Integration of Geospatial Data into the Cadastre System

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Abstract

Remote sensing serves as a fundamental tool for the creation and regular updating of cadastral maps. In the era of digital technologies, the integration of data obtained from unmanned aerial vehicles (UAVs), satellites, and multispectral sensors significantly enhances the precision and efficiency of cadastral activities. Remote sensing systems encompass advanced methods such as photogrammetry, geographic information systems (GIS), geoinformatics, and statistical modeling, contributing to comprehensive spatial data analysis. The implementation of a phased approach to digital mapping—at national (1:100,000), regional (1:10,000), and local (1:2,000) scales—forms the basis for the systematic maintenance of state cadastres. This study highlights the importance of remote sensing in acquiring high-resolution, reliable data for sustainable land management and effective cadastral planning.

1. Introduction

1.1 Remote Sensing and Its Role in Cadastral Works

Remote sensing materials serve as the main source for creating and updating cadastral maps. Remote sensing of the Earth is considered the study of the earth from the air, i.e., by means of unmanned aerial vehicles (UAVs), airplanes, drones, and spacecraft. It is a complex system that includes remote imaging of the Earth, visualization and systematic image processing, photogrammetry, as well as sciences such as geomatics, geoinformatics, geographic information systems (GIS), space geography, statistical data processing, monitoring formation, and forecasting. The main task of Earth remote sensing is to create topographic and thematic maps.

Currently, in the 21st century, the age of information technology, remote sensing of the Earth is carried out using unmanned aerial vehicles (UAVs), drones, airplanes, and helicopters, as well as artificial earth satellites. Also, digital cameras, scanners, video images, radar, and thermal sensors are widely used in obtaining Earth remote sensing materials. Earth remote sensing is a field that requires obtaining fast, accurate, and reliable data and is widely used in environmental management.

In addition, the creation of multi-spectral sensors through satellite technologies has further increased the possibilities in the field, creating a basis for obtaining information about the environment over very large areas of the earth that is imperceptible to the human eye with the help of these technologies .

1.2 Digital Cadastral Mapping at Different Scales

It is also advisable to make extensive use of Earth remote sensing materials to obtain high-precision data for the perfect maintenance of cadastral works. For the purpose of systematic maintenance of state cadastres, recommendations have been developed for the phased formation of digital maps of the 20 existing state cadastres in the context of the relevant scales. Here, it is initially envisaged to form the general state of all state cadastres at a scale of 1:100,000 at the national level; in the second stage, a scheme for creating cadastral maps and forming a geodatabase at a scale of 1:10,000 for regions and 1:2000 for districts has been developed (Figure 1).

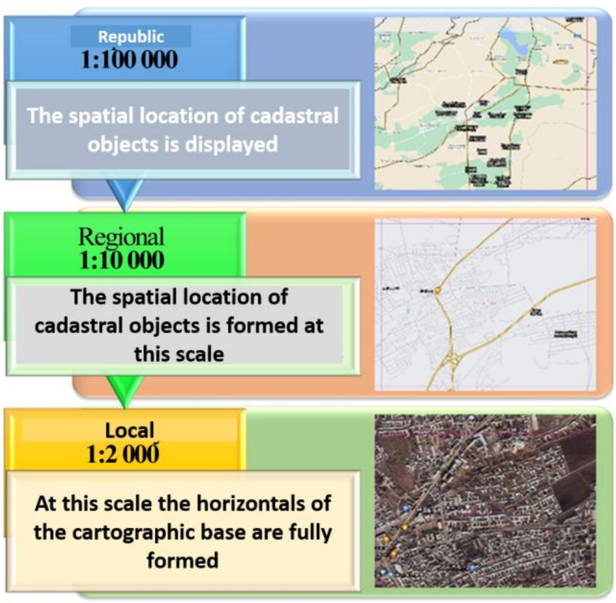

Figure 1. Scheme for forming a geodatabase at different scales

Based on the scheme shown above, the formation of state cadastre objects at appropriate scales is analyzed and implemented to serve the intended purpose. For example, when establishing interactive services for the government, the level of specified tasks is indicated when conducting query analyses. These levels are implemented locally, regionally, and at the Republic level. Digital cadastral maps formed in the 1:2,000 scale geodatabase are widely used for solving cadastral issues at the local level.

Before drones were introduced in our Republic, topographic surveys were carried out based on on-site geodetic work to create 1:2,000 scale digital cadastral maps. Carrying out geodetic works required several field research studies. In this case, it was required to conduct topographic-geodetic field research using an electronic tacheometer to create digital cadastral maps. This takes 2-3 days to topographically and geodetically survey an average land area of 10 hectares. If this research is conducted at the local or regional level, the topographic-geodetic field survey requires at least 4-5 months. However, conducting topographic-geodetic field research using UAVs, drones, or airplanes takes 1 hour for a 10-hectare area, and 5-10 days at the local or regional scale. For this purpose, during systematic research, it was determined that it is expedient to create digital cadastral maps using geo-images obtained from Earth remote sensing devices.

Remote sensing materials are considered primary data for the systematic maintenance of the cadastre and for creating and updating digital maps. After the first drones were brought to our Republic, the work of creating 1:2000 scale electronic digital cadastral maps using drones was launched for the maintenance of the "Buildings and Structures" state cadastre. This greatly served to increase work efficiency. Nevertheless, some errors occurred when using these remote sensing materials to create cadastral maps and plans. Due to these errors, the topological mismatch of cadastre objects exceeded 5 meters, and in some places, 10 meters. This, in turn, caused the incorrect reflection of the boundaries of some land parcels. As a result, the probability of legal and technical disagreements increased. (Figure 2).

Figure 2. Errors that occurred when mapping buildings and structures onto a cadastral map using remote sensing materials.

For conducting regional-level analyses, digital cadastral maps created in the 1:10,000 scale geodatabase are used. For Republic-level analyses, it is recommended to use 1:100,000 scale digital cadastral maps. With these maps, large- and small-scale analyses are carried out effectively. Maps of each scale have their own level of detail and scope of generalization. Small-scale maps are mainly intended to provide generalized information. Therefore, cadastral maps serve as an important tool in management and planning at various scales.

For creating 1:10,000 and 1:100,000 scale digital cadastral maps, it was deemed most optimal to create them based on images obtained through remote sensing (Figure 3).

1.3 Challenges, Errors, and the Need for New Methodologies

The results of systematic research and literature review showed the need to create a new methodology for creating and updating digital cadastral maps and plans in order to eliminate this error. Based on the objective, the need was identified to create a new methodology based on the maximum use of remote sensing materials for registering 1:2000 scale cadastre objects and their precise geospatial placement on digital cadastral maps.

Currently, data from the Landsat 8 spacecraft is mainly used for creating and updating state digital cadastral maps. Improving the mechanism for the geospatial placement of cadastre objects based on appropriate coordinates and for forming and maintaining cadastral information in a geodatabase is an important issue today.

Figure 3. 1:10,000 scale satellite image of the Charvak reservoir

2. Systematization of State Cadastre Data

Information on the 20 existing state cadastres is being collected by the relevant authorized organizations according to the tables provided in the annexes of the Regulation "On the composition of state cadastre data for the unified system of state cadastres and the procedure for their submission".

The information request for each state cadastre is provided in the annex of this Regulation, according to which there are guidelines that define the quality and quantity indicators of cadastre objects. As a result of the research, the systematization and domain-setting of the request attribute columns for these state cadastres were carried out. Recommendations were developed for the on-site topographic investigation of cadastre objects, the formation of analyzed information in the cadastre geodatabase, and the systematization of filling the attribute data table.

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3. Stages of Cadastral Map Formation

According to this recommendation, it was determined to be appropriate to carry out the work of maintaining and systematically forming state cadastres based on the four principles listed below (Figure 4):

1. Conducting on-site research (topographic-geodetic works);
2. Converting necessary information related to the cadastre object into the geodatabase;
3. Visualizing cadastre objects based on the created geodatabase;
4. Filling cadastral attribute data tables.

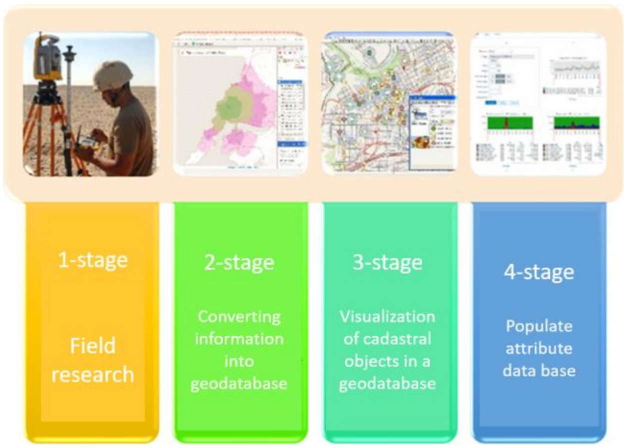

Figure 4. Stages of maintaining and forming state cadastres

In the first stage of maintaining and forming state cadastres, the results of on-site research conducted using geodetic instruments, i.e., a tacheometer and Global Navigation Satellite System (GNSS), are downloaded to a computer and projected based on a rectangular coordinate system. In this case, the results of the tacheometer survey are projected in the rectangular coordinate system, while the results obtained using GNSS are projected based on the geographic coordinate system. After the coordinates in these two systems are reconciled, it becomes possible to create accurate cadastral drawings based on their combined model. Also, this data is processed in GIS programs and serves to create digital maps.

In the second stage, after the tacheometer survey results were downloaded to the computer, they were exported to the GIS geodatabase. The ArcGIS program was used to convert the results obtained using GNSS from the geographic coordinate system to the rectangular coordinate system when converting them to the GIS geodatabase. Analyzing the quality and quantity indicators of cadastre objects formed based on the geographic coordinate system causes several inaccuracies in the ArcGIS program. To eliminate these inaccuracies, the geographic coordinates of cadastre objects obtained using GNSS were converted to the rectangular coordinate system and exported to the GIS geodatabase (Table 1).

Thus, the projection results are formed in the GIS geodatabase and entered into one of these two types of geodatabases. The data entered into this database subsequently serves as the main source for analysis, monitoring, and report preparation. As a result, a high level of accuracy and reliability of the cadastre system is ensured.
In the third stage, thematic layers are created and visualized in the established order using the example of cadastre objects. The creation of thematic layers was studied during the research and is reflected in Table 2 below (formed on the example of 5 state cadastres; analyses for the remaining 15 state cadastres are provided in the appendix).

Coordinate System	System Unit	Projection Name	System Conversion Sequence
WGS 84	Geographic	Cylindrical	WGS 84 (geographic)-CK42 (geographic)-CK42 (rectangular)
CK-42	Rectangular	Gauss-Kruger (Azimuthal)	

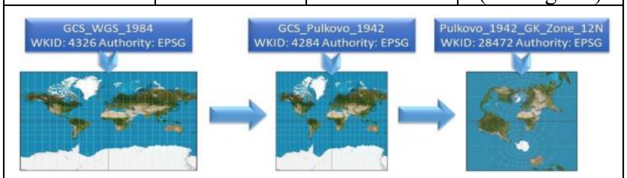

Table 1. Scheme for converting from one coordinate system to another. * 2021

№	State Cadastre	Vector Layer	Layer Type
1	State cadastre of areas with high technogenic risk	1. Enterprises with a high technogenic risk zone	point
		2. Zones where high technogenic risk may occur	areal
		3. Evacuation or relocation of people from the zone	linear
		4. Description of fire safety of buildings and structures	point

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		5. Fire-fighting water sources	areal
		6. Facilities for the production, processing, storage, and use of radioactive products, radioactive and other substances	areal
		7. Enterprises with radiation risk	areal
		8. Zones where radiation risk may occur	areal
2	State Water Cadastre	1. Water bodies — surface waters	areal
		2. Water levels, Water discharge	point
		3. Groundwater deposit resources	point
		4. Approved reserves of groundwater deposit sites	point
		5. Water withdrawal facilities	areal
		6. Use of groundwater	point
		7. Use of water for various needs in territories	point
3	State Forest Cadastre	1. Forestry departments	areal
		2. Forest quarters	areal
		3. Forested lands	areal
		4. Non-forested lands	areal
4	State cadastre of flora objects	1. Lower plants	areal
		2. Vascular plants	areal
		3. Fungi	areal
		4. Description of the state of natural vegetation cover of pastures and hayfields	point
5	State cadastres of protected natural areas	1. Protected natural areas	areal
		2. Flora of protected natural areas	areal
		3. Fauna of protected natural areas	areal
		4. General description of state natural monuments	point
		5. Main results of nature protection activities in protected natural areas	point

Table 2. Classification of State Cadastre Objects in the Form of Layers

In the table above, analytical work on the state cadastre has been carried out, and it is determined that the data for each state cadastre should be maintained based on an average of 5 vector layers. During the research, recommendations were made on the optimal type of vector layers to use (Figure 5).

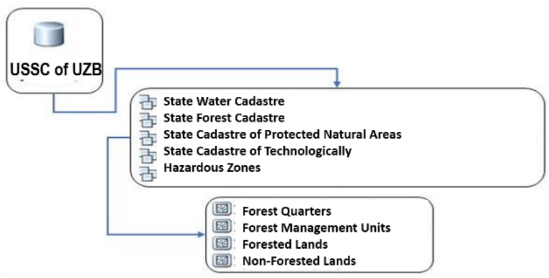

Figure 5. Vector layers of state forest cadastre objects in the geodatabase

In the fourth stage, we will consider the formation of objects for the forest cadastre as an example of filling attribute data tables. For the forest cadastre, 4 thematic layers in the form of areas are formed. As a result of loading the conducted topographic field research into this Geoinformation System (GIS) geodatabase and filling in the attribute data, it is visualized as shown in the following figure (Figure 6.). In addition, for the state cadastre of buildings and structures, data is formed by regional cadastral agencies and entered into the geodatabase in the form of an area layer.

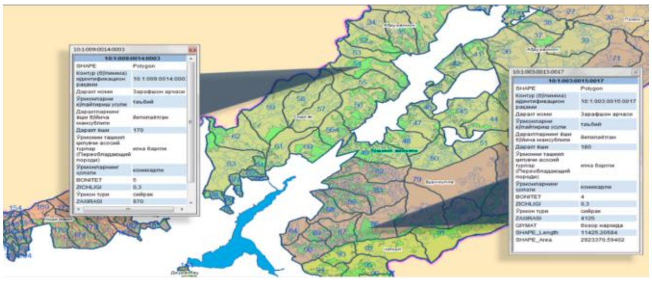

Figure 6. View of the State Forest Cadastre in the geodatabase.
*State Cadastres data, 2024.

According to the state cadastre of areas with high man-made risk, the vector layers of enterprises with high man-made risk zones have also been maintained in an area layer to this day. This, in turn, causes topological errors and creates problems in performing analytical operations and cartographic visualization.

For this reason, during the research, it was recommended to form the vector layers of cadastral objects differently. As a result, the visualization of cadastral maps was brought to the required level (Figure 7.)

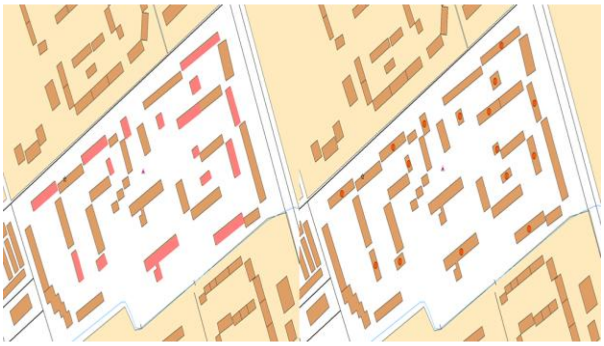

Figure 7. Visualization level of cadastral objects in the geodatabase

In the maintenance of all state cadastres, the land cadastre and the digital maps of the building and structure cadastre play an important role. These digital cadastral maps serve as a basis for maintaining all cadastres and for the geospatial positioning of cadastral objects. As a result of land accounting in our republic, the land balance is formed. Land balance data is maintained in the ArcGIS program in the form of an electronic digital map. As a result, land cadastre information is formed. In the same way, state cadastre data for buildings and structures is also maintained in the ArcGIS program.

4. Accuracy and Advantages of the Combined Method

Based on systematic analyses, it was found expedient to create the improvement of the methodology for using remote sensing materials in creating and updating digital cadastral maps on the basis of the Overlay system. In creating this methodology, the necessity of relying on a single projection, a single coordinate system, a single digital cartographic basis, and a single scale theory was determined. Because the single vector digital cartographic basis created on the basis of the Overlay system is implemented according to the relevant nomenclature. In this, first, a 1:2000 scale digital cadastral cartographic basis for the republic is created using remote sensing materials, then this created digital cadastral cartographic basis is provided as a digital cartographic layer to the relevant organizations by region, and from the regions, it is provided to the district cadastral departments.

This methodology of using remote sensing materials for creating and updating cadastral maps was implemented in four main stages. In this, the first stage envisages the creation of a 1:2000 scale vector cadastral cartographic basis for the territories. The second stage covered the issues of transferring the digital 1:2000 scale vector cartographic basis to the territories, as well as the geospatial positioning and acceptance of thematic cadastral layers. The subsequent stages covered the issues of forming cadastral layers in districts and creating 1:2000 scale digital map layers of networks (Figure 8).

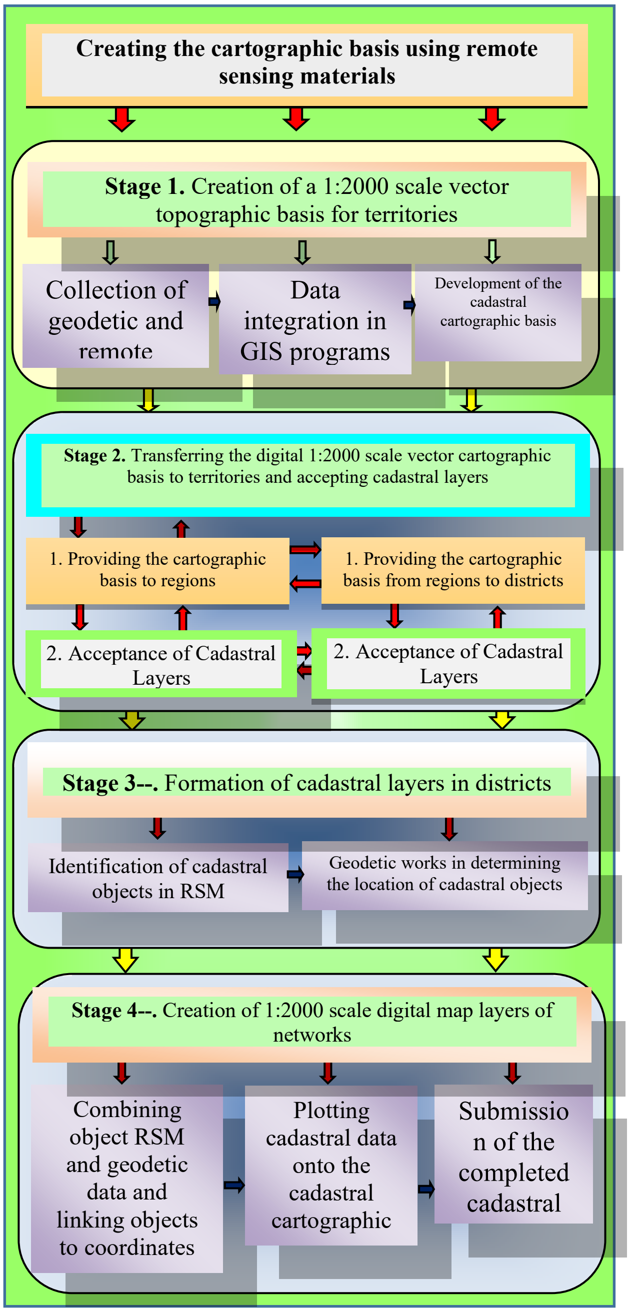

Figure 8. Methodology for creating a cartographic basis using remote sensing materials in the GIS Overlay system

The interconnection in the first and second stages of improving the methodology for applying remote sensing materials in creating and updating cadastral maps is achieved by integrating the accuracy of remote sensing technologies with geodetic data.

This method increases the efficiency of the cadastral system, reduces errors in land resource management, and improves monitoring processes. Also, integrated systems allow for the rapid updating and analysis of high-accuracy data.

In the stage of creating a 1:2000 scale vector topographic basis for territories, the main focus was on collecting remote sensing materials (RSM), selecting geodetic, topographic, and GIS programs, and developing the cadastral cartographic basis. In creating this cadastral cartographic basis, remotely sensed data, the results of geodetic field measurements, and cartographic sources were widely used. Their mutual overlay created a foundation for increasing the accuracy of the spatial location of cadastral objects on the map.

In the second stage of the methodology for creating a cadastral cartographic basis from remote sensing materials on the basis of the Overlay system, taking the map scale as 1:2000 ensures the mutual joining of map sheets based on the nomenclature.

In this case, the initially created cartographic basis of the republic is provided to its respective territories by region, and then transmitted from the region to the districts. In the districts, cadastral objects plotted on the cartographic basis are formed in a separate layer, and when necessary, the layer containing information about the cadastral objects is provided to users. These sent layers ensure their proper spatial positioning on the cartographic basis of the higher organization, i.e., the region and the republic.

In the third stage, the main work was focused on identifying cadastral objects in remote sensing materials (RSM) and on geodetic works to determine the location of the objects.

Applying the combined method was accepted as the most effective way to form cadastral layers in districts and to increase their locational and spatial positioning accuracy. Currently, while only remote sensing materials (RSM) have been used to place cadastral objects on the cartographic basis, the accuracy of this data was 5–10 meters. However, the results of geodetic measurements increased the accuracy of this indicator to 1–2 meters. This shows the necessity of implementing high-accuracy spatial analysis methods to ensure the reliability of cartographic data. (Figure 9).

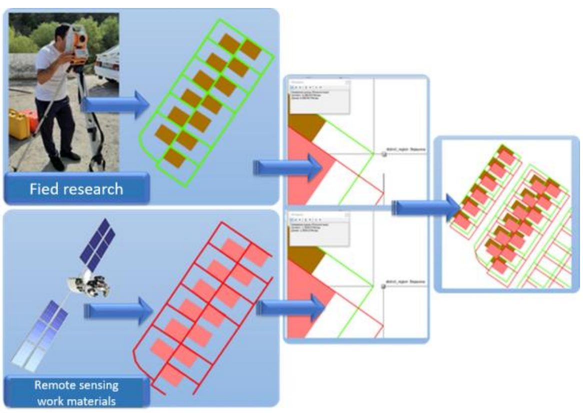

Figure 9. Difference in objects in the application of the combined method

When comparing field geodetic measurement results and remote sensing materials (RSM) data, we can see that a 5-10 meter error occurred. It is possible to achieve this accuracy even without fully implementing the combined method. In this case, when surveying at the mahalla (neighborhood) level, survey work is carried out on the sides of the starting and ending objects of the streets, and the obtained results are overlaid with remote sensing data (Figure 10).

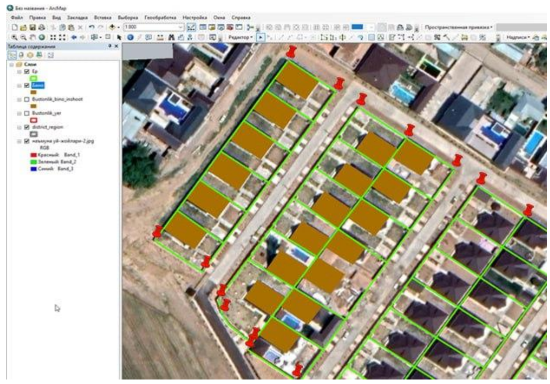

Figure 10. Points to be geodetically surveyed

Based on the cadastral map scale, and considering that the map accuracy is 0.2 meters at a 1:2000 scale, the positional accuracy of intermediate objects is brought to 2 meters, which is considered high accuracy for cadastral maps. This level of accuracy is especially important in identifying land parcels, defining legal boundaries, and formalizing property rights. Furthermore, high spatial accuracy data increases the reliability of the cadastral system and ensures efficiency in digital map creation processes. This situation also facilitates seamless integration with geoinformation systems (GIS).

In the fourth stage of the methodology for using remote sensing materials in creating and updating cadastral maps, the tasks of creating 1:2000 scale digital map layers, combining object remote sensing data and geodetic data, geospatially linking objects, plotting objects onto the cadastral cartographic basis, and submitting the created cadastral layer to the higher organization are carried out.

The formation of cadastral maps was carried out on the basis of developing the composition of structures and sequences. Selecting elements for geographic databases for these objects and developing serial sections of maps on a thematic basis; creating legends; compiling instructions for generalization; and justifying the sequence of links are of great importance.

Creating a series of cadastral maps at the specified scale serves as a source for the initial set of maps. In this process, first, the cadastral information system of the lower-level territorial divisions, i.e., at the district level, is formed. Then, for the middle (regional level) and high (republican level) territorial divisions, special maps are developed for differentiating, studying, and evaluating cadastral objects.

As a result of developing a method for creating state cadastre maps based on the Overlay system using remote sensing materials for creating and updating cadastral maps, a 1:2000 scale cadastral cartographic basis was created for the districts of Tashkent city and the Bostanliq district. In this process, cadastre-related cartographic-geodetic data were collected and studied. As a result of targeted research, remote sensing data for the area under investigation were collected, and using the combined method, they were integrated with geodetic cartographic data, and changes were identified by overlaying the objects.

Cadastral maps created based on the combined method are considered to have high accuracy. In creating the base map series for state cadastres, the initial set of maps serves as a basis. In this process, first, the cadastral information system of the lower-level territorial divisions, i.e., at the district level, is formed. Then, it is recommended to produce special maps for differentiating, studying, and evaluating cadastral objects for the middle (regional level) and high (republican level) territorial divisions.

5. Conclusion

In conclusion, it should be noted that implementation based on the integration of remote sensing materials and geodetic field research work within the Overlay system has created a foundation for increasing the geospatial positioning accuracy of state cadastre objects and for eliminating topological errors when converting them to a topographic basis.

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