Correcting Cadastral Maps Errors in Armenia Using Geospatial Technology

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SUMMARY

In 2021, Armenia implemented a legislative framework to address and correct errors in the country's cadastral maps, a critical component for managing land ownership and property rights. The new legal framework established the use of orthophotos, with an up to 30 cm spatial resolution, as a primary tool for identifying and correcting locational, geometric, and dimensional errors in cadastral data. This methodology represents a major advancement in land management, as it integrates modern geospatial technology with the country's state registration system, ensuring more precise and reliable cadastral maps.

The methodology outlines the steps for identifying and correcting errors such as incorrect locations, geometric forms, linear dimensions, and ownership inconsistencies. Notably, the methodology also includes a specific approach for adjusting agricultural plots, reflecting the unique challenges posed by this category of land use.

As of 2024, over 485 settlement cadastral maps, representing approximately 47 % of the total, have already been corrected as part of this ongoing initiative.

The work continues, with further updates expected to improve land data accuracy across the country. This process not only enhances the reliability of cadastral spatial data layers but also provides a transparent and legally sound framework for managing property rights.
This reform in Armenia's cadastral mapping system is a significant leap forward in land administration. By incorporating orthophotos into cadastral map correction processes, Armenia sets a regional benchmark for using modern technology to ensure accurate land records.

This approach enhances property rights management, supports urban and rural planning, and serves as a model for other nations looking to modernize their land administration systems.

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1. INTRODUCTION

Cadastral mapping is a fundamental component of land administration systems, forming the basis for the management of land rights, property transactions, and spatial planning (Cichocinski, 1999; Williamson and Enemark, 1996; Navratil and Fogliaroni, 2013). Globally, the accuracy of cadastral data has long been a concern due to errors that can arise from outdated technologies, human mistakes, and evolving land use patterns (Hanus et al, 2018) (Pullar and Donaldson, 2022). However, advancements in geospatial technologies, including Geographic Information Systems (GIS) and remote sensing, have provided significant opportunities for enhancing the accuracy and reliability of cadastral maps (Al-Hameedawi et al, 2017; Bennett et al, 2020). These innovations are particularly valuable for countries aiming to modernize their land administration systems and improve governance and economic development.

In Armenia, as in many countries (Gundelsweiler et al, 2007; Enemark, 2010; Enemark et al, 2005; Enemark and Sevatdal, 1999), the cadastral system underpins the legal and administrative framework for property rights, land use, taxation, and economic development. Accurate and up-to-date cadastral maps are critical for ensuring transparency, reducing disputes over land ownership, and enabling effective governance. The integration of modern geospatial technologies into the cadastral mapping process is therefore crucial for improving land administration, not just for legal clarity but also for supporting broader economic and social development.

Despite advancements in geospatial technologies, challenges in cadastral mapping persist. As (Williamson and Enemark, 1996) note, cadastral maps serve different functions across various jurisdictions, and the attributes of these maps can vary significantly. In some countries, cadastral maps are simple graphic representations, often outdated and imprecise, used for purposes such as land valuation or taxation. In contrast, in jurisdictions like Australia and Denmark, cadastral maps are often based on precise field surveys, with varying levels of accuracy depending on the system in place (Williamson and Enemark, 1996). However, even in these more advanced systems, cadastral errors can still arise from factors such as discrepancies in surveying techniques, geospatial inconsistencies- referring to discrepancies or mismatches between spatial data from different sources or time periods, which can arise from variations in measurement techniques, data resolution, or coordinate reference systems used. These inconsistencies may lead to inaccurate positioning of boundaries, features, or other elements on a map. Additionally, cadastral maps are sometimes designed for specific roles—such as charting or land registration—rather than serving multi-purpose functions, which can lead to inconsistencies in their accuracy and completeness. In developing countries, such as Armenia, outdated cadastral systems, combined with limited technological infrastructure and resources, can further hinder efforts to maintain accurate and up-to-date land records.

In Armenia, comprehensive cadastral mapping was conducted during the 2000s, with the majority of geodetic work being carried out using traditional methods. Traditional methods during this time primarily relied on manual field surveys, with land measurements taken using optical instruments like theodolites and tape measures. The data was then recorded manually or on paper, and any adjustments were made manually on physical maps. These methods were time-consuming, prone to human error, and limited by the accuracy of the instruments and the need for precise, labor-intensive fieldwork. In comparison, modern methods, such as GIS technologies, provide significant advantages. GIS allows for the integration of diverse datasets, including satellite imagery, GPS data, and field survey results, into a single digital platform. This enables dynamic mapping, real-time updates, and automated error detection, significantly reducing the chances of human error. Unlike traditional methods, GIS can process and analyze vast amounts of data quickly, improving both accuracy and efficiency. Ultimately, modern geospatial technologies streamline the entire mapping process, making it far more efficient, accurate, and scalable compared to traditional methods.

While traditional methods were limited by the accuracy and efficiency of the tools used, these challenges persisted in the data, leading to discrepancies that complicated the management and updating of cadastral information. Discrepancies in the data primarily stem from issues related to the integration of coordinate reference systems and inaccuracies in measurements. The mapping process was performed at scales of 1:500 to 1:2000 within settlements, and at scales ranging from 1:1000 to 1:10000 in outside settlements. Until 2021, corrections to errors in cadastral maps were carried out under the authority of the head of the Cadastre Committee, a process that provided very limited opportunities for making changes. It is noteworthy that most corrections were made as part of the routine maintenance of cadastral maps. Prior to 2020, cadastral maps of settlements were managed in a separate environment, which did not facilitate systematic tracking of changes. This lack of integration meant that modifications made by different specialists were not always recorded in terms of their identification or timing. Additionally, the archiving and storage of data were performed at irregular intervals, further limiting the ability to manage and update the cadastral information efficiently.

Thus, the need for a more refined and simplified approach to error correction in the cadastral system became clear. This led to the recognition that modern geospatial technologies could play a significant role in improving the accuracy and efficiency of error correction in cadastral maps.

In 2021(Government of the Republic of Armenia 2021), Armenia introduced a new legislative framework that marked a significant advancement in the country's land administration system. This reform focused on the use of high-resolution orthophotos, with a spatial resolution of up to 30 cm, as the primary tool for identifying and correcting locational, geometric, and dimensional errors in cadastral data. The orthophotos provide high-resolution, geographically accurate images of land, serve as the primary tool for aligning the cadastral map with real-world features. The integration of orthophotos into the cadastral correction process was a major step forward, combining modern geospatial technology with the country's state registration system to ensure more precise and reliable cadastral maps.

This methodology enabled a more precise detection of errors, including mislocated features, geometric distortions, and dimensional inconsistencies, which were previously challenging to identify using traditional techniques.

2. METHODOLOGY

2.1 Correction of administrative boundaries of communities in cadastral maps

The correction of cadastral map errors is a complex process that occurs across three key levels: administrative units, districts, and individual land parcels. Each of these levels is critical for ensuring that the cadastral data is accurate and reflects the true spatial and legal boundaries of land ownership. This multi-level approach is crucial for addressing discrepancies and ensuring that cadastral information aligns with real-world features. At the level of administrative boundaries, the correction of community borders is a critical task carried out by the Cadastre Committee.

This process, guided by a clear legal framework and in collaboration with local authorities, begins with aligning cadastral boundaries to legally defined descriptions, ensuring that the adjustments reflect the true limits of each community. Mutual consent from the local governments of adjacent communities is vital to resolving any discrepancies and ensuring that cadastral information accurately reflects real-world features. During this process, both the 2021 and 2014 orthophoto maps have been utilized, with a spatial resolution of 10-30 cm.. These images are sufficient for the task at hand, as the errors addressed in the adjustment process are related to the creation of the original cadastral map layers. In other words, the discrepancies identified in the initial cadastral data are not due to boundary mismatches arising from land use, but rather from inaccuracies in the original mapping materials.

The data used for cadastral boundary corrections is vector data, which includes the boundaries of administrative units, districts, and land parcels. The coordinate reference system used in the data model is WGS-84 (ARMREF 02), the official national geodetic coordinate reference system of Armenia. The enhanced vector data is stored in Shapefile format, a widely used format in GIS for its compatibility and ease of integration with different GIS platforms.

The quality improvement process of the cadastral maps is carried out using open-source GIS software, primarily QGIS (Quantum GIS). QGIS is employed for its robust set of tools and functionality, allowing for detailed corrections to be made, including boundary adjustments, spatial data integration, and analysis of discrepancies.

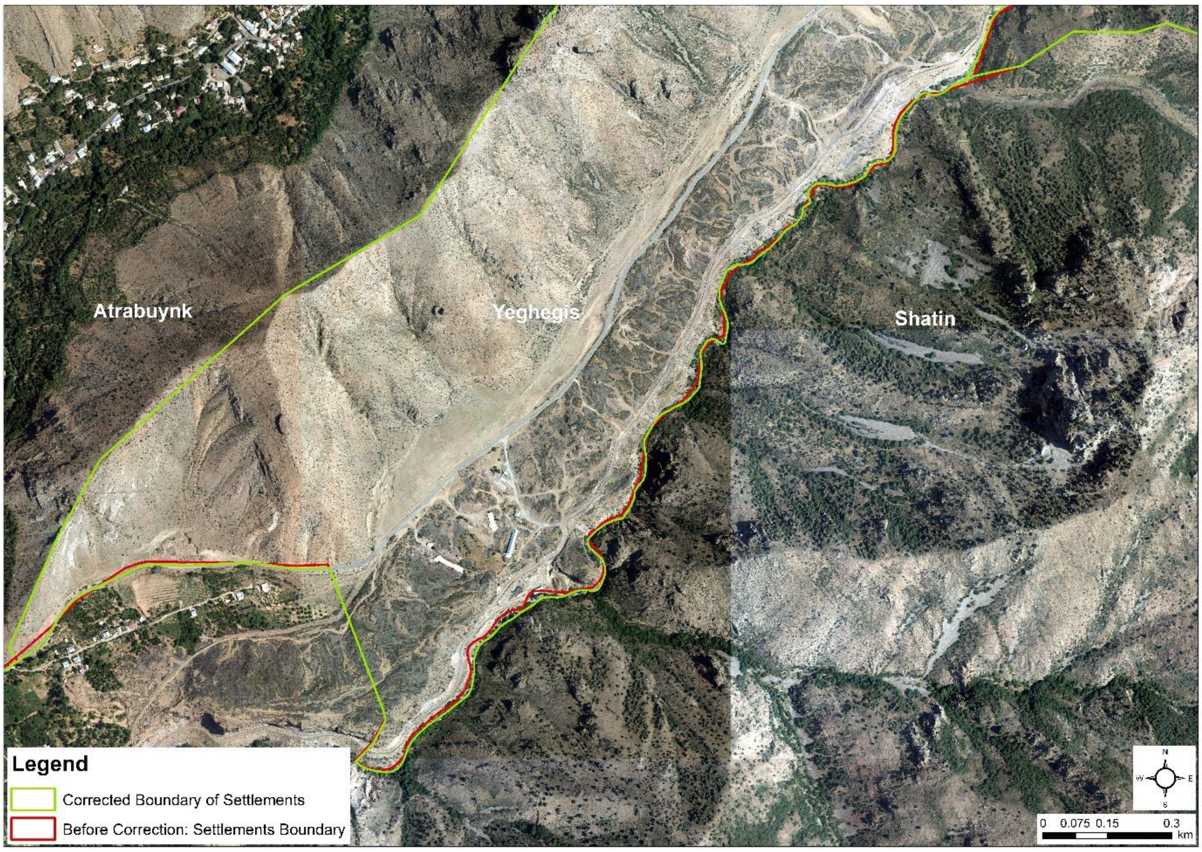

Figure 1: Comparison of settlements boundaries

The Cadastre Committee prepares a correction project, utilizing tools such as as GIS software, and orthophotos, which is then shared electronically with the leaders of the involved communities. Once the correction project is presented, community leaders are asked to provide written feedback, which may include approval or objections. If disagreements arise, the project is revised and resubmitted for further consideration. In cases where community leaders are unable to reach a mutual agreement, the unresolved issues shall be referred to the relevant commission, for further deliberation and resolution.

After the boundaries have been corrected, any newly included land parcels are classified as community property. The use of these parcels is determined based on available data, such as orthophotos, which reflect both the intended use and actual land usage. The methodology ensures that all boundary corrections are conducted in a legally sound manner, with active participation from local authorities and transparency in the process, supported by public access to updated cadastral maps.

2.2 Correction of district boundaries in cadastral maps

The correction of cadastral district boundaries is a vital process carried out by the Cadastre Committee to ensure that cadastral data accurately reflects the real-world geographic and legal boundaries of districts. The primary aim of this process is to realign district boundaries with physical and natural features—such as roads, rail networks, rivers, and other significant geographical markers—visible in high-resolution orthophotos. These orthophotos serve as precise reference points, allowing for the adjustment of cadastral maps to align with actual territorial limits. An example of an adjusted district can be seen in Figure 2, showing the updated and current boundaries

Figure 2. Corrected cadastral district boundaries: Updated and current boundaries

The methodology involves the use of orthophotos to review and correct the district boundaries. This tool provides up-to-date, accurate spatial data, enabling the Cadastre Committee to make adjustments without altering the geometric shape or surface area of the districts. This careful approach ensures that cadastral maps maintain consistency in land data, preventing legal or administrative complications, while also reflecting the true topography of the area.

Once corrections are completed, the revised cadastral maps are shared electronically with community leaders, who review and provide feedback. If disagreements arise, further discussions are conducted to address concerns, and if consensus cannot be reached, the issue is escalated to a relevant government commission for resolution. This ensures transparency and accountability in the process.

This methodology ensures that changes to district boundaries are made in accordance with actual topographical features, with minimal impact on individual land parcels unless necessary. The iterative process includes continuous community review and compliance with legal guidelines, maintaining the accuracy, transparency, and integrity of the cadastral system. If necessary, changes are made without prior agreements, particularly when it becomes essential to adjust the boundaries of key infrastructure such as roads, railways, rivers, and other significant features.

2.3 Correction of cadastral parcel errors

Cadastral parcel errors refer to discrepancies between the actual boundaries of land parcels and the information depicted on the cadastral map. These errors can have significant legal implications, including changes in ownership, land use categories, or other critical attributes of the land. Correcting these errors involves a systematic approach that integrates legal, technical, and administrative procedures, ensuring the accuracy of cadastral data and the protection of property rights.

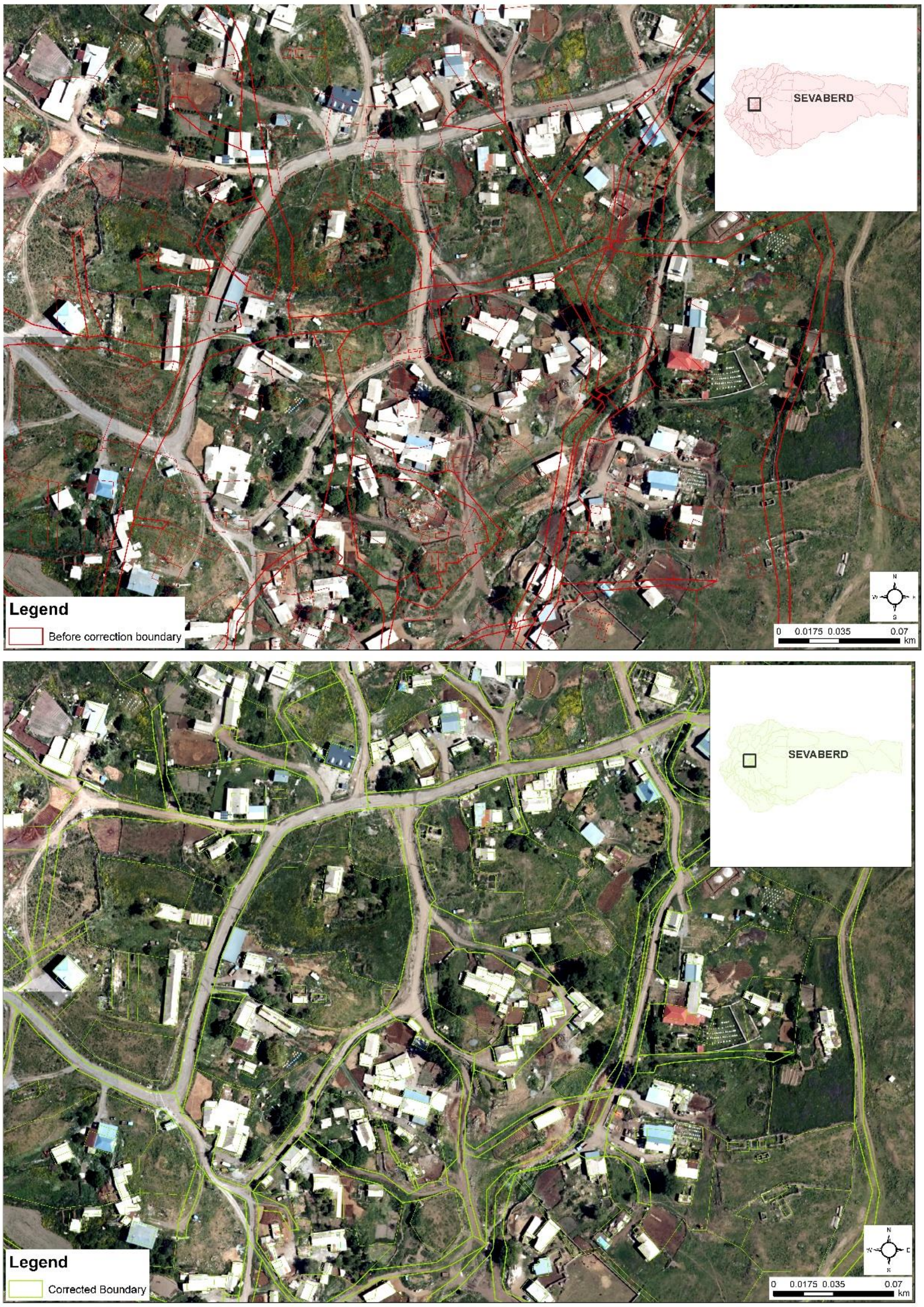

Figure 3. Comparison of cadastral map boundaries (before and after correction)

An example of a cadastral parcel adjustment is presented in Figure 3, which illustrates how the road unit was adjusted to match its actual position.

The correction process begins with identifying the specific types of errors that may exist in cadastral data. Common errors include the absence of a land parcel on the cadastral map, incorrect location of a parcel, errors in dimensions or shape, discrepancies with state registration data, land use discrepancies, and incorrect ownership information. Each of these types of errors requires different corrective measures based on the severity and impact of the error.

In cases where the errors fall within acceptable limits of deviation—such as minor discrepancies in parcel dimensions or shape—corrections can often be made directly by the Cadastre Committee without requiring approval from other stakeholders, particularly when physical boundary markers like fences or walls clearly delineate the land. For more significant errors, such as those involving changes to ownership or land use categories, a more comprehensive approach is required. These cases necessitate the consent of the affected parties, including landowners, community leaders, and other stakeholders with legal rights to the land.

The Cadastre Committee utilizes orthophotos to correct many cadastral parcel errors, particularly when discrepancies involve the location or dimensions of parcels. Corrections are made by comparing cadastral maps to these orthophotos, ensuring that boundaries and parcel details are accurate and consistent with physical features on the ground.

For parcels that are registered but do not appear on the cadastral map, the Cadastre Committee can add these parcels based on available documents, such as land registration certificates, and orthoimages. This ensures that all legally registered parcels are accurately represented in the cadastral system, with no omissions or errors. In cases where corrections to cadastral data impact the registered area of a land plot, such corrections are made only with the consent of the property owners involved. Additionally, the updated plans must be approved by the heads of the relevant communities.

The correction process follows clear principles to ensure accuracy and transparency. However, when corrections affect more significant aspects of the cadastral data, such as boundaries, ownership, or land use, written consent from affected stakeholders is required. All corrections are made based on official documents, including state registration certificates and legal documentation outlining ownership and land use.

By following these methodologies, the Cadastre Committee ensures that cadastral maps are corrected in a manner that is legally sound, transparent, and reflective of actual conditions on the ground. These measures help prevent legal disputes, protect property rights, and maintain the reliability of cadastral information across Armenia.

3. ACCURACY AND QUALITY CONTROL

In the process of cadastral surveying and mapping, ensuring the accuracy of linear measurements is critical, especially when it comes to important features such as boundary markers for capital structures, roads, rivers, and other permanent objects. The required precision for cadastral surveys is determined based on the scale of the map and the type of objects being surveyed. For example, the accuracy for measuring corner points of building enclosures, well centers, and other clearly identifiable objects is typically within a mean square error (mt) range of 0.02–0.03 meters at a 1:2000 scale. It is important to note that the accuracy levels of 2 to 5 cm refer to the measurements obtained using a total station or similar surveying instruments. For smaller scales, such as 1:5000 and 1:10,000, boundary error margins increase, with permissible errors reaching up to 200–300 meters for the largest scale. Similarly, for permanent structures such as asphalt road intersections, village block boundaries, or river edges, the mean square error in the plan can range from 0.04–0.05 meters at the 1:2000 scale, and boundary errors may increase at smaller scales. For other less stable features such as land boundaries, dirt roads, or forest paths, the mean square error typically ranges from 0.06 to 0.1 meters at 1:2000 scale, with boundary error tolerances increasing significantly as the scale decreases.

In cases involving natural areas such as forests or grazing lands, where boundary features may be subject to change over time or may not be as clearly defined, the accuracy requirements are broader, with square errors ranging from 0.11 to 0.15 meters at the 1:2000 scale. As the scale increases, these errors can extend up to 1100–1500 meters at a 1:10,000 scale. During cadastral mapping and digitization using orthophotos, linear and surface errors may arise due to various influencing factors, which are contingent upon the spatial resolution (pixel size) of the orthophotos. The following error thresholds are considered permissible for different spatial resolutions:

- For orthophotos with a resolution of 10 cm, 20 cm, and 30 cm, the permissible linear deviations in geometric accuracy are 15 cm, 30 cm, and 45 cm, respectively.
- For the plotting of land parcels on orthophotos with resolutions of 10 cm, 20 cm, and 30 cm, the maximum permissible surface errors are 0.5%, 1.5%, and 3%, respectively.

These tolerance levels are essential for ensuring the reliability and accuracy of cadastral data during the digitization process. While the majority of data adhered to these thresholds, in some cases—particularly with lower-resolution orthophotos or manual adjustments—thresholds were exceeded. However, these instances were infrequent, and high-resolution orthophotos, combined with additional ground surveys, effectively minimized exceedances.

4. IMPLICATIONS AND RESULTS

As of 2024, over 485 settlement cadastral maps, accounting for approximately 47 % of the total, have already been corrected as part of an ongoing initiative aimed at modernizing the national cadastral system. This progress underscores the importance of ensuring the accuracy and reliability of cadastral data, which is critical for effective land management, property rights, urban planning, and resolving territorial disputes. The corrections made so far have significantly improved the alignment of cadastral maps with real-world boundaries, helping to address inaccuracies in administrative boundaries, land use, and property ownership records. The workflow for these works is presented in Figure 4.

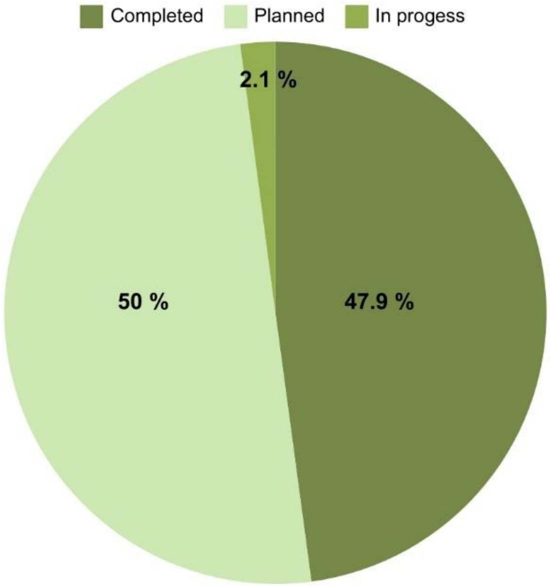

Figure 4. Workflow overview for the map improvement process

The work continues, with further updates expected to expand coverage and refine cadastral data across the country. In the coming years, the continued corrections will provide a more comprehensive and accurate land information system, which will support better decision-making in land policy and development. As more maps are updated, this initiative will also contribute to reducing conflicts over land ownership, improving land tax collection, and enhancing transparency in the real estate market. The figure 5 illustrates the extent of the adjustments made to settlement cadastral maps as of 2024 December.

Figure 5. Map of adjusted settlement cadastral maps

The community representatives have provided feedback and suggestions regarding the changes to the presented cadastral maps. From the proposed suggestions, the draft projects of 35 communities have been accepted and revised, and 35 revised projects have been submitted to the communities, which, according to the legal documents, are part of the ongoing task.

The remaining suggestions, which were primarily submitted verbally, have not been considered. These can be categorized into the following types, which are presented in figure 6:

1. Complaints/suggestions related to property boundaries, which are not considered within the scope of this work.

2. Changes to the boundaries of two neighboring settlements, particularly those adjusted by the Cadastre Committee in accordance with the description of community boundaries defined by the Law on Administrative Territorial Division of Armenia.
3. Other.

The "Other" category includes suggestions related to textual information on their own paper/archival maps and unregistered properties.

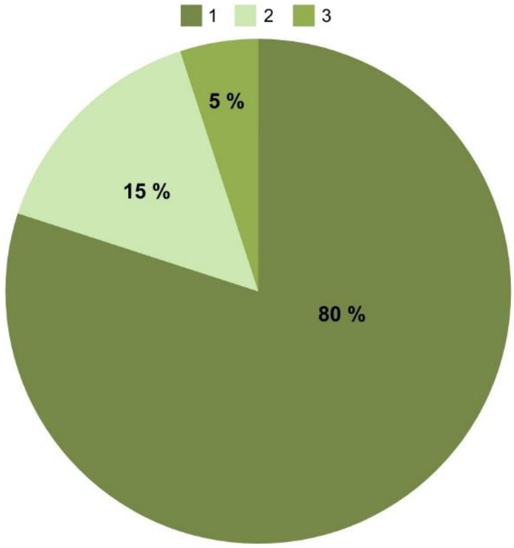

Figure 6. Distribution of feedback and suggestions

4.1 Geometric, topological and semantic error analysis

Armenia’s mountainous terrain, characterized by significant vertical zonality, has necessitated the classification of geometric deviations into two categories: one for mountainous settlements and another for flatland settlements. This classification allows for a more accurate understanding of the variations in cadastral data across different geographical areas.

In flatland settlements, the observed deviations in boundaries and buildings are as follows:

- Deviation in districts and buildings: ranging from 0.5m to 3m.

In contrast, mountainous settlements exhibit larger deviations:

- Deviation in districts and buildings: up to 210m.

The statistical distribution of geometric deviations for land areas and administrative units has been further categorized by settlement type:

- For flatland settlements:
  - Administrative unit deviation: between 0.5m and 10m.
  - Land plot deviation: between 0.5m and 3m.
- For mountainous settlements:
  - Administrative unit deviation: ranging from 0.5m to 100m.
  - Land plot deviation: up to 210m.

In addition to geometric deviations, topological errors were analyzed across different settlement types. The following errors were identified:

- For an urban settlement example, Kapan city:
  - Overlay: 150
  - Gaps: 152
  - Buildings located outside land parcels: 2
- For a rural settlement example, Saravan village:
  - Overlay: 7
  - Gaps: 17

The table below summarizes the key findings from the analysis of geometric and topological errors:

Table 1: Summary of geometric, topological, and semantic errors

Error type	**Category**	**Flatland settlements**	**Mountainous settlements**
Geometric deviation	Point deviation	0.5m – 3m	Up to 210m
	Land area deviation	0.5m – 3m (land parcel)	Up to 210m (land parcel)
		0.5m – 10m (administrative unit)	0.5m – 100m (administrative unit)
Topological errors	Overlay	150 (Kapan city)	7 (Saravan village)
	Gaps	152 (Kapan city)	17 (Saravan village)
	Buildings outside parcels	2 (Kapan city)	0 (Saravan village)

Semantic errors were also identified in the cadastral data. These include:

- Duplicate cadastral codes for land parcels and buildings.
- Cadastral codes for land parcels or buildings that do not correspond with registered property rights.
- Discrepancies between building codes and corresponding land parcel codes.

- Mismatch between the intended functional use of land parcels and the registered property rights.

Quantitative data on semantic errors includes the following examples:

- Duplicate cadastral codes: 4 property units in Kapan city.
- Building code mismatch with land plot code: 18 property units in Kapan city.

5. FUTURE PROSPECTS AND CONCLUSION

The ongoing efforts to correct and modernize the cadastral maps in Armenia represent a significant step toward improving the accuracy and reliability of land administration systems. By leveraging modern geospatial technologies, including high-resolution orthophotos and GIS tools, Armenia has made substantial progress in addressing long-standing errors in cadastral data. As of 2024, nearly half of the country's settlement maps have been corrected, with continued efforts aimed at enhancing land management, reducing property disputes, and fostering transparency in land governance.

This initiative not only enhances the accuracy of land records but also supports broader socio-economic development by improving property rights, enabling efficient taxation, and facilitating urban planning. Furthermore, the integration of advanced technologies ensures that the updated cadastral system aligns with real-world conditions and meets international standards.

Looking ahead, the potential for further technological advancements in geospatial data collection, processing, and analysis will continue to refine the accuracy of cadastral data. With a more comprehensive and updated cadastral system, Armenia will be better positioned to manage its land resources sustainably and promote economic growth. The establishment of an accurate and reliable cadastral infrastructure is a crucial foundation for the country's continued development and alignment with best practices in global land administration.

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BIOGRAPHICAL NOTES

Suren Tovmasyan is the Head of the Cadastre Committee of Armenia. With a strong background in geodesy, he has worked in various roles, including as a geodesist and consultant in multiple governmental and private sector projects. Since his appointment as Head of the Cadastre Committee in 2019, Mr. Tovmasyan has played a key role in modernizing Armenia's cadastral system, driving the integration of advanced geospatial technologies. Mr. Tovmasyan has authored 35 scientific articles and five educational manuals.

Gevorg Manukyan is the Deputy Head of the Cadastre Committee of Armenia, a position he has held since October 2023. He holds a Bachelor's degree in Urban Cadastre and a Master's degree in Cadastre and Applied Geodesy, along with a Ph.D. in Technical Sciences. Mr. Manukyan has extensive experience in the cadastral sector.

Mariam Petrosyan is an advisor to the Head of the Cadastre Committee of Armenia. She is a GIS specialist and holds a Master's degree in Cartography. Mrs. Petrosyan has extensive experience in GIS application and geoanalysis, having contributed to various projects that focus on the implementation of geospatial technologies.

Vahagn Muradyan is a geographer with extensive expertise in GIS and environmental ecology. He holds a PhD in Geography, specializing in landscape-ecological assessment through GIS. Since 2023, he has been the Head of the Geodesy and Land Management Department at the Cadastre Committee of Armenia, following his leadership of the Geomatics Center from 2020 to 2023. Mr. Muradyan is also an Associate Professor at several Armenian universities and a Leader of Data Science and Machine Learning Group at the Ecological-Noosphere Research Center.

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