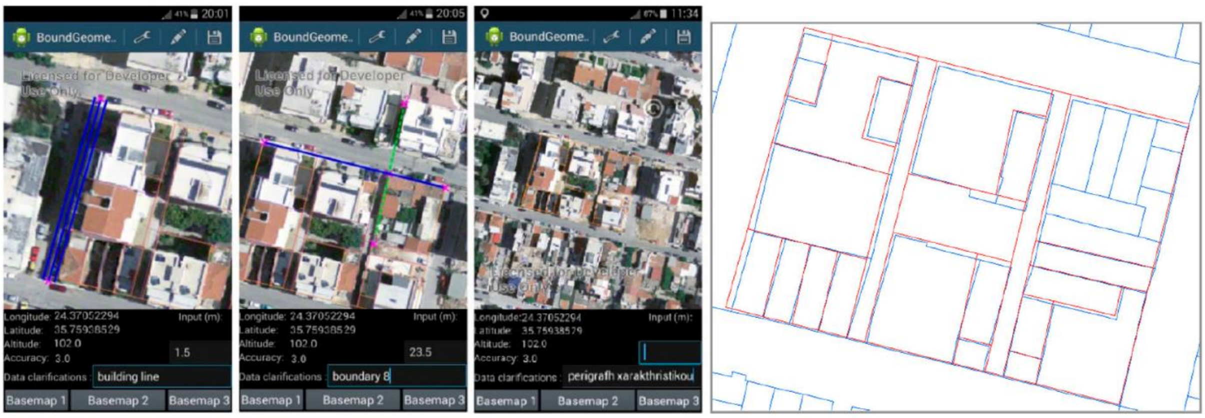
For measuring the facades, a tape was used to record distance values in meters, which were then input into the Collector for ArcGIS environment. To accurately determine more complex boundaries between properties, especially when identifying exact boundaries between small houses or areas with non-fixed boundaries, the volunteers overcame the difficulties by utilizing the geometrical tools available in the BoundGeometry application. Figure 5.5 (b) presents the outcomes, showing several challenges faced during the identification process.

(a) (b)

Figure 5.5 (a) *Crowdsourced property boundaries in Kaisariani area.* (b) *Complex boundaries in the case study area. Source: Apostolopoulos et al., 2018.*

Regarding the facades of the blocks, the volunteers took advantage of the fact that the parcel boundary aligned with the building facade and ran parallel to the road lines. They digitized the pavement line visible on the orthophoto and utilized the parallel lines tool for alignment purposes. Additionally, internal boundaries of the land parcels were identified either by conducting simple field measurements using tape or by digitizing points on the visible boundary lines from the orthophotos. The geometrical tools available in the application were used in combination to allocate these boundaries (Figure 5.6 (a)).

The entire recording process lasted approximately 3 hours, a timeframe that could have been reduced significantly with the participation of more volunteers. Subsequently, a comparison was made between the digitized crowdsourced polygons and the official cadastral land parcels of the Hellenic NCMA. Figure 5.6 displays the result of this comparison for the block shown in Figure 5.5.



(a) **(b)**

Figure 5.6 (a) *Geometrical tools used in the registration process.* ***(b)*** *Comparison of the crowdsourced dataset and the official cadastral map. Source: Apostolopoulos et al., 2018.*

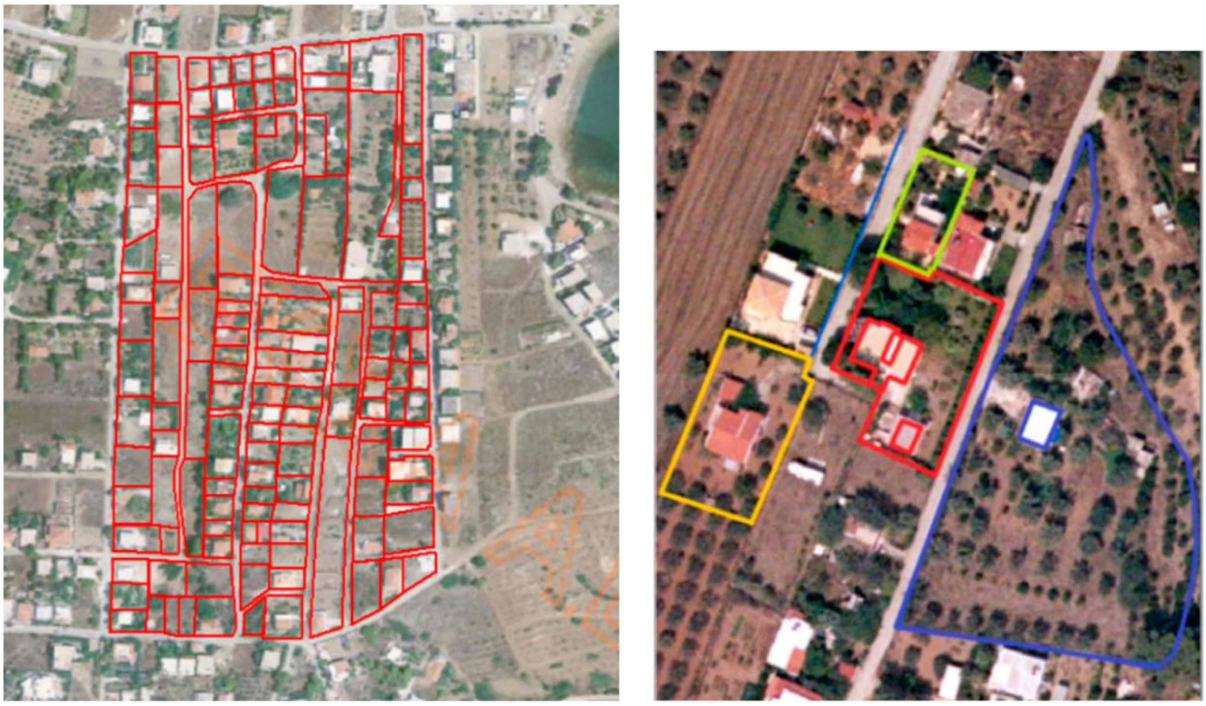
Some distortions in the shape and orientation of the property boundaries were observed due to errors introduced during the digitization of boundary nodes or the use of geometric constraints that do not necessarily exist in the field, such as absolutely vertical or parallel lines. However, these deviations were minor and did not significantly impact the general location of the land parcels, nor did they affect the cadastral information related to those parcels. The maximum positioning error in determining boundary nodes was around 1 meter, while the overall recording procedure achieved a relative accuracy of about 0.5 meters. It is also worth noting that the accuracy of the crowdsourced polygons aligns with the VLSO accuracy of 0.2 meters, which satisfies the requirements of the Hellenic NCMA since these VLSO series were specifically produced for the compilation of the Hellenic Cadastre.

5.3.2 Pilot study in a suburban area

The second pilot study involves a suburban area called Ayia Marina in Keratea, which is situated in the eastern part of the Attica peninsula. Ayia Marina is a recently developed small coastal informal settlement that is in relatively good condition. In this pilot case, a team of three volunteers, who were unfamiliar with the specific area and not property owners there, was assembled. The primary goal of this experiment was to assess the geometric accuracies achieved.

To digitize the land parcels, the volunteers used the Collector for ArcGIS and Bound Geometry applications, working with 126 land parcels (Figure 5.7 a). The smartphones' GPS had a location accuracy of 3–5 meters in the area, which was sufficient only for a rough positioning of each land parcel on the basemap. They had access to three different basemaps for the area: (a) a large-scale orthophoto (LSO) produced by Hellenic NCMA, in 2007, used for official cadastral surveys, (b) a topographic map of the area, made up of existing survey diagrams of the land parcels and (c) another large scale orthophoto from 2001, covering the study area.

The suburban area presented different challenges compared to mapping the urban area. There was no single building line defined by the parcel boundaries' facades. Additionally, both parcels and buildings had complex shapes. The major difficulty encountered during the recording process was the presence of hidden parts in the available basemaps, primarily due to existing vegetation. To address this issue, the Bound Geometry application was utilized in combination with the services provided by the Collector for ArcGIS (Figure 5.7 b). Boundary recording involved digitizing points or line segments to describe the properties and buildings. The registration could be done by selecting features from the basemaps or using geometric implementation tools as in the pilot study in the urban area.



(a) (b)

Figure 5.7 (a) *Crowdsourced land parcels in Ayia Marina.* ***(b)*** *Derived land parcel boundaries by the exploitation of geometrical tools. Source: Apostolopoulos et al., 2018.*

A weak Internet connection in the region posed a challenge during the digitization of the polygons. To overcome this, the volunteers preferred using the offline mode of the Collector for ArcGIS, as they had downloaded the three available basemaps directly to their mobile phones. However, when the Internet connection was sufficiently strong, they also used the online mode for both applications to double-check locations and store the collected data on the fly. The recording procedure involved a combined use of online and offline modes for both applications. Alternatively, a basemap offered by ESRI, suitable for offline or online use, could also be utilized.

The entire procedure took approximately 7 hours, a time that could have been reduced with more volunteers, especially those familiar with the area. The duration of recording varied depending on the complexity, size, hidden elements of the property or building, and the users' abilities. Overall, registering properties in the suburban area by volunteers was more challenging and time-consuming than in the urban area.

After completing the fieldwork, the results were exported using the ArcGIS Online server, and a draft crowdsourced cadastral map was generated. To verify the accuracy of the results obtained through this process, an official cadastral map of the area, showing land parcel boundaries and buildings, was used as reference data. The comparison yielded satisfying results, as there were no major discrepancies, and the average deviation was 0.6 meters, with a maximum deviation of approximately 1.7 meters. It is essential to note that this accuracy represents relative accuracy and is based on the LS0's accuracy, which is 0.5 meters (Figure 5.85.8).

***Figure 5.8** Comparison between the crowdsourced cadastral map (red) and the official cadastral map (blue). Source: Apostolopoulos et al., 2018.*

5.3.3 Pilot study in a rural area

The third pilot study focuses on a rural area located approximately 10 km away from Mytilene, near the village of Panayiouda, on Lesvos Island, Greece. A team of three volunteers, all property owners in the region, was formed for this specific case. To map the property boundaries and adjacent properties, the team utilized Collector for ArcGIS along with a large-scale orthophoto provided by the Hellenic NCMA as a basemap. They also used GPS receivers from mobile phones for rough positioning, similar to the approach used in the previous studies.

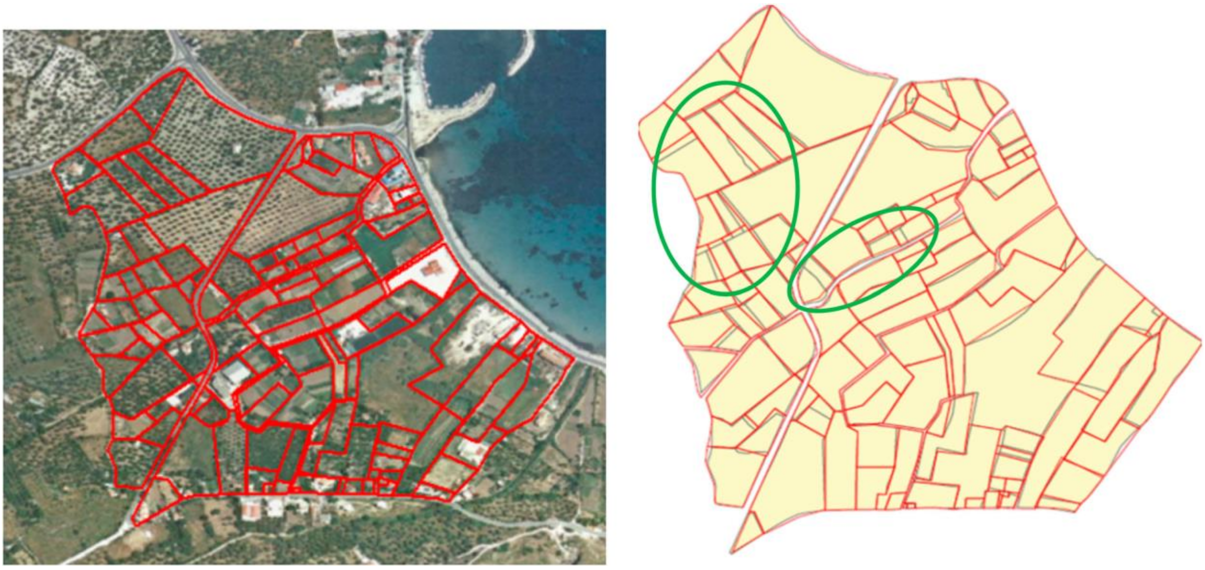
Digitizing the property boundaries and adjacent land parcels was generally successful, with the volunteers being familiar with the area and able to accurately identify most of the boundaries. However, due to the limited number of volunteers and some properties being fenced, accessing and digitizing certain property boundaries was challenging. The volunteers, who were knowledgeable about the neighboring parcels, overcame this obstacle by using the orthophoto.

The rural area posed additional difficulties because most land parcels had irregular shapes, with sides not being parallel or perpendicular to each other. Consequently, using the Bound Geometry application, which relies on standard geometric shapes, was not very helpful in this context. The entire process of recording the land parcels, which consisted of 107 properties, took two hours (Figure 5.9). This time could have been significantly reduced if more volunteers were available.

The digitized polygons were uploaded into the application through ArcGIS for Server. To evaluate the accuracy of the crowdsourced cadastral map, a comparison was made with the official cadastral survey produced by the Hellenic NCMA. Figure 5.9 (b) presents the discrepancies identified between the two cadastral survey datasets. The accuracy of the crowdsourced dataset matches that of the basemap (orthophoto), which is 0.5 m.

During the recording process of this pilot study, several challenges were encountered. The most significant issue encountered is the shifting of property boundaries, particularly noticeable in the west green circle of Figure 5.9 (b). This error is mainly due to hidden parts of the property and the volunteers' inability to identify boundaries accurately using the basemap of the Hellenic NCMA and the GPS of their mobile phones, with a GPS accuracy of 3–5 meters. To address this problem, the use of a touch pen for mobile phones or devices with larger screens (e.g., tablets) could be helpful in facilitating digitization. Moreover, involving property owners in the process may lead to better identification of boundaries.

Another challenge arises from the absence of legal property boundaries marked on the ground. This issue is particularly evident in cases of parcel subdivision that volunteers were unaware of, and no physical markers were present in the field. Two such instances are visible within the eastern green circle of Figure 5.9 (b). This problem could be mitigated by encouraging more property owners to participate and accurately determine the boundaries of their land parcels, as they are generally well informed about their own and neighboring properties.



(a) **(b)**

Figure 5.9 (a) *Crowdsourced land parcels in Panayiouda, Lesvos Island.* ***(b)*** *Comparison of the crowdsourced cadastral map (red) and the official cadastral map (blue). Source: Apostolopoulos et al., 2018.*

Complex property boundaries pose difficulties during digitization due to their intricate shapes. For instance, shapes with multiple corners and short sides are challenging to recognize accurately from the orthophoto of the Hellenic NCMA, especially when the GPS accuracy of smartphones is low. To address this issue, involving surveyors equipped with better GPS devices could provide a solution.

To conclude, the goal of the implemented pilot studies was to promote an approach that encourages the active involvement of property owners and citizens in cadastral mapping procedures, aiming to make these processes faster, cost-effective, reliable, and more efficient. Several factors influence the accuracy of the resulting crowdsourced cadastral maps, including the quality and precision of the basemap, the experience of the volunteers in identifying boundary points, the complexity of property boundary shapes, and the potential obstruction of boundary points by trees and vegetation on the orthophoto.

In situations where property boundary shapes are intricate, and tree cover obscures boundary corners on the map, utilizing applications equipped with geometric tools becomes essential. This approach reduces reliance on the GPS accuracy of smartphones and enhances map accuracy.

The effectiveness of this method largely depends on the active participation of property owners and volunteers. To encourage their involvement, a gamification procedure is proposed, where participants could be rewarded with fee discounts or similar incentives. Additionally, using tablets instead of smartphones could facilitate the mapping work.

The suggested land administration model fosters a novel relationship between professionals, property owners, and citizens. Collaboration with property owners and citizens allows cadastral surveyors to adopt a new role, involving training property owners and volunteers and evaluating the crowdsourced data they collect.

5.4 Case Study No. 3 - Testing procedure in urban/ suburban and rural environment and citizen engagement

To test the accuracy of the proposed procedure for 2D reliable crowdsourced cadastral surveys three pilot studies were conducted in Greece and Romania. In Greece, the pilot study took place in Gounaris village, Sparta Municipality, while in Romania, two pilot studies were conducted in the built-up areas of Ciugud village in Alba County and Caracal city in Olt County.

For these studies, volunteers and right holders, under the guidance of a team leader trained by a cadastral surveyor, used ESRI's Collector for ArcGIS in Greece (ESRI, 2017) and the open-source MapIT GIS application in Romania. They collected cadastral parcel boundaries, building footprints, and descriptive information like property rights and right holder data, along with parcel and building photos. Once the field procedures were completed, a comparison was made between the crowdsourced cadastral map and the official cadastral map of each country.

5.4.1 Pilot study in a rural area in Greece

This case study took place in Gounaris village, located near the city of Sparta in the Prefecture of Lakonia, Greece. According to the 2011 census, the village has a population of 186 inhabitants, primarily engaged in agricultural activities, particularly citrus, vine, and olive cultivation.

To guide the right holders effectively, an established video guide was utilized. It aimed to educate them on how to install, use, and operate ESRI's Collector for ArcGIS application, along with its capabilities. They were specifically trained to identify their parcel boundaries using the GNSS feature on their smartphones or tablets using the Hellenic NCMA's orthophotos from 2007. Additionally, they were taught to include right holder identity data and upload photos or scanned deeds.

A team of 27 volunteers/right holders was assembled and successfully digitized 114 land parcels, representing a majority of the village's parcels (Figure 5.10). The entire case study spanned a total of 15 hours, conducted over three consecutive days with five hours each day.

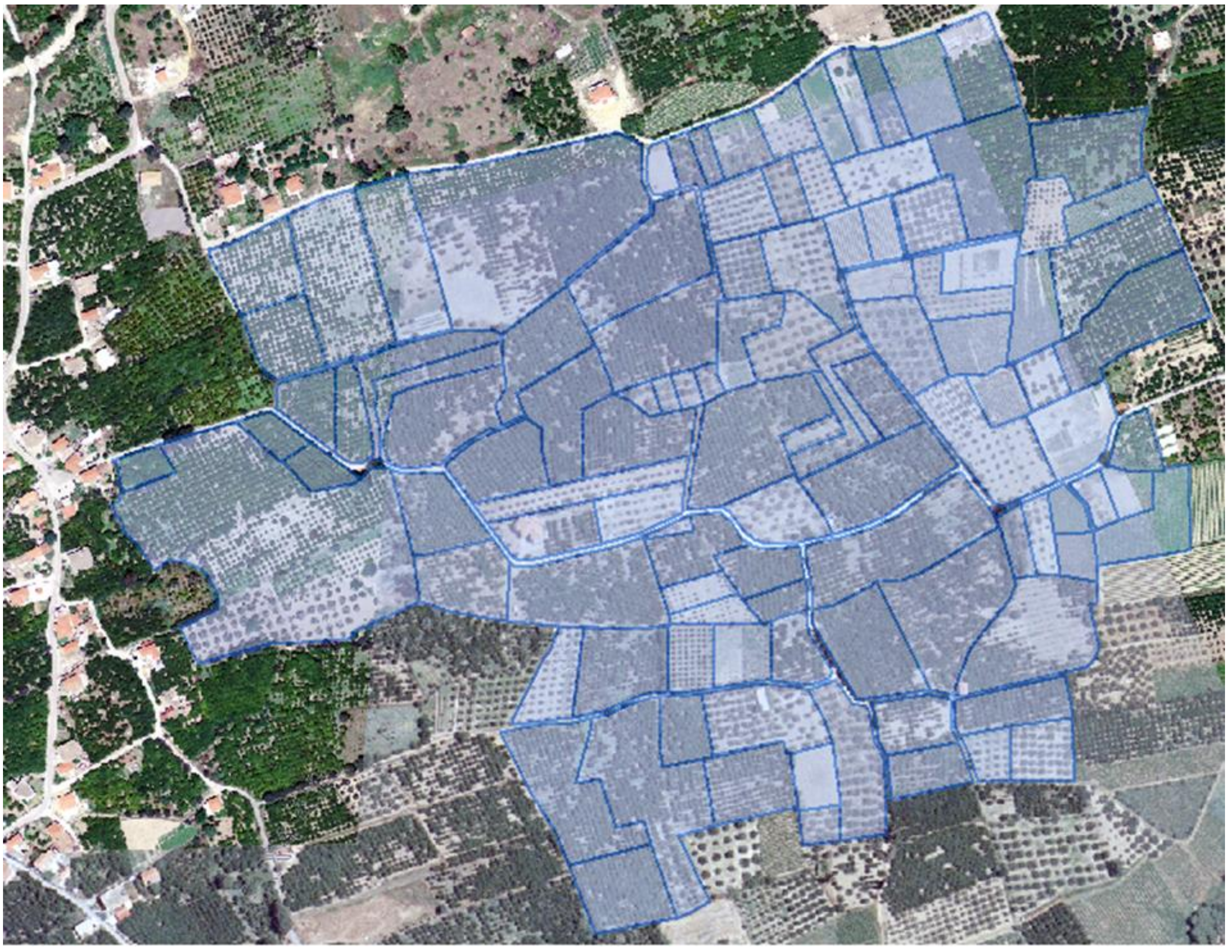


Figure 5.10 *Crowdsourced cadastral map in Gounaris village. Source: Potsiou et al., 2020.*

The volunteers used the GNSS feature on their smartphones to register the properties, benefiting from a strong signal in the area, resulting in a positioning accuracy of 1-3 meters. In cases where property boundaries were not clearly distinguishable on the orthophotos (e.g., when boundaries matched building facades or were fixed in the field), they used the Measure tool of Collector for ArcGIS. Facades were measured using a tape, and the measurements were then transferred into the Collector for ArcGIS environment.

Upon completing the field procedures, the polygons digitized by the volunteers were imported into the application via ArcGIS for Server. The results were exported using the cloud server of ArcGIS Online, generating the draft crowdsourced cadastral map. This application featured two basemaps, one from ESRI and another WMS layer from NCMA, along with an additional layer created in ArcGIS Desktop where citizens digitized their properties. This information was made publicly available and released on the ArcGIS Online cloud server.

To verify the results obtained through the proposed crowdsourced procedure, an official cadastral map of the area (Figure 5.12) was used as a reference. A comparison was made, determining the deviation of the nodes of the crowdsourced cadastral diagrams based on NCMAs' specifications for the geometric compatibility of cadastral land parcels.

The comparison revealed only five obvious errors, concerning land parcels 19, 20, 23, 25, and 43. Land parcels 19 and 20 had different separations, and there was a discrepancy in the recorded boundary between parcel 23 and parcel 25 (Figure 5.12 a). Additionally, land parcel 43 was mistakenly presented as two separate parcels, likely a recording error in the formal cadastral procedure (Figure 5.13 b).

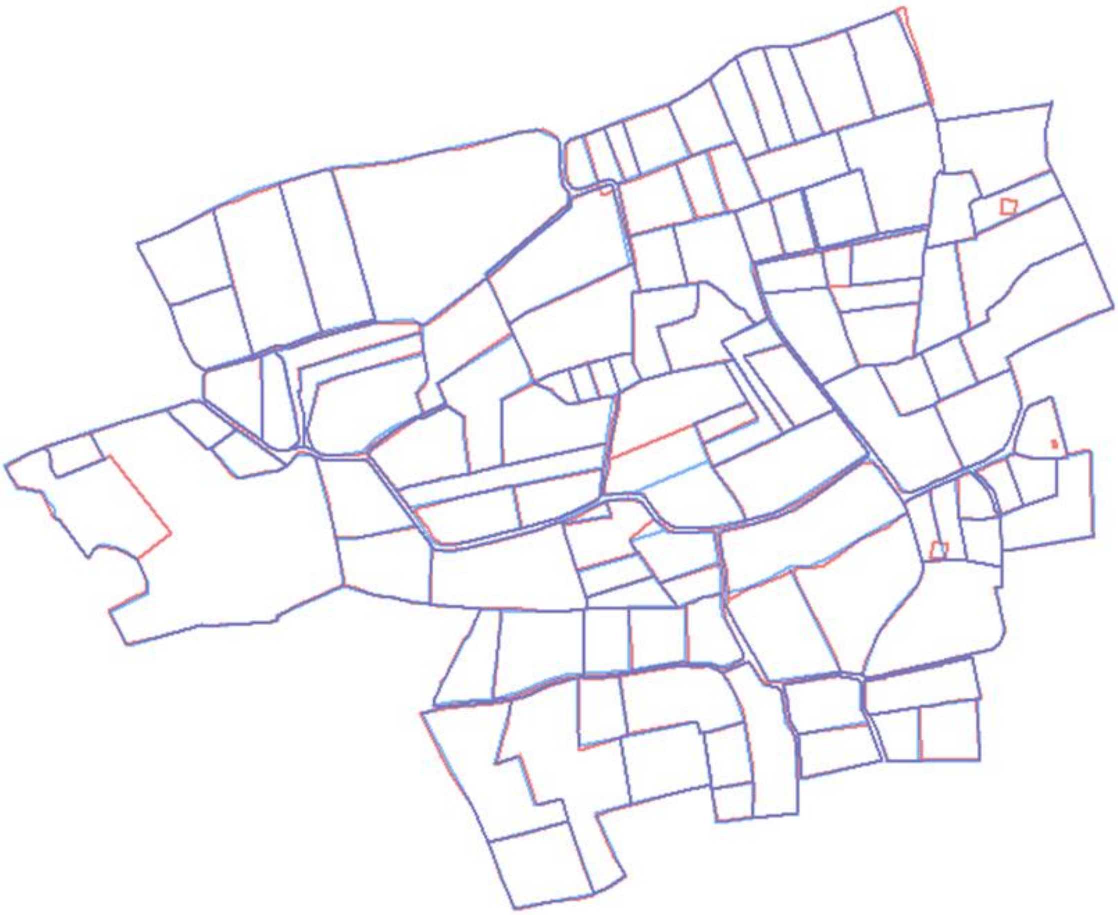
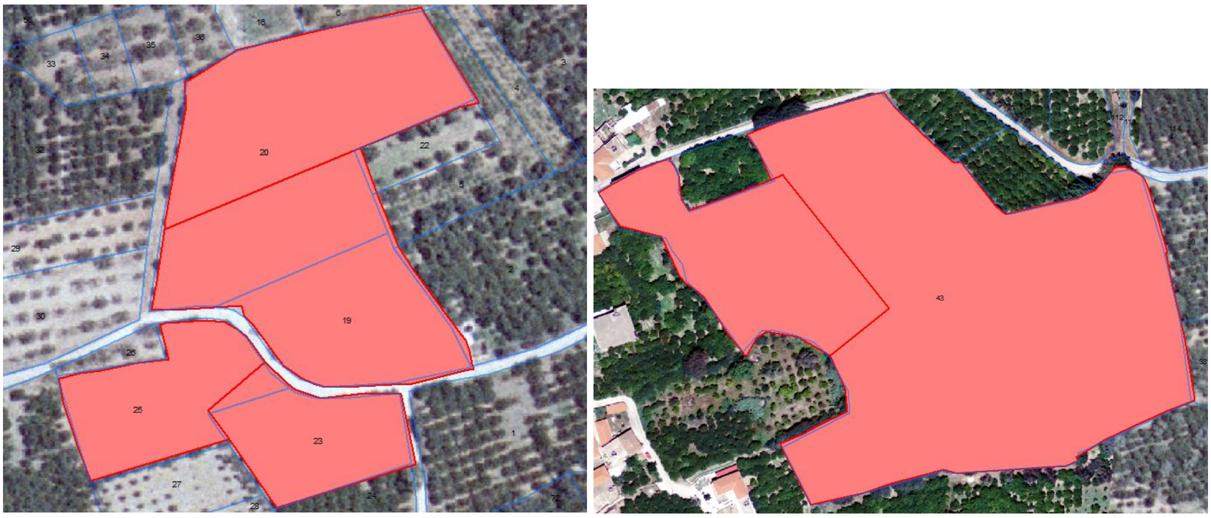


Figure 5.11 *Comparison between the crowdsourced cadastral diagrams (blue) and official cadastral diagrams (red). Source: Potsiou et al., 2020.*



(a) **(b)**

Figure 5.12 *Obvious errors in land parcel boundaries:* ***(a)*** *Property boundaries recorded differently,* ***(b)*** *Land parcel digitized as two land parcels. Source: Potsiou et al., 2020.*

As for the remaining 109 land parcels, according to the technical specifications of the Hellenic NCMA, the calculation method for determining the 'accuracy tolerance' and the number of land parcels falling within this value was identified.

Specifically, the calculation of the 'accuracy tolerance' is described below.

For each land parcel with area (A) and perimeter (P) based on cadastral data, the following are defined:

a. The 'elevated square' which represents an ideal square with sides $\sqrt{A}$, area $E_a = A$, and perimeter $P_a = 4\sqrt{A}$.

b. The "expanded elevated square," which represents an ideal square with sides increased by a size of 2Uo, and area $Ed_a = (\sqrt{A} + 2U_o)^2$. The value of the 'accuracy tolerance' of the land parcel's area is calculated using the formula: $A = [Ed_a - A] \times P/P_a$.

The accuracy in determining the boundaries of the land parcels is determined by the size of U_o, which takes values of $U_o = 0.50$ m for urban areas and $U_o = 2.00$ m for rural areas.

The value of a is $0.2 \text{ m} \le \alpha \le 0.3\text{m}$ for urban areas and $0.95 \text{ m} \le \alpha \le 1.50 \text{ m}$ for rural areas.

Therefore, according to the official specifications, 17 out of the remaining 109 land parcels (representing 15.5% of the crowdsourced diagrams) were not within the accuracy tolerance. These 17 plots are highlighted in light blue in Figure 5.13 (b). The average accuracy deviation of the land parcel boundaries was approximately 0.55m, and the maximum deviation was around 1.8m, both well within the limits of the Hellenic NCMA's technical specifications.

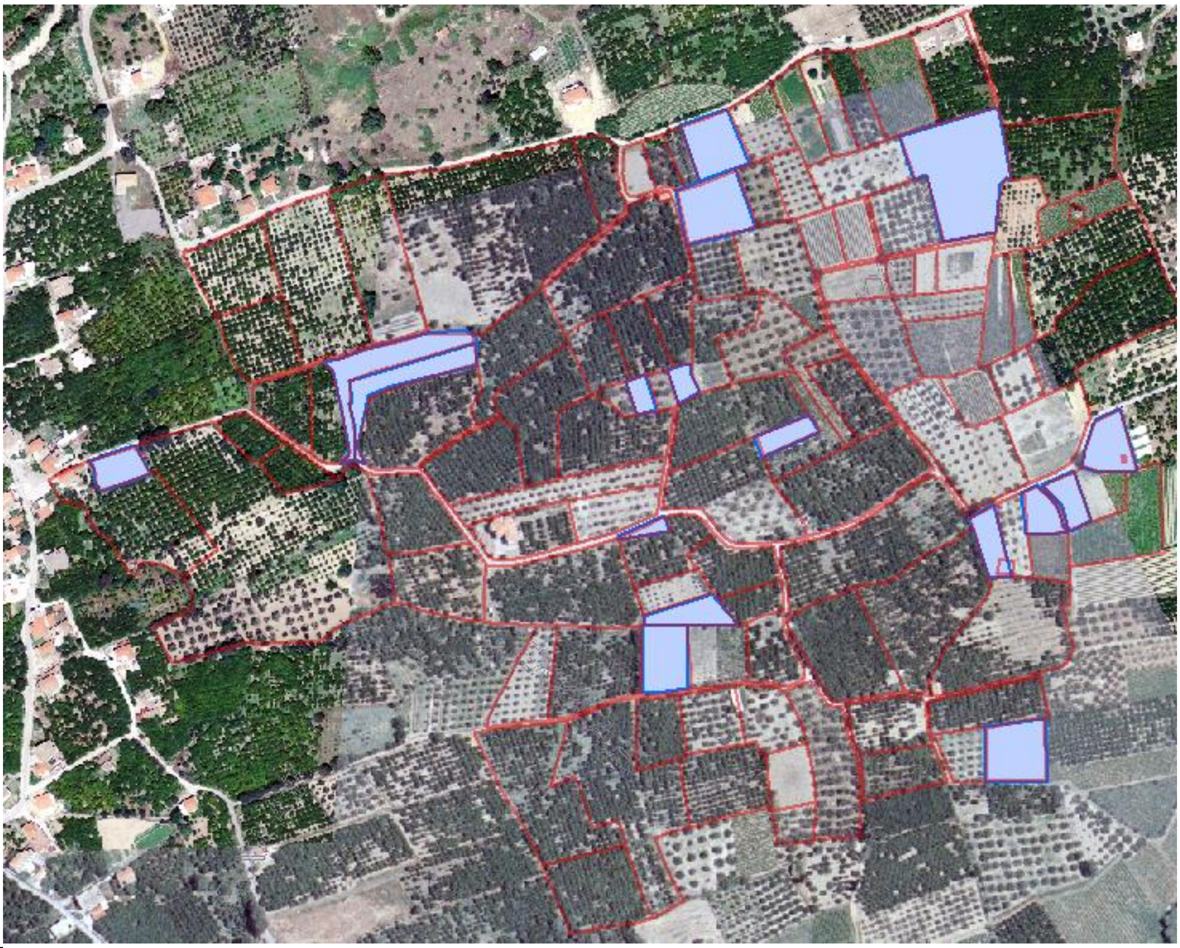


Figure 5.13 *Crowdsourced land parcels not within 'accuracy tolerance'. Source: Potsiou et al., 2020.*

5.4.2 Pilot study in urban and suburban areas in Romania

Two areas in Romania were chosen for this study. The first area encompasses the built-up region of Ciugud village, located in Alba County, while the second area is a portion of the city of Caracal, situated in Olt County. These case studies demonstrate the advantages of implementing modern techniques and involving citizens in cadastral surveying.

The build-up area of Ciugud spans approximately 0.6 km^2 of flat terrain, while the test zone in Caracal covers about 0.9 km^2 of plain terrain. To collect cadastral data for both areas, an open-source data collector was developed using the MapIT application. During the development of the cadastral data collector, it was necessary to define property boundaries and building attributes (Figure 5.14) and create new layers for this information. In addition, unmanned aerial systems were utilized to generate up-to-date and high-quality orthophotos, a more cost-effective and time-saving alternative to traditional large-format aerial camera image systems (Nache et al., 2017; Amhar et al., 2020).

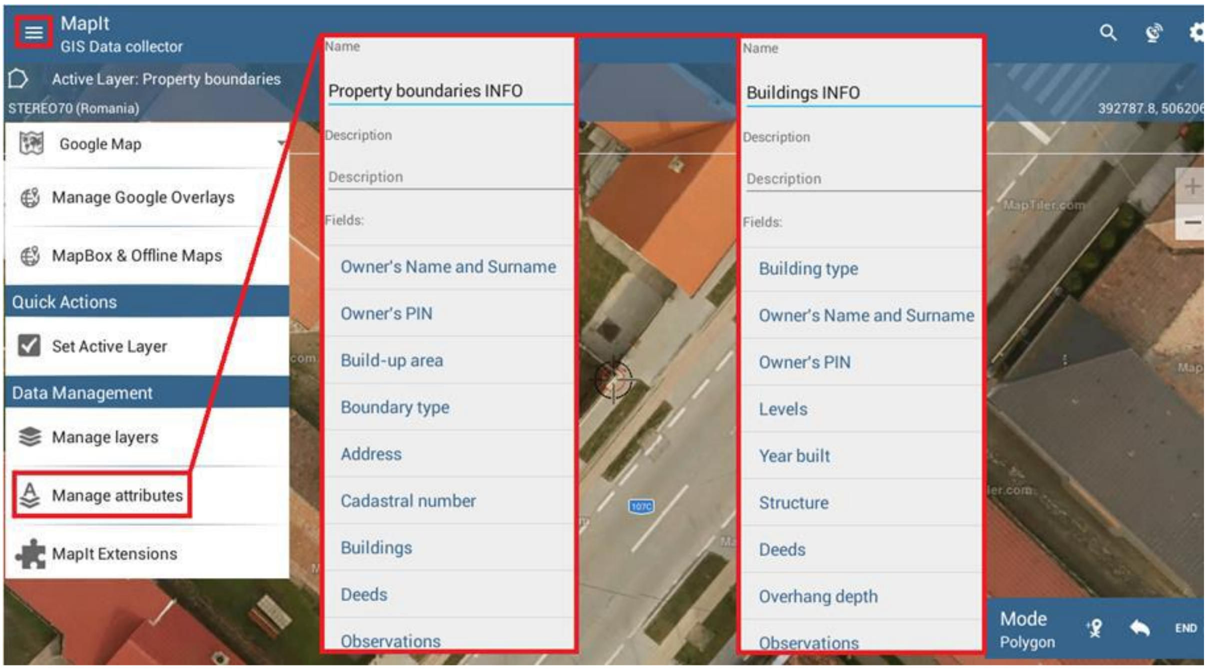


Figure 5.14 *MapIT application interface. Source: Potsiou et al., 2020.*

With the aid of this application, the volunteers utilized their tablet devices and conducted an approximate digitization of property and building boundaries. These boundaries were derived from the orthophoto, which possessed a pixel dimension of 5 cm. Subsequently, the extracted boundaries underwent further adjustments and rectification at the office to accurately determine the property boundaries and identify the footprint of buildings.

During the boundary digitization process, relevant cadastral data concerning property owners, deeds, and other pertinent information about the selected entity/property were concurrently gathered (Figure 5.15). Additionally, photos of the digitized properties were taken (Figure 5.16).

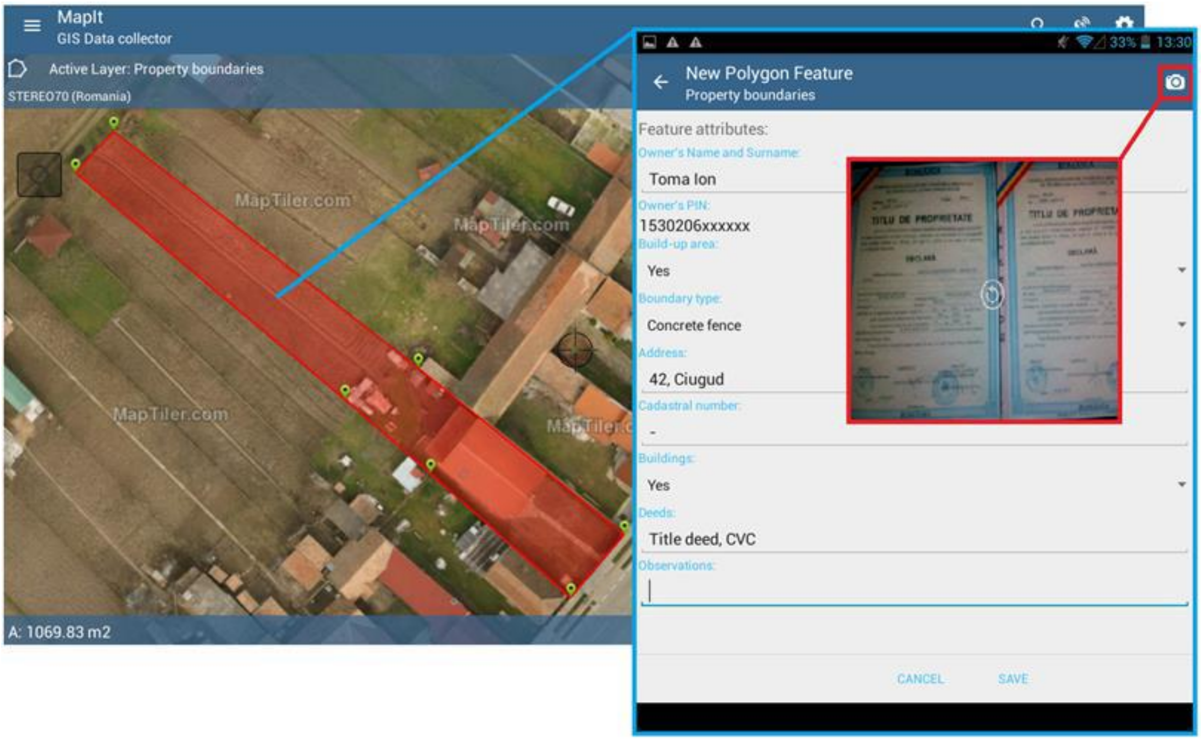


Figure 5.15 Map IT application feature for boundaries digitization and uploading of deeds. Source: Potsiou et al., 2020.

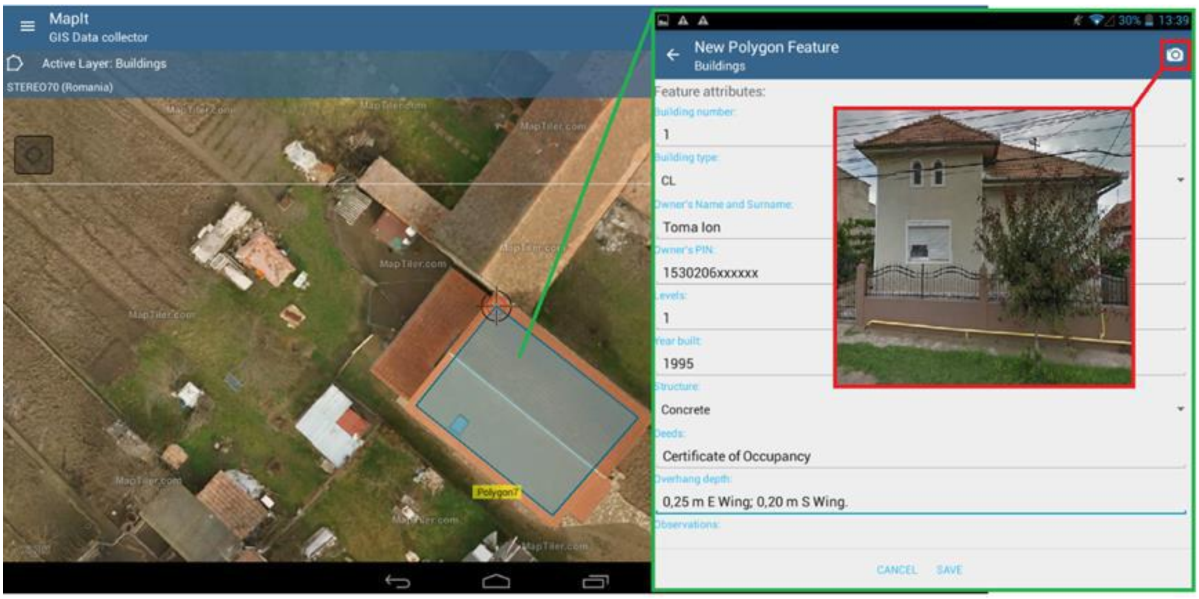


Figure 5.16 Map IT application feature for boundary digitization and uploading of property photos. Source: Potsiou et al., 2020.

To enhance the accuracy of building footprint determination in the office, the right holder measured the overhang depth during fieldwork. In this particular case study, a land surveyor also measured the building's perimeter using a laser telemeter. Following the data acquisition phase, the property boundaries and building outlines were exported as shapefile format files.

In cases where the areas could not be precisely determined (approximately 12% of the total), a land surveyor employed GNSS systems and/or a total station to measure these areas. To further optimize the process of building footprint determination, the point cloud resulting from image pixel correlation was utilized to ascertain the overhang depth, which was found to be 70 cm (as depicted in Figure 5.17).

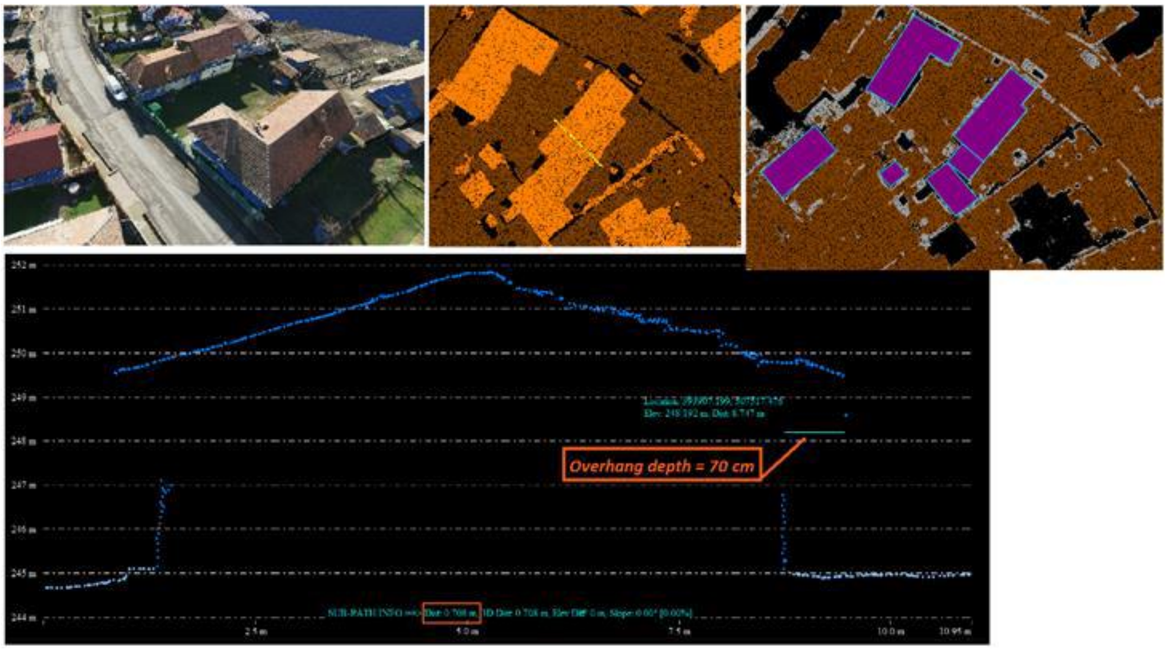


Figure 5.17 *Utilizing the associated point cloud to determine the building's footprint. Source: Potsiou et al., 2020.*

The crowdsourced cadastral data for the rural area - the build-up area of Ciugud village (Figure 5.18) - was gathered over a period of nine hours by two teams of volunteers and right holders. This dataset comprises 156 polygons containing information about property boundaries and 520 polygons containing data about buildings.

(a) **(b)**

Figure 5.18 *Crowdsourced cadastral data of* ***(a)*** *Caracal city* ***and (b)*** *Ciugud village. Source: Potsiou et al., 2020.*

After the field procedures were completed, a 5-day cadastral survey campaign was conducted in both areas to verify the accuracy of the crowdsourced cadastral data. The survey measurements were carried out using the Leica TS 02 total station. Upon comparing the two datasets, it was found that the crowdsourced cadastral data falls within the official accuracy range specified by the Romanian NCMA. For urban areas, RMSxy is 0.4 m, while for non-build-up areas, it is 1.0 m (as shown in Figure 5.19).

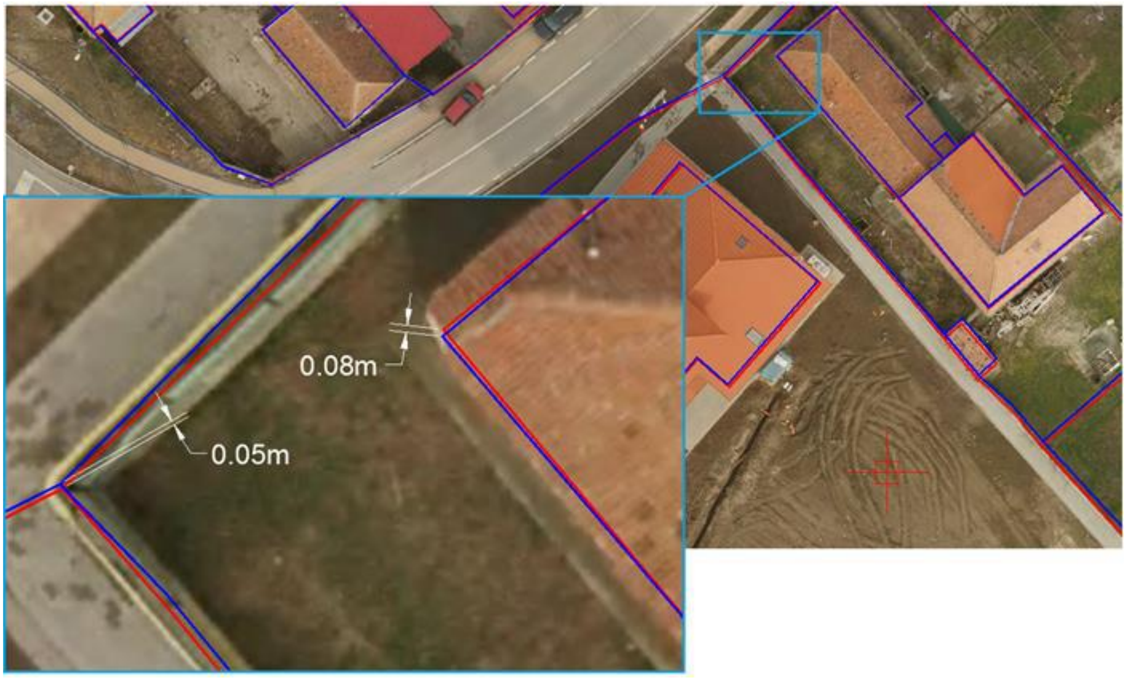


***Figure 5.19** Comparison between the crowdsourced cadastral diagrams (blue) and official cadastral diagrams (red). Source: Potsiou et al., 2020.*

The results from the case studies in urban, rural, and suburban areas in both countries provided valuable insights. The crowdsourced cadastral diagrams were found to meet the accuracy tolerance of the official specifications from the NCMAs. Additionally, the data collection process was significantly more cost-effective and time-efficient compared to traditional methods. Most importantly, the results did not show any obvious errors, gross errors, or gaps in all case studies.

The use of an established video guide greatly enhanced the crowdsourced cadastral procedure. The right holders were well-informed about the installation, usage, operation, and capabilities of the applications. They were trained to identify their parcel boundaries using the GNSS feature on their smartphones or tablets, with the assistance of NCMA's orthophotos. Furthermore, the right holders were able to add their identity data and upload photos or scanned deeds. In Romania, the volunteers and right holders went beyond parcel boundaries and also digitized building footprints.

It should also be mentioned that the quality and accuracy of the chosen basemap significantly impact the outcome. The availability of funds dictates the type of basemap that can be utilized, which may range from aerial photos, OpenStreetMap, Google Maps, and orthophotos, to very large-scale orthophotos. Employing open-source applications like MapIT application, along with a high-quality orthophoto as the basemap, yields equally efficient and reliable results. These case studies have demonstrated that by combining accurate orthophotos with crowdsourcing, satisfactory geometric accuracies can be achieved, meeting the technical specifications for an AAA cadastre.

5.5 Case study No. 4 - Testing open-source application with gamification elements

In this case study, the developed open-source application with gamification elements ('PropReg') is tested in an urban area. The selected area for the case study is Chalandri, Greece. Chalandri is a municipality in the Northern Sector of Athens, in the Attica Region, with 74,192 residents as of 2011 and an area of 10.805 km^2. The area's elevation ranges from 185 to 230 m.

A section of the urban area of Chalandri was selected as the study area, which includes densely and sparsely built building blocks. The goal is to collect the necessary geometric and descriptive information using the developed tool, aiming to create a crowdsourced cadastral map of the area and evaluate the motivation and user engagement in the cadastral processes.

Figure 5.20 *Case study area – Chalandri urban area.*

A team of 19 volunteers, who were not right holders in the area, enthusiastically engaged in the data collection process, making use of innovative gamification tools to boost their participation. By incorporating gamification elements, such as badges, leaderboards, and progress bars, the volunteers were motivated to actively contribute to the cadastral survey. The process was carefully designed to maximize their motivation, create a pleasant and engaging experience, and maintain their interest throughout.

Utilizing the described gamified approach, the team efficiently digitized a remarkable total of 124 land parcels in the study area (Figure 5.21). The incorporation of gamification not only facilitated the data collection but also fostered a sense of enjoyment and accomplishment among the volunteers, encouraging them to actively participate in subsequent initiatives and further similar projects. This novel combination of crowdsourcing and gamification proved to be an effective and successful approach in ensuring the accurate and efficient completion of the cadastral survey.

The total surface area was calculated to be approximately 45,500 m^2. The average time required to record each property through the developed application was approximately 8 minutes. This time may vary depending on the user's familiarity with using a mobile phone and the effort required to accurately determine the property's boundaries.

Figure 5.21 Crowdsourced cadastral map derived by the proposed procedure.

The results of this case study were used to create a draft crowdsourced cadastral map. Subsequently, the collected data was tested for accuracy and completeness using an officially produced cadastral map as a reference (Figure 5.22). The comparison results revealed that there were no significant discrepancies in the boundaries of the land parcels between the two cadastral maps.

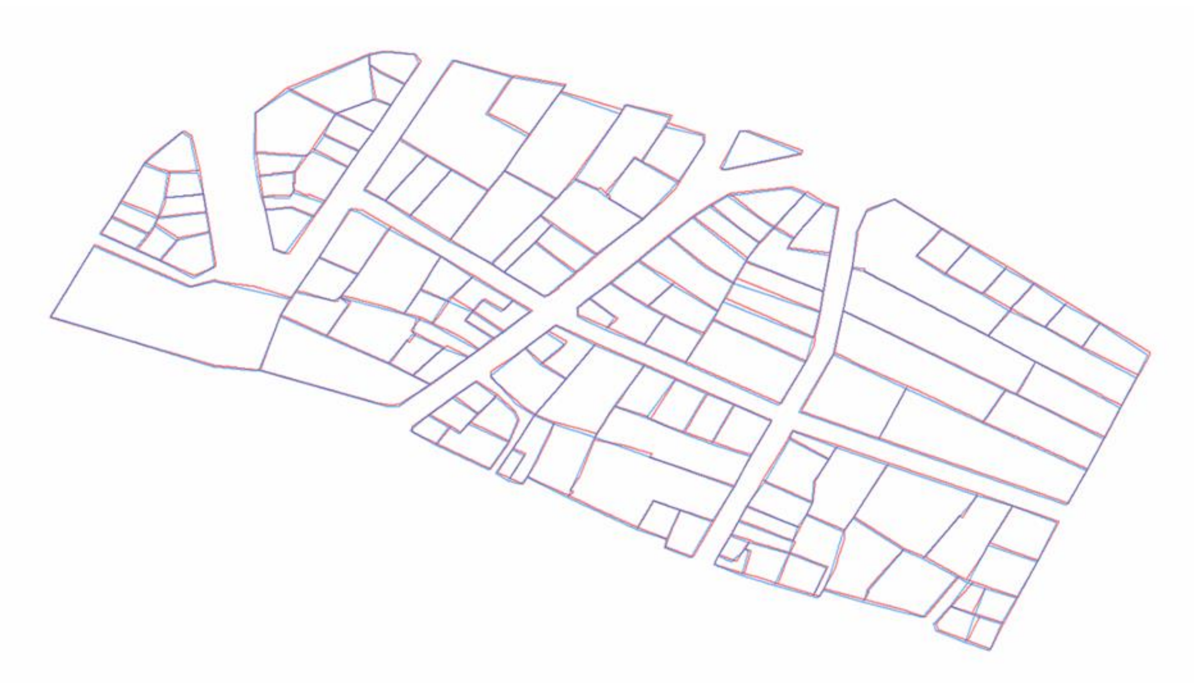


Figure 5.22 Comparison between the draft crowdsourced cadastral map (blue) and official cadastral map (red).

According to the official specifications of the Hellenic NCMA, it has been identified (according to the official procedure, implemented in the previous case study as well), that 18 land parcels out of the remaining 124 do not fall within the acceptable accuracy tolerance (Figure 5.23). This accounts for approximately 14.5% of the crowdsourced diagrams.

The average deviation in accuracy between the two datasets was 0.48 m, with a maximum deviation of around 1.2 m both of which fall within the Hellenic National Cadastre and Mapping Agency's (NCMA) technical specifications (where RMSxy for urban areas is 0.71 m and RMSxy for rural areas is 1.41 m). It is worth noting that this maximum deviation occurred in instances where there were numerous obstructions and the boundaries were not accessible in the field.

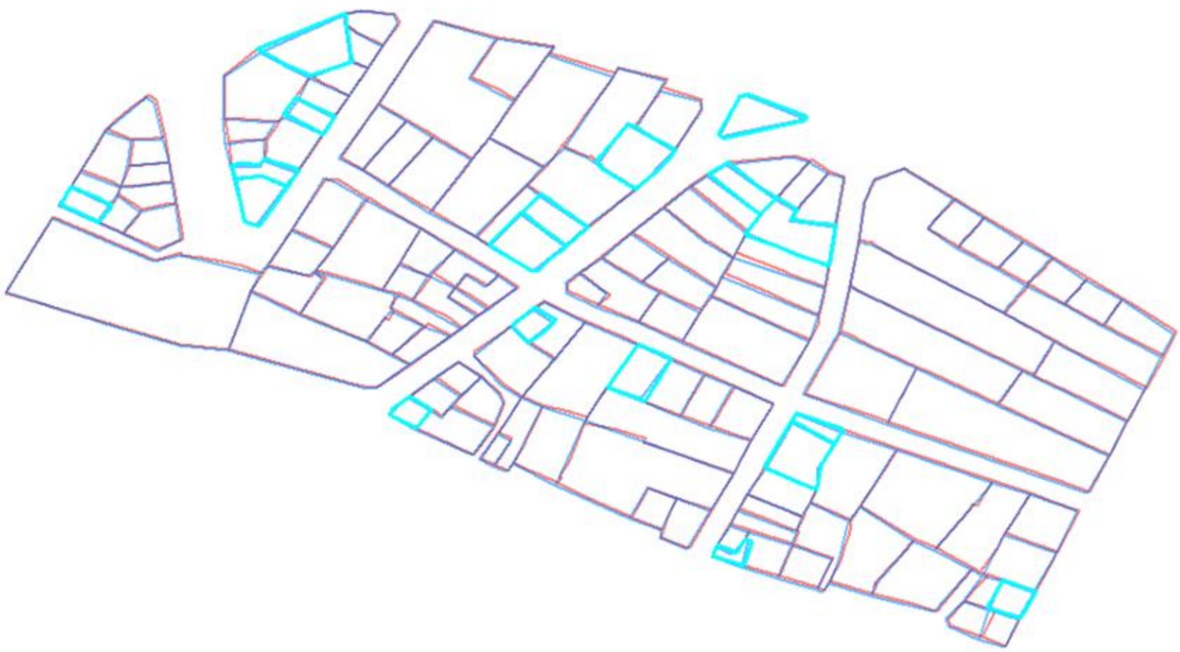


Figure 5.23 *Crowdsourced land parcels not within the acceptable tolerance of the Hellenic NCMA.*

The results of the case study showcase that the implementation of gamification is recommended in the compilation of a crowdsourced, dependable, efficient, and cost-effective cadastral procedure. During the design process, attention should be given to optimizing motivation, fostering a positive user experience, and sustaining the active participation of volunteers. Integrating gamification can be particularly beneficial if volunteers are engaged in additional tasks or steps of the cadastral survey, such as assisting with the preparation of the preliminary basemap that will be utilized by property right holders.

Moreover, the following conclusions were also drawn from the responses of citizens/property owners in the crowdsourced cadastral process:

- The problems encountered mainly focused on the use of smartphones and tablets. It was observed that users familiarity with smartphones/tablets had no issues using the application.

- Citizens of all ages and educational levels expressed a desire to participate in the process.

- The majority of citizens showed a strong willingness to participate in the property recording process.

- Citizens were receptive to the entire procedure and considered their involvement in the official cadastral survey process to be beneficial. By being part of it, they could contribute to its accurate recording and avoid time-consuming correction processes for any errors, which could delay the completion of the cadastral survey.

- Most of them expressed a desire to repeat this process and participate in similar participatory initiatives.

5.6 Case Study No. 5 - Investigation of using new technologies and collection of additional geospatial information from a distance

A preliminary case study was conducted, aiming to evaluate the effectiveness of the methodology incorporating cutting-edge technologies and remote collection of geospatial data. The case study was focused on a section of the western coastal zone in Attica, Greece, known as the Athenian Riviera. This specific area is currently undergoing a targeted upgrade project and encompasses the Anavyssos, Palaia Fokaia, and Thymari beaches (Figure 5.24).

The primary reason for selecting this particular coastal region was its proximity to the AMA (Archaeological Museum of Athens) and its accessibility to both tourists visiting the ancient sites of Athens and the temple in Cape Sounio. During the summer months, there is a substantial amount of daily travel between the AMA and the study area, as tourists and Athenians frequently visit these beaches. The study area stretches for 11.7 km, and a buffer width of approximately 400 m was chosen for the investigation. In total, the study area covers an approximate surface of 4.6 km^2.

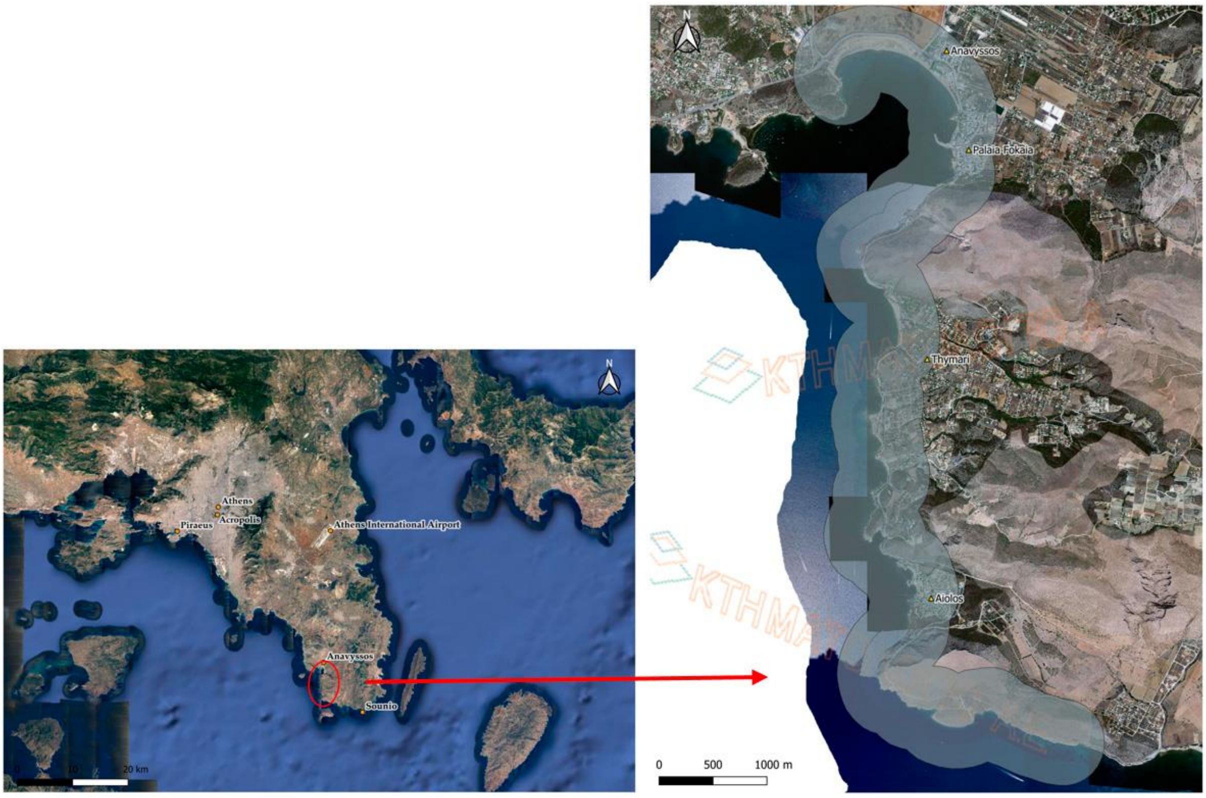
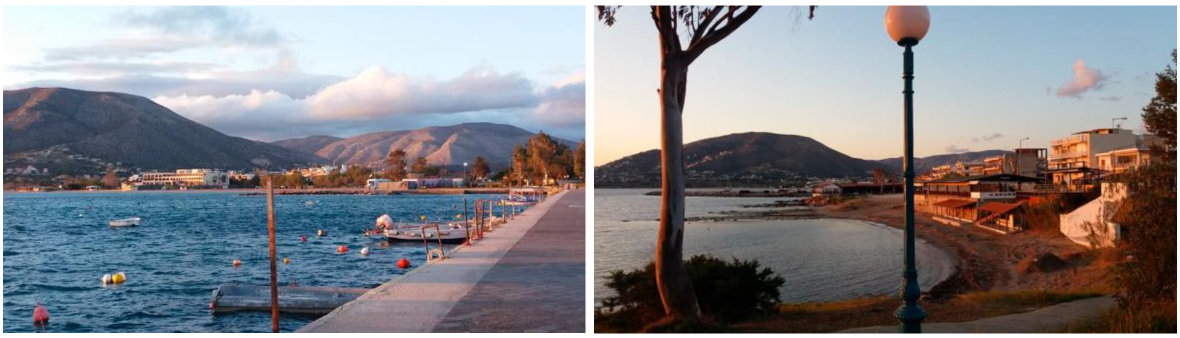


Figure 5.24 *Case study area—a section of the western coastal zone in Attica. Source: Bakogiannis et al., 2021.*

5.6.1 Data collection process

During this case study, two citizens were invited to participate as volunteers in the data collection workshop. Following a concise training session conducted by a professional, the volunteers were assigned the task of recording geospatial data, as outlined in Table 4.1. To accomplish this, they utilized Google Maps, specifically employing the Street View tool. Due to the COVID-19 pandemic's lockdown restrictions, conducting fieldwork was not feasible during this research.

In Figure 5.25, various perspectives of the case study area are displayed, with the specific locations where these photographs were taken marked on the final crowdsourced map (designated as points 1, 2, 3, and 4 in Figure 5.28).



(a) **(b)**

(c)

(d)

Figure 5.25 *Case study area views* ***(a)*** *Palaia Fokaia port,* ***(b)*** *Palaia Fokaia beach.* ***(c)*** *Thymari beach and* ***(d)*** *Palaia Fokaia old pier. Source: Chryssy Potsiou's Personal Archive.*

The geospatial data were recorded on NCMA orthophotos from the year 2007, which were properly georeferenced with the assistance of QGIS software. The georeferencing procedure followed the Hellenic Geodetic Reference System (HGRS87), ensuring that the recorded data remained within acceptable error limits. The collected data was then organized into three shapefile categories - points, lines, and polygons.

After that, volunteers received comprehensive information and training on the geospatial data collection process and its significance. They were also taught how to effectively utilize QGIS and Google Maps/Street View tools during their training session. Furthermore, the volunteers were motivated and encouraged to remain committed to their voluntary participation. The training session lasted for approximately one hour, following which the volunteers independently began collecting the required geospatial information using their laptops.

The entire data collection and mapping process was carefully timed to calculate and compare the total working man-hours required for the two volunteers to complete the task successfully. Remarkably, the two volunteers managed to finish the data collection process within a single day.

5.6.2 Editing and Quality Control by a Surveyor

After the data collection phase was completed, a surveyor conducted the data validation process. The professional was responsible for ensuring quality control and performing the final editing of the geospatial data gathered by the two volunteers. The professional was well-qualified for remotely monitoring the collection process and providing assistance to the volunteers whenever needed.

During the editing process, the professional focused on verifying the completeness and geometric accuracy of the shape and snapping points of the lines and polygons digitized by the volunteers. Figure 5.26 revealed that while the volunteers correctly identified the required geospatial information, the final geometric accuracy was weak, resulting in gaps between different layers. The professional rectified this error and carried out necessary edits to improve the overall accuracy.

Another error detected during the digitization process in the collection phase was the incorrect identification of the Anavissos city plan area (Figure 5.27). The professional corrected this by digitizing the missing sections and adjusting the shape of the residential polygon on the basemap based on knowledge of the precise city plan boundaries. The completion of the editing phase led to the final crowdsourced geospatial map of the area, as presented in Figure 5.28.

***Figure 5.26** Comparison between the crowdsourced map derived by the volunteers **(a)**, **(c)** and **(e)** and the edited map by the surveyor **(b)**, **(d)** and **(f)**. Source: Bakogiannis et al., 2021.*

(a) (b)

Figure 5.27 *Comparison between **(a)** the crowdsourced map derived by the volunteers and **(b)** the edited map by the surveyor. Source: Bakogiannis et al., 2021*

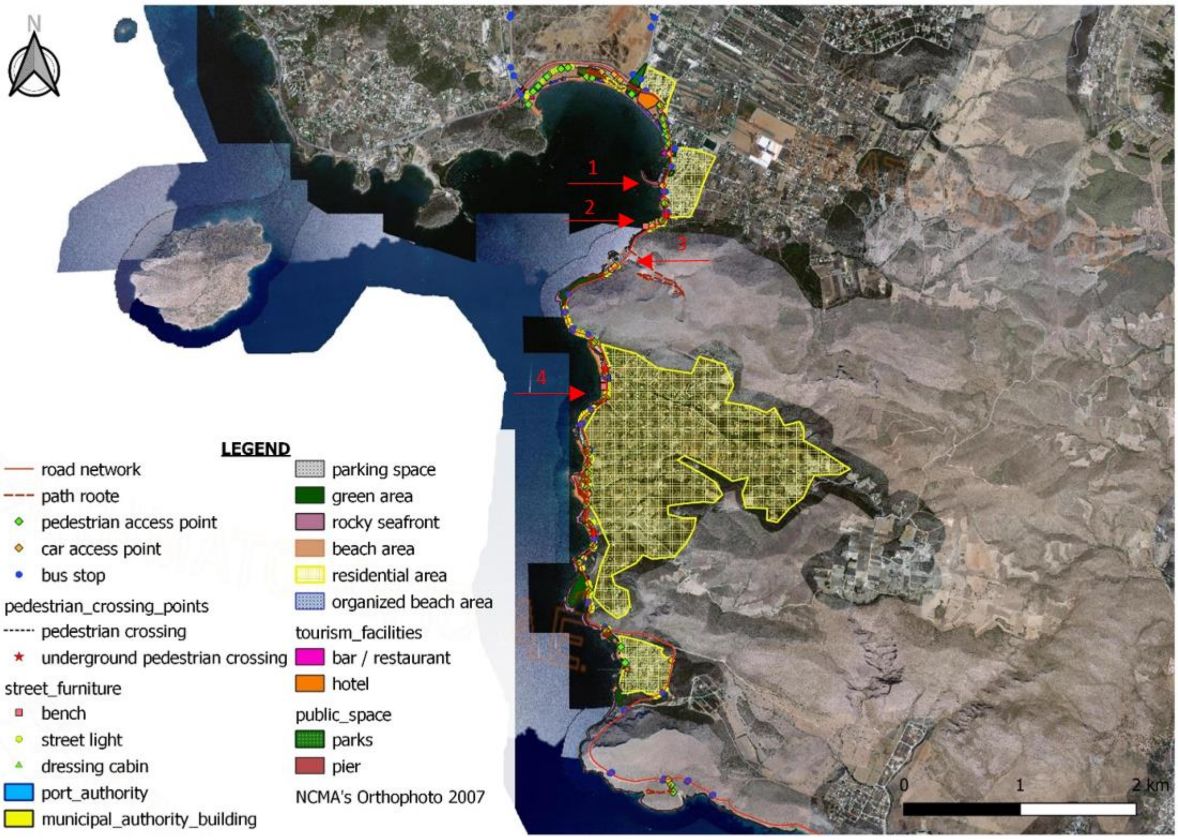


Figure 5.28 *Final edited crowdsourced map of the case study area. Source: Bakogiannis et al., 2021*

The pilot study focused on an 11.7 km area and required a total of seven man-hours. To develop the geospatial data infrastructure for the entire Athenian Riviera, which extends approximately 60 km, an estimated 48 man-hours would be necessary. Most of the required data could be derived from freely available open databases, and volunteers can remotely collect the necessary information quickly, reliably, and at a low cost.

The professional editing phase, comprising approximately 11 man-hours of office work, involved completing missing data (polygon, linear, point-data) and correcting the geometric accuracy of digitized shape files' various boundaries. Additionally, the process required man-hours for making decisions about specific datasets, their technical preparations (e.g., georeferencing), preparing the e-course, and training volunteers (approximately eight man-hours each).

Through the proposed methodology, the study verified that combining VGI (Volunteered Geographic Information) and crowdsourcing with professional data validation can effectively build the required geospatial infrastructure for coastal management and tourism planning in a remote and fit-for-purpose manner, quickly and affordably.

The main limitation of the method was the inability to conduct on-site data checking due to lockdown restrictions. However, this can be addressed by involving local residents as volunteers, who can easily visit the sites and provide accurate data.

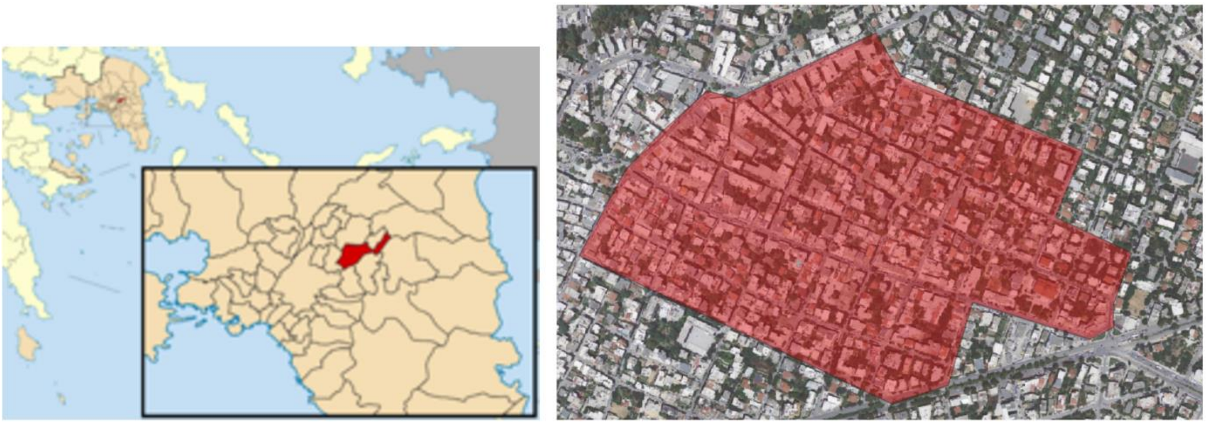
To apply this methodology in practice, a platform, and social media could be used to call for volunteers, with community participation and engagement being important factors to explore further. It is preferable for the volunteers to be committed local residents familiar with the area, invested in improving its management, and capable of collecting missing data on-site.

Alternatively, or additionally, tourists may be invited to participate during their leisure time, fostering a new model of participatory tourism. Working from home, tourists can actively contribute to planning their preferred vacation destinations remotely, gaining a deeper understanding of the site and increasing their interest in visiting those places.

5.7 Case Study No. 6 - Investigation on how to improve the Quality of Crowdsourced Cadastral Surveys

In order to assess the effectiveness of the suggested approach in creating a crowdsourced advanced cadastral basemap, two separate pilot studies were conducted, representing urban locations in the Attika region of Greece - Chalandri and Glyfada.

The first chosen location is a neighborhood within the Chalandri municipality in the Attika region of Greece (Figure 5.29 a). This selection was made because there exists an official cadastral survey for this urban region, enabling a meaningful comparison of the outcomes. Furthermore, urban areas are more intricate in structure compared to rural ones, making this neighborhood an ideal test subject. The study area covers approximately 0.26 km^2 and consists of 46 city blocks (Figure 5.29 b).



(a) **(b)**

Figure 5.29 *Case study area:* ***(a)*** *Chalandri municipality in Attika region.* ***(b)*** *Coverage of the selected area. Source: Apostolopoulos and Potsiou, 2022.*

The main aim of this case study is to put the suggested methodology to the test, specifically evaluating its geometric accuracy, completeness, and efficiency. Additionally, the study aims to explore the potential of the team of trained volunteers to engage in similar projects in the future. The focus is on the phase where the trained volunteers actively participate in updating the cadastral basemap.

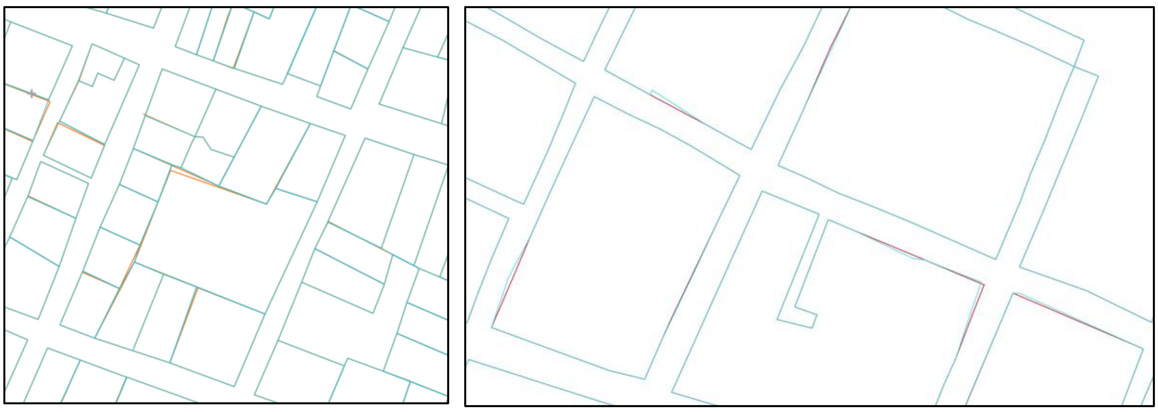
This case study requires a dedicated and skilled small group of young volunteers who are proficient in digital applications (Cetl et al., 2019). After undergoing a one-hour training session conducted by the cadastral surveyor, a team of 11 volunteers takes on the responsibility of collecting geospatial data using ESRI's ArcGIS Collector application, in combination with ESRI's ArcGIS online platform (Mourafetis et al., 2015).

The primary basemap used is the NMCA orthophoto from 2007, available as open data, and it is georeferenced using ESRI's ArcGIS software, adhering to the Hellenic Geodetic Reference System (HGRS'87).

To maintain motivation and encourage further voluntary engagement, the volunteers are offered certificates of acknowledgment. The data collection process entails capturing various elements from a distance, including land parcel boundaries, points of interest, and the road network (Figure 5.30).

Figure 5.30 *Advanced crowdsourced cadastral basemap. Source: Apostolopoulos and Potsiou, 2022.*

Figure 5.31 (a) presents the crowdsourced land parcels (green) and the professional's editing in terms of completeness, geometric accuracy, and line snaps (orange). Figure 5.31 (b) shows the crowdsourced road network (light blue) and the professional's editing concerning completeness, geometric accuracy, and line snaps (red).



(a) **(b)**

Figure 5.31 *Differences between* ***(a)*** *the crowdsourced land parcels (green) and edited land parcels (orange),* ***(b)*** *the crowdsourced road network (light blue) and the edited road network (red). Source: Apostolopoulos and Potsiou, 2022.*

To assess the achieved accuracies, a comparison is made with the official cadastral map, detecting any deviations from the crowdsourced cadastral basemap. The Hellenic Cadastre specifications are used for Quality Control (QC).

The geometric positional accuracy of the crowdsourced nodes is evaluated based on the methodology employed by the Hellenic Cadastre (Greek Government Gazette, 2016). This involves comparing the coordinates of the crowdsourced cadastral data with those of the official cadastral data to calculate relevant statistical deviations, thereby determining the level of accuracy of the crowdsourced cadastral data.

For an optimal distribution of the sample, a polygon orthogonalization defining the study area is necessary, accomplished by fitting a rectangular shape to the study area in an optimal manner. Within the resulting rectangular shape, at least 20% of the check points (CPs) should be distributed in each quadrant. The density between the CPs should approximately correspond to 1/10 of the length of the diagonal line of the rectangle (Figure 5.32). This method adheres to the Hellenic Cadastre QC, following ISO 2859-2:1985 (ISO, 1985; Greek Government Gazette, 2016).

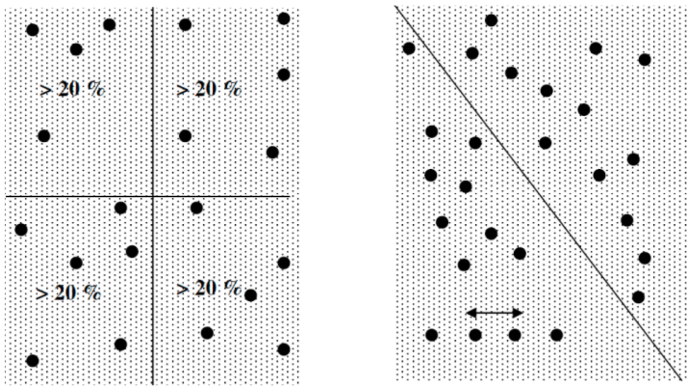


Figure 5.32 *Check Points distribution for cadastral data evaluation. Source: Apostolopoulos and Potsiou, 2022.*

The number of sample points required varies depending on the size of the area under consideration. In the case of urban areas with a scale of 1/1000, the formula for calculating the number of Check Points (CPs) is as follows:

Number of CPs = [(Area in hectares × 0.1)/12,000] × 20 points.

Before proceeding with the calculation of geometric compatibility and deviations, a professional undertakes a crucial step of eliminating any apparent errors. These errors are commonly found in the land parcels that have been either segmented, unified, or represented in an unconventional manner on the official cadastral maps. To identify such errors, they are marked with a distinctive red circle in Figure 5.33. However, these errors can only be clarified during the declaration submission phase.

Figure 5.33 *Comparison between edited crowdsourced land parcels (light blue) and official cadastral land parcels (red). Source: Apostolopoulos and Potsiou, 2022.*

The method used to determine the geometric compatibility of a parcel's size is based on the 'accuracy tolerance' method of the Hellenic NCMA (Greek Government Gazette, 2016).

Based on this method, 14% of the total land parcels (79 out of 571) have not achieved the required accuracy and are deemed unacceptable. Figure 5.34 presents the comparison between these two datasets. The average accuracy deviation is 0.58 m, and the maximum deviation is 1.77 m, both of which fall within the accepted limits.

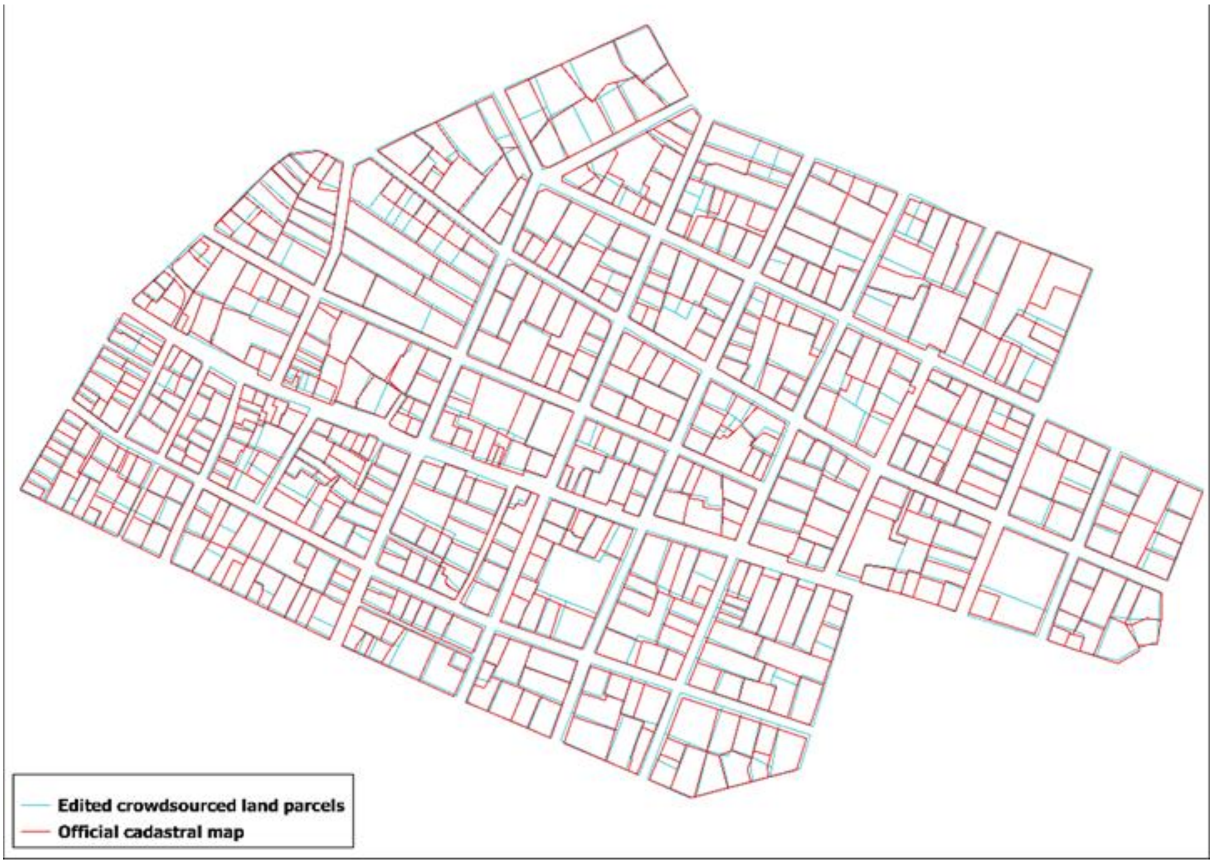


Figure 5.34 Comparison between the edited crowdsourced cadastral basemap (light blue) and the official cadastral map (red). Source: Apostolopoulos and Potsiou, 2022.

The edited advanced crowdsourced cadastral basemap is depicted in Figure 5.35. The editing process took a total of 3 hours to complete.

Figure 5.35 *Advanced crowdsourced cadastral basemap. Source: Apostolopoulos and Potsiou, 2022.*

The second chosen location is a neighborhood within the Glyfada municipality in the Attika region of Greece (Figure 5.36). Glyfada is a captivating coastal region nestled in the southern part of Attica with an urban development that incorporates green spaces and parks. It has been chosen for its complex urban structure and the availability of an official cadastral survey.

The study aims to evaluate the geometric accuracy, completeness, and efficiency of a proposed methodology for updating cadastral basemaps. Additionally, the study seeks to explore the potential of trained volunteers to contribute to similar projects in the future.

The study area in Glyfada covers approximately 1.07 km^2 and comprises 93 city blocks. A dedicated and skilled team of 22 young volunteers, proficient in digital applications, was selected for the project. The volunteers received a one-hour training session conducted by a cadastral surveyor to use the QGIS software application.

Figure 5.36 *Case study area – a part of Glyfada municipality in Attica Region, Greece.*

The primary basemap used for data collection is the Hellenic NCMA orthophoto from 2007, adhering to the Hellenic Geodetic Reference System (HGRS'87). The volunteers were tasked with capturing land parcel boundaries and points of interest in order to create a cadastral basemap that can be used for the declaration phase in the proposed methodology. They digitized 853 land parcels and 25 points of interest in a workshop that lasted 5 hours.

Once the digitization process concluded, a cadastral surveyor took charge of the data validation stage. This professional was responsible for ensuring quality control and performing the final editing of the geospatial data gathered by the 22 volunteers. The surveyor had the necessary qualifications to remotely monitor the collection process and offer assistance to the volunteers whenever required.

During the editing process, the professional primarily focused on verifying the completeness and geometric accuracy of the lines and polygons digitized by the volunteers, paying close attention to the shape and alignment of the points based on the urban characteristics of the area.

The QGIS software includes a tool named 'topology checker' that could be used to facilitate the professional needs for the editing of the crowdsourced dataset. It includes two rules, the 'must not overlap' rule and the 'must not intersect' rule that can be used to detect any gaps (between the lines of the neighboring land parcels) and obvious errors (such as holes in the building blocks) on the basemap (Figure 5.37).

Based on these rules, 769 errors were detected that refer mainly to minor gaps between land parcel boundaries and the intersection of the lines of the facades of the land parcels. An example of the results of the implementation of these rules is presented in Figure 5.38.

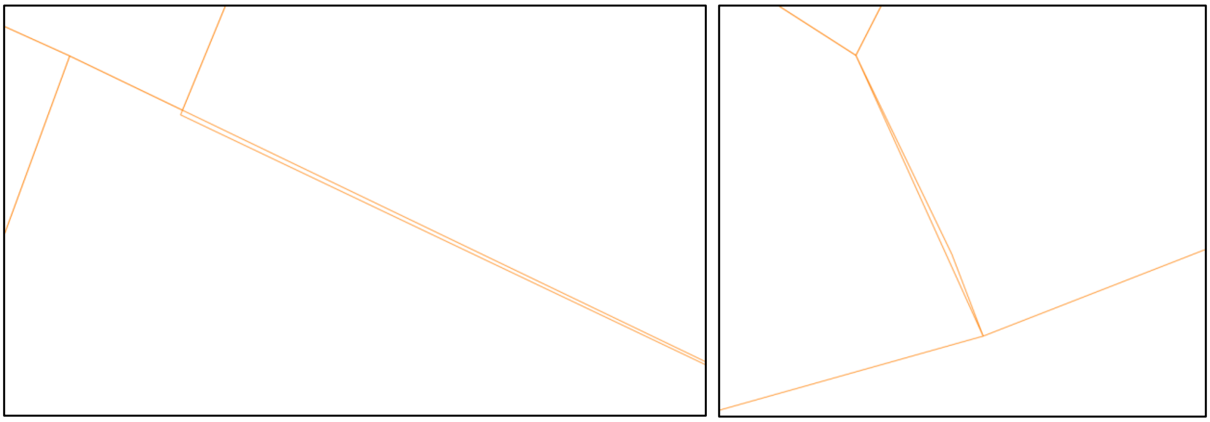


Figure 5.37 *Example of the results of the implemented rules in QGIS software.*

Having completed the editing of the detected errors, the professional edited the land parcel boundaries based on the urban characteristics of the area and the visible boundaries on the basemap. The editing phase involves approximately 9 man-hours of office work. Figure 5.38 presents some examples of the editing phase by the professional.

Figure 5.38 *Differences between the crowdsourced land parcels (orange) and edited land parcels (blue).*

To validate the edited crowdsourced cadastral basemap, an official cadastral map of the area was utilized as a point of reference (Figure 5.39).

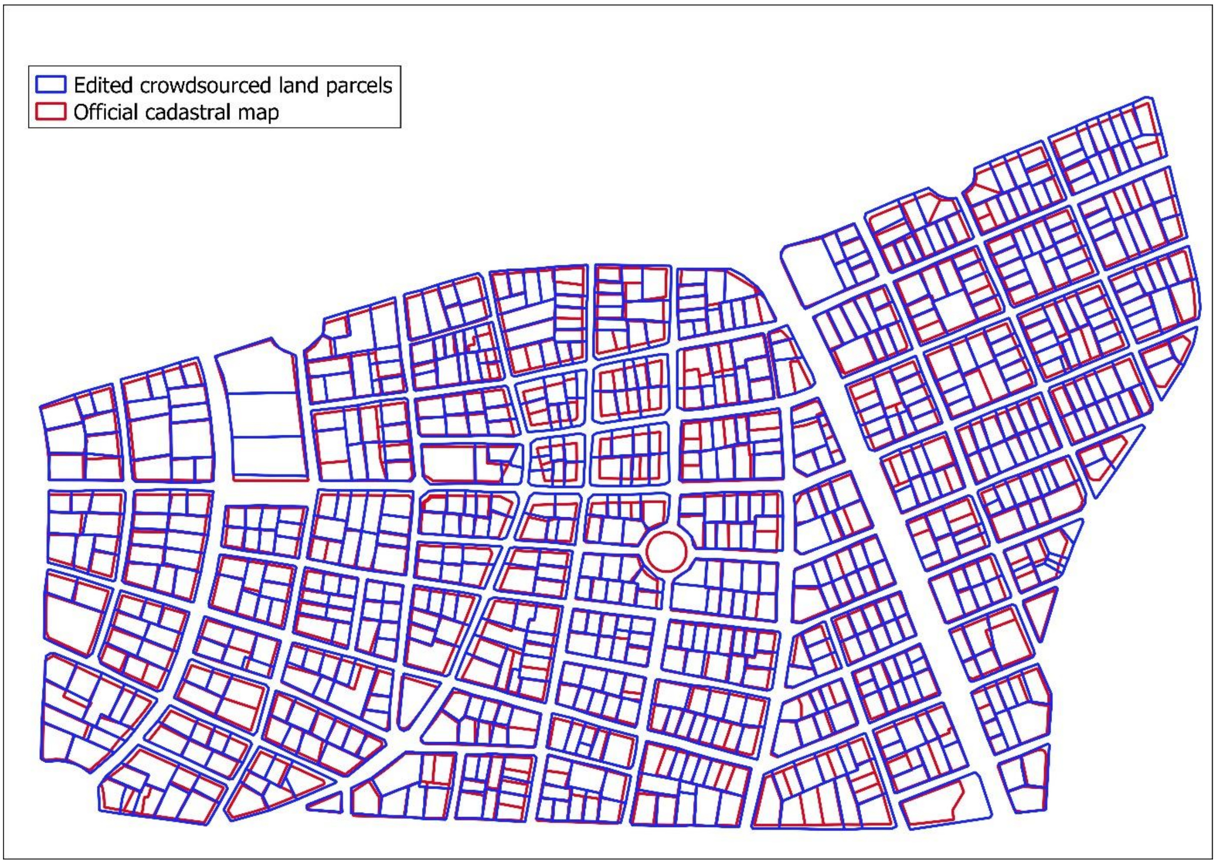


***Figure 5.39** Comparison between the edited crowdsourced cadastral basemap (blue) and the official cadastral map (red).*

The examination exposed some obvious errors (in 57 total) referring mainly to incorrect digitization of the land parcel facade (Figure 5.40) and failure to recognize a land parcel as two separate land parcels (Figure 5.41). However, both of these types of errors could not have been avoided, except during the declaration phase.

Figure 5.40 *Examples of obvious errors in the digitization process – incorrect digitization of land parcels' façade.*

Figure 5.41 *An example of an obvious error in the digitization process – failure to recognize a land parcel as two separate land parcels.*

As for the remaining 796 land parcels, the geometric positional accuracy of the crowdsourced nodes was evaluated based on the Hellenic Cadastre's QC/QA methodology as implemented in the previous pilot study. The geometric compatibility of the land parcels was determined using the 'accuracy tolerance' method of the Hellenic NCMA. Out of 796 land parcels, 95 (12%) did not achieve the required accuracy and were deemed unacceptable. The average accuracy deviation was 0.62 m, and the maximum deviation was 1.69 m, both within accepted cadastral limits.

Figure 5.42 presents the edited crowdsourced cadastral basemap within the Glyfada region of Attica.

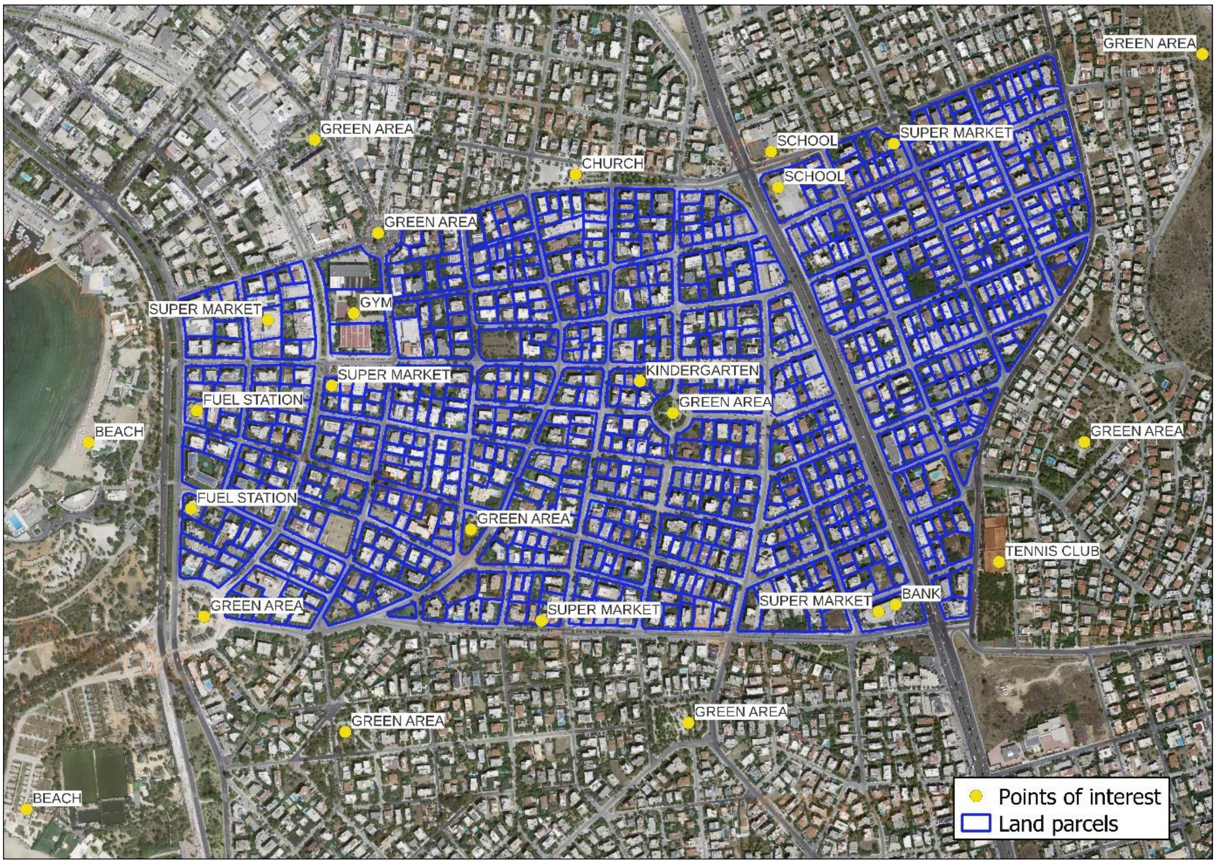


Figure 5.42 *Edited crowdsourced cadastral basemap.*

An in-depth evaluation of the proposed methodology based on these two pilot studies revolves around three main aspects: data completeness, achieved geometric accuracy, and the project's duration.

Regarding data completeness, it is acknowledged that utilizing more recent orthophotos, if available, could have led to a more comprehensive dataset. In certain regions where information may have been obscured, for instance, due to tree cover hiding boundaries, the recording was done approximately. The integration of up-to-date orthophotos and the possibility of conducting field visits in parallel could help mitigate such weaknesses.

As for geometric accuracy, some minor issues arose in the shape representation of various parcel polygons. Complex parcel shapes and those obscured by trees appeared differently when compared to the official maps. Improving geometric precision is crucial to enhance the quality of the cadastral basemap.

Concerning the capabilities of volunteers, discrepancies were observed in differentiating land parcel boundaries from the road network. Non-professionals might lack sufficient perception of precise land parcel boundaries. However, through extended commitment and experience gained during the project, volunteers can improve their performance in this aspect.

The assessment of costs and time reveals that recording an area as of the Chalandri case study area (0.26 km^2) required six working hours, with each volunteer covering approximately 22,000 m^2. The professional, on the other hand, spent about 3 hours completing the editing process for the entire dataset. For the broader scope of the Chalandri municipality (10.8 km^2), 240 man-hours would be needed, equivalent to around 28 days of work for the team of 11 volunteers. The editing phase itself would account for 100 man-hours, which included data completion, geometric accuracy corrections, decision-making processes, as well as the preparation of e-courses and volunteer training, amounting to approximately eight man-hours.

5.8 Concluding remarks

In conclusion, this chapter has undertaken a rigorous examination of the proposed Fit-for-Purpose cadastral model, evaluating its adaptability, resilience, and ability to address challenges in crowdsourced land administration while catering to diverse landscapes and communities. Through a series of case studies conducted in urban, suburban, and rural environments, in Greece and Romania, the proposed model's applicability has been thoroughly investigated, along with its integration of modern IT tools and gamification elements to facilitate citizen engagement in the cadastral process.

The case studies have highlighted the effectiveness of leveraging advanced IT tools and m-services in empowering citizens to actively participate in cadastral surveys. Moreover, the integration of gamification elements has demonstrated its potential in enhancing citizen engagement and encouraging active contributions to land parcel identification, and boundary delineation as well as participating in the compilation of advanced cadastral basemaps.

The examination of the developed open-source application with gamification elements in an urban environment showcased its positive impact on cadastral data accuracy, user satisfaction, and overall effectiveness in modern land administration practices. Additionally, the investigation of utilizing new technologies for remote geospatial data collection has demonstrated the potential to complement the crowdsourced cadastral model and enhance geospatial infrastructures and cadastral database comprehensiveness.

Finally, the focus on improving crowdsourced cadastral survey quality through data validation processes, feedback mechanisms, and citizen training has highlighted the importance of implementing necessary QA/QC measures to enhance data accuracy and reliability in the proposed model.

Overall, this chapter's multifaceted analysis and assessment of the Fit-for-Purpose cadastral model have shed light on the potential benefits, challenges, and future prospects of adopting this innovative approach in achieving AAA crowdsourced cadastral surveys. By embracing citizen engagement and modern IT tools, the proposed model offers a promising pathway to transform land administration practices and empower communities to manage their land resources effectively.

6 Results, Discussions and Further Research Proposals

6.1 Introduction

The primary objective of this study was to introduce a proposed model for a new FFP cadastral procedure, encompassing keynotes, main lessons, principal components, practical applications, and essential proposals. The research extensively examined both the technical and social aspects related to this specific context. However, legal aspects, especially concerning data security, were not within the scope of this investigation.

The Hellenic and Romanian cadastral projects served as guiding examples, but the research aimed to create generalized proposals and findings applicable to land administration projects worldwide. To achieve this, the study analyzed existing theoretical research and previous practical experiences in the field.

A proposed model was formulated to address its shortcomings improve its functionality and draw insights from practical experiences. Six different case studies were conducted to enhance theoretical knowledge with real-world outcomes.

This final chapter summarizes the research's outcomes, classifying them into two main categories: technical outcomes and motivation factors and actions to enhance citizen engagement in crowdsourced cadastral surveys. Moreover, it presents a succinct compilation of potential avenues for future research, along with emerging trends and opportunities.

6.2 Discussion

The realm of geospatial data has undergone a transformative revolution over the last two decades. This revolution, often referred to as the neogeography movement, has redefined how geospatial data and expertise are generated, shared, and utilized. A prominent outcome of this evolution is the emergence of volunteer geographic information (VGI), which capitalizes on the internet to create, exchange, visualize, and analyze user-generated geospatial data. This concept has been realized through diverse computing devices and platforms, thus heralding a profound shift in the acquisition, maintenance, analysis, visualization, and application of geospatial data. This neogeography revolution bears relevance to the context of cadastral surveys, significantly impacting their methodologies and outcomes.

VGI and the neogeography revolution have catalyzed a transition from traditional practices to an era marked by comprehensive, real-time, and location-based acquisition of geospatial data. Citizens have become active participants in data generation, enabled by novel technologies that support citizen science. This collective effort contributes substantially to the development of reliable geographic information systems (GIS) and geospatial data infrastructure. The paradigm of crowdsourcing, an extension of VGI, acknowledges the vast potential of user-generated geographic and geo-tagged digital information sources maintained by both the public and private sectors, alongside official geospatial data. This shift from authoritative sources to collective contributions is shaping the dynamics of spatial data infrastructures (SDIs).

However, the dynamic nature of crowdsourced data necessitates tailored methodologies that align with intended purposes and contexts, ensuring quality and reliability. Crowd engagement emerges as a crucial aspect, mirroring the principles of planned field survey works. Strategies for recruiting, maintaining, and engaging crowdsourced participants require dedicated resources to effectively harness their contributions. Decisions regarding data capture, validation methods, and tool selection demand careful consideration, with project-specific factors influencing the approach.

Cadastral projects, in particular, present unique challenges due to the involvement of participants with diverse expertise and methodologies. Integrating VGI and crowdsourcing into cadastral surveys has evolved through the stages of the internet revolution - from basic data sharing (Web 1.0) to active user participation and crowdsourcing (Web 2.0) and the data-enriched environment of Web 3.0. National Cadastral and Mapping Agencies (NCMAs) have adapted to these technological shifts, with many utilizing geospatial portals and crowdsourcing techniques to enhance their operations.

The potential of these technologies extends beyond operational improvements; they hold the key to bridging the geospatial digital divide, achieving the goals of the Agenda 2030 for Sustainable Development, and fostering citizen engagement. By involving citizens in geospatial data collection and interpretation, governments can bolster the usability of data and stimulate the digital economy. Integrating these technologies into cadastral surveys requires a comprehensive investigation of their potential, the development of guidelines, and alignment with legal and policy frameworks.

In this regard, this research illuminates the historical progression of the Sustainable Development and Agenda 2030, showcasing the integral role played by cadastre and geospatial information in these global objectives. Furthermore, insights gleaned delve into the citizen participation and gamification tools in governmental initiatives, shedding light on the seamless integration of VGI and gamification into land administration endeavors. The findings also spotlight best practices surrounding citizen participation and voluntarism within the domain of land administration, while presenting practical instances of collaboration involving government entities, the private sector and right holders, exemplified through the lens of the Hellenic Cadastre project.

Parallel to this, the research uncovers valuable insights from international publications, unveiling the dynamic evolution of the Fit-for-Purpose (FFP) Land Administration Approach over time. The effectiveness of this approach comes to the fore via a curated selection of case studies, showcasing successful real-world implementations of the Fit-for-Purpose Land Administration approach. In essence, it unravels the intricate synergy between Fit-for-Purpose Land Administration and VGI. This symbiotic interplay between technological advancement, civic involvement, and evolving methodologies underscores the transformative potency of their convergence.

6.3 Findings

The findings of the present research study are classified into two distinct areas: technical aspects resulting from the implemented case studies and motivational aspects and/ or gamification elements that could be implemented in the crowdsourced cadastral surveys to enhance citizen engagement. The outcomes outlined below stem from a comprehensive exploration that blends practical experimentation and theoretical analysis, serving as the primary results of this research endeavor.

6.3.1 Technical aspects

Both earlier studies and the current thesis attest to the fact that technical challenges and technological challenges do not present a limitation within the context of crowdsourced cadastral surveys. The accuracy of the cadastral maps produced through this method is influenced by a variety of factors, with the rough location accuracy contingent upon the specific mobile phone utilized and the existing network of GPS antennas. However, it is important to underscore that the crux of the proposed methodology's accuracy is inherently tied to the utilization of an exceptionally precise basemap such as high-resolution orthophotos produced by the responsible NCMA.

A notable advantage of this approach is its adaptability to field conditions. The option for volunteers to work online or in the field stands as a testament to its flexibility, particularly valuable in regions where internet connectivity might be weak. This versatility guarantees seamless data collection, regardless of the challenges posed by network availability.

The cost-efficiency of this approach is a compelling facet. Despite the expenditures associated with volunteer training, professional data editing, and volunteer incentives, the overall project cost experiences a substantial reduction due to the substantial contributions made by volunteers. Moreover, the financial viability of the procedure is an asset, with the responsibility for costs potentially resting entirely with the responsible NCMA or contractors/ authorized cadastral surveyors.

In situations where precise basemaps are unavailable, the proposed methodology offers a solution through the utilization of globally accessible maps like Google Streetview, Google Earth, or Bing Maps. While this substitution might lead to a certain degree of geometric imprecision, the resulting crowdsourced cadastral maps can nevertheless fulfill their intended purpose, effectively addressing the pressing need for land registration.

Moreover, the accurate identification of land parcels, facilitated by the GPS capabilities of smartphones used by volunteers, eliminates the inherent risk of errors that accompany parcel recognition via orthophotos. Volunteers, equipped with GPS, can directly access property boundaries on-site, significantly diminishing the chances of inaccuracies. Additionally, the proposed methodology permits volunteers to not only identify their own properties but also those of their neighbors, thus enabling a cross-verification of registered properties.

The participation of experts plays also a crucial role in ensuring the quality of the cadastral products. In cases where there is a lack of professional staff, it might be necessary to enlist volunteers or college students with specialized training. Well-established institutions such as universities can also offer valuable direction in this regard. This helps to ensure a strong land administration system, even when the necessary infrastructure is lacking. In this direction, the suggestion of utilizing cloud-based data storage aims to reduce expenses, although this approach is subject to differing regulations concerning the protection of personal information.

A granular assessment of the methodology, based on a comprehensive case study, delves into various dimensions such as information completeness, geometric accuracy, and project duration. In terms of information completeness, the integration of more recent orthophotos is acknowledged as a potential enhancement. Challenges arise in regions where information is obscured, such as boundaries concealed by trees, leading to approximate recordings. By supplementing recent orthophotos with field visits, these shortcomings can be effectively addressed. Geometric accuracy is impacted by minor discrepancies in the shape of parcel polygons, especially those that are complex or partially concealed by foliage. Over time, as volunteers gain experience and expertise, these issues are expected to diminish.

These technical key elements have a bearing on the overall effectiveness, precision, and completion of the proposed model and are presented below:

a. The quality and accuracy of the chosen basemap, which is intrinsically tied to project funding and sustainability. Basemap options encompass a spectrum ranging from aerial photographs to open-source alternatives like the developed open-source application, with each influencing results to varying degrees.

b. The capability of volunteers to identify parcel boundaries on the basemap, and if needed, through the assistance of smartphone GNSS or manual cursor adjustments.

c. The complexity of the cadastral area's built and natural environment, dictating the optimal surveying approach, whether it be crowdsourcing, photogrammetric, field survey, or a combination thereof.

d. The challenge of potentially hidden boundary points on the basemap by vegetation is mainly noticeable in rural regions, and in urban settings, tall buildings can also obscure property boundaries. This might result in the necessity of conducting fieldwork for precise completion.

e. The digital literacy of right holders, which may be mitigated by the presence of volunteer students, team leaders and professionals.

Moreover, to enhance location accuracy and non-professional parcel identification, an innovative approach introduces the compilation of an advanced crowdsourced cadastral basemap. This advanced basemap incorporates additional information such as road names, settlements, rivers, green areas, points of interest, urban blocks, building footprints, and other landmarks. Trained volunteers collaborate to compile this comprehensive basemap, thereby significantly improving the accuracy of parcel identification.

The proposed methodology also advocates for enhancing the advanced basemap with pertinent geospatial data from previously ratified projects. This additional layer of information serves to rectify potential errors during the declaration submission phase and ultimately enhances the overall quality of the final cadastral product.

Depending on available resources and the unique circumstances of each project, this research introduces intermediate and final quality assurance and quality control measures, either supervised by professionals or the responsible NCMA. The efficacy of these measures is underscored by research on the Hellenic cadastral project. Intermediate quality checks are identified as critical to achieving the desired accuracy in the final crowdsourced cadastral survey.

In terms of logistical considerations, the methodology showcases its efficiency through tangible results. For instance, the completion of a substantial area, like a part of Chalandri, necessitates relatively few man-hours due to the combined efforts of volunteers and professionals. The procedure includes various stages, including data completion, geometric accuracy correction, decision-making, and volunteer training, each contributing to the comprehensive and accurate cadastral outcome.

In summary, the synthesis of the above-described technical aspects within crowdsourced cadastral surveys presents a promising avenue for efficient and cost-effective land registration. The methodology's efficacy hinges upon a careful interplay of technical factors, community engagement, and professional oversight, culminating in precise and comprehensive crowdsourced cadastral maps.

6.3.2 Citizen engagement and gamification elements

The successful implementation of crowdsourced cadastral surveys relies on addressing key motivation aspects and parameters for citizen participation and engagement. One of the biggest challenges is ensuring that people recognize the value of the cadastral project and understand the benefits it brings. Experiences from Greece and Romania have shown that long delays and errors in formal cadastral surveys led to disappointment among right holders, resulting in a lack of willingness to participate. To overcome this, it is crucial to demonstrate that citizen participation can save time and expenses, unblock the market, and expedite the cadastral registration process.

International experience, such as the case studies in Colombia and Ethiopia, has proven that utilizing FFP cadastral methods can accelerate cadastral registration and reduce costs. However, careful planning of registration fees and property taxation policies is essential to ensure that right holders remain motivated to participate and declare their rights.

The proposed crowdsourced 2D cadastral survey model introduces a new form of relationship between professionals and citizens. This approach fosters cooperation, with surveyors taking responsibility for training volunteers and evaluating data collected by the crowd.

In the context of the Hellenic Cadastre, citizens are technically and legally allowed to participate voluntarily in the cadastral surveying procedure through e-services. However, limited communication regarding the benefits of this e-service has hindered wider participation. Introducing "gamification tools" could be a solution to stimulate citizens' interest and ensure efficiency, error reduction, and cost-effectiveness in cadastral surveys.

Gamification can maximize motivation, create a pleasant experience, and maintain volunteer engagement. Incentives such as certificates, recommendation letters, smartphones, or reduced registration fees for successful identification and declaration submission can further enhance participation.

To leverage gamification effectively, citizens' innate psychological needs, such as autonomy, competence, and relatedness, should be taken into account. Emphasizing the societal benefits of cadastral registration can satisfy citizens' desire for competence and self-confidence. Highlighting the role of citizens in tackling challenges like reducing corruption and increasing transparency through property registration can appeal to their sense of autonomy. Moreover, promoting a sense of social inclusion and significance in participating in a nationwide project can foster a connection among volunteers.

Expanding citizen involvement in more tasks of the cadastral survey, such as preparing the preliminary basemap, requires thorough planning and organization. While this approach may involve fewer volunteers, it requires a longer commitment duration.

In conclusion, a successful crowdsourced cadastral survey hinges on effective communication, incentivization through gamification, and addressing citizens' psychological needs for autonomy, competence, and relatedness. By incorporating these elements, the cadastral project can engage citizens and create a collective effort to achieve a nationwide cadastral registration with numerous benefits for society.

6.4 Further Research Proposals, Trends and Opportunities

Further research proposals in the field of cadastral surveying and land administration should focus on several key areas to address existing challenges and leverage new technologies. Firstly, it is essential to investigate the achieved accuracies in countries with less accurate infrastructure available. This will provide insights into the potential impact of modern technologies on improving accuracy and efficiency in such settings.

Another critical aspect worth exploring is the potential involvement of crowdsourcing in more phases of cadastral surveying. The study should identify how local authorities can play a new role in facilitating the cadastral survey through the engagement of committed volunteers. This could lead to the development of a gamified framework for crowdsourced cadastral surveying, which should not only be practically pleasing but also designed with a clear purpose. The objective should be to attract volunteers who will actively participate, generate innovative ideas, and contribute to a fit-for-purpose surveying procedure.

To assess the capacity of volunteers and promote their involvement, parameters such as the speed of data collection and achieved accuracies should be investigated. Additionally, the research should delve into the factors that affect the accuracy and completeness of the crowdsourced cadastral procedure, including the quality of the basemap, the volunteer's ability to identify parcel boundaries, and their capability to deal with complex built and natural environments. With crowdsourcing becoming a pivotal element in cadastral surveying, enhancing the accuracy and reliability of such data through sophisticated machine learning validation models is crucial. These models could correct errors in crowdsourced data automatically, ensuring higher data quality.

Moreover, to implement the proposed model effectively, a platform needs to be established, and the possibility of a call for volunteers through social media should be explored. Community participation and engagement should also be considered to ensure that volunteers are local residents with a good understanding of the area and a vested interest in improving land administration. Additionally, the concept of involving local citizens in ongoing cadastral projects during their free time could be investigated, fostering participatory procedures.

Furthermore, it is crucial to investigate the legal framework for implementing gamified cadastral surveys and introduce reliable validation tools to ensure the efficiency and accuracy of this method.

As the research progresses, it should also focus on modeling cadastral data maintenance and updating procedures using the crowdsourced methodology. This aspect holds great value, especially for urban areas where changes in land use are not systematically recorded.

Therefore, the research should utilize artificial intelligence to predict future land use changes based on historical data and current trends. This can help in proactive planning and management of land resources. It could also focus on developing algorithms that accurately forecast urban expansion. Moreover, the research could focus on the implementation of machine learning techniques to automatically identify parcel boundaries from satellite images and other geospatial data. This can drastically reduce the manual effort required in traditional cadastral surveying and increase the accuracy and efficiency of land registration processes.

To conclude, by incorporating advanced technologies such as machine learning and AI and active citizen participation, the field of cadastral surveying can make significant strides towards more efficient and accurate land administration practices, ultimately contributing to sustainable development goals.

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