БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ

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GIS FOR LAND RESOURSE MANAGEMENT

ГИС В УПРАВЛЕНИИ ЗЕМЕЛЬНЫМИ РЕСУРСАМИ

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по специальностям «география»,
«землеустройство, кадастры,
геодезия и геоматика»*

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Рассмотрены вопросы управления земельными ресурсами с использованием геоинформационных систем на основе данных дистанционного зондирования, геодезических съемок, глобальных навигационных спутниковых систем, сканированных планово-картографических материалов и векторных данных. Применение ГИС-картографирования земельных ресурсов показано на примере опыта Республики Беларусь. Приведены вопросы для самопроверки и практические задания.

Для студентов учреждений высшего образования, обучающихся по специальностям «география», «землеустройство, кадастры, геодезия и геоматика».

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PREFACE

Today in the Republic of Belarus the widest application of geographic information systems (GIS) is noted in the field of information support and automation of land surveying works, land cadastre and monitoring of land resources. GIS specialists have an important role in information support of decision-making on organisation of effective land use, its improvement and protection. They should be proficient in technologies of creating and filling geodatabases, using remote sensing data, geodetic surveys and global navigation satellite systems, vector and raster data in geoinformation mapping of land resources.

The coursebook on the discipline “GIS for Land Resource Management” is prepared in accordance with the curriculum for students of the Master's degree specialities “Geography”, “Land Management, Cadastres, Geodesy and Geomatics” and consists of 6 chapters.

The first chapter discusses of using of GIS in land resources mapping, provides information on the establishment and development of GIS methods in this area, software, and the specifics of this area in Belarus. The second chapter highlights the classification of remotely sensed data used for land resources management, and describes the methods and techniques of image interpretation. The third chapter reveals process of GIS-mapping of lands based on geodetic surveys and global navigation satellite systems. The fourth chapter considers the main stages of GIS-mapping of land resources on the basis of cartographic materials and gives examples of using these materials in Belarus. The fi th chapter outlines the peculiarities of design and symbolisation of land cadastral maps with the help of GIS and gives examples of using vector models. The sixth chapter contains practical tasks on GIS-mapping of land resources.

1. BASICS OF GIS FOR LAND RESOURCE MANAGEMENT

1.1. Geoinformation Mapping of Land Resources

Land resources are understood as land, plots of land, which are used or may be used in economic or other activities. Land resources play an important part in the development of human society. Land represents the basis of human life activity, and at the same time it is a natural resource, the bearer of fertility, the source of material goods, the territorial basis for placing structures and communications, a special commodity and an object of legal relations, etc. The appearance of land farms brought about the problems of demarcation, delimitation, allotment, redistribution of land resources, regulating the economic use and later the protection of land. Effective solution of these problems required precision spatial positioning of land and map-making.

For quite a long time the *process of land mapping*, which is understood as a complex of activities to create land-cadastral maps, was carried out by traditional methods of cartography based on field instrumental surveys. The appearance of aerial and space imagery simplified the process of map-making and made it much cheaper.

Modern cartographic materials are created in digital form basing on the *geographic information systems (GIS)*, i.e. information systems which provide collection, storage, processing, access, display, and dissemination of spatially coordinated data.

Currently the approach to land mapping is undergoing certain changes, comparable perhaps with those, which accompanied the transition from hand-drawn maps to printed ones. The interaction of geoinformation systems and cartography has given birth to a new subject – *geoinformation mapping*, which is automated compilation and use of maps basing on geoinformation technologies and geographical (geological, environmental, social-economic, etc.) databases.

Within the scope of geoinformation mapping we can highlight a separate area, which is situated at the intersection of geoinformatics, land management, and land cadastre, as well as cartography – **geoinformation mapping of land**, which lies in automated compilation and use of maps of the land-cadastral system basing on geoinformation technologies and the land information geodatabases (GDB).

In many countries geoinformation mapping of land has almost completely replaced traditional methods of making and issuing maps in this area. Programme-managed mapping gives a new coverage to many traditional problems, related to the choice of the mathematical basis and the layout, the introduction of new graphics, generalization, etc. We are now seeing the merger of the two major branches of cartography: the making and the use of maps. A lot of cartometric operations which earlier used to be considered laborious, such as image transformations or superimposition or overlapping of images, as well as a lot of others, have now become routine procedures. Today creating and using maps of the land-cadastral system is one single integrated process.

Geoinformation mapping of land in the Republic of Belarus *must provide*:

• keeping a register of administrative-territorial units (ATU) and territorial units (TU) of the Republic of Belarus;

• establishment and restoration of boundaries of land plots, servitudes, encumbrances, and limitations;

• registration of titles to land plots;

• cadastral assessment of land plots;

• compilation of cartographic attachments to legal documents;

• carrying out land management, taking decisions about monitoring land, land resources management, assessment and forecasting the condition of land;

• keeping the state accounting of land;

• compiling projects of organization of territory;

• supervising the use and the protection of land;

• preparation of reference data about using land for appropriate executive and administrative authorities;

• fulfil the functions of land-surveying documentation when urban planning and architectural bodies take decisions of territorial and spatial planning.

The major sources of data for the purposes of GIS-mapping of land resources are:

• data from remote sensing of Earth;

• results of land-surveying (geodesic, satellite positioning systems);

• cartographic materials (raster or paper);

• digital data in the vector, GRID- and TIN-formats.

1.2. Formation and Development of GIS-methods of Mapping of Land Resources

We can distinguish three major stages in the formation and development of GIS-methods of mapping of land resources:

• the pioneer period (1960s);

• the state initiatives period (1970s);

• the commercial development period (1980s – present).

The pioneer period developed against the background successes of computer technology (the appearance of electronic computers, digitizers, plotters, graphic displays the other peripheral devices), with the simultaneous, and often independent, creation of software algorithms and procedures of graphic representation of information on displays and with the help of plotters, formal methods of tridimensional analysis, software means of databases management. The appearance and the rapid development of GIS was predetermined by the richest experience of topographic and especially thematic mapping, by the successful attempts to automate the mapping process, as well as by the revolutionary achievements in the areas of computer technology, computer science, and computer graphics.

The first major success of GIS-mapping of land was the development and creation of the GIS of Canada. The history of this large-scale GIS started in the 1960s, and it has been supported and developed up to the present day. The purpose of the GIS of Canada was to analyze digital data, accumulated by the Canadian service of land accounting, and to receive statistical data about land to be then used in developing land management maps of vast areas of predominantly agricultural purposes. This required the creation of land classification using the data on their agricultural, recreational, environmental, forestry suitability, to refle t the existing structure of land usage, including land-owners. The weak point of the project was the securing the effective input of initial cartographic and thematic data. To achieve this the developers of the GIS of Canada, having no experience in the internal organization of large arrays of spatial data, had to create a new technology, had not been used anywhere earlier, which allowed them to operate separate layers and carry out cartometric measurements. There was also developed a conceptual solution about attributive data tables. This allowed separating the files of spatial (geometric) geoinformation about the location of features and the files containing thematic (substantial) information about these features. They even designed and built a special scanning device to input large-size land maps.

The work of Swedish school of geoinforamtics was focused on the GIS of land-accounting specializations, particularly the Swedish Land Data Bank, which is intended for automation of land plots (land holdings) and real estate accounting. Maps were mostly built in the form of rough alphabetical-digital printouts – images consisting of letters and numbers, which created the primitive effect of halftone images by means of different density.

The second half of the 1960s is noted for the works of the Harvard Laboratory for Computer Graphics and Spatial Analysis. The software created here has become a classic in the sphere of automated mapping. Due to these works the leading role in modern geoinformation systems was finall assigned to cartographic data models, cartographic method of research, cartographic ways of presenting information.

In ***the period of state initiatives*** in the beginning of the 1970s GIS were aimed at purely utilitarian tasks of land resources inventory, land cadastre and accounting in order to improve the system of taxation. Those tasks were solved by means of automation of land-record documents circulation in the form of data banks of appropriate specialization. The first and the principal step to bring GIS out of the circle of general purpose databases was to introduce an indicator of space into the number of attributes of operating features (land plots, buildings, physical and legal persons, areas of land use, soils appraisal or forest inventory), no matter the form of location indicator (coordinates, administrative hierarchy, in terms of belonging to the cells of regular networks of territory division) in which it is expressed. Specifying coordinates of centroids of features was already revolutionary enough – a method actively used in Sweden.

During this period there formed the concept of spatial features, described by their positional and non-positional attributes. The two alternative lines of representation formed – raster and vector structures, including topological representations. There were put up and solved the tasks which form the core of geoinformation technologies: overlay of layers, buffer zones generation, Thiessen polygons, and other operations of spatial data manipulation, including determination of a point's belonging to the polygon, computational geometry operations in general. There were found effective solutions of other geometric problems, algorithms of analytical operations and graph-analytic constructions.

One of the examples of a land informational system (LIS) of this period is the LIS of the state of Minnesota. It was started as a joint project of The Center for Urban and Regional Affairs of the state of Minnesota, the Minnesota State University and the Planning Agency of the same state. At that time in many states there started the development of land GIS, which was driven by the desire to streamline land taxes collection. The LIS of the state of Minnesota had some special features, but the main thing was that for the first time the whole project was carried through to the end and proved effective. The system was raster, with large grain raster (slightly above 0,16 km^2), and nevertheless turned out to be quite effective.

The period of commercial development started in the 1980s, when certain software for data processing and maps preparation transformed into a system, capable of helping man take important decisions. At the same time there were created local and global computer networks, which made revolutionary changes to databases access. There was observed an extraordinary dynamism of GIS development. The development of commercial software of GIS, connected in no small measure with the possibilities of mini- and macro-configurations of computing facilities, and later of PCs as well, changed all geoinformation industry substantially, the appearance of which is related exactly to this period. The creation of GIS started to base not on unique software and hardware means of individual design, but on the adaptation of functional opportunities of quite operationally universal software of products with regard to the problems analyzed. It was this time that became the period of mass creating of GIS based on personal computers.

One of the bright examples of this period is the appearance of the most popular software in the world – ARC/INFO in Environmental Systems Research Institute (ESRI, Inc.), USA. Its creation was caused by joining the standard relational database management system (INFO) with the program (ARC). Today this software has grown into the program complex ArcGIS – a powerful means for GIS-mapping, including that of land resources.

This is the period of introduction of GIS into the sphere of mapping land resources in our country. The infrastructure of local, regional, and central LIS of the Republic of Belarus was formed. The GDB of local LIS are filled with spatial land-cadaster data. GIS were introduced in the process of registration of land plots, monitoring and protection of land fund. Server and web GIS began to develop.

1.3. The Market of Software for GIS-mapping of Land Resources

The rapid spreading of geoinformation technologies led to the fact that today on the Belarusian market there already function several dozen organizations and firms which distribute GIS software, necessary for the purposes of GIS-mapping of land. One can point out several classes of software, which differ by their functional options and technological stages of geoinformation processing. However, it is necessary to distinguish the systems of free distribution, those distributed commercially, and special products, designed for individual projects and not possessing the necessary universality, support of development, printed documentation written in popular language, and a number of other properties, characteristic of market goods.

By their functional options the software for GIS-mapping of land can be divided into fi e main classes of usage.

The first class of software, most functionally full, is the ***instrumental GIS***. They may fulfil most diverse tasks: organized input of information (both cartographic and attributive), its storage (including distributed storage which supports network functioning), processing difficult information requests, solving spatial analytical tasks, building derivative maps, and, finall , preparing the output of cartographic production layouts. As a rule, instrumental GIS work both with raster and vector images, have a database as store of digital and attributive information. Local LIS in the Republic of Belarus are created in software products of the company ESRI, USA (the instrumental GIS *ArcGIS*). As examples of instrumental GIS we can point out *MapInfo Pro* (MapInfo Corp., USA), *GIS Panorama* (Panorama, Russia), etc.

The second important class is presented by so called ***GIS-viewers***, i.e. software products providing the use GIS-projects created with the help of instrumental GIS. As a rule, GIS-viewers provide the user with extremely limited options to view an internal structure of GIS-projects. All GIS-viewers are supplied with tools to perform positioning and zooming operations of cartographic images. Naturally, viewers always come as a component of instrumental GIS; this allows saving expenses on creating the part of workplaces not endowed with rights to replenish GDBs. Most viewers make it possible to organize the output of GIS-project. The most widespread viewer product is *ArcReader* (ESRI, USA).

The third class consists of ***software for processing and classification of aerial and space imagery***. This includes packages for processing images, equipped – depending on the price – with different mathematical apparatus, which allows carrying out operations of data processing (radiometric, topographic and atmospheric correction) and visual and automated image classification Among these GIS products it should be noted *ERDAS Imagine* (Hexagon Geospatial, USA), *ENVI* (Visual Information Solutions, USA), *PHOTOMOD* (Rakurs, Russia), and others.

The fourth class is ***programmes-vectorizers***. These GIS-packages specialize on scanning, joining and correcting paper cartographic materials with subsequent vectorization of their contents in an automatic or semi-automatic mode. The examples of these software products are *Easy Trace* (Easy Trace Group, Russia), *ArcScan for ArcGIS* (ESRI, USA), and others.

The fi th class is the ***software for processing field geodesic surveys***. These packages provide for the import of information from Global Navigation Satellite Systems (GNSS) receivers, electronic tachometres, levels and other automated geodesic equipment, processing and analysis of data, calculation of coordinates of land plots, as well as creating plans of land plots boundaries with their means, or for data export to instrumental GIS. In Belarus most often the processing of results of ground instrumental survey is carried out via *aGeodesy Suite* and *tGeodesy Suite* (Belgiprozem, Belarus), *Trimble Geomatics Offi e* (Trimble, USA), *CREDO_DAT* and *CREDO TOPOPLAN* (Kredo-Dialog, Belarus), and others.

1.4. GIS-mapping of Land Resources in the Republic of Belarus

1.4.1. Land Information System of the Republic of Belarus

One of the examples of geoinformation mapping of land resources which is most detailed and successfully implemented on the example of many ATU of the Republic of Belarus is **the land information system** (LIS), which is a complex of program-technical tools, databases of spatially-attributed data, information-sharing channels and other resources, providing automation of accumulation, processing, storage and providing information about the condition, distribution and usage of land resources in electronic form, including by means of geoinformation technologies.

The LIS of the Republic of Belarus is created and used for information supply and automation of land management works, monitoring land resources and is designed to solve the following major *tasks*:

1) forming state statistic reporting about the condition and usage of land resources;

2) carrying out mass primary state cadastral accounting of land plots and state registration of titles on them;

3) compilation of documents, certifying the right to use, the right of lifelong heritable ownership of a land plot, and the title to a land plot;

4) preparation of materials on preliminary approval of places for feature placement, withdrawal and allocation of land plots, their ownership transfer, inclusion of land plots into urban area, changing the boundaries of administrative-territorial units;

5) control over establishing (recovery) of land plots boundaries;

6) forming cadastral maps;

7) state continuous survey of land, etc.

The LIS of the Republic of Belarus has a three-level structure. It consists of ***Local LISs*** (created within district (settlement) boundaries of Belarus; run by land-management and geodesic service of the corresponding district (settlement) and one of the State Property Committee enterprises, which is authorized to carry out technical support of Local LISs), ***Regional LISs*** (created within the boundaries of the regions of the Republic of Belarus basing on the data provided by Local LISs; run by the Republican Unitary Enterprise "Project Development Institute Belgiprozem" and its subsidiary enterprises), and the ***Central LIS*** (is being created within the State boundary of the Republic of Belarus basing on the data provided by Local and Regional LISs; run by the Republican Unitary Enterprise "Project Development Institute Belgiprozem" and its subsidiary enterprises).

The LIS of the Republic of Belarus is created in the conformal transverse-cylindrical Gauss-Krüger map projection, calculated in three-degree zones according to the parameters of the Krasovsky ellipsoid in the 1963 coordinate system.

The spatial data of Local LISs of the districts of the Republic of Belarus are created with the accuracy of a topographic map of 1 : 10,000 scale. Medium errors in the spatial position of terrain features and clear outlines relative to the nearest points of geodesic basis should not exceed 5 m (0,5 mm in 1:10 000 scale).

The spatial data of Local LISs of settlements of the Republic of Belarus are created with the accuracy of a topographic map of 1 : 2,000 scale. Medium errors in the spatial position of terrain features and clear outlines relative to the nearest points of geodesic basis should not exceed 1 m (0,5 mm in 1 : 2,000 scale). In areas of multi-level building errors in the mutual position of points of the nearest important outlines (capital facilities, buildings, etc.) should not exceed 0,8 m (0,4 mm in 1 : 2,000 scale).

The GDB of the LIS of the Republic of Belarus contains information about land plots, their boundaries and administrative-territorial properties, distribution of land by categories and classes, land owners and land users, types of land (land covering), and their reclamation condition, restrictions on land use, current changes in land composition and distribution, as well as elements of topographic content. The spatial layers of the GDB of the LIS of the Republic of Belarus are combined into a number of layer groups (table 1.1). The GDB also contains a number of information and reference tables.

Creating of GDB of a Local LIS includes several stages: 1) preparatory work; 2) processing the materials of high resolution aerial or space-based surveying; 3) creating the raster spatial basis; 4) creating a digital land cadastral plan (map); 5) forming the GDB of a Local LIS; 6) forming a computer cadastral map; 7) compilation of a technical report on the creation of the GDB of a Local LIS; 8) transfer of the GDB of a Local LIS to operation.

The subject of a LIS record is land resources of the Republic of Belarus, their condition and usage; the feature of a LIS record is land classes.

According to The Code of the Republic of Belarus about Land the land of the Republic of Belarus can be subdivided into 14 classes according to their natural-historical characteristics, condition and pattern of use.

The classes of land of the Republic of Belarus are: 1) arable land; 2) fallow land; 3) land under permanent crops; 4) grassland; 5) woodland; 6) scrubland; 7) swampland; 8) land under water objects; 9) land under roads and other transport communications; 10) land under streets and other public spaces; 11) building land; 12) disturbed land; 13) unused land; 14) other land.

Table 1.1

Spatial layers of the GDB of the LIS of the Republic of Belarus

Groups of layers	Layers	Types of layers	Contents
Boundaries	Administrative-territorial units (Admi)	Polygonal	Features of administrative-territorial and territorial division
	Turning points of the boundaries land plots (Lots1)	Point	Turning points of the boundaries, the boundaries the actually land plots owners, owners, of users, tenants
	The boundaries land plots (Lots2)	Linear	
	Land plots (Lots3)	Polygonal	
	Land use restrictions (Serv)	Polygonal	Water protection zones, coastal strips, sanitary protection zones, water intakes, sanitary protection strips of water conduits, protected zones of telecommunication lines, protected zones of power lines, protected zones of pipelines, zones of radioactive contamination, land for recreational purposes, land for recreational purposes, land of historical and cultural purposes, land for nature protection purposes; land with restrictions on construction, landscaping, etc.; other zones
Land	Land (Land)	Polygonal	Land contours
	Ameliorative condition of land (Melio)	Polygonal	The contours of land reclamation types
	Soil	Polygonal	Type, humidification grain composition, underlayment, genesis of plots of soil varieties

Continuation of the table 1.1

Groups of layers	Layers	Types of layers	Contents
Intersections	Intersection of contours of land holdings, restrictions, land and amelioration (CrosTab)	Polygonal	Features formed by intersection of Lots, Serv, Land, and Melio layers
Details	Communications (Comm)	Linear	Communication objects
	Fencing (Fence)	Linear	Fencing
	Out-of- scale features and symbols (Obj)	Point	Point features and symbols
	Annotations (Text)	Point	Names and labels of features or groups of features
	Sheets of land-cadastral map (MapList)	Polygonal	Scheme of cutting sheets of the land-cadastral map of a LIS territory
Rasters	Ortho10000	Image catalogues	Mosaic raster orthophoto map of a district (settlement)
	Ortho5000		
	Ortho2000		
	Topo10000	Image catalogues	Mosaic raster topographic maps (plans)
	Topo5000		
	Topo2000		
	Topo1000		
	Topo500		
	Zem10000	Image catalogues	Mosaic raster land-cadastral map of a district
	Sady2000	Image catalogues	Raster plans of horticultural associations
	Sady1000		
	Sady500		
Changes	Project plots (Lots New)	Polygonal	Project land plots

End of the table 1.1

Groups of layers	Layers	Types of layers	Contents
	Registered land plots (LotsREG)	Polygonal	Contours of land plots registered in the Unified state registry of real estate and transferred to the LIS to be entered in the Lots layer
	Dot feature changes (PointsUp)	Point	Areas of change in the content of point layers of the GDB of LIS
	Line feature changes (LinesUp)	Linear	Areas of change in the content of linear layers of the GDB of LIS
	Polygonal feature changes (PolyUp)	Polygonal	Areas of change in the content of polygonal layers of the GDB of LIS

According to the Technical Code of Established Practice the GDB of a Local LIS uses special attribute coding types on the “Land” layer to Identify ***types*** (LandType) and ***subtypes of land*** (LandSubtype). Note that there is no unequivocal association between the types and/or subtypes of land and the classes of land.

The class **arable land** includes agricultural land, systematically cultivated (ploughed up) and used for crops of agricultural cultures, including crops of perennial herbs with a term of use, stipulated by the scheme of crop rotation, as well as emergency fields covered soil plots (hotbeds, greenhouses, and conservatories), and bare fallow. In the GDB of LIS this class applies to the type ***cultivated land*** (LandType code 101), subtype *arable* (LandSubtype code 3).

Agricultural land, which earlier were used as arable and remain uncropped for more than one year after harvesting and not are not prepared to be left fallow are related to the class **fallow land**. In the GDB of LIS this class applies to the type ***cultivated land*** (code 101), subtype *fallow* (code 4).

The class of **land under permanent crops** includes agricultural land occupied by artificially created tree and shrub vegetation (plantations) or plantations of herbaceous perennial plants intended for harvesting, food, technical and medicinal plant raw materials, as well as for landscaping. In the GDB of LIS this class of land refers to the ***permanent crops*** type (LandType code 102), subtypes orchards (LandSubtype code 6), berry fields (7), plantations (8), fruit nurseries (9) and others (5). The *orchards* subtype includes land occupied by perennial, more often tree plantations (seed-bearing, stone fruits), created to obtain fruit and berries; *berry field* – occupied by perennial shrubs, semi-shrubs and herbaceous plants, intended for obtaining berries; *plantations* – occupied by perennial plantations for cultivation of special technical, medicinal, ornamental crops; *fruit nurseries* – plots intended for growing planting material of fruit and berry crops.

The **grassland** class of land contains agricultural land used principally for cultivation of perennial grasses, land with artificial herbage or land undergone measures to improve natural grasses (improved), as well as land covered by natural meadow herbage (natural). In the GDB of LIS this class of land refers to the ***grassland*** type (LandType code 103).

According to the cultural and technical condition, grassland is divided into flooded upland, waterlogged, clean, shrubby and improved. *Flooded* (subtypes 111–114) are meadow land located in the floodplains of rivers, lakes and lowland, flooded by hollow waters for a significant period (at least 10 days), causing changes in the composition of vegetation; *upland* (subtypes 121–124, 171–173) – located on elevated and well-drained landform elements, moistened mainly by atmospheric precipitation, as well as located in river floodplains briefly and not systematically flooded by hollow waters (for a period of less than 10 days), which do not cause changes in the composition of vegetation; *waterlogged* (subtypes 131–132, 181–182) – located on low and poorly drained relief elements, in conditions of excessive moisture, determined by moisture-loving composition of herbaceous vegetation; *clean* (subtypes 111, 121, 131, 171, 181) – not covered with shrubs, stumps, trees, hummocks, stones, or when they evenly cover no more than 10 % of the area of the plot; *shrubby* (subtypes 112, 122, 132, 172, 182) – evenly overgrown with shrubs, occupying from 10 to 70 % of the plot area; *improved* (subtypes 113, 123, 173) – land undergone measures to improve herbage, as well as occupied by sown perennial grasses, used for 7 or more years.

The class of **woodland** includes lands of the forest fund, covered with forests, as well as not covered with forests, but intended for its restoration (clearings, burnt areas, sparse areas, wasteland, clearings, dead forest stands, areas occupied by nurseries, plantations and unclosed forest crops, etc.), allotted for forestry. In the GDB of LIS this class of land refers to the following types: forests, tree plantings, coppice and other nonwooded areas.

Forests (LandType code 201) include lands whose area is covered with tree crowns by more than 20 %. According to the species composition, forests are divided into *coniferous* (subtypes 291–293) – forested, in which approximately 75 % or more of all plantations are coniferous tree species; *deciduous* (subtypes 301–303) – forested, in which approximately 75 % or more of all stands are deciduous tree species; *mixed* (subtypes 311–313) – covered with forest, in which coniferous and deciduous tree species are equally presented; those not rated as either coniferous or deciduous forests. In addition, there are forests *without specifying of tree species composition* (subtype 326).

The ***plantings*** type of land (LandType code 202) is divided into subtypes according to their species composition: *coniferous* (subtype 294), *deciduous* (304), *mixed* (314), and *without specifying of tree species composition* (327).

Similarly, there is *coniferous* (subtype 295), *deciduous* (305), *mixed* (315) and *without specifying of tree species composition* (328) ***coppice*** (LandType code 203) – land plots with trees up to 4 m tall, the areas of which are covered with crowns by more than 20 %.

Among ***other nonwooded areas*** (LandType code 205), we can distinguish the following: *cutting areas* (subtype 324) – cutting areas or their parts, on which the stand has been cut down, and a new one has not yet closed; *burnt areas* (subtype 325) – forest areas damaged by fire to the point of growth cessation, as well as *other areas* (subtype 329).

The **scrubland** class of land includes land covered with tree and shrub vegetation (plantations) that is not included in the forest fund. In the GDB of LIS this class of land refers to ***other wooded areas*** type (LandType code 204). This type maps as *tree-shrubbery vegetation* (subtype code 321) and *forest and scrub belts* (subtype code 322).

The **swampland** class is excessively moistened lands covered with a layer of peat. In the GDB of LIS this class of land refers to the type ***swamp*** (LandType code 206). The subtypes are mapped as: *lowland* swamps (code 34) – located on low relief areas, moistened by ground or surface waters (according to the species composition, these swamps are sedge or reed-reed swamps); *upland* (code 35) – located on elevated areas of the relief, moistened by atmospheric precipitation (moss) and *transitional* (code 36) – occupying a middle position between upland and lowland, moistened by atmospheric precipitation, ground and surface waters (moss-sedge).

The **land under water objects** class of land includes lands occupied by the concentration of natural waters on the land surface (rivers, streams, springs, lakes, reservoirs, ponds, digging ponds, canals and other surface water bodies). In the GDB of LIS, this class of land refers to two types: ***watercourses*** (LandType code 301) and ***reservoirs*** (code 302). In the watercourses land type the subtypes of *streams* (subtype code 401), *rivers* (40), *rivers and streams* (400), *canals and drains* (43) are mapped separately, in the reservoirs type – *lakes* (subtype code 41), *reservoirs and ponds* (42), *other water bodies* (39).

The class **under roads and other transport communications** is formed by lands occupied by roads, clearings, runs, linear structures. In the GDB of LIS, this class of land refers to three types: roads, railways and communication elements.

The ***roads*** type (LandType code 401) is divided into a number of subtypes according to the degree of technical perfection of the road surface. These are *improved roads* (carriageway (subtype code 446), roadsides (447), ditches (448), slopes (449), dividing lanes (450)) – motor roads having a solid base and a pavement of asphalt, concrete or cement concrete with the carriageway width of at least 7 meters; *country roads* (subtype code 445) – unprofiled unpaved, connecting settlements, foresters' houses, etc., serve as an exit from settlements to improved roads; *clearings* (code 444) – narrow strips cut through a forest to mark the boundaries of quarters, for construction purposes, power lines, pipelines, etc.; *fiel and forest roads* (code 441) – natural dirt roads with seasonal or sporadical traffic mainly during field work, logging, peat extraction areas and *cattle passes* (code 704) – roads designed to drive livestock along them.

The ***railways*** type (LandType code 402) separately maps the following subtypes: *bed* (subtype code 701), *ditches* (702), *slopes* (703), and *cargo and passenger platforms* (705).

Communication elements (LandType code 403) include *pipelines* (subtype code 442); *bridges and overpasses* (443), as well as *under other communication elements* (440).

The class of **land under streets and other public places** includes land occupied by streets, avenues, squares, driveways, embankments, boulevards, squares, parks and other public places. In the GDB of LIS, lands of this class completely form the type of ***green spaces*** (LandType code 502), where they are represented by the following subtypes: *boulevards* (code 455), *lawns and flo er-beds* (456), *parks, and squares* (460). In addition, the majority of subtypes of *squares* (451), *streets and driveways* (452), *carriageways of streets and driveways* (453), *sidewalks and footpaths* (454)) – they are represented in the type ***square and street*** (LandType code 501) and in one subtype (*other common areas*, code 457) in the type ***yards*** (LandType code 503).

The **building land** class is made up of lands occupied by permanent structures (buildings, structures), as well as lands adjacent to these features and used for their maintenance. In the GDB of LIS, lands of this class completely form the type ***buildings*** (LandType code 504), which is divided into *residential* (codes 454–466) and *non-residential* (467–469), with the latter group including buildings for industrial, utility-storage and public purposes, as well as into subtypes *fire-resistan* (464, 467), *non-fire-resistan* (465, 468) and *mixed-fire-resistant* (466, 469). Fire-resistant buildings include buildings with walls and roofs made of refractory material: walls – brick, reinforced concrete, gas silicate or expanded clay concrete blocks; roofs – metal, tiled (ceramic, cement-sand, metal) and slate. Non-fire-resistant buildings include wooden buildings, and mixed buildings are those in which the lower floor is made of fire-resistant materials, and the upper and (or) roof is made of non-fire-resistant materials, or the entire building is wooden, but with a thin fire resistant cladding.

Building land also form most of the subtypes referring to the type ***constructions*** (LandType code 505). These are the subtypes *light-type constructions* (code 470), *greenhouses* (471), *silo pits* (462), and *other constructions* (472). In the ***yards type*** (LandType code 503), *utility yards* (subtype code 461), *open-air warehouses* (463), *paddocks* (473), and *estate land* (67) are mapped. In the type ***squares and streets*** (LandType code 501) there are *porches and blind areas* of buildings (subtype code 458) and *stairs* (459).

Note that in the urban territories in the 1: 2,000 scale, all terrain features (residential and non-residential buildings, porches and blind areas of buildings, sidewalks and footpaths, orchards, etc.) are interpreted and digitized, but when creating the LIS of this territories in the 1: 10,000 scale, – only buildings, with the rest of the plot digitized and interpreted as estate land (subtype code 67).

The class **disturbed land** is lands that have lost their natural and historical features, condition and nature of use as a result of harmful anthropogenic impact and are in a state that precludes their effective use for the original intended purpose. In the GDB of LIS, lands of this class completely form the ***disturbed land*** type (LandType code 601). Among the subtypes, there are lands *disturbed in the result of mining* (code 49), *disturbed in the result of peat and sapropel extractions* (50), *disturbed during construction works* (51), *other disturbed land* (48).

The **unused land** class includes land that is not used in economic and other activities. In the GDB of the LIS of the Republic of Belarus, they constitute the type ***unused land*** (LandType code 602). This type is formed by *sands devoid of vegetation* (subtype code 54), *ravines and gullies* (55), *ramparts* (56), *burnt peatland* (58), *former agricultural land contaminated with radionuclides* (59), *mounds* (662), *pits* (663), *soaks* (664), *other unused land* (53).

The class **other land** includes lands that do not refer to any of the above types. In the GDB of LIS, these are the following types: ***improved land*** (LandType code 701, subtypes: *under melioration construction* (code 23); *under fertility restoration* (24)), ***mineral extraction and construction sites*** (LandType code 702, subtypes: *peat and sapropel extraction sites* (37); *waste dumps and waste heaps* (665); *quarries* (668); *construction sites* (669)), ***dump sites*** (LandType code 703, subtypes: *household waste dump sites* (63); *industrial waste dump sites* (64); *contaminated by radionuclides dump sites* (65); *other dump sites* (62)), ***burial places*** (LandType code 704, subtypes: *cemeteries* (60); *cattle burial sites* (61)), ***other land*** (LandType code 705, subtypes: *under* *brows* (57); *other land* (666)), as well as two subtypes of the ***constructions*** type (LandType code 505, subtypes: *dams* (661); other *slopes* (667)).

The **ameliorative state of land** is mapped in the GDB of a Local LIS in the layer “Ameliorative condition of land” (Melio). The attribute table encodes the type and subtype of the ameliorative state (table 1.2).

Table 1.2

Types and subtypes of ameliorative conditions of land

Type (MelioType)	Subtype (MelioCode)	Name of ameliorative condition
1 – drainage	1	Drained by an open net
	2	Drained by a closed net
2 – irrigation	3	Irrigated
	4	Irrigated on drained by an open network
	5	Irrigated on drained by a closed network
	50	Irrigated
	60	Irrigated on drained
3 – two-way regulation	30	Drained by an open network with two-way regulation
	40	Drained by a closed network with two-way regulation
	6	Bilateral regulation with open network
	7	Bilateral regulation with closed network
	8	Polders
4 – water logging	9	Waterlogged
	10	Waterlogged in hollows

1.4.2. Automated System of the State Land Cadastre

The state land cadastre (SLC) is a set of systematized information and documents on the legal regime, condition, quality, distribution, economic and other usage of land, land plots.

In the Republic of Belarus, the SLC consists of:

• the unified registry of administrative-territorial (ATU) and territorial units (TU) of the Republic of Belarus (Registry of ATU and TU);

• the unified state registry of real estate, title to it and transactions with it (USRRE);

• the registry of prices for land plots from the State Land Cadastre (Price Registry);

• the registry of the cost of land plots from the State Land Cadastre (Value Registry);

• the registry of land resources of the Republic of Belarus.

Information support of *the automated system of the State Land Cadastre* (SLC) consists of the databases of registers (registries) of the SLC automated system, digital cadastral maps, input and output forms and documents of subsystems of the SLC automated system; archives and other digital documentation.

Digital cadastral maps are SLC documents created by geo-information mapping about the location of features of state registration, their addresses, boundaries, cadastral numbers and other information. Depending on the purpose, cadastral maps are divided into four classes: basic cadastral maps (class A), cadastral maps of administrative and territorial division (class B), cadastral maps of the land fund condition and usage (class C), auxiliary and thematic cadastral maps (class D).

Cadastral maps of the administrative-territorial division (class B) are created as part of the **Register of ATU and TU**, which contains information about the names, sizes and boundaries of ATU and TU and their administrative centers. Digital cadastral maps of this class include a topographic base (road network layers, hydrography, vegetation), and ATU and TU (layers of the state boundary of the Republic of Belarus, boundaries of regions, boundaries of districts, boundaries of village councils, boundaries of cities and urban-type settlements, boundaries of rural settlements, boundaries of the territories with a special usage regime). The ISATF (Indications System for Administrative-Territorial Formations) codes are used to fill in the ATU and TU attributes. Maps of the administrative-territorial division of the republic (class B1, scale 1 : 500,000), administrative-territorial division of a region (class B2, scale 1 : 200,000), and administrative-territorial division of a district (class B3, scale 1 : 50,000–1 : 100,000) are created.

The **USRRE** contains information and documents regarding registered land plots and real estate objects located on them, including information about the location of land plots, their size, boundaries, purpose, titles to these plots, restrictions (encumbrances) of titles to land plots, including land easements, as well as information about transactions with them. Within this register, a layer of land plots registered in the USRRE is formed basing on coordinate catalogues, as a SHP-file with the corresponding attribute tables of land users (LotsREG). Using these spatial data, ***basic cadastral maps (class A)*** are created. These are maps of cities and urban-type settlements or rural settlements (class A1, scales 1 : 2,000–1 : 10,000), as well as maps of district land (class A2, scale 1 : 10,000). A registry of street and road names (Street Registry) is maintained within the USRRE. The spatial information of this registry in vector form is used when entering the addresses of real estate objects into the USRRE.

The **Price Registry** contains information about prices for land plots and real estate objects located on these plots, fi ed at the time of transactions with these plots and real estate objects. Spatial information is contained in vector form and includes such attributive data as the address of a real estate object, its main characteristics, the date and price of the deal.

The **Value Registry** contains information on the cadastral value of land plots obtained during their cadastral valuation. Within this registry, digital layers of appraisal zoning are formed, as well as information of urban planning, environmental, socio-cultural purposes regarding ATU and TU of the Republic of Belarus, used in the cadastral valuation of land. Auxiliary spatial information forms ***class D1 cadastral maps*** on this subject.

The **Registry of Land Resources** of the Republic of Belarus contains information on the distribution of land by categories, classes and land users, composition, structure, condition, quality and economic use of land, other information about land. Within this class, ***cadastral maps of the land fund condition and usage (class C)*** are formed, which contain data on the structure of land, their quantity, quality, distribution by category, land owners, and land users. Class C maps are used for the purposes of state land registration, evaluation, land management, etc. These are maps of cities, other settlements (class C1, scale 1 : 2,000), as well as land of agricultural, forestry and other enterprises (class C2, scales 1 : 5,000–1 : 10,000). The LIS of the Republic of Belarus serves as a source for creating maps of this class.

Auxiliary maps (subclass D1) include cadastral maps created in the course of keeping the State Land Cadastre: individual land plots, refle ting the presence of real estate objects on them, as well as easements, encumbrances and restrictions on property rights; appraisal zones amps; overview maps, designed to highlight cadastral blocks. They are created in 1 : 200–1 : 2,000 scale.

Thematic maps (subclass D2) include: land tenure maps (agricultural enterprises, forestries and other enterprises, institutions and organizations), refl cting a set of information characterizing the condition and usage of land; soil, geobotanical and other maps characterizing the qualitative condition of land. They are created in 1 : 10,000–1 : 100,000 scale.

Any cadastral map is formed by overlaying the data of a certain date from the State Land Cadastre on the cartographic basis. The source of cartographic basis for class A, B and D cadastral maps is class C cadastral maps or topographic survey materials.

1.4.3. Land Management

Land management in the Republic of Belarus includes:

• development of projects of usage and protection of land resources, projects of land management of ATU and TU, territories of special state regulation;

• development of projects for inter-farm land management, including projects for allocation of land plots, execution of technical documentation and establishment (restoration) of the territorial boundaries of land plots;

• development of projects for on-farm land management of agricultural organizations, including peasant (farm) enterprises, projects for the organization and arrangement of territories of settlements, horticultural associations, specially protected natural areas and other territorial units;

• development of projects for land reclamation, protection of soils from erosion and other harmful effects, conservation and improvement of soil fertility and other beneficial properties of land, as well as other projects related to the protection and improvement of land;

• inventory of land, systematic identification of unused or misused land;

• carrying out geodetic and cartographic works, soil, geobotanical and other surveys and surveys carried out for the purposes of land management, compiling cadastral and other thematic maps (plans) and atlases of the condition and usage of land resources;

• copyright supervision over implementation of projects of land management;

• implementation of land management activities in the course of land monitoring, keeping of the State Land Cadastre, including in the course of cadastral valuation of land, land plots, exercising state control over the usage and protection of land;

• implementation of research and development work, as well as the development and modernization of the hardware and software complex (software) necessary for the implementation of land management activities;

• preparation of land management materials for land disputes settlement.

Carrying out these activities is nowadays impossible without geoinformation mapping. Information support and automation of land management are carried out by means of LIS.

When drawing up **projects for land management of districts**, both the textual and the cartographic part are formed, the latter refle ting the modern land usage of the district and the restrictions on it, as well as proposals on promising areas of land usage. The ***cartographic part*** includes the main maps of the district in 1 : 50,000 scale, thematic maps in 1 : 100,000 scale, fragments of maps of other scales, and map diagrams. This part is mainly compiled on the basis of Local LIS. The *main maps* include: 1) current land usage; 2) restrictions on land usage; 3) long-term land usage.

The composition and content of *thematic maps* is not limited and is determined by the assignment for the development of a land management project. Thematic maps show the current condition of the relevant land management objects and the changes resulting from the proposals and activities of the land management project. The production of thematic maps, which refle t the results of an assessment of natural conditions and of a complex resource assessment, visually reasoned for the concept and strategy of land management, is mandatory.

The composition and content of maps, graphs, diagrams, photographs and other illustrative materials in the text of the land management project, as well as of insets on maps, is not regulated.

During inter-farm land management, in the **process of withdrawal and provision of land plots**, Local LISs of the districts of the Republic of Belarus are used. Thus, at the *stage of preliminary approval of the location of a land plot* (if this stage is necessary) and when drawing up the project of a land plot allocation, digital land cadastral plan (map) is used, which is drawn up within the boundaries of towns of district subordination, rural settlements, urban-type settlements in 1 : 2,000 scale, outside them – in 1 : 10,000 scale. Essentially the plan (fragment of the plan) is a printed out Local LIS.

Having *established the territorial boundaries of an allotted land plot and the state registration of the creation of the land plot and the emergence of the title to it*, the spatial information about the land plot according to the catalogue of coordinates of the turning points of its boundaries is entered into the USRRE, and then in the form of a SHP file (LotsREG) with the corresponding attribute tables of the land users (land owners) is entered into the Local LIS (layers “Lots1, Lots2, Lots3).

When developing **projects for inter- and intra-farm land management**, the spatial information of a local level LIS in raster and vector form is also actively used. After the project is carried out in nature, the information on the land fund structure is entered into the GDB of a local LIS.

Questions for self-assessment

1. What is geoinformation mapping? What is geoinformation mapping of land resources?
2. Enumerate the main sources of data for geoinformation mapping of land resources.
3. During which period of GIS methods of land mapping development did the firs land information systems appear?
4. What functional groups is the software used in GIS-mapping of land divided into?

5. Identify and describe the three levels of the LIS of the Republic of Belarus.

6. Which scale topographic map accuracy are Local LIS of the Republic of Belarus created?

7. Enumerate the groups of spatial layers of the GDB of the LIS of the Republic of Belarus.

8. How are land classes associated with land types and subtypes of the GDB of the LIS of the Republic of Belarus? Provide examples.

9. Enumerate the types of ameliorative conditions of the land of the GDB of the LIS of the Republic of Belarus.

10. Which classes, depending on their purpose, are digital cadastral maps in the Republic of Belarus divided into? Describe each of the classes.

11. Identify the main directions of application of geoinformation mapping for the purposes of land management in the Republic of Belarus.

12. What scales are maps related to the cartographic part of land management projects for the districts in the Republic of Belarus created?

2. LAND RESOURCE MANAGEMENT BASED ON REMOTE SENSING DATA

2.1. Remote Sensing Data Used for the Purposes of GIS-mapping of Land Resources

Remote sensing means obtaining information about the Earth's surface (including objects located on it) without direct contact with it, by registering incoming electromagnetic radiation from it. **Remote sensing data** (RSD) obtained in this way in the digital form are intensively used in land resource management. To extract spatial information about the land recourses from the initial data, special methods of image classification are required. But before classification of data, it is necessary to understand what properties they have and choose the data optimal for solving the problems of land resource management.

RSD can be systematized on several grounds: 1) by the height from which the survey was made; 2) by the scale and spatial resolution; 3) by the range of registered radiation; 4) by technological methods of obtaining images.

According to the **height from which the survey was made**, there are ***aerial images*** (AI) (acquisition sources: airplanes and helicopters, radio-controlled models; preferred altitudes range from 500 m to 10 km) and ***satellite images*** (SI) (acquisition sources: automatic satellites, spacecraft, manned orbital stations; altitude – more than 150 km). AI and SI have important differences when they are used for GIS land mapping. The benefit of AI are: very high detail and efficiency when it comes to small areas. In the Republic of Belarus it is the AI that serve as the basis for the creation of LIS at the local level. SI have a number of special properties (great visibility, complex display of geospheric components, regular recurrence of surveys, simultaneous surveys in different ranges of detected radiation), which make it possible to use them for GIS mapping of the structure and dynamics of the land fund.

The classification of RSD **by scale** is applicable to AI, which is due to their processing precisely in the scale of shooting. As a rule, the ratio between the scales of the AI and the compiled map does not exceed 3 : 1, and more often the image scale is twice as large as the map scale or close to it. Depending on the pattern of use, AI are divided into ***super-large-scale*** (larger than 1 : 5,000), ***large-scale*** (1 : 10,000–1 : 25,000), ***medium-scale*** (1 : 50,000–1 : 60,000), and ***small-scale*** (1 : 100,000–1 : 200,000). Large-scale and super-large-scale aerial photographs are used for geoinformation mapping of land in the Republic of Belarus.

Most SI are not interpreted in the scale shooting, like AI, but with a significant zoom. The original scale of the image can be three to fi e or even ten times smaller than the scale of the map compiled from it. As a result, for SI, it is not so much the scale that is important, but the **spatial resolution**, which characterizes the real size of the smallest detail reproduced in the image. This indicator depends on the altitude of shooting, the properties of the lens of the shooting equipment and other factors, and is determined by the size of the image element, the pixel (fig 2.1). Depending on the tasks to be solved, there may be used the data of ***very low*** (more than 1 km), ***low*** (300 m – 1 km), ***medium*** (50–200 m), ***high*** (1–40 m) and ***very high*** (0.1–0.9 m) resolution. For GIS mapping of land resources, it is preferable to use SI of high and very high spatial resolution.

a *b*

Fig. 2.1. Space images with different spatial resolution:
a – pixel size 1 m (QuickBird); *b* – pixel size 30 m
(Landsat-7 ETM+; combination of red, green and blue zones of the visible range)

The range of registered radiation (spectral resolution) indicates which parts of the spectrum of electromagnetic waves are recorded by the sensor. Conventionally, the entire range of wavelengths used in obtaining remote sensing data can be divided into fi e sections: **radio frequency** range (wavelength over 1 mm); ***middle and far infrared*** (thermal) range

(3–1000 μm); ***near infrared*** range (0.7–3 μm), ***visible*** range (0.4–0.7 μm); ***ultraviolet*** range (wavelength shorter than 0.4 μm). This division is due to the difference in the interaction of electromagnetic waves and the Earth's surface, the difference in the processes that determine the refle tion and radiation of electromagnetic waves.

The most commonly used range of electromagnetic waves is *visible light* and adjacent to it *shortwave infrared radiation*. In this range, refle ted solar radiation carries information mainly about the chemical composition of the surface. Just as the human eye distinguishes substances by color, a remote sensor captures "color" in the broader sense of the word. So, if the human eye perceives the visible region of the spectrum, then modern sensors are able to distinguish tens and hundreds of zones, which makes it possible to accurately determine objects and phenomena by their previously known spectrograms. For many practical problems, such detailedness is not always necessary. If the objects of interest are known beforehand, you can choose a small number of spectral zones in which they will be most noticeable. For example, the near infrared range is very effective in assessing the condition of vegetation. Some combinations of spectral zones better show land under vegetation, others under anthropogenic objects, and still the others under water bodies, etc.

Usually, optical survey is carried out either at once in the entire visible range (*panchromatic*) or in several narrower spectral zones (*multizonal*).

Thermal infrared radiation carries information mainly about the surface temperature. In addition to direct determination of the temperature regimes of visible objects and phenomena (both natural and artificial) thermal images make it possible to indirectly reveal what is hidden underground: rivers, pipelines, etc.

The centimeter range of *radio waves* is used for radar survey. The most important advantage of this class images is their all-weather capability. Since the radar registers its own radiation refle ted by the Earth's surface, it does not require sunlight for its operation. In addition, radio waves of this range penetrate continuous cloudiness freely and are even able to penetrate to a certain depth into the soil. The refle tion of centimeter radio waves from the surface is determined by its texture ("roughness") and the presence of various films on it. A characteristic feature of radar imaging is its high sensitivity to soil moisture, which is also important for agricultural applications.

There are three main **technological methods of obtaining images**: photographic, optoelectronic and radar. In the ***photographic method***, the spatial distribution of the spectral brightness of the elements of the Earth's surface is recorded directly on light-sensitive materials (black and white, color, spectrozonal films) The advantage of this method is the possibility of obtaining images with a very high resolution, high geometric and photometric properties. This method is used mostly in aerial photography of land resources. The disadvantage of this method when shooting from space is its slowness. In addition, the RSD obtained in this way require subsequent scanning before being used in a GIS.

The principle of the ***optical-electronic method*** for obtaining RSD consists of element-by-element reading along a narrow band of radiation refle ted by the Earth's surface, and the image is scanned due to the movement of the carrier, so it is received continuously. The radiation received from the source is converted into an electric signal, then sent to the Earth in the form of a radio signal, where it is again converted into an electric signal and recorded on magnetic media. The images obtained in this way are discrete (consist of pixels) and suitable for direct processing and interpreting in GIS. The spatial resolution of such data depends on the pixel size.

In ***radar imaging***, the Earth's surface is sounded with a radio signal using a special device – a radar, which is an active microwave sensor capable of transmitting and receiving polarized radio waves in a given frequency range. High brightness of a pixel in the images means that most of the signal returned to the antenna, low brightness means the opposite. A distinctive feature of radar images is the presence of so called speckle noise.

In addition, in recent years, video filming and filming with digital cameras based on the use of fiber optics have appeared and are becoming increasingly important. In the Republic of Belarus, data obtained by photographic and optical-electronic methods are most often used for the purposes of GIS-mapping of land.

2.2. Digital Image Preprocessing

A **digital image** is a raster image of the Earth's surface stored on a magnetic carrier. RSD in a raster model of representing spatial data is stored as a uniform cellular structure that forms a rectangular matrix, in which each element (pixel) takes on a certain value of spectral brightness inherent in a real spatial object.

After obtaining the necessary RSD and immediately before geoinformation mapping of land resources, the images are subjected to **preliminary processing,** which includes a number of stages:

- geometric correction;
- radiometric calibration;
- radiometric correction of the influen e of the atmosphere;
- recovery of missing pixels;
- brightness transformations;
- filtering

Geometric correction includes elimination of geometric distortions of an image (orthorectification) and georeferencing. The main causes of geometric distortions of images are the curvature of the Earth's surface, the influen e of the terrain, the rotation of the Earth and the movement of aircraft, from which the survey is carried out. The result of geometric transformations is geo-referenced, projected and orthorectified images with a given reference ellipsoid.

Radiometric calibration arises from the need to obtain correct values of the spectral brightness of objects. Images originally received from satellites are recorded in the form of so-called “raw” brightness values. Data in this format cannot be adequately compared with data from other surveys. The task of radiometric calibration is to convert these values into physical units by special formulas. This correction deals with the variation of pixel brightness values caused by the failure or malfunction of detectors, the influen e of the terrain, and atmospheric effects.

Radiometric correction of the influen e of the atmosphere is due to the peculiarities of the composition and state of the atmosphere during the recording of electromagnetic radiation by the sensor. When passing through the atmosphere, electromagnetic waves are absorbed and scattered. The reason is the content of ozone, water vapor, carbon dioxide, oxygen, methane, dust and smoke in the atmosphere. Cloudiness also interferes with shooting in the optical range. These phenomena cause distortion of the brightness values of the pixels in images. The main methods of atmospheric correction are:

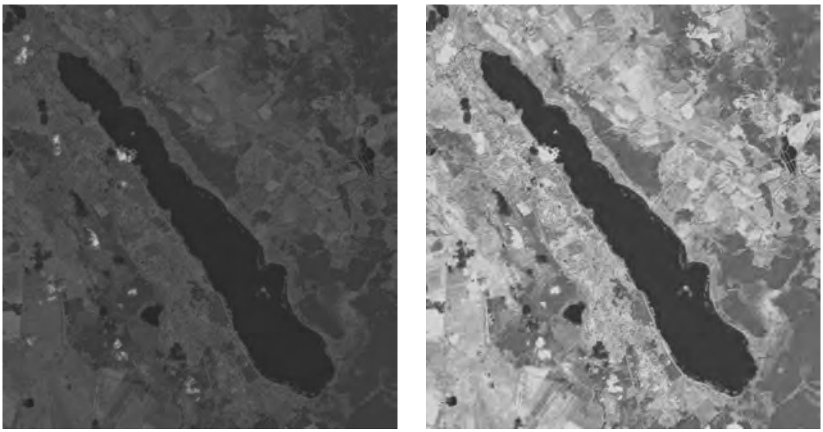
1) assessment of the content of water vapor and aerosols (smoke) in the atmosphere from images that include areas occupied by water surfaces (clouds and fogs are clearly visible against the background of water, since in the red and infrared parts of the spectrum, the water surface in its optical characteristics is close to an absolute black body);

2) the use of mathematical methods of constructing models of the atmosphere conditions, taking into account the types of scattering in the atmosphere, seasons, and meteorological data.

Restoration of missing pixels in the image is carried out, if during the shooting or data transfer the brightness values of the entire row were replaced by the values of the adjacent row. Such phenomena can interfere with the thematic processing of the image. Restoration is carried out by interpolation with a certain error.

The **brightness transformations** of a digital image consist of changing the transfer function, which characterizes the relationship between the brightness on location and the level of brightness in the digital image. Brightness transformations of panchromatic images include contrasting, edge enhancement, quantization, and color coding. The most common methods of brightness transformations of multi-zonal images are the synthesis of a color image, mathematical operations (ratio and subtraction, calculation of vegetation indexes, the Kaut-Thomas transformation) and the method of principal components.

Image contrast is the difference between the maximum and minimum brightness values. ***Contrasting*** is performed by converting the histogram of images, which characterizes the distribution of brightness in the image (for each of the 256 levels). There are several methods of enhancing contrast through digital processing. With *linear histogram stretching* (fig. 2.2, *a* and *b*), all image brightness values (for example, 35–226) are assigned new values in order to cover the entire possible range of brightness changes (0–255). When the histogram is *normalized* over the entire possible interval of brightness change, then not the entire histogram is stretched, but its most intense section. In the process of *equalization* (linearization) of the histogram, the brightness values of the pixels are changed in such a way that for each brightness level there is the same or close number of pixels.



a *b*

Fig. 2.2. Example of contrasting the original Landsat ETM+ image (0.52–0.90 μm) (*a*) using the linear histogram stretching method (*b*)

In the process of ***edge enhancement***, the brightness value of each pixel is compared with its "nearest neighbors" (the pixels directly adjacent to it). The subsequent mathematical operations make it possible to detect boundary pixels and increase their brightness values.

In ***quantization***, image brightness levels are grouped into several relatively large steps. In the image thus obtained, the patterns of brightness distribution become more pronounced.

Color coding improves the quantized image by replacing the grey scale with a color one. However, the use of this transformation is only expedient, if the number of brightness levels lies within the range of 10–30.

According to the principle of ***color image synthesis*** the image in each of the shooting channels is assigned its own color. Raster image processing programs most often use the RGB color scheme. According to this scheme, any image on a color screen is formed from three primary colors – red, green and blue, as well as additional ones. Most often, three zonal images are synthesized into one. It is possible to synthesize not only zonal images that make up a multizonal image, but also images obtained as a result of more complex transformations, and multi-temporal images. Synthesis of images with different spatial resolution is also possible.

The following *standard combinations of zones* are usually used:

1) red, green and blue zones create a *true color composition* (fig 2.3, *a*). True color means that objects look as they would be perceived with the naked eye;

2) near infrared, red and green zones create a *false color composition*. This composition looks similar to the image in the infrared part of the spectrum, in which, for example, vegetation appears red, water appears dark blue or black, etc. (fig 2.3, *b*).

a *b*

Fig. 2.3. Variants of color synthesis of a fragment of a multi-zone satellite image Landsat ETM+. The colors red, green and blue are assigned respectively to the images in the shooting areas:
a – 3 (0.63–0.69), 2 (0.53–0.61), 1 (0.42–0.52);
b – 4 (0.78–0.90), 3 (0.63–0.69), 2 (0.53–0.61)

The most commonly used ***mathematical operations*** are dividing the brightness values of two zonal images when working with multi-zone images and subtracting them when analyzing two nonsimultaneous images.

A *vegetation index* is an indicator calculated as a result of operations with different spectral channels of RSD, and related to vegetation parameters in a given image pixel. The main assumption about the use of a vegetation index is that some mathematical operations with different RSD channels can provide useful information about vegetation. This is supported by a wealth of empirical evidence. The second assumption is the idea that the exposed soil in the image will form a straight line in spectral space (the so-called soil line). Almost all common vegetative indexes only use the ratio of red (RED) to near infrared (NIR) channels, assuming that the open soil line lies in the near infrared region. This line is meant to mean zero vegetation.

Nowadays, there are two approaches to calculating the direction lines of identical vegetation (isovegetation lines): 1) all isovegetation lines converge at one point; 2) all isovegetation lines run parallel to the soil line. In the first approach, the line slope between the convergence point and the RED–NIR point of the ratio in a pixel is measured (indices NDVI, SAVI, and RVI). When using the second approach, the perpendicular distance from the soil line to the RED–NIR point in a pixel is measured (indices PVI, WDVI, and DVI).

To determine the amount of photosynthetically active biomass the most widely-used is the *normalized difference vegetation index* (NDVI), calculated by the formula: NDVI = (NIR – RED)/(NIR + RED). Index values vary from minus 1 up to 1 (fig 2.4). Dense vegetation has a value of 0.7, sparse – 0.5, open ground – 0.025, clouds – 0, water – −0.25, asphalt, concrete – −0.5.

During the *Kaut-Thomas transformation*, as a result of rotating the axes corresponding to the brightness of a digital image in three zones representing the axes of three-dimensional space, the zonal features of the image are regrouped, in which the main part of the information is characterized by two features: "brightness", i.e. the soil index, and "greenness", the vegetation index.

The ***method of principal components*** is based on the fact that multi-zone images have a significant degree of correlations between zones. The core of the method is to transform the original multi-zone image by creating new zones – components, with practically no correlation between them. Image processing based on this method makes it possible to obtain the structurometric characteristics of the image, since it fi es the frequency of brightness features occurrence, which is directly related to their spatial distribution.

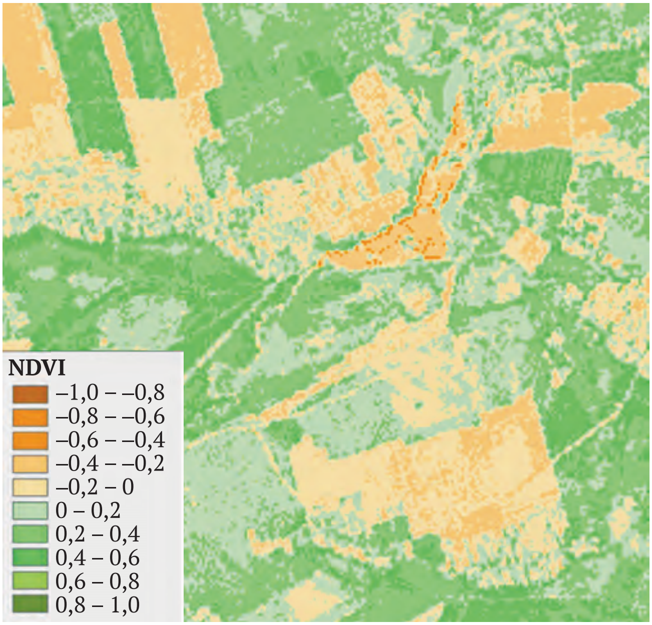


Fig. 2.4. Vegetation index NDVI

Image **filtering** allows enhancing of reproduction of certain objects in the picture, suppress unwanted veiling and eliminate other random noise. One of the simplest filtering methods is the sliding window transform. With this transformation, the brightness values of all pixels in the image are recalculated. Recalculation occurs for each pixel in this way: when this pixel is the central one in the window that "moves" over the image, it is given a new value that is a function of the values surrounding it in the pixel window. The window size can be, for example, 3 × 3 or 5 × 5 pixels. Each time the window is shifted by 1 pixel and moves until the entire image is covered. For all the pixels of the window, weight coefficients are set based on the goals of interpretation.

2.3. Methods of Image Interpretation

After carrying out the necessary stages of processing of remote sensing data, GIS mapping of land resources is performed by means of image interpretation.

Image interpretation is a method of studying objects, phenomena and processes on the Earth's surface, which consists of recognizing objects by their features, determining characteristics, establishing relationships with other objects. Depending on the content, interpretation is divided into *topographic* and *special* (thematic, branch). During topographic interpretation, information is obtained from images about the Earth's surface and objects located on it. During special interpretation, thematic information of agricultural, forestry, geological and other purposes is selected.

The process of interpretation begins with the *formulation of a general problem*. The task is set taking into account the real possibilities of obtaining survey materials, the availability of appropriate equipment, the qualification of interpreters, etc. The classes of land (types and subtypes of land of the GDB of the Local LIS of the Republic of Belarus) are identified by remote sensing data.

With any of the interpretation methods, a **preparatory stage** is obligatory. In the Republic of Belarus, when creating a GDB of a Local LIS, this stage includes preparatory work, processing of aerial or satellite imagery materials, and creation of a raster spatial basis.

As part of the *preparatory work*, they collect, study, determine the quality and possibility of use, the necessary preparation of the original cartographic, aerial and space survey and factographic materials and data to create a raster spatial basis for interpretation.

The following are used as the *main cartographic materials and data* in the creation of the GDB of a Local LIS in the Republic of Belarus: land management maps in 1 : 10,000 scale; land tenure maps of the district in 1 : 50,000, 1 : 10,000 scales and/or settlements in 1 : 10,000, 1 : 2,000 scales; topographic maps and plans in 1 : 10,000, 1 : 5,000, 1 : 2,000, 1 : 1,000 and 1 : 500; plans of the territory of horticultural associations on in 1 : 500–1 : 5,000 scale and a number of additional materials.

The following are *aerial and space imaging materials*: digital AI, digital SI, digital orthophotomaps in 1 : 10,000 or 1 : 2,000 scales, materials of photogrammetric processing of aerial or space survey data.

As the main *factual materials and data*, the following are used: data on current accounting of the state and use of land; cases on establishing, restoring the boundaries of land plots; boundaries of land plots registered in USRRE; data of the unified register of ATU and TU of the Republic of Belarus; data of the register of names of streets and roads USRRE; materials on the transfer of land of rural settlements to the jurisdiction of rural (settlement) Councils of Deputies; data on the transfer of forests under the jurisdiction of forestry authorities; materials on the inventory of ameliorative systems; data on the establishment of water protection zones and coastal strips on rivers and reservoirs; materials schemes of land management of districts; data of cadastral valuation of land of settlements, etc.

The processing of aerial or space photography materials includes the sequential execution of several types of work. When used as a basis for interpretation of aerial photography materials, the following is performed:

aerial photography > measurement and calculation of the coordinates of photographing centers using satellite geodetic equipment > photolaboratory work > AI horizontal and vertical reference > adjustment of the coordinates of survey substantiation points and identification marks determined using satellite geodetic equipment > AI scanning and obtaining digital AI > photogrammetric work on orientation of digital AI, equalization of phototriangulation results and construction of a digital photogrammetric system project. Processing of space imagery materials includes the following types of works: the formation of a digital photogrammetric system project and loading digital SI into the project > plan-altitude reference of space images > photogrammetric work on external orientation of space images and equalization of phototriangulation results.

In the process of these works, digital photogrammetric systems of the Photomod (Rakurs, Russia) and photogrammetric scanners are used.

The ***raster spatial base*** is formed on the basis of scanned and georeferenced source cartographic materials, as well as digital orthophotomaps created in the environment and by means of digital photogrammetric systems and georeferenced.

There are three main **ways of image interpretation**: field cameral and combined.

Field image interpretation consists of comparing the image in the shots with the terrain, as a result of which objects are identified and their properties are determined. Interpretation can be terrestrial or aerovisual, continuous or selective (route). In the field remote sensing data is connected (orientated) to the terrain, and then the interpretation is carried out directly, which consists of identification of objects and their designation in the image. If there are objects that are not refle ted in RSD, then they are applied to images using receivers of satellite systems for determining coordinates or using the methods of alignments, soundings, linear resection, etc. The main advantages of this method are the highest completeness and reliability of the results; on the other hand, the disadvantage is that this method is highly laborious, as well as time- and money-consuming.

Cameral interpretation consists of the logical analysis of images using the entire complex of interpretation characteristics (visual-logical version) or standard images of typical areas interpreted in the field (re erence version), as well as involving special software (automated version) in the laboratory. The main advantages of this method are: saving time and money, comfortable working conditions, the use of various technical means of automation, the possibility of using auxiliary sources of information. However, when doing interpretation of objects in this way, errors are quite possible, and they will affect the reliability of interpretation and require field refinement of interpretation materials.

Combined interpretation combines the processes and techniques of field and cameral methods. Its main advantages are high economic efficienc and reliability of the results obtained. It is the combined method that is used in interpretation the land in the Republic of Belarus.

At the ***first stage***, in cameral conditions, the objects of the *digital land cadastral plan (map)* (DLCP) are interpreted and digitized in stereo or monoscopic modes on a raster spatial basis created from aerial or space imagery. In addition, the formation of the plan (map) objects occurs on the basis of additional data (digitization of original cartographic materials, as a result of their construction from coordinate catalogues or other geodetic survey data, as a result of importing other information systems from the geodetic database). In cameral interpretation, the following procedure of digitizing features of the DLCP is applied:

- features of administrative-territorial division (first coordinated, then the rest) in the Admi layer;
- land plots (first coordinated, and then the rest; first of legal entities, then the rest) in the Lots 3 layer;
- water and hydrotechnical features (Land layer);
- features of the street-road network (Land layer);
- land within settlements (Land layer);
- reclaimed land;
- agricultural land (Land layer);
- forests and shrubs (Land layer);
- swamps and wetland (Land layer);
- other land (layer Land);
- fence layer features;
- features of other layers Comm, Obj, Serv, Melio.

The *project of field work* is formed in the process of cameral interpretation and digitization of objects of the DLCP. Uninterpreted polygonal and line objects of the DLCP are highlighted in red on the map, and uninterpreted point objects or undefined feature signatures are marked with red question marks. The results of cameral interpretation and digitization are printed out in the form of photographic maps and serve as the source material for field interpretation. Photomaps display combined images: a digital orthomosaic (in the form of a halftone image), digitized DLCP objects in the form of simplified conventional signs and their captions (in the form of a line image, possibly with fill elements), marginal design elements. In addition to the field work project, a text document is formed, which should contain a list of questions for clarification in the process of field interpretation and references to the object numbers of the field ork project.

Based on the materials of the completed cameral interpretation, areas of continuous field interpretation, optimal routes for field control and survey are outlined in such a way as to cover all objects that are not interpreted in cameral conditions and to ensure full control of cameral interpretation and, first of all built-up areas.

At the ***second stage***, *fiel interpretation* is carried out. Here all objects that have not been interpreted in cameral conditions are examined and plotted on the photographic map; then comes connecting the objects that are not displayed on aerial photographs (space images) and plotted on the photographic map in the course of field work, to the objects digitized in the process of cameral interpretation; control of the results of the cameral interpretation in the process of moving along the routes and correction of the identified errors in the cameral interpretation is carried out; the objects lost by the time of field work are marked on photographic maps (by means of crossing out); then instrumental determinations of the numerical characteristics of new objects and the objects, about which information is absent in the preparatory work materials.

At the ***third stage***, in cameral conditions, digitization and editing of the objects of the DLCP, identified and refined as a result of the fiel interpretation, as well as control printing, topological and editorial verification of the obje ts and layers of the DLCP, are carried out.

The **methods of interpretation RSD**, with all their diversity, come down to two main ones: **visual** and **automated**. With visual interpretation, information from images is read and analyzed by a human. Automated classification is carried out completely via special software. A human determines the tasks and sets the algorithm of processing RSD.

It should be noted that in the case of computer processing of RSD, the analysis of the image is carried out according to formal features; therefore, the results obtained are devoid of subjectivity. However, experiments to assess the reliability of computer classification show that the number of correctly identified objects is 60–80 %. The result is the better, the more different in the optical properties of objects are. A certain subjectivity of the results of visual interpretation is not always negative, being similar to the subjectivity of the map. Thus, the comparison of visual and automated interpretation methods shows that both of them have their advantages and disadvantages, therefore, depending on the task, either preference is given to one of them or both are used simultaneously.

2.4. Visual Interpretation of Land Resources

Visual interpretation in the GIS environment involves interpretation and digitization of land fund objects by a interpreter in stereo or monoscopic modes based on aerial or space imagery in raster form. Successful interpretation depends not only on the quality of the materials used, but also on the interpreter, the special features of its visual and logical perception. The process of visual analysis of an image is usually divided into three stages: *detection*, *recognition*, and *interpretation.* The latter presupposes revealing the essence of the object, attributing it to some category provided for by the legend of the DLCP or previously known to the interpreter, i.e. associated with logical understanding. The first two stages represent special features of visual perception (perception of brightness, color, size and volume). Interpretation and digitization in the stereoscopic mode is carried out using special digital photogrammetric systems, in the monoscopic mode – in any of the instrumental GIS.

During visual interpretation the interpreter relies on the diagnostic apparatus which includes **interpretational characteristics** – the properties of objects which are directly reflected in the image and used to recognize these objects.

It is customary to subdivide interpretation characteristics into **direct** – the properties of objects which are directly displayed on the image, and **indirect** or indicative – interconnections and interdependence of natural and artificial objects that characterize the object of interpretation indirectly, through any direct interpretational feature of other natural or anthropogenic objects or their complex.

Direct interpretational characteristics are usually divided into three groups:

1) ***geometric*** (form, shadow, size);

2) ***brightness*** (tone, brightness level, color, spectral representation);

3) ***structural*** (texture, structure, pattern).

The *form* is a sufficient feature to the separate the objects of natural and artificial origin. Artificial objects usually possess correct configuration For objects of natural origin, irregular, often complex shape is typical.

The *shadow* allows you to judge about the spatial shape of objects. There is own shadow (part of an object not illuminated by direct sunlight) and drop shadow (shadow from an object on the Earth's surface or the surface of other objects). Own shadow allows you to judge about the surfaces of objects possessing a three-dimensional shape, the drop shadow determines the vertical extent, the silhouette of the object.

In most cases the *size* during interpretation is estimated relatively. By size, it is possible to identify the class of roads, the size of buildings, forest and tree-shrub vegetation, etc.

A *tone* is the optical density of an image in black and white images. This characteristic is a function of the integral or zonal brightness of an object. A tone is assessed visually by attributing the image to a certain step of the non-standardized achromatic scale (white, almost white, light grey, grey, dark grey, almost black, black). The number of steps is determined by the threshold of light sensitivity of the visual apparatus of the interpreter. This feature is not informative enough, since objects that are completely different in color can be displayed in a black and white image in the same tone.

In a digital image, the integral or zonal brightness of an object is encoded in the *brightness levels* of a grey scale (from 0 to 255 shades of grey).

A *color* is a more informative interpretational characteristic than the tone of a black and white image. In color images, differences in the spectral brightness of objects are transmitted precisely by this characteristic. It should be noted that the color sensitivity of the human eye is much higher than the achromatic one.

In multi-zone images, differences in the spectral brightness of objects are displayed as a set of tones or brightness levels in zones and are called *spectral representation*.

A *texture* is the character of optical density distribution over the image field of an object. Through the texture, the structural characteristics of the object are transmitted – the shape, size and relative position of the elements that make up the object or the elements that form its surface and their brightness. While visual interpretation, the texture is described by one or two adjectives, for example, grainy, spotty, striped, reticulated. A regular texture is typical of objects associated with human activity; an irregular texture is typical of natural formations. Texture is one of the most informative features. It is by texture that forests, gardens, settlements and many other objects are unmistakably identified Structural characteristics are often divided into *texture*, *structure*, and *pattern*. This gradation is rather conditional; it is related to the size of textural characteristics and varies depending on the scale.

Indirect interpretational characteristics are divided into natural, artificial and natural-artificial ***Natural*** (landscape) ones include interrelations and interdependence of objects and phenomena in nature. For example, dependence of the type of vegetation cover on the type of soil. With the help of ***artificia*** characteristics, objects created by man are identified In this case, functional links between objects, their position in the general complex of structures, zonal specifics of the organization of the territory, communication support are used. For example, a livestock farm of an agricultural enterprise can be identified by the totality of the main and auxiliary buildings, the internal planning of the territory, intensively carved runs, and the road network character. ***Natural-artifi ial*** ones include: dependence of human economic activity on certain natural conditions, manifestation of properties of natural objects in human activity, etc. Example: according to the placement of certain types of crops, one can make a certain judgment about the properties of the soil.

It should be noted that interpretational characteristics are usually used collectively, without subdivision into any groups. The image in the iterprited area is perceived by the interpreter as a single whole – as a terrain model.

In the Republic of Belarus, visual image interpretation is the predominant method of GIS mapping of the land. In most cases, black-and-white digital orthomosaics are used as the initial data. interpretation is carried out in the context of land classes (types and subtypes of land of the GDB of the Local LIS of the Republic of Belarus).

Arable land in the image are characterized by the clarity of their boundaries, determined by the "geometry" of the shape (fig 2.5). The tone of the image of land plots occupied by arable land is predominantly light, but it cannot be a sufficiently reliable independent eature. Even in one and the same shot, the tone of different areas of arable land may change, which is associated with different species composition of crops and the peculiarity of their display on RSD, as well as the season of surveying. The informativity of the color of an arable land image is much higher. The characteristic striated texture of arable land is caused the presence of various crops or different plowing times. However, it is unstable over time. The most probable errors in interpretation of arable land are attributing some contours of arable land to fallow land and vice versa, as well as the attributing grassland plowed for the purpose of their radical cultivation to arable land.

Fig. 2.5. Image of arable land

The interpretational characteristics of **fallow land** and arable land are very close. Borders and traces of tillage and, accordingly, the striated texture of the image are preserved for many years. However, over time, there appear signs of the termination of cultivation – local fuzziness of the texture, appearance of spots (grains) showing weeds and wood vegetation (fig 2.6). An indirect sign of a fallow is the confinement of land to ravine and gully relief elements.

The main interpretational characteristic of **land under permanent crops** is the grid or striated texture of the image (fig 2.7). If there is information about the types of plantations found in the area of interpretation, the reliability of recognition of this land increases.

Fig. 2.6. Image of fallow land

Fig. 2.7. Image of land under permanent crops

The shape and size of the plots occupied by **grassland** are uncertain, since their boundaries are the boundaries of arable land, fallow land, forests, as well as topographical elements of the terrain. The texture of the image changes depending on the qualitative characteristics of meadows. An even and uniform tone of meadow vegetation, depending on the lighting conditions during aerial photography and the degree of moisture, can vary from light to dark grey (fig 2.8). When interpretation grassland, indirect interpretational characteristics play an important role. Thus, grassland used for hayfields are marked by confinement to certain natural complexes, a lack of possibility to drive cattle to the plot and, in general, absence of signs of its systematic grazing. On the contrary, meadow land used for pastures are determined by their position in relation to settlements and, in particular, to cattle yards, with the establishment of possibility to drive cattle to the pasture plot, the presence of many paths carved by cattle, trampled at watering and stopping places, the presence of special structures (pens, sheds, etc.).

Fig. 2.8. Image of grassland

The main interpretational characteristic of **woodland** and **scrubland** is the distinctive irregular texture of image, which is expressed in irregularly shaped granularity created by the alternation of rounded spots (projections of tree crowns) and gaps of differing contours between them, partially or completely taken by dark spots of shadows cast by trees. With stereoscopic viewing, the height of the trees is perceived quite distinctly. The size and shape of the grains depend on the size and structure of the crowns of trees on location, as well as on the forest density. Apart from the picture, taking into account the tone of the photographic image is also helpful. As a rule, coniferous forests are characterized by darker tones than deciduous ones. Great opportunities for recognizing the composition of plantings are provided by using multi-zonal satellite images.

According to the character of the texture and the height of plantations, determined by their shadows, one can quite reliably distinguish mature forests, natural forest verdure, young plantings, woodland, shrubs (fig 2.9, 2.10). Solid thickets of shrubs are characterized in the images by fine-grained, sometimes somewhat "smeared" structure of the image, grey and dark grey tone, small drop shadows, and usually rounded or scalloped contours. Shrub thickets differ from forest verdure by a more even tone, due to their uniform composition.

Fig. 2.9. Image of woodland

Fig. 2.10. Image of scrubland

Forest belts and protective forest plantations are reliably recognized by direct interpretational characteristics. Burnt areas have a spotted pattern of a light tone and torn borders fringed by a strip of forest, usually sparse. Among burnt areas, individual trees and small areas of growing forest are often noticeable. On littered burnt areas, fallen trees in the form of white strokes and dead trees, distinguishable by sparse light crowns, are clearly visible. Clearings are identified by their light tone and the regular shape of their areas.

The main interpretational characteristic of **swampland** is the image texture (fig. 2.11). Depending on the type of swamps, their shrub (forest) density, passability and other characteristics, the texture is very diverse and heterogeneous. But in most cases it is quite specific Treeless swamps are distinguished by grey tones; they are characterized by smooth, soft contours with single trees or dark spots of wetland. Indirect interpretational characteristics of swampland are their confinement to vast fla -horizontal areas of the terrain, absence of traces of agricultural work, presence of country and field ypass roads, as well as of peat extraction areas.

Land under water objects are interpreted with a high degree of reliability in black and white and, especially, in color AI according to direct interpretational characteristics. Water spaces have dark tones in black and white shots. The tone of a hydrographic image is influen ed by such factors as optical conditions of aerial photography, depth, bottom color, purity and transparency of water, its color, waves, and the presence of aquatic vegetation (fig 2.12). Typically, as the depth increases, or in silty, clayey, or peaty soils, the tone of the image becomes darker. Small rivers and lakes with a sandy or rocky bottom are predominantly light in color in aerial images. Turbid and foamy water also gives a lighter tone to the image.

Fig. 2.11. Image of swampland

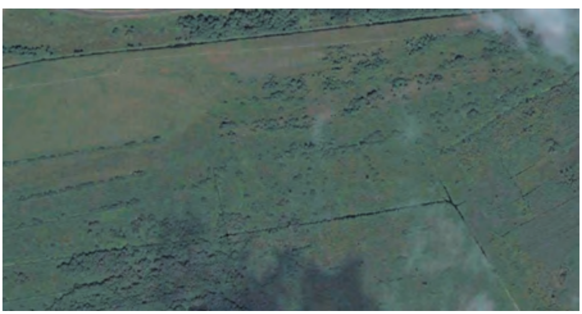


Fig. 2.12. Image of land under water objects

The shape of the land occupied by water objects makes it possible to judge about their natural or artificial origin. The coastline of reservoirs and ponds over a long distance does not differ from the coast of natural water bodies, but there is always a straight section – a dam (weir), by which they can be distinguished from lakes. Ameliorative canals and ditches belong to the category of contrasting objects; therefore, even with a small width, they are well interpreted by their characteristic rectilinear shape and the dark tone of the image. It is difficult to interpret small rivers and streams hidden under the canopy of a forest or shrub. This can be done only after a careful stereoscopic examination of the image.

If the survey was not made during the period when the water level is averagely stable (summer period), it is necessary to use auxiliary materials to interpret the coastline; those are large-scale topographic maps, since the coastline is plotted on them instrumentally.

Land under roads and other transport communications have specific direct interpretational characteristics – on ordinary black and white AP they are displayed as light lines (stripes) (fi . 2.13). On wet sections of unpaved roads, the tone of their image may be darker. Indirect interpretational characteristics of roads are their position on location, their connection with other topographic objects, the presence of structures serving roads, the character of their intersection with other objects, and the location of associated tree and shrub vegetation. Bridges and overpasses are interpreted by direct characteristics.

Fig. 2.13. Image of land under roads and other transport communications

Waysides and railway tracks are well distinguished in the AP. Waysides bordering forests, arable land and other land on both sides of a road, are usually covered with grassy vegetation and are characterized by an even grey tone. Railway sections of significant length are straight, and their turns are smooth, rounded. Absence of sharp turns, as well as presence of a large number of embankments and cuttings makes it easy to distinguish railways from highways in aerial photographs. In addition, stations, booths, which are located in the waysides next to the roadbed, are a reliable interpretational characteristic of railways.

Highways differ from railways by sharper turns, and in some places, by a noticeable steepness of ascents and descents. There are relatively fewer embankments and cuttings on motor roads, and their waysides are usually narrower than those of railways. Other roads approach motor roads from different directions.

The specifici y of interpretational characteristics of **land under streets and other public places**, as well as **building land** eliminates the possibility of confusing them with other objects (fig 2.14). Elements of a settlement – building lanes, homestead land, streets, squares, driveways – are easily identified by cameral and especially stereoscopic observation. Most artificial objects are identified with a high degree of reliability using indirect caracteristics, for example, by their location in a populated area, by the functional conditionality of the elements of a complex of structures, by the image of cars, barrels and other objects in the territory of the interpreted object.

Fig. 2.14. Image of land under streets
and other common areas, as well as building land

Fig. 2.15. Image of disturbed, unused and other land

Disturbed, unused and **other land** have their own specific direct (shape, size, tone, texture, etc.) and indirect (their certain territorial confinement natural and climatic conditions, etc.) characteristics (fig 2.15). The reliability of cameral recognition of such land is often low. Some land belonging to these species are identified in stereos opic mode.

2.5. Automated Land Classification

The **automated image classificatio** is based on the *classifi ation of objects*. In this case, it is assumed that each pixel of a multi-zone image corresponds to a set of values of spectral features or a vector in the spectral space, whose dimension is equal to the number of image zones. Thus the classification process is reduced to a distribution of all elements of the raster into classes in accordance with refle tivity (the value of the spectral brightness) of each object in one or several zones of the spectrum.

The automated classification is divided into two main types: classificatio with training and classification without training

Classification with training (supervised classification is a process where the brightness value of each pixel is compared with references, which results in each pixel being attributed to the most appropriate class of objects. This kind of classification is applicable if it is known beforehand which objects are refle ted in the image, or there is a small number (up to 30) of object classes and these classes are clearly distinguishable.

In controlled classification the rules for the transition from spectral brightness indices to object classes are developed by creating *signatures* – image fragments that unambiguously refer to a certain class of objects, and then automatically apply them to the rest of the image. The sources by which the references are selected can be materials of specially conducted field work, cartographic materials, interpreted images. All class reference images can be concentrated in one area or scattered throughout the image.

Supervised classification is carried out through algorithms using different methods of accounting the spectral characteristics of signatures.

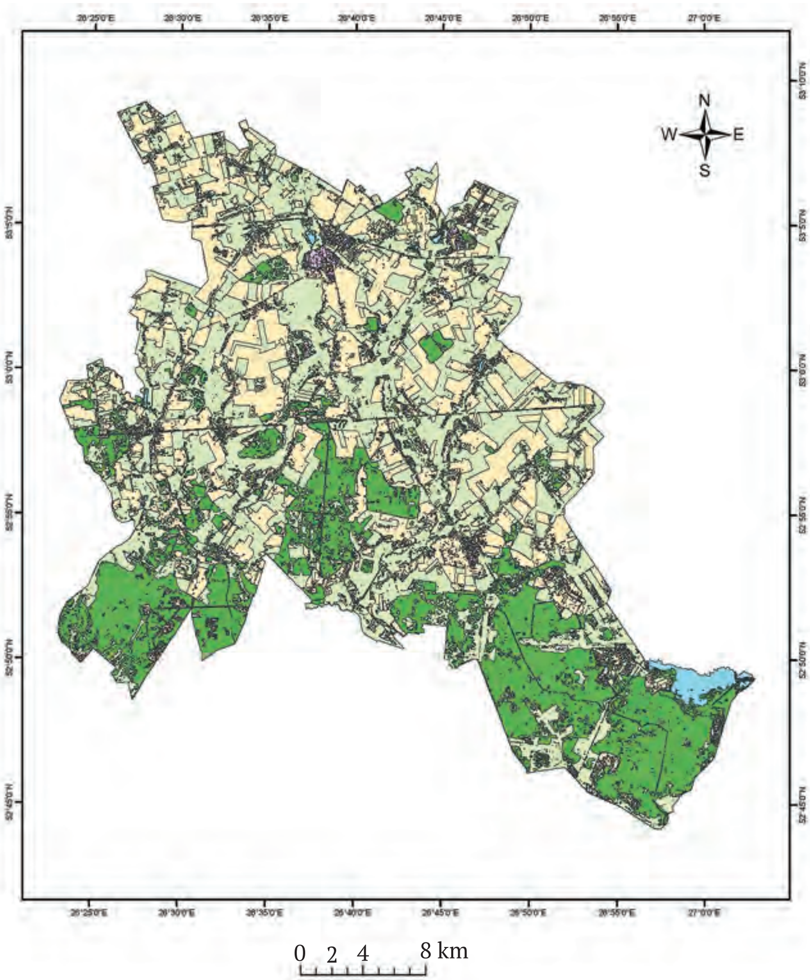
The ***minimum distance classifi ation method*** makes it possible to attribute classified objects to a certain class by calculating the Euclidean distance in the feature space between the tested and the reference pixels and attributing each pixel to the class in which this distance to the reference is minimal. The method is expedient to use when the number of classes in the training set is limited. The disadvantage of the method is that its application does not take into account the distribution (dispersion) of the brightness value of pixels in the signatures.

The ***parallelepiped method*** implements an algorithm in which closed rectangular areas are selected in the feature space, whose boundaries are set depending on the choice of characteristic ranges according to the histograms of the brightness distribution of reference objects in two, three or more zones of the spectrum, and then each pixel of the image is attributed to the class in whose parallelepiped it falls by its brightness values. The advantage of this method is a simple and fast calculation, the disadvantage is frequent overlapping of parallelepipeds, which causes uncertainty in the classification

The **maximum likelihood method** calculates the probability with which a given pixel refers to a certain class. The number and the parameters of classes are set by the user by specifying training samples. Each pixel refers to the class to which it is most likely to belong. When calculating the probability, the brightness of a pixel and the brightness of its surrounding pixels are taken into account. It should be noted that this method is used in practice most frequently (fig 2.16).

Classification without training (unsupervised classification) is a process in which the distribution of image pixels occurs automatically, based on the analysis of statistical distribution of pixel brightness. Note that before starting this kind of classification the interpreter often does not know how many and which objects are displayed in the image. After the classification it is necessary to interpret the resulting classes in order to determine which objects they correspond to. Classification without training is implemented if it is not known beforehand which objects are refle ted in the image, and there is a large number of object classes (more than 30) with complex boundaries. It can also be used as a preliminary step before supervised classification

The most common classification methods without training are ISODATA and K-Means.



- Arable land, fallow land
- Grassland
- Woodland, scrubland, land under permanent crops, swampland
- Land under water objects
- Building land, land under roads and other transport communications, land under streets and other public spaces
- Disturbed land, unused land, other land

Fig. 2.16. Result of classification with training (maximum likelihood method) of the classes of land of the Kletsk district of the Minsk region

The ***ISODATA method*** (Iterative Self-Organizing Data Analysis Technique) is based on cluster analysis. One class includes pixels with brightness values the closest in the space of spectral features.

The **K-Means method** differs from the ISODATA method in that it requires initial setting a certain number of average values to form the initial classes, therefore, this method is used when the objects in the image are quite distinct.

The result of classification (both with and without training) is a raster image, where each of the pixels is attributed to a certain class. Such rasters often require subsequent class merging and filtering These procedures allow us to perform *cartographic generalization* and improve the classifica ion raster significantl . In addition, using the standard procedures for *converting a raster to a vector* in a GIS, specialist can operate with the classification result in a vector form.

After the classification process is over, it is necessary to evaluate the reliability of the obtained results. *Classifi ation reliability* is assessed visually or quantitatively (i.e., control areas of the classified image are compared with maps, large-scale images, literature data). In quantitative assessment, a *matrix of errors* is compiled. It can be used to judge about the reliability of each particular object (class) and the reliability of the classificatio in general. Reliability assessment is also carried out for visual image interpretation.

The use of algorithms for automated classification of multi-zone SI for GIS-mapping of land resources in the Republic of Belarus is currently in the making. The main problems hindering the development of this area of geoinformation mapping today are high cost of obtaining high-resolution multi-zone SI, a lack of clearly defined classification units for interpretation. And while the first problem is solved with the commissioning of the Belarusian space monitoring system, the second problem requires close attention.

Mapping the land fund in the context of classes, and even more so of types and subtypes of land in the GDB of the Local LIS causes great difficulties for automated classification Many classes (types, subtypes) cannot be correctly classify by this method. In addition, the spatial resolution of RSD comes to the forefront. It is often not enough to classify land resources correctly. In addition, nowadays there is still an open question of choosing the optimal software, classification methods and algorithms, as well as training specialists in such methods.

One example of a successful project of land resources classification is the CORINE (Coordination of information on the environment) program initiated by the European Commission in 1985. This program allowed to combine the efforts of scientists and specialists from Western European countries to collect, unify and coordinate geospatial and thematic information on the condition of land, vegetation and water bodies, distribution of natural resources, level of urbanization, etc., as well as development of new approaches to obtaining and processing data in order to improve the efficienc of management decisions.

The CORINE program widely uses methods of remote monitoring of the Earth. By the beginning of the 1990s, digital maps of land covers had been compiled for several countries of Western Europe in 1:100,000 scale using the materials of aerospace surveys from the Landsat and SPOT satellites. The important result of the CORINE programme was the creation of a unifie nomenclature of land covers for the territory of Europe (CORINE Land Cover Classification System). This is a multi-level classification scheme with objects divided into 5 classes on the 1st level, 15 classes on the 2nd level, and 44 classes on the 3rd level. The nomenclature of land cover classes with its levelization, developed jointly by European countries in the CORINE LCC system, is presented in table 2.1. It should be emphasized that the CORINE LCC classification scheme allows, if necessary, further refinement in the form of increasing additional levels.

Table 2.1

Earth cover classes according to the CORINE LCC nomenclature

Level 1	Level 2	Level 3
1. Artificial surfa es	1.1. Urban fabric	1.1.1. Continuous urban fabric (residential, build-up, artificial
		1.1.2. Discontinuous urban fabric (residential, build-up, artificial
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units (industrial; retail)
		1.2.2. Road and rail networks and associated land (road and rail landuse)
		1.2.3. Port areas (harbour)
		1.2.4. Airports (aerodrome)
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites (quarry)
		1.3.2. Dump sites (landfill
		1.3.3. Construction sites (construction)
	1.4. Artificial, non-agricultural vegetated areas	1.4.1. Green urban areas
		1.4.2. Sport and leisure facilities

End of the table 2.1

Level 1	Level 2	Level 3
2. Agricultural areas	2.1. Arable land	2.1.1. Non-irrigated arable land (farmland, cropland)
		2.1.2. Permanently irrigated land (farmland, cropland)
		2.1.3. Rice field
	2.2. Permanent crops	2.2.1. Vineyards
		2.2.2. Fruit trees and berry plantations (orchard)
		2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures (meadow)
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops
		2.4.2. Complex cultivation patterns
		2.4.3. Land principally occupied by agriculture, with significant areas of natural egetation
		2.4.4. Agro-forestry areas
3. Forest and seminatural areas	3.1. Forests	3.1.1. Broad-leaved forest
		3.1.2. Coniferous forest
		3.1.3. Mixed forest
	3.2. Scrub and/ or herbaceous vegetation associations	3.2.1. Natural grassland
		3.2.2. Moors and heathland
		3.2.3. Sclerophyllous vegetation (scrub)
		3.2.4. Transitional woodland-shrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, sands
		3.3.2. Bare rocks
		3.3.3. Sparsely vegetated areas (scrub)
		3.3.4. Burnt areas
		3.3.5. Glaciers and perpetual snow
4. Wetland	4.1. Inland wetland	4.1.1. Inland wetland (marsh)
		4.1.2. Peat bogs (bog)
	4.2. Maritime wetland	4.2.1. Salt marshes
		4.2.2. Salines(salt_pond)
		4.2.3. Intertidal flat
5. Water bodies	5.1. Inland waters	5.1.1. Water courses
		5.1.2. Water bodies
	5.2. Marine waters	5.2.1. Coastal lagoons
		5.2.2. Estuaries
		5.2.3. Sea and ocean

The land cover information collected by the beginning of the 1990s, systematized in accordance with the CORINE LCC nomenclature and supplemented by the data from ground based observations and measurements, formed the contents of the CLC1990 database.

In subsequent years, other countries gradually joined the CORINE project (by 2000, their number in the project had reached 29), with the catalogue of the CLC1990 database replenished accordingly. From 2000 to 2005 by the initiative and support of the European Environment Agency (EEA), a large amount of work was carried out to improve the quality (correction) of the CLC1990 database contents and to update it using orthorectified materials of actual satellite images from the Landsat-7 spacecraft; also, technical requirements for the results of object classification in space images were formulated.

Surveys provided almost complete (without gaps) coverage of the entire territory of the European continent with shots, after which they were interpreted automatically. This made it possible not only to form a refined and detailed map of land cover, but also to solve an urgent and important problem of identification and assessment of temporary changes in the natural environment of Europe. The updated database was named CLC2000, and 32 countries took part in its compilation. The CLC1990, CLC2000 databases are available via the portal of the European Environment Agency. In addition, this site provides access to the CLC2006 database, which refle ts the changes that took place from 2005 to 2010. At present, 37 European countries are participating in the project.

Questions for self-assessment

1. What is remote sensing? How are RSD classified
2. What is digital image? Which spatial data model does a GIS use to store digital images?
3. Enumerate the main stages of preliminary processing of RSD. Reveal the essence of each stage.
4. What is the principle of color image synthesis? What combinations are most common?
5. Outline the main ways and methods of image interpretation.
6. Enumerate and characterize the direct and indirect interpretational characteristics used in image interpretation.
7. Outline the main features of visual interpretation of land resources.
8. What is the essence of automated RSD classification? What are the types of classifications? What are their similarities and dif erences?
9. Which algorithms are used to implement the classification with training?
10. In what way is the reliability of image classification results valuated?

3. LAND RESOURCE MANAGEMENT BASED ON GEODETIC SURVEYS AND GLOBAL NAVIGATION SATELLITE SYSTEMS

3.1. Technology and Methodology of Geodetic Surveys

The main topographic and geodetic works for GIS mapping of land are **surveys for establishment (restoration) of boundaries of land plots**.

According to Art. 1 of the Code of the Republic of Belarus on Land, the *boundary of a land plot* is a conditional line on the surface of the Earth and a conventional vertical plane along this line, separating the land plot from other land, land plots. According to Art. 11 of the Code, the boundary of a land plot is established (restored) on location with fixing of its turning points by landmarks in accordance with the decision on withdrawal and allotment of a land plot (*fi ed boundary*). It can also be established (restored) according to planned and cartographic materials with an accuracy determined by their scale, without fixing its turning points with landmarks on location in accordance with the decision on withdrawal and allotment of a land plot (*unfi ed boundary*, fig 3.1).

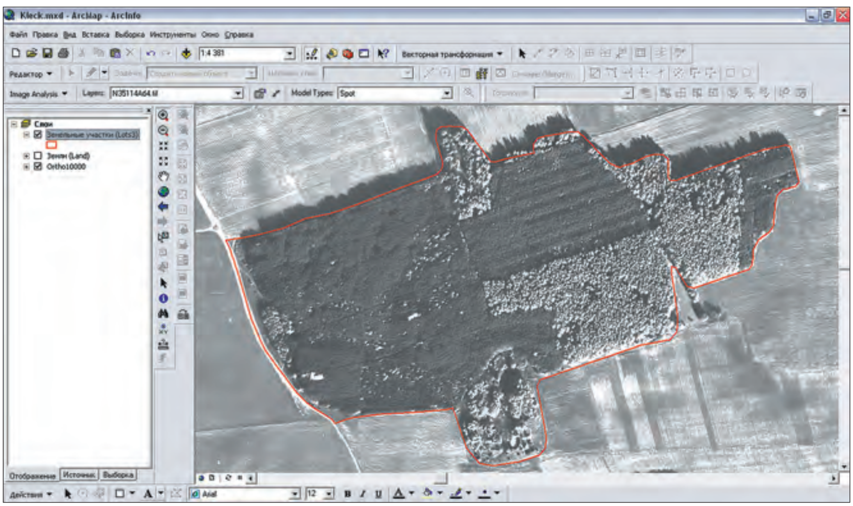


Fig. 3.1. Unfi ed boundary of a land plot of a state forestry institution

Works to **establish the boundaries of land plots** complete the process of land acquisition and are carried out in order to determine on location (in place) the exact geometric dimensions and position of the boundaries of land plots allotted on the basis of the decisions of the President of the Republic of Belarus, the Council of Ministers of the Republic of Belarus, appropriate executive and administrative bodies in accordance with the procedure established by the legislation of the Republic of Belarus, and for the preparation of documents certifying the titles to land plots. Establishment of boundaries of land plots is carried out in cases of formation, in accordance with the established procedure, of new, as well as reorganization or streamlining of existing land holdings and land uses.

Restoration of boundaries of land plots is carried out in case of complete or partial loss of landmarks and signs of boundary lines on location, at the request of land users, landowners, owners and tenants of land plots, as well as in resolving land disputes between adjacent land users, landowners, owners and tenants of land. In these cases, the boundaries of a specifi land tenure are subject to restoration and fixing with new landmarks of the established form instead of the lost and worn-out ones.

Measures to establish and restore the boundaries of land plots should ensure the indisputable determination on location of the boundaries of land plots (landmarks and boundary lines); accounting of land with the necessary and sufficient accuracy; the possibility of indisputable restoration of the boundaries of land tenure in the event of loss (destruction) of landmarks and boundary lines; subsequent state control over the targeted and rational use of the allotted land plots; reliability of calculation of payments for land; correct legal and technical registration of the boundaries of land plots for state registration and protection of the titles to land plots of land users, land owners, owners and tenants of land plots.

The establishment and restoration of the boundaries of land plots can be carried out by geodetic methods uses the different ways of defi ing coordinates known in geodetic practice.

Works on establishing and restoring the boundaries of land plots in the territory of the Republic of Belarus are carried out in the ***unified state system of geodetic coordinates of 1995***. In settlements, these works can be carried out in the local coordinate systems adopted earlier.

The ***geodetic basis*** for the work on establishing and restoring the boundaries of land plots are the points of the state geodetic network (points of state triangulation and polygonometry) of the 1st, 2nd, 3rd and 4th classes, the points of satellite coordinate determination, the points of concentration networks of the 1st and 2nd categories and the points of a geodetic substantiation survey. In addition, it is allowed to use as initial data previously installed on location and coordinated landmarks, corners of permanent structures, fences, manholes, etc., as well as the remaining points of the planned binding of AI and SI.

3.2. Stages of Carrying Out Activities to Establish and Restore Boundaries of Land Plots

The main stages of carrying out activities to establish and restore the boundaries of land plots are: 1) preparatory work; 2) field work; 3) cameral work.

At the stage of **preparatory work**, the collection, systematization, studying of documents and materials on the basis of which the land plot is allotted are carried out. After studying the available documents and materials, the possibilities of using various methods of transferring the boundaries of the land plot to the terrain are determined, the location of landmarks, the laying of theodolite passages and ways of connecting them with points of the geodetic network are outlined. Based on the available land cadastral materials (LIS, land allotment project, large-scale plans, topographic plans), a ***layout drawing*** of establishing or restoring the boundaries of the allotted land plot on location is prepared (fig 3.2).

A layout drawing displays: 1) the boundaries of the allotted land plot; 2) the turning points of the boundaries of the land plot, fi ed and previously fi ed by landmarks; 3) the numbers of turning points of the boundaries of the land plot; 4) the points of geodetic networks used for connection with fi ed landmarks of the boundaries of the land plot; 5) the schemes of designed traverses, as well as other geodetic constructions in order to connect the boundaries of the land plot with the points of the geodetic network; 6) geodetic data (angles and lengths of lines) necessary to establish the turning points of the boundaries of the land plot; 7) the corners of capital buildings, as well as other fi ed points of the situation used to determine the location and connection with them of the installed landmarks; 8) additional geodetic data (angular and linear), as well as coordinates (in the local system) of the starting points or increments of coordinates between them, necessary for transferring the project of a land plot allotment to the area; 9) adjacent land plots and plots of other (outside) land users, land owners, owners, tenants of land plots, indicating their last names or surnames, firs names and patronymics; 10) the legend; 11) stamp of the organization. In the case of establishing and restoring the boundaries of the allotted land plots within their actual boundaries, making of the layout drawing may be omitted.

Field works to establish, restore and fix on location the boundaries of an allotted land plot using a geodetic method include: 1) reconnaissance of the plot; 2) transfer to the locality of the boundaries of the allotted land plot; 3) fixing the turning points of the boundary of the allotted land plot with landmarks; 4) cutting clearings, in accordance with the established procedure, in forested and bushy areas, providing mutual visibility of adjacent landmarks; 5) carrying out the necessary geodetic measurements in order to determine the coordinates of the installed landmarks and to link them with the solid contours of the terrain; 6) familiarization on location of interested parties or their representatives with the established boundaries of the land plot; 7) carrying out control measurements and determinations.

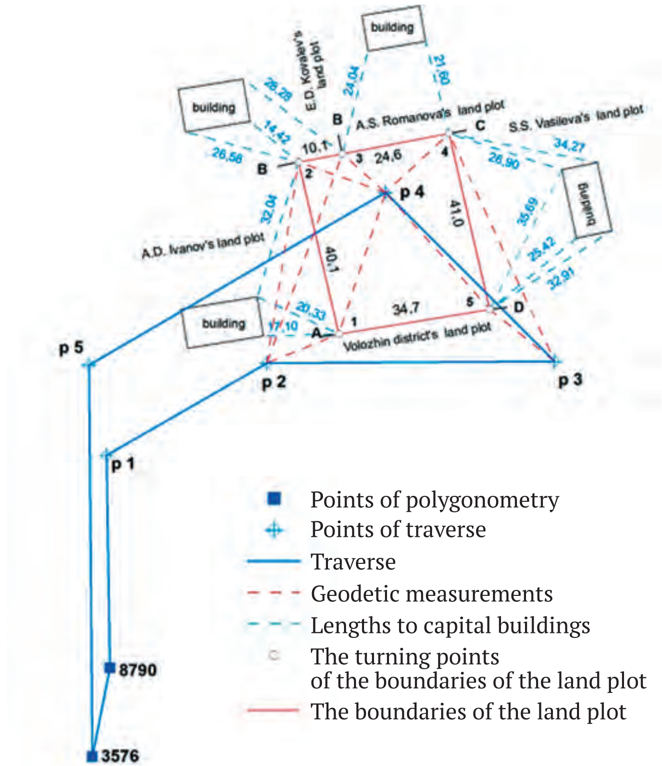


Fig. 3.2. A layout drawing

Fixing of the turning points of the boundaries of the allotted land plot transferred to the terrain is carried out by *landmarks* of the established form. After installing or restoring the landmarks, the angles and lines are measured, as well as the coordinates of these marks are determined in the state or local system of geodetic coordinates. When measuring angles and lines with geodetic instruments without electronic memory, a ***field log*** and an ***outline*** are kept. If electronic theodolites and tacheometres with memory are used, then only the ***outline*** is kept.

Installed and coordinated landmarks must allow indisputable identificatio of their location on location, restoration and use to establish the boundaries of adjacent land tenures. Therefore they are subject to connection (binding) by measuring linear segments with the corners of capital buildings, small architectural forms, with the centers of manholes of manholes, poles of power transmission and communication lines, free standing trees and other solid contour points of the terrain. Based on the measurements obtained, a ***scheme***

of connection (referencing) of landmarks with objects and terrain contours is drawn up (fig 3.3). If there are no objects and contours on location to connect the landmark installation, it is allowed to issue a description of the location of the landmark or the location of the boundary of the land plot in the form of a separate document.

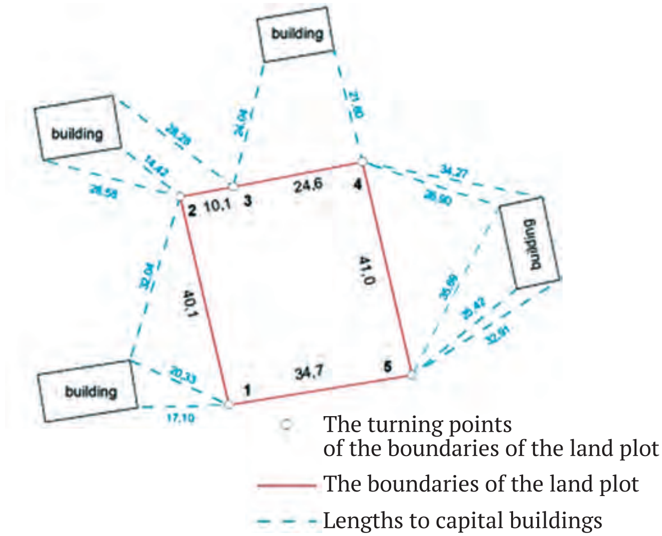


Fig. 3.3. Scheme of connection (referencing) of landmarks with objects and terrain contours

The establishment, restoration and fixing of the boundaries of the allotted land plot on location is carried out in the presence of the person to whom the land plot is allotted, the land user, land owner, owner, tenant of the land plot, from whose land this land plot is withdrawn, and, if necessary, adjacent land users, landowners, owners, tenants of land plots; then an ***act on familiarization of the interested parties on location with the established (restored) boundaries of the land plot*** is drawn up.

The **restoration of the boundaries of a land plot** consists of finding the position of the lost landmark on location and fixing of the found position with a new landmark. The technical basis is provided by geodetic data obtained as a result of establishing the boundaries of this section in previous years, the outlines of landmarks and the layout drawing.

The simplest way to restore the boundaries is to determine the location of the landmark visually, as well as to take control measurements of the lengths of the lines between visually found landmarks; to measure the length of the line on the plan and on location between the found landmark and the contour point of the situation; to measure the lengths of lines when finding the position of the lost landmark along the alignment between the contour points, perpendicular to the alignment, and other ways. In more difficult conditions, in the presence of geodetic data along the boundary of the land plot, the search for the position of the lost landmarks is carried out using the polar method. In the absence of geodetic data along the boundary of the land plot, they are calculated from the known coordinates of the starting points of the state geodetic network and concentration networks and the graphic coordinates of the landmark being sought by solving inverse geodetic problems with control.

At the stage of **cameral work** after completion of field work to establish and restore the boundaries of the allotted land plot and measure them, it is necessary to draw up a ***scheme of connection (referencing) the boundaries of the land plot with the points of the state geodetic network, networks of thickening with nodal landmarks, the position of which is determined by satellite or other methods, marks of geodetic networks in settlements*** (fig 3.4).

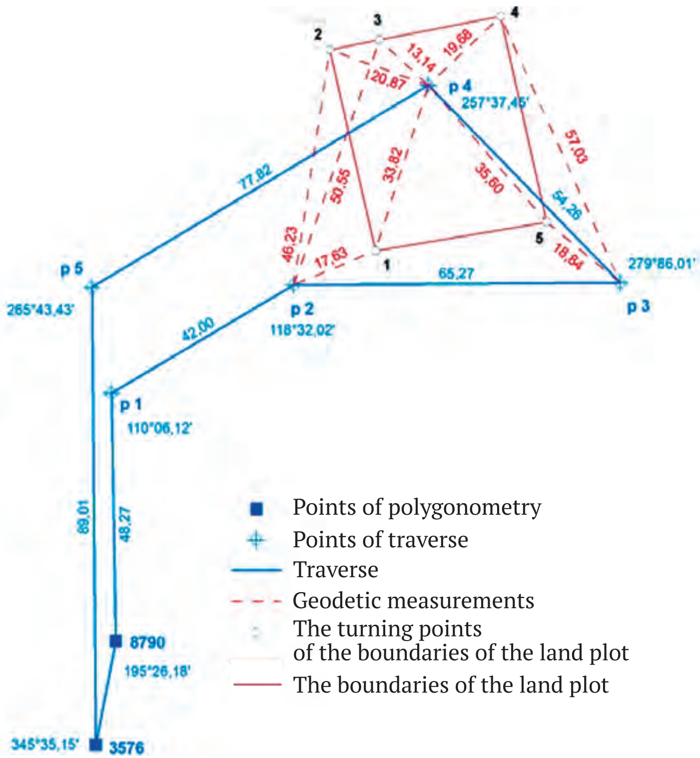


Fig. 3.4. Scheme of connection (referencing) of the boundaries of the land plot with the points of the state geodetic network

The processing of field measurements, calculation of coordinates of the landmarks installed, restored on location along the boundary of the allotted land plot, compilation of catalogues of coordinates and calculation of the area of this land plot are performed using personal computers in packages for processing field geodetic observations (for example, *aGeodesy Suite* and *tGeodesy Suite* (BelNICzem, Belarus), *Trimble Geomatics Offi e* (Trimble, USA), *CREDO_DAT* and *CREDO TOPOPLAN* (Credo-Dialog, Belarus). In addition to the listed software packages, these types of work can also be performed in GIS, for example, *ArcGIS* (Survey Analyst module).

The calculation of coordinates is preceded by equalization of measurement results. Accuracy assessment of measurement results functions (direction angles, coordinates, areas) based on equalization materials is performed in the process of equalization calculations. The average measurement results and their equalized values with accuracy assessment, as well as all problems solution, are printed out and attached to the case materials for establishing (restoring) the boundaries of the allotted land plot. After completing equalization calculations, a ***catalogue of the coordinates of the turning points of the boundaries of the land plot*** is compiled (fig 3.5).

By the obtained coordinates the total area within the established (restored) boundaries is calculated and a ***plan of the boundaries of the land plot*** is drawn up (fig 3.6). The scale of the plan of the boundaries of the land plot is selected depending on its size and configuration in such a way that the plan can show all the turning points of the boundaries of this land plot and interspersed (outside) plots of other land tenures. The latter are allowed to be taken out of the general plan of the boundaries of the main land plot to a free place using a larger scale.

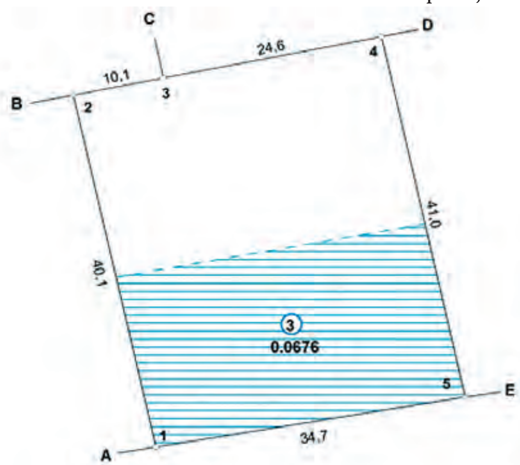
local coordinate system

№ in catalogue	Turning point number	Type of fixing of the boundary turning points	Coordinates, m		Direction angles, °, ′	Distances, m
			X	Y		
1	1	fence corner	3393,05	12134,67	278°26,18′	34,53
2	2	fence corner	3387,98	12156,21	15°12,0′	35,12
3	3	landmark	3353,39	12136,05	105°55,02′	21,19
4	4	landmark	3367,75	12167,12	195°03,00′	16,54

Plot area 813 m^2 (0.0813 ha)
Polygon perimeter 27.98 m
Plot area RMS 0.1 m^2 1 : 450
Permissible square discrepancy 0.00001 ha

Fig. 3.5. Example of compiling a catalogue of coordinates of turning points of a land plot boundary

Total lands within the boundaries of the plan – 0,1406 ha
Allotted for use as ownership – 0,1406 ha



Lands with restrictions on use

Sanitary protection zone
of underground water source

Description
of the boundaries of adjacent lands

From A to B – A. D. Ivanov's land plot
From B to C – E. D. Kovalev's land plot
From C to D – A. S. Romanova's land plot
From D to E – S. S. Vasileva's land plot
From E to A – Volozhin district's land plot

Fig. 3.6. Plan of the boundaries of a land plot

The plan of the boundaries of a land plot must display: 1) all the turning points of the boundary of a land plot; 2) the main traverses, if they were laid to survey rivers, streams, and so on, which serve as boundaries of land plots; 3) the lines of upland boundaries, boundaries passing along fences, contours of permanent buildings, rivers, streams and other water sources, with measured distances to them from the landmarks in the continuation of the boundary line; 4) the numbers of points and lengths of equalized lines or lines calculated from the coordinates of the turning points of the boundary of the land plot; 5) the boundaries of land tenures located within the boundaries of the allotted land plot, as well as the boundaries of reserve land, the special fund of land reserves; 6) the boundaries, codes and areas of land with restrictions on use.

The plan of the boundaries of the land plot indicates: 1) total lands within the boundaries of the plan, ha; 2) allotted for use (lifetime inheritable possession or transferred to ownership, lease, etc.), ha; 3) description of the boundaries of adjacent lands; 4) symbolic representation of lands with restrictions on use; 5) the scale of the plan; 6) the stamp of the organization, initials, signatures of executors and dates.

The information about the boundaries of a land plot is entered into the LIS by the organization operating the LIS in the place of location of this land plot. At the same time, this organization coordinates the information about the boundaries of a land plot with the information about the boundaries of adjacent land plots, as well as the terrain objects previously entered into the LIS, and in case of discrepancies between the entered and available information, the information about the boundaries of land plots with a lower precision is corrected if these discrepancies are within the limits of legitimate value. After entering the information about the boundaries of the land plot in the LIS, the organization operating the LIS in the place of location of the land plot draws up and places in the land management file a ***certifi ate of amendments to the land accounting documentation*** or returns the materials to the executor for correction.

After the cameral work, an explanatory note is drawn up, and all the materials are brochured into the ***land management file on the establishment (restoration) of the boundaries of the land plot on location (in place***), which should contain: 1) the title page of the works executor indicating the number and date of receipt of a special permit (license) for geodetic and cartographic activities; 2) a list of case documents; 3) an explanatory note; 4) a petition (application) of the person who has been allocated a land plot to carry out works on establishing or restoration of the boundaries of the land plot allotted to them; 5) a copy of the certificate of the state registration of a legal entity or an individual entrepreneur who has been allotted a land plot (if necessary); 6) a copy of the decision to allot a land plot to a legal entity, citizen or individual entrepreneur; 7) materials collected at the stage of preparatory work; 8) a layout drawing for establishing or restoring the boundaries of the land plot; 9) materials of field and cameral work; 10) a catalogue of coordinates of the turning points of the boundaries of the allotted land plot; 11) a scheme of connection (referencing) of the boundaries of the land plot with the points of the geodetic network; 12) a scheme of connection (referencing) of landmarks of the boundaries of the land plot to objects and contours of the area; 13) a plan of the boundaries of the land plot with restrictions on the use of land (if there are any); 14) an act on familiarization of the interested parties on location with the established (restored) boundaries of the land plot; 15) acts on control and acceptance of the work executed; 16) a certificate of amendments to the land registration documentation.

The land management file on a land plot allotment and the establishment of its boundaries on location with an application for the state registration of the creation of a land plot and the emergence of title to it is transferred to the territorial organization for the state registration of a real estate and the title to it. After the state registration of the creation of a land plot and the emergence of the title to it, the state registration organization transfers the certificate of the state registration to the person to whom the land plot was allotted.

Questions for self-assessment

1. What is a boundary of a land plot? What is fi ed and unfi ed boundary?

2. In what cases is the boundary of the land plot established, and in what cases is it restored?

3. What is the geodetic basis for establishing (restoring) the boundaries of land plots in the Republic of Belarus?

4. Enumerate the main stages of carrying out measures to establish and restore land boundaries.

5. What documents are drawn up as part of the preparatory work for establishing and restoring the boundaries of land plots?

6. Identify the special features of the field stage of activities to establish and restore land boundaries.

8. What software complexes are used to process data from field geodetic measurements?

9. How are the Local LIS of the regions of the Republic of Belarus used in the process of carrying out activities to establish and restore boundaries of land plots?

4. LAND RESOURCE MANAGEMENT BASED ON CARTOGRAPHIC MATERIALS

4.1. Stages of GIS-mapping of Land Based on Cartographic Materials

The existing cartographic materials (land management maps and plans, land tenure maps of regions and settlements, topographic maps and plans, plans of the territory of gardening communities, etc.) are an important source of data for geoinformation mapping of land. When creating the LIS of the Republic of Belarus, the cartographic material forms a group of layers "Rasters" (table 1.1). The raster spatial basis of the LIS is formed on the basis of initial cartographic materials (ICM), scanned and georeferenced to the state coordinate system, as well as georeferenced digital orthomosaics created in the digital photogrammetric systems.

There is a number of requirements for raster copies of ICM. They must be formed within the framework of the corresponding nomenclature sheets of topographic maps (plans) with the dimensions of the sides and diagonals not differing from their theoretical dimensions. The spatial resolution should correspond to 0.07 mm ICM scale, and the format of raster copies should be TIFF with PackBits compression. It is also required that the border decoration be absent or be made a separate layer. The background pixel value of bitmap ICM copies must be NoData or 255 (white). Raster copies must be georeferenced to the ICM coordinate system.

Digital orthophotomaps (plans) must meet the following requirements: be formed within the nomenclature sheets of a topographic map in 1 : 10,000 scale or topographic plans in 1 : 5,000 or 1 : 2,000 scale; the dimensions of the sides and diagonals are the same as the theoretical ones; spatial (geometric) resolution should be no worse than 0.4 m/pix; georeferencing – to the state coordinate system; generated in SID, JP2 or JPG formats; background pixel value should be "NoData" or "255" (white color).

The **generalized technological scheme for the use of cartographic materials in GIS** consists of the sequential execution of a number of operations: 1) scanning; 2) creation of a vector model of the mathematical basis (frames of nomenclature sheets, directly coal coordinate grid) in the ICM coordinate system; 3) transformation and georeferencing; 4) creation of raster catalogues in the geodatabase; 5) digitization of information contained in planning cartographic materials (if necessary).

Scanning of cartographic materials should be performed with a resolution of 300–400 dpi and, as a rule, on scanners providing scanning "in one pass". Scanned copies of ICM are viewed on the monitor screen and, if necessary (for example, if there are any defects in the image), they are retouched by means of systems such as Autodesk Raster Design. In case of unsatisfactory quality of raster copies, as well as in the absence of a part of the ICM image on them, they are scanned again.

Raster copies of ICM are saved in TIFF files File names must contain the nomenclature of the topographic map (plan). If divided publishing originals were used as ICM, then the corresponding suffi es are added to the name of the nomenclature, denoting the publishing original of the corresponding element of the content of the map or plan.

A **vector model of the mathematical basis of ICM** created using the GIS-project “Mathematical basis” (Matbase). The result of the work executed is the Autodesk Map project, which contains a description with the frames of topographic maps (plans) and lines of a rectangular coordinate grid (fig 4.1).

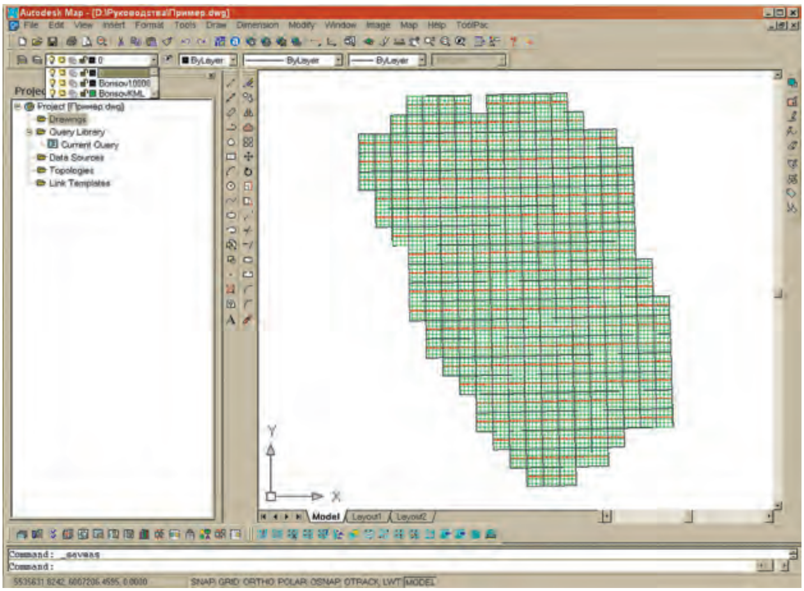


Fig. 4.1. Vector model of the mathematical basis in Autodesk Map

Transforming and georeferencing raster images to the ICM coordinate system are performed in the Autodesk Map environment using the Autodesk RasterDesign module. The Image/Correlate/RubberSheet command superimposes a raster image with the vector layer of its frame by four corner points (fig. 4.2). The calculated transformation errors should not exceed 0.2 mm when using the Polynominal method (and the exponent of the transformation polynomial should not exceed 3) or be equal to zero when using the Triangular method. Otherwise, it is necessary to specify the position of the corresponding points or remove some of them, achieving a uniform distribution of points over the field of the transformed raster. The result of the process are files of transformed raster images and files of their oordinate reference.

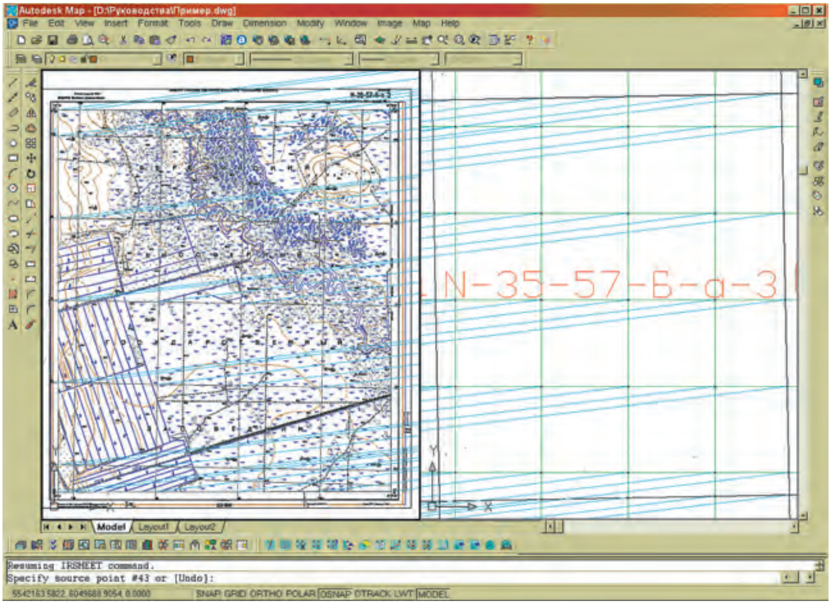


Fig. 4.2. Transforming and georeferencing a raster in Autodesk Map

The **formation of a catalogue of images** is performed by means of GIS ArcGIS in order to provide software organization of raster files for joint "seamless" viewing. Using ArcCatalogue, the RASTERS GDB and the corresponding raster catalogues are created, into which the transformed ICM raster images are uploaded. Through image catalogues, sets of oriented raster copies of ICM can be presented in the form of unified information units – the corresponding mosaic topographic maps (plans).

If it is necessary to convert a raster image into a vector form, it is digitized in ArcGIS GIS. **Vectorization** is possible in manual mode using the ArcMap editor or in manual, semi-automatic and automatic mode using the tools of the Arc Scan module (fig 4.3).

Fig. 4.3. ArcScan toolbar

Automatic vectorization using this module significantly reduces the time spent on digitizing raster images. There are two ways to vectorize in this mode: centerlines and contours. In the first case, the central lines of raster linear objects and the boundaries of areal objects are constructed. In the second case the boundaries of all raster related components are constructed as polygons. The result is a set of polygons.

Semi-automatic or ***interactive vectorization (tracing)*** is used when more control over the vectorization process is required or a small part of the image needs to be vectorized. The cursor sets the starting point and tracing direction, after which the center line is automatically drawn from the starting point to the end of the raster line, unless a polygon object or an intersection point with another line is encountered along the way. If the center line hits the intersection point, then the tracer stops and waits for the operator to again indicate the direction in which to continue tracing. If the central line stops at the boundary of an areal object, then the operator has to switch to the manual digitizing mode and digitize this object.

Manual vectorization allows the operator to keep the vectorization process under continuous control by setting the position of each vertex of the center line using the cursor. It is used to vectorize raster images of poor quality, images containing several thematic layers at once, and in the presence of complex line types. It is also useful for digitizing straight lines. In this mode, there is a special tool – raster locking, which allows the operator to automatically bind the starting point to the center line, line intersection point, line ends or corners. Quick placing the cursor over specific points improves accuracy and increases digitizing efficiency by eliminating the need of frequent zooming on the screen.

4.2. The Usage of Cartographic Materials in GIS-mapping of Land Resources in the Republic of Belarus

4.2.1. Creation of the “Soil” Layer of the Geodatabase of Land Informational System of the Republic of Belarus

The “Soils” thematic layer (digital soil map) is created to be used in carrying out work on the on-farm organization of territories, planning agrotechnical, amelioration measures, for accounting soil resources, carrying out appraisal and economic valuation of soils, as well as for comparative assessment of the conditions of the operation of agricultural enterprises, conducting soil zoning for scientific and applied purposes

The thematic layer “Soils” of the LIS is created on the basis of digital soil maps of individual agricultural enterprises (land tenures). Creating a layer is the combination and joining of digital soil maps created in the territory of individual agricultural enterprises, for which author's soil maps have already been created. The work on the creation of digital soil maps is carried out jointly by specialists from soil teams and departments of the LIS RUE "Project Development Institute "Belgiprozem".

The creation of digital soil maps for individual agricultural enterprises is performed in the ArcGIS **Maps_Soils geodatabase**. In the GDB, information about soils is presented in the form of ***spatial data*** (table 4.1). ***Soil attribute data*** consist of: 1) attribute information of feature classes; 2) informational tables: classifier of soil features (Kod_Leg_Pochv), classifier of subsoils (Leg_podstil), classifier of boundaries of land classes (Land_lin), nomenclatural list of soils (Spisok_Pv); 3) reference tables: land classes (Land_dop), meliorative condition of land (Melio), land types (t_LandTypes)).

Table 4.1

Datasets of the GDB "Maps_Soils"

Feature Datasets	Feature classes	Contents
MAPS (soil maps of land tenures)	Soil_<NZ>	Soil varieties (polygon)
	Land_p_<NZ>	Land classes (polygon)
	Land_L_<NZ>	Land classes boundaries (line)
	Land_t_<NZ>	Codes of classes and ameliorative condition of land (point)
SL_SOIL (generated soil map of a land tenure)	Pochv	Soil varieties of the generated soil map (polygon)
SKETCH (auxiliary information for execution of the printed soil map of a land tenure)	Admi_<NZ>	Boundaries of adjacent settlements
	Smejniki_<NZ>	Information about the adjacent
	Tab1_Exp_<NZ>	Table for forming a nomenclatural list of 1 column
	Tab2_Exp_<NZ>	Table for forming a nomenclatural list of 3 columns
	Leg_Tab1_<NZ>	Templates for execution of soil color fills and hatching (Tab1_Exp)
	Leg_Tab2_<NZ>	Templates for execution of soil color fills and hatching (Tab2_Exp)
	Pochv_s	Polygonal class of soil varieties of the generated soil map

Notes.

1. The name of the feature class in the MAPS and SKETCH datasets includes layer rank and land tenure number <NZ>.

2. Feature classes in the SKETCH dataset that do not contain a land tenure number in their name, are templates.

A digital soil map of the territory of an agricultural enterprise is created in one of the ways, depending on the type of the Local LIS (vector or LIS on a raster cartographic basis). The process of creating a digital soil map consists of a number of stages given in table 4.2.

Table 4.2

The main stages of creating a digital soil map

Stage	Type of work	Executor
Preparatory	Selection and analysis of raw materials Preparation of the soil map legend	Soil detachment
	Digitization of land tenure boundaries, water bodies (rivers, canals and ditches, lakes, reservoirs and ponds), railways and improved roads in the land tenure area	LIS department
Creation of raster ICM	Creation of a contour map with a summary of contours and codes of soil varieties of adjacent land uses	Soil detachment
	Scanning of the initial cartographic material (ICM) – a contour or copyright soil map Geodetic connection and transforming of raster ICM	LIS department
Creation of vector soil map of a land tenure	Raster ICM digitizing Joining the boundary contours of soil varieties of the generated soil map with the contours of previously created adjacent soil maps Coordination of the boundary layer of soil variety contours with the GDB layers of the Local VIS of the corresponding area	LIS department
	Preparation of a report and issuing a file on a digital soil map of a land tenure creation	Soil detachment
Forming of the “Soils” layer of the GDB of the Local LIS	Export of the soil varieties layer created within the land tenure boundaries to the “Soils” (Soil) layer of the GDB of the Local LIS	LIS department

At the stage of preparatory work, the initial data are collected and analyzed about the territory of the land tenure for which a digital soil map is created. The initial data are: the author’s soil map of land tenure with a legend, compiled basing on the materials the latest soil survey and containing soil codes according to the nomenclatural list of soils of Belarus; land usage materials; information on the soils of the land tenure, clarifying or supplementing the data of the author’s soil map. In addition, the legend of the soil map is prepared as a table with soil types and varieties identification The legend data of the author's soil map are presented a table Kod_pochv, which contains the codes of soil varieties of land tenure in the GDB "Maps_Soils". The table Kod_pochv is created on the basis of the prepared template table Leg_shablon.

When creating a soil map as a "Soils" layer of the Local LIS on a raster cartographic basis, the boundaries of a land tenure are digitized (Lots layer, information about the land users is placed in the Users table), as well as water bodies (rivers, canals and ditches, lakes, reservoirs and ponds), railways and improved motor roads (Land) layer) on a raster cartographic basis, taking into account the changes displayed in the materials of graphic accounting.

The following can be used as a raster ICM for creation of a vector soil map: *author's soil map of a land tenure* or contour soil map. A contour soil map is created in the cases when, from the moment of creation of the author's soil map to the creation of a digital soil map, there has been a change in the boundaries of the land tenure or when the soil map is created as the "Soils" thematic layer of the Local LIS on a raster cartographic basis.

The creation of a contour soil map is as follows. On a transparent basis, according to the data of the Local LIS, the land tenure boundaries are plotted, including outside land users, rivers, lakes, reservoirs, ponds, main canals, railways and improved roads. Then, the features plotted on the transparent base are combined with the corresponding features on the copyright soil map. From the copyright soil map, the boundaries and numbers of soil varieties are transferred to the transparent base, and a summary of the contours of soil varieties of author's soil maps of adjacent land tenures is carried out. If necessary, a new legend of the soil map is compiled.

The creation of a digital raster basis for the contours of soil varieties is carried out by scanning the original cartographic material (contour soil map or author's soil map). ICM is scanned at 300 dpi. The scanned image is reviewed and cleaned if necessary. In the case of ICM scanning in parts, joining of its fragments is performed. Transformation and georeferencing of a raster to the coordinate system of the Local LIS is performed in the AutodeskMap environment using the Autodesk RasterDesign module or in the ArcMap GIS ArcGIS using the Georeferencing command.

Vectorisation of the boundaries of soil varieties is performed using raster ICM. In automatic and semi-automatic modes of vectorizer programmes (Autodesk RasterDesign, ArcScan for ArcGIS), a contour soil map is digitized, in semi-automatic and manual modes, c author's soil maps are digitized. The digitized information is placed on the "Pochv" layer of the "Maps_Soils" GDB. The contours of soil varieties are coded according to the index values available on the author's soil map, which are placed in the Code field of the attribute table.

The digitized boundaries of soil varieties (digital soil map) must be coordinated with the boundaries of the contours of previously created digital soil maps of adjacent land tenures, as well as with the layers Land and Melio of the GDB of the Local LIS.

The formation of the *"Soils" layer* of the GDB of LIS is carried out by connecting the attribute table of the polygonal layer "Pochv" of the GDB "Maps_Soils" with the legend table of the soil map Kod_Pochv and loading the created digital soil map of the land tenure into the "Soil" layer (Soil) of the GDB of the Local LIS (the Phocv layer of the GDB "Maps_Soils"). The structure of the attribute table of the "Soil" layer of the GDB of LIS is presented in table 4.3.

Table 4.3

The structure of the attribute table of the "Soils" layer of the GDB of the Local LIS

Data name	Field name	Field type	Note
Classification status of soi	SoilCode1	Textual	Codification according to the Nomenclatural List of soils of Belarus
Genesis of parent rocks	SoilCode2	Textual	
Granulometric or botanical composition of soil	SoilCode3	Textual	
The character of the underlying	SoilCode4	Textual	
Ameliorative condition and development	SoilCode5	Textual	

4.2.2. Creation of Digital Elevation Models and Three-dimensional Elevation Models

A **Digital Basic Cartographic Terrain Model** (DBCTM) is an element of automated technology for joint land cadastral and topographic interpretation of aerial photography materials and the construction of a multipurpose digital terrain model as a basis for creating digital land cadastral (LIS) and topographic (digital maps) terrain models.

In terms of its content, a DBCTM is, on the one hand, a final product – a result of complex work on aerial photography and digital interpretation for the purposes of the land cadastre and topography. In this capacity, it can serve as a source of digital cartographic information for the construction of thematic GIS, maps and plans for various sectors of the national economy of the Republic of Belarus.

On the other hand, a DBCTM is an intermediate product intended for the formation of a land information system and digital large-scale topographic maps and plans. With these goals in mind, the content of a DBCTM is define in such a way that the formation of LIS and digital topographic maps and plans is carried out in cameral conditions by constructing queries and reorganizing information.

A DBCTM is created only when the object of work requires creation or updating of both LIS and digital topographic maps or plans. It is a complex of interrelated and complementary GIS of geodetic, cartographic and land cadastral content. The list of GIS that make up a DBCTM is given in table 4.4.

Table 4.4

The composition of GIS included in the DBCTM

GIS name	GIS contents	GIS designation
Mathematical basis	Nomenclature layout of topographic maps and topographic plans, rectangular coordinate grids for the entire scale range	MatBase
Planned-altitude base	Elements of the state geodetic network, concentration networks, survey networks	GeoBase
Raster topographic base	Raster oriented mosaic topographic maps in 1 : 10,000 scale, topographic plans in 1 : 2,000 scale, orthophotomaps	Rastr
Boundaries	Administrative-territorial and administrative units, model boundaries	Boundaries
Aerogeodetic data	Aerial photography route schemes, aerial photography frame schemes, photocondensing results, digital aerial photographs	AeroGeo
Three-Dimensional Model	Contour lines, elevation marks, cut lines, edges, cliffs, retaining walls	3D model
Terrain model	Water and land cover, aboveground and underground structures, hydrographic and road network, communications and other linear features, point features, annotations	Model

The **GIS “Mathematical basis”** covers the entire territory of the Republic of Belarus; it is transferred to the enterprises that execute the work of DBCTM formation.

The **GIS “Planned-altitude base”** and **“Raster topographic base”** are created for the entire territory of the Republic of Belarus gradually – as the work on the formation of the DBCTM of the regions of the republic progresses. The GIS “Raster topographic base” is developed on the basis of topographic maps of the appropriate scale and is used as an auxiliary material for cameral interpretation.

The **GIS "Three-Dimensional Model"** is created on the basis of topographic maps of the appropriate scale and is supplemented with vector information about the characteristic elements of natural and artificia landforms, obtained by digitizing the stereo model. The vector elevation model is a layer of a digital topographic map, and is also used to build a matrix relief, which, in turn, serves as the source material for creating orthophotographic maps.

The **GIS "Aerogeodetic data"** is formed on the basis of scanned negatives of aerial photographs, aerial photography parameters and data from photocondensing projects.

ATU and TU coverage, included in the **GIS "Borders"**, is created for the entire territory of the Republic of Belarus. It is transferred to the enterprises that execute the work of DBCTM formation and is periodically updated as changes and additions are made to the register of ATU and TU (including those based on the results of work on DBCTM formation).

The **GIS "Terrain Model"** is developed by digitizing according to a stereomodel or an orthophotographic map of objects that are common for both topographic maps and LIS, and is used to create digital plans and maps.

The ***digital elevation model (DEM)***, according to the structure of the DBCTM, is included in the GIS "Three Dimensional Model", which is created in the territory of the Republic of Belarus gradually – as the DBCTM progresses. The information model of the GIS "Three Dimensional Model" is given in table 4.5.

Table 4.5

GIS "Three-dimensional model" attribute tables structure

Data	Field	Representation
Elevations		
Contour lines		
Streams		
Coastlines		
Slope edges		
Roofs		
Feature code by classifie	Code	Numeric
…		
Feature code by classifie	Code	Numeric

All attribute tables of the topics of a given GIS have the same structure. The coordinates of elevations (X, Y, Z) are contained in the model in the coordinates of the corresponding graphic primitives – 3d points. The contour heights are contained in the model in the level (Z coordinate) of graphic primitives of the model – polylines. The information about the height of buildings and structures (features of the Roof layer) is also contained in the level (Z coordinate) of graphic primitives of the model – polygons. The information about the height of all other GIS features is contained in the Z coordinates of the 3d-polyline vertices.

The features of the layers "Streams", "Coastlines", "Slope edges" and "Roofs" of the GIS "Three-dimensional model" are templates of the corresponding features of the GIS "Terrain model". When converting (unloading) features from one model to another, they are converted from 3D to 2D.

The average height accuracy of the model elements additional to the contour lines is 1 m. Streams are digitized with reference to the contour lines they intersect. Channels and ditches less than 5 m wide are not digitized in the 3D vector model.

A three-dimensional model is created in order to build orthophotomaps and vectorization of buildings and constructions correctly. The formation of the model is carried out within the boundaries of the DBCTM. The DEM of DBCTM is created in *three stages*:

1) creation of a vector relief model;

2) addition and editing of the three-dimensional vector model of the relief;

3) digitization of buildings and constructions.

First, according to the raster topographic map of the GIS "Raster topobasis" using vectorizer programs, contour lines and elevations and water lines are digitized. Then, along the routes, in accordance with the scheme of aerial photography, the relief model is supplemented and edited by digitizing by digital stereopairs on the Digital Photogrammetric Station (DPS) with uploading fragments of digitized contour lines of characteristic elements of artificial and natural relief forms (edges of cliffs, slopes of embankments and cuts, thalwegs, etc.). The Roof coverage is formed along the routes by digital stereo-pairs in the same projects at the cameral stage of interpretation.

The *technology for constructing a DEM* based on the vectorization of raster topographic maps is as follows:

1) scanning of topographic maps in scale 1:10,000;

2) georeferencing of obtained images;

3) vectorization of rasters;

4) verification the results of digitization

5) summary of the results obtained for the entire area of work;

6) vectorization of characteristic relief elements (edges, slopes, cliffs, edges of rivers and reservoirs);

7) summary of received models in autodeskmap, arcgis or photomod dtm;

8) verification and appr val of the composite model, fig 4.4.

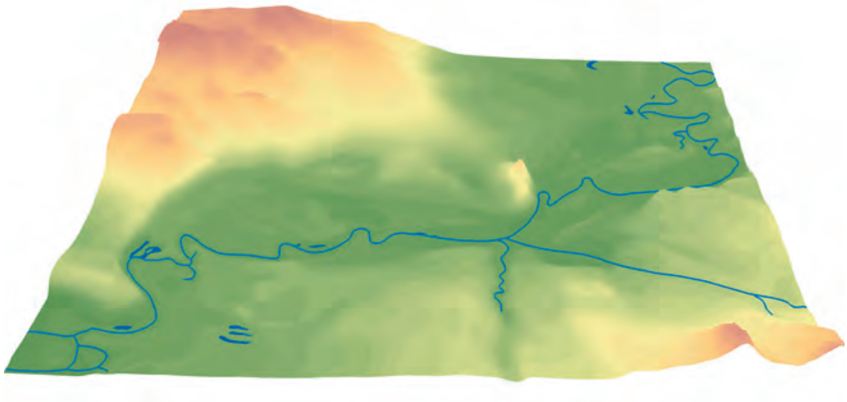


Fig. 4.4. DEM (area of the educational geographic station of the BSU "Western Berezina"), obtained using the Topo to Grid interpolation method (GIS ArcGIS)

The next step in the formation of a three dimensional terrain model is the vectorization of characteristic elements of the DTM according to the prepared Photomod projects. The digitization of edges of slopes, cliffs, retaining walls, edges of roofs of buildings and constructions, edges of watercourses and reservoirs is carried out. Vectorization is carried out using Photomod StereoDraw.

After summarizing all the digitized relief elements (contour lines, elevations, cliff edges, slopes, retaining walls, shorelines of watercourses and reservoirs) into a single model, its verification follows. Model summary is done using ArcGIS or Photomod DTM:

1) building a tin-model;

2) building contours according to TIN-model;

3) comparison of the original contour lines and elevations with the received ones and editing the original ones, if necessary.

At the final stage, after merging two vector models, a TIN model is built, according to which the combined model is viewed and thus checked and, if necessary, the original vector features are corrected.

4.2.3. Creation of Maps of Boundaries of Land Plots

Creation of **plans of the boundaries of plots of gardening communities** is carried out within the process of formation of land management affairs to establish (restore) boundaries on location (in place). When creating new or changing the boundaries of existing communities, as well as for their state registration and obtaining documents certifying the titles to land plots, measures are taken to establish (restore) the boundaries with the entire complex of geodetic surveys. When preparing a land management file based on the materials of previously performed (before the widespread use of GIS technologies in land management practice) steps to establish (restore) boundaries, it is possible to use cartographic data available from these materials. It is important that since the creation of the materials in gardening community there have been no changes in its external boundary, the boundaries of public land and plots of citizens. In this case, the **main stages of work** are:

1) creation of the outer boundary of gardening community in the local lis according to the catalogue of coordinates;

2) scanning the paper plan of the land of gardening community;

3) transformation of the resulting raster file and its georeferencing to the coordinated outer boundary;

4) vectorisation of the boundaries of public land and plots of citizens; comparison of the actual areas of the plots with the areas indicated on the plan;

5) creation of catalogues of coordinates of the turning points of boundaries and plans of land boundaries.

The ***outer boundary of gardening community*** is created according to the catalogue of coordinates available in the boundary setting materials in the Lots3 layer of the Local LIS. The "Add X, Y data" tool is used when the catalogue of coordinates is generated electronically as a Microsoft Offi e Excel or Microsoft Offi e Access table, or "Absolute X,Y" in the ArcMap edit mode of the GIS ArcGIS. If the coordinate catalogue was created in a coordinate system other than the LIS, the work is done in the original system, and then the data are reprojected. At this stage, it is important to check whether the actual area of the community corresponds to the area indicated on the plan and in the materials of boundaries establishment. By converting polygons into lines and points, turning points of the boundary and line boundary of gardening community are created in the layers Lots1 and Lots2 of the GDB of the Local LIS.

Scanning of a paper plan of land plots of gardening community is performed with a resolution of at least 300 dpi. The scanned image is reviewed and cleaned. If the plan is scanned piecemeal, the joining of its fragments is performed. ***Transformation and georeferencing*** of a raster to the coordinated outer boundary of gardening community is performed in the AutodeskMap using the Autodesk RasterDesign software system or in ArcMap of the GIS ArcGIS using the Georeferencing command.

Vectorization of the boundaries of public land and plots of citizens is carried out by means of editing with ArcMap of the GIS ArcGIS in the layers

Lots3, Lots1 and Lots2 of the GDB of the Local LIS. Topology editing compares the actual areas and lengths of the plot boundary lines with the areas and lengths specified on the plan. After checking the accuracy of comparison, the topology of the GDB of the Local LIS is also checked.

Creation of catalogues of coordinates of the turning points of the boundaries (fig 4.5) is carried out by exporting the attribute table of the Lots1 layer to a text file Plan of the boundaries of land plots of gardening community and plans of the boundaries of citizens' plots (fig 4.6) are generated in the layout mode of ArcMap.

1963 coordinate system

Point No.	X coordinate, m	Y coordinate, m	Distances, m	Directional angles, °,′
1	2863.91	51684.33	8.5	278°26.16′
2	2875.34	51678.24	15.1	8°12.18′
3	2884.57	51672.11	28.7	58°34.27′
4	2886.89	51623.63	21.4	77°55.33′
5	2864.33	51622.34	26.7	13°15.56′

Plot area 613 m^2

Fig. 4.5. Catalogue of coordinates of the turning points of the boundaries of a land plot

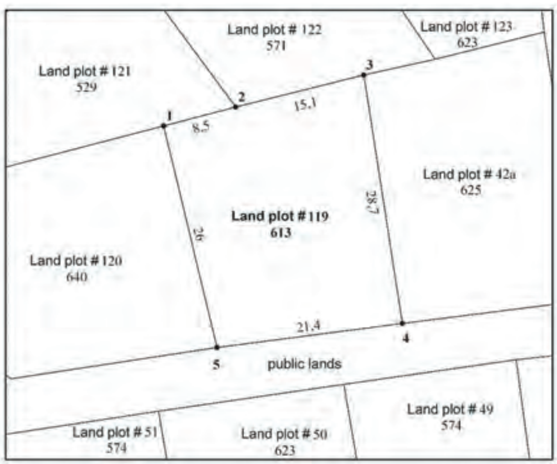


Fig. 4.6. Land boundary plan

Questions for self-assessment

1. What is the sequence of operations when using cartographic materials for geoinformation mapping of land?

2. What resolution is optimal when scanning cartographic materials for subsequent GIS mapping?

3. What does the process of transformation and georeferencing of scanned cartographic materials consist of?

4. What modes in GIS is it possible to use for vectorization of scanned and georeferenced cartographic materials?

5. Enumerate the main stages of creating a digital soil map based on cartographic materials.

6. What purposes does the technological process of creating the GIS “Three-dimensional model” for the DBCTM serve and what are its special features?

7. In what cases is the creation of plans for the boundaries of the land of gardening communities carried out according to cartographic materials?

8. Enumerate the main stages of creating plans for the boundaries of the land of gardening communities based on cartographic materials.

5. LAND RESOURCE MANAGEMENT BASED ON VECTOR DATA. LAYOUT OF LAND-CADASTRAL MAPS

5.1. General Recommendations for Mapping. Main Elements of Maps

Cartography can be described as a set of graphic principles, including a range of technologies, as well as scientific and artistic approaches, necessary for the creation of geographical maps. Originating many centuries ago, cartography has come a long way of development and continues to improve. In recent decades, a lot of new developments have appeared in cartography, and the means of cartography are also being transformed, taking into account advances in the study of human psychology and visual perception.

Traditionally, the creation of maps was determined by the function of storing spatial information in them in the form of an image. The introduction of geoinformation technologies into geographic research has given rise to a systemic revolution in cartography.

The traditional approach to maps, the *message paradigm*, viewed a map as an end product designed to communicate spatial distributions through the use of symbols, classifications, and so on. However, this is a limited approach to cartography, as the map doesn't give the user the initial, unclassifie information. In other words, the user, having only the final product, cannot rearrange the data to obtain greater returns under changing circumstances or needs.

An alternative approach to cartography, which maintains the storage of original data to enable later reclassification was developed around the same time that map makers began to use the advances in computer technology. In this approach, called the *analytical paradigm*, the original attribute data is stored on computer media and displayed based on the needs of the user and with the use of their classifications. An early forerunner of computer mapping and GIS itself, this method is now much more fl xible in application than its predecessor. The impetus for its development is the idea that a map, especially with the use of computer technology, should not only communicate information, but also allow its analysis.

When preparing different types of maps, it is necessary to adhere to a number of **general recommendations** for their creation. It is important to understand the **purpose of the map** and **its audience**. As a rule, the purpose of a map is the storage of spatial information. Trying to convey too much information on one map only confuses its user. It is much better to create two maps, each having its own purpose. It is also necessary to understand what audience the cartographic product is to serve.

The **physical size** of a map relative to the area displayed on it dictates its scale and determines how the actual size and the quantity of objects shown on the map will be represented. The *carrier* also plays an important role, as a map printed on newsprint does not reproduce fine details much better than the same map printed on high quality paper.

Emphasis is what the map designer wants to focus on first Usually cool colors (shades of purple, blue, light blue) are used for background information, while warm colors (red, yellow and green) attract the attention of map readers.

The map must be **visually balanced**. This implies the evenness of all the map elements relative to each other, the dominant position of the cartographic image, and the absence of large empty spaces.

The **completeness** of the map implies the content on it of a number of **obligatory elements**, such as mathematical basis, cartographic image and accessories, additional data.

The main elements that represent the **mathematical basis** of the map are the projection and scale of the map. The ***projection*** is a mathematical formula that transforms the locations of spatial objects from a three-dimensional Earth's surface to a fl t map surface. Projections can cause distortions in line lengths, areas, shapes, and directions.

Accordingly, the type of projection is usually indicated on the map so that its readers understand how accurate information that they can get from the map is. The ***graticule*** of the map is associated with the map projection. Quite often, the direction is shown using the ***north arrow***. The map can show true and magnetic north. However, if the map is gridded, it is not necessary to add a north arrow.

Scale provides information to help map readers determine distances. The map scale is the ratio of one unit of length measurement on the map to the corresponding distance on location. It can be numerical (1 : 10,000), linear (scale bar) or named (ten kilometers in one centimeter).

Cartographic image (data frame) is the main area of a map (fig 5.1). You can place one or more data frames within one document. For example, you can place multiple images showing different but related information, such as dynamics of changes in the land fund by year.

The elements of the **auxiliary equipment** of a map include the *legend* (symbols and their textual explanations) and *reference data* (the title of a map, the author, the sources used, the place and year of publication).

Additional data may also be present on a map. These are ***additional maps*** (locator map, detail map). Besides, additional data includes ***textual*** and ***numerical data***, as well as ***diagrams, graphs, photographs, tables*** that complement and enrich the map.

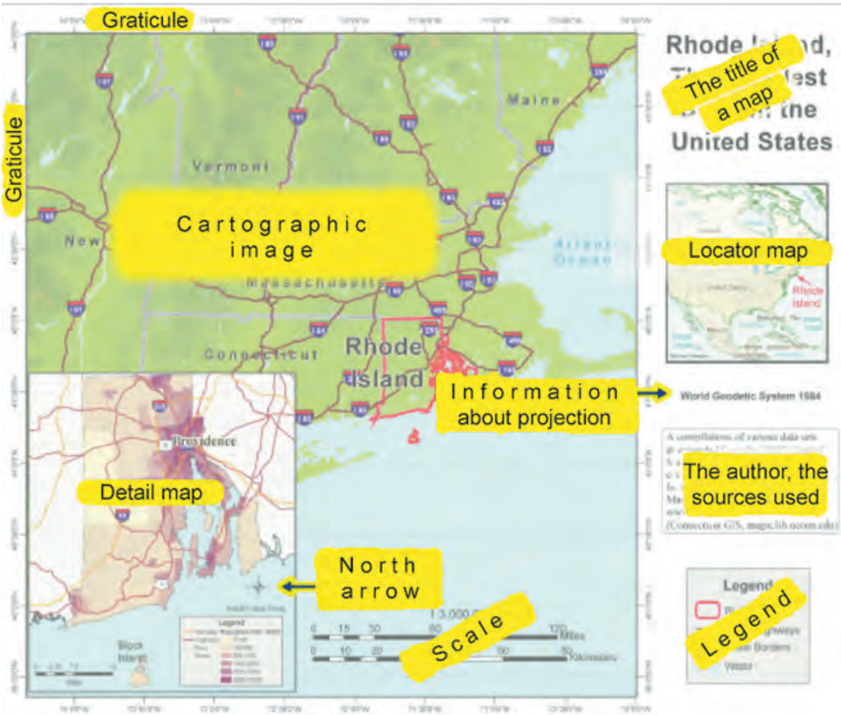


Fig. 5.1. Some elements of a map

5.2. Stages of Design and Layout of Maps in GIS. External and Internal Factors of Cartographic Design

The **process of designing and laying out a prepared map in GIS** has several steps. All operations are carried out in the layout mode of the GIS programme.

At the **first stage**, the layout of the map is developed. The developer selects the type of the map he is going to create, places all the elements on it, forms its general view, guided by the basic recommendations for mapping. This stage is very intuitive, its result is the general plan of the map.

At the **second stage**, the development of techniques for the design and symbolization of the map is carried out. The developer chooses how to display the cartographic image, selects symbols for displaying objects, class intervals, colors, line types and other graphic elements. Here the sizes of objects and the distances between them are selected; this is usually done very carefully, depending on the scale of the map. All the necessary annotations are created and placed.

At the **third stage**, all errors and defects are corrected, and the finished map is printed. The final step in the design process is fine setting of what was done at the previous stage. Only small changes can be made to the map layout here. The main thing is to create a prototype of the finished map on the monitor screen before printing. Now it is necessary to take into account the possible differences in images on the monitor screen and on paper, due to the use of special languages for controlling peripheral devices (mismatch between fonts and colors of GIS data input and output devices). Here you can recommend to output a reduced copy of the map or part of it in order to evaluate the compliance and, if necessary, make adjustments before printing the entire map.

At all stages of designing and laying out maps in the GIS, it is necessary to take into account **external and internal factors of cartographic design**.

The **external factors of cartographic design** determine the nature of the map created, the types of graphic elements used, and the internal cartographic design principles applied. These include the purpose of the map, its realism, the availability of data for mapping, the target audience and the conditions of using the map, as well as the technical limits of the equipment for creating and printing the finished map

The first and most important factor is the ***purpose of the map***, while the essential task is related to the nature of the information to be displayed. Thematic maps created in the GIS are designed to represent specific results of analysis. Simplicity is very important here: the more focused the output, the easier it is to understand. Another aspect of the purpose of the map – ergonomics – is not so much about what is displayed, but how it is done. Having decided what will be displayed on the map, it is also necessary to choose a form of presentation that can adequately convey its message. If a map shows land use restrictions, then its design should clearly demonstrate their importance.

The second factor is ***realism***, which means that each area has its own characteristics that impose restrictions on the applicability of design criteria. Geographical analysis usually involves areas with complex physical, transportation, social, or economic structures. This complexity can severely limit naming options, character sizes and styles, hatch types, etc. Such limitations are inevitable, and only a working knowledge of the field of study and the nature of the data about it can be of help. Knowing the constraints a priori will help you choose the best design strategy beforehand, rather than at the later stages, when making changes can be much more difficult

The third factor is ***data availability***. Most geodatabase of GIS have a significant volume. For example, a map with a hundred categories of land use is quite feasible, but creating a hundred distinguishable colors is very problematic. In this case, the design procedure should be modified to include a subdivision hierarchy with different colors and hatch types for each subdivision. There may be a counter-problem with the availability of data: the data is either insufficient to display, or it is old and collected on different principles, or too sparse a sample was used for it. For example, it will not be easy to compare centuries old vegetation data with the modern RSD. The former will most likely contain only a few general categories, often influen ed by the personal experience of the data collector, while the RSD will have a large number of categories derived from computer classification algorithms. The representation is also partly dependent on the scale of the map. Its scaling down reduces the detail of the map and proportionally reduces its symbols. But at some point, further reduction of symbols becomes impossible due to the loss of their distinguishability. Therefore, when designing a map, the choice of objects, simplification and generalization (generalization) become of great importance.

The next factor is the ***target audience***. Many users of GIS output documents do not have knowledge and experience in geography and cartography. Under such conditions, the map should be read as easily as possible, by retaining only the most important objects and names, and by using well-known symbols. At the same time, advanced users will be able to extract additional information from a denser representation with abstract symbols.

The ***conditions of use*** play an important role in map design. This includes not only options for a poster map or a desktop document. If the map is to be used in the field for example for field interpretation of land, then it may need lamination. The entire set of conditions of working with the map must be considered before the final design is a cepted.

Finally, the design of the map is affected by the ***technical limits of the equipment***. Obviously, a color map cannot be printed on a black and white printer. Cheap color printers often have only a small number of reproducible colors. The spatial resolution of the output device is also significant, limiting the size of symbols and the level of detail. All these factors must be taken into account.

Since the maps are perceived as a unit (as opposed to a text which is read sequentially word by word), it is necessary to pay special attention to the **internal factors of cartographic design**. Among them: the ratio of the main image and the background, legibility, visual contrast and hierarchical structure.

The ***ratio of the main image and the background*** on the map plays an important role. When creating a map layout, you need to take into account the fact that you will have to place its elements in a limited area. A lot of maps look uninteresting because they have too much or too little white background. A map that consists entirely of the main image is less desirable than a map with some amorphous background that separates the main image and gives a sense of belonging to land. The background also raises contrast and visual appeal. A map that has too much background reduces the value of the main image and may lead the viewer to suspect that it is not complete. But the picture–background correlation contains more than just aspect ratio. If land and water surfaces have the same color, the viewer can easily confuse them. Adding names, familiar boundary lines, map grids, and shading will allow the user to distinguish between the studied and not analyzed areas of the map easily.

Graphic symbols on a map must first of all be ***legible***: individual lines separable, colors distinguishable, shapes recognizable. The sizes of symbols are determined by the distance from which the map is viewed and which can vary from tens of centimeters for individual work to several meters for demonstration to a team. At the same time, the physical limitations of the equipment and the human eye must also be kept in mind.

Another factor of legibility is the visibility of the characters themselves. For example, lines are easy to see, so there is no need to make them particularly wide. Some color combinations enhance distinguishability (black letters on a white background), others hamper it (the same black letters on a dark blue background). Finally, the use of easily recognizable symbols and their combinations helps legibility – the classic example is the figures used on road signs, they convey the message without using text.

Visual contrast is also necessary to distinguish between graphics and text against existing backgrounds, as well as when they are close together. If some elements look almost the same due to the similarity in size, shape, shading, or other parameters, then it may be useful to introduce additional variations to increase contrast. In this case, one should not "go too far", since too much contrast can fatigue the viewer during a prolonged viewing.

The final principle of graphic design is ***hierarchical organization***. All graphic elements present on a map should be organized in such a way as to emphasize what is most important. This principle is poorly applied on general geographic maps, since their goal is to enable users of different interests to focus on the elements that are important to them, so all the elements of such kind of map should have equal importance. And thematic maps, most common in the GIS environment, must to highlight specific objects. This can be done through hierarchical organization or by separating elements into levels of visual significan e. There are three main methods for achieving hierarchical organization.

The *stereogram method* requires the selection and modification of graphic techniques in order to allow the most significant elements to look placed higher than the less important elements. This is a useful technique for improving the figure–ground correlation. The keys to depth perception can be the use of 3D objects, differences in line thickness, color, brightness, or size.

The second method of hierarchical organization is called *expansion* and is most commonly used to rank linear or dot features. For example, main roads should look more prominent than secondary roads. Here you can vary the thickness of the lines, their brightness or internal structure (line brokenness, stroke length, etc.), as well as combinations of these properties to show the significan e of each linear object.

The last method of creating a hierarchical graphic organization, called the *subdivisional hierarchy method*, is mainly used to show differences in the internal arrangement of areas. Thus, for example, pastures can be divided into actively, moderately and little used. The same method is used when denoting the borders of states with thick lines, while the internal administrative division is shown as thin lines.

In addition to the main internal factors of cartographic design, when creating a map, it is necessary to take into account or use ***variations in the form of vectors*** representing dot, linear, and areal objects so that these objects are distinguishable. The main parameters that can be changed are the shape, size, orientation and color. In addition, to fill areal objects, hatching can be used, which is characterized by its organization (regular or random), frequency of the elements, which makes them look lighter or darker, and the orientation of these elements. All of these options can be changed to improve the graphic representation of objects and their groups.

Tables and charts on a map can enhance the understanding of cartographic results greatly. As with maps, these elements also have their own design principles. Tables in GIS are most commonly found in map legends for associating attribute data with map graphic objects and as printouts of attribute values of objects. They may also be accompanied by the contents of a data dictionary to describe the data in detail and complete the map legend.

Text output design considerations include general ideas of purpose, readability, and target audience. In the question of purpose, consideration should be given to how effectively the text and tables can supplement or completely replace cartographic output.

Text and tables are understandable to almost everyone, and issues of readability are fairly well known: a simple font should be used; the color and brightness of the characters and the background should form a good contrast; tables and text should preferably be separated from the map by a frame; abbreviations should not be abused – the less explanation a table requires, the more convenient it is; for groups of rows or columns that are close in meaning, you can use additional highlighting, for example, by color.

Graphing has become quite a trivial task thanks to the computer. The programs for constructing them offer a lot of additional options: the use of colors, three-dimensional letters, lines and figures entertaining symbols, etc. In fact, such embellishments are in most cases superfluous they only worsen the readability of the output and strain the eyesight.

The most important thing here is that graphic solutions follow the main criterion – simplicity and legibility. The main principles of plotting are as follows: significant lines should stand out against the general background; the coordinate grid should not be too frequent and obscure the graph itself; the coordinate axes must reach the maximum values of the displayed values, it is also desirable to put the maximum and minimum values of the coordinates on the axes; when combining several graphs, care should be taken that the scale for each indicator does not mislead the viewer that small values are larger than they are in reality, and vice versa.

5.3. Using Vector Models for Land Resource Management

Already existing spatial data in the vector form are often used as initial data in geoinformation mapping of land. As an example, we can cite the use of GDB layers of the Local LIS and other electronic sources of spatial information when compiling **cartographic parts of land management projects**.

A land management project is a land use planning document that defines the concept and strategy of sustainable land use, the prospects for redistribution, transformation, improvement and protection of land within the boundaries of the region, and is intended for local executive and administrative bodies, land management and geodetic services, other state bodies and organizations in accordance with their competence to regulate and manage the use and protection of land, as well as for other interested parties. The cartographic part of the land management project should refle t the current land use of the area and restrictions on it, proposals for promising ways of land use. It includes **main and thematic maps**.

The main source intended for information support of land management projects is the LIS of the Republic of Belarus. In this regard, the most rational way to organize the spatial data of a land management project is to create a GDB (the main format of the GIS ArcGIS).

Spatial data, on the basis of which land management projects are developed, are systematized in the GDB in the form of feature classes: spatial and object. Spatial classes contain geometric descriptions in the form of points, lines, polygons, and labels (annotations). Object classes contain various characteristics of objects that are used in calculations, when creating tables and graphs, and filling in the a tribute fields of spatial classes

The GDB of a land management project, which serves as the basis for creating the cartographic part of the scheme, includes data that is extracted from various vector formats, such as ESRI exchange format (*.shp), ArcInfo coverages (*.adf, *.e00), CAD drawings (*.dxf, *.dwg), MapInfo worksheets (*.mif, *.tab), etc. For this purposes, the ArcGIS Data Interoperability GIS module is used, which provides the ability to import data from widespread vector formats.

Many of the feature classes for the GDB of land management project are obtained by modifying the content of other classes taken from LIS or other electronic sources of spatial information. For this, operations of *vector GIS-analysis* are used. Among them, the following operations can be singled out: elementary spatial analysis (viewing data on vector geoobjects, analysis of attributes, cartometric measurements, compiling thematic cartograms by attributes), spatial statistics (statistical processing of attributes, statistics of selection; working with databases attribute information, advanced spatial statistics operations), as well as advanced spatial analysis (overlay operations, buffering, reclassification regionalization, generalization, and geoprocessing).

The *main sources for vector GIS-analysis* are LIS layers – Admi, Lots, Comm, Land, as well as the cartographic base. The Land layer can also act as a cartographic base, but it is preferable to create a base from several thematic layers, including, in addition to the hydrographic and road network, types of land, settlements, the signatures of these objects, as well as other significant obje ts.

The development of cartographic materials for land management projects is based on a set of *cartographic display methods*. These include methods of qualitative and quantitative background, cartograms, map diagrams, line symbols, signs and signs of motion.

The *procedure for preparing each map in a land management project using GIS* is as follows:

1) defining the map oncept;
2) specification of its ontent;
3) adaptation of spatial data to the content of the map;
4) development of symbols for displaying spatial data on a map;
5) editing spatial data for better perception of the map;

6) arrangement of elements for printing a map;
7) production of an electronic version of the map;
8) making the required number of copies.

On the first of the **main maps** of the land management project ***Modern use of land***, the main content is displayed by applying the following information layers: classes of land, generalized and grouped for the purposes of the land management project; the main land users in the district; conditional boundaries of forest areas; settlements (cities, urban-type settlements, rural settlements); specially protected natural territories (reserves, national parks, reserves and natural monuments of republican and local significance); motor roads (international, republican, local); railways; border checkpoints; pipelines (main), communication and power lines of 110 kV or more; boundaries of the administrative region in the form of a line with outlining (state, regional); signatures (directions of roads that go beyond the area; names of hydrographic objects, agricultural organizations, settlements, forestry organizations, specially protected natural areas, neighboring areas, road numbers, land user numbers, numbers of agricultural organizations).

The following information layers of the GDB of the land management project are plotted on the main map ***Restrictions on the use of land***: the main land users in the district; forest land, divided forest groups (forests of the 1st group, forests of the 2nd group, especially valuable forest ecosystems); settlements (cities, urban-type settlements, rural settlements); hydrographic objects; specially protected natural territories and their protected zones; proposals for the development of specially protected natural areas (creation of new ones, changing the boundaries of existing ones, boundaries of protected zones); habitats of protected animal species, habitats of protected plant species, especially valuable meadow and swamp communities; monuments of archeology, architecture and history; motor roads (international, republican, local); railways; border checkpoints; pipelines (main), communication and power lines (over 100 kV); the boundaries of the administrative region in the form of a line with a stroke (state, regional, district); livestock farms and complexes; cemeteries, treatment facilities, landfi ls, livestock dumps; sanitary protection zones of cemeteries, treatment facilities, livestock farms and complexes; zones of sanitary protection of water intakes; water protection zones; suburban areas; green areas; border zone; the boundary of the territory contaminated with radionuclides and the density of contamination; signatures (directions of roads that go beyond the area; names of hydrographic objects, names of settlements, specially protected natural areas, neighboring areas, numbers of monuments of archeology, architecture and history).

On the main map ***Perspective land use*** the content is displayed by applying the following information layers: promising classes of land, generalized and grouped for the purpose of creating a land management scheme, including land transferred to agricultural organizations from the land of village councils; fund (reserve) of land redistribution; the main land users in the district; settlements within existing boundaries (cities, urban-type settlements, rural settlements); the boundaries of the planned expansion of settlements; specially protected natural areas (reserves, national parks, wildlife preserves and natural monuments of republican and local significan e); boundaries of the projected expansion of specially protected natural areas; motor roads (international, republican, local); railways; border checkpoints; boundaries of the administrative region in the form of a line with a stroke (state, regional, district); the boundaries of the spatial limits of the village councils with a stroke; the boundaries of agricultural organizations that do not coincide with the boundaries of the spatial limits of village councils; signatures (roads directions leading beyond the area; names of hydrographic objects, agricultural organizations, settlements, specially protected natural areas, neighboring areas, road numbers, land user numbers, numbers of agricultural organizations).

In addition to the main content, these maps in 1 : 50,000 scale additionally display mandatory elements (map name, symbols, the table "Technical and economic indicators of the scheme of land management", the stamp "for official use", copyright, brand) and optional elements (photos, the map "Confli t (environmentally hazardous) territories" in the inset, diagrams (distribution of land by categories of land users; distribution of the land fund by types of land; dynamics of land of agricultural and forestry organizations; dynamics of the area of the natural frame land), in the inset – the map "Assessment of the production potential of agricultural organizations").

The composition and content of **thematic maps** are not limited. They are carried out on a scale of 1 : 100,000. A possible list of them is as follows: administrative-territorial division and main land users; development and placement of the agro-industrial complex; road network and roadside service facilities; land plots intended for placement of real estate objects; placement of horticultural associations; resettlement of the population and the main characteristics of settlements; ecological framework and especially valuable natural areas and objects; regional ecological network; placement of health-improving institutions, memorial complexes, museums, sports and tourist facilities; estimated zoning of settlements; integrated assessment of land according to land usage conditions, etc. When preparing thematic maps, information layers of the geographic data base of the land management scheme are used, prepared by vector GIS analysis of the geographic data layers of the Local LIS and other spatial data in digital form.

5.4. Special Features of Design and Symbolization of Land Cadastral Maps of the Republic of Belarus

In the process of creating and operating LIS, various cartographic materials are formed (both digital and on a solid carrier): orthophotomaps and photomaps, land cadastral and soil maps, maps of districts, land tenure plans and land boundaries, as well as copies from them. Cartographic materials are produced on the following scales: 1 : 1,000, 1 : 2,000, 1 : 5,000, 1 : 10,000, 1 : 25,000, 1 : 50,000. The planned accuracy of the cartographic materials corresponds to the accuracy of the spatial layers of the GDB of the Local LIS.

Digital cartographic materials are prepared in vector, raster or vector-raster form in the formats: mxd (ArcMap ArcGIS), pmf (ArcReader ArcGIS), pdf (Adobe Reader), TIF (with compression PACKBITS). Cartographic materials on a solid basis are made in the standard framework of the nomenclature sheet of a topographic map or plan, or in arbitrary frames on sheets of A4, A3, A2, A1 formats. The arrangement of cartographic material in arbitrary frames is carried out in such a way that the sheets of maps (plans) have the smallest possible format, and the break lines of multi-sheet documents are made mainly along the boundaries of land plots or land cover contours. When forming a multisheet cartographic material, an auxiliary layer of its cutting into sheets is created and used.

Cartographic materials prepared according to the GDB of the LIS of the Republic of Belarus are drawn up in one of the two options:

1) **with full filling of the rame of the cartographic image**;

2) **with partial filling of the rame of the cartographic image**.

Depending on the method adopted, the location of the mandatory and optional elements of the layout of the cartographic document changes.

The ***mandatory elements of the layout of cartographic materials*** include: 1) the frame of the cartographic material (black line 0.7 mm thick) at a distance of at least 1.5–2.0 cm from the edge of the sheet; 2) a cartographic image frame corresponding to one of the standard nomenclature sheet or arbitrary (black line 0.3 mm thick) at a distance of 1.0 cm from the outer frame in the first case and at an arbitrary one in the second; 3) the name of the cartographic document with the territorial reference of the mapped territory (region, district, settlement); 4) the name of the department, enterprise, executor and inspector who produced the document, and the date of its production; 5) source of cartographic information; 6) scale for displaying cartographic information; 7) stamp of the cartographic document; 8) conditions for replicating a cartographic document.

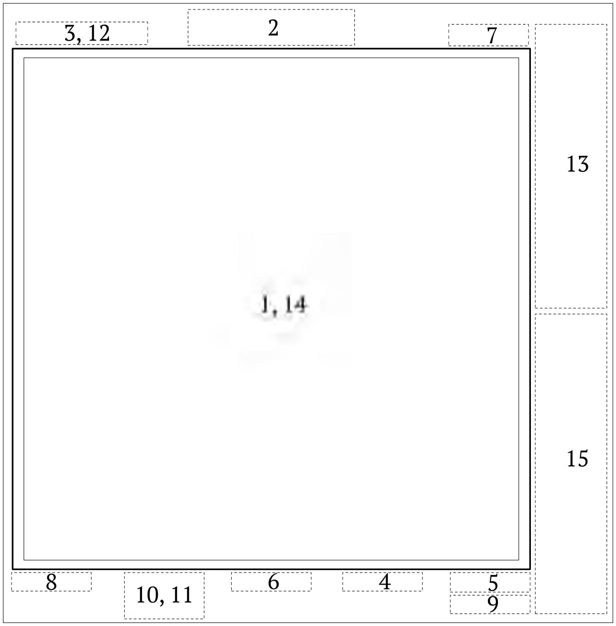
Optional elements of the layout of cartographic materials: 1) the scale corresponding to the initial accuracy of cartographic information – in the case of producing a cartographic document with the accuracy of an adjacent smaller scale (scale plan 1 : 5,000 with a scale accuracy of 1 : 10,000 or 1 : 1,000 – with an accuracy of 1 : 2,000); 2) layout of sheets, indication of their number and sheet number – for multi-sheet cartographic documents; 3) north direction arrow – if the cartographic image was rotated during the formation of the layout of the cartographic image; 4) symbols of the objects of the cartographic image; 6) textual data, usually in tabular form. The text part of the cartographic materials prepared according to the data of the GDB of LIS is recommended to be performed using the Arial font in all its varieties: straight and oblique, normal width and narrow, normal and bold thickness (table 5.1).

Table 5.1

Examples of the design of the textual part of cartographic materials prepared according to the data of the GDB of the LIS of the Republic of Belarus

Design areas	Font	
	Headline	Contents
Name	ARIAL NARROW 22 PT	
Territorial binding	**Arial 16 pt**	
Name of the department, enterprise, executor and inspector who produced the document, and the date of its issue	Arial Narrow 10 pt (8 pt)	
Cartographic information source	Arial Narrow 10 pt (8 pt)	
Scale	**arial 16 pt**	arial 10 pt
Classification stam	*Arial Narrow 13 pt*	
Replication conditions	Arial Narrow 10 pt (8 pt)	
Planned accuracy	Arial Narrow 10 pt (8 pt)	
Signature and inscriptions of the sheets layout, indication of their quantity and sheet number	ARIAL 13 PT	Arial 10 pt
Legend	**ARIAL 13 PT**	Arial 10 pt
Grid labels	ARIAL NARROW 9PT	
Tabular data text	**ARIAL 13 PT**	Arial 10 pt

In the case of preparation of *cartographic materials* with partial fillin of the cartographic image of their frame, the main part of the mandatory design elements is concentrated in the stamp of the document. Examples of layouts of cartographic documents with full and partial filling of its frame are shown in fig 5.2 and 5.3.



Design areas:

1 – cartographic image;
2 – name;
3 – territorial binding;
4 – manufacturer;
5 – source of information;
6 – scale;
7 – stamp;
8 – replication conditions;
9 – planned accuracy;
10 – scheme of sheets;
11 – number and sheet number;
12 – arrow to the north;
13 – symbols;
14 – coordinate grid;
15 – tabular information.

Fig. 5.2. Registration of LIS cartographic materials with full filling of the fram

In the case of designing and preparing *orthophotomaps* for printing, it is assumed that digital orthophotomaps will be involved in the process of layout and the creation of a coordinate grid and marginal design. The preparation of cartographic materials is carried out by selecting the required fragment in the required scale from the corresponding catalogue of images for the entire territory of the Local LIS. Orthophotomaps can be made within the nomenclature sheets of topographic maps and plans or within arbitrarily specified boundaries. The design of orthophotomaps should correspond to the form shown in fig 5.2 and 5.3.

Photomaps are used for field interpretation, land acquisition, and resolution of land disputes. To create them, a layout of a digital orthophotomap, vector features of digital land-cadastral map (plan) or GDB of the Local LIS, objects of the field work project and marginal registration is carried out. The symbolization of vector objects is carried out by simplifie conventional signs, the color and graphic design of which ensures their unambiguous visual perception against the background of a black and white halftone image of an orthophotomap.

Land cadastral maps are formed for planned cartographic support of current accounting of the state and use of land resources of regions and settlements of the Republic of Belarus. They display digital layers of contours of the features of administrative-territorial division, land plots, annotations, features and symbols, communications, fences, ameliorative state of land, land contours, land cover and intersections. To symbolize the features of the land cadastral map, special symbols are used. Signatures of features of administrative-territorial division, land numbers of users, land cover features, features of communication layers, objects and symbols, as well as areas (in hectares with an accuracy of two decimal places), features of the intersection layer and other layer labels are created on the map annotations.

When creating a *soil map*, the design and layout process involves the layers of ATE, land plots and outside land users, landmarks of adjacent land plots, land contours, land coverage, ameliorative state of land, soil characteristics, soil contours, intersections of the Land, Melio layers. and Soil_Clip as well as annotations. The layers of soil characteristics of the map are performed using queries to the "Soils" layer: moistening, erosion, underlayment, granulometric composition. Soil map features are symbolized using special conventional designations. Features of ATU layers, land tenure plots, landmarks of adjacent land plots participate in the formation of signatures. In addition, signatures of codes for land and ameliorative state, as well as numbers of soil contours, are created.

Tables are placed on the soil map: 1) nomenclature list of soils; 2) land plots of adjacent land users, indicating the initial and final marks of the boundaries and their names.

According to the attribute table of the intersection layer, textual applications of the soil map are formed: 1) explication of land by soil varieties; 2) explication of the qualitative condition of land.

The *map of a district* is a generalized land cadastral map of a district of the Republic of Belarus. It is intended for planned cartographic support of land management and geodetic service of the corresponding district, region and the country as a whole. Its compilation involves digital layers of ATU contours, labels boundaries of adjacent areas, land plots (a selection of the largest land users of the area (agricultural, forestry enterprises, peasants, subsidiary farms, gardening associations, etc.)), annotations, communications (a selection of axial improved roads and watercourses with a width of more than 10 m), zones of restricted land use (a selection of land subjected to radioactive contamination), land coverage (a selection of objects with an area of at least 2.5 ha). To symbolize the objects of the map of the area, special symbols are used. The map must contain the signatures of the ATE of the district and adjacent districts, names or numbers land users, reservoirs, roads and streams. In addition, on the map of the district there is a table of names of land users, land use, the serial numbers of which are displayed on the map. The design of the map sheet of the area should correspond to the form shown in fig 5.3.

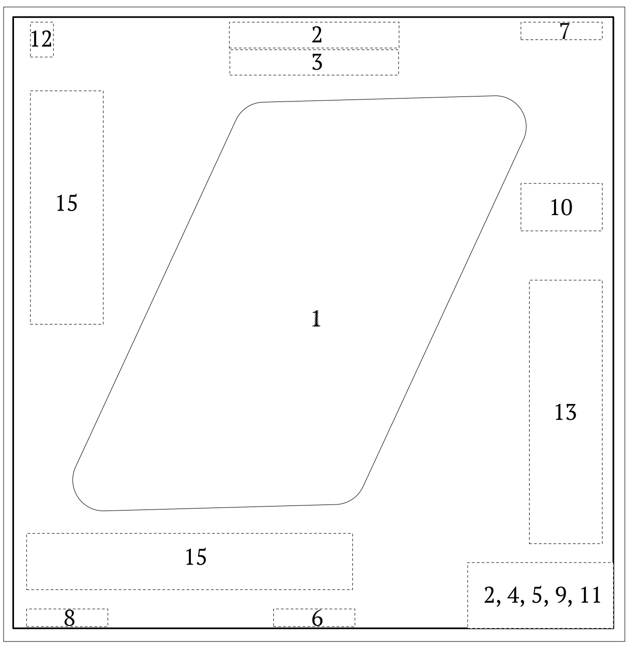


Fig. 5.3. Registration of LIS cartographic materials
with incomplete filling of the frame (see design areas in fi 5.2)

A land cadastral map (plan) within a particular land tenure is called a *land tenure map (plan)*. It is intended for planned and cartographic support of the economic activities of a legal entity or a natural person – the owner of land tenure, as well as for coordinating the boundaries of land tenures when they are established or restored. The land tenure plan can be made either exactly within the boundaries of the land plots, or using a 200 m wide buffer zone around them.

If a land tenure plan is prepared within the boundaries of land plots, it contains the layers of ATU contours, land tenure plots and outside land users, landmarks of adjacent land plots, annotations, objects and symbols, communications, fences, ameliorative condition of land, land contours, land cover within the land tenure and intersections. To symbolize the objects of the land tenure plan, special symbols are used. The following labels are created on the map: ATU; land tenure plots, outside and adjacent plots; land cover, communications, objects and symbols, as well as areas (in hectares with an accuracy of two decimal digits) of objects of the intersection layer and other labels for the annotation layer. The land tenure plan contains a list of outside and adjacent land users.

When preparing a land tenure plan for coordinating the results of work on establishing or restoring the boundaries of land plots, it is supplied with another text attachment – the land explication of the land tenure. The design of the land tenure plan sheet must comply with the form shown in fig 5.3.

The *land plot boundary plan* is a graphic attachment of title documents of the land tenure (land management files for establishing or restoring the boundaries of land plots). Its formation involves the layers of the turning points of the boundaries of land plots of the land tenure, boundaries of land plots of the land tenure and outside land users, landmarks of the boundaries of adjacent land plots, of land use restriction zones within the land plots of the land tenure, annotations. The symbols used to symbolize the objects of plans of the boundaries of land plots are given in table 5.2 and 5.3. As labels there are the numbers of turning points, land plots of land tenure, their areas and ordinal numbers of outside land users, landmarks of adjacent land plots boundaries, types and areas of restricted zones.

Table 5.2

Symbolization and annotation of objects in the layers of land boundaries

Layer	Object	Symbolization	Signature	
			Contents	Font
Turning points of land plots boundaries	Fixed on location	O 1.0	Point numbers	Arial 6–8 pt
	Not fi ed on location	• 0.8		Arial 6–8 pt

End of the table 5.2

Layer	Object	Symbolization	Signature	
			Contents	Font
Land plots boundaries	of the land tenure	0.2 ———	–	–
		0.2 ———	–	–
	of the adjacent ones	5.0 0.6 ——— A	Symbolic marks of adjacent plots boundaries: A–Z	Arial 13 pt
Land plots	of the land tenure	*Plot № 1* *25.05*	Numbers and plot area, ha	*Arial 9 pt*
	of the outside ones	(2) 6.0	Filing number	Arial 10 pt

Notes.

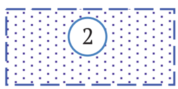
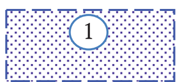
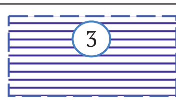
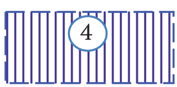
1. All dimensions are in mm.

2. Black color shows the upland areas of land plots boundaries, green – passing along the banks of reservoirs and streams, streams, ditches.

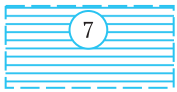
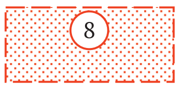
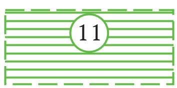
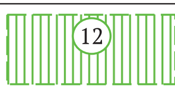
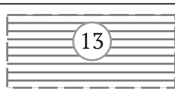
3. Plot numbering is omitted if there is only one plot in land tenure.

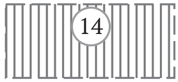
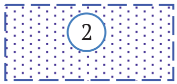
Table 5.3

Symbolization and annotation of features in the "Land use restrictions" layer

Layer	Symbolization	Label	
		Contents	Font
Water protection zones of rivers and reservoirs	 14.09	Zone code: 1 (rivers) or 2 (water bodies); area, ha	Arial 7–8 pt
Coastal strips of rivers and water bodies	 114.22		
Surface and underground sources of household water use sanitary protection zones	 120.02	Zone code – 3; area, ha	
Sanitary protection strips of water passages	 20.01	Zone code – 4; area, ha	

Continuation of the table 5.3

Layer	Symbolization	Label	
		Contents	Font
Security zones of communication and radio lines	 15. 02	Zone code – 5; area, ha	
Security zones of power transmission lines	 0.02	Zone code – 6; area, ha	
Security zones of main pipelines, gas supply	 12.13	Zone code – 7; area, ha	
systems and other linear engineering structures	 0.12	Zone code – 8; area, ha	
Areas subjected to radioactive contamination	 145.99	Zone code – 9; area, ha	
Health-improving areas	 59.12	Zone code – 10; area, ha	
Recreational areas	 44.40	Zone code – 11; area, ha	Arial 7–8 pt
Areas of historical and cultural value	 87.02	Zone code – 12; area, ha	
Conservation areas	 70.45	Zone code – 13; area, ha	

Layer	Symbolization	Label	
		Contents	Font
Areas with restrictions on construction, improvement, etc.	 62.33	Zone code – 14; area, ha	
Areas with other restrictions	 14.09	Zone code: 1 (rivers) or 2 (water bodies); area, ha	

The following tables are placed on the land plot boundaries plan: 1) land plots of adjacent land users, indicating the initial and end landmarks and their names; 2) land plots of outside land users, indicating their names and areas of the plots. The design of the land plot boundaries plan must comply with the form shown in fig 5.3.

Excerptions from cartographic materials prepared according to the information of the GDB of the Local LIS are, as a rule, used as a spatial basis of various purposes of land management documentation. They contain the same composition of layers in the same graphic representation as the original cartographic material. They are produced on sheets of the required format of a portrait or landscape orientation using a design template with incomplete frame filling (see fig. 5.3). At the same time, the name of the cartographic document in the stamp should begin with the words "Excerption from...", the title in the upper part of the sheet will be the title of the land management document drawn up on the basis of this excerption, and the empty lines of the stamp are for placing the names and signatures of the document executors.

Questions for self-assessment

1. Give general recommendations for creating maps, including using GIS.
2. What are the main elements of a map?
3. Enumerate the main stages of the process of designing and laying out a finishe map in GIS.
4. What external and internal factors of cartographic design is it necessary to consider when creating maps in GIS?
5. What are the special features of using vector models for representing spatial data for GIS-mapping of land?

6. What operations of vector GIS analysis are used in the formation of feature classes of the GDB of the land management project of a district in the Republic of Belarus?

7. What order of preparation is recommended to follow when creating each of the maps within the land management project of a district in the Republic of Belarus?

8. What are the special features of the design and symbolization of land-cadastral maps with the help of GIS in the Republic of Belarus?

6. EXERCISES FOR GIS-MAPPING OF LAND RESOURCES

Practical exercises allow students to study the main GIS-operations and technologies applied in GIS-mapping of land resources in the Republic of Belarus. Tutorial materials contain author's methodological data and instructions on laboratory, practical and controlled independent work. The exercises were developed for using of the licensed ESRI Inc. software (ArcGIS with additional modules). The initial geodata for the exercises include digital materials provided for the educational process by the State Property Committee of the Republic of Belarus, as well as digital information freely available on the Internet.

Exercise 1. Creation a Geodatabase (on an Example of the Geodatabase of Land Informational System of the Republic of Belarus).

Purpose of the exercise: to study an algorithm of the building a geodatabase in the ArcCatalog GIS ArcGIS software (on an example of the geodatabase of Land informational system (LIS) of the Klieck district of the Minsk region).

Basic concepts and their definitions

The geodatabase is the native data structure for ArcGIS and is the primary data format used for editing and data management. A key geodatabase concept is the ***dataset***. It is the primary mechanism used to organize and use geographic information in ArcGIS. The geodatabase contains three primary dataset types: feature classes, raster datasets, tables.

A feature class is a collection of geographic features that share the same geometry type (such as point, line, polygon or annotation) and the same attribute fields or a common area.

Raster datasets represent geographic features by dividing the world into discrete square or rectangular cells laid out in a grid. Each cell has a value that is used to represent some characteristic of that location, such as temperature, elevation, or a spectral value. Raster datasets are commonly used for representing and managing imagery, digital elevation models, and numerous other phenomena.

In the geodatabase, attributes are managed in ***tables*** based on a series of simple, yet essential, relational data concepts: tables contain rows, all rows in a table have the same columns, each column has a data type, such as integer, decimal number, character, and date, a series of relational functions and operators (such as SQL) is available to operate on the tables and their data elements.

Feature dataset holds a collection of spatially related feature classes, or build topologies, networks, cadastral datasets, and terrains.

Attribute domains specify a list of valid values or a range of valid values for attribute columns. Domains are often used to enforce data classification (such as road class, zoning codes, and land-use classifications)

Subtypes manage a set of feature subclasses in a single feature class. This is often used on feature class tables to manage different behaviors on subsets of the same feature type.

Exercise progress

Step 1. Start ArcCatalog. Right-click the folder where you want to create the file geodatabase, point to New, and click *File Geodatabase* (fig. 6.1). Type a new name *LIS-Klieck* for the file geodatabase

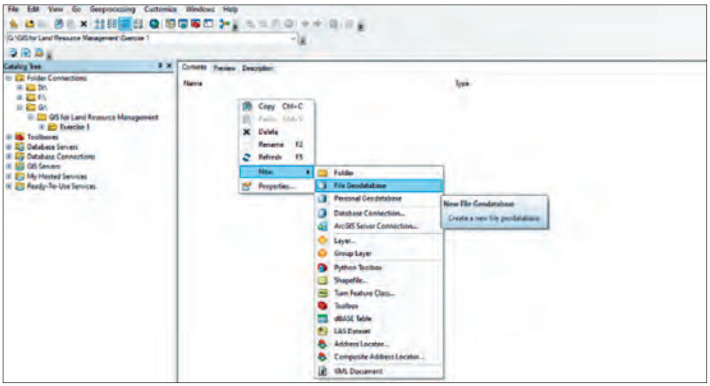


Fig. 6.1

Step 2. Right-click the LIS-Klieck geodatabase, click New → *Feature Dataset* (fig 6.2). Type a name *ALLMS* for the feature dataset.

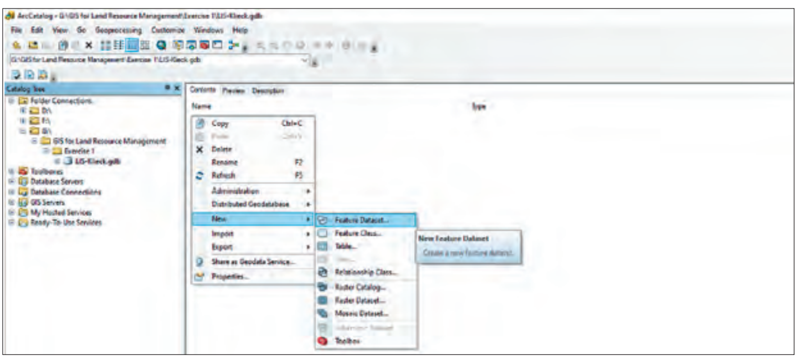


Fig. 6.2

Navigate to the *WGS_1984_UTM_Zone_35N* spatial reference for the feature dataset. Choose the coordinate system that will be used from XY coordinates from the folders Projected Coordinate Systems → Utm → → WGS 1984 → Northern Hemisphere. Do not choose *Z* and *M* coordinate system.

Step 3. Similarly, as in step 2, create a new *Objects* feature dataset.

Step 4. Right-click the ALLMS feature dataset to create a new feature class. Point to New → *Feature Class*. Type a name for the feature class according to the table 6.1. Choose from the drop-down list the geometry type of features that will be stored in this feature class according to the table 6.1. Click Next and Finish. Similarly, create all feature classes according to the table 6.1., fig 6.3.

Table 6.1

Feature classes	Geometry type
Admi	Polygon
Lots1	Point
Lots2	Line
Lots3	Polygon
Serv	Polygon
Land	Polygon
Meleo	Polygon
CrosTab	Polygon

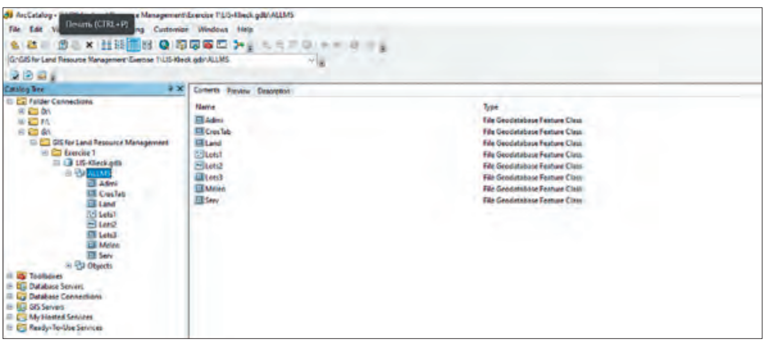


Fig. 6.3

Step 5. Similarly, as in step 4, create all feature classes according to the table 6.2 in *Objects* feature dataset.

Table 6.2

Feature classes	Geometry type
Comm	Line
Fence	Line
Obj	Point
Texts	Point
MapLis	Polygon

Step 6. Right-click the *Land* feature class, point to Properties. Click the Field tab. To add a new field to the feature class, click the next blank row in the *Field Name* column, then type a name. Click the *Data Type* column next to the new field s name and click its data type. Create all fields according to the table 6.3, fig 6.4.

Table 6.3

Field name	Data type
LandType	Short Integer
LandSubtype	Short Integer
Texts	Text (Length 20)
Name	Text (Length 20)

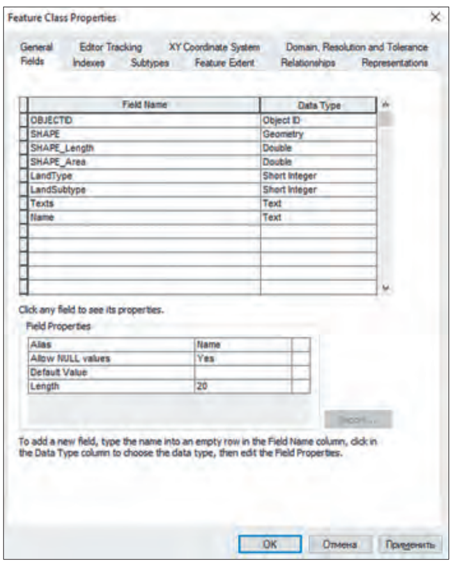


Fig. 6.4

Step 7. Right-click the LIS-Klieck geodatabase and click Properties. This opens the Database Properties dialog box. Click the Domains tab. Click the first empty field under Domain Name and type *LandTypeDomain* for the name of the new domain. In the Description field type *Land types*.

Under *DomainProperties*, click the drop-down for the Field Type and click *Short Integer*. This defines the data type of the column to which the domain can be applied. Click the drop-down for the Domain Type and click *Coded Values*. Click the drop-down for the Split policy and click *Duplicate*, fig 6.5.

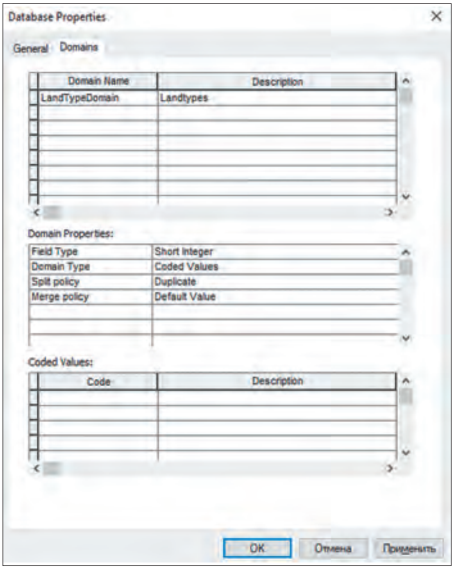


Fig. 6.5

Click the first empty field in the *Code* column under *Coded Values*: and type “101”. Click the *Description* field beside it and type “Cultivated land” for the code’s description. Add all another 25 coded values according to the table 6.4.

Table 6.4

Code	LandType	Code	LandType
101	Cultivated land	202	Tree plantings
102	Permanent crops	203	Coppice
103	Grassland	204	Other wooded areas
201	Forests	205	Other nonwooded areas

End of the table 6.4

Code	LandType	Code	LandType
206	Swampland	504	Buildings
301	Watercourses	505	Constructions
302	Reservoirs	601	Disturbed land
401	Roads	602	Unused land
402	Railways	701	Improved land
403	Communication elements	702	Mineral extraction and construction sites
501	Squares and streets	703	Dump sites
502	Green spaces	704	Burial places
503	Yards	705	Other land

Similarly, create all 26 domains according to the table 6.5., fig 6.6. Use the same domain properties for new domains (Field Type – Short Integer, Domain Type – Coded Values, Split policy – Duplicate).

Table 6.5

Domain name	Description	Coded values	
		Code	Description
Plants101	Cultivated land	3	Arable land
		4	Fallow land
Plants102	Permanent crops	5	Other permanent crops
		6	Orchards
		7	Berry field
		8	Plantations
		9	Fruit nurseries
Plants103	Grassland	111	Flooded, clean
		112	Flooded, shrubby
		113	Flooded, improved
		114	Other floode
		121	Upland, clean
		122	Upland, shrubby
		123	Upland, improved
		124	Other upland
		131	Waterlogged, clean
		132	Waterlogged, shrubby
		134	Other waterlogged

Continuation of the table 6.5

Domain name	Description	Coded values	
		Code	Description
Forests201	Forests	291	Coniferous
		301	Deciduous
		311	Mixed
		326	Without specifying of tree species composition
Forests202	Tree plantings	294	Coniferous
		304	Deciduous
		314	Mixed
		327	Without specifying of tree species composition
Forests203	Coppice	295	Coniferous
		305	Deciduous
		315	Mixed
		328	Without specifying of tree species composition
Forests204	Other wooded areas	321	Tree-shrubbery vegetation
		322	Forest and scrub belts
Forests205	Other nonwooded areas	324	Cutting areas
		325	Burnt areas
		329	Other areas
Forests206	Swampland	34	Upland
		35	Transitional
		36	Lowland
Waters301	Watercourses	40	Rivers and streams
		43	Canals and drains
Waters302	Reservoirs	39	Other water bodies
		41	Lakes
		42	Reservoirs and ponds
Roads401	Roads	441	Field and forest roads
		444	Clearings
		445	Country roads
		446	Improved roads
		447	Roadsides
		448	Ditches

Continuation of the table 6.5

Domain name	Description	Coded values	
		Code	Description
		449	Slopes
		450	Dividing lanes
		704	Cattle passes
Roads402	Railways	701	Bed
		702	Ditches
		703	Slopes
		705	Cargo and passenger platforms
Roads403	Communication elements	440	Other communication elements
		442	Pipelines
		443	Bridges and overpasses
Buildings501	Squares and streets	451	Squares
		452	Streets and driveways
		453	Carriageways of streets and driveways
		454	Sidewalks and footpaths
		458	Porches and blind areas
		459	Stairs
Buildings502	Green areas	455	Boulevards
		456	Lawns and fl wer-beds
		460	Parks and squares
Buildings503	Yards	67	Estate land
		457	Other common areas
		461	Utility yards
		463	Open-air warehouses
		473	Paddocks
Buildings504	Buildings	464	Residential, fire-resistan
		465	Residential, non-fire-resistan
		466	Residential, mixed-fire-resistan
		467	Non-residential, fire-resistan
		468	Non-residential, non-fire-resistan
		469	Non-residential, mixed-fire-resistan
Buildings505	Constructions	470	Light-type constructions
		471	Greenhouses
		472	Other constructions

End of the table 6.5

Domain name	Description	Coded values	
		Code	Description
		462	Silo pits
		661	Dams
		667	Slopes
Bedland601	Disturbed land	48	Other disturbed land
		49	Disturbed in the result of mining
		50	Disturbed in the result of peat and sapropel extractions
		51	Disturbed during construction works
Bedland602	Unused land	53	Other unused land
		54	Sands devoid of vegetation
		55	Ravines and gullies
		56	Ramparts
		58	Burnt peatland
		59	Former agricultural land contaminated with radionuclides
		662	Mounds
		663	Pits
		664	Soaks
Others701	Improved land	23	Under melioration construction
		24	Under fertility restoration
Others702	Mineral extraction and construction sites	37	Peat and sapropel extraction sites
		665	Waste dumps and waste heaps
		668	Quarries
		669	Construction sites
Others703	Dump sites	62	Other dump sites
		63	Household waste dump sites
		64	Industrial waste dump sites
		65	Contaminated by radionuclides dump sites
Others704	Burial places	60	Cemeteries
		61	Cattle burial sites
Others705	Other land	57	Under brows
		666	Other land

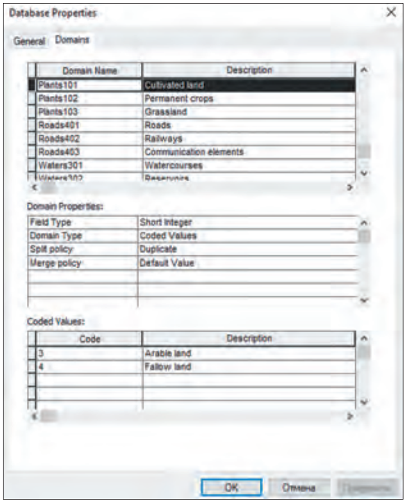


Fig. 6.6

Step 8. Double-click the Land feature dataset in the LIS-Klieck geodatabase to open its Properties. Click the Field tab. Click the *Domain* drop-down list for the LandType field and click *LandTypeDomain* to set it as the default attribute domain (fig 6.7).

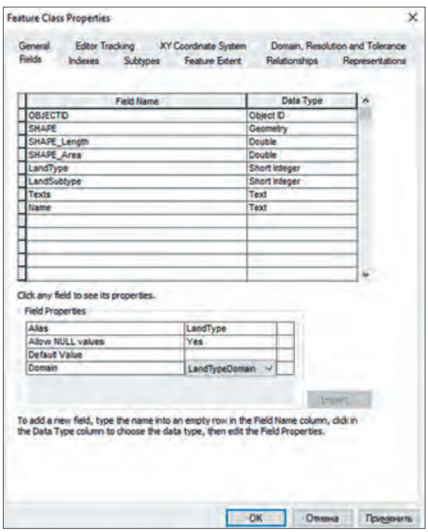


Рис. 6.7

Step 9. Click the Subtypes tab in the LandType Properties dialog box. Click the *Subtype Field* drop-down arrow and click LandType.

Add subtype codes and their descriptions according to the table 6.6. For all new subtypes, set the domain according to the table 6.6 for the LandSubtype field fig 6.8.

Table 6.6

Subtype code	Description	Domain for LandSubtype fiel
101	Cultivated land	Plants101
102	Permanent crops	Plants102
103	Grassland	Plants103
201	Forests	Forests201
202	Tree plantings	Forests202
203	Coppice	Forests203
204	Other wooded areas	Forests204
205	Other nonwooded areas	Forests205
206	Swampland	Forests206
301	Watercourses	Waters301
302	Reservoirs	Waters302
401	Roads	Roads401
402	Railways	Roads402
403	Communication elements	Roads403
501	Squares and streets	Buildings501
502	Green spaces	Buildings502
503	Yards	Buildings503
504	Buildings	Buildings504
505	Constructions	Buildings505
601	Disturbed land	Bedland601
602	Unused land	Bedland602
701	Improved land	Others701
702	Mineral extraction and construction sites	Others702
703	Dump sites	Others703
704	Burial places	Others704
705	Other land	Others705

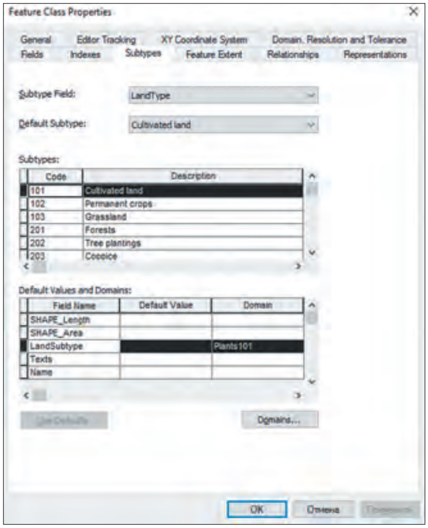


Fig. 6.8

Questions

1. What types of geometry can you set for the geodatabase feature class? Give a brief description of each type.
2. What types of attribute fields can be set for the attributes of the geodatabase feature class? Give a brief description of each type.
3. What types of domains can be created in the geodatabase? Give a brief description of each type.

Exercise 2. Creating a Geodatabase Topology (on an Example of the Geodatabase of Land Informational System of the Republic of Belarus).

Purpose of the exercise: to study an algorithm of the creating a geodatabase topology in the ArcCatalog GIS ArcGIS software (on an example of the geodatabase of LIS of the Klieck district of the Minsk region).

Basic concepts and their definitions

Topology is a collection of rules that, coupled with a set of editing tools and techniques, enables the geodatabase to more accurately model geometric relationships. ArcGIS implements topology through a set of rules that defin how features may share a geographic space and a set of editing tools that work with features that share geometry in an integrated fashion. A topology is stored in a geodatabase as one or more relationships that define how the features in one or more feature classes share geometry. The features participating in a topology are still simple feature classes – rather than modifying the definition of the feature class, a topology serves as a description of how the features can be spatially related. The topology includes three sets of parameters: rules, ranks, and cluster tolerances.

Topology rules define the permissible spatial relationships between features.

Creating topological relationships involves analyzing the coordinate locations of feature vertices among features in the same feature class as well as between the feature classes that participate in the topology. Those that fall within a specified distance – ***a cluster tolerance*** – of one another are assumed to represent the same location and are assigned a common coordinate value (in other words, they are colocated).

The coordinate accuracy ***ranks*** you specify for feature classes in a geodatabase topology control the movement of feature vertices during validation. The rank helps control how vertices are moved when they fall within the cluster tolerance of one another.

Violations of topology rules are initially stored as ***errors*** in the topology. Error features record where topological errors were discovered during validation. Certain errors may be acceptable, in which case the error features can be marked as ***exceptions***.

Exercise progress

Step 1. Start ArcCatalog. In the Catalog tree, navigate to the ALLMS feature dataset in the LIS-Klieck geodatabase. Right-click the ALLMS feature dataset, point to New, then click *Topology*. The New Topology wizard starts. Click Next (fig 6.9).

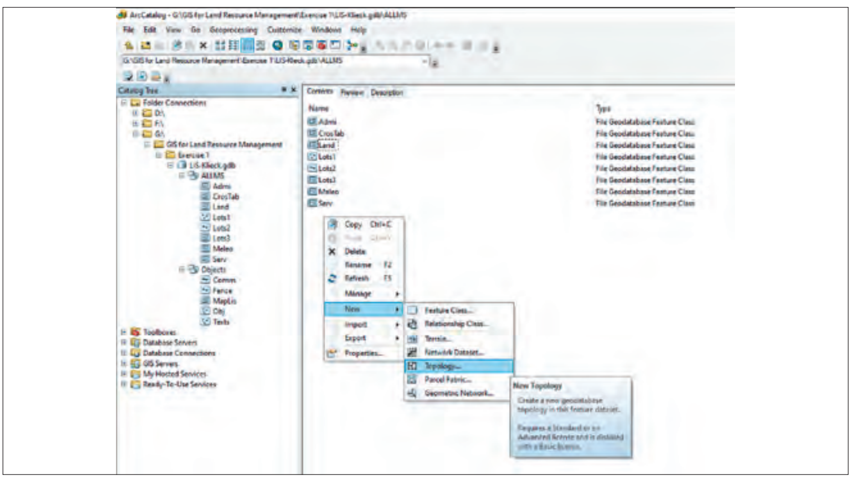


Fig. 6.9

Step 2. The wizard presents a default name and cluster tolerance for the topology. You will accept the default *name* that the wizard provides. The default cluster tolerance is based on the XY tolerance of the Landbase dataset. Type 0,001 to set the new *cluster tolerance*. Click Next.

Check all feature classes with the exception of CrossTab, fig 6.10. These feature classes will participate in the ALLMS Topology. Click Next.

Type 3 for the number of ranks. Choose 1st rank for Lots1, Lots2 and Lots3 feature classes, 2nd rank for Admi and Land feature classes, 3rd rank for Melio and Serv feature classes (fig 6.11). Click Next.

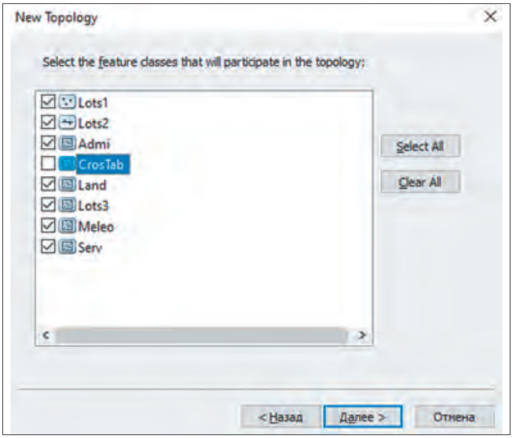


Fig. 6.10

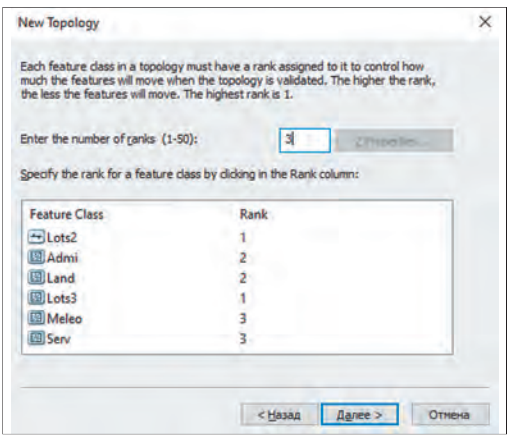
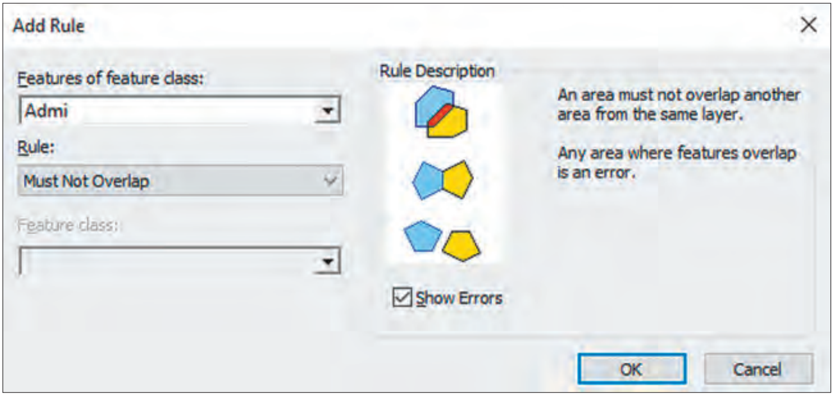


Рис. 6.11

Step 3. Create topology rules. To create each rule, click *Add Rule*. In the Add Rule window, click the Features of feature class drop-down arrow and click required class. Click the Rule drop-down arrow and click required rule. If necessary, click the Feature class drop-down arrow and click required class (fig 6.12). Set the topology rules according to the table 6.7. Click Finish.



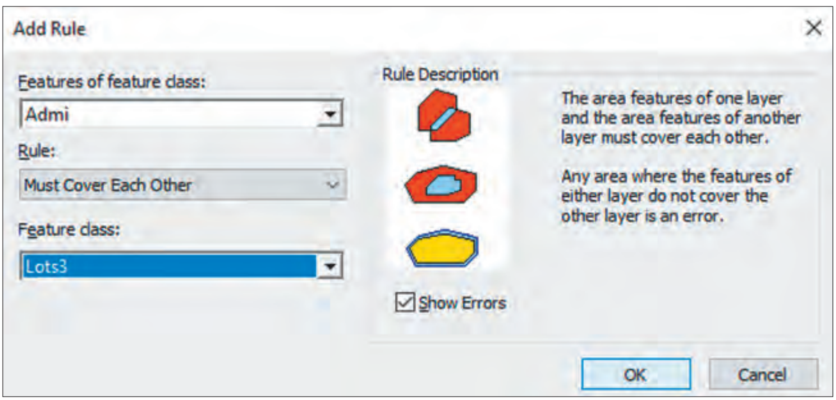


Рис. 6.12

Table 6.7

Features of feature class	Rule	Feature class
Admi	Must Not Overlap	
Admi	Must Cover Each Other	Lots3
Lots1	Point Must Be Covered By Line	Lots2

End of the table 6.7

Features of feature class	Rule	Feature class
Lots2	Endpoint Must Be Covered By	Lots1
Lots2	Must Not Have Pseudo Nodes	
Lots2	Must Not Intersect	
Lots2	Must Be Single Part	
Lots2	Must Not Intersect Or Touch Interior	
Lots2	Must Not Self-Intersect	
Lots3	Boundary Must Be Covered By	Lots2
Lots3	Must Be Covered By	Admi
Lots3	Must Not Overlap	
Lots3	Must Not Have Gaps	
Land	Must Be Covered By	Lots3
Land	Must Not Overlap	
Land	Must Not Have Gaps	
Melio	Must Not Overlap	

Step 4. In the Catalog tree, navigate to the Objects feature dataset in the LIS-Klieck geodatabase. Create new topology with Comm and Fence feature classes (cluster tolerance – 0,001, number of ranks – 1). Set the topology rules according to the table 6.8. Click Finish.

Table 6.8

Features of feature class	Rule	Feature class
Fence	Must Not Intersect	
Fence	Must Be Single Part	
Fence	Must Not Intersect Or Touch Interior	
Fence	Must Not Self-Intersect	
Comm	Must Not Have Pseudo Nodes	
Comm	Must Not Intersect	
Comm	Must Be Single Part	
Comm	Must Not Intersect Or Touch Interior	
Comm	Must Not Self-Intersect	

Questions

1. Create a description and list the possible errors for each topology rule of ALLMS_Topology.

2. List the main topology parameters of ALLMS_Topology and give their characteristics.

3. What is the peculiarity of the vector-topological model of the representation of spatial data in GIS, in contrast to vector-non-topological.

4. What spatial problems are solved in GIS by creating a topology?

Exercise 3. Visual Interpretation of Land Types and Subtypes of the Geodatabase of Land Informational System of the Republic of Belarus Based on Aerial Photography Materials.

Purpose of the exercise: to master the algorithms of visual interpretation of land types and subtypes in the GIS ArcGIS software (on an example of a fragment of the Klieck district of the Minsk region)

Initial data:

GDB "LIS-Klieck", formed as a result of exercises 1 and 2 (*LIS-Klieck.mdb*);

• a shape-file containing the border of a fragment of the Klieck district (*Area_Border.shp*);

• a table containing the coordinates of the turning points of the settlement border, obtained as a result of establishing its borders using the geodetic method (*Settlement_Border* in the database *Settlement.mdb*);

• a shape-file containing the borders of the land plots obtained as a result of establishing them using the geodetic method (*Geodesy.shp*);

• color and transparent templates of the legend of the layer *Land* (*Land.lyr*);

• an orthorectified and georeferenced photoplan (scale 1:10,000) of a fragment of the Klieck district (*Orthophotomap.tif*);

• an unattached fragment of a topographic map on a scale of 1:100,000 (*topo.tif*);

• orthorectified and georeferenced multizone satellite images obtained by the Landsat 7 satellite ETM+ imaging system (*10* – band 1, visible mode, blue spectral range, spatial resolution 30 m; *20* – band 2, visible mode, green spectral range, spatial resolution 30 m; *30* – band 3, visible mode, red spectral range, spatial resolution 30 m; *40* – band 4, near infrared (IR) mode, near IR range, spatial resolution 30 m; *50* – band 5, shortwave IR mode, mid-IR range, spatial resolution 30 m; *70* – band 7, shortwave IR mode, mid-IR range, spatial resolution 30 m; *80* – band 8, panchromatic mode, spatial resolution 15 m);

• the results of field interpretation of the lands of a fragment of the Klieck district (*Field survey_orthophotoplan.tif*).

3A. Preparation of Initial Data for Visual Interpretation of Land. Preliminary Analysis of the Study Area.

Purpose: to master the algorithms for adding and symbolizing data in GIS ArcGIS, georeferencing raster images, coordinate digitizing and combining channels of multizone images; perform a preliminary analysis of the study area using the initial raster data.

Exercise progress

Step 1. Open the ArcCatalog of the GIS ArcGIS. Load the data of shape-file *Area_Border.shp* into the *Land* feature class of the LIS-Klieck GDB. Right-click Land feature class, click Load → *Load data* (fig 6.13).

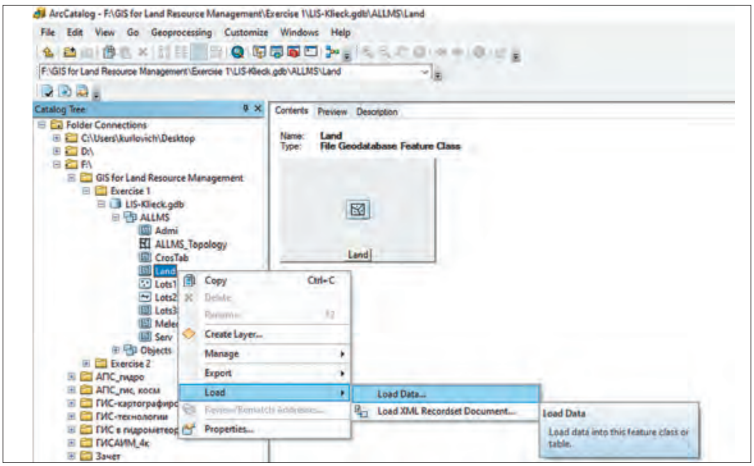


Fig. 6.13

In the window *Simple Data Loader*, click *Next*. In the next loading step, select the shape-file "Area_Border.shp" (fig 6.14) as input data and click the *Add* button. Leave the options for the next loading steps as default. Finally, click the *Finish* button.

Step 2. Open the ArcMap of the GIS ArcGIS. Create a project *Visual Interpretation of Land*. To do this, use the *Save As* option in the *File* menu. Save the project in your folder.

Add the original *raster* (Orthophotomap.tif, topo.tif, 10, 20, 30, 40, 50, 70, 80) and *vector* (set of ALLMS dataset classes of the LIS-Klieck GDB) data to the project using  the "Add data" icon. Do not build *Pyramidal layers* for rasters. Leave only the layers topo.tif and Land in the *visualization* (check only these layers in the table of contents). *Hide* all layer legends. Zoom the extent of the data frame to the *Land* layer (right-click on layer → Zoom to Layer).

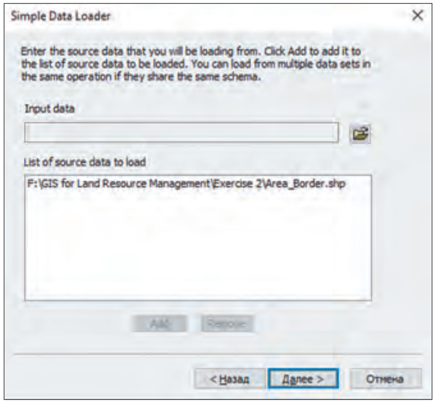


Fig. 6.14

Step 3. Perform the georeferencing of the fragment of a topographic map at a scale of 1:100,000 (topo.tif). When you spatially reference a raster dataset, you locate it in the map coordinates and set the coordinate system. Georeferenced raster data can be displayed and analyzed along with other geographic data.

Open the *Georeferencing* toolbar (Customize → Toolbars → Georeferencing). Pull the panel to the top of the working window to a place convenient for you.

In the Georeferencing toolbar (fig 6.15), choose the georeferencing layer – topo.tif. Then perform the operation *Fit to Display* (Georeferencing → → Fit to Display). Thus you will move the topo.tif raster to the desired area. In addition, tick the option (Georeferencing → Auto Adjust).

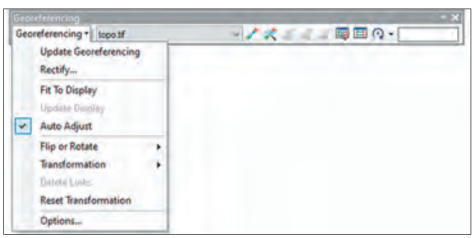


Fig. 6.15

Symbolize the *Land* layer. To do this, open the *Layer Properties* window (right-click on the Land layer → Properties). Select the *Symbology* tab and set the display function *Features*: *Single Symbol* for this layer. Click on the icon of the symbol and select for it: *Fill Color* – No color, *Outline Color* – Mars Red, *Outline width* – 1 (fig 6.16).

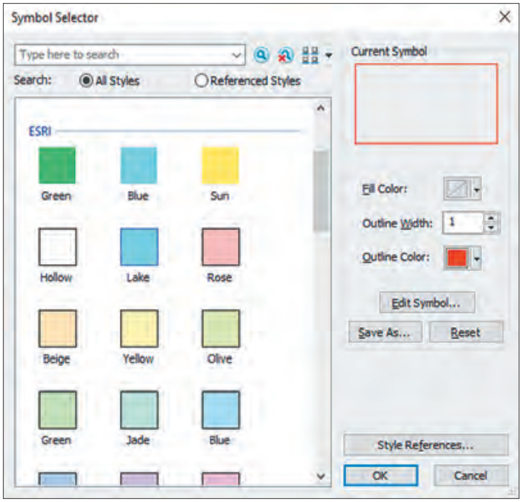


Fig. 6.16

Open the *Snapping* toolbar (Customize → Toolbars → Snapping). Pull the panel to the top of the working window to a place convenient for you. Choose Snapping → *Use Snapping*. Set available only the icon *Vertex Snapping* in the Snapping toolbar.

Perform the georeferencing of the border of the interpretation area on the topo.tif raster (marked with a purple outline, fig 6.17, *a*) to the border of the interpretation area located in the Land layer (symbolized in red, fig 6.17, *a*).

To do this, use the icon *Add Control Points* on the Georeferencing toolbar. After clicking the icon, the cursor will turn into a crosshair. Place the cursor on the upper left corner of the border of the study area, indicated on the raster, and click left mouse button (LMB). A green crosshair will remain at the control point.

Find the equivalent corner of the study area border in the Land vector layer (you symbolized it with a red outline). Move the cursor to the corresponding point of the vector layer. Once the *Snapping* option is enabled, click on it. The raster image will shift and the control point on the raster and on the vector layer will be connected. This image shift is a one-point transformation based on the combination of one control point on the raster and the corresponding control point in the target data (in our case, the Land layer) and is called a ***link***.

Do the same for other control points representing the corners of the study area border on the raster, and link them to the same corners in the vector layer, fig 6.17, b. In case of an error, you can also delete link by opening the window *View Link Table* on the Georeferencing toolbar.

a *b*

Fig. 6.17

After creating all links, perform the operation Georeferencing → *Update Georeferencing.*

Step 4. Add the turning points of the border of the settlement "Ruda", located in the study area, surveyed using a geodetic method, using the *Add XY data* operation in the File → Add data menu.

In the *Add XY Data* window, select the Settlement_Border table from Settlement.mdb database. Define the fields of the *Settlement_Border* table containing the X coordinate and the Y coordinate. Set the coordinate system to WGS_1984_UTM_Zone_35N, it is located in the Projection Coordinate Systems → Utm → WGS 1984 → Northern Hemisphere → WGS_1984_UTM_Zone_35N section (fig 6.18). As a result, the *Settlement_Border Events* point layer appears in the data frame.

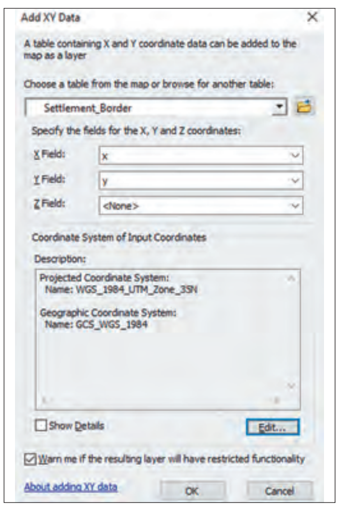


Fig. 6.18

Step 5. Label the numbers of the turning points of the border of the settlement. To do this, go to *Layer Properties* "Settlement_Border Events", in the *Labels* tab check the box *Label features in this layer*, select *OBJECTID_1* as the label field and symbolize the labels in a font and size convenient for you (fig 6.19).

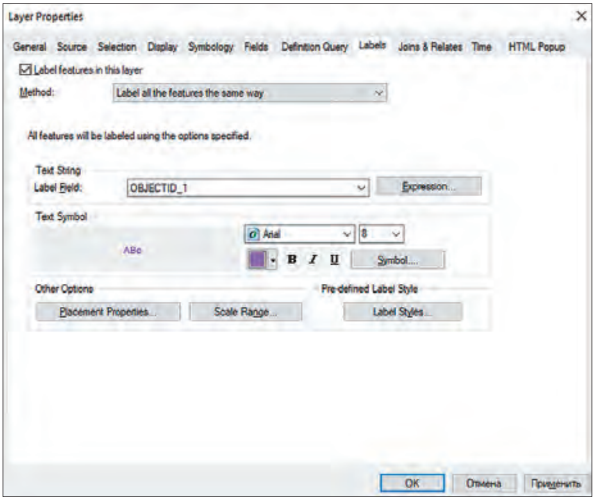


Fig. 6.19

Step 6. Create a vector polygon feature of the "Ruda" settlement in the Admi layer from its border turning points ("Settlement_Border Events" layer). To do this, use the tools of the *Editor* panel (Settings → Toolbars → Editor), shown on fig 6.20.

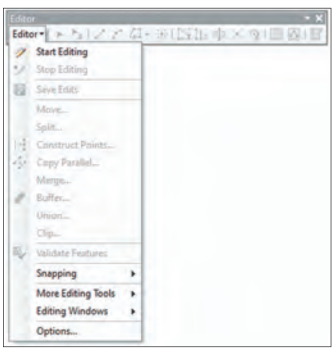


Fig. 6.20

Start the editing session (Editor → Start Editing). Select the LIS-Klieck personal geodatabase for editing. In the *Create Features* window (appears automatically after the start of an editing session), fig 6.21, select the *layer to which the new features will belong*. This layer will be the Admi (administrative division) layer. For the *Construction Tool*, choose Polygon.

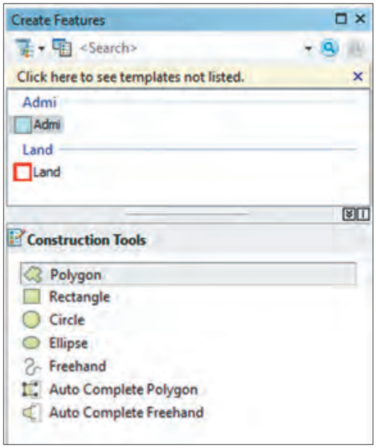


Fig. 6.21

Since you will be creating a new feature based on another layer, it is necessary that the vertices of the sketch of the new feature correspond to the points of the "Settlement_Border Events" layer. To do this, set the option *Point Snapping* on the Snapping toolbar, fig 6.22.

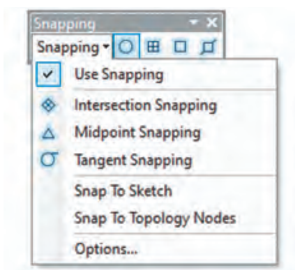


Fig. 6.22

Now you can start creating the border of the settlement. Zoom in the extent of the data frame around the first turning point of the corners of the settlement border and lock on it (click with LMB).

Continue snapping to each subsequent point of the "Settlement_Border Events" layer by making one click with LMB. The map extent can be varied using the tools *Zoom In*, *Zoom Out*, *Fixed Zoom In*, *Fixed Zoom Out*, *Pan*. If you put the vertex of the sketch in the wrong place it can be deleted by clicking RMB near the vertex and selecting *Delete Vertex*. It is necessary to double click the last point with LMB (fig 6.23). Thus, the border of the settlement "Ruda" in the Admi layer based on the turning points of the border has been created. *Stop your editing session* (Editor → Stop Editing). Choose a symbol for the Admi layer that is convenient for you.

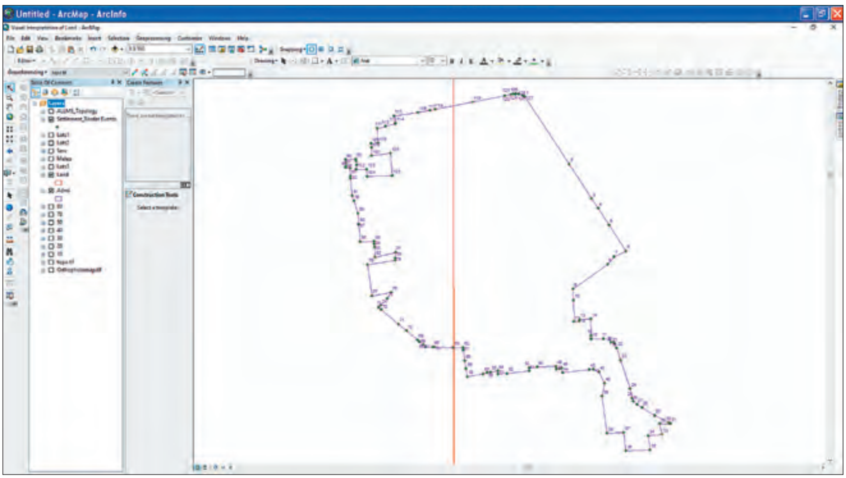


Fig. 6.23

Step 7. Composite the bands of the multizone satellite image obtained by the ETM+ imaging system of the Landsat 7 satellite. To do this use the *Composite Bands* tool. Open the *ArcToolbox*, find the required tool (Data Management → Raster → Raster Processing → Composite Bands). In the tool window in the *Input Data* section you should sequentially select the first second, and third rasters corresponding to the required bands.

For the *Composition of the 4th, 3rd and 2nd bands* (the "artificial colors" composition), we sequentially select the following rasters that you previously added to the project: 40, 30 and 20 (fig 6.24). The *output raster* with composited bands must be saved under the name *432*. After the necessary calculations, the program will add a raster with composited bands to the project.

Repeat this sequence of operations to composite the 3rd, 2nd and 1st bands (the "natural colors" composition).

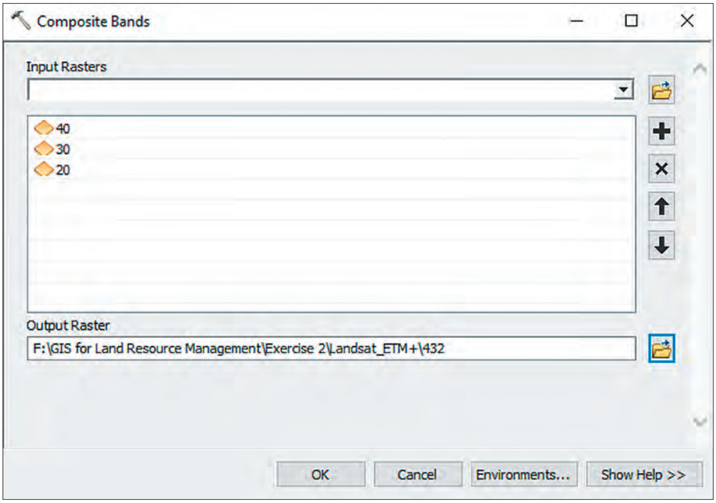


Fig. 6.24

Step 8. *Save* the project "Visual interpretation of lands" (File → Save).

Step 9. Using all the original raster data, as well as the rasters obtained by composition of bands, perform a preliminary GIS analysis of the study area for the spatial location of land types.

Questions

1. List the basic sequence of steps for georeferencing a raster image in the GIS ArcGIS. Describe the structure of the world file

2. List the basic sequence of steps for creating a vector feature in the GIS ArcGIS based on existing vector features. What is the essence of the *Snapping* function?

3. What composition of bands (beside the "natural colors" and "artificial colors" compositions) can be produced with multizone images Landsat ETM+? How will land types be refle ted in different compositions?

3B. Visual Interpretation of Land Types and Subtypes.

Purpose: to master the algorithms for editing, overlay operations, loading data from one feature class to another in the process of visual interpretation of land types and subtypes in the GIS ArcGIS software.

Exercise progress

Step 1. Open the ArcMap of the GIS ArcGIS. Open the project *Visual interpretation of land.mxd* created in Exercise 3.1 (File → Open).

Step 2. Organize the vector data into a *group layer*. First, it allows you to group several layers, and, second, to display or not to display all them in the map extent. To create a group layer, right-click on the *Layers* data frame and select *New Group Layer*. Rename it to LIS. By dragging the ALLMS_Topology layers, as well as Admi, Land, Lots1, Lots2, Lots3, Melio, Serv, and CrosTab, up all the way to the LIS group layer, drop them into this group layer. In the same way as for the LIS group layer, create the following group layers for raster data: *Orthophotomap* (should contain Orthophotomap.tif layer), *Topomap* (topo.tif layer), *Landsat_ETM+* (layers 10, 20, 30, 40, 50, 70, 80), *Composition of Landsat_ETM+ bands* (layers 432 and 321) (fig 6.25).

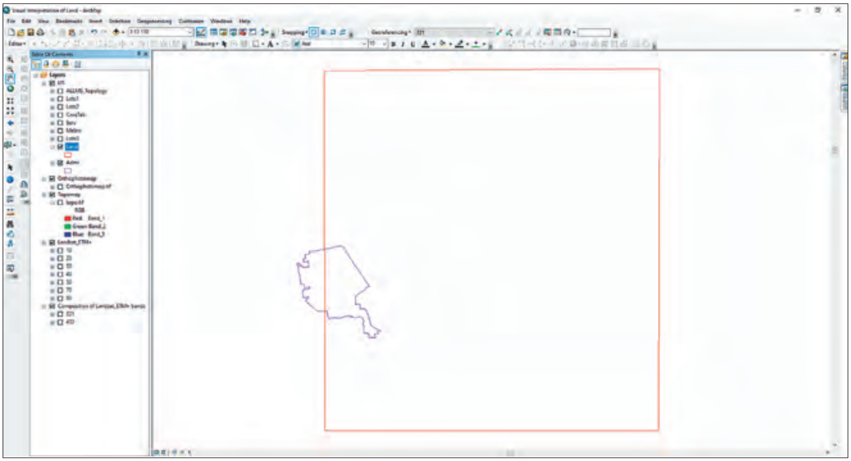


Fig. 6.25

Step 3. Add to the project the layer *Geodesy.shp*, which contains the boundaries of land plots obtained as a result of their establishment using the geodetic method and corresponding to land types (use the Add data icon).

Perform an overlay operation of overlaying a polygonal feature, which is the border of a fragment of the Klieck district and located in the *Land* layer and polygons of the Geodesy.shp layer. To do this, use the *Identity* tool (ArcToolbox → Analysis Tools → Overlay → Identity). In the tool window, mark the Land layer as the *Input Features*, the Geodesy.shp layer as the *Identity Features*, Land_Identity as the *Output Feature Class* (save it in the LIS-Klieck geodatabase), *Join Attributes* as All (fig 6.26). After the necessary calculations, the program will add the *Land_Identity* layer to the project.

Start editing the LIS-Klieck geodatabase (Editor → Start editing). Set the Tables of contents "Layers" display option *List By Selection* (the button is located in its upper part). Make only the features in the *Land* layer selectable. Select the only feature located in this layer (the border of the fragment of the Klieck district), using the tool *Select Features* (fig 6.27) and delete it, pressing the Del key on the keyboard. Finish editing by saving all changes (Editor → End Editing). Delete the *Land* layer from the project (right click on the layer in the table of contents → Delete).

Close ArcMap after saving the project "Visual land decryption."

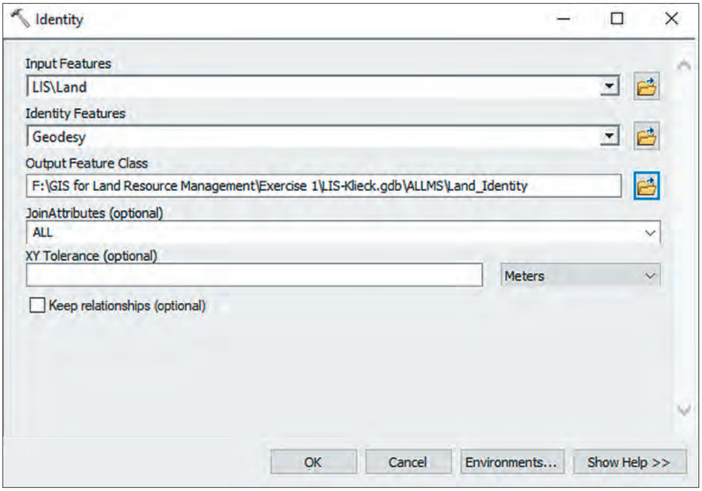


Fig. 6.26

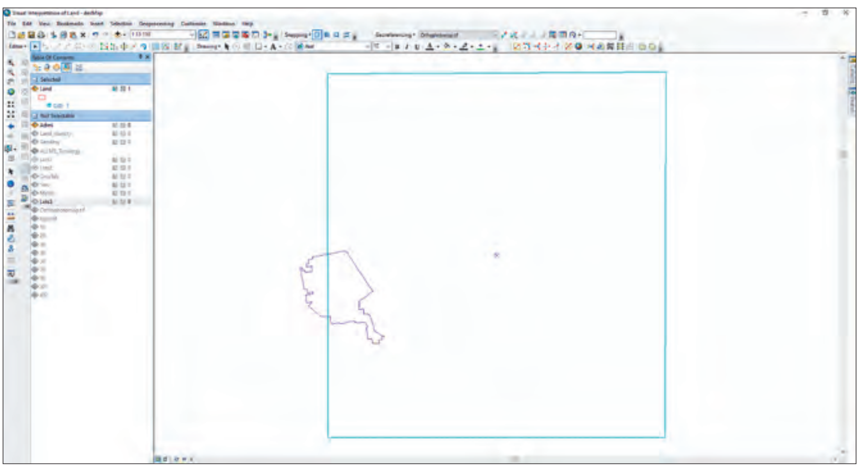


Fig. 6.27

Step 4. Open the ArcCatalog of the GIS ArcGIS. Load the Land_Identity feature class data into the Land feature class of the LIS-Klieck GDB. To do this, click on the Land → Load → Load Data. In the *Simple Data Loader* window, click Next. In the next loading step, select the Land_Identity class as input and click the *Add* button. For the *Target Field* LandType of the Land feature class set the LANDTYPE *Matching Source fiel* of the Land_Identity feature class. Similarly, for the LandSubtype fiel – the LANDCODE field (fig 6.28). *Close* ArcCatalog after loading the data.

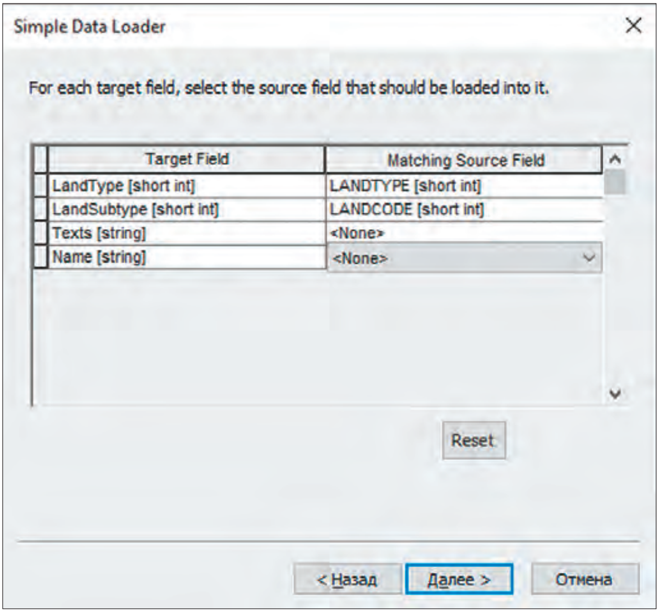


Fig. 6.28

Step 5. Open ArcMap. Add the Land_color.lyr file to the project (to the LIS group layer) (use  the *Add Data* icon). This file contains color symbolization for all types and subtypes of the *Land* layer.

Set the Land feature class of the LIS-Klieck geographic database as the *data source* for the Land.lyr layer. To do this, go to the *Properties* of the Land_color.lyr layer (right-click on the layer → Properties), select the *Source* tab and press the *Set Data Source* button.

Step 6. Add the following additional editing tools: *Topology* and *Advanced Editing* (Editor → More Editing Tools) (fig 6.29, 6.30) and drag them to the top of the working window to a place convenient for you.

Fig. 6.29

Fig. 6.30

Step 7. *Start an editing session* (Editor → Start Editing). Select the *LIS-Klieck personal geodatabase* for editing.

Set the Table of contents “Layers” display option to *By selection*. Make selectable only the features in the *Land* layer. With the *Select Features* tool, select the only non-coded feature in the *Land* layer, which is the result of the previous overlay between the Land layer and the Land_Identity layer (fig 6.31).

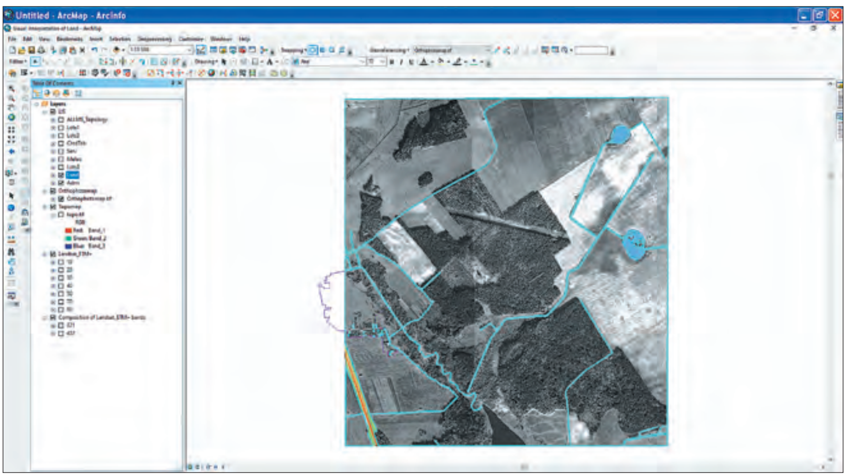


Fig. 6.31

This feature is multipart. To explode it, use the *Explode Multipart Feature* tool on the *Advanced Editing* toolbar. The multipart polygon will be divided into a series of singlepart polygons.

Step 8. On the Snapping toolbar, set *Vertex Snapping* option. Also check the *Snap to Sketch* option by choosing Snapping → Snap to Sketch.

Step 9. Perform a visual interpretation of the types and subtypes of land within the settlement “Ruda”. *Zoom in the extent* of the data frame to a settlement using  the *Zoom In* tool. Turn on the display of the "Orthophotomap" group layer.

Start by interpretation of the *Streets and driveways* land sybtype. Create a polygon feature of the *Squares and streets* land type using the direct interpretational characteristic of the road network – light lines (stripes) on the orthophotomap, as well as the indirect characteristic – the fences of individual plots (dark straight lines) and detail it into the *Streets and driveways* subtype.

To create a vector feature using  the *Select Features* tool, select a non-coded polygon feature in the *Land* layer, which is located on the site of a street in a settlement. Using  the *Cut polygons* tool on the *Editor* toolbar and pressing the V key on the keyboard (allows you to see all the vertices of the existing vector features of the Land and Admi layers), start ***cutting*** the selected non-coded polygon, placing the first vertex of the sketch outside the selected polygon, the subsequent ones – within the selected polygon and closing on the tops of the layers Land and Admi, and the last one – outside the borders of the selected polygon (fig 6.32).

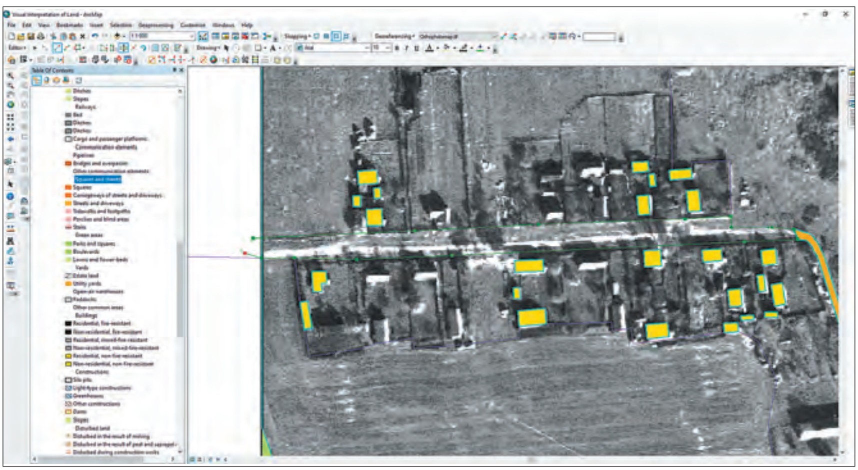


Fig. 6.32

After creating the last vertex of the sketch by double-clicking finis cutting the polygon. *This sequence of operations is used if the cutting feature is located at the borders of the editing area.*

Use  the *Select Features* tool to select the newly created polygon feature. Using  the *Attributes* tool on the *Editor* toolbar, select the required type (Squares and streets) and subtype (Streets and driveways) of land for the created feature (fig 6.33).

Start interpretation the land type of *Buildings* in the settlement “Ruda”. Based on the main interpretational characteristics – the geometry of shapes, as well as the shadows depicted on the orthophotomap, find buildings and create new features of the “Buildings” land type in the Land layer by *cutting a non-coded polygon*.

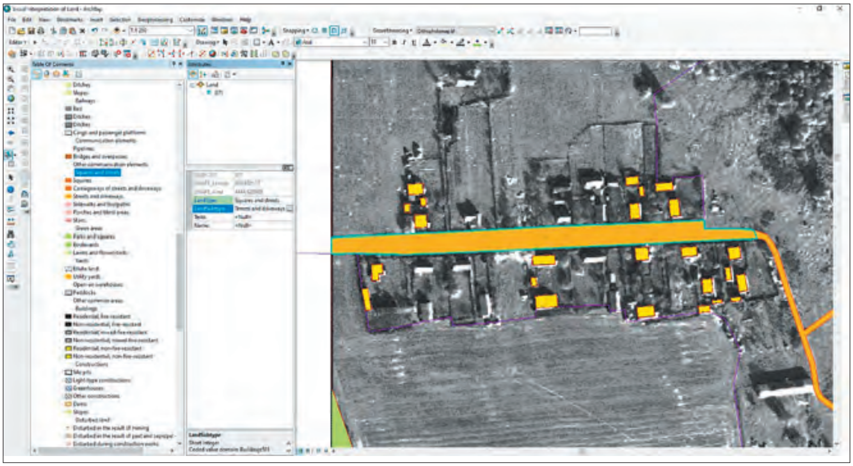


Fig. 6.33

To do this, using  the *Select Features* tool, select a non-coded polygon feature of the Land layer, which is located in the place of the Buildings feature, using direct and indirect interpretational characteristics. Using  the *Cut Polygons* tool on the *Editor* toolbar, start cutting the selected polygon. Put all the vertices of the sketch in the corners of the building to be deciphered (fig 6.34). The last vertex should be snapped to the first one and double clicked to complete the sketch. *This sequence of operations is applied if the cutting feature is inside the borders of the edit area*.

Do the interpretation of all lands of the *Building* type within the Ruda settlement by clipping polygon feature s from the non-coded polygon. Buildings located near the street, refer to the subtype *Residential non-fire resistant*, located away from the street – *Non-residential non-fire-resistan* (fig 6.35). To do this, use  the *Attributes* tool.

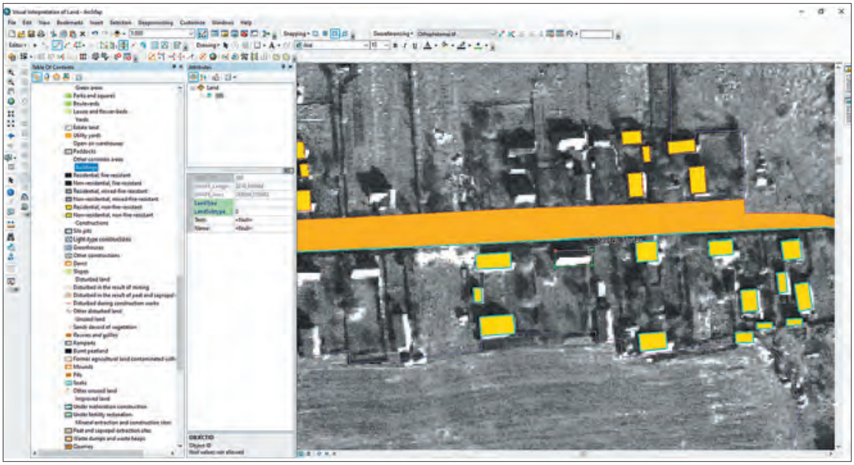


Fig. 6.34

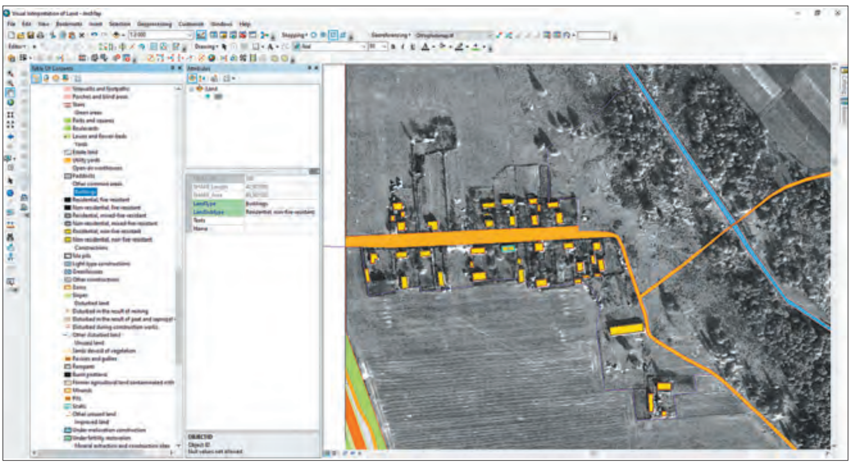


Fig. 6.35

In the similar way carry out the interpretation of the lands of the subtype *Estate land* of the *Yards* type. For this lands, the direct interpretational characteristics are: the originality of the form, the specifici y of the texture, the geometric dimensions. Estate land are also well recognized by indirect characteristic – by the presence of fences that limit the plots of individual land users and landowners. In a black and white photograph, they are dark geometric stripes. Another indirect characteristic is the presence of buildings on the estate land.

Using the tool  *Cut polygons*, cut three poligons of *Estate land* within the borders of the settlement "Ruda" from a non-coded polygon (fig 6.36). Snap on the already interpreted features of the *Land* layer and the border of the settlement in the Admi layer.

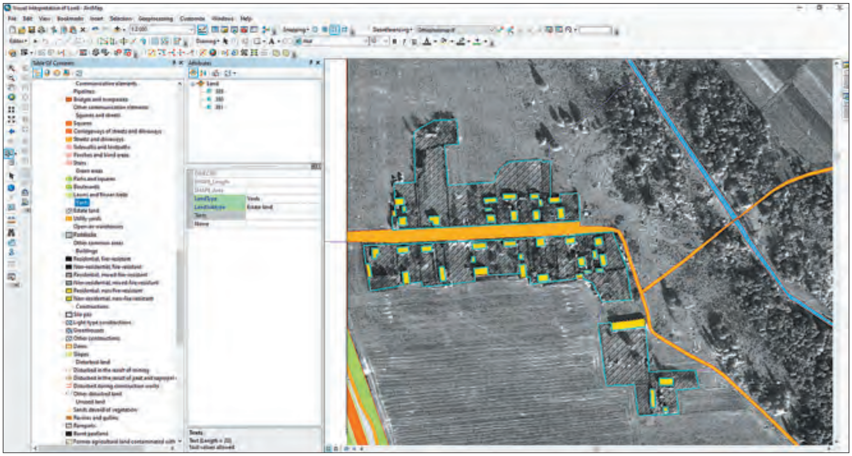


Fig. 6.36

Step 10. Interpret the land under roads and other transport communications. Most of this land within the study area was preliminarily photographed by instrumental methods. Analyze the peculiarities of direct and indirect interpretational characteristics of these lands on the orthophotomap.

Note that roads appear as light lines (streaks) in black and white aerial photographs. In addition, on the Improved road (southwestern part of the study area), even the road markings and the number of lanes are visible. Field and forest roads are less clearly visible in the image. Indirect interpretational characteristics of roads are their position on the ground, their connection with other topographic features, the presence of structures serving the roads, the nature of the intersection with other features, and the location of the accompanying forest and scrub belts.

Using the tool  *Cut polygons*, interpret on the basis of orthophotomap the land type *Roads*, the subtype *Field and forest roads* from the non-coded polygon (fig 6.37, 6.38). Snap to existed features in the *Land* layer.

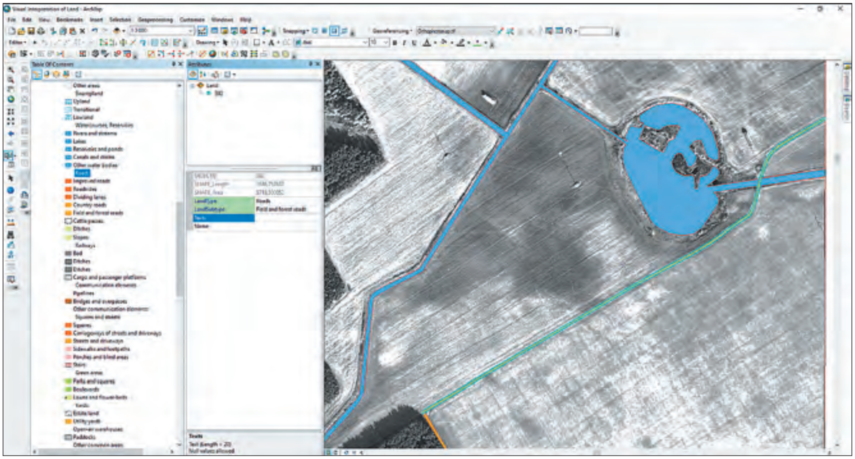


Fig. 6.37

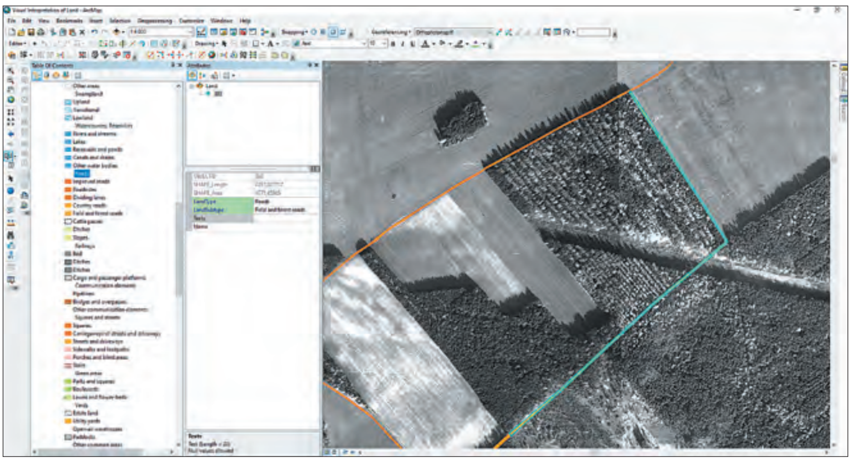


Fig. 6.38

Step 11. Do the interpretation of the land under water objects. They could interpret with a high degree of certainty in black and white and especially reliable on color aerial photographs based on direct interpretation characteristics. Most of the lands under rivers and streams and reservoirs and ponds within the study area were indicated by geodesic methods. Analyze the peculiarities of direct and indirect interpretational characteristics of these lands on the orthophotomap. In addition, using the rasters of composition of various bands of the Landsat ETM+ imagery, as well as the orthophotomap, try to recognize reservoirs and ponds that remained uninterpreted, and cut them out of the non-coded polygon of the Land layer, coding the cut polygon vectors as the land type *Reservoirs*, subtype *Reservoirs and ponds* (fig 6.39).

In the similar way interpret and cut out from the non-coded polygon of the Land layer the features belonging to the type of land *Watercourses*, the subtype *Canals and drains* (fig 6.40).

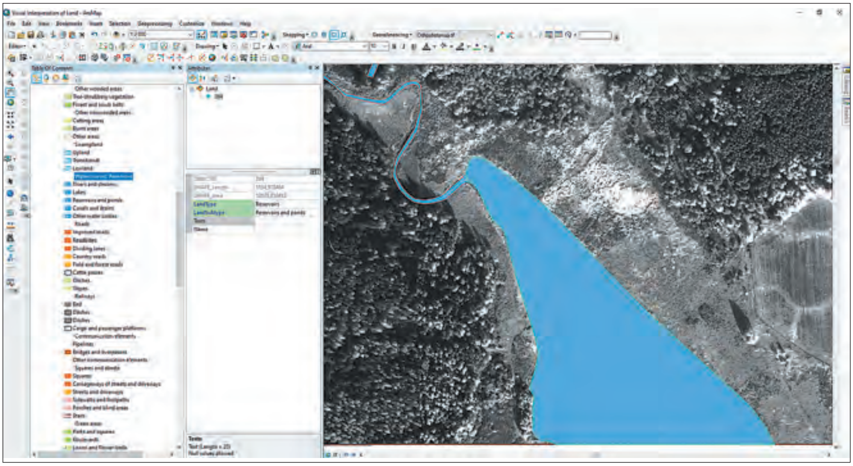


Fig. 6.39

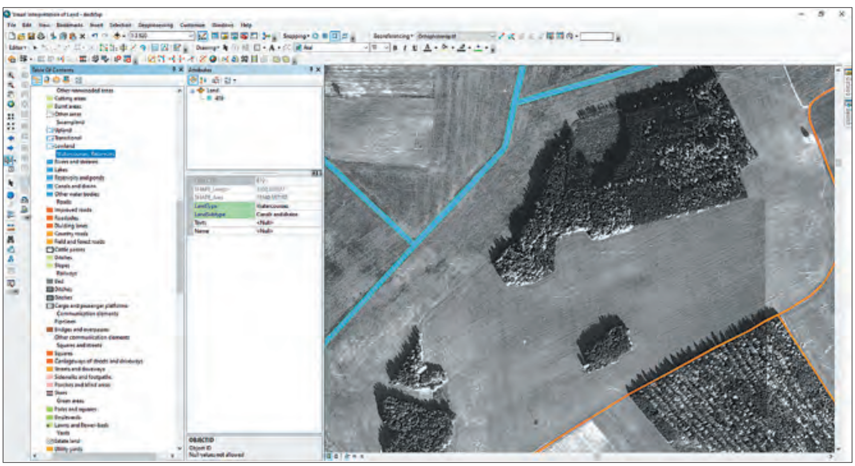


Fig. 6.40

Step 12. Perform the interpretation of swampland. The main interpretation characteristic of swamps is the texture of the image. It, depending on the type of swamps, their overgrowth (forest cover), passability, is very diverse and heterogeneous, but in most cases it is quite specific Indirect interpretation characteristics of swamps are confinement to vast fla - horizontal areas of the terrain, the absence of traces of agricultural processing, the presence of country and field bypass roads, and the presence of peat mining.

Interpret and cut out features from the non-coded polygon of the Land layer that can be attributed to the *Swampland* land type. As you have no information about the subtypes of swamps, code them as *Transitional* (fig 6.41).

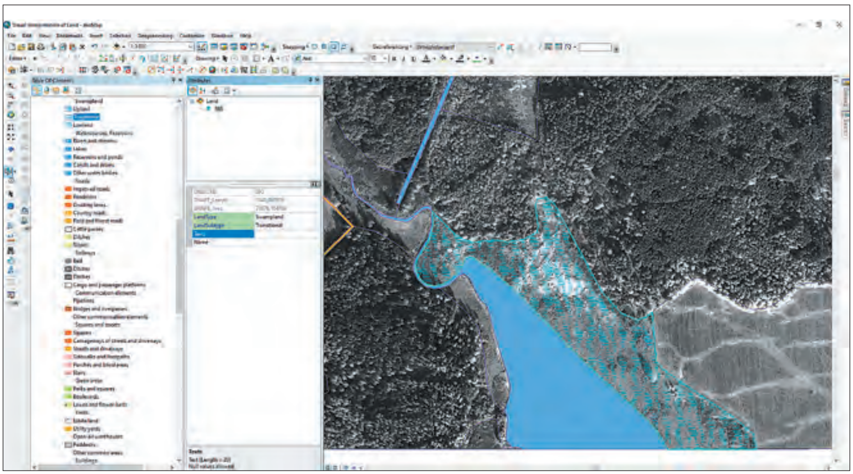


Fig. 6.41

Step 13. Perform the interpretation and cut out features of the *Forests* land type from the non-coded polygons of the Land layer. Use the rasters of composition of various bands of the Landsat ETM+ imagery as an auxiliary material.

As a subtype, use *Without specifying of tree species composition*, since you cannot judge the composition of the forests (fig 6.42). Remember that the main interpretation characteristic of forests is the texture.

Do the interpretation and cut out the land type *Other wooded areas*. For the subtype, use *Tree-shrubbery vegetation* (fig 6.43).

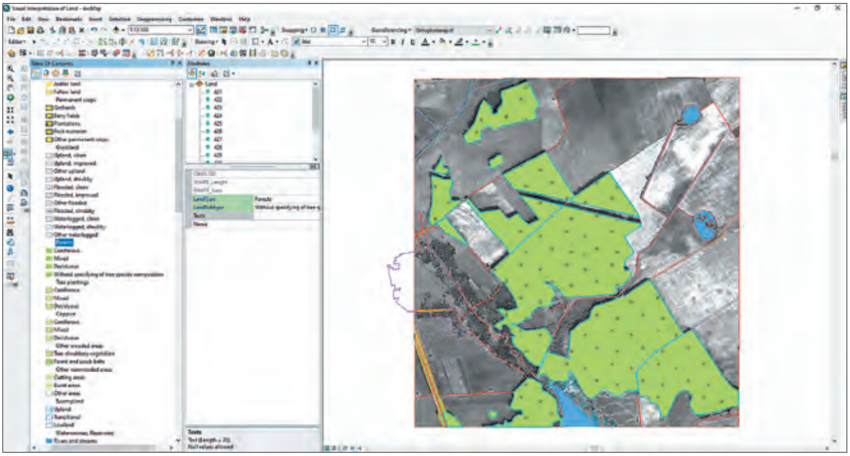


Fig. 6.42

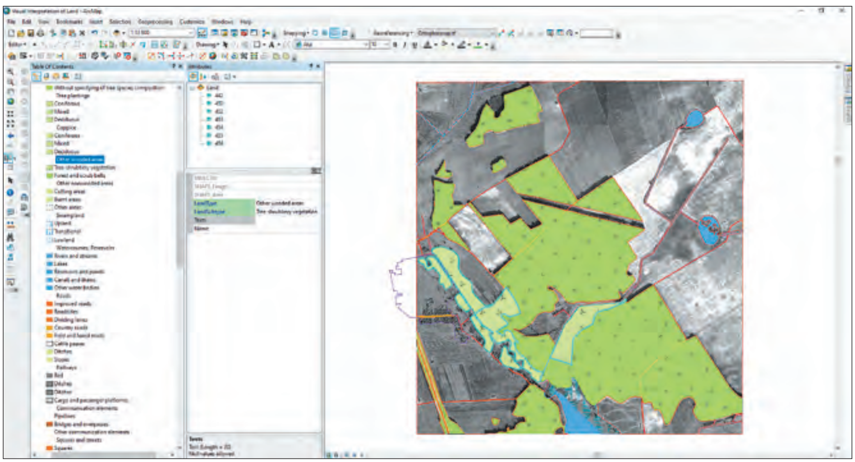


Fig. 6.43

Step 14. The main interpretation characteristics of arable land are: clarity of borders, certain geometric shape of the fields texture of the image, color of the image. Carry out interpretation and extraction from non-coded polygons of the Land layer of the arable land. Use *Arable land* as a subtype, *Cultivated land* – as landtype (fig 6.44).

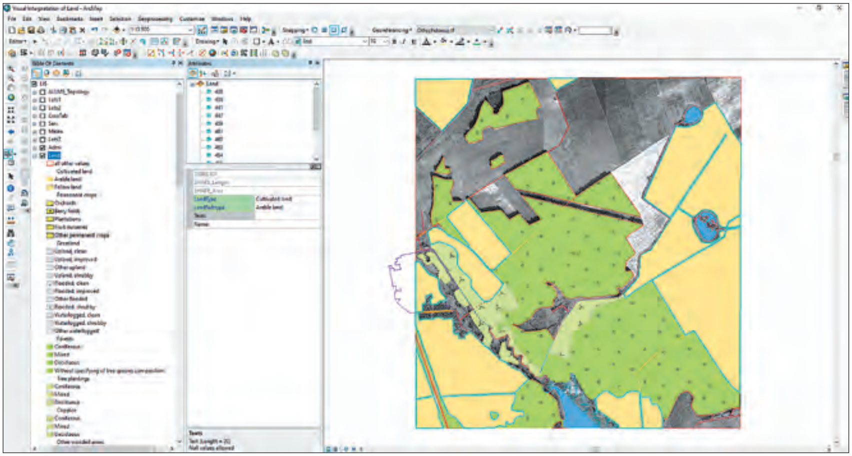


Fig. 6.44

Step 15. Carry out interpretation and cut features of the *Grassland* (fig 6.45). Use *Other waterlogged* as a subtype, since you cannot judge the state of grassland from remote sensing data. Remember that the shape and size of the grassland plots are uncertain, since their borders are the borders of arable land, fallow land, forests, as well as topographical elements of the terrain, and the texture changes depending on the qualitative characteristics.

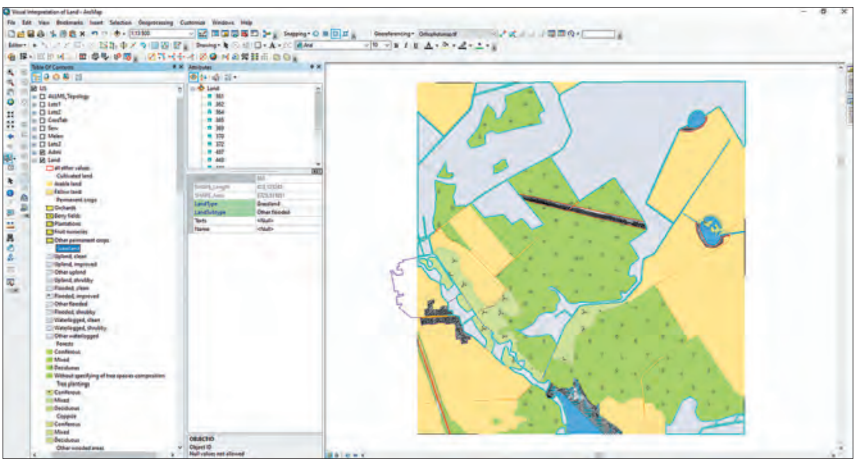


Fig. 6.45

Step 16. Interpret the remaining non-coded lands in attributes as type *Other land*, subtype *Other land* (fig 6.46).

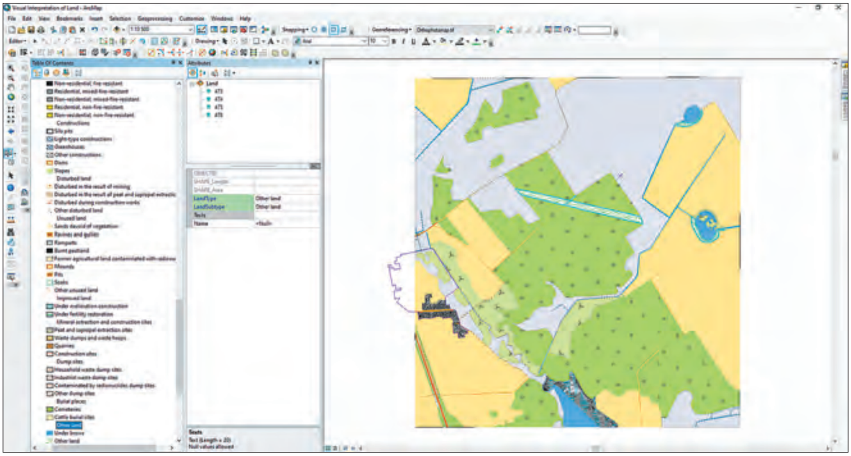


Fig. 6.46

Step 17. *Check and edit the topology* of the geodatabase "LIS-Klieck". To do this, in the table of contents, enable the display ALLMS_Topology layer. Zoom the extent of the data frame to the *Land* layer. Using the *Validate Topology in Current Extent* tool on the *Topology* toolbar, check the topology of GDB. Open the tool *Error Inspector*. With the help of *Fix Topology Errors Tool* select the extent of all layers. In the *Error Inspector* window there will appear topology errors (if any). Correct all errors. Save editing the GDB, saving all changes (Editor → Stop Editing). Save the project (File → Save).

Questions

1. List the basic sequence of steps for creating vector features by cutting out fragments of an existing polygon vector in the GIS ArcGIS.
2. What tool is used to make changes to the attributes of vectors in the GIS ArcGIS? How do geodatabase domains and subtypes work?
3. What is the workfl w for checking and editing a topology in the GIS ArcGIS? Where are topology errors stored?

3C. Correction of the Results of Visual Interpretation Based on the Field Interpretation

Purpose: to master the algorithms for editing vectors, their attributes, checking and editing the topology in the GIS ArcGIS using the example of correcting the results of visual interpretation based on the field interpretation.

Exercise progress

Step 1. Open the ArcMap of the GIS ArcGIS. Open the Visual Interpretation of Land.mxd project created in task 3.1 and 3.2 (File → Open).

Step 2. Add a non-georeferenced raster *Field survey_orthophotomap.tif* to the project (use  the "Add data" icon). This raster, which is the territory of visual interpretation of land in the Klieck district of the Minsk region, presents the results of field interpretation. All polygonal features that require editing are marked with a violet contour on the raster and signed in red as compared to the visual interpretation carried out as part of task 3.2 (fig. 6.47).

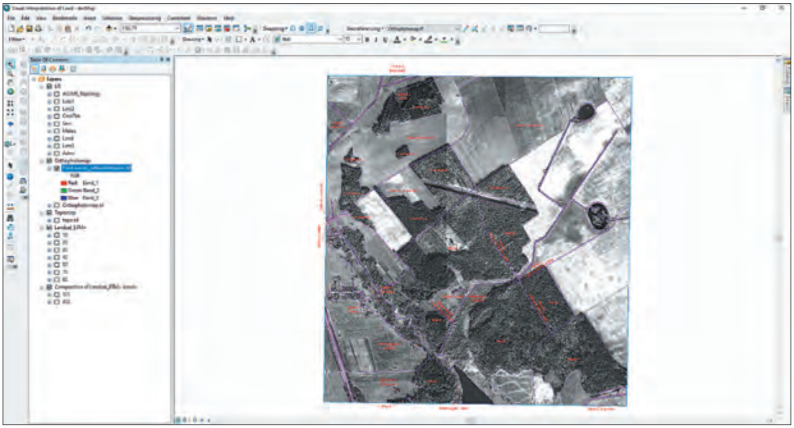


Fig. 6.47

Step 3. Georeference the raster *Field survey_orthophotoplan.tif* using the coordinates of four points known on it (table 6.9). In the table of contents "Layers", right-click the *Field survey_orthophotoplan.tif* layer and select *Zoom To Layer*. On the Georeferencing toolbar, in the *Choose Georeferencing Layer* setup, select the *Field survey_orthophotoplan.tif* raster to georeference.

Table 6.9

Raster corners	X	Y
Top left	466425.999	5865961.643
Top right	469060.353	5865977.094
Bottom right	469052.923	5863143.323
Bottom left	466429.674	5863142.250

Zoom the map extent to the desired corner, for example top left. On the raster, the border of the fragment of the Klieck district is marked with a blue outline. Place the initial control point on the corner of the blue contour on the raster (the *Add control points* icon). A green crosshair will remain at the reference point. To set the coordinates of the final reference point, click with the right mouse button and select *Input X and Y*. In the *Enter coordinates* window, type the coordinates of the given corner of the raster (fig 6.48). After finishing entering click OK.

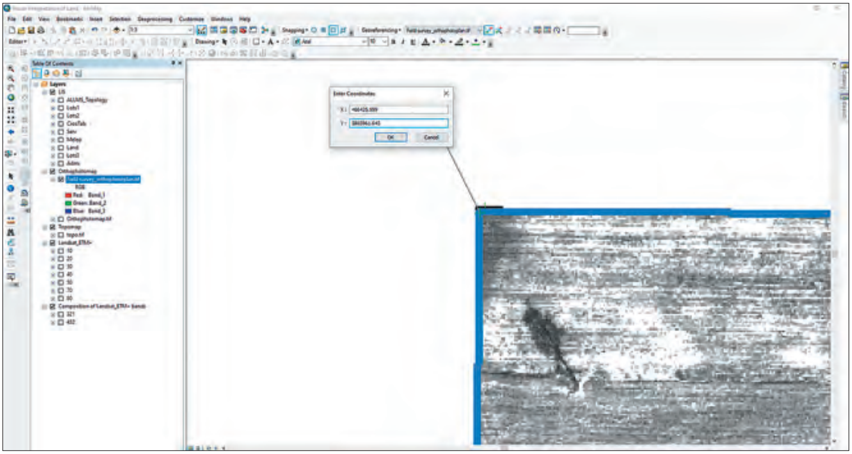


Fig. 6.48

After performing this operation, the "*Field survey_orthophotoplan.tif*" raster will move to the fragment area of the Klieck district. In the table of contents, right-click the *Field survey_orthophotoplan.tif* layer and select *Zoom To Layer*. Repeat this algorithm of operations for the remaining corners of the "*Field survey_orthophotoplan.tif*" raster (fig 6.49).

After creating all control points, perform a raster transformation using the operation Georeferencing → Transformation order → *Projective transformation*. Create a georeferencing file by choosing Georeferencing → → *Update Georeferencing*.

Step 4. Loading a transparent legend for the Land layer. Delete the *Land* layer from the project (right-click on the layer in the table of contents → → Delete). Add the Land_transparent.lyr file to the project (to the LIS multiple layer) (use the "Add data" icon). This file contains transparent symbolization for all types and subtypes of the *Land* layer.

Set the data source for the Land_transparent.lyr layer to the Land feature class of the LIS-Klieck geographic database. To do this, go to the *Properties* of the layer Land_transparent.lyr (RMB click on the layer → *Properties*), select the *Source* tab and press the *Set data source* button (fig 6.50).

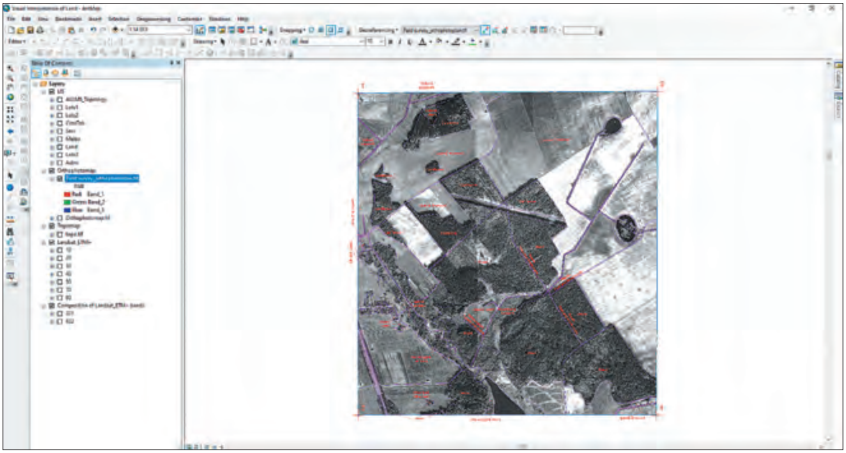


Fig. 6.49

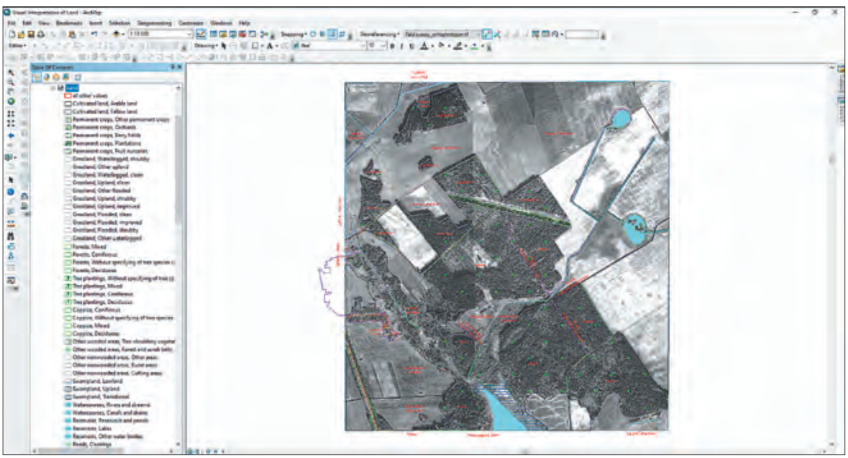


Fig. 6.50

Step 5. Edit the features referred after field interpretation to another type and subtype of land to compare with visual interpretation. Such features signed in red on the "Field survey_orthophotomap.tif" raster. Start an editing session (Editor → *Start Editing*). Select the LIS-Klieck personal geodatabase for editing.

Set the table of contents "Layers" display option to *List By selection*. Make selectable only the features in the *Land* layer.

Use the *Select Features* tool to select one of the features referred after field survey to a different land type and subtype compared to visual interpretation. Using the *Attributes* tool on the *Editor* toolbar, select for this feature the required type and subtype of land (fig 6.51).

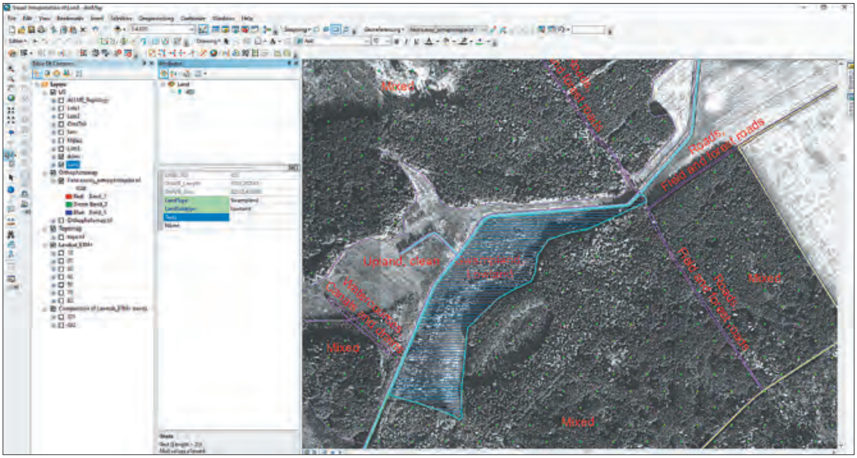


Fig. 6.51

In the same way, edit all features of the *Land* layer referred after fiel interpretation to a different type and subtype of land compared to visual interpretation. Analyze interpretational characteristics.

Step 6. Edit the features referred after field interpretation to a different land subtype compared to visual interpretation (land type has not changed). Such features have a signature in red of only the changed land subtype on the "*Field survey_orthophotoplan.tif*" raster. Using the *Select Features* and *Attributes* tools, assign these features to the desired subtype (fig 6.52). Analyze the interpretational characteristics.

Step 7. In the process of visual interpretation, some lands are quite difficult to identify. They are identified in the process of field interpretation, the results of which are their creation or editing in the Local LIS geodatabase.

To create features that belong to the *Grassland* land type, use the already familiar editing algorithm, which consists in cutting polygons.

On the *Snapping* toolbar, set the *Vertex Snapping* option. Also check the *Snap to Sketch* option by choosing *Snapping* → Snap to Sketch.

Use the *Select Features* tool to select a feature in the *Land* layer, from which you need to cut a new one. Using the *Cut Polygons Tool* on the

Editor toolbar and pressing the V key on the keyboard (allows you to see all the vertices of the existing vector features of the Land and Admi layers), start cutting the selected polygon, closing the first vertex of the sketch at the top of the selected polygon, the subsequent ones – within selected polygon and the last one at the top of the selected polygon (fig 6.53). Complete cutting the polygon by double-clicking on the last vertex of the sketch. After creating a new feature, encode the *Attributes* which are necessary for it.

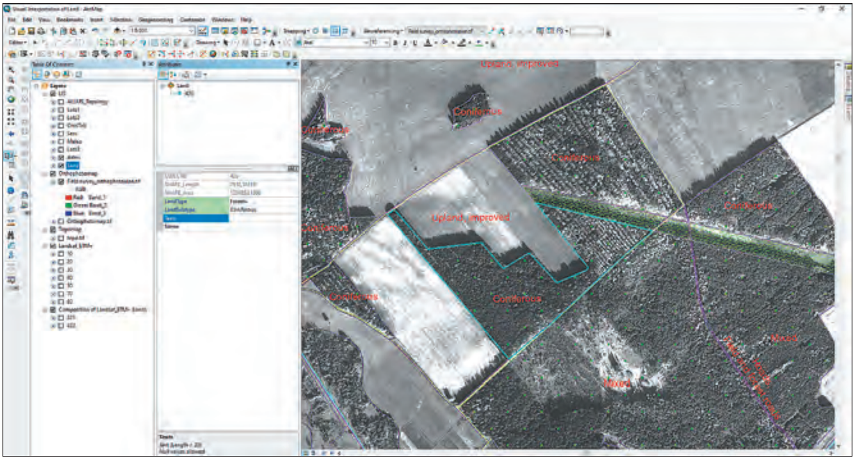


Fig. 6.52

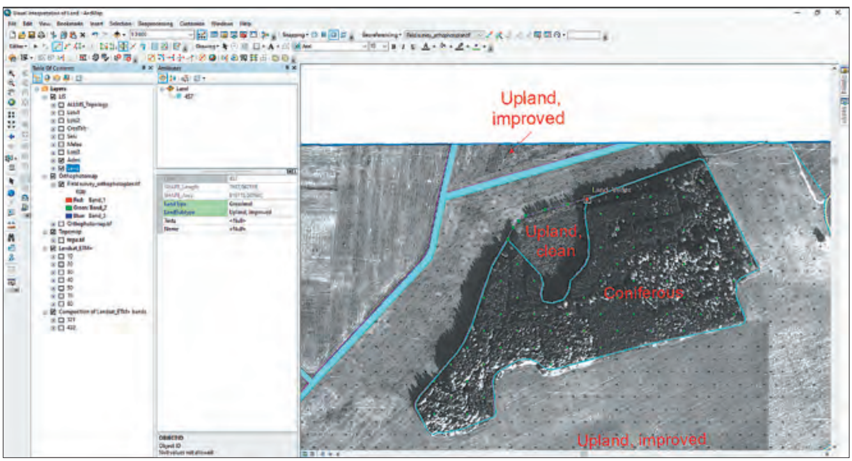


Fig. 6.53

Step 8. To create new features that belong to the Roads land type, Field and forest roads subtype, use the new editing algorithm, which consists in creating a new polygon and then clipping all existing ones in the layer along it.

Leave the Selections and *Snapping* options the same as in the previous step. In the *Create Features* window, select the layer to which the new features will belong. This layer will be the *Land* layer (*Roads, Field and forest roads)*. For the *Construction Tools*, select *Polygon*. By pressing the V key on the keyboard (allows you to see all the vertices of the existing vector features of the Land and Admi layers), start creating a new polygon according to the fi ld survey materials and close on the vertices of the existing vector features of the *Land* layer. Complete the creation of the new polygon by double-clicking on the last vertex of the sketch (fig 6.54).

After creating the vector, you need to clip the newly created polygon from all the polygons that intersect it and belong to the edited layer.

To do this, use the *Select Features* tool to select the newly created polygon (check in the *Attributes* window that only this feature was selected, otherwise you will need to click RMB to execute Remove the selection, as shown in fig 6.55). To cut the created feature from the overlapping features, use the *Clip* tool (Editor → Clip). In the clipping parameters use *Buffer distance* – 0.000, when clipping features – *Delete the area that intersects*.

After the clipping process is completed, especially in cases where the intersection feature overlapped several polygons, compound polygon features can be formed (fig 6.56). Explode them into separate ones using the *Explode Multipart Feature* tool on the *Advanced Editing* toolbar (fig 6.57). After exploding, edit the attributes of these polygons, if necessary.

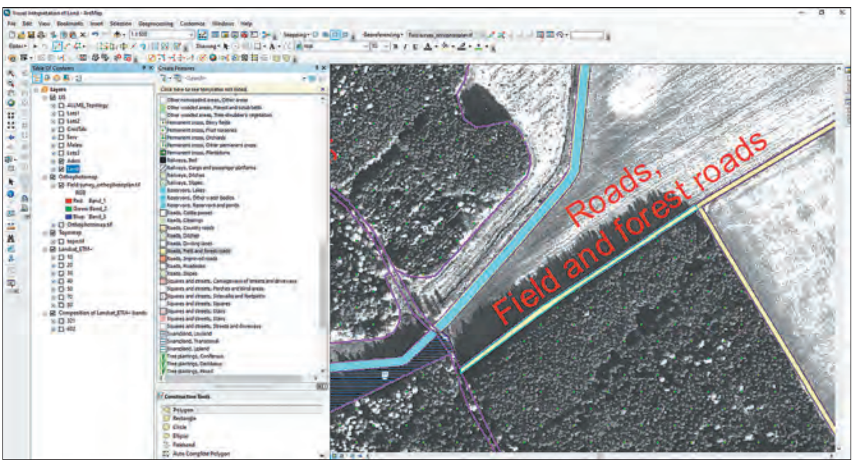


Fig. 6.54

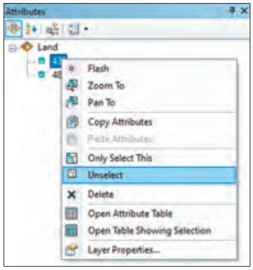


Fig. 6.55

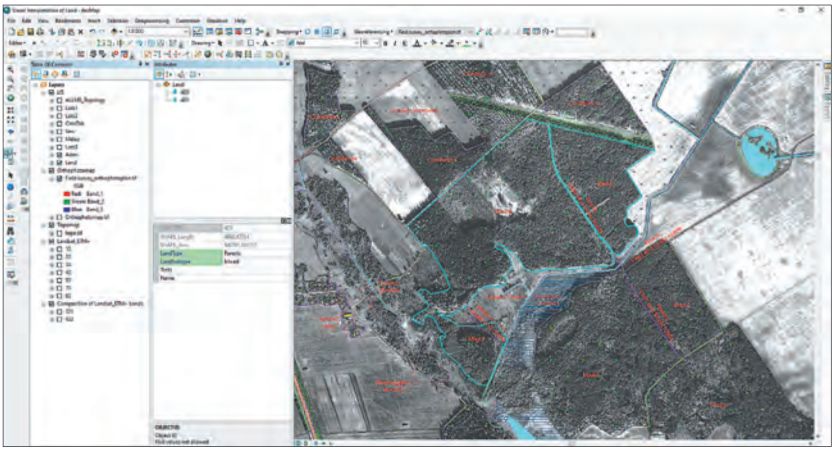


Fig. 6.56

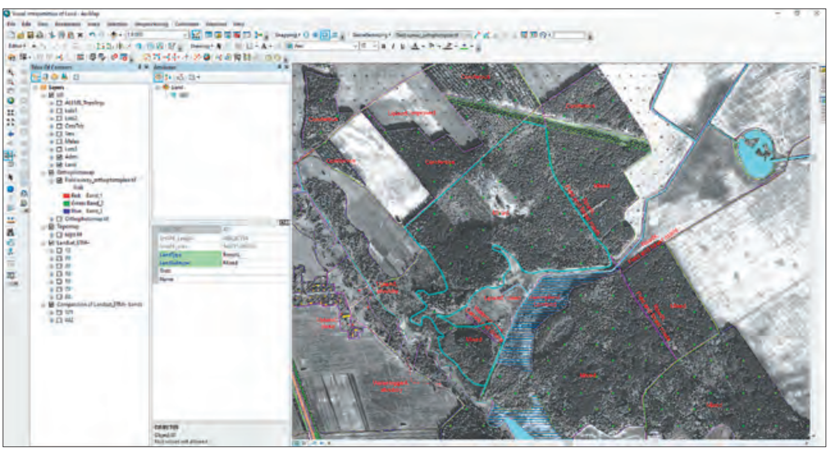


Fig. 6.57

Step 8. In the same way as in the previous step, create new features that belong to the *Watercourses* land type, *Canals and drains* subtype. To create features, use the editing algorithm, which consists in creating a new polygon and then clipping all existing o features in the layer along it (fig 6.58).

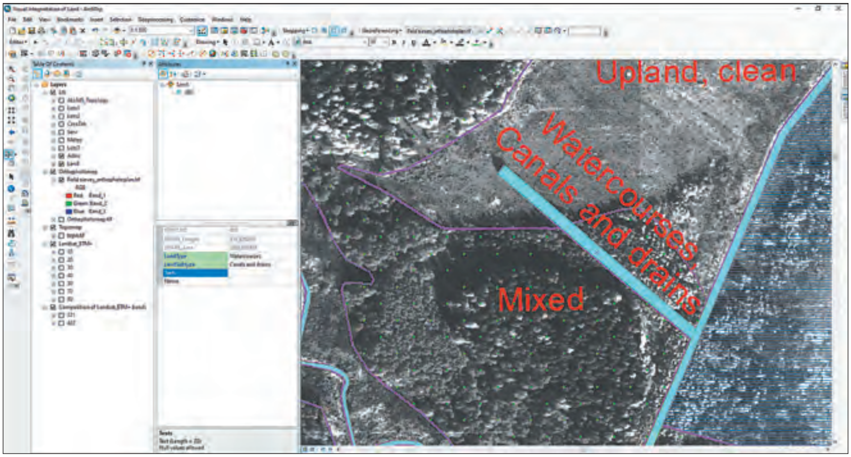


Fig. 6.58

Step 9. *Check and edit the topology* of the geodatabase "LIS-Klieck". To do this, in the table of contents, enable the display ALLMS_Topology layer. Zoom the extent of the data frame to the *Land* layer. Using the *Validate Topology in Current Extent* tool on the *Topology* toolbar, check the topology of GDB. Open the tool *Error Inspector*. With the help of *Fix Topology Errors Tool* select the extent of all layers. In the *Error Inspector* window there will appear topology errors (if any). Correct all errors. Save editing the GDB, saving all changes (Editor → *Stop Editing*). Save the project (File → *Save*).

Step 10. Load a color legend for the *Land* layer. To do this, delete the Land layer from the project (right-click on the layer in the table of contents → → Delete). Add the Land_color.lyr file to the project (use the Add Data icon). This file contains color symbolization for all types and subtypes of the *Land* layer. Set the data source for the Land_color.lyr layer to the Land feature class of the LIS-Klieck geographic database. To do this, go to the *Properties* of the Land_color.lyr layer (click the right mouse button on the layer → *Properties*), select the *Source* tab and press the *Set data source* button (fig 6.59). Save the project (File → Save).

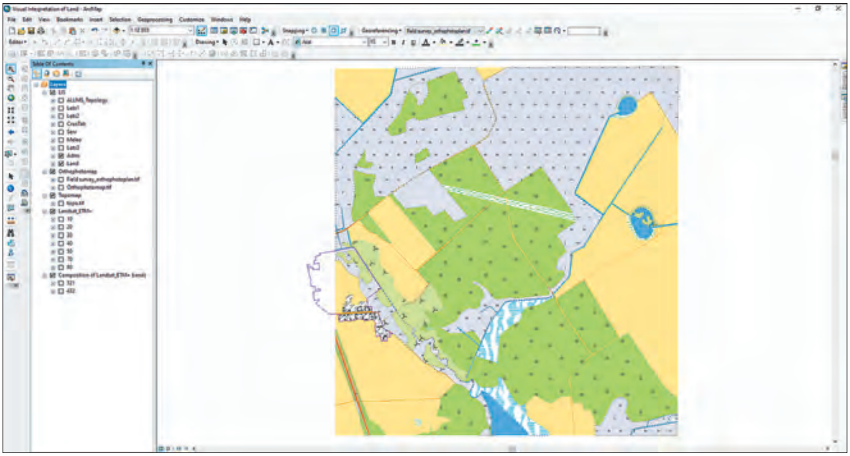


Fig. 6.59

Questions

1. List the main interpretational characteristics of land types.

2. What is the difference between georeferencing a raster to a vector layer and using points on a raster with known coordinates?

3. List the main sequence of operations for creating a new vector feature; clipping a fragment from an existing vector; creating a new one and clipping it to all existing ones in the GIS ArcGIS.

Exercise 4. Automated Classification of Land Classes Using Multizone Satellite Images.

Purpose of the exercise: to master the technique of automated classification of land classes based on materials of multizone satellite information using the GIS ArcGIS (on the example of a fragment of the territory of the Klieck district of the Minsk region).

Initial data:

• a feature class of GDB «Automated_classification» containing the border of a fragment of the territory of the Klieck district (Border);

• a raster data set of GDB «Automated_classification» containing a composition of "artificial colors" (4, 3 and 2 bands) of a multizone satellite image Landsat 7 ETM+ (432);

• a raster data set of GDB «Automated_classification» containing a fragment of the territory of the Klieck district, refle ting the actual state of the land fund in the context of land classes (data obtained as a result of a field su vey) (land).

Exercise progress

Step 1. Open the ArcMap of the GIS ArcGIS. Create an "Automated land classification project. To do this, use the *Save As* option on the *File* menu. Save the project in your folder.

Step 2. Add to the project a raster data set of GDB «Automated_ classification» containing a composition of "artificial colors" (4, 3 and 2 bands) of a multizone satellite image Landsat 7 ETM+ (432) using the "Add data" icon.

Step 3. Go to the menu Customize → Extensions and check the box for the *Spatial Analyst* extension. Open the *Image Classifi ation toolbar* (Customize → → Toolbars → Image Classification) fig 6.60.

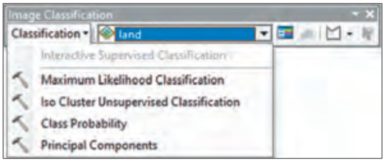


Fig. 6.60

Step 4. On the *Classifi ation* toolbar, enable *Training Sample Manager*. Using the *Draw Rectangle* tool, create a training sample that displays on the composition of "artificial colors" (4, 3 and 2 bands) of a multizone satellite image Landsat 7 ETM+ (432) the *Arable* land class (turquoise color in the image). In the "Training Sample Manager" window, write "Arable" in the *Class Name* field select orange in the *Color* field (fi 6.61).

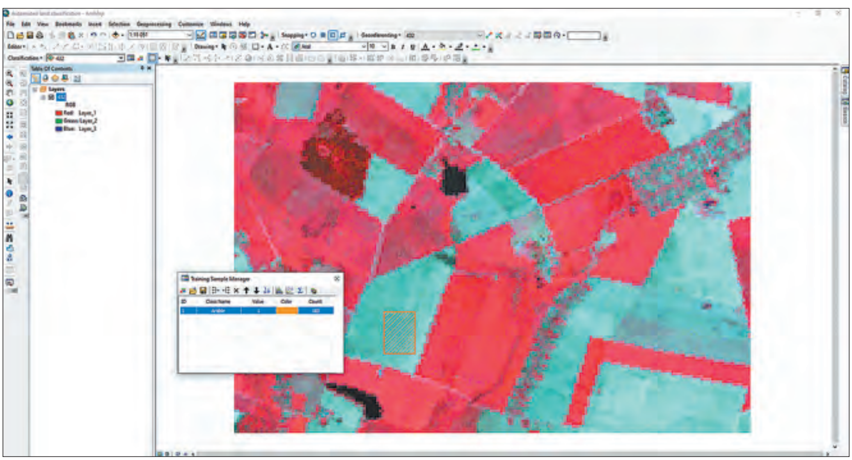


Fig. 6.61

Create a series of training samples for arable land, and then combine them with the one class already created earlier by selecting them all and clicking the button *Merge training samples* in the window “Training Sample Manager”.

Step 5. Using the algorithm described above, create training samples for other land classes (groups of classes): grassland (red color in the image); woodland and scrubland (wine-colored); land under water objects (black); land under roads and other transport communications, land under streets and other public spaces, building land (green-blue). In the *Class Name* field assign names to them according to fig 6.62. In the *Color* box, select the appropriate colors.

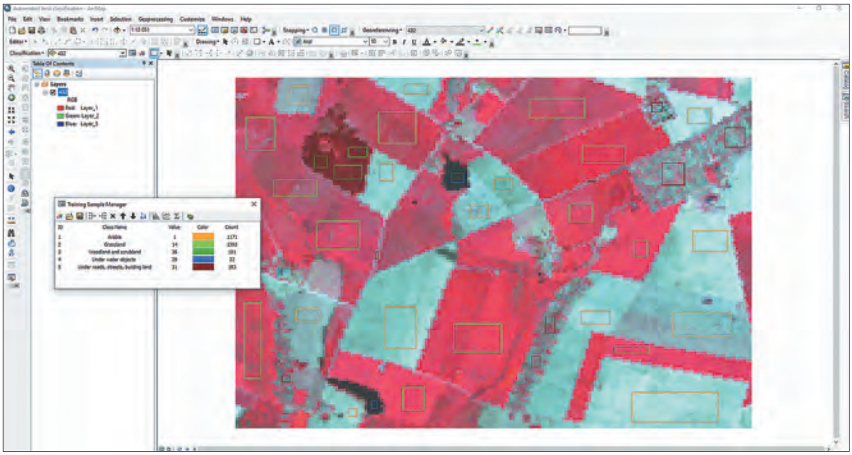


Fig. 6.62

Step 6. Save the training samples as a feature class in the GDB «Automated_classification» using the *Save Training Samples* in the Training Sample Manager window.

Step 7. Perform an automated classification of land classes (groups of classes) in the fragment of the Klieck district using the maximum likelihood method, fig 6.63. Use the *Interactive Supervised Classifi ation* tool (Classification → Interactive Supervised Classification) to do this

Step 8. Close the “Training Sample Manager” window and click the *Clear Training Samples* button on the toolbar “Classification .

Save the raster of classification results in the GDB «Automated_classification» To do this, right-click on the “Classification_432 layer and select Data → Export Data. In the “Export raster data” window, in the *Location* field specify the location in the GDB «Automated_classification» in the *Name* field leave “Classification_432 as the file name. After that click OK. The saved raster will be automatically added to the project. Delete the unsaved raster.

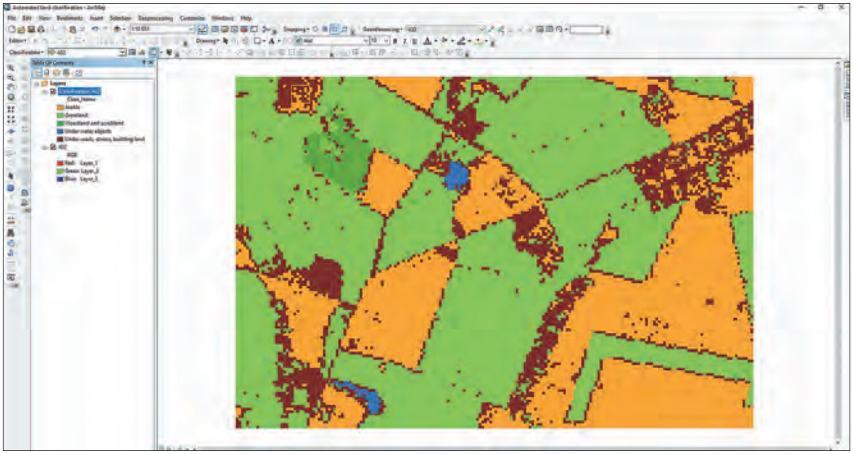


Fig. 6.63

Step 9. Add a raster of a fragment of the territory of the Klieck district to the project, refle ting the actual state of the land fund (data obtained as a result of a field survey), using the icon "Add data" (fig 6.64). Download the layer legend. To do this, go to "Layer *Properties*" (right-click on the layer in the table of contents → *Properties*) and select the "Symbology" tab. Select "Unique Values" and click the "Import" button. Select the *land.lyr* legend for the raster from the source data folder.

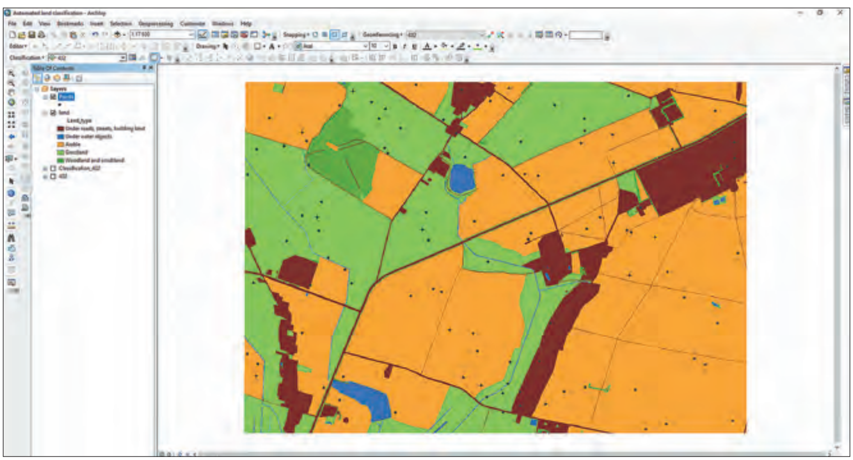


Fig. 6.64

Visually compare the results of the automated classification with data on the actual state of the land fund.

Step 10. Evaluate the accuracy of the automated classification Create a point vector containing 100 random points within the fragment of the Klieck district for which the assessment will be made. To do this, open the *ArcToolbox* , find the *Create Randomly Placed Points* tool (Data Management → → Sampling → Create Random Points). In the tool window, under *Output Location* select the GDB «Automated_classification» designate "Points" as the *Output point feature class*, choose "Same as layer land" as *Constructing Extent*, *Number of points* – 100, *Minimum Allowable Distance* – 10 m (fig 6.65).

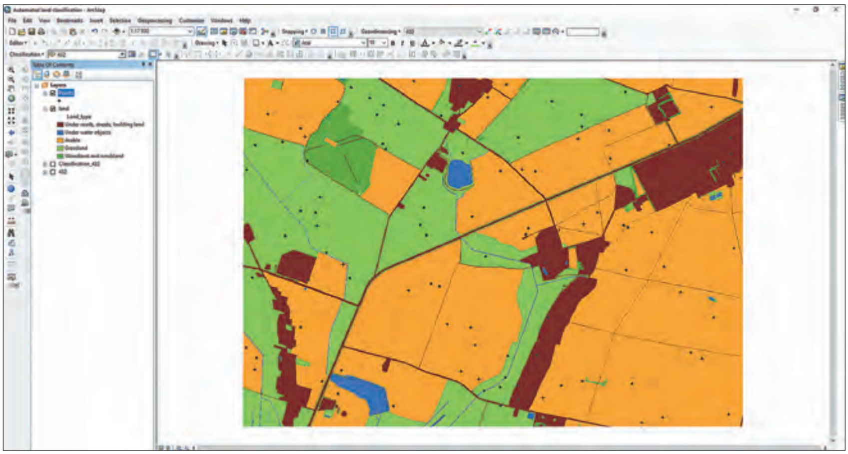


Fig. 6.65

Step 11. For each randomly generated point, obtain the values of the land classes (groups of classes) according to the field survey data (raster *land*) and according to the results of automated classification (raster *Classifi ation_432*). Open the *ArcToolbox* , find the *Sample* tool (Spatial Analyst Tools → → Extraction → Sample). In the *Tool* window, select the "land" raster as the *Input rasters*, as well as the "Classifi ation_432". As *Input location raster or point features*, select Points layer, Save the *Output table* in the GDB «Automated_ classification» under the name "Accuracy_assessment" (fig 6.66).

After the necessary calculations the table *Accuracy_assessment* will be added to the project. Open the table (right-click on the table → Open). In the table, for each point, the code of the type (group of types) of lands from the "land" raster, as well as from the "Classification_432 raster (fig 6.67) is entered. Codes of types (groups of types) of lands can be specified by opening the attribute table of the corresponding raster (right-click on the raster → Open attribute table).

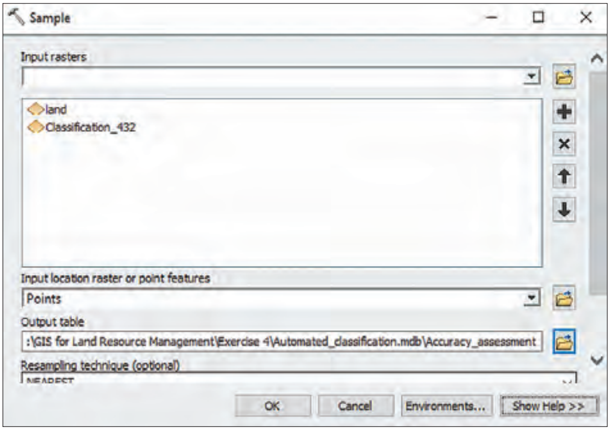
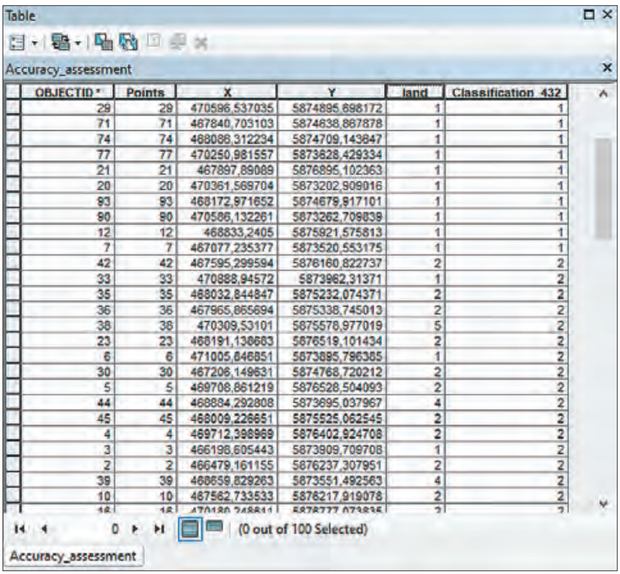


Fig. 6.66



Table

Accuracy_assessment

OBJECTID *	Points	X	Y	land	Classification_432
29	29	470596,537035	5874895,698172	1	1
71	71	467840,703103	5874638,867878	1	1
74	74	468086,312234	5874709,143647	1	1
77	77	470250,981557	5873628,429334	1	1
21	21	467897,89089	5876895,102363	1	1
20	20	470361,569704	5873202,909016	1	1
93	93	468172,971652	5874679,917101	1	1
90	90	470586,132261	5873262,709839	1	1
12	12	468833,2405	5875921,575813	1	1
7	7	467077,235377	5873520,553175	1	1
42	42	467595,299594	5876160,822737	2	2
33	33	470888,94572	5873962,31371	1	2
35	35	468032,844847	5875232,074371	2	2
36	36	467965,865694	5875338,745013	2	2
38	38	470309,53101	5875578,977019	5	2
23	23	468191,138683	5876519,101434	2	2
6	6	471005,846851	5873895,796365	1	2
30	30	467206,149631	5874768,720212	2	2
5	5	469708,861219	5876528,504093	2	2
44	44	468884,292808	5873695,037967	4	2
45	45	468009,226651	5875525,062545	2	2
4	4	469712,398969	5876402,924708	2	2
3	3	466198,605443	5873909,709708	1	2
2	2	466479,161155	5876237,307951	2	2
39	39	468659,829263	5873551,492563	4	2
10	10	467562,733533	5876217,919078	2	2

(0 out of 100 Selected)

Accuracy_assessment

Fig. 6.67

Step 12. To assess the accuracy of automated classification it is necessary to create an error matrix (an example of an error matrix is given in table 6.10).

According to the error matrix, you can judge the reliability of each specifi feature (class) and the reliability of classification as a whole. In matrix the number of correctly classified feature s of a certain class and the number of features assigned to one class or another for some reason are indicated. The criterion for the quality of classification as a whole is the proportion of correctly classified features. It is calculated by dividing the sum of correctly classified features located along the diagonal of the matrix by the number of all checked features. It is 67% for the data given in table 6.10:

$$(28 + 32 + 3 + 1 + 3) / 100 = 67\ \%.$$

In addition, one can calculate the reliability of classification of each of the features (classes). Thus, the ratio of the number of correctly classifie features of the arable land class (28) to the sum of all features classified to this type (50) characterizes the reliability of classification this class (5 %).

After creating an error matrix for automated classification evaluate the reliability of classification of each land class and determine the main reasons for the incorrect recognition of some features.

Table 6.10

Field Survey Result (raster «land»)	Classification result (Classification_432 raster)						
	Arable	Grassland	Woodland and scrubland	Under water objects	Under roads and other transport communications, land under streets and other public spaces, building land	Total	Decrypted corerectly, %
Arable	**28**	20	0	0	2	50	56
Grassland	0	**32**	0	0	1	33	97
Woodland and scrubland	0	1	**3**	0	0	4	75
Under water objects	0	0	0	**1**	0	1	100
Under roads and other transport communications, land under streets and other public spaces, building land	5	4	0	0	**3**	12	25
Total	33	57	3	1	6	**100**	**67**

After the necessary calculations the table *Accuracy_assessment* will be added to the project. Open the table (right-click on the table → Open). In the table, for each point, the code of the type (group of types) of lands from the “land” raster, as well as from the “Classification_432 raster (fig 6.67) is entered. Codes of types (groups of types) of lands can be specified by opening the attribute table of the corresponding raster (right-click on the raster → → Open attribute table).

Questions

1. List the main sequence of steps for the automated classification of land classes based on multizone satellite images in the GIS ArcGIS.

2. How are different land classes displayed on the composition of "artificial colors" (4, 3 and 2 bands) of a multizone satellite image Landsat 7 ETM+?

3. List the main sequence of steps for evaluating the accuracy of automated classification results

Exercise 5. Creation of Plans of Boundaries of Land Plots in GIS Based on Geodetic Surveys.

Purpose of the exercise: to study the algorithms of processing of geodetic survey data in GIS ArcGIS using the example of creating a plan of the boundaries of land plots of the gardening community "Mayak" (GC "Mayak").

Initial data:

- a shape-file containing geodetic points of the state geodetic network, which served as reference points for laying the theodolite traverse through the GC "Mayak" (*polygonometry_points.shp*);
- a shape-file ontaining traverse points (*traverse_point.shp*);
- a shape-file ontaining the sides of the traverse (*traverse_sides.shp*);
- a shape-file containing additional geodetic points, measured by the polar method from the points of the traverse, necessary to determine the turning points of the boundaries of the land plots in places of their difficult visibility from the points of the traverse (*additional_points.shp*);
- a shape-file containing the turning points of the boundaries of the land plot of GC "Mayak" and the citizens' plots, measured by the polar method from the points of the traverse and the additional geodetic points (*turning_points.shp*);
- a shape-file containing polar links of tacheometric survey (*polar_links.shp*).
- GDB Gardening_community.mdb containing feature classes *Gardens* (it will be used for creation of the land plot polygon of the GC "Mayak"), *Lots1* (the turning points of the boundaries of the land plot of GC "Mayak", the turning points of citizens' plots and the turning points of public lands), *Lots2* (external boundary of the GC "Mayak", boundaries of citizens' plots, boundaries of public lands), *Lots3* (GC plot, citizens' plots, public lands). Feature classes participate in topology (table 6.11).

Table 6.11

Features of feature class	Rule	Feature class
Gardens	Must Not Overlap	
Gardens	Must Be Covered By	Lots2
Gardens	Boundary Must Be Covered By	Lots3

End of the table 6.11

Features of feature class	Rule	Feature class
Lots2	Must Be Covered By Boundary Of	Lots3
Lots2	Must Not Have Dangles	
Lots2	Must Not Self-Intersect	
Lots2	Must Not Self-Overlap	
Lots2	Must Be Single Part	
Lots2	Must Not Intersect Or Touch Interior	
Lots2	Endpoint Must Be Covered By	Lots1
Lots3	Must Not Overlap	
Lots3	Boundary Must Be Covered By	Lots2
Lots3	Must Be Covered By Feature Class Of	Gardens

Exercise progress

Step 1. Open the ArcMap of the GIS ArcGIS. Open the *Mayak.mxd* project. Repair data sources for project layers (these operations are necessary when the project files have been moved to another location on the hard disk or to another disk). Repair data source for the layers of the *Geodetic survey* group layer to shp-files of the same name (right-click on the layer → Data → *Repair Data Source*), fig.re 6.68. For the layers of the *Gardening_community* group layer, also set the sources to the feature classes of the same name from the feature dataset *Garden* in the Gardening_community GDB.

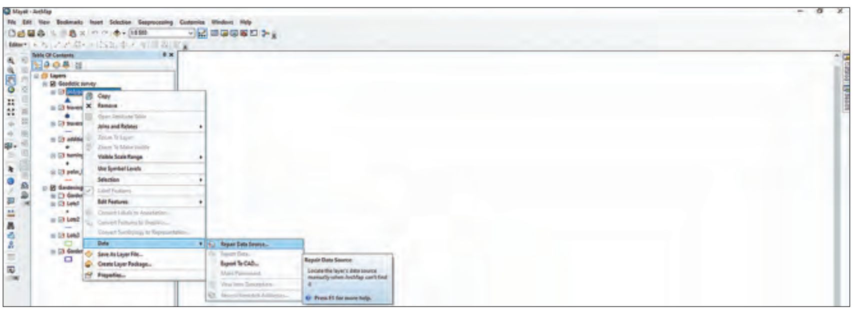


Fig. 6.68

Step 2. Explore the spatial data of the geodetic survey of the gardening community "Mayak" (fig 6.69).

The work on establishing the boundaries of the land plot of GC "Mayak" was carried out in accordance with the requirements of. The external boundary of the GC "Mayak" was surveyed by the polar method from the points of the theodolite traverse. Polygonometry points 8422 and 9338 served as reference points for the position of the traverse. Horizontal angles and line lengths were measured with a Trimble 3305DR station. The turning points of citizens' plots and public lands were measured by the polar method from the points of the theodolite traverse and from additional geodetic points.

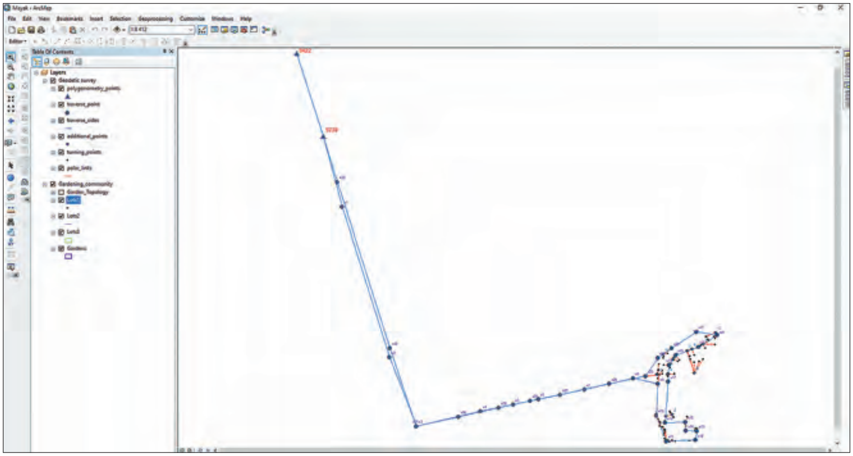


Fig. 6.69

The data of geodetic measurements were imported into the CREDO_DAT program of the CREDO software from a Trimble 3305DR station. This program allows for automated cameral processing of field geodetic data. Initially, the theodolite traverse was adjusted. The absolute discrepancy was 0.420 m, the relative error was 1:2000, the angular discrepancy was $7.0''$, while the allowable error was $20.0''$. Then, the coordinates of the turning points of the external boundary of the GC "Mayak", citizens' plots and public lands were calculated.

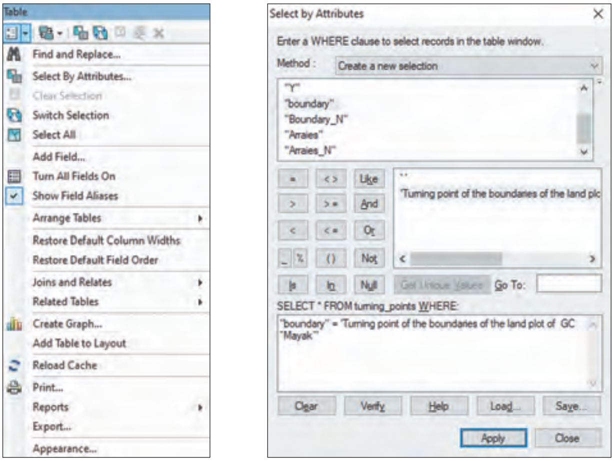
All survey data were exported from CREDO_DAT in the GIS ArcGIS as shp-files (in the Mayak.mxd project they are placed in the *Geodetic survey* multiple layer).

Step 3. Create a land plot of the GC "Mayak" based on the data of geodetic survey.

Select the turning points of the external boundary of the GC "Mayak" from the "turning_points" layer. Open the attribute table for this layer (right-click on the layer in the table of contents → *Open Attribute Table*). Click the  Table Options button and select the *Select By Attributes* tool (fig 6.70, *a*).

In the window *Select by Attributes* that will open, form the query "Boundary" = 'Turning point of the boundaries of the land plot of GC "Mayak"'.

To do this, double-click on the field of the attribute table "Boundary", then on the operator "=" and on the "Turning point of the boundaries of the land plot of GC "Mayak" (use the button Get Unique Values) (fig 6.70, *b*). Then click the Apply button. As a result of the selection, all turning points of the external boundary of the GC "Mayak" will be selected.



a *b*

Fig. 6.70

Export the turning points of the external boundary of the GC "Mayak" from the " turning_points " layer to a separate shp-file Close the attribute table of the layer (note that features selected by attributes remain selected in the view). Export the selected data to a separate feature class in the GDB "Gardening_community" by right-clicking on the "turning_points" layer, then Data → *Export Data* (fig 6.71). Save the data using the same coordinate system as this layer's source data. Name the new feature class as *Turning_points_external_boundary* in the GDB "Gardening_community". Agree to add the exported data to the project. Also, deselect the features in the "turning_points" layer using the menu Selection → *Clear Selected Features*.

Label the layer just added to the data frame, *Turning_points_external_boundar*. Go to Layer *Properties* (right click on layer → *Properties*). Go to the Labels tab, in the *Labels* tab check the box *Label features in this layer*, select *Boundary_N* as the label field and symbolize the labels in a font and size convenient for you (fig 6.72).

Turn off the display of the *Geodetic survey* group layer and hide its legend.

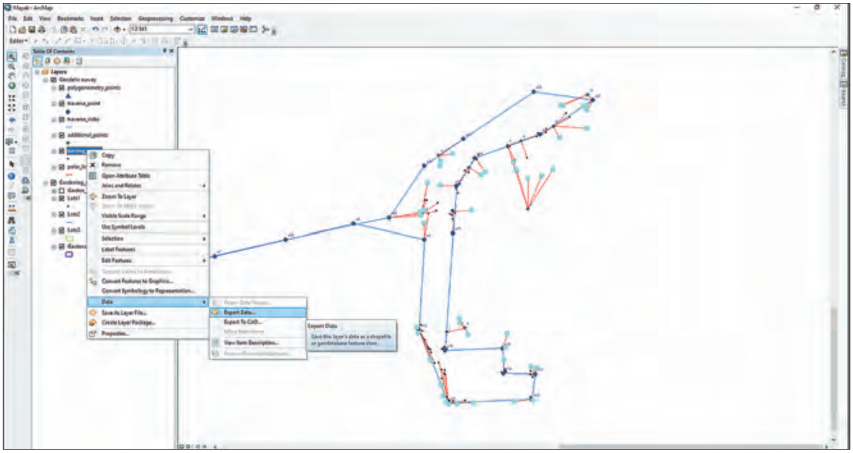


Fig. 6.71

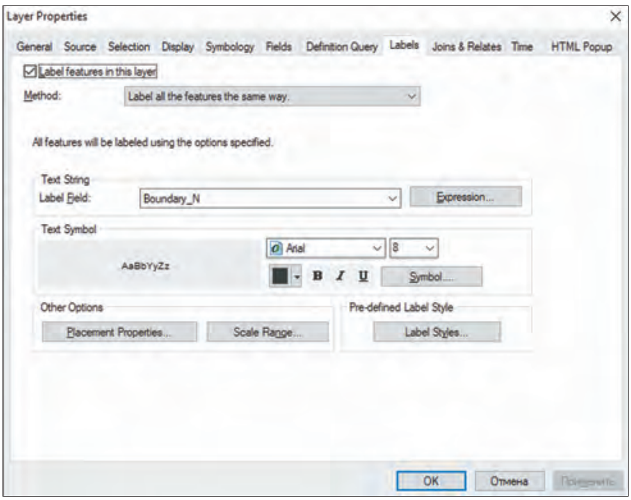


Fig. 6.72

Create a vector polygon feature of the external boundary of the GC “Mayak” in the *Gardens* layer using its turning points. To do this, use the tools of the *Editor* panel.

Start the editing session (Editor → Start Editing). Select the GDB “Gardening_community” for editing. In the *Create Features* window (appears automatically after the start of an editing session), select the *layer to which* *the new features will belong*. This layer will be the *Gardens* layer. For the *Construction Tool*, choose Polygon.

Since you will be creating a new feature based on another layer, it is necessary that the vertices of the sketch of the new feature correspond to the points of the *Turning_points_external_boundar* layer. To do this, set the option *Point Snapping* on the Snapping toolbar.

Now you can start creating a vector polygon feature of the external boundary of the GC "Mayak". Zoom in the extent of the data frame around the first turning point of the boundaries of the land plot of GC "Mayak" and lock on it (click with LMB). Continue snapping to turning point of the boundaries of the land plot by making one click with LMB. If you put the vertex of the sketch in the wrong place it can be deleted by clicking RMB near the vertex and selecting *Delete Vertex*. It is necessary to double click the last point with LMB. *Stop your editing session* (Editor → Stop Editing) (fig 6.73).

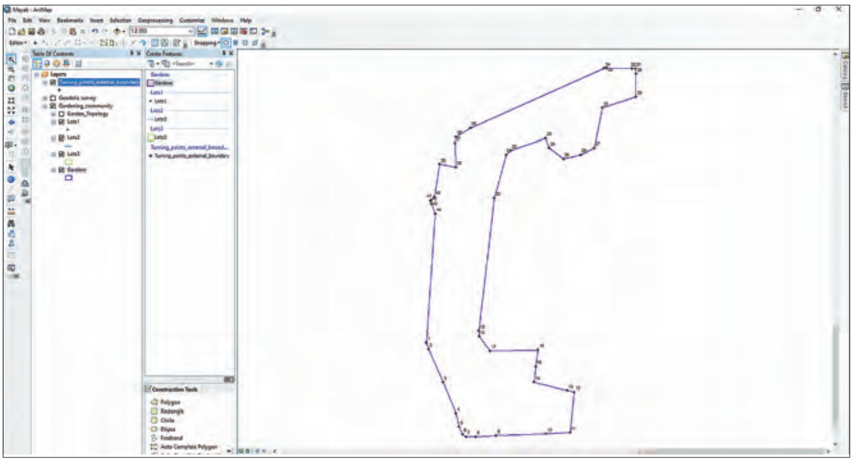


Fig. 6.73

Step 4. Select the turning points of arrays of citizens' plots from the "turning_points" layer (attribute field "Arrays", values "Turning point of the boundaries of citizens' plots. Array 1" – "Turning point of the boundaries of citizens' plots. Array 8"). Export the selected data to a separate feature class in the GDB "Gardening_community". Name the new feature class as *Turning_points_arrays_citizens_plots*. Agree to add the exported data to the project. Also, deselect the features in the "turning_points" layer using the menu Selection → → *Clear Selected Features*. Turn off the display of the Survey multiple layer and hide its legend. Label the features of the "Turning_points_arrays_citizens_plots" according to the field Arrays_N.

Open the attribute table of the layer "Turning_points_arrays_citizens_plots". Perform a selection of the turning points of the array of citizens' plots No. 1 from the layer (attribute fiel – *Arrays*, value – *Turning point of the boundaries of citizens' plots. Array 1*). Close the attribute table.

Create a vector polygon feature of the array of citizens' plots No. 1 in the *Lots3* layer using its turning points. To do this, start editing the personal GDB "Gardening_community". In the *Create Features* window, select the *layer to which the new features will belong*. This layer will be the *Lots3* layer. For the *Construction Tool*, choose Polygon. Zoom in the extent of the data frame around the turning points of the array of citizens' plots No. 1 and create a polygon (fig 6.74). In the Attributes window of the newly created feature, in the *Name* field write its name – "Array of plots 1".

By analogy, create in the *Lots3* layer the remaining arrays of citizens' plots based on geodetic survey. In the attribute table field *Name* of the Lots3 layer, specify the names of the arrays. After creating all the plots, end the edit session saving the changes.

Label the features of the *Lots3* layer. To do this, go to the properties of this layer. On the *Fields tab*, click the button *Number Format* to change the number format of the *SHAPE_Area* field Set rounding to 0 decimal places. Now the area values (in m^2) of citizens' plots will be rounded to integers. Go to the *Labels* tab. Check the box *Label features in this layer* and click the *Expression* button. Create the expression [Name]&VBnewline&[SHAPE_Area]. The 'VBnewline' part of the expression is keyboard-typed and means "from a new line", & is also keyboard-typed and means "and". Using this expression the labels of the layer will consist of two lines: the top line – the name of the array of citizens' plots, the bottom – the area in m^2 (fig 6.75).

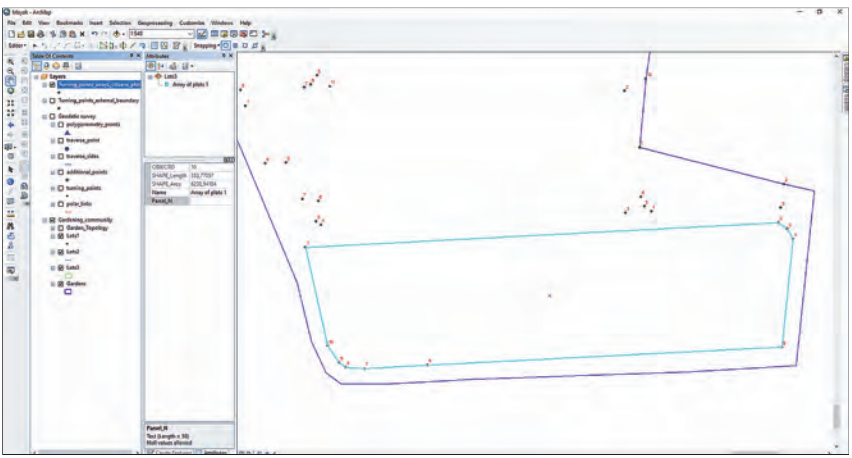


Fig. 6.74

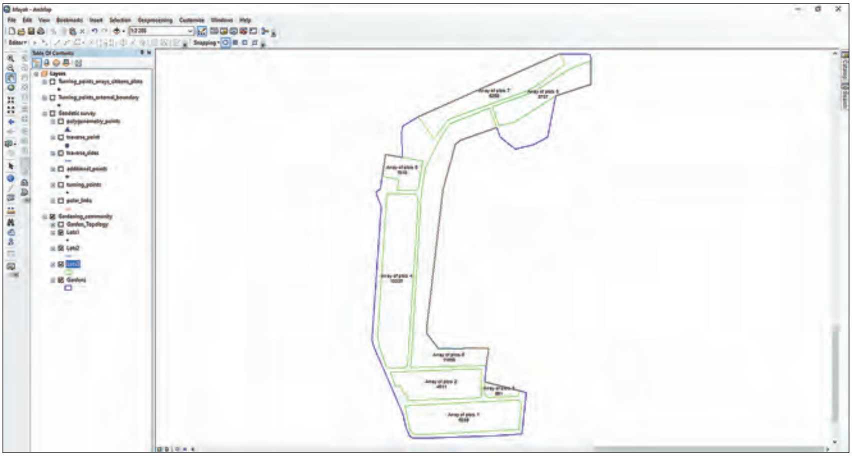


Fig. 6.75

Step 5. Close the Mayak.mxd project saving the changes. Open the ArcCatalog of the GIS ArcGIS.

Create a linear feature class *Lots2* (external boundary of the GC "Mayak", boundaries of citizens' plots, boundaries of public lands) based on the created polygons of the GC plot and arrays of citizens' plots. To do this, use the GIS tool to convert polygonal features to linear features.

Open the *ArcToolbox* . Open the Feature to Line tool (Data Management Tools → Features → *Feature to Line*). In the tool window, in the *Input Features* section, select the *Gardens* polygon feature class of the GDB "Gardening_community". Save the *Output Feature Class* in the same database as *Gardens_FeatureToLine*.

Repeat this GIS-tool for the polygonal feature class *Lots3*. After the necessary calculations, the program will create a line feature class *Lots3_FeatureToLine* in the GDB "Gardening_community".

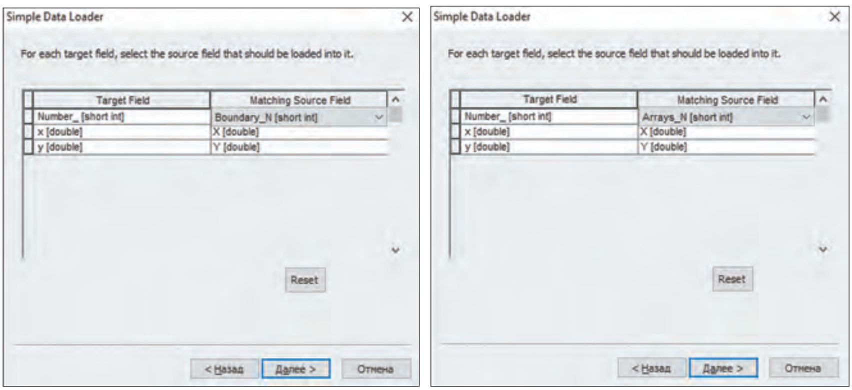
The next task is to split two linear feature classes "Gardens_FeatureToLine" and "Lots3_FeatureToLine" into a set of separate lines. To do this, open the ArcToolbox tool Split Line at Vertices (Data Management → → Features→ *Split Line at Vertices*). In the tool window, in the *Input Features*, select the "Gardens_FeatureToLine" feature class. Save the *Output Feature Class* in the GDB "Gardening_community" as *Gardens_FeatureToLine_SplitLine*.

Repeat this GIS-tool for the linear feature classes "Lots3_FeatureToLine". After the necessary calculations, the program will create a line feature class *Lots3_FeatureToLine_SplitLine* in the GDB "Gardening_community".

Load the created linear features into the “Lots2” class. To do this, right-click on this feature class in the GDB “Gardening_community”, select Load → → *Load Data*. Select the class “Gardens_FeatureToLine_SplitLine” as *input data*, click the *Add* button, leave the following loading steps as default. Repeat this process to load the “Lots3_FeatureToLine_SplitLine” class into the “Lots2” feature class.

Step 6. Create a point feature class *Lots1* (the turning points of the boundaries of the land plot of GC “Mayak”, the turning points of citizens’ plots and the turning points of public lands). To do this, load into this class of spatial features from the classes “Turning_points_external_boundary” and “Turning_points_arrays_citizens_plots” of the GDB “Gardening_community”. Right-click the “Lots1” feature class, choose Load → *Load Data*. Select the *input data* “Turning_points_external_boundary”, click *Add*. Set the matching of the target field and the sour e field (fi 6.76, *a*).

Similarly, load into the “Lots1” feature class the point features from the “Turning_points_arrays_citizens_plots” class. Set the matching of the target field and the sour e field (fi 6.76, *b*).



a *b*

Fig. 6.76

Step 7. Create a public lands polygon by erasing the Lots3 feature class from the Gardens class. To do this, use the ArcToolbox *Erase* tool (Analysis Tools → Overlay → *Erase*). In the tool window, in the *Input Features* section, select the “Gardens” feature class of the GDB Gardeners, in the *Erase Features* section, select the “Lots3” class. Save the output feature class in the Gardeners database under the name *Public_lands*.

Step 8. Close the ArcCatalog. Open the ArcMap of the GIS ArcGIS, project “Mayak.mxd”.

The loaded data appeared in the layers Lots1 and Lots2.

Add the "Public_lands" feature class from the GDB "Gardening_community" to the project on the Gardening_community group layer using the "Add data" icon.

Step 9. Symbolize the layers of the Gardening_community group layer. Right-click on the "Public_lands" layer, open layer *Properties*. Select the Symbology tab and set the layer's display option to "Features: Single Symbol". Click on the icon of the symbol and select for it "Fill color" – *Olivine Yellow*, "Outline Color" – *no color*, "Outline width" – *0*.

Symbolize the rest of the layers (Lots1, Lots2, Lots3, Gardens). For the "Lots3" layer, select "Fill Color" – *no color*, "Outline Width" – *1*, "Outline Color" – *Black*.

For the "Lots2" layer, set Color to *Black* and Width to *1*.

Layer "Lots1" symbolize as follows: "Category" – *Circle 2*, "Color" – *Red Mars*, "Size" – *5*; "Gardens" layer – "Fill color" – *no*, "Outline width" – *1.5*, "Outline color" – *Black*.

Step 10. Label features in layers. In the layer properties go to the Labels tab. Label the features of the "Lots1" layer by the field *Number_*(font – *Arial,* size – *8*, color – *Mars red*); "Lots2" layer – by the *SHAPE_Length* field (in the "Fields" tab, set rounding to *2 decimal places*, *pad with zeros*; *Arial* font, size – *8*, color – *black*. "Lots3" layer will be labeled with the expression composed in step 4; *Arial* font, size – *10*, color – *Amethyst*.

Step 11. In the Data Frame *Properties* window (View → Data Frame *Properties*) on the *Data Frame* tab, set the map to *Fixed scale* equal to 1:1000 (fig 6.77).

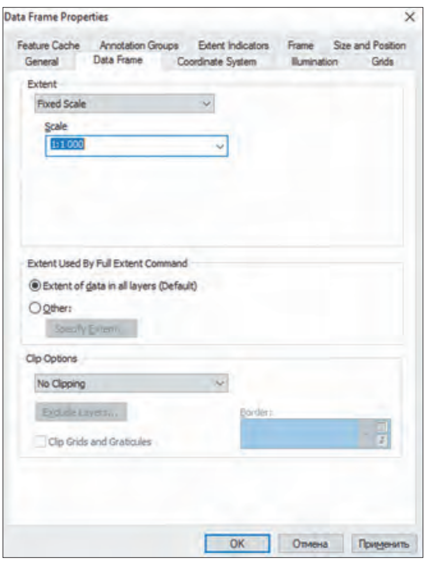


Fig. 6.77

Step 12. Convert layer labels (Lots1, Lots2, Lots3) to annotation. To do this, right-click on the layer and select *Convert Labels to Annotation*. In this way, you will be able to transform interactive labels into stable graphics. Save annotation *in the map* document (fig 6.78).

Fig. 6.78

Move the labels using the *Select Elements* tool located on the main toolbar so that they do not overlap with other labels and vector features. Try to place the numbers of the turning points turning points of arrays of citizens' plots inside the arrays, lengths of the external boundary of the GC "Mayak", arrays of citizens' plots – on the outside, the numbers of the turning points of the boundaries of the land plot of GC "Mayak" – also on the outside (fig 6.74).

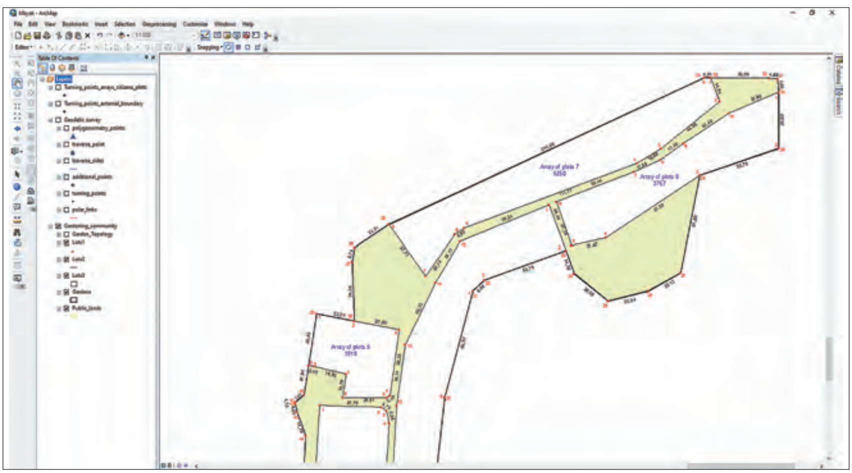


Fig. 6.79

Step 13. Layout the plan for the boundaries of the land plot of GC "Mayak". To do this, go to "Layout View" (View → *Layout View*). In the "Page and Print Setup" menu (File → *Page and Print Setup*), set the A2 *paper size* for the plan. Use the option *Use Printer Paper Setting* for map page size (fig 6.80).

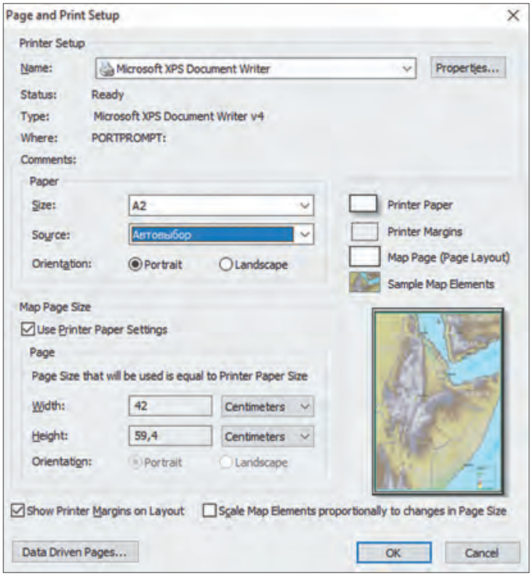


Fig. 6.80

Using the *Select Elements* tool, stretch the data frame page size. Using the tool *Move*, place the land plot of the GC "Mayak" in the center of the sheet.

Using the *Text* tool located on the *Drawing* toolbar, create the text *Plan of the boundaries of land plots of the gardening community "Mayak"* (font *Arial*, size – *28*, color – *black*). Use the *Select Elements* tool to move the created label to the top center.

Similarly, create a text (font *Arial*, size – *20*, color – *black*) (fig 6.81):

The total area of the gardening community is 5.84 hectares.

The area of land for common use is 1.46 ha.

The area of land of the members of the community is 4.38 hectares.

Insert the scale text in the bottom center of the map sheet (Insert → *Scale text*). Use font *Arial*, size *26*, color *black*.

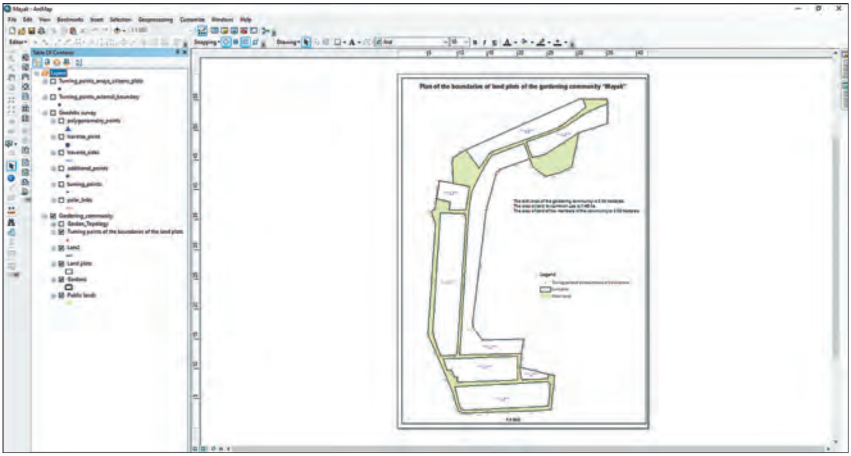


Fig. 6.81

Create a legend of map (Insert → *Legend*). Define the layers "Lots1", "Lots3", and "Public_lands" as legend points. Rename the specified layers (right-click on the layer → Properties → General tab → *Layer name*). Rename the "Lots1" layer *Turning points of the boundaries of the land plots*, "Lots3" – *Land plots*, "Public_lands" – *Public lands*.

Questions

1. List the basic steps to create a layout maps and their design in the GIS ArcGIS.
2. What operations of converting vector features from one type to another (for example, a polygon to a line) are possible in the GIS ArcGIS? In what cases is this necessary?
3. What overlay operations can be performed in the GIS ArcGIS? For what purposes are they used?

Exercise 6. Creation of Plans of Boundaries of Land Plots of Gardening Communities Using Cartographic Materials.

Purpose of the exercise: to study the algorithms of working with scanned cartographic materials in the GIS ArcGIS for creating a plan of the boundaries of the land plots of the gardening community "Zarya" (GC "Zarya").

Initial data:

• GDB Gardening_community.mdb containing feature classes *Gardens*, *Lots1*, *Lots2*, *Lots3*, topology *Gardens_Topology*. The structure and content of the GDB are similar to those used in task 5;

• a scanned "Plan of the boundaries of the land plots of the gardening community "Zarya" (Plan_Zarya.tif);

• a catalogue of coordinates of the turning points of the boundaries of the land plot of GC "Zarya" (table Turning_points in the database "GC_Zarya. mdb").

Exercise progress

A member of the GC "Zarya" Nadezhda Ivanova wants to get her land plot No. 168 in the GC "Zarya" into private ownership. The chief specialist of your organization visited the archive of the Department of Land Resources and Land Management and discovered that it contains Materials on establishing boundaries and preparing catalogs of coordinates in order to issue title documents for the public lands of the GC "Zarya" (1988). In these materials there are a Catalogue of coordinates of the turning points of the boundaries of the land plot of GC "Zarya" and a Plan of the boundaries of the land plots of the GC "Zarya". From the point of view of economic feasibility, these materials turn out to be sufficient for filing the case Materials on the transfer of land plot No. 168 to private ownership, since there have been no changes in the external boundary of the GC "Zarya" and the boundaries of citizens' plots since the boundaries were established by the geodetic method in 1988. The chief specialist of the organization instructed you to carry out this task. At the first stage, you scanned the "Plan of the boundaries of the land plots of the gardening community "Zarya" (Plan_Zarya.tif) and using the Microsoft Access program created the database GC_Zarya.mdb" with the table "Turning_points", in which the coordinates of the turning points of the boundaries of the land plot of GC "Zarya" were entered.

Step 1. Open the ArcMap of the GIS ArcGIS. Create a "Zarya" project. To do this, use the *Save As* option on the *File* menu. Save the project in your folder.

Add the "Garden" feature dataset to the project from the GDB "Gardening_community" using  the "Add data" icon. Four layers (Lots1, Lots2, Lots2, Gardens) and a topology (Garden_Topology) will be added to the project.

Symbolize the added layers as shown in fig 6.82.

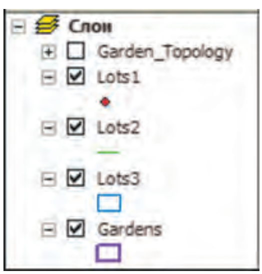


Fig. 6.82

Step 2. Add the turning points of the boundaries of the land plot of GC "Zarya", surveyed using the geodetic method, by performing the *Add XY Data* operation in the File → Add data → *Add XY Data* menu. In the "Add XY Data" window, select the "Turning_points"| table from "GC_Zarya.mdb" database. Define the fields of the "Turning_points" table containing the *X* coordinate and the *Y* coordinate. Set the coordinate system to "WGS_1984_UTM_Zone_35N", it is located in the Projection Coordinate Systems → Utm → → WGS 1984 → Northern Hemisphere → *WGS_1984_UTM_Zone_35N* section (fig 6.83). As a result, a point layer *Turning_points Events* will appear in the data frame. Zoom the data frame to this layer.

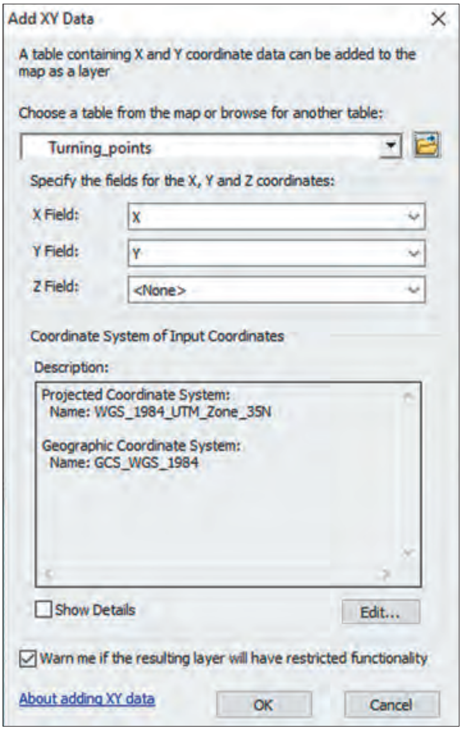


Fig. 6.83

Step 3. Copy the features of the "Turning_points Events" layer to the *Lots1* layer. To do this, go to the attribute table of the "Turning_points Events" layer (right-click on the layer in the table of contents → *Open Attribute Table*). Press the *Table Options* button and select the *Select All* tool. After the selection, close the attribute table.

Start an editing session (*Editor* → Start Editing). Select to edit the GDB "Gardening_community.mdb". Execute Edit → *Copy*. Now all features of the "Turning_points Events" layer are copied to the clipboard. Finish editing session, then start it once again. Paste these features using the *Edit* → *Paste* command. In the *Paste* window, select "Lots1" as the *Target Layer*.

Deselect all features (Selection → *Clear Selected Features*). Open the attribute table for the *Lots1* layer. Note that in addition to the features themselves, their attributes were also copied. Assign the values of the "OBJECTID" field to the "Number_" field Right-click on the field name "Number_" and select *Field Calculator*. In the "Field Calculator" window, define the assignment by the "Number_" field of the values of the *OBJECTID* field (fi 6.84).

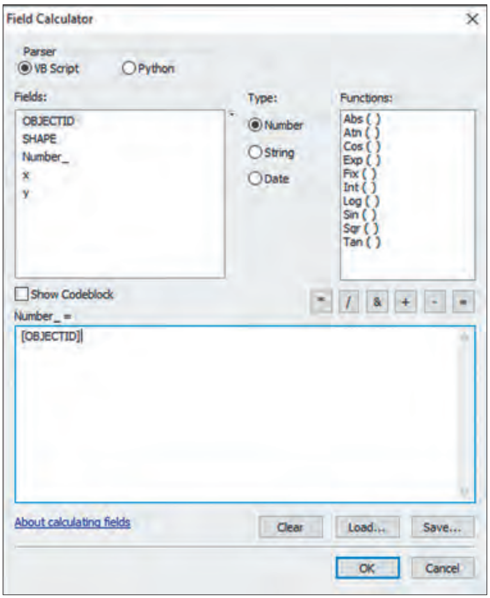


Fig. 6.84

Close the attribute table for the "Lots1" layer. Save your edit changes (*Editor* → *Save Edits*). Delete the "Turning_points Events" layer from the project (right-click on the layer → *Remove*).

Step 4. Go to the "*Properties*" layer "Lots1". In the "Labels" menu, check the *Label features in this layer* function, select the "Number_" label fiel and symbolize the labels with a font and size that is convenient for you (fig 6.85).

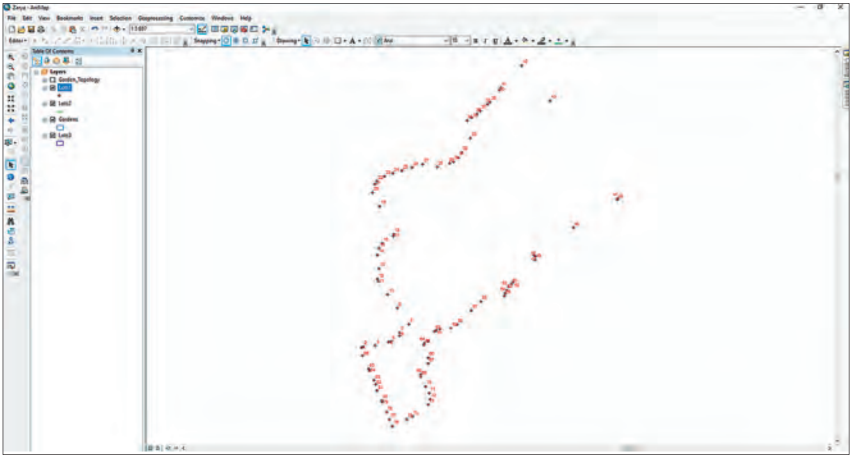


Fig. 6.85

Step 5. Create a polygon feature of the land plot of the GC "Zarya" in the *Gardens* layer using the turning points of the external boundary of the GC located in the "Lots1" layer. To do this, in the *Create Features* window, select the layer to which the new features will belong. This layer will be the *Gardens* layer. For the *Construction Tool*, select *Polygon*.

Since you will be creating a new feature based on another layer (Lots1), then you need the vertices of the sketch of the new feature to correspond to the points of this layer. To do this, set the option *Point Snapping* on the *Snapping* toolbar.

Zoom the extent of the data frame in the area of the first turning poin of the external boundary of the GC and lock on this point (click with the left mouse button). Continue *Snapping* to each subsequent point of the layer "Lots1" by making one click with LMB. Double click on the last point with LMB.

Using  the *Attributes* window specify the name of the created polygonal feature in the "Name" fiel – GC "Zarya". Label the "Gardens" layer. On the |*Fields* tab click on the button to change the number format of the SHAPE_Area field In the "Number Formats" window, set rounding to *Number of decimal places* – 0. Now area values (in m^2) will be rounded up to integers. Go to the *Labels* tab. Check the box next to *Label features of this layer* and click the Expression button. Create the expression [Name]&VBnewline&[SHAPE_Area].

Stop the editing session (*Editor* → *Stop Editing*) (fig 6.86).

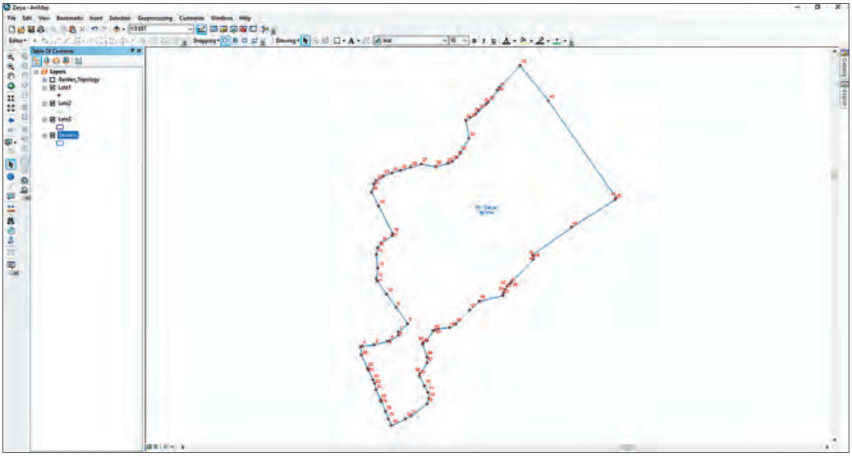


Fig. 6.86

Step 6. Add a scanned “Plan of the boundaries of the land plots of the gardening community “Zarya” (*Plan_Zarya.tif*), using the icon “Add data.”

Open the *Georeferencing* toolbar (Customize → Toolbars → *Georeferencing*).

In the Georeferencing toolbar, choose the georeferencing layer – “Plan_Zarya.tif”. Then perform the operation *Fit to Display* (Georeferencing → Fit to Display). Thus you will move the “Plan_Zarya.tif” raster to the desired area. In addition, tick the option (Georeferencing → *Auto Adjust*).

Perform a georeferencing of the raster “Plan_Zarya.tif” to the turning points of the boundaries of the land plot of GC “Zarya” located in the “Lots1” layer. On the *Snapping* toolbar, set the *Snapping to points* option.

Zoom the extent around the location of the 42nd turning point of the boundaries of the land plot of GC “Zarya” on the raster. Click the *Add Control Points* icon on the Georeferencing toolbar. After clicking the icon, the cursor will turn into a crosshair. Place the cursor on the turning point on the raster and click with the left mouse button. A green crosshair will remain at the control point.

Find the equivalent turning points of the boundaries of the land plot of GC “Zarya” in the “Lots1” layer. Move the cursor to the corresponding control point of the vector layer. Once the *Snapping* option is enabled, click on it. The raster image will shift and the control point on the raster and on the vector layer will be connected.

Continue georeferencing the raster by turning points 44, 8 and 20. This is necessary for the raster to have control point on different sides, otherwise, if you perform the georeference sequentially from the 1st to the 87th point, severe raster distortion may occur.

Do the same for other control points representing the turning points of the boundaries of the land plot of GC "Zarya" (fig 6.87). Snap option can be turned on and off.

Fig. 6.87

In case of an error, you can also delete link by opening the window *View Link Table* on the Georeferencing toolbar. After creating all control points, perform a raster transformation using the operation Georeferencing → → Transformation → *Projective Transformation*. Perform the operation Georeferencing → *Update Georeferencing*

Step 7. Start an editing session (Editor → *Start Editing*). Select GDB "Gardening_community.mdb" for editing.

Set the option *Point Snapping* on the *Snapping* toolbar. In the *Create Features* window, select the layer to which the new features will belong. This layer will be the *Lots3* layer. For the *Construction Tool*, select *Polygon*.

Zoom the extent around the array of land plots No 166, 167, 168 and create polygon of this array snapping on the turning points of the boundaries of the land plot of GC "Zarya" (fig 6.88).

Set the Tables of contents "Layers" display option *List By Selection*. Make only the objects in the *Lots3* layer selectable. Using the tool *Select Features*, select the newly created polygon.

Using the *Cut polygons* tool on the *Editor* toolbar and pressing the V key on the keyboard (allows you to see all the vertices of the existing vector features), cut the array into parts corresponding to land plots (fig 6.89).

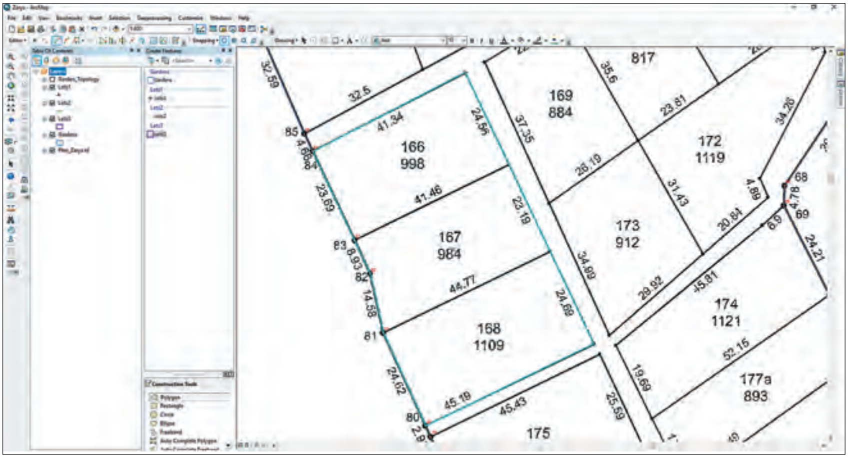


Fig. 6.88

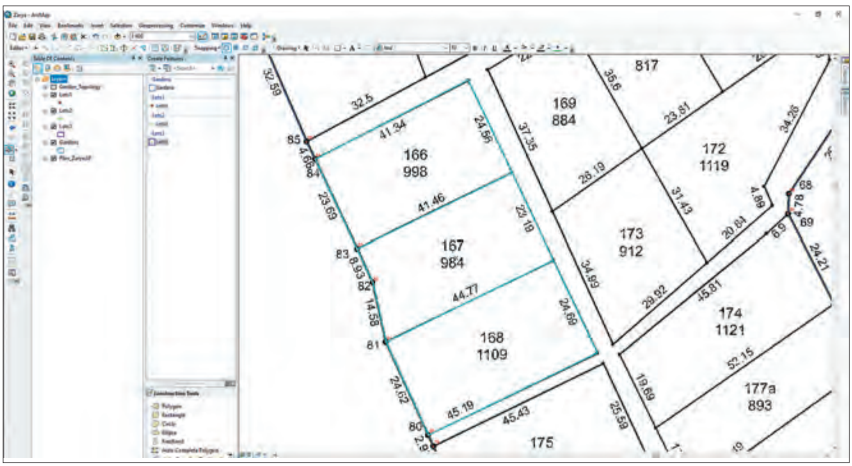


Fig. 6.89

In the same way, create land plots of neighboring array located to the east (fig 6.90).

With the creation of land plots in the southernmost array of the GC “Zarya” let’s do it in a different way. Using the *Create Features* window, create one land plot in this array (fig 6.91).

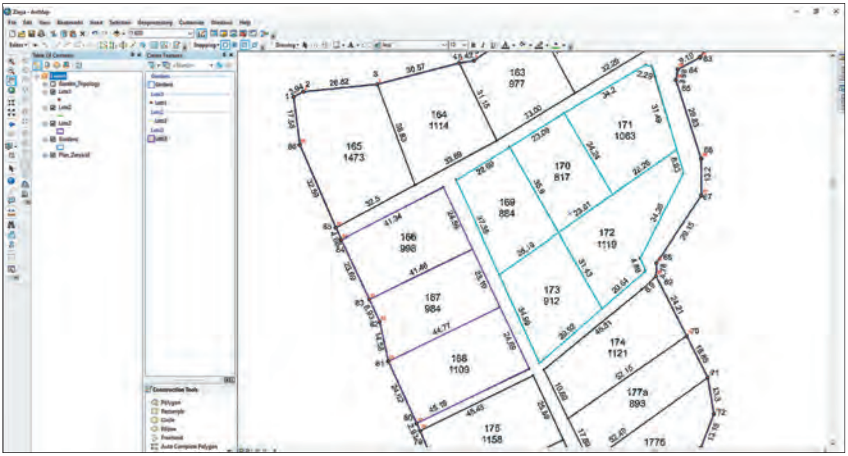


Fig. 6.90

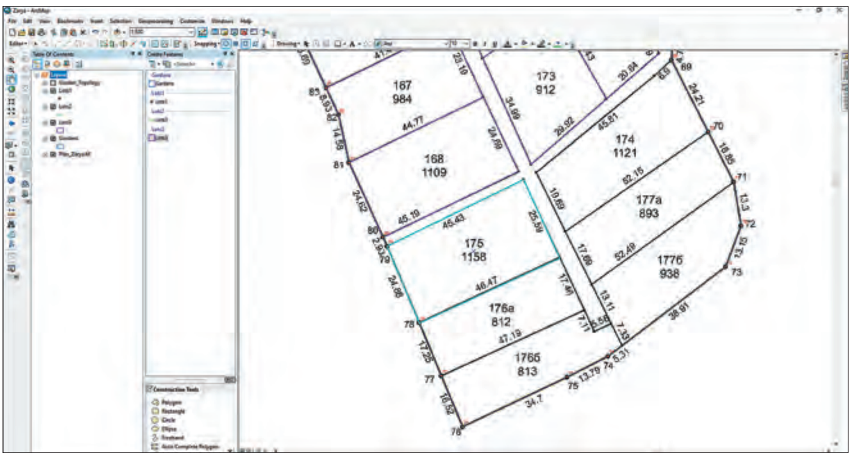


Fig. 6.91

Next, using the *AutoComplete Polygon* in "Construction tool" section in the *Create Features* window, create a land plot nearby, closing only on the common vertices of the adjacent polygon (fig 6.92). Thus, create all plots within this array. If necessary, enable the *Vertex Snapping* and *Edge Snapping* options on the *Snapping* toolbar.

After creating the plots, write in the *Attributes* window in the *Plot_N* field the number of each land plot according to their internal numbering in the gardening community.

Label the features of layer "Lots3" (fig 6.93). To do this, go to the properties of this layer. On the *Fields* tab, click the button to change the numeric format of the *SHAPE_Area* field In the "Number Formats" window, rounding to *Number of decimal places* – 0. Area values (in m^2) will be rounded up to integers. Go to the *Labels* tab. Check the box next to *Label features of this layer* and click the Expression button. Create the expression [Parsel_N]&VBnewline&[SHAPE_Area].

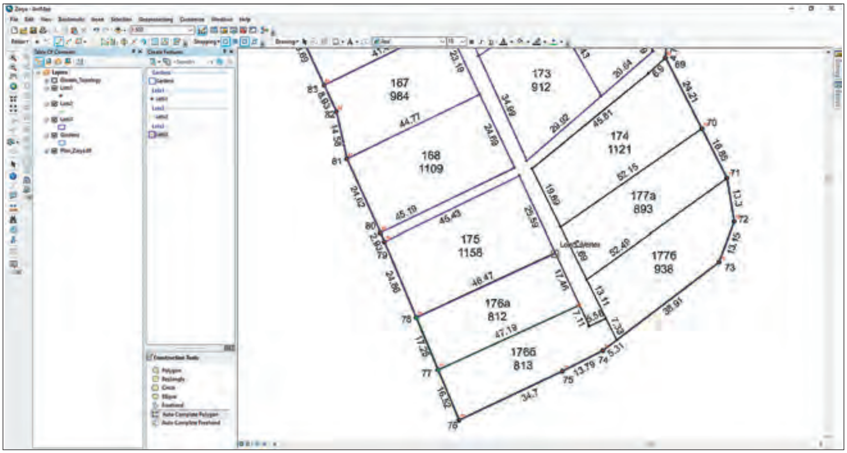


Fig. 6.92

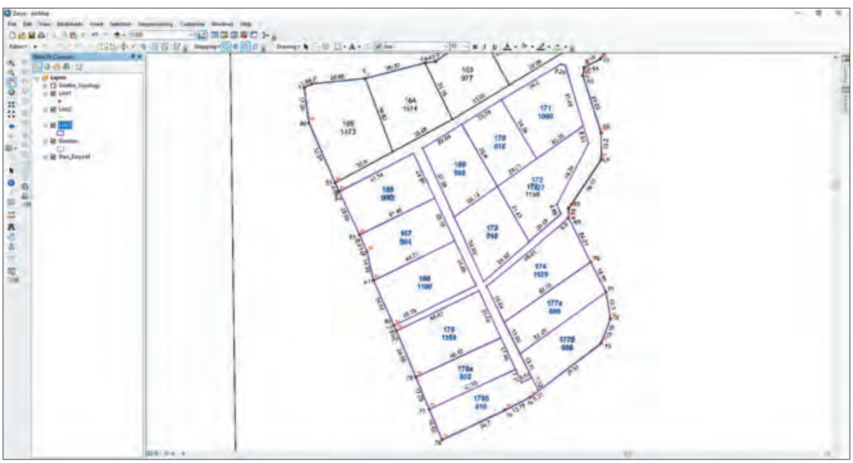


Fig. 6.93

Step 8. Based on the land plots of the “Lots3” layer, create their boundaries in the “Lots2” layer. To do this, go to the attribute table of the “Lots3” layer (right-click on the layer in the table of contents → *Open attribute table*). Press the *Table Options* button and select the *Select All* tool. After the selection, close the attribute table.

Press Edit → *Copy*. Now all features of the “Lots3” layer are copied to the clipboard. Finish editing session, then start it once again. Paste these features using the *Edit* → *Paste* command. In the *Paste* window, select “Lots2” as the *Target Layer*. Deselect all features (Selection → *Clear Selected Features*).

Now you need that each segment of the boundary to be a separate line. To do this, you need to split all the lines were they intersected. Go to the attribute table of the “Lots2” layer and select all features of this layer (Table options → *Select All*). Once selected, click the tool *Planarize Lines* on the Advanced Editing toolbar (*Editor* → More Editing Tools → *Advanced Editing*).

Label the “Lots2” layer with the *SHAPE_ Length* field On the *Fields* tab, click the button to change the numeric format of the *SHAPE_ Length* field In the “Number Formats” window, rounding to *Number of decimal places* – 2. Check *Pad with zeros*. Now all line lengths (in m^2) of land plots will be rounded to two decimal places (fig 6.94).

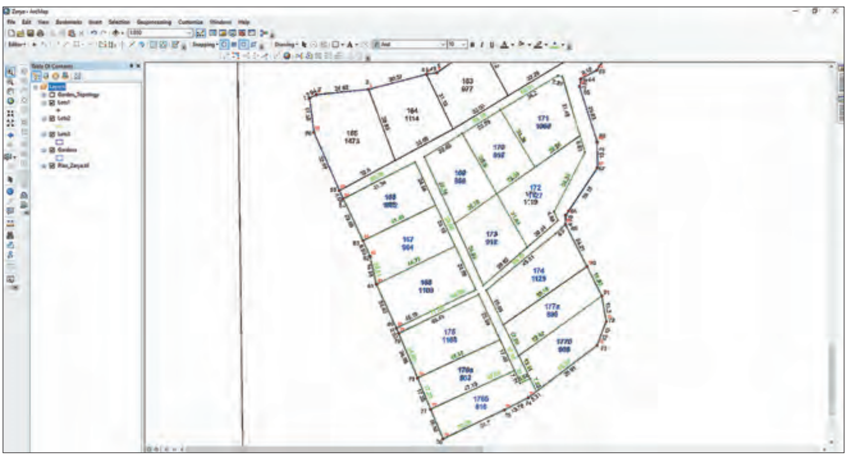


Fig. 6.94

Due to the fact that not all sides of the boundaries of land plots have a intersection with each other (first of all, these are the extreme sections of the arrays), it is necessary to perform their splitting in manual mode. To do this, set the display option “Tables of contents” to *List By selection*. Make selectable only the features in the layer “Lots2”. Using the *Select Features* tool, select the side of the plot boundary where the segments were not completely split automatically. Split sides of the plot boundary with the *Explode Tool* on the *Editor* toolbar.

Step 9. Create the turning points of the boundary of the land plot No. 168, owned by citizen Nadezhda Ivanova. In the *Create Features* window, select the layer to which the new features will belong. This layer will be the *Lots1* layer. For the *Construction Tool*, select *Point*.

After creating features, write in the *Attributes* window in the *Number_* field the number of each point starting from the bottom left within the land plot, and then continue numbering clockwise (fig 6.95).

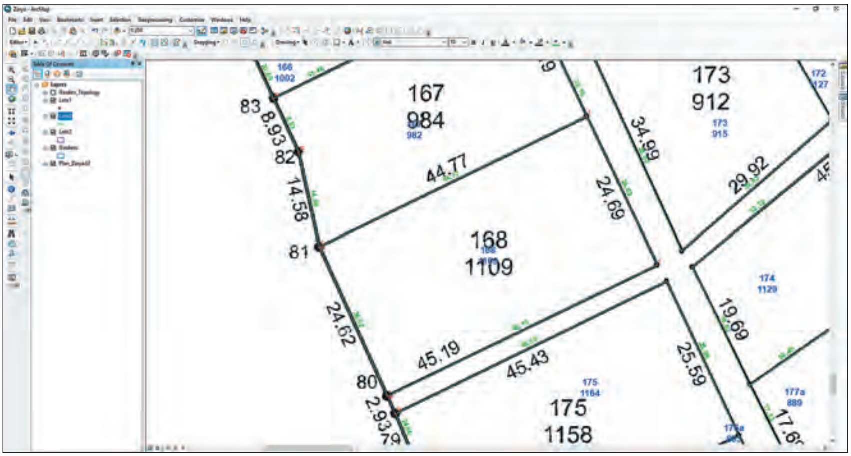
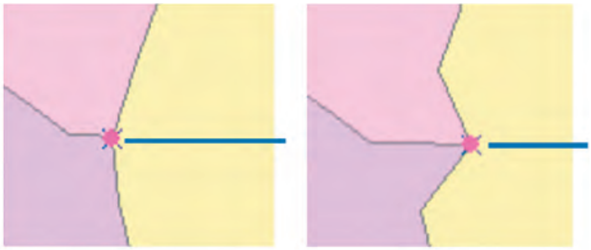


Fig. 6.95

Step 10. During the initial digitization, it is rather difficult to obtain the required areas of land plots and the lengths of their boundaries. Your task is to get the vector layers to fully correspond to the dimensions indicated on the scanned paper plan, i.e. so that each line vector of the boundary of land plot has the same length as indicated on the plan, also with the area of each land plot. The most convenient way to achieve this is to use the *Topology Edit Tool* on the *Topology* toolbar.

The *Topology Edit Tool* allows you to simultaneously edit the features of all layers involved in the topology. The procedure for using this tool is as follows: select this tool and then click on the vertex you want to edit. It will be highlighted in purple color (fig 6.96, *a*). After that, you can move this vertex to the place you need. Together with the vertex, all the vertices of the layers participating in the topology will move (fig 6.96, *b*).

Disable the *Snapping* option (Snapping → *Use Snapping*). Using the *Topology Edit Tool* tool, make sure that all line vectors of the boundary of land plot No. 168, as well as the area of this plot, correspond to those indicated on the raster plan (fig 6.97). At the same time, do not topologically edit those turning points of the land plot that correspond to the turning points of the external boundary of the gardening community "Zarya".



a *b*

Fig. 6.96

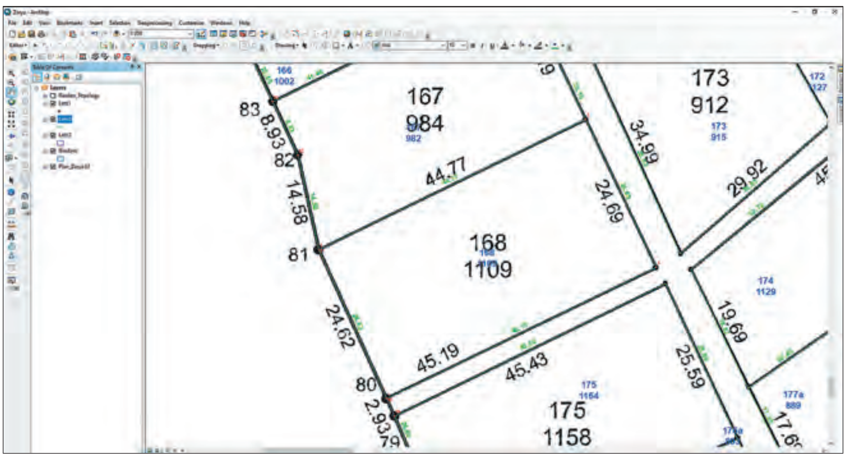


Fig. 6.97

In the same way, edit all the lengths of the lines and all the land plots areas of the three arrays of citizen plots you digitized (fig 6.98). Do not subject to topological editing those sides of the boundaries of the land plot, which are the sides of the external boundary of the gardening community.

After topological editing, save the changes editing (Editor → *Save Edits*).

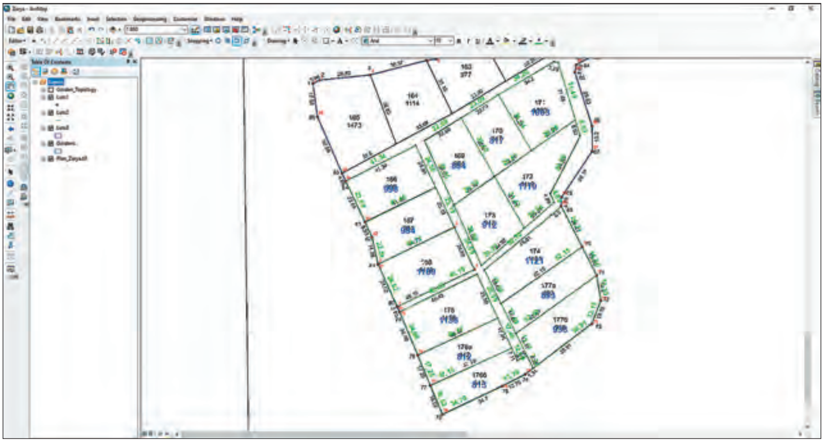


Fig. 6.98

Step 11. Zoom the extent of the data frame to the *Lots3* layer. Turn on the display of the *Garden_Topology* layer. Use the  *Validate Topology in Current Extent* tool (found on the "Topology" toolbar) to check the topology. Open the  *Error Inspector* tool. With the help of the  *Fix Topology Errors Tool* select the entire extent of "Lot3" layer. Topology errors will appear in the *Error Inspector* window.

The error group *Boundary Must Be Covered By* (*Gardens* polygons, *Lots2* lines) as exceptions. To do this, select these errors and right-click → *Mark as exception* (fig 6.99).

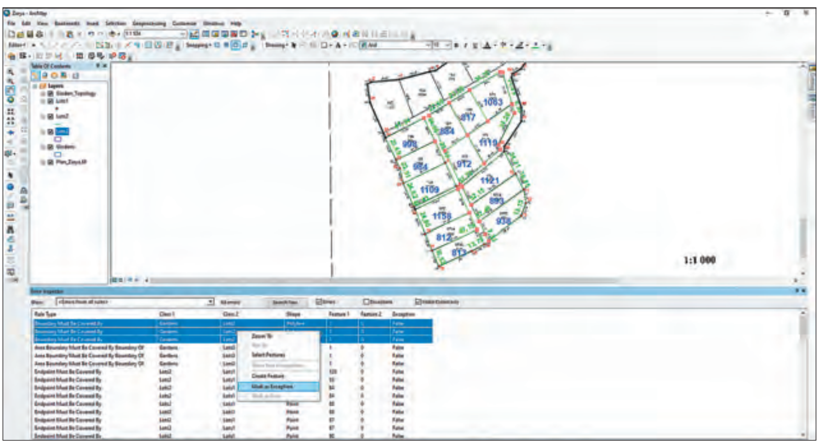


Fig. 6.99

In the same way, mark as exceptions the group of errors *Endpoint must Be Covered By* (lines *Lots2*, points *Lots1*) (fig 6.100).

The remaining group of errors *Area Boundary Must Be Covered By Boundary Of* (*Gardens* polygons, *Lots3* polygons) also mark as exceptions (fig 6.101).

After correcting all topology errors, close the “Errors Inspector”, turn off the display of the “Garden_Topology” layer, and save your editing changes (Editor → Editor → *Save Edits*).

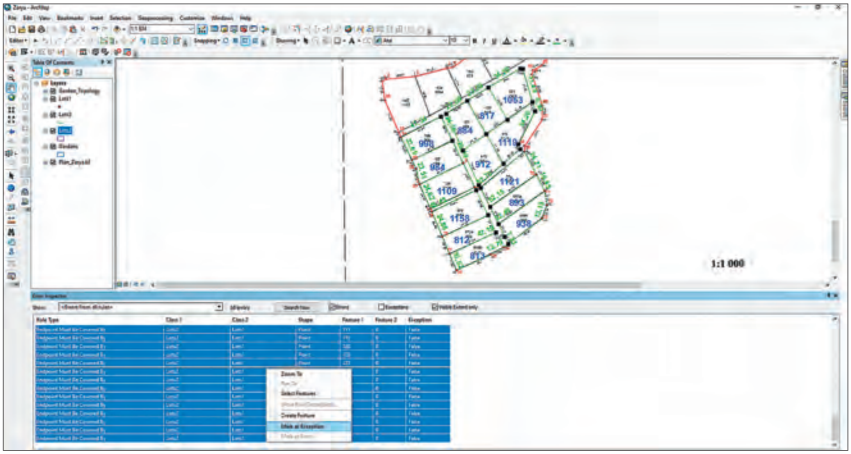


Fig. 6.100

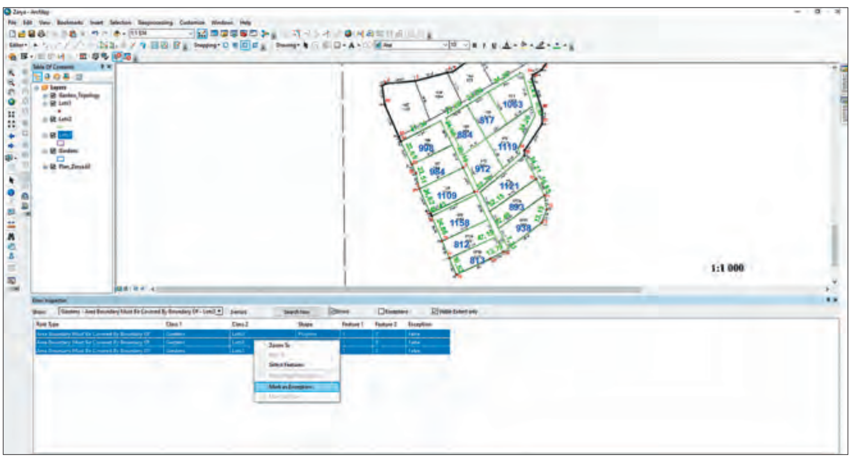


Fig. 6.101

Step 12. Open the attribute table of the *Lots1* layer, select the points that are the turning points of the boundaries of the land plot No. 168 and click the  *Show selected records* button. Calculate the *X coordinate* for the selected points (right click on the X field name → *Calculate Geometry*) (fig 6.102). In the "Calculate Geometry" window, select the *X Coordinate of Point* in the *Property* section (fig 6.103).

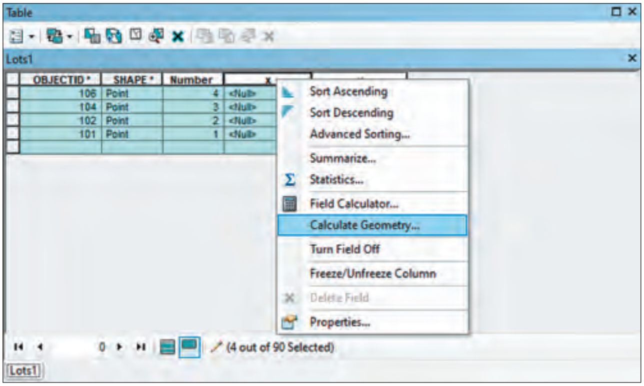


Fig. 6.102

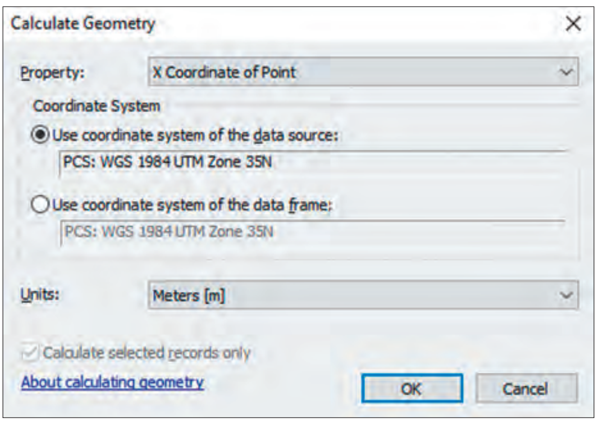


Fig. 6.103

In the same way calculate the *Y coordinate* in the "Y" field by selecting the expression *Y Coordinate of Point* in the *Calculate Geometry* window in the *Property* section.

End the editing session (Editor → *Stop Editing*).

Step 13. Export the coordinates of the selected points as a text file. To do this, in the attribute table, select Table Options → *Export* (fig 6.104). Save the entries as a text file in your folder under the name 168 (fig 6.105). Do not add the export result to the project.

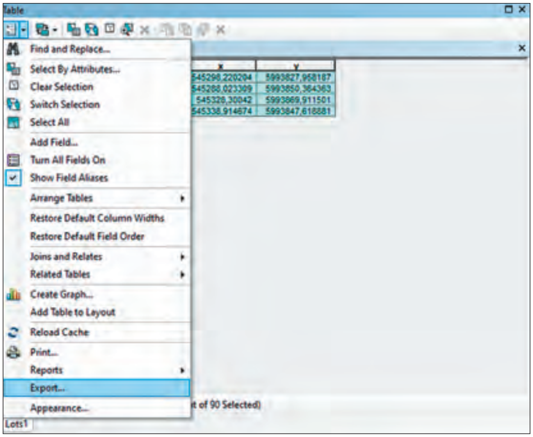


Fig. 6.104

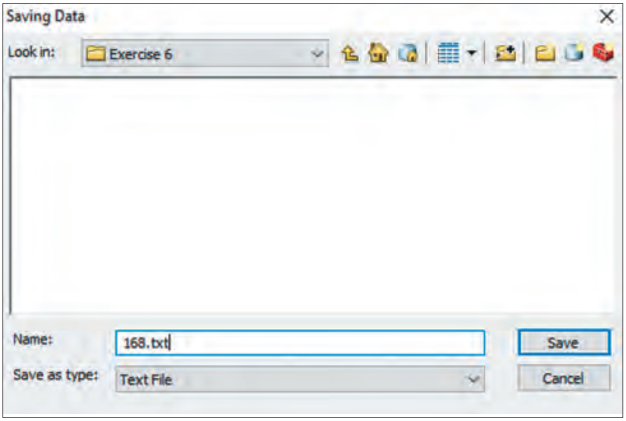


Fig. 6.105

Step 14. Open Microsoft Excel. Launch the option Data → *From text*. Load exported from the GIS ArcGIS text fi e of the turning points of the boundary of the land plot No. 168. Use a semicolon as a separating character.

By copying data from a Microsoft Excel spreadsheet, create a catalogue of coordinate in Microsoft Word as shown below (fig 6.106).

Catalogue of coordinates
of the turning points of the boundaries of the land plot No. 168,
provided for private ownership
by Nadezhda Ivanova
in the gardening community "Zarya"
coordinate system UTM zone 35N

Point Number	X coordinate	Y coordinate
1	xxx	xxx
2	xxx	xxx
3	xxx	xxx
4	xxx	xxx

Plot area xxx m^2

Compiled by ______________ Ivanov D. A.
Checked by ______________ Petrov I. G.

Fig. 6.106

Step 15. Export the turning points of the boundary of the land plot No. 168 to separate shape-files To do this, open the attribute table of the "Lots1" layer and select only the turning points of the boundaries of the land plot No. 168 (fig 6.107).

Close the attribute table. Export the features of layer "Lots1" (right click on layer Lots1 → Data → *Export data*) to a shape-file named *Point_168* in your folder. Agree to add the new shape-file to the proje t.

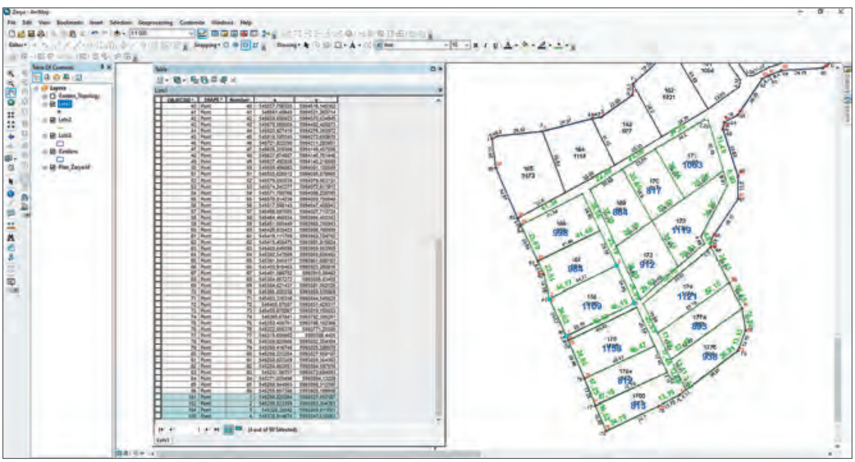


Fig. 6.107

Set the display option in the "Table of Contents" to *List By selection*. Make only *Lots2* layer available for selection. Using the *Select Features* tool, select all line fragments of the boundary of the land plot No. 168 (fig 6.108).

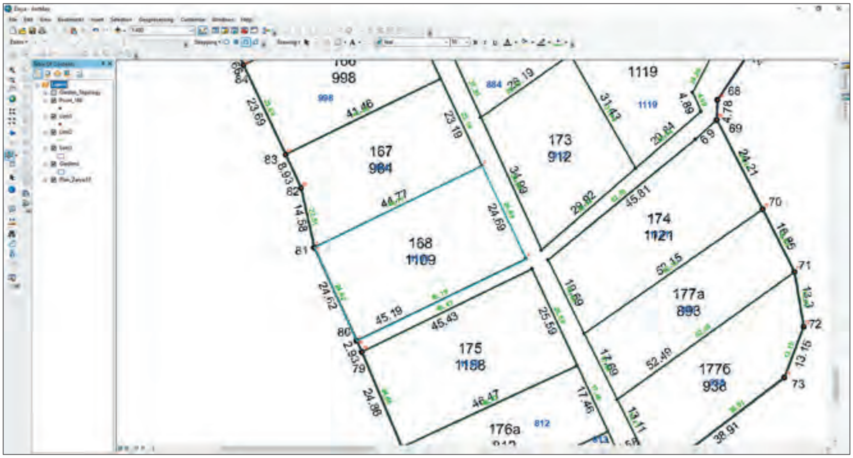


Fig. 6.108

Export the features of the "Lots2" layer (right click on the "Lots2" layer → → Data → *Export Data*) to a shape-file named *Lines_168* in your folder. Agree to add the new shape-file to the proje t.

Step 16. In the table of contents, leave the following layers in the visualization: *Points_168*, *Lines_168*, *Gardens* and *Lots3*. Right-click on the *Points_168* layer, open layer *Properties*. Select the *Symbology* tab and set the layer's display option to "Features: Single Symbol". Click on the icon of the symbol and select the *Circle 2* category for it, color – *black*, size – *5*.

Symbolize the rest of the layers ("Lines_168", "Gardens" and "Lots3") using the Single symbol display method. For the *Lines_168 layer*, set the color to *black* and the width to *0.2*. Symbolize the *Gardens* layer as follows: fill color – *none*, outline width – *0.5*, outline color – *black*. For the *Lots3* layer, set the fill color to *none*, the outline width to *0.2*, and the outline color to *black*.

Step 17. Label the features in layers. In the layer properties go to the *Lebels* tab. Lebel the features of the *Points_168* layer by the field *Number_*, font *Arial*, color – *black*, size – *14*; *Lines_168* layer – by the *SHAPE_Length* fiel (preliminarily, in the *Fields* tab for the *SHAPE_Length* field set the rounding "Number of decimal places – 2", "Pad with zeros"), font – *Arial*, color – *black*, size – *16*. Label the features of the *Lots3* layer according to the expression [Parsel_N]&VBnewline&[SHAPE_Area]. The inscription font is *Arial*, bold, color is black, size is 18.

Step 18. On the View menu (View → *Data Frame Properties*), on the *Data Frame* tab, set the *Extent* as *Fixed Scale*, equal to *1:500*.

Convert labels from *Points_168*, *Lines_168*, *Lots3* layers to annotations (right click on the layers name → *Convert Labels to Annotation*, use option *In the map*). Annotation is one of the ArcGIS options for storing text that appears on maps. The annotation simultaneously stores the text string itself, its location, and display properties. In contrast, a label 's text and location are dynamically generated according to a set of placement rules.

After converting the labels to annotations, place them as shown in fig 6.109 using the *Select Elements* tool located on the *Tools* or *Drawing* toolbar.

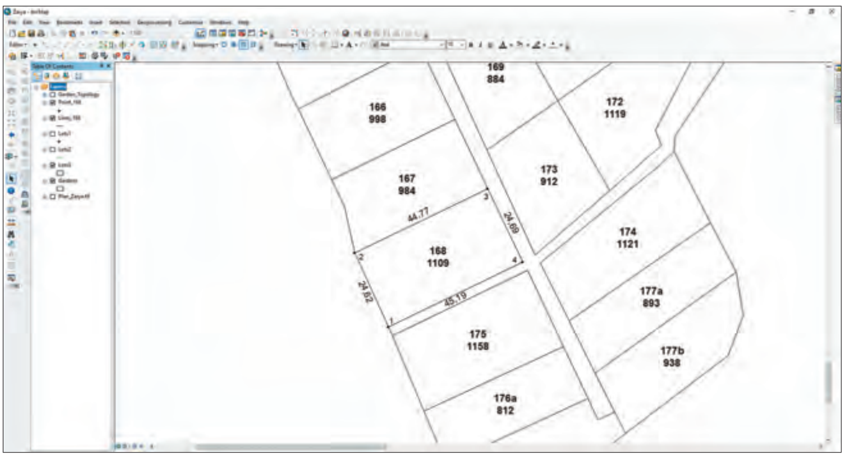


Fig. 6.109

Use the *Text* tool on the *Drawing* toolbar to create annotations for adjacent land users (fig 6.110), and then place them using the *Select Elements* and *Rotate* tools on the same toolbar.

You can select the font of annotations by right-clicking on it with the *Select Elements* tool and choosing *Properties*.

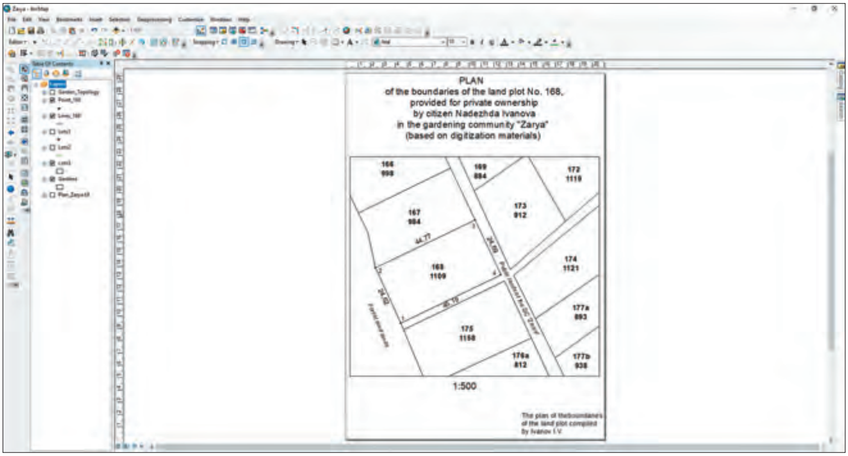


Fig. 6.110

Step 19. Layout the plan. To do this, go to "Layout View" (View → *Layout View*). On the File menu (File → *Page and Print Setup*) set an A4 sheet, portrait orientation.

Using the  *Select elements* tool, place the data frame in the center of the page. Using the  *Move* tool, place land plot No.168 in the center of the sheet.

Insert at the bottom of the map sheet in the center the *Scale Text* (Insert → → *Scale text*). Use font – *Arial*, size – *22*, color – *black*).

Using the  *Text* tool, create the text *PLAN of the boundaries of the land plot No. 168, provided for private ownership by citizen Nadezhda Ivanova in the gardening community "Zarya" (based on digitization materials)* (font – *Arial*, size – *22*, color – *black*). Similarly – the text *The plan of the boundaries of the land plot compiled by Ivanov I.V.*

Place the plan layout elements as shown in fig 6.110.

Questions

1. In the GIS ArcGIS, what is a label and what is an annotation? Are there any differences between them?

2. What is the difference between topological editing of vector features in the GIS ArcGIS and non-topological?

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The issues of land resource management using geoinformational systems based on remote sensing data, geodetic surveys, global navigation satellite systems, scanned cartographic materials and vector data are considered. The application of GIS-mapping of land resources is shown on the example of the experience of the Republic of Belarus. The theoretical material is accompanied by self-evaluation questions and practical tasks.

For students of higher educational institutions studying on specialities "Geography", "Land Management, Cadastres, Geodesy and Geomatics".