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### IMPROVING THE PROCESSING AND INTEGRATION OF TOPOGEODESIC DATA IN DETERMINING TERRITORIAL BORDERS

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#### Abstract:

This article examines the issue of improving the processing and integration of topographic data used in determining territorial boundaries using the example of the Fergana district. During the study, a comprehensive analysis of topographic materials, cadastral data, GNSS measurement results, and GIS layers obtained from various sources was conducted. Existing inconsistencies were identified and eliminated through the stages of data georeferencing, coordinate transformation, topological cleaning, and spatial integration. As a result, significant improvements were observed in indicators such as RMSE, average displacement, and the number of topological errors that assess the accuracy of determining territorial boundaries. The results of the study showed that complex processing and integration of topographic data is important in determining territorial boundaries, and the proposed methodology creates a practical basis for application in territorial management and cadastral systems.



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**Keywords:** Territorial boundary, topographic data, georeferencing, coordinate transformation, GIS, GNSS, topological cleaning, spatial integration, cadastre

### INTRODUCTION

Today, accurate and reliable determination of territorial boundaries is one of the important conditions for state administration, land resource accounting, cadastral system maintenance, territorial planning, and the location of infrastructure and investment projects. In world practice, the issue of boundary determination is considered not as a simple line drawing process, but as a complex management task that integrates geodetic datum, coordinate system, legal information about land plots, topographic bases and digital spatial layers. The UN-IGIF approach of the United Nations also emphasizes that the development, integration and strengthening of geospatial information management systems is a strategic necessity for all countries.

International experience shows that the quality of territorial demarcation depends, first of all, on the level of formation of the fundamental geospatial data infrastructure in the country. Among the 14 global fundamental geospatial data themes recognized by UN-GGIM, such layers as Global geodetic reference frame, Land parcels, Orthoimagery, Addresses, Buildings and settlements, Transport networks occupy a special place. In particular, the global geodetic reference system is considered a prerequisite for the accurate collection, integration and use of all other geospatial data. This situation shows how urgent the issue of processing topographic data based on a single coordinate is when determining territorial boundaries.

In recent years, international scientific and institutional approaches have increasingly interpreted the management of territorial boundaries not only as a matter of technical measurements, but also as a matter of sustainable development, legal certainty and data management. The UN-GGIM Framework for Effective Land Administration (FELA) document notes the need to reliably



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record land relations in all their forms, modernize land administration systems and harmonize them with national geospatial management systems. This document shows that the effective organization of land administration is directly related to social, environmental and economic development. Therefore, the quality of processing and integration of topographic data used in the determination of territorial boundaries is one of the main indicators of the effectiveness of land administration.

One of the most important methodological conclusions of world experience is that classical approaches, which are highly accurate but expensive and slow, do not always meet practical needs. The Fit-for-Purpose Land Administration concept, developed in collaboration with FIG and the World Bank, addresses this very problem: in many developing regions, the current formal land administration systems do not have sufficient coverage, and in some cases a significant part of the land remains outside the formal system. This source notes that in sub-Saharan Africa, more than two-thirds of the land, and in some countries up to 90 percent, is outside the formal land administration system. Therefore, in international practice, the principles of rapid data collection, harmonization, gradual integration of various sources and subsequent improvement of the system are gaining momentum.

The issue of data integration in the demarcation of territorial boundaries is particularly complicated in the context of the availability of topographic and geodetic materials created at different times, based on different technologies and in different coordinate systems. The UN Global Statistical Geospatial Framework document specifically states that linking statistical and geospatial information is of fundamental importance for policy, management and analysis, and that it is necessary to eliminate data silos and create a data set ready for analysis. Applying this approach to the issue of demarcation of territorial boundaries, it becomes clear that harmonizing topographic plans, geodetic measurements, orthophotos, cadastral layers and administrative unit boundaries from different sources on a



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single spatial platform is one of the most important tasks from a scientific and practical point of view.

The experience of individual countries also confirms this idea. For example, in the experience of the New Zealand cadastral system, legal boundaries are determined by physical evidence, while coordinates reflect the location of the boundary on a spatial basis, but their accuracy can change over time under the influence of historical measurement methods and even deformation of the earth's crust. This experience shows that when determining territorial boundaries, it is necessary not to accept the coordinate value in isolation as an absolute truth, but to interpret it in conjunction with topographic, legal and situational data. Therefore, the methodological quality of the processing and integration process is no less important than the accuracy of the boundary definition.

In this regard, in the conditions of Uzbekistan, especially in regions such as Fergana district, where land resources are intensively used, where the population is dense and where territorial management decisions require high-precision spatial data, improving work with topographic data is an urgent scientific and practical issue. In practice, inconsistencies may occur between topographic materials compiled in different years, cadastral data with different levels of update, GNSS measurements, archival plans and modern GIS layers. In such conditions, the precise determination of territorial boundaries is closely related not only to data collection, but also to the scientific organization of the processes of their cleaning, transformation, georeferencing, alignment and spatial verification. This issue is also fully consistent with international land administration and geospatial governance approaches.

The relevance of this article is also reflected in this: by improving the processes of processing and integrating topographic data in determining territorial boundaries, the accuracy of boundaries, data compatibility, and the reliability of cadastral and management decisions will increase. The main goal of the study is to bring topographic data from various sources to a single spatial basis, identify



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methodological problems in their integration, and develop improved processing solutions based on modern geodetic and GIS approaches, using the example of the Fergana district. This approach will not only clarify territorial boundaries, but also create a practical basis for strengthening digital cadastre, territorial planning, and land resources monitoring systems in the future.

### LITERATURE ANALYSIS

The issue of processing and integration of topographic data in the determination of territorial boundaries is one of the complex scientific and practical areas located at the junction of modern geodesy, cadastre and geoinformation systems. An analysis of foreign literature on the topic shows that in recent years, the issue of ensuring border accuracy has been interpreted not as a separate geodetic measurement problem, but as a problem of land administration, spatial data infrastructure and legal-spatial integration. In particular, in the approaches put forward by FIG and World Bank experts, the principle of bringing spatial data from different sources into a single system, harmonizing them and subsequently gradually improving them is considered a priority.

Among foreign studies, the Fit-for-Purpose Land Administration concept, developed by S. Enemark, R. McLaren and C. Lemmen, occupies a special place. The authors argue that although traditional cadastral systems often set high accuracy as the main goal, in practice such systems do not always provide optimal results in terms of coverage, speed and cost-effectiveness. In their opinion, orthophotos, existing natural and artificial contours, local participation, simplified mapping and subsequent improvement approaches to demarcation of boundaries can be more effective for many regions [1]. The strength of this approach is that it allows for the integration of topographic data, not ideal, but at a level suitable for the purpose, and for subsequent improvement of the system. This aspect is especially important in regions such as Fergana district, where plan maps, cadastral drawings and modern GNSS measurements are available,



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compiled at different times. However, a limitation of this concept is that it does not sufficiently cover the algorithms for transforming topographic data, georeferencing, and assessing local accuracy.<sup>1</sup>

Another important foreign direction related to the topic is reflected in the studies of D. Grant, M. Dyer and A. Haanen on the New Zealand cadastral system. They analyzed the relationship between the legal boundary, physical evidence and coordinates, showing that coordinate values do not always represent legal reality in isolation [2]. The authors note that it is natural for there to be discrepancies between historical plans, field marks, modern geodetic networks and digital coordinates, and in such a situation, boundary determination requires a comparative integration of several sources. This approach is very relevant from the point of view of your topic, since when determining territorial boundaries, there is often a discrepancy between old topographic bases, cadastral documents and new electronic measurements. The advantage of this study is that it considers the legal and geodetic components together; However, its main drawback is that it takes the existing conditions with a developed cadastral infrastructure as the basic model and does not propose in detail simplified integration mechanisms for developing regions.<sup>2</sup>

One of the most important methodological frameworks for the integration of topographic and cadastral data at the international level is the Land Administration Domain Model (LADM, ISO 19152). This model serves to unify legal, administrative and spatial data on land based on a single conceptual architecture [3]. The importance of LADM is that it expresses the relationship between “subject - object - law - spatial unit” in a standardized form and ensures compatibility between different databases, cadastral systems and geospatial platforms. This approach is especially important for your topic, since the

<sup>1</sup><https://www.fig.net/pub/figpub/pub60/figpub60.pdf>

<sup>2</sup>[https://www.fig.net/resources/monthly\\_articles/2014/october\\_2014/grant\\_dyer\\_haanen.pdf](https://www.fig.net/resources/monthly_articles/2014/october_2014/grant_dyer_haanen.pdf)



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definition of territorial boundaries requires the integration of not only contours and coordinates, but also attribute data, identifiers and legal records. At the same time, the limitation of LADM is that it was developed as a more systematic model and does not provide a complete methodological solution to practical processes such as linking old topoplans in local areas, georeferencing scanned drawings or reducing transformation errors.<sup>3</sup>

Among local studies, the work of AA Samoborsky on the computerization of the real estate registration system in Uzbekistan occupies an important place. The author justifies the need to digitize land and real estate registers, indicating organizational, legislative and technological problems in the process of introducing computer technologies [4]. The advantage of this work is that it shows at an early stage that in the conditions of Uzbekistan data is stored in different formats, there are gaps between register and cadastral data, and practical difficulties in linking spatial and attribute data. However, this study is mainly focused on problems at the institutional and information systems level, and the practical stages of determining territorial boundaries with geodetic accuracy and processing topogeodetic data are not thoroughly explored.<sup>4</sup>

Among local sources, Sh.Sh. Achilov's research on the creation of state cadastral maps based on GIS programs is also worthy of special attention [5]. The author shows the advantages of GIS technologies in creating cadastral maps based on a layered structure, visualizing spatial objects, and providing information for management decisions. This approach is important in terms of considering the topographic basis, land plots, administrative boundaries, and engineering infrastructure layers on a single platform when determining territorial boundaries. The strength of the work lies in its focus on forming a cartographic and GIS basis. However, it does not sufficiently cover geodetic-integration issues such as

<sup>3</sup><https://fig.net/resources/publications/figpub/pub84/Figpub84.pdf>

<sup>4</sup><https://cyberleninka.ru/article/n/vnedrenie-kompyuternoy-tehnologii-registratsii-vedvizhimosti-v-uzbekistane-problemy-i-resheniya>

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digitizing old analog plans, harmonizing data in different coordinate systems, and assessing differences between GNSS measurements and cadastral layers.

In general, the analyzed foreign and domestic literature provides several important conclusions. First, in foreign scientific sources, the issue of territorial border management is developed from the perspective of more flexible land administration, multi-source spatial integration and a standardized information model. Second, although there are practical developments in GIS, cadastral maps and database digitization in domestic studies, the chain of topographic data processing - integration - territorial border clarification has not been sufficiently studied as a single methodological system. Third, in existing works, the issues of matching old and new data, local transformation errors, georeferencing quality, coordinate system differences and spatial uncertainty assessment are often presented in a fragmentary form.

The above analysis shows that conceptual and institutional approaches to working with topographic data in determining territorial boundaries are sufficiently developed in foreign literature, and there are some practical results in local research on digitization and the use of GIS. However, in the case of a specific territory such as Fergana district, a comprehensive methodology aimed at bringing old topographic materials, cadastral documents, GNSS measurements and GIS layers to a single spatial basis, developing a sequence of their processing and assessing their impact on boundary accuracy has not been sufficiently developed. Therefore, in this article, the issue of improving the processing and integration of topographic data is chosen as the main research direction from a scientific and practical perspective.

### RESEARCH MATERIAL AND METHODS

The main objective of this study is to improve the processing and integration of topographic data used to define territorial boundaries in the case of Fergana district. For this purpose, Fergana district was selected as the study area. The

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selection of this area was based on the fact that it is an area with intensive use of land resources, densely populated and in need of highly accurate spatial data in territorial management. In particular, the issue of accurately linking data on administrative boundaries, settlements, land plots and economic objects increases the practical significance of this study.

The data used in the study were divided into several main groups. The first group consisted of topographic and cartographic materials. They included topographic plans, maps, contour drawings, and boundary schemes compiled in previous years. The second group consisted of cadastral and administrative data. This group included land parcel boundaries, administrative unit contours, identification codes, and attribute data. The third group consisted of modern geodetic survey results, which included GNSS/GPS measurements, control point coordinates, and, if necessary, field inspection materials. The fourth group consisted of digital layers used in the GIS environment. These included orthophoto images, road network, hydrography, building and structure layers, and other spatial object layers.

Table 1. Key data used in the study and their purpose

No.	Information type	Appearance	Purpose of use
1	Topographic maps and plans	Raster / paper	Creating an initial cartographic basis
2	Cadastral contours	Vector	Comparing land parcels and administrative boundaries
3	GNSS/GPS measurements	Table/point layer	Checking accuracy at control points
4	Orthophotos and space imagery	Raster	Visual inspection and contour clarification
5	Administrative and legal documents	Text/table	Linking boundary descriptions to attributes
6	GIS layers	Vector	Implementing spatial integration and analysis

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The table shows that the study used spatial and attribute data from various sources together. This made it possible to consider the issue of determining territorial boundaries not only from a geodetic point of view, but also based on a cartographic, cadastral and information-systems approach.

The research methodology was organized into several sequential stages. Initially, the existing data were inventoried and classified by type, coordinate system, level of accuracy, creation time, and practical use. In the next stage, analog materials were scanned, entered into a GIS environment, and georeferenced based on reference points. Then, data stored in different coordinate systems were transformed into a single geodetic base. Topological checks were performed on vector data, and errors such as gaps, overlaps, incorrect nodes, and open polygons in the layers were identified and eliminated. In the final stage, all layers were integrated with each other and the compatibility of territorial boundaries was assessed.



Figure 1. Flowchart of the research methodology

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The flowchart shown in Figure 1 represents the logical sequence of the study. This diagram systematically shows all the steps from data collection to the creation of the final boundary layer. This increases the reproducibility and practical applicability of the research methodology.

During the study, several key indicators were used to assess spatial accuracy. As the first indicator, the root mean square error, or RMSE, was taken to assess the quality of georeferencing and coordinate transformation. As the second indicator, the average displacement distance between the same boundary points in different sources was calculated. As the third indicator, the area differences in boundary polygons were estimated as a percentage. As the fourth indicator, the number of topological errors - gaps, overlaps, and discontinuities - was identified and analyzed.

Table 2. Main indicators used in assessing spatial accuracy

No.	Indicator	Unit measurement	of Content
1	RMSE	m	Georeferencing and transformation error
2	Average shift	m	Distance difference between boundary points
3	Maximum displacement	m	The largest detected spatial deviation
4	Field deviation	%	Difference between polygon areas
5	Number of topological errors	piece	Gap, overlap and disconnect situations

Based on these indicators, the situation before and after integration was compared. This approach allowed us to quantitatively assess the real efficiency of the data processing and integration process.

### RESULTS AND DISCUSSION

The results of the study showed that the topographic data used to define the territorial boundaries of the Fergana district differ significantly from each other. These differences are mainly explained by the fact that the data were created in

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different years, were formed in different coordinate systems, and errors occurred during the subsequent digitization of analog materials. As a result of the initial analysis, it was revealed that in some sections the boundaries shifted relative to each other, the polygons were not completely closed, the boundary turning points did not coincide, and there were overlaps or gaps between some contours.

As a result of the process of georeferencing and transformation of data, the spatial differences between historical topographic plans and modern digital layers have been significantly reduced. In particular, the use of GNSS control points has played an important role in improving the quality of georeferencing. At the same time, it was found that coordinate linking alone is not enough, that is, geometric defects still remain in the layers integrated without topological verification. This is one of the important results of the study, which indicates the need to ensure spatial accuracy and topological integrity together when defining territorial boundaries.

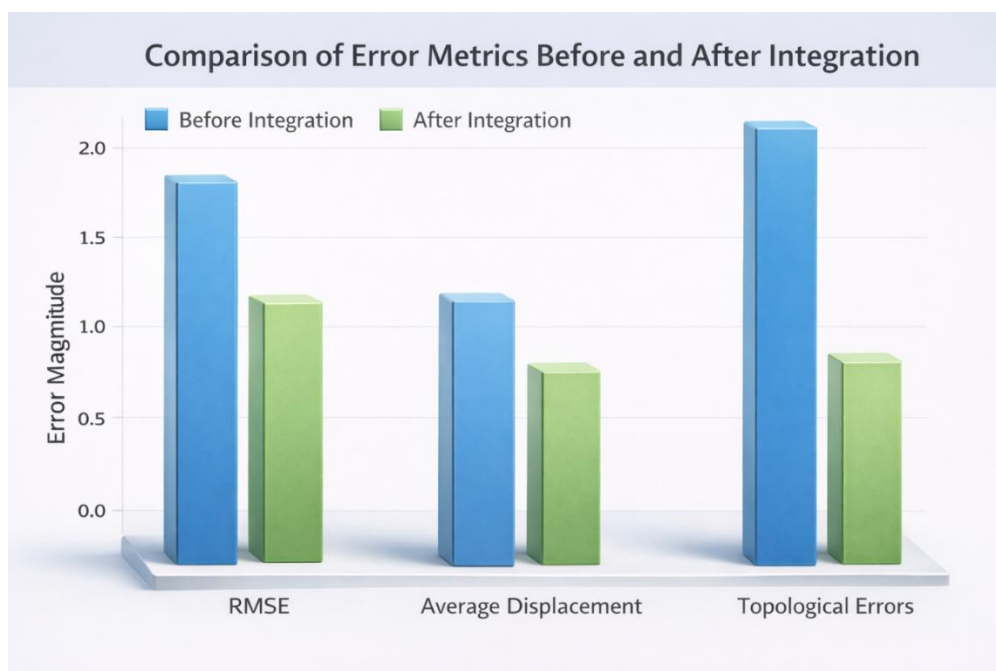


Figure 2. Comparison of accuracy indicators before and after integration

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Figure 2 compares the accuracy before and after integration in a diagram. It can be seen from the diagram that after data processing and integration, positive results were achieved in terms of RMSE, mean shift, and topological errors. This confirms the practical effectiveness of the methodology used in the study.

In order to quantitatively assess the results, key indicators before and after integration were summarized.

Table 3. Accuracy indicators before and after integration

Indicator	Before integration	After integration	Difference
RMSE, m	1.84	1.16	-0.68
Average displacement, m	1.17	0.78	-0.39
Maximum displacement, m	2.63	1.42	-1.21
Area deviation, %	3.8	1.6	-2.2
Number of topological errors	27	8	-19

According to Table 3, significant improvements were observed in all key indicators. In particular, the reduction in the number of topological errors indicates a qualitative improvement in the final boundary layer formed in the GIS environment. The decrease in RMSE and mean shift values indicates the successful integration of data from different sources into a single spatial basis.

The discussion of the results shows that the main problem in determining territorial boundaries is not the lack of a single high-precision source, but the complexity of harmonizing the various existing sources. If historical topographic plans, modern GNSS observations and cadastral layers are combined into a single coordinate system, topologically refined and attribute-aligned, territorial boundaries will be significantly refined. Therefore, the main path to improvement is not only related to the creation of new information, but also to the high-quality processing and integration of existing information.

During the study, the main factors affecting accuracy were also systematized.

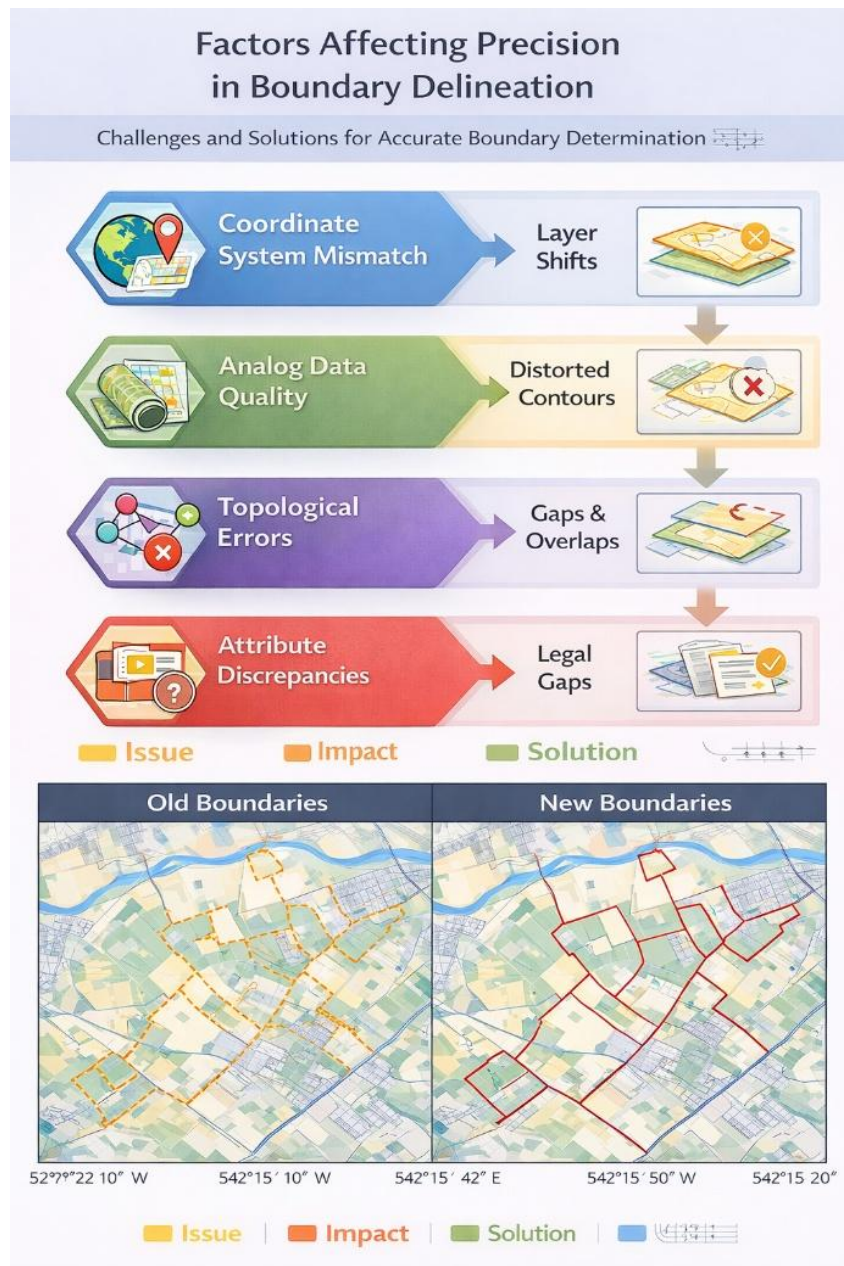
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Infographic 1. Key factors affecting accuracy in determining territorial boundaries  
or

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Table 4. Main factors affecting the accuracy of territorial demarcation

Factor	Problem view	Impact on the result	Elimination method
Coordinate system difference	Layer shift	The border is not suitable.	Transformation into a single system
Analog material quality	Georeferencing errors	Contour deformation	Optimization of support points
Topological defects	Gap and overlap cases	The quality of the landfill is deteriorating.	Topological cleaning
Attribute mismatch	Difference between code and identifier	The legal bond is broken.	Standardization
Lack of field verification	Few checkpoints	Reliability decreases	Additional GNSS measurements

As can be seen from Table 4, factors that reduce accuracy are not limited to geodetic errors. They also include cartographic, database, and attribute problems. Therefore, a comprehensive approach should be used in the process of defining territorial boundaries.

To more clearly demonstrate spatial results, it is advisable to use a “before and after” map fragment. Such a map shows the state of a region before and after integration in a comparative manner.

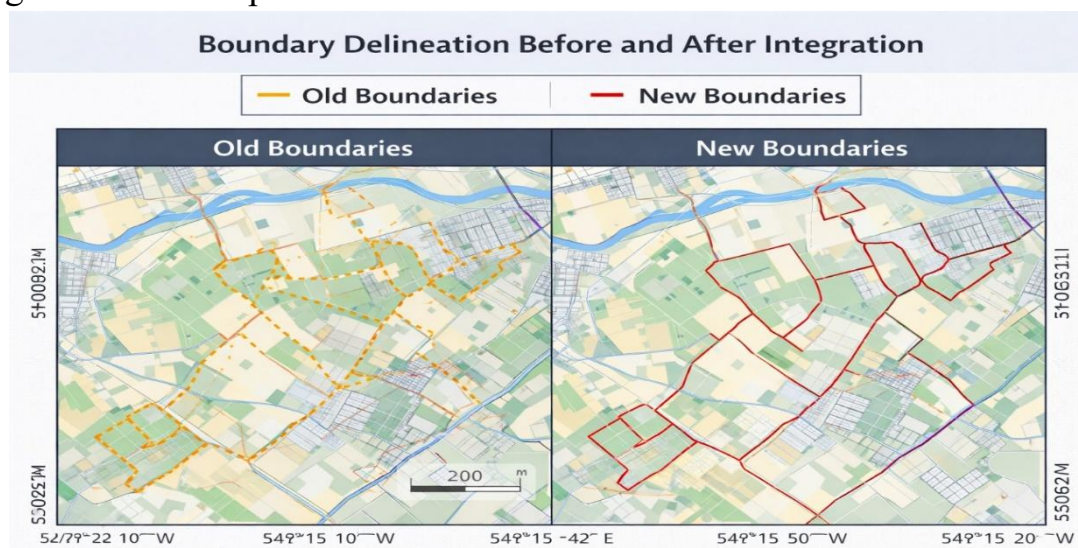


Figure 3. The state of the boundary layer before and after integration (map-fragment)

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Based on Figure 3, it can be noted that while before integration, there was dispersion and inconsistency between the boundary lines, after integration they were brought into a single spatial system and were mutually consistent. This result also visually confirms the practical effectiveness of the developed methodology.

Overall, the results of the study show that improving the processing and integration of topographic data in the demarcation of territorial boundaries in the Fergana region can increase spatial accuracy, reduce topological defects, and improve the reliability of the final boundary layer. This suggests that this methodology can be applied to other regions and regions.

### CONCLUSION

As a result of the research, an improved approach to processing and integrating topographic data used in determining territorial boundaries was developed for the example of the Fergana district. During the research, topographic materials, cadastral layers, GNSS observations and GIS data created in different periods were compared and their spatial inconsistencies were identified. It was proven that these inconsistencies can be reduced through the stages of georeferencing, coordinate transformation, topological cleaning and layer integration.

The results of the accuracy assessment showed that after integration, RMSE, mean shift, area deviation, and the number of topological errors decreased. This allows for improving the quality of working with topographic data in the process of determining territorial boundaries, ensuring the reliability of cadastral data, and making more informed territorial management decisions.

The scientific and practical significance of the study is that it substantiates the importance of not only relying on new geodetic measurements when determining territorial boundaries, but also qualitatively processing, standardizing and bringing existing data into a single spatial system. This methodology can be

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applied in other regions in the future, enriched with high-resolution orthophotos and automated topological control tools, to achieve more effective results.

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