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Department of land resources management and cadastre

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Lecture notes on the discipline
"LAND RESOURCES INFORMATION SYSTEM".
For applicants in the field of knowledge
19 "Architecture and Construction"
specialty 193 "Geodesy and Land Management"

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In the lecture notes on the discipline “Land resources information system” for applicants specialty 193 "Geodesy and Land Management" the main material taught in the first semester of the first year of study at the master's degree level (Double diploma programs) is presented. The discipline covers the subject of research of the land resources information system, its connection with other disciplines, possibilities of using GIS technologies, capabilities of modern GIS packages, representation of attribute and spatial information in GIS, possibilities of thematic mapping in GIS, the main directions of expanding the analytical capabilities of GIS.

CONTENTS

INTRODUCTION

Map creation and geographic analysis is not something completely new, but modern land information systems and GIS technology provide a new, more efficient, convenient and fast approach to analyzing problems and solving tasks facing humanity in general and a particular organization or group of people in particular. It automates the analysis and forecasting process. Prior to the use of information systems, only a few had generalized and fully analyzed geographic information for the purpose of making informed decisions based on modern approaches and tools.

The data accumulated by humanity about real objects and events in our world to some extent contain the so-called "spatial" component. Even if we are talking about the citizens of our country, the existing "registration" guarantees that each citizen is "tied" to a specific postal address associated with a residential building that has an exact location in the city. The spatial aspect is contained in the information on buildings and structures, land plots, water, forest and other natural resources, transportation routes and utilities. Thus, all information on certain objects has constant or variable spatial coordinates. It is impossible to find a real material object or an event related to an object that would not have coordinates on the Earth's surface and could not be displayed on a map. A digital map has many additional and useful features compared to a paper map. Of course, it can be easily scaled, moved in any direction, objects can be added or deleted, any fragments of the territory can be printed, etc. However, a computer or digital map has other properties as well. After selecting an object, you can request attribute information about this object (for example, the height and area of a building, land plot, year of construction, etc.) The map can be colored in different colors depending on the value of the parameter related to a certain area of the displayed territory. This is how we produce maps that we know in paper form as thematic maps. The results of statistical information processing, when superimposed, for example, on a city map, can reveal some very useful patterns.

The task of studying the discipline is the formation of a specialist in theoretical knowledge and practical skills in the use of information systems in land management and in the land cadastre for the purpose of inventorying land resources and landowners, forecasting the state of the land fund, monitoring the use and protection of soils, registering and protecting the rights of citizens and subjects management, etc.

The main disciplinary learning outcomes, after completing the lecture course "Land resources information system":

- to know the domestic and foreign experience of using information systems of land resources, hardware and software, features of GIS for cadastral systems, data on the land fund and methods of their display, GIS and other automated systems for data processing, topological spatial objects of the geodatabase;

- be able to collect, enter, and edit spatial and attributive information on the basis of forms 6-zem, 2-zem, regular cadastral plan, cadastral plan by category, land ownership, land use in terms of territorial communities, register of land plots, register of restrictions and encumbrances regarding use of land, data of soil assessment, data of economic assessment of the land of the district (city), expert monetary assessment; create the structure of the geospatial data base, fill the attribute data base and display the necessary information on the map; to select the necessary information from the database; use space images to create and update cartographic material; use GIS for the purpose of inventorying land funds and landowners; apply GIS for the purpose of landscape and ecological zoning of the territory; use GIS to forecast the state of land funds; use GIS for the purpose of technical and economic substantiation of the use and protection of land resources.

MODULE 1. METHODOLOGICAL FEATURES OF THE INFORMATION SYSTEM

LECTURE 1

TOPIC 1. INFORMATION SYSTEM (GEOINFORMATICS) – SCIENCE AND TECHNOLOGY

Plan

1. Concept of information system and geoinformatics, definition of research subject.

2. History of formation and development of geoinformatics.

3. Connection of geoinformatics with other disciplines.

1. Concept of information system and geoinformatics, definition of research subject.

The basis of any land information system is the territorial binding of infrastructure to the topographical plan of the territory, based on land cadastre data. Solving practical problems that require analysis and assessment of complex information about the infrastructure of the territory in combination with spatial cartographic data is expedient to solve with the help of modern geoinformation technologies. They are basic technologies for the functioning of the land information system. Such technologies ensure the accumulation of territorially combined data, their systematic analysis, interpretation in the form of cartographic images by means of machine graphics.

The purpose of the land information system is to provide at any time objective information about land resources, changes in their condition, quality and structure, dynamics of land use and land uses for the purpose of developing and implementing a rational state land policy, creating a favorable information, technological and regulatory - the legal environment to ensure the transition to sustainable economic development.

The main task of LIS (land information system) is the creation of a dynamic multi-level information space, in which information about the natural-geographical environment, its anthropogenic transformation, and the socio-economic conditions of the population's life would be presented in its subject isolation and systemic relationship in time and space, unified and united on the basis of spatial coordination unity.

As a science, the term "geoinformatics" is a very closely related to computer science. The term "informatics" originated in the early 60s of the 20th century and is associated with two concepts - information and automation, that is, automatic work with information. Today, the term "informatics" is used to refer to science, technology, and a separate field.[1]

Geoinformatics is a part of informatics that deals with spatial (spatially distributed, spatially coordinated) information. The most general definition of geoinformatics is as follows: geoinformatics is a science, technology, and applied activity related to the collection, storage, processing, analysis, and display of spatial data, as well as to the design, creation, and use of geographic information systems. The set of means, methods and methods of automated collection, storage, manipulation, analysis and display (presentation) of spatial information are united under the common name "geo-information technologies"[2].

In general, geoinformatics is closely related to geographic information systems (GIS), since the main theoretical ideas of geoinformatics as a science are implemented in modern GIS at the technical and technological levels. This gives reason to consider geoinformatics as "the science, technology and production activity of scientific substantiation, design, creation, operation and use of geographic information systems."

But all definitions have many common features. First, GIS is an information system, i.e. "a data processing system that has the means of accumulating, saving, restoring, searching and issuing data." Secondly, this information system belongs to the category of automated information systems that use computers at all stages of information processing", the computer is an indispensable attribute and basis of geo-information technology. Thirdly, this information system provides opportunities for manipulation and processing of spatial (spatially distributed, spatially-coordinated) information. Today, there are a large number of definitions of geographic information systems[3].

A distinctive feature of geographic information systems is the presence in their composition of specific methods of spatial data analysis, which together with means of input, storage, manipulation and presentation of spatially coordinated information form the basis of geographic information systems technology, or GIS technology. In geography, GIS process geographic flows that are formed within the geographic envelope and are an information display of the system of geographic study objects.

Taking into account the current trends in the development of geoinformation technologies, it is advisable to use the following as a working variant of the definition of a geoinformation system: a geographic information system (GIS) is an integrated set of hardware, software and information tools that provide input, storage, processing, manipulation, analysis and display (presentation) spatially coordinated data. Any geographic information system consists of a hardware complex, a software complex and an information block.

2. History of formation and development of geoinformatics. Canada's GIS, developed in the mid-60s of the 20th century on the basis of the first computers and a batch data processing system, is considered to be the first real working geographic information system in the world. The main purpose of Canada's GIS was to process and analyze data accumulated by the Canadian Land Registry for use in the development of land management plans for vast areas of mainly agricultural use.[4]

Within the already almost fifty-year period of the history of the development of geoinformation technologies, the following stages can be distinguished with a certain degree of convention: 1) the end of the 1950s - the end of the 1970s; 2) the 80s and 3) the 90s of the 20th century - the beginning of the 21st century.

The first stage (the end of the 50s - the end of the 70s of the 20th century) along with the creation of the first geographic information systems, primarily in Canada and the USA, is characterized by the development of the first computer systems for the spatial analysis of raster images and automated mapping using linear and feather plotters. The first and most famous software package that realized the functions of constructing cartograms, isoline maps and trend surfaces was the SYMAR package.[5] Characteristic for this time was also the improvement of spatial data analysis methods and their encoding and presentation technologies. In particular, it was during this period that the theoretical foundations of geostatistics (France), vector topological structure of spatial data DIME-structure (USA), technologies of graphic representation of three-dimensional surfaces, etc. were developed. The second part of this period is characterized by a tendency to strengthen interdisciplinary ties in the environment of GIS developers, primarily between scientists and engineers. However, in this period, geoinformation systems still remain specialized, created on the basis of powerful and very expensive computers, as a result of which they are unique systems with a limited number of users.

The second stage (80s of XX century). In the second half of the 70s - at the beginning of the 80s of the XX century. in the West, significant investments have been made in the development and application of GIS technologies by both government and private agencies, particularly in North America. Hundreds of computer programs and systems were created during this period. The development (1973-1978) and widespread distribution of inexpensive computers with a graphic display (which received the name "personal") made it possible to abandon the "batch" mode of data processing and switch to a dialog mode of communication with the computer using commands in English. This contributed to the decentralization of research in the field of GIS technologies. The close integration of interdisciplinary studies, their focus on solving complex tasks related to territorial design, planning and management, led to the creation of integrated GIS, which were characterized by greater or lesser universality[6].

An important stimulating role in increasing interest in GIS was played by the desire to adapt for the solution of both scientific and practical tasks (including on a commercial basis), already accumulated by that time arrays of Earth remote sensing data. The development of geoinformation systems, especially capable of integrating remote sensing data ("integrated GIS"), is considered a necessary condition for the effective use of remote sensing materials.[7]

In the 80s of the XX century. GIS software packages (instrumental GIS) are being developed, the future leaders of the world GIS software - the ARC/INFO package developed by the Environmental Systems Research Institute (ESRI) (1982), the Mapinfo package (1987), the IDRISI package developed at Clark University (1987), Intergraph's Modular GIS Environment (MGE) package (1988) - all in the USA. In the late 80s of the XX century. the global GIS industry was formed, which included GIS hardware and software and their maintenance. In 1988, for example, only direct costs for these articles in the world exceeded 500 million US dollars, and in 1993, they amounted to about 2.5 billion dollars[8].

The third stage (90s of the 20th century - the beginning of the 21st century). Progress in GIS technology in the 90s of the last century was largely associated with the progress of hardware, and both computers - the emergence of 32-bit, and then 64-bit mini- and micro-computers, as well as means of input and output of spatial information - digitizers, scanners, graphic displays and plotters. The same period is characterized by the wide distribution of so-called commercial GIS packages ("instrumental GIS"), which appeared as early as the 80s of the XX century. For the most part, they are a software environment that allows the user to either simply create geographic information systems according to his own requests and capabilities, or to solve tasks related to spatial information using geoinformation technologies. The world leaders among commercial GIS packages are the software products of ESRI (Arc/Info and ArcView GIS), Intergraph (MGE), Mapping Information System (Mapinfo). The total number of software GIS packages is calculated by more than one dozen[9].

In the former Soviet Union, research in the field of geoinformation technologies began in the eighties and was mainly related to the adaptation of foreign (Western) experience. The research was conducted by the Institute of Geography and the Far Eastern Scientific Center of the Academy of Sciences of the USSR (Department of Cartography and Geoinformatics), Kazan, Tbilisi, Tartu and Kharkiv Universities. During this period (the middle and second half of the 80s of the 20th century), the first automated mapping systems were developed, research was carried out on spatial analysis, cartographic-mathematical modeling, thematic mapping and their automation (O.M. Berlyant, N. L. Beruchishvili, V. T. Zhukov, P. V. Petrov, S. M.

Serbeniuk, Y. G. Simonov, V. S. Tikunov, I. G. Chervanov, V. A. Cherv'yakov, etc.), on the theoretical foundation and development of the first geoinformation systems (N.L. Beruchishvili, I.V. Garmiz, V.S. Davidchuk, V.P. Karakin, A.V. Koshkarev, V.G. Linnyk , M.V. Panasyuk, A.M. Trofimov, etc.). The first GIS developed in the former Soviet Union was probably the geo-information system of the Martkop Physico-Geographic Station of the Tbilisi University (Beruchishvili, 1986).

Geoinformation technologies in Ukraine developed in the mid-90s of the 20th century. Among the positive factors characterizing the current state of application of geoinformation technologies in the country, the following should be noted:

- formation in state institutions and organizations of groups of specialists who actively work in the direction of the application of GIS in various spheres of human activity, in particular: in the Dipromisto State Design Institute (Kyiv); at the Research Institute of Geodesy and Cartography (Kyiv); in the Department of Land Resources of the Odesa Regional Administration; at Odesa National University named after I.I. Mechnikova; at the National University "Lviv Polytechnic" (Lviv); at the National Mountain Academy (Dnipropetrovsk); at Kharkiv Technical University of Radio Electronics; in the Ukrainian Center for Land and Resource Management (Kyiv) and a number of others;

- creation of the GIS Association (1997) and the Association of Geoinformatics (2003) of Ukraine, which contribute to the activation and consolidation of geoinformation activities in the country;

- annual holding of GIS forums (1995-2001), conferences "Geoinformatics: theoretical and applied aspects" (since 2002), conferences of users of ESRI products in Crimea (since 1998, JSC ESOMM), as well as separate thematic conferences , seminars, meetings dedicated to the use of geoinformation technologies (for example, "Geoinformation technologies today" (Lviv, 1999); "Geoinformational education and municipal management" (Mykolaiv, 2000) "The possibilities of GIS/D33 technologies in helping to solve the problems of the Black Sea region" (Odesa, 2003) and others);

- creation of state-owned enterprises and commercial companies specializing in the development and/or use of geoinformation technologies, in particular: the state-owned research and production enterprise "Geosystem" (Vinnytsia) and the research and production center "Geodeskartinformatica" (Kyiv); commercial companies "Intellectual Systems, Geo", "Institute of Advanced Technologies", "ESOMM", GEOCAD, "Arcade", "Geonica" (Kyiv); "High Technologies" (Odesa), etc.;

- development of specialized geo-information package "Relief processor" - Kharkiv National University named after V. N. Karazin, vector-raster instrumented GIS desktop type OKO - OJSC "Geobiomika" (Kyiv); GEO+CAD and GeoniCS software complexes designed for processing research data and geoengineering design in the field of civil, industrial and transport construction - the company "GEOKAD", JSC "Arkada" and NPC "Geonica" (Kyiv) and others.

- creation of an electronic atlas of Ukraine - a pilot version of the computerized National Atlas of Ukraine (2000) - by the Institute of Geography of the National Academy of Sciences of Ukraine and the company "Intelligent systems, Geo" (Kyiv);

- introduction of courses in GIS and geo-information technologies to the training program for specialists in natural sciences and environmental specialties in many higher educational institutions of the country; the opening of some of them training courses for specialists in the field of geoinformation systems and. of technologies, in particular, at Lviv Polytechnic University (Lviv) - within the framework of the Cartography specialty, at Odesa National University named after I.I. Mechnikova — as part of the specialty "Geography", at Odesa State Environmental University - as part of the specialty "Information technologies", at the National Mining Academy of Ukraine (Dnipropetrovsk) - on the specialty "Geoinformation systems and technologies".

Factors restraining the development of geoinformation technologies include the generally low level of computerization in the country and the lack of a sufficient number of relevant specialists.

3. Connection of geoinformatics with other disciplines. Technologically, historically and "genetically" geoinformatics was formed and continues to develop in the environment of related sciences and technologies, related to it in subject and method. Algorithms and methods of geoinformatics are close to computational geometry and computer (machine) graphics, automated design systems (ADS). The non-positional (attributive) part of spatial data was traditionally stored and managed by means of database management systems (DBMS), the methodology of creating GIS databases continues to be among the important tasks in their design. A single digital habitat combines GIS with global positioning systems and automated (digital) terrain surveying technologies (for example, using electronic total stations or laser scanning devices) and their processing systems (for example, digital photogrammetry methods). Finally, the hardware environment for the implementation of geoinformation technologies - the so-called computing equipment, namely computers with peripheral devices for data input, storage and output - draws the latest information, including telecommunications, technologies studied by general informatics into the orbit of interests and conditions of existence of geoinformatics. In terms of the closeness of the connection, the level of interaction, methodological and technological closeness, and the possibilities of integration, the closest environment of geoinformatics is formed by cartography and remote (aerospace) sensing.

In the system of geographic sciences, geoinformatics occupies an important place and is positioned as a universal method of collecting, accumulating, analyzing and visualizing various geographic data in both the fields of natural and social geography. Forestry, management of natural resources, agriculture - separate areas of applied application of geoinformatics.

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[1] Informatics is a fundamental natural science because it is the science of means, methods and ways of collecting, exchanging, saving and processing information using automated means. Information technologies - a system of information transformation procedures for the purpose of forming, processing, distributing and using information. The basis of modern information technology is: computer processing of information according to specified algorithms, storage of large volumes of information on magnetic media and transmission of information over any distance in a limited time.

[2] Due to the fact that today these methods and methods are most fully implemented in geographic information systems (GIS) (see the next paragraph), the term "geoinformation technologies" is often replaced by the term "geographic information systems technologies", or by analogy with it the English-language equivalent is the term "GIS technologies".

[3] According to most sources, geographic information systems are: - an information system that can provide input, manipulation and analysis of geographically determined data to support decision-making (1984);

- a repository of the system of knowledge about the territorial aspect of the interaction of nature and society, as well as software that simulates the functions of search, input, modeling, etc., implemented with the help of automated means (EC). (1984);

- a set of tools for collecting, saving, searching, transforming and displaying data about the surrounding world with a specific purpose (1986);

- an information system designed to work with spatial or geographic coordinates (1990);

- a hardware and software human-machine complex that provides collection, processing, display and distribution of spatially coordinated data, integration of data and knowledge about the territory for effective use in solving scientific and applied geographical tasks related to inventory, analysis, modeling, forecasting and management of the environment and territorial organization of society (1991);

- a set of hardware, software tools and procedures designed to provide input, management, processing, analysis, modeling and display of spatially coordinated data for solving complex planning and management problems (1991);

- scientific and technical complexes of automated collection, systems of automation, processing and presentation (issuance) of geoinformation in a new quality with the condition of obtaining knowledge about the studied spatial systems (Serbenyuk, 1990);

- a set of hardware and software tools and algorithmic procedures designed for collection, input, storage, mathematical-cartographic modeling and visual presentation of geospatial information (Simonov, 1991);

- a set of technical, software and information tools that provide input, storage, processing, mathematical-cartographic modeling and visual integrated presentation of: geographical and associated attributive data for solving problems of territorial planning and management (1997);

- an information system that provides collection, storage, processing, access, display and distribution of spatially coordinated (spatial) data (1997).

[4] The development of the first geoinformation systems (Canadian GIS, Natural Resources Information System of the State of Texas (1976), Australian Resource Information System (1979-1982), etc.) was the result of the realization of a quite obvious desire to apply the unique and ever-growing capabilities of computers that appeared in the 50s of the 20th century, for the storage and manipulation of large masses of heterogeneous information accumulated at that time about the natural and socio-economic conditions and resources of the territories.

[5] (SYngrahis Marring System), developed in 1967 at the Harvard Laboratory of Computer Graphics and Spatial Analysis of the Massachusetts Institute of Technology (head - Howard Fisher, USA). Later (70s - early 80s of XX century) other software packages (GRID, САЛFORM, ODYSSEY, etc.) were developed in the same laboratory, which provided both map digitization and automatic mapping, as well as spatial analysis . At the same time, similar software products, known depending on their main purpose as either "map analysis packages" or "automated mapping systems", were developed in other scientific centers of North America and Western Europe. The most popular in the world from these later developments was the package for analysis of raster data MAR (Mar Analysys Rasket), which implemented cartographic algebra algorithms, the foundations of which were developed by S.D. Tomlison, USA (1983). This package, as well as its later versions PMAR, aMar, etc. distributed by Yale University (USA) at a very low price (about $20).

[6] In North America in 1983, there were more than a thousand GIS and automatic mapping systems. In Europe, the development of GIS was carried out on a smaller scale, but the main steps in the field of development and use of GIS technology were also made here. Sweden, Norway, Denmark, France, the Netherlands, Great Britain and West Germany should be especially noted.

For the 80s of the XX century. in general, the growth of scientific, political and commercial interest in GIS is characteristic. This was due to the awareness of the need to create state integrated GIS, especially in connection with the management of natural resources and environmental monitoring. Indicative facts for this period are the official recognition in Great Britain in 1984 of spatial data processing methods as research priorities and the creation in the USA of the National Center for Geographic Information and Analysis of the National Academy of Sciences (1987), designed to conduct basic research in the field of geographic analysis using geographic information systems.

7 In particular, in 1985 the European Space Agency became a sponsor of research related to integrated GIS, and the British National Space Center issued orders for contracts for the development of GIS. In the same period, a number of international periodicals devoted to various theoretical and applied aspects of GIS began to be published, including theoretical (International Journal of Geographical Information Systems) - since 1987, and devoted mainly to applied aspects of GIS - magazines "GIS World" - since 1988, (GIS Europe) - since 1992, etc., many scientific and scientific-practical conferences of various levels (from regional to worldwide) dedicated to GIS are held annually.

8 The realization of the powerful integration potential of GIS technology began in the mid-1980s of the XX century. a number of international and global projects for monitoring the natural environment, such as SORINE - Geoinformation System of the European Community (since 1985) and GRID - Global Resource Information Data Bank (since 1987).

9 In the developed countries of the world, GIS technology is becoming a widely used technology for processing, analyzing and presenting spatially coordinated information when solving various tasks in geography, geology, ecology, especially when performing large interdisciplinary projects, urban planning, transport, cadastral activities, regional planning and management and many other areas of human activity. In 1995, GIS was used in more than 93,000 locations worldwide, 65% of which were in North America and 22% in Europe. Fantastic during this period is the progress of hardware, the constant renewal and modernization of well-known commercial GIS packages, the appearance of some new ones. However, in general, the GIS software market is already divided between the main and traditional manufacturers. There is a trend of mass interest switching from large professional GIS tools running on workstations or large company computers to desktop GIS tools.

LECTURE 2

TOPIC 2. MODERN GIS PACKAGES AND THEMATIC MAPPING

Plan

1. Thematic mapping as the basis of GIS modeling.

2. Possibilities of thematic mapping in GIS.

3. Classification of modern GIS.

4. Use of GIS in the creation of electronic thematic atlases.

1. Thematic mapping as the basis of GIS modeling. Cartography, especially thematic, is closely related to geoinformatics and remote sensing. This especially applies to the relationship between geoinformatics and cartography, maps and GIS. The appearance of geoinformation systems marked a revolution in the toolkit for modeling geographic space in general, which has not yet been sufficiently understood and appreciated, implementing a fundamentally new way of describing and presenting it in the form of digital models and breaking the existing monopoly of maps and other geoimages as the only means of modeling space and, even more so it is important to solve spatial problems, allowing to replace graphic (figurative-symbolic) models of objects on the earth's surface with digital ones, and in a number of applications to push traditional cartographic models out of those areas where their use is impossible or impractical. The development of digital cartography does not change anything in essence: remaining within the cares and interests of cartography, digital maps are not maps; like any digital spatial data (including GIS data), they cannot be perceived by humans visually. That is why, despite all their independence and fundamental differences, cartography and geoinformatics are "doomed" to a strong and long interaction. Two sides are traditionally distinguished in this interaction: maps and other cartographic images are among the main sources of mass output data for GIS and are the most common form of presenting the results of its operation using methods of cartographic visualization of data in the form of computer and electronic (video screen) maps (fig.1).

However, the current nature of their interaction is not eternal and will remain until:

1) exclusively all mass data sources for GIS will not become digital (meaning the most mass of them - maps);

2) a direct interface between the human brain and computer memory will not be found (until then, the card will have to perform the role of an irreplaceable interface between man and machine);

3) algorithms for solving all spatial problems will not be found and implemented exclusively in the digital environment, bypassing the need to involve maps for this.

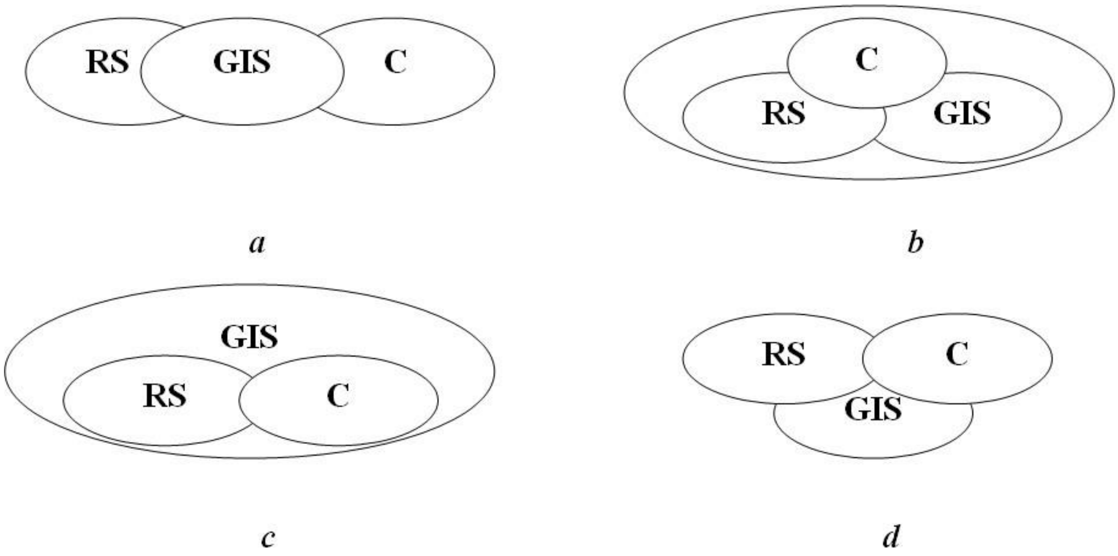

Fig. 1. Models of correlation between cartography (C), remote sensing (RS) and geographic information systems (GIS): *a - linear model; b - dominance of cartography; c - dominance of geographic information systems; d - triple interaction model*

2. Possibilities of thematic mapping in GIS. Creating thematic maps as independent layers in GIS allows you to realize the following important possibilities:

▪ Thematic maps using the method of dimensional symbols are not necessarily created on the basis of point objects. Dimensional symbols can be constructed for any typical graphic objects. Therefore, even if the base map contains areas or linear objects, it is still possible to create thematic maps using the method of dimensional symbols.

▪ You can create several thematic maps based on one layer of map information. At the same time, there is no need to copy the base map layer to create each subsequent thematic layer. You can view several thematic layers at the same time, as well as create dual-thematic maps.

▪ Using the "Manage Layers" dialog, you can adjust the display of thematic layers. The base layer can also be displayed. You can set your own scale effect for each of the thematic layers.

To date, the great applied value of thematic GIS cartography has been noted and repeatedly verified[10].

Diagrams play a special role in creating a cartographic model (Appendix 1). Like bar charts, pie charts allow you to analyze the values of several thematic variables at the same time. On such a map, the values of the variables determine the value of the corresponding segment of the diagram. It can be compared to other segments in the same chart or to similar segments in other charts. When displaying a thematic map, MapInfo automatically creates a legend for this map, which reflects what values are reflected by certain colors, symbols or sizes of objects.

3. Classification of modern GIS. In recent decades, a large number of various geoinformation systems have been developed in the world. Usually, geographic information systems are classified according to the following characteristics:

- according to purpose - depending on the intended use;
- by problem-thematic orientation - depending on the field of application;
- by territorial coverage — depending on the size of the territory and the large-scale range of digital map data that make up the GIS database.

By purpose, geoinformation systems are divided into multipurpose and specialized. Multipurpose systems, as a rule, are regional GIS designed to solve a wide range of tasks related to regional management. Specialized GIS provide one or more related functions. As a rule, they include geoinformation systems:

- informative and reference;
- monitoring;
- inventory;
- decision-making;
- research;

- educational.

In particular, research GIS are created to provide a solution to any scientific problem or set of scientific problems using spatio-temporal analysis and modeling methods. An example can be the geoinformation system of the Butenya river basin (Kyiv region, Boguslav field experimental hydrometeorological base of UkrNDGMI), created to solve the problem of forecasting the spatial redistribution of radionuclides in the small river basin as part of the international project (SPARTACUS, 2000)[11].

Educational GIS are developed to support the educational process, as a rule, in higher educational institutions. As an object in such geo-information systems, the territories of field hospitals - the bases of educational field practices of students are most often considered[12].

According to the problem-thematic orientation, types of geographic information systems corresponding to the "main areas of GIS application" are usually distinguished, i.e.:

- land cadastre;
- ecological and nature-friendly;
- engineering communications and urban management:
- emergency situations;
- navigational;
- socio-economic;
- geological;
- transport;
- trade and marketing (Appendix 3);
- archaeological;
- military;
- others[13].

In terms of territorial coverage, the most logical division of geoinformation systems into:

- global;

- nationwide;
- regional;
- local.

Global geographic information systems cover either the entire globe, such as the Global Bank for Natural Resource Information (GRID), or some significant part of it as a geo-information system of the European Community COPINE. National GIS, as the name implies, covers the territory of the entire country, regional GIS - some part of it, such as an economic district, an administrative region or a group of adjacent regions, the basin of a large river, etc. The "local GIS" category includes geographic information systems with a smaller territorial coverage, but there are no recommendations on the territorial limitations of local GIS. This category, as a rule, also includes municipal geoinformation systems (MGIS) - a specific category of geoinformation systems developed for the territory of the city or its part.

4. Use of GIS in the creation of electronic thematic atlases. The Electronic Atlas of Ukraine is a pilot project of the National Atlas of Ukraine, implemented by employees of the Institute of Geography of the National Academy of Sciences of Ukraine and the Limited Liability Company "Intellectual GEO Systems"[14].

The atlas was developed using the latest research results from the institutes of the National Academy of Sciences of Ukraine (geography, geophysics, geological sciences, botany, zoology), the Ukrainian Research Hydrometeorological Institute and data from the State Statistics Committee, the Ministry of Economy and some other ministries and agencies, among which the authors are especially note the active assistance of employees of the Ministry of Environmental Protection and Nuclear Safety as consultants and experts (Atlas of Ukraine., 2000). The electronic atlas of Ukraine, using a system of maps, provides an informational image of the state in relation to its natural, social, economic and ecological features. The atlas can become a guide for studying Ukraine and its regions.

The main component of the information support of the Atlas is a set of electronic maps. But the Atlas also includes text, diagrams, tables and photographs, which significantly complement the cartographic information. It is structured according to thematic blocks:

- general information about the country;
- natural conditions and natural resources;
- population;
- economy;
- ecology.

In total, the Atlas has 40 chapters, 176 maps, 200 graphs and 110 photographs. Information support is provided, as a rule, as of January 1, 1998. Other dates are indicated in the map legends and additional materials. With the help of Atlas, you can solve the following tasks:

- in the environmental sphere - analysis of the state and dynamics of the ecological situation in Ukraine and its regions;

- in the field of economic activity - provision of state, regional and local management structures with comprehensive information about the development and functioning of the economy, economic relations, their dynamics and possible directions of transformation;

- in the social sphere - analysis of the placement and movement of the population, its ethnic and cultural features, social processes taking place in society;

- in the field of education - provision of school, university and other levels of education and enlightenment with available analytical and integrated information about the state and its regions.

The software implementation of the Electronic Atlas of Ukraine was made using modern Internet technologies, namely: HTML, JavaScript, ArkhiveX objects. Choice of implementation method caused primarily by the possibility of viewing it with the licensed software that the user has. In this case, it is Microsoft Internet Explorer. Use of language HTML provides the ability to structure the Atlas with the help of so-called frames - frames on HTML pages. The main window of the Atlas is divided into three frames (fig. 2).

Fig. 2. Structure of the main window of the Atlas of Ukraine

The top frame, or "Navigation", performs functions moving through informational materials of the system. The left ("Content") and right ("Result") frames provide an opportunity to select and view maps, text descriptions, photographs and other informational materials included in the Atlas. If a map is loaded in the right frame, an additional control panel appears on the right side of the frame, which allows you to interactively move the map, change its scale, get information about objects on the map and search for them, view the map legend and description, etc., i.e. perform typical GIS operations of spatial data manipulation.

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[10] Any economic operation at the enterprise is accompanied by the formation of a document confirming its implementation. Since large volumes of information are stored in electronic spreadsheets of trade and marketing reports, and a significant amount of information about customers, trading points of the city is on paper and in computer memory, a system is needed that will allow the computer not only to quickly process data, and visually display using their spatial components. Electronic cartography is such an analysis system. With the help of cartographic modeling (using the GIS package MapInfo Professional 6.0.), you can quickly and easily see the location of customers, the size of symbols marking their location may depend on the volumes of sales and sales, follow the intensity of consumer flow or turnover of a retail enterprise on a unit of the store's sales area, or to quickly compare past indicators with current ones and identify the reasons for their decline or growth. All this makes the visualization of statistical data more visible and easy to understand and further spatial analysis. To improve the analytical capabilities of GIS,

special economic indicators are calculated. In particular, for wholesale and retail trade enterprises, this is the intensity of the consumer flow (person/hour*working day); intensity of turnover per unit of retail space (UAH/sq.m.).

11 The spatial data base of the geoinformation system of Buteni consists of more than thirty layers of data characterizing the relief (a digital model of the relief and maps derived from it of slopes, exposures, longitudinal and transverse curvature of slopes, etc.), a hydrographic network (maps of local current lines, catchments, "higher elements", slopes, hydraulic stiffness, etc.), soil cover (maps of genetic types of soils, soil-forming rocks, erodibility, as well as parameters characterizing water-physical and anti-erosion properties of soils and their radioactive contamination), natural and cultural vegetation (maps of forests, agricultural lands, crop rotation and parameters characterizing them) and land use (maps of land use types, road network, etc.).

12 Examples of educational GIS are GIS "Satino", developed at the Faculty of Geography of the Moscow State University named after M.V. Lomonosov (Lurie, 1998) and GIS of the Educational Geographical Station "Krynychki" (north of Odesa region), which is being developed at the Faculty of Geology and Geography of Odesa National University named after I.I. Mechnikova. The latter consists of a bank of spatial (cartographic) information and related attribute data for the territory of the field hospital with a total area of about 100 km2 and a library of applied modules that implement educational, scientific and applied tasks based on the data bank and capabilities of geoinformation technologies.

13 In the category of "others" in this classification, a fairly large number of types of PS can be mentioned, and one that continues to increase, since the scope of GIS application is not limited to the list of the above-mentioned areas and continues to expand.

14 Project manager - Doctor of Geographical Sciences, Academician of NASU L.G. Rudenko, co-leader - Candidate of Physical and Mathematical Sciences V.S. Chabanyuk, manager - A.I. Bochkovskaya For the creation of the Atlas of Ukraine on February 24, 2003, the Presidium of the National Academy of Sciences at its meeting awarded L.H. Rudenko and the first deputy director of "Intellectual systems of GEO" LLC, candidate of technical sciences O.E. Lytvynenko Prize named after V.I. Vernadskyi.

LECTURE 3

TOPIC 3. APPLICATION OF INFORMATION SYSTEMS

Plan

1. The main functions of modern GIS.

2. Practical application of GIS technologies (in urban management and regional administration, ecology, cadastral systems, etc.).

3. Application of GIS in forestry.

4. Use of GIS in the agricultural sector.

5. Application of GIS in ecology and rational nature management.

1. The main functions of modern GIS and practical application. Conventionally, GIS functions can be divided into five groups, while the first three belong to traditional functions of geoinformation technologies, the last two - to new ones that have developed in the last decade.

1. Information and reference function - creation and maintenance of banks of spatially coordinated information, including:

- creation of encrypted (electronic) atlases. The first commercial project for the development of digital atlases - the Digital Atlas of the World - was released in 1986 by Delorme Marring Systems (USA). It is also possible to note the Digital Atlas of Great Britain on optical discs as a result of the British Domesday Project (1987), the Digital Chart of the World (Digital Chart of the World) on a scale of 1:1000000, developed by the Mapping Agency of the US Department of Defense in 1992, etc. and, finally, - the electronic version of the National Atlas of Ukraine, developed by the Institute of Geography of the National Academy of Sciences of Ukraine with the firm "Intellectual System and Geo" (Kyiv, 2000);

- creation and management of data banks of monitoring systems. Examples include the Global Resources Information Database GRID, created under the auspices of UNESCO in 1987-1990, and the Geoinformation System of the countries of the European Community SORINE, developed in 1985-1990;

- creation and operation of cadastral systems, primarily automated land information systems (AZIS), or Land Information Systems (LIS), and municipal (or city) automated information systems (MAIS), as well as spatially distributed automated water and forest information systems cadasters, real estate cadasters, etc. Software for working with spatial data in cadastral systems consists of GIS software packages ARC/INFO, ArcView GIS, MGE Intergraph, Mapinfo (USA), SICAD (Germany), ILWIS (Netherlands), etc.

2. The function of automated mapping is the creation of high-quality general geographic and thematic maps that meet modern requirements for cartographic products. An example of the implementation of this function is the activity in Ukraine of the Institute of Advanced Technologies (Kyiv) for the preparation and printing of educational geographical and historical atlases of the territory of Ukraine, as well as Moldova and Russia based on the capabilities of GIS packages of the company ESRI, USA.

3. The function of spatial analysis and modeling of natural, natural-economic and socio-economic territorial systems, which is based on the unique opportunities provided by cartographic algebra, geostatistics and network analysis, which form the basis of analytical blocks of modern instrumental GIS with developed analytical capabilities. It is implemented in scientific research, as well as solving a wide range of applied tasks in territorial planning, design and management.

4. The function of modeling processes in natural, natural-economic and socio-economic territorial systems. Examples are modern spatially distributed models of surface runoff, soil washing and transport of slope and channel deposits, various types of pollutants, in particular, LISEM, Csredis (Netherlands), WEPP (USA). It is implemented in the assessment and forecast of the behavior of natural and natural-economic territorial systems and their components when solving various scientific and applied tasks, including those related to the protection and rational use of natural resources.

5. Decision support function in planning, design and management. This direction is most actively developing in Ukraine in urban planning and design. There are

certain successes in the field of geoinformation provision of emergency situations. The range of examples here can be quite wide, if you flexibly approach the definition of the concept of "decision support system" (DSPR), which should include:

- software-organized banks of spatial and attributive information;
- a knowledge base consisting of an analysis and modeling block, which contains a set of models of spatial analysis and spatio-temporal modeling, as well as a reference and information block, which contains a formalized reference and normative base on the problem under consideration;
- a block of artificial intelligence technologies, which provides a formal-logical conclusion and decision-making mechanism based on information available in the database, a reference-information block in the results of spatio-temporal analysis and modeling;
- user interface.

In many cases, integrated computer systems containing a system of software-implemented models, a bank of reference information, and a data bank are considered in practice as an integrated computer system. Analysis and evaluation of simulation or optimization modeling results are performed outside the system by a qualified expert or a group of experts.

2. Practical application of GIS. The main fields of application of GIS nowadays are:

- management of land resources, land cadasters;
- inventory and accounting of distributed production infrastructure objects and their management;
- thematic mapping in almost any sphere of its use;
- marine cartography and navigation;
- aeronautical mapping and air traffic control;
- navigation and management of land transport traffic;
- remote sensing;
- management of natural resources (water, forest, etc.);

- modeling of processes in the natural environment, management of environmental protection measures;

- environmental monitoring;

- response to emergency and crisis situations;

- geology, mineral resources and mining industry;

- planning and operational management of transportation;

- design, engineering research and planning in urban planning, architecture, industrial and transport construction;

- planning the development of transport and telecommunication networks; complex management and planning of the development of the territory, the city;

- agriculture;

- marketing, market analysis;

- archeology;

- security, military affairs and intelligence;

- general and special education.

Note that the list includes only the "main", "largest" areas of GIS use, without taking into account scientific research, in which the use of geoinformation systems and technologies is becoming more and more widespread. In addition, the given list is not final, as the scope of GIS use is constantly expanding. To it, in particular, you can add medical geography, epidemiology, protected affairs, tourism - areas of human activity in which the use of GIS has become more and more common in recent years.

3. Application of GIS in forestry. GIS tools can be used to support a variety of forest resource management functions, such as: development of long-term timber supply strategies, five-year stock forecasts, selection of logging systems, calculation of least-cost road construction, visual landscape analysis with plot overlay, resolution of boundary disputes property, setting the boundaries of natural habitats, modeling scenarios of the spread of forest fires, implementing tactical planning for fire suppression and much more.

The main properties of ARC/INFO, which make this software the leader of GIS in solving tasks of the forestry industry, are as follows:

- Powerful and flexible data model;
- Integrated management of tabular and geographic data;
- Vector topology (point, line and polygon) and raster data models;
- Data integration;
- Integration of many environments (for example, raster and vector images);
- Support of standard image formats and digital display;
- Communication with satellite positioning systems (GPS);
- Possibilities of data exchange in more than 30 standard formats;
- Automatic mapping, reporting and analysis;
- Display of standard maps and compilation of tables;
- Thematic maps, requests and types of analysis;
- Integration of databases and delivery of standards throughout the organization;
- Direct access to databases in the GIS environment;
- Support for many standard industrial relational databases and network functions;
- Functions of reliable security of databases;
- Map library management capabilities;
- Comprehensive spatial analysis and query capabilities;
- Overlapping point-, line-, polygon-polygon, connections of neighborhood and closeness;
- Modeling on a regular grid using ARC/INFO extensions;
- Analysis of linear networks.

Forest management planning involves making predictions of how the forest will look as a result of certain management practices. The possibility of this analysis is crucial for almost all aspects of management forecasting, especially in the area of long-term assessments of timber products and natural habitats. Forecasting involves applying a management strategy - usually in the form of a model - to forest GIS cadasters and projecting the effect of the strategy on the forest and other related land objects in the future. This means that forestry information systems should not only describe the current state of the forest, but also be able to work with the dynamics of forest development and changes in large landscape areas, both in the short and long term.

Modern GIS provide an opportunity to view databases, set model parameters, observe results, add important parameters, both temporal and spatial. Within the framework of the cadastre and the selected model, the user can observe how the forest may look in the future in 5, 10, 25 or 100 years.

Other applied tasks solved by ARC/INFO GIS users when planning forest approaches and roads include:

- Analysis of surface and slope stability using ARC/INFO TIN;
- Calculations of excavations and embankments;
- Visibility analysis;
- Leveling and leveling calculations;
- Study of traffic corridors;
- Assessments of the impact on the natural environment;
- Integration of shooting data using ARC/INFO COGO;
- Analysis of values and flows using ARC/INFO NETWORK;
- Graphic display of road construction costs based on topography, slopes and surfaces.

4. Use of GIS in the agricultural sector. Objective information about the size and condition of agricultural land is necessary for the management of an agricultural enterprise producing crop production. A large volume of spatial and attributive information can be qualitatively processed and analyzed only with the help of special software that takes into account both spatial reference and special information about fields. Specialized GIS for agriculture in Europe and the USA has long been no longer exotic, but a necessary component of the system of complex management of the economy.

The cartographic materials available in the farms of Ukraine, which are the basis of GIS, are usually incomplete, largely outdated and do not meet the modern requirements put forward by intensive agricultural technologies for the cartographic basis. All cartographic materials can be conditionally divided into three groups: land management, soil, agrochemical. Land management materials are represented either by intra-farm land management plans of the Soviet period or by modern cadastral plans. Soil materials are represented by soil maps compiled mostly only 20-30 years ago and maps of agro-production groups of soils. Both those and others, as practice shows, are absent in most farms. Agrochemical materials are represented by agrochemical cartograms (content of humus, mobile phosphorus, mobile potassium, Ph) of different ages.

Modern agronomic GIS involves streamlining the process of filling the system with cartographic materials, filling the database with information about soil indicators, phytosanitary status of crops, entering information about proposed agricultural technologies, developing proposals for the use of GIS in farms, training farm specialists, educational and project organizations, developing and using GIS in crop production.

In the full version, the agronomic GIS should include a multi-layered electronic map of the farm and an attribute database of the history of the fields, taking into account all the performed agrotechnical measures. The number of thematic layers of the electronic map depends on the complexity of the landscape and ecological conditions and the level of intensification of agricultural technologies (determined by the yield and amount of expenses per hectare). In general, the electronic field map should include the following layers:

- meso-relief (showing relief mesoforms, slope forms);
- steepness of slopes;
- exposure of slopes (warm, cold, neutral);
- microrelief (showing contours with a predominance of certain forms of microrelief that have agronomic significance);
- microclimate;
- the level of groundwater, its mineralization and composition;
- soil-forming and underlying rocks;
- soil cover microstructure (soil map);
- humus content in the soil;
- supply of mobile forms of elements of plant mineral nutrition and trace elements;
- Ph value of soils;
- physical properties of soils;
- pollution by heavy metals, radionuclides and other toxicants;

• soil erosion, erosion danger and other types of physical degradation (landslides, landslides, etc.);

• waterlogging and waterlogging of soils, in particular secondary hydromorphism, flooding, etc.

• soil salinity (types and degrees of salinity);

• soil sunshine;

• plant cover with an assessment of the state of natural fodder lands;

• forest vegetation with an assessment of the condition of natural forests and forest plantations;

• distribution of useful species of animals, birds, useful entomophages, assessment of their territorial influence;

• phytosanitary state of crops.

One of the basic elements of resource-saving technologies in agriculture is "precision agriculture" (or as it is sometimes called "precision agriculture"). Precision agriculture is the management of crop productivity taking into account the intra-field variability of plant habitat. Relatively speaking, this is optimal management for each square meter of the field. The goal of such management is to obtain the maximum profit under the condition of optimizing agricultural production, saving economic and natural resources. At the same time, real opportunities for the production of quality products and preservation of the environment are opened.

This approach, as shown by international experience, provides a much greater economic effect and, most importantly, allows to increase the reproduction of soil fertility and the level of ecological purity of agricultural products. For example, a farmer from Germany, when introducing elements of precision agriculture, achieved a 30% increase in yield while simultaneously reducing the costs of mineral fertilizers by 30% and inhibitors by 50%.

Precision farming involves many elements, but they can all be broken down into three main stages:

• Collection of information about the economy, field, culture, region;

• Analysis of information and decisions;

• Execution of decisions - carrying out agrotechnological operations.

For the implementation of precision farming technology, modern agricultural machinery controlled by an on-board computer and capable of differentially carrying out agrotechnical operations, devices for precise positioning on the terrain (GPS receivers), technical systems that help to detect the heterogeneity of the field (automatic samplers, various sensors and measuring complexes, collecting machines with automatic harvest accounting, devices for remote sensing of agricultural crops, etc.) The core of precision agriculture technology is software that provides automated maintenance of spatial and attributive data of the card file of agricultural fields, as well as the generation, optimization and implementation of agrotechnical solutions taking into account the variability of characteristics within processed field.

5. Application of GIS in ecology and rational nature management. The use of geoinformation systems allows you to quickly receive information on request and display it on an electronic map, assess the state of the ecosystem and forecast its development.

GIS capabilities:

• input, accumulation, storage and processing of digital cartographic and environmental information;

• construction of thematic maps reflecting the current state of the ecosystem based on the received data;

• study of the dynamics of changes in the ecological situation in space and time, construction of graphs, tables, diagrams;

• modeling the development of the ecological situation in different environments and researching the dependence of the state of the ecosystem on weather conditions, the characteristics of pollution sources, and the values of background concentrations;

• obtaining comprehensive assessments of the state of environmental objects based on heterogeneous data.

GIS is actively used in environmental monitoring systems. In such GIS, remote monitoring systems are actively used - satellite and aerial photography in combination with local monitoring systems.

GIS is also used where operational management of resources and quick decision-making is necessary. According to some estimates, 80-90% of all information can be presented in the form of GIS. GIS makes it possible to accumulate information, give it to you in a form convenient for you, and manipulate this spatially referenced data.

Within the framework of GIS, it is possible to carry out a complex of scientific and practical works aimed at creating a "Register of stationary sources of emissions of pollutants into the atmospheric air", which will allow the implementation of the accounting subsystem and, at the same time, provide the necessary information systems for the analytical subsystem of atmospheric air pollution assessment.

According to forecasts in 5 years, this register will cover more than 2,000 man-made environmental risk facilities with more than 200,000 stationary emission sources and 5 million pollutant emissions warehouses. The database will be replenished by batch input (import) from other software packages. The integrity of the database is supported by special reference dictionaries. With the help of this GIS, a specialist operator can solve a whole set of analytical problems, from assessment and examination of the influence of a separate source of emissions of an enterprise before the development of a consolidated project of normatively permissible emissions.

At the request of the State Administration of Ecology and Natural Resources in the Sumy Region, the Institute of Telecommunications and Global Information Space of the National Academy of Sciences of Ukraine and the State Research and Production Center "Nature" of the National Academy of Ukraine of Ukraine developed a specialized ecological GIS to ensure management at the regional level of environmental protection, ecological safety, and rational use renewable natural resources and the development of the nature reserve fund[15]. The GIS information fund was formed based on the analysis of the main functions of the State Department of Ecology and Natural Resources in the Sumy region, which are directed to the implementation of the state environmental policy and the implementation of systemic management methods:

- protection of atmospheric air, water, land resources and soil, subsoil;

- waste management;

- the development of a natural reserve fund and a strategy for the protection, use and reproduction of biological resources.

According to the basic concept of GIS, the developed system consists of thematic layers, which can be conventionally combined into three blocks according to their content:

- topographic basis;

- man-made factors of environmental safety;

- naturally - a reserve fund.

The topographic basis of the system is a vector electronic map of the Sumy region M 1:200000, developed by order of the Ministry of Emergency Situations of Ukraine. It includes the following basic topics: administrative and territorial organization; settlements; network of paths; surface water resources; soils; relief. The thematic layers of the next two blocks were formed from the data obtained from the funds of the State Department of Ecology and Natural Resources in the Sumy Region as of January 1, 2005. Cartographic models of man-made environmental safety factors were developed separately for each of the 18 districts of the region. Features of man-made load on their natural ecosystems inherent in each district were reflected in the corresponding legend - conventional markings on the map. The attributive information of the objects included in the GIS is structured in the relevant databases available in interactive modes. Their analysis gives grounds for the conclusion that the ecological state of the territory of the Sumy region can be characterized as stable and manageable.

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[15] Довгий С.О., Трофимчук О.М., Зотова Л.В. ІТГІП НАНУ, м.Київ; Черненко В.В.Сумська ОДА, м.Суми; Красовський Г.Я., Греков Л.Д., Волошкіна О.С., Крета Д.Л., ІПНБ РНБОУ, м. Київ; Готинян В.С., ДНВЦ «ПРИРОДА», м.Київ. Екологічні геоінформаційні системи (на прикладі Сумської області).

MODULE 2. FEATURES OF USING MODERN INFORMATION SYSTEMS

LECTURE 4

TOPIC 4. DATA IN GEOINFORMATION SYSTEMS

(MODULE 2)

Plan

1. Spatial information in GIS.

2. Geographic data in GIS.

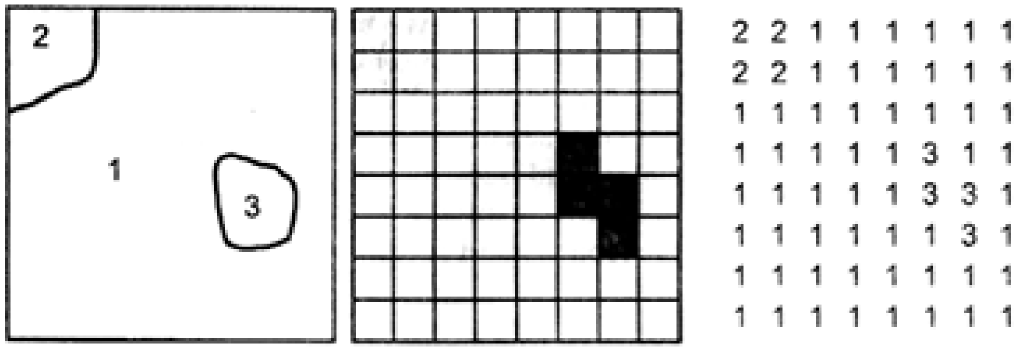
3. Attributive data in GIS.

4. Models and databases in GIS.

1. Spatial information in GIS. Spatial (cartographic) information is the basis of the GIS information block, therefore the methods of its formalization are the most important component of the technology of geographic information systems. Spatial information of the PS contains a metric part that describes the positional properties of objects, as well as related meaningful (semantic, thematic) attributes, or simply - "attributes", as they are commonly called in English-language scientific literature[16]. Spatial data is entered and stored in a computer in a formalized form. Two main methods of spatial data formalization are used - raster and vector, corresponding to two fundamentally different methods of description (models) spatial data. In the first method, spatial information is correlated with cells of a regular grid as elements of the territory (raster representation), in the second - a system of elementary graphic objects is used, the position of which in space is determined using coordinates (vector representation).

The raster method of spatial data formalization has two varieties - regular networks[17] (grid cells) and actually raster[18] (raster), which do not differ in principle from one, since both are based on the formalization of spatial information by cells (cells) of a regular network that continuously covers the territory. In each cell of this network, information is displayed as one number[19].

In the raster model, spatial information is encoded in the form of a rectangular matrix - by rows and columns, the size of which corresponds to the size of the original raster (fig. 3). In this regard, the position of each raster element in space is determined by the column and row numbers in which this element is placed. During rasterization in cartographic images, columns are usually placed in the north-south direction, and rows - west-east. As the initial cell (with coordinates 0, 0 or 1, 1) the cell placed in the upper (or lower) left corner of the raster[20] is most often used.



a **b** **c**

Fig. 3. Raster representation of spatial information: *a) fragment of land use (1 - arable land; 2 - natural steppe vegetation; 3 - forest); b) its raster representation; c) the corresponding digital data array*

The combination of semantic and positional information, which is the main positive of raster models of spatial data, at the same time determines one of their significant negatives - the need for a large memory capacity to store digitized data in a computer. Thus, a standard picture from the US artificial Earth satellite of the Landsat series (Landsat), covering about 30000 km^2 with a nominal pixel size of 30x30 m, consists of 35 million pixels, which is equivalent to about 35 MB when recording in a 1:1 format.

2. Geographic data in GIS. Geographical maps remain relevant as a source of spatial data for GIS. Topographic maps are used for spatial linking and copying of data during the construction of many cartographic databases, including thematic maps and digital relief models - general geographic maps of universal purpose that depict the terrain in detail. Topographic maps are divided into large-scale (1:50 000 and more), medium-scale (1:100 000 - 1:500 000) and small-scale, or survey-topographic (smaller than 1:500 000).

Large-scale topographic maps (1:50 000, 1:25 000 and 1:10 000) are created based on the materials of field topographic surveys, and all others are compiled in-house based on larger-scale maps[21]. The error when displaying any object on the polygraphic print of the map should not exceed 0.1 mm. Based on this value, it is possible to determine the value of the systematic error and, accordingly, the accuracy of the digital map built on the basis of the topographic map of the selected scale. For a scale of 1:200 000, the built-in error will be about 20 m, for 1:100 000 - 10 m, for 1:10 000 - 1 m. Thus, to obtain the final accuracy of a digital map of 1 m and below, it is necessary to use topomaps of scale 1: 10 000 or materials of a special topographic survey.

Refraction ellipsoids - geometric models of the averaged surface of the globe - are used to determine height coordinate systems.

The following spatial objects can be determined and directly digitized by topographic maps:

- coordinate system (geographical or topographical);
- the location and height of reference geodetic network points;
- estimates of relief heights, contours and depth of erosional forms;
- location of hydrographic objects, assessment of water cuts, depths, channel width, speed and direction of current;
- name of the settlement, number of houses, type and contours of large buildings, quarries, etc.;
- type of covering, width of roadway and roadsides for highways, construction, length and carrying capacity of bridges, height (depth) of embankments and ditches;
- contours of forest massifs or areas of natural vegetation, type of tree species, height and density of vegetation, width of forest strips;
- the location and type of linear technical infrastructure elements (power lines, pipelines).

The most reliable source of information about the contours of water spaces, the depth and nature of the bottom are navigation maps that have the same scale range as topographic ones.

Domestic land management schemes, which also contain information on soil cover, are usually made at scales of 1:25,000 and 1:10,000. For settlements, there are architectural plans of various scales (1:5000, 1:2000, 1:500), on which the street network, contours of buildings, boundaries of land use plots, underground and surface engineering communications are drawn. However, these materials are made in a conventional coordinate system, and for their use together with other sources, it is necessary to perform certain spatial transformations.

Various general geographic and thematic maps can also be a source of data for GIS[22].

Remote sensing of the Earth (RS) data is also actively used in GIS. They are based on the registration and subsequent interpretation of reflected solar radiation from the surface of the soil, vegetation, water and other objects. Taking the recording devices into the air or near-Earth space allows you to get a much wider coverage of the territory compared to ground-based research methods. In remote sensing, the spectral range of the survey, spatial accuracy, radiometric accuracy, spatial coverage, responsiveness and repeatability of the survey, and the cost of the data have a significant impact on the quality and applicability of the received data[23].

Fig. 4. High-resolution image of the city of Uman from the Landsat remote sensing system

Nowadays, there are several commercial remote sensing systems, the data of which are actively distributed in Ukraine. The data of the American Landsat system (fig. 4), the French SROT, the Indian Irs are quite common. Data of high spatial accuracy are offered by Iconos and QuickBird shooting systems (USA).

Additional processing and analysis of RSE data (selection and comparison of different spectral ranges, combination of images with different spatial resolution, classification and selection of zones with defined characteristics) are performed with the help of special software. The most famous software packages for data processing of RSE are ERDAS IMAGINE (USA) and ErMarrer (Australia).

Data from electronic geodetic instruments is a file with coordinates and identifiers of survey points. Such files can also contain information about the measurements - vertical and horizontal angles, distances. Data files can be created in special proprietary formats or in standard ASCII text format. Special software packages for processing data of geodetic measurements or modules of coordinate geometry of PS tool packages (Invent-Grad package (Ukraine); CPEDO software packages) of the company "Credo Dialog" (Belarus), extension of Survey Analyst, family of ArsGIS packages of the company ESRI (USA) and etc.) read such data using special converters.

Text data is transformed into the coordinates of anchor points, for which the locations of points along the contours of objects (houses, roads, etc.) are determined by the measured angles and distances a graphic vector file is created. If the device supports the input of identifiers and descriptions of objects during shooting, these data can be automatically entered into the attribute database.

3. Attributive data in GIS. Information that either has no spatial binding or characterizes spatial objects without specifying their location is classified as attributive. For example, serial numbers of spatial objects, their proper names, numerical quantitative or qualitative values. A block of attributive information tied to any spatial object can contain from one to many hundreds of individual attribute values of various types characterizing various parameters of this object[24].

One of the most common attributes of spatial objects are their proper names - the names of settlements, administrative units, relief areas, rivers, reservoirs, natural tracts, economic objects, etc. This type of attribute identifies an object, distinguishes it from other objects of the same type, and allows you to refer to this object. This method of describing an object's attribute is called nominal - the object simply receives its own name, it is equivalent in the list of the same objects.

Attributes showing the location of the object among other similar objects, their mutual hierarchy, priority are called ordinal attributes. In this way, the hierarchy is described: sections of the road network (freeways, highways, roads with an improved surface, unpaved roads); elements of the river network (tributaries of the first, second or third order); hierarchical levels of landscape units, ranks of settlements, etc. In most cases, such attributes are described by the serial number of some ranking scale.

For quantitative data (temperature, pressure, content of pollutants in air, water or soil, altitude above sea level, number of plants per square meter, humus content and etc.) open or closed numerical scales are used[25]. Various classification and coding systems allow to reduce the descriptions of various spatial objects to one or several dozen characters. Nowadays, alphanumeric coding systems have been developed for geological, soil, landscape, and geobotanical maps. For digital topographic maps and architectural and urban plans, departmental positional codes - classifiers[26] have been developed. After certain processing, attribute information can be organized in the form of a database of a certain format. The source of attributive data for GIS can be standard reporting forms of various state, commercial and public organizations, scientific reports and publications, observation data at hydrometeorological stations, etc. Most of such documents are created and submitted digitally in the formats of Word, Excel, and Assessment software packages. Most GIS packages that work with relational tables to store attribute data include special modules for import and export of data in Excel and Access formats.

4. Models and databases in GIS. A database is an information model of the real world and is a collection of data organized according to certain rules that establish general principles of data description, storage and manipulation[27]. Database objects can be described in various ways: in the form of textual descriptions, digital codes, combined alphanumeric classifiers, numerical values of various types, calendar dates, etc. Each database object of the same type is described by the same set of attributes, thus, the database consists of separate records characterizing each object and indicators of relationships between them.

In most cases, databases are designed so that one or more attributes uniquely identify a record. The set of values of these attributes is called the key of the record, and the attributes themselves are called the key attributes. A record key can be thought of as a unique record name by which a user can always find that record.

In the conceptual scheme, the entire set of records of the same type is represented by a single abstract record, called a record type. Each record type has a name and a list of attributes. Similarly, a set of connections of the same type available in the database corresponds to one type of connection in the conceptual scheme[28]. The database is created and accessed using a database management system (DBMS). Personal databases are allocated for working with data related to the job duties of an individual official; databases of divisions, enterprises serving several different specialists as part of a local computer network; corporate (for example, municipal) databases serving several thousand specialists and hundreds of thousands external users in the mode of shared access, using various software, hardware, various network protocols and forms of data presentation.

The basis of the database is the data model - a fixed system of concepts and rules for presentation of data on the structure, state and dynamics of the problem area in the database. At different times, hierarchical, network and relational models were consistently used data Nowadays, the object-oriented approach to the organization of GIS databases is becoming more and more widespread.

Hierarchical data model. Often, objects are in relations, which are called hierarchical: relations "part is the whole"[29]. Objects that are in hierarchical relations form a tree "directed graph", which has only one vertex, not subject to any other vertex (this vertex is called the root of the tree);

any other vertex of the graph is subject to only one other vertex (fig. 5)[30].

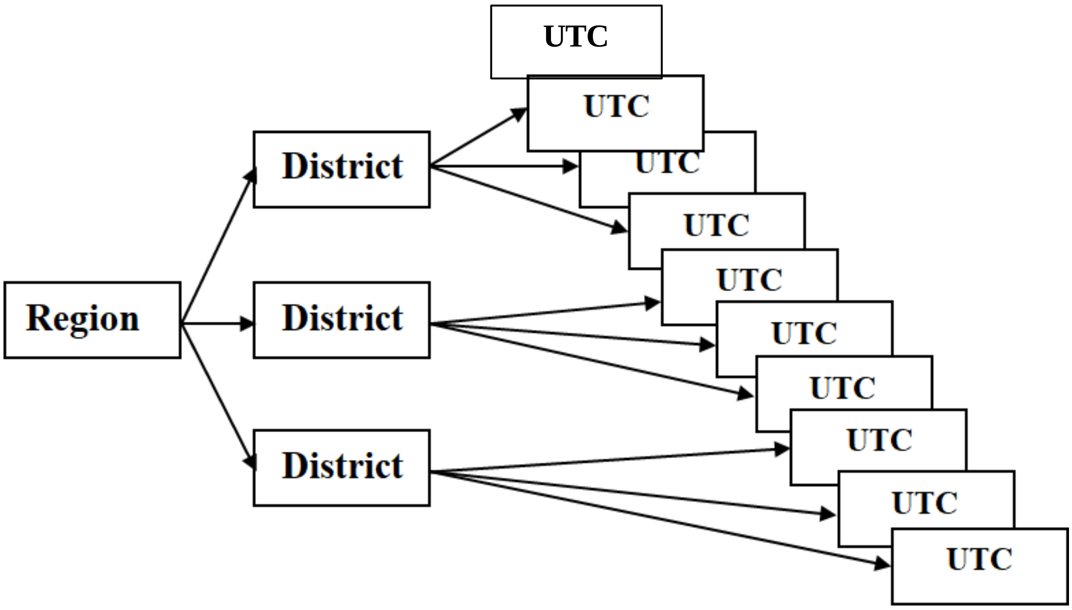


Fig. 5. Scheme of relationships between objects in a hierarchical database

Hierarchical databases are navigable, that is, access is possible only through predetermined connections. When modeling events, as a rule, many-to-many relationships are needed. Duplication of objects can be proposed as one of the possible solutions for removing this restriction. However, the duplication of objects creates the possibility of inconsistency in their actions. The advantage of a hierarchical database is that its navigable nature provides quick access when traversing along predetermined connections. However, the inflexibility of the data model and, in particular, the lack of direct access to the data make it unsuitable for frequent execution of queries that are not planned in advance. Another disadvantage of the hierarchical data model is that the information search from the lower levels of the hierarchy cannot be directed to the higher nodes.

Network model. In the network data model, the concepts of master and subordinate objects are somewhat expanded. Any object can be both a master and a subordinate (in the network model, the master object is denoted by the term "set owner", and the subordinate - by the term "set member"). The same object can simultaneously perform both the role of the owner and the role of the member of the set. This means that each object can participate in any number of relationships.

Similar to the hierarchical one, the network model can also be represented as a directed graph. But in this case, the graph may contain cycles, that is, a vertex may have several parent vertices. This structure is much more flexible and expressive than the previous one and is suitable for modeling a wider class of tasks. In this model, the vertices are essential, and the edges connecting them are relations between them (fig. 6).

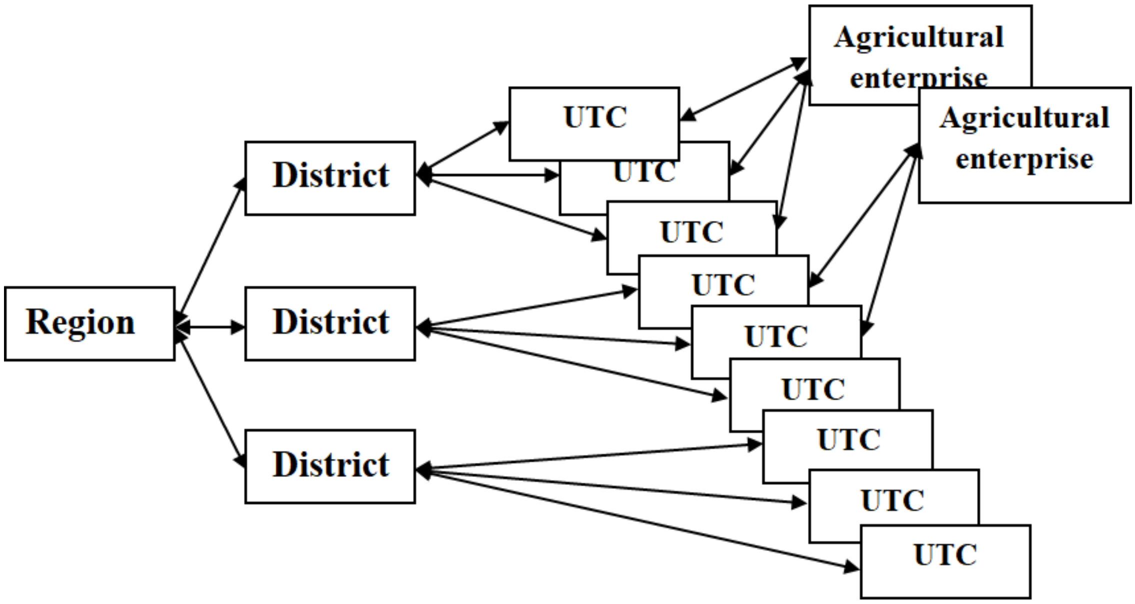


Fig. 6. Scheme of relations between objects in a network database

As complex as the representation schemes of hierarchical and network databases are, it is so time-consuming to design specific application systems based on them. As experience shows, long periods of development of applied systems often lead to the fact that they are constantly at the stage of development and refinement. The complexity of the practical implementation of databases based on hierarchical and network models determined the creation of a relational data model. In the relational data model, objects and relationships between them are represented using tables. Relationships are also represented as objects. Each table represents one object and consists of rows and columns. The table must have a primary key (key element) - a field or a combination of fields that uniquely identify each row in the table (fig. 7).

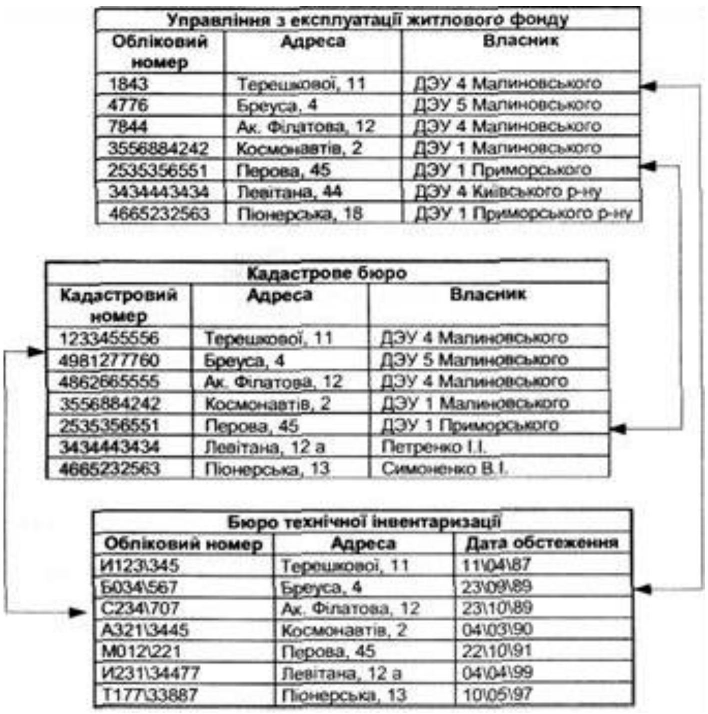
The name "relational" is due to the fact that each record in the data table contains information related to (related) some specific object. In addition, data of even different types in the model can be considered as a whole[31].

The order of rows and columns in the table is arbitrary; a table of this type is called a relation. In modern practice, the term is used for a line "record", and the term "field" for a column[32].

The disadvantage of the relational data model is redundancy in terms of fields (for creating connections between different database objects). Practically all existing commercial databases and software products for their creation use the relational data model.

The object-oriented model is a further development of GIS database technology. In this case, the entire set of data that will be stored and processed in the database is presented not as a set of individual map layers and tables, but as objects of a certain class. An object-oriented model, along with geometric and attributive information, stores the program code that determines the behavior of objects of one or another class when entering and editing, analyzing or presenting data[33].

A database object is a complete entity, for example, a river, a lake, a house, an institution. In addition to the sign on the map and the entry in the tabular database, the object has a defined behavior. A special interface will control the entire process of working with an object of the specified class: check the correctness of the digitization of the object (for example, will not allow the use of a line for digitizing the contour of the house); check the correctness of filling in the tabular database (types and format of data, filling in mandatory fields); to check the topology of different map layers (for example, prohibition of mutual crossing of certain types of objects); check the mutual location of objects on one map layer (for example, places where pipes of different diameters join (necessary adapter), connection of roads of different classes (necessary equipped exit, etc.). Objects have a certain intelligence when organizing requests, analysis, presentation of data, which to a large extent allows automating data processing, creating various data processing scenarios in which most conflict situations will be tracked and corrected without operator involvement.



Управління з експлуатації житлового фонду		
Обліковий номер	Адреса	Власник
1843	Терешкової, 11	ДЭУ 4 Малиновського
4776	Бреуса, 4	ДЭУ 5 Малиновського
7844	Ак. Філатова, 12	ДЭУ 4 Малиновського
3556884242	Космонавтів, 2	ДЭУ 1 Малиновського
2535356551	Перова, 45	ДЭУ 1 Приморського
3434443434	Левітана, 44	ДЭУ 4 Київського р-ну
4665232563	Піонерська, 18	ДЭУ 1 Приморського р-ну

Кадастрове бюро		
Кадастровий номер	Адреса	Власник
1233455556	Терешкової, 11	ДЭУ 4 Малиновського
4981277760	Бреуса, 4	ДЭУ 5 Малиновського
4862665555	Ак. Філатова, 12	ДЭУ 4 Малиновського
3556884242	Космонавтів, 2	ДЭУ 1 Малиновського
2535356551	Перова, 45	ДЭУ 1 Приморського
3434443434	Левітана, 12 а	Петренко І.І.
4665232563	Піонерська, 13	Симоненко В.І.

Бюро технічної інвентаризації		
Обліковий номер	Адреса	Дата обстеження
И123\345	Терешкової, 11	11\04\87
Б034\567	Бреуса, 4	23\09\89
С234\707	Ак. Філатова, 12	23\10\89
А321\3445	Космонавтів, 2	04\03\90
М012\221	Перова, 45	22\10\91
И231\34477	Левітана, 12 а	04\04\99
Т177\33887	Піонерська, 13	10\05\97

Fig. 7. Diagram of relationships between objects in a relational database

Data management in GIS. DBMS, designed for creating and maintaining GIS databases, provide the user with a wide set of functions characteristic of ordinary, "non-spatial" DBMS, as well as a number of special "spatial" functions. These are the functions of creating the structure of new databases in the "designer" mode, changing the structure of existing tabular databases, adding and deleting fields and records, using formulas to fill and change field values, linking two or more tables for data presentation. Some special functions include functions of constructing spatial objects based on coordinate values from tables, determining object coordinates, lengths, perimeters, and areas of objects with recording the obtained values in the appropriate field.

[16] Modern technologies for inputting spatial data into a computer, their interpretation and preservation provide for elemental division of the content of existing maps. To enter, for example, a topographic map, it is necessary to divide it into layers ("themes") of homogeneous information containing data on the relief, hydrographic network, settlements, road network, administrative boundaries, etc. Banks of cartographic data in GIS, thus, contain homogeneous layers of information, which, however, can be combined with each other by means of GIS in a different ratio according to the requirements of the tasks to be solved. Taking into account the fact that the cartographic data bank in GIS can contain hundreds of layers of uniform spatial information, this opens wide opportunities for building primary originals of elemental maps based on layers of uniform cartographic data stored in the computer.

[17] The method of regular networks is usually understood as a manual method of digitizing spatial data by averaging or generalizing the values of the element being digitized in each square of the grid - the average value of the height of the earth's surface, the length of the hydrographic network, the concentration of the pollutant, the predominant type of soil cover, etc. which historically preceded the appearance of automatic methods of rasterization of spatial information, but is still used today. The first examples of the implementation of this method as one of the methods of analytical mapping by V.G. Linnyk (1990), referring to the work of U. Tobler (USA), attributes it to 1951. Today, it seems appropriate to consider the method of regular networks as a way of encoding spatial information within the framework of a raster data model. It should also be noted that recently this method is rarely mentioned in the special literature in connection with the widespread transition to automated methods of creating digital raster maps.

[18] The raster method of spatial data formalization, or the raster model of spatial data, in the simplest case consists in the representation of spatial objects in the form of a mosaic that completely covers the territory. This mosaic is called a raster. Each raster element is called a raster cell or pixel (from the English pixel, which is an abbreviation of risture element - image element).

[19] Square-shaped cells are most often used, although triangular and hexagonal cells are quite widely known. Triangular tessellation is more flexible than quadrilateral and, in principle, is better suited for modeling three-dimensional surfaces. A hexagonal mosaic (with cells represented by equal regular hexagons) is attractive because all neighboring cells are equidistant, that is, the distance between the centers of all neighboring cells is the same, which cannot be said, for example, about square and even more so rectangular raster cells.

[20] Layers of raster information for a GIS database, as noted above, can be prepared manually - by coding information for each raster cell and then entering it into a computer using a text editor or spreadsheets. However, such work can be carried out practically only with a raster size of several tens or hundreds of elements, which is not typical for modern geoinformation systems. The experience of solving tasks related to the assessment of the dynamics of material flows in agrolandscape systems using GIS shows that in many cases the size of the grid cell should not exceed 20x20 m. It is not difficult to calculate that in this case, for a 10x10 km area, the grid will be have a size of 500x500 and contain 250,000 cells. The digital model of the Earth ETORO5, created by the US National Center for Geophysical Data (ETORO5..., 1988), contains more than 9 million surface cells measuring 5x5 minutes in latitude and longitude. Of course, only automatic methods of preparing raster models of spatial data are possible here - with the help of scanners, as well as computer rasterization of vector images. Remote sensing data from Earth's artificial satellites also have a raster structure.

[21] One of the most important elements of maps that affect the accuracy of the representation of objects in space by x, y, z coordinates is the coordinate and height systems. For topographic maps created in the system of cartographic institutions of the former USSR, and later in Ukraine, the Gauss-Kruger coordinate system is used - a system of flat rectangular coordinates and an equiangular cartographic projection with the same name. In the Gauss-Kruger projection, the surface of the ellipsoid on the plane is displayed in meridian zones, the width of which is equal to 6" (for maps with a scale of 1:500,000-1:10,000) and 3° (for maps with a scale of 1:5,000-1:2,000) Topographic sheets display a cartographic frame with both geographic coordinates (degrees/minutes/seconds) and topographic coordinates (meters relative to the origin of the zone coordinates).

[22] Most of such maps are made at a scale smaller than 1:1,000,000 in various cartographic projections and have significant linear or angular distortions. Digitization of such materials requires

taking into account the parameters of map projections, data on which are available in most map editors. In the process of processing such maps, general or local image transformation procedures may be required to link the coordinate system of the data source to the coordinate system of the general database of the GIS project.

[23] Fixation of radiation is performed both using chemical photographic methods and electronic photosensitive elements. In the first case, the image of the Earth's surface is recorded on photographic film, which requires its delivery to the Earth's surface, development and printing of images. The next shooting session requires the launch of a new spacecraft, so nowadays this technology is practically not used on automatic satellites (mainly on manned orbital stations and ships). The main volume of RSE data is produced with the help of electronic devices that photoregister the reflected solar radiation of the so-called devices with a charge connection - PZZ. These devices make it possible to register different wavelength ranges of reflected solar radiation both in the visible and in the ultraviolet and infrared spectral zones. On the basis of such elements, electronic scanning devices are created that can be installed on various spacecraft designed to photograph the atmosphere, ocean and land surface. Processing of incoming information is carried out at ground stations: geometric correction is carried out (angular distortions of edge zones, linear distortions along the survey line, etc. are eliminated); radiometric correction (obstacles arising during recording, transmission and reception of data, atmospheric obstacles are eliminated, illumination is equalized); cutting into sections of a certain size, binding to the coordinate system, etc. Such materials can be given to the customer within a week after the shooting. Many commercial systems can survey a specific area, for which the angle of inclination of the camera or the orbit of the satellite changes. Large archives of digital data are accumulated in information processing centers.

[24] Attributive data in GIS can have different methods and technologies of formalization, processing and presentation. To process text data, methods of their grouping, formalization, and conversion into tabular form are being developed. Automated text recognition methods can be used when processing paper sources. For use in the GIS environment, attributive information is subject to systematization, structuring, and formalization, which allows the use of various automated search, calculation, and visualization tools for its further input and processing. For each type of spatial objects, a set of attributes is selected that allow identifying a specific type of object among others and describe its properties as fully as possible. After defining the list of attributes, methods of their formalization are chosen.

[25] These values can be compared with each other, and various mathematical operations can be performed on them. When using a universal open scale, numbers can take on values from "minus infinity" to "plus infinity", the closed numerical scale is limited to two extreme values that characterize the set of permissible values for some subject area (for example, 0-100%; 0-1 dimensionless units ; 0-360 compass degrees; 0-90 degrees of inclination, etc.).

[26] The entire list of mapped objects is divided into separate thematic groups, the sections of which are hierarchically subordinated. For example, "Classifier of information displayed on topographic maps of scales 1:10000, 1:25000, 1:50000, 1:100000, 1:200000, 1:500000, 1:1000000" provides for the allocation of nine main classification groups, each of which is broken down into standard subdivisions.

[27] In databases, depending on the purpose (enterprise database, municipal database, administrative district or oblast database), various information can be stored and processed: lists of employees of enterprises with their credentials, lists of buildings and their technical characteristics, legal or statistical descriptions of land plots, objects of administrative management, etc. Similarly,

depending on the purpose of the database, the list of objects described in the database may change; composition of attributes describing these objects; method and degree of formalization of attributes; organization of communication between various objects of the database, etc.

[28] The concept of databases can be shown in more detail on the example of a municipal database. The usual set of municipal database is streets, houses and structures, engineering communications, city technical services, subjects of administrative distribution (city districts), etc. The totality of all buildings and structures on the territory of the city can be used as an object; this object is described by a set of parameters containing: address data; belonging to some organization; details of owner organizations; technical characteristics of buildings (floor space, area, construction materials); operational characteristics (current condition, repair dates). Thus, any type of database object can have a relationship with one or more object types. Such connections are called relations. Relationships between objects can be of different types: one-to-one, one-to-many, one-way and two-way. The following are examples of tasks that can be solved with the help of such a database: - given the registration number of the building, it is necessary to find the street address, and vice versa; - given the address of the building, find its owner; - given the owner (land user), find all buildings belonging to him; - find all buildings whose last repair period exceeds 20 years.

[29] for example, an administrative region consists of districts, village and city councils, settlements, etc.); types of relationship (for example, houses are residential, industrial, etc.); relationship of subordination (for example, the governor - the mayor of the city).

[30] The conceptual scheme of the hierarchical model is a set of record types connected by the types of links in one or more trees. All types of relationships in this model belong to the "one-to-many" type and are depicted as arrows. Thus, relationships between objects resemble relationships in a family tree, with the only exception: for each derived (child) type of object, there can be only one input (parent) type of object. That is, the hierarchical data model allows only two types of relationships between objects: "one-to-one" and "one-to-many".

[31] The table has the following properties: - each table element represents one data element; - there are no repeated groups; - all columns in the table are uniform; this means that the elements of the column are of the same nature; - columns are assigned unique names; - there are no two identical rows in the table.

[32] The main difference between searching for data in hierarchical, network and relational databases is that hierarchical and network data models carry out communication and search between different objects by structure, and relational ones - by the value of key attributes (for example, you can find all records, the values of which are in the field "house number" is 3, but the 3rd line cannot be found). Since the relational structure is conceptually simple, it allows you to implement small and simple (and therefore easy to create) databases, even personal ones, the very possibility of which was never even considered in systems with a hierarchical or network model.

[33] Object classes represent a hierarchical structure — they are understood as a common parent class (for example, a workspace), based on the properties of which derivative classes (vector, raster, TIN-spatial data) are defined and described. In turn, the classes of the third, fourth and other lower levels (for example, lines, points and polygons of vector representation of spatial data) are described on the basis of derived classes of the second level. Derived objects inherit all the properties of the parent object, only some specific functions are added to the program code. Objects can be standard for the environment of some GIS software package (defined rules of data processing by specific software modules and functions). The properties and behavior rules of the object can also be defined by the user. When using standard object classes, the user receives a predefined data structure: identifiers, types and sizes of tabular database fields, a set of processing methods.

LECTURE 5
TOPIC 5. SUBJECT: ENTERING AND SUBMITTING INFORMATION IN GIS
(MODULE 2)

Plan

1. Automated data entry.

2. Vectorization.

3. Geocoding.

4. Manual data entry. Hardware and screen digitization.

5. Quality control of creation of digital maps.

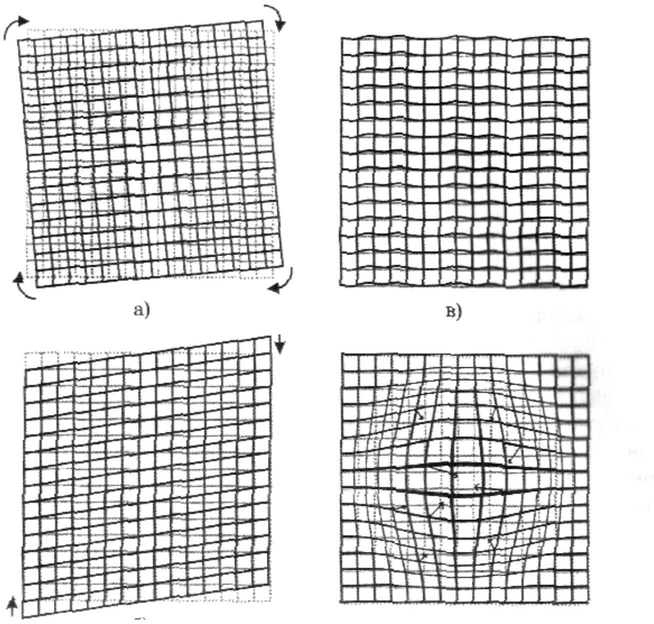
6. Submission of information in GIS.

1. Automated data entry or scanning nowadays is one of the main types of image conversion from paper (film, etc.) types of media into various electronic image formats. The very term "scanning" means that the plane of the original image is viewed sequentially in strips, each strip, in turn, is divided into separate elements[34]. The quality of the scan is determined by the accuracy of the location of the scanning elements of the scanner (the difference between the position of the pixel on the original document and in the electronic file, which can be calculated using special software), and the quality of color reproduction (in most cases, determined by the user's eye).

The process of scanning maps, as a rule, is carried out from the environment of some graphic editor (MapEdit, Easy Trace, Descartes) and allows you to make two main types of transformations: change the number of pixels in the image, change the location of a group of pixels inside the image plane (geometric correction); change the color mode or color characteristics of the entire image or group of selected pixels (brightness and color correction).

Image skew is one of the most common errors that occur in the scanning process. Even slight deviations of fractions of a degree from the baseline at large map sizes lead to linear distortions of several millimeters. This is especially noticeable at the joints of individual fragments when stitching large sheets. In the presence of coordinate grid lines or markers, the skew can be eliminated using the "Rotate the image by an arbitrary value" function. The rotation angle is determined by providing baselines (north-south, frame line, etc.) against which the correction is calculated. If necessary, the entire image field can be rotated 90° clockwise or counterclockwise, or the image flipped 180°. In many cases, it is necessary to create the necessary image from separate fragments. Such stitching can be carried out both in the form of merging individual files, and by assembling "mosaics" from individual files[35].

The affine transformation can correct displacement, rotation and stretching separately along the X and Y axes. All transformations are linear for the entire raster, that is, parallel lines remain parallel (fig. 8 a, b). Three points that do not lie on the same straight line are enough to start the transformation. Polynomial transformation corrects more complex, including non-linear distortions. If affine transformations help to get rid of the incorrect position of the sheet on the plane, then quadratic transformations help to correct bending of the sheet, distortion of the scan, etc. (fig. 8 c, d). To start the transformation, several points are needed, and they should be located as randomly as possible. If, for example, some four points will form a rectangle parallel to the coordinate axes, then the transformation will not work correctly.



c) d)

Fig. 8. Geometric transformations of raster images: *a) affine transformations of angular distortions; b) affine transformations of skews; c) polynomial*

transformations of scanning distortions; d) polynomial transformations of distortions when the sheet is bent.

A scanned image (for example, maps) with an accuracy of 800 400 dpi will create a graphic file up to 50-100 Mb in size. The total size of scanned data for a large city or district can amount to tens and hundreds of gigabytes. Hardware complexes that are used for scanning and preparation of initial map data, must have significant volumes of operational and magnetic memory, graphic accelerators, systems creating backup copies of data on optical media. To reduce the size of files when saving and sending them, various graphic information compression technologies are used, for example, the MrSiD format is used to save and quickly decompress large arrays of compressed graphic data.

2. Vectorization. Scanned raster map materials are used to create vector digital maps. If the quality of the source maps is good (good distinction of lines and contours, absence of background and pollution, clear color rendering), systems for recognizing graphic images and automatically drawing their contours can be used. The procedures of raster recognition and drawing of vector graphic primitives are denoted by the term vectorization. Vectorization can be manual or semi-automatic. Semi-automatic vectorization is mainly used for linear data, point objects are entered in manual mode, polygonal objects are also closed in manual mode.

The process of fully automatic or manual tracing of a line by its image on a raster is called tracing[36]. The vectorization process is controlled by a set of trace parameters that can be combined in a trace strategy. Automated vectorization requires the use of previously prepared raster materials (fig. 9). It is recommended to use materials with pre-separated thematic layers, i.e. the vectorized map should have elements of the same type - relief horizons, river network, roads, outlines of buildings, etc. To increase the brightness and contrast of the raster map, the color inversion procedure is used, in which the white color becomes black, and vice versa colors. In the process of creating vector objects, identifiers are assigned (numbers of pipelines, buildings, street names, relief horizontal heights, etc.). One of the modes of automatic identification is the assignment of height values to the relief horizontal lines, depths and other isolines with an equal step of changing values[37].

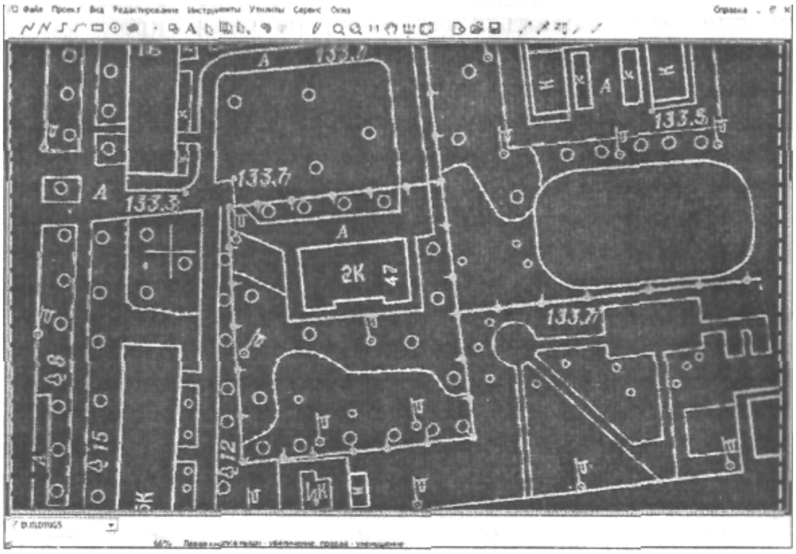


Fig. 9. The working screen of the Easy Trace vectorizer with a section of the city plan

3. Geocoding is a method and process of positioning spatial objects relative to some coordinate system and their attributes. Geocoding requires a tabular set of coordinate data — latitude and longitude, X and Y coordinates, a street address, a spatial database file, in the coordinates of which the location of the point will be searched, as well as the establishment of a point object with specified attributes in these coordinates.

Nowadays, in various GIS packages, functions of address binding of data are implemented using special format files in which information from street networks is formalized (StreetMap, fig. 10, 11)[38].

4. Manual data entry. Hardware and screen digitization. Manual digitization (digitization, digitalization) is currently the most common way of entering spatial data into GIS databases. The process of manual digitization itself is the recognition by the user of an object on the source map and the creation of a vector elemental graphic object by drawing the boundaries of this object. The source map can be used both in the form of a paper original fixed on the digitizer, and in the form of its scanned copy, which is displayed on the display screen in a special map editor. In the first case, hardware digitization is forged, in the second - digitization using a standard "mouse" input device (screen digitization).

Fig. 10. Representation of the street network in StreetMap format

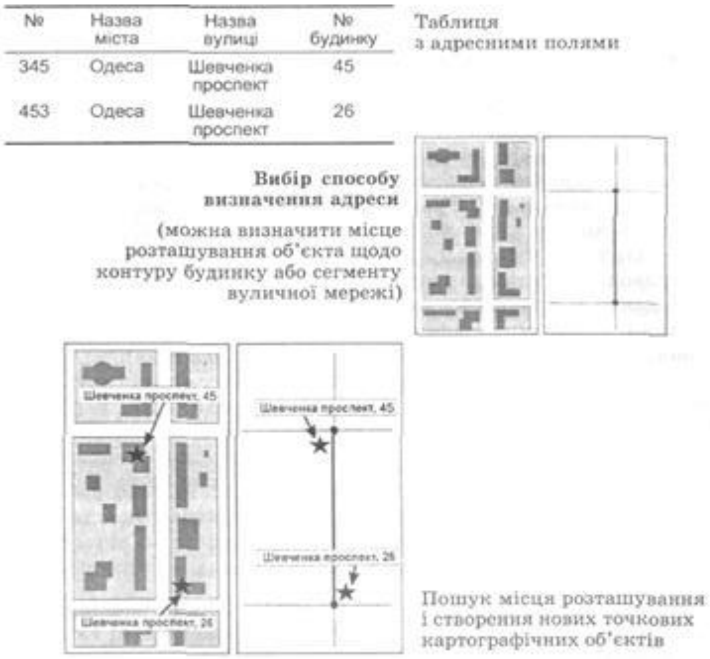


Fig. 11. Geocoding the location of buildings by address binding in the StreetMap database

During hardware digitization using a special device - a digitizer - original paper or plastic cartographic materials of high quality are used. Many GIS software packages include special modules for configuring and controlling the operation of various models of digitizers[39]. When the read button is pressed, the coordinates of the point are recorded in the corresponding active database file; corresponding attribute data is entered by keyboard. The accuracy and speed of data entry depend on the operator's qualifications.

In recent years, due to the high dependence on scarcely available paper originals of maps, the presence of distortions and damage to paper maps, the complexity of editing digital maps, as well as the high cost of the devices themselves, hardware digitizer technologies have gradually been replaced by screen digitization technologies.

During on-screen digitization, the incoming pre-scanned and spatially bound map material is in the background of the screen. One or more derived layers are superimposed on it, within which, visually comparing with the contours of the original objects on the substrate layer, outlines of copy objects are performed.

Thus, before starting work, the scanned substrate map and at least one of the layers previously created on the basis of this substrate should be displayed on the screen. To enter, delete or change some spatial objects, it is necessary that the working layer be edited[40].

5. Quality control of creation of digital maps. Depending on the field of use of digital cards, different requirements are placed on them. Nowadays, two main areas of use of digital maps can be distinguished:

1) as a basis for creating various paper maps or cartographic illustrations;

2) as a basis for spatial measurements, calculations, analysis.

In the first case, the spatial accuracy is determined by the accuracy of the polygraphic print of the created map and depends on the printing method, system of conventional signs, displayed scale, etc.[41].

In the case when the digital map is the basis for calculating distances, areas and volumes in cadastral, construction or navigation GIS, spatial errors can cause significant distortions of the final spatial calculations, which, in turn, leads to errors in the calculation of the value of land plots, the cost of construction , taxation, etc. In such applications, the spatial accuracy is determined by the accuracy of the instrument measurements used (up to 0.1 mm on the ground). Systematic errors in the creation of digital cartographic products arise as a result of various objective and subjective reasons (lack of necessary equipment, inconsistency of the technical characteristics of the equipment with the required accuracy, lack or weak formalization of classifiers of digitized objects, input errors due to unprocessed instructions for inputting various situations, low qualification of operators, lack of control).

Nowadays, the tower of digital maps, especially in non-specialized institutions and organizations, is done manually, so the subjective factor, that is, the qualification of the operator and controller, is the main restraining factor for increasing the number of high-quality digital products. To train a qualified operator for screen or hardware digitization requires several years of practical work with appropriate geodetic, cartographic or geographic education. As a result, the increase in the cost of skilled labor of specialists is becoming an increasingly significant factor in cartographic production. Therefore, the main line of growth in the productivity of digital mapping is the further development of automated input methods: improving the quality of recognition of cartographic images of scanned maps and Earth remote sensing data.

6. Submission of information in GIS. Presentation of information in an understandable and user-friendly form is one of the main functions of any data processing system. Since GIS are mainly focused on the processing of spatially distributed data, they present the processed information in the form of various maps, cartograms, three-dimensional and animated images. Several windows with different thematic maps can be displayed on the display screen for their joint visual analysis; electronic maps are easily scalable with the possibility of automated generalization; special editing tools allow you to quickly change captions, conditional designations and the general composition of the map image. In the presence of a cartographic database, the user gets the opportunity to make quick interactive inquiries about the properties of this or that object with the mouse cursor, make inquiries using mathematical and logical functions, make samples, build thematic maps and map diagrams. The user can ask the information system questions such as: "Which settlements with what total population are located 100 km from the NPP", "Which gardens and vineyards are within a two-hour drive from the city" - and receive answers in map and tabular form.

Due to the ease of construction and analysis of maps in the presence of ready-made cartographic databases, cartographic analysis and data presentation are quite common in such areas of activity as land marketing, delivery of goods and provision of services to the population, territorial management, education, etc.

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[34] The reflected optical electromagnetic radiation of each image element is registered by a light-sensitive sensor, while the color and brightness characteristics are averaged (the image element can now be considered a pixel); depending on the current settings of the scanner, the pixel is assigned a certain code in bit, gray-color, or RGB formats, after which information about the pixel's ordinal

position and color is written to a bitmap graphic file. The material to be scanned must be properly prepared, not crumpled, not have folds or tears. Very worn documents should be glued on cardboard. If necessary, markers can be applied to the document to mark the scanning area or for orientation in relation to the north-south (top-bottom) line. The prepared document is placed on the surface of the scanner (it is fed into the rollers, fixed on the drum). Spatial accuracy when scanning a map depends on the fine details of the source image. For topographic maps, it is usually enough to set 200 or 300 dpi (sometimes 400-600 dpi can be used for automated object recognition systems), 100-150 dpi may be enough for contour or hand-made plans. Depending on the size of the scanning area, color depth and spatial resolution, the size of the final file (for uncompressed TIFF format) is automatically calculated.

35 Stitching of two fragments (one of which is basic) is carried out by different methods, which use the designation of several common points in the image plane, in connection with which the fragments to be stitched should largely overlap each other. Two, three or more common points may be indicated; when connecting fragments, angular rotations, linear or planar image transformations are performed.

36 In various software packages for vectorization, different tracing tools are pre-linked to certain combinations of raster elements. Of course, this is the main tracer designed for tracing solid and dotted lines, as well as a tracer for orthogonal (curving only at right angles), broken, dotted lines, closed rectangular contours, a tool for contouring shaded areas and a tool for contouring filled spots. To start tracing a solid or dotted line in automatic mode, the starting point is marked at in the "correct" area, where no complications are expected for the automatic tracer. To start tracing a dashed or dotted line, you need to specify two adjacent points in sequence, thus specifying a sample step and direction. Additional line tracing operations include: the maximum break distance between line fragments, the maximum angle of rotation of the line and the maximum distance of finding the beginning of another line at an angle from the direction of the previous line, the maximum and minimum thickness of the traced line, the distance between reference points along the line, etc. In the event of a delay, the operator can take control of the vectorization process at any time.

37 For automatic identification, a group of closely spaced lines is crossed out with a perpendicular segment, for which the initial value and the step of changing the values are set. Analyze the sequence of crossing lines and assign values in the order of crossing lines. Known in Ukraine the traffic jam vectors are the Digital package of the state research and production enterprise "Geosistema" (Vinnytsia).

38 The street network of the city is divided into separate quarter segments, for each segment the name of the street, the house number of the starting point of the segment on the right side, the house number of the last point of the segment on the right side, the house number of the starting point on the left side and the house number of the end point are described in the database on the left side of the street. The right and left sides are determined by the direction of digitization of the street segment. When geocoding the address of the house, described by the street name and house number, there is a segment with the required name and the interval of house numbers, then on the corresponding side (even / odd numbers) there is an approximate location of the house based on the difference between the house numbers at the beginning and end of the plot. The size of buildings and possible gaps between them are not taken into account in this method. Using geocoding methods, you can quickly create cartographic databases for information that has a textual coordinate binding. In addition to street address coordinates, there are templates for creating objects (point or planar) based on the names of cities and administrative units, postal district codes, etc. It is necessary to control the identity of the address coordinates in the geocoded database and the coordinate reference database - geographical and topographic coordinates must be in the same numerical format as the basic coordinate system; street names in both data sets should not have different readings, abbreviations; letter identifiers of buildings (for example, building Za) should be stored in a separate field, etc.

39 The map sheet to be digitized is fixed on the surface of the digitizer tablet with the help of pressure bars or a transparent sheet of plastic. At the beginning of the work, the coordinate determination procedure is performed - four or more control points are indicated on the map, their coordinates are entered using the keyboard method, and the error of determining the coordinate system is determined. The extreme angular coordinates of the digitizing area can also be specified to reduce the volume of spatial calculations. Also, within the working area of the digitizer, areas for operations can be allocated, for example, overhead instrument panels. To facilitate the operator's work, special overlay menus of tools for entering and editing spatial objects have been developed for some GIS packages. When moving the digitizer cursor to the menu area, the device automatically switches to the selection of the appropriate tool. A sheet with such a menu is placed on the surface of the digitizer. The operator uses the digitizer cursor to trace the contours of spatial objects, manually or in semi-automatic mode by reading the coordinates of reference points.

40 There are specially developed "tools" for digitizing various types of spatial objects. Depending on the type of instrumental GIS and spatial data model (topological, non-topological, CAD), the set of such tools and the organization of the user interface for working with them can differ significantly. Usually, the tools for digitizing and editing vector data are collected in a special menu of the GIS tool package and duplicated on pictographic menus. Depending on the specific package, a set of such tools may have different components and be marked with different terms and icons. For any active object or group of objects, the operations of copying to the clipboard and pasting from the clipboard to another place of the same map layer or to another layer are available. The object can be moved to another place of the working area by dragging with the mouse cursor. The dimensions and proportions of the active object can be changed, its mirror transformation can be performed vertically, horizontally or diagonally, the object can be rotated by a given angle or an arbitrary value. Simultaneously with the end of entering a graphic object, a new record is created in the linked database. Descriptive information can be entered into the database both directly at the time of entering a spatial object and at any other time manually from the keyboard, copied from other sources, calculated by various analytical procedures, etc.

41 When creating this type of map, you can limit yourself to the visual similarity of cartographic objects, a spatial error of 0.1-0.2 mm is allowed in the visible scale of the map. When creating maps, the amount of spatial error may not be considered a determining factor of quality, sometimes distortions are deliberately introduced into the spatial basis to better reflect the qualitative, illustrative characteristics of the displayed phenomenon or objects.

LECTURE 6

TOPIC 6. SUBJECT: WORKING WITH ELEMENTARY GIS BASED ON PACKAGE MS OFFICE

(MODULE 2)

Plan

1. Justification of the need to use the MS Office package for GIS.

2. Practical application of elementary GIS techniques.

3. Development of elementary GIS environmental monitoring.

4. Positive features of elementary GIS.

1. Justification of the need to use the MS Office package for GIS. The rapid development of informatics in the last quarter of the 20th century brought about a real revolution not only in industrial, but also in scientific and educational technologies. However, there are objective obstacles to the application of informatics in spatial research, namely, the absence or shortage of computer equipment in most institutions and educational institutions, the lack of skills in working with special software adapted for special tasks among managers, scientists and teachers. Another aspect of the application of the developed toolkit is purely strategic, namely the popularization of the idea of GIS among representatives of municipal bodies, small and medium-sized businesses, emergency services and other users who today do not have the financial opportunity to purchase rather expensive special software and train staff to use it.

So, on the one hand, there is a need to keep up with modern information technologies, on the other hand, there is a rather significant problem - the degree of elementary computer training of the average user. Based on this, the goal was to find a synthetic means of simultaneously overcoming computer illiteracy and not straying from the path of the latest information technologies. Geoinformation technologies (GIS), the idea and main content of which were implemented in the fairly common and popular Microsoft Office package, will be considered as "latest".

Initially, the "interface" of the GIS being developed was deliberately simplified. However, in the proposed elementary GIS there is still an opportunity to acquire practical skills of vectorization, binding of attribute information to specific geographic objects in the Word environment, which brings users closer to understanding the internal content of such professional GIS as "MapInfo", "ArcView", "GeoGraf", "GeoDraw" and others.

Elementary GIS is a system that only partially uses the functions of traditional geographic information systems. In our case, there is no coordinate (geographical coordinates) binding of the data, since the map images are built according to the "built-in" settings of the "Page Options". The main advantage of GIS compared to paper maps is preserved in the proposed elementary GIS, namely, the possibility of quick access and visualization of spatially bound information.

The ideology of creating GIS in the text editor "Word" does not diverge from the main theoretical provisions of informatics, cartography and spatial analysis. The so-called graphic environment serves as the basis for the visual presentation of data using GIS technology. In the general case, models of spatial (coordinate) data can have a vector or raster (cell) representation, contain or not contain topological characteristics. Vector data models are built on vectors that occupy part of the space, which determines their main advantage - the availability of an order of magnitude less computer memory for storage and less time spent on processing and presenting information. When building vector models, objects are created by connecting points with straight lines, arcs of circles, and polylines. Planar objects, areas are defined by sets of lines. In vector models, the term polygon (polygon) is synonymous with the word area. Based on the above, the proposed elementary GIS can be attributed to vector non-topological models[42].

2. Practical application of elementary GIS techniques. The first attempt at the practical implementation of the proposed methodological tool was the development of a GIS trade of the region Kryvyi Rih in the text editor "Word". A scanned tourist map-scheme of Kryvyi Rih was taken as the cartographic basis of the GIS with all meaningful information, which was later displayed in separate layers. The set of layers forms the integrated basis of the graphical part of the GIS. The sequence of creating a cartographic base:

The raster image is transferred with the help of a scanner and saved as a separate file with the extension JPG, TIFF or another (that is, the one that the converter perceives when inserting the image into the "Word" field), then it is inserted into the "Word" page and aligned "Centered".

With the help of the "built-in" graphic editor "Word" a geographical (cartographic) basis is created, that is, separate layers (overlays or base maps) are created and saved as separate files, but already with the extension "doc". When working on layers, the graphical capabilities of "Word" are actively used, especially the breakdown of nodes and their modification. At the same time, the requirement that the vectorized object be a "polygon", that is, continuous (closed), and therefore editable, is important. "Binding" to one system of conditional coordinates is performed by the main menu function "Page parameters", which remain unchanged when working with each layer. At the same time, it would be desirable to change the value of binding to the grid in the "Actions" menu from 0.32 to 0.03, which will increase the resolving power of the entire system by an order of magnitude.

Next, an analogy of cartographic generalization is made using the context menu items "Group" and "Order". So, for example, if a lot of objects (points, lines, curves, autoshapes, etc.) were processed when working with graphics, including redundant ones, the appropriate selection is made with the help of the "Group" command. Those objects that need to be grouped into one are highlighted when the mouse is hovered over them while simultaneously pressing the "Shift" or "Control" button, then they are grouped. If it is necessary for the created objects to be edited (primarily for binding hypertext), that is, they can be highlighted when the cursor is placed on them, with the command

The "order" should be to move them "to the foreground".

At the next stage, attribute information is linked to spatially distributed geographical objects using hyperlinks. The main type of such information in our case are tables in which all data about retail outlets are entered: name, address, telephone, specialization, working hours, product range. However, experience shows that such information can be text, a picture, an Excel graph, a sound track, a video clip, or another more detailed map. First, the geographic object to which the information will be attached is highlighted by clicking on it with the cursor. Then the context menu calls up a hyperlink, and then indicates the path to the file to which you need to refer. When calling up the necessary information in the ready-made version, when the cursor is brought to the object, a hand with an extended index finger appears on it.

Creating a cartographic base is the most time-consuming stage. First, a new document is created using the "Create" command, located in the "File" section of the main menu, or on the toolbar. Then a scanned image of the map is inserted ("Insert"/"Image"/"From file..."/(Filename)). An image will appear on the blank field. This drawing is saved in a file with the extension doc. using the "Save" command ("File" / "Save"). Next, it is determined which layers the map will consist of. These are four layers: blocks, streets, street names and house numbers.

With the help of one of the types (types) of lines, the boundaries of the quarters are displayed by drawing lines over the boundaries on the raster image. The scanned image that was used was of high resolution and small size, so the scale is increased to 500% for more convenient work with the document. After completing the mapping of the boundaries of the district, the operation of changing the nodes is performed for better repetition of the contour. For this, the required line is selected and the "Start changing nodes" command is used. To get a better result, you can change the properties of the node by selecting it and pressing the right mouse button (at the same time, a menu with properties will appear on the screen). After all the necessary blocks have been circled, it is necessary to separate these blocks from the scanned map. To do this, highlight the map with the left mouse button, press the right button and when the menu appears, select the "Cut" command. After that, the map will be in the buffer and only quarters will remain on the sheet. Next, all lines are highlighted and grouped. To do this, use the "object selection" button located on the drawing panel to circle all quarters with a rectangle, after which they become selected and then combined with the "Group" command. Finally, the image is saved to a file called "Quarters" using the "Save As..." command (File menu).

The creation of the second layer is similar to the creation of the first, only in it, instead of block boundaries, streets are drawn with lines. Next, the lines are grouped and the color, for example, yellow, line thickness and other necessary attributes are changed in the "Autoshape Format" menu. It is also saved as a separate file called Streets.

The next layer is not like the first two because it consists of street names. First, as in the previous layers, you need to open the file with the raster map and increase the scale. Simple text insertion is not suitable because street names can run vertically or at an angle. Therefore, the Word Art application was used for object labels. To do this, you need to click the "Add Word Art object" button, which is located on the drawing panel, or in the menu - "Insert" / "Drawing" / "Word Art object". After that, you need to choose a simpler type of inscription, write the name of the street in the window that opens, set the font size to 8 and click "OK". The entered street name will appear above the map. Since the map is small, the eighth font is too large, so you need to change the size of the inscription. If you choose the right size, the inscription will fit on the image of the street. But some streets run vertically or at an angle. To correctly place the inscription, the "Free rotation" function is used. When the inscription is set at the desired angle, the "Free rotation" button is pressed again to close the rotation mode. When you are done with all the inscriptions, they are grouped and saved in the "Names" file.

The last layer consists of house numbers. Its creation is similar to the creation of the previous layer. Put numbers on the image of quarters. After finishing work on the layer, the file is saved with the name "Numbers".

So, all the necessary layers are ready. Then they unite. To do this, a new document is created, the "Quarters.doc" document is opened, the grouped quarters are selected and copied to the clipboard. Then an image of the quarter is inserted into the new document using the "Insert" command (main panel). Similar operations are performed with files "Streets.doc", "Names.doc" and "Numbers.doc". In the end, overlapping layers are obtained. Layers are grouped for further image editing. The final map is shown in fig. 12.

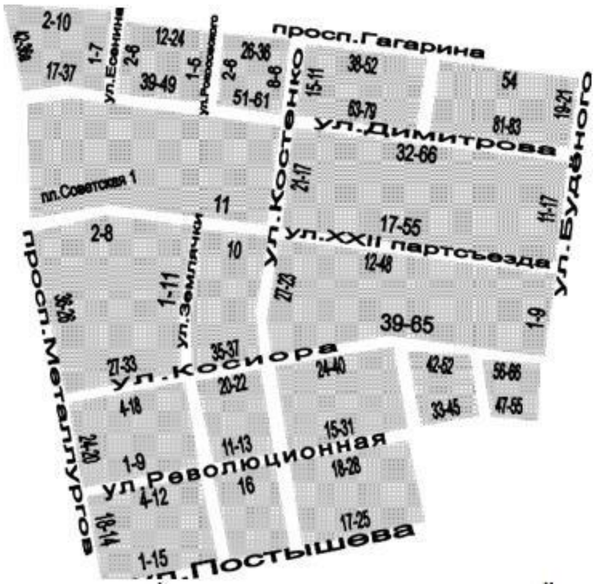

Fig. 12. The final map of the elementary GIS "Trade of the Social City of Dzerzhynskyi district of Kryvyi Rih"

3. Development of elementary GIS environmental monitoring. Further experience in using the proposed methodology was embodied in the development of a geo-information system for environmental monitoring of KryvBas using Microsoft Office tools at the request of the environmental department of the Kryvyi Rih City Executive Committee. The geoinformation system of environmental monitoring of KryvBas consists of 535 files in the format of "MS Word document" and "MS Excel book", located in 75 hierarchically arranged directories.

The starting file of the system is the "List of enterprises" document, which includes a complete, alphabetically arranged list of enterprises for which there is information on atmospheric air pollution. Structurally, the document consists of a table, which includes 5 main and 4 subordinate columns (fig. 13).

The first column has the heading "Enterprise Name". In this column, the enterprises of the city of Kryvyi Rih are located in alphabetical order. The search for the required enterprise in this list can be carried out using both standard search tools in MS Word (Edit⇒Search or keyboard shortcut – Ctrl+F) and with the help of a specially developed ecological map, which has a system of hyperlinks to search objects.

The second column is called "Enterprise Information". Yes, if in this column there is a red letter "I" opposite the enterprise, by hovering over it with the mouse cursor, you can get basic information about the enterprise (name of the enterprise, postal address, surname and telephone number of the head of the enterprise, surname and telephone number of the responsible employee of the environmental protection service, information about the organization that implemented the GDV project, the names of the responsible executors who took part in the development of the GDV draft regulations). In general, you can enter any information here, which can always be displayed on the monitor in the future.

The next column is called "Map Location". (Appendix 2). It allows you to go from the alphabetical pointer to the location of the enterprise on the map.

The fourth column "Project of GDV" indicates the availability of the reference system "Project of maximum permissible emissions" of the corresponding enterprise in the database. The availability of this document is indicated by a check mark. When you move the cursor over this tick, it turns into a palm with an extended index finger. By clicking on this icon with the left mouse button, you can go to the "GDV Project" of the corresponding enterprise. The GDV Project contains general data about the enterprise, characteristics of the enterprise as a source of atmospheric air pollution, and two tables in the "MS Excel Book" format, which contain a list of pollutants emitted into the atmospheric air and a list of pollutants of each structural department of the enterprise. Entering these data into the MS Excel format is conditioned by the availability of specialized tools for statistical and analytical processing of available information and submitted annual "Reports on Atmospheric Air Protection".

The last main column "Report on the protection of atmospheric air" includes four subordinate rows with the names "1999", "2000", "2001", "2002", which should be understood as the presence (indicated by a check mark) of the report according to each year in question enterprises.

The development of the "Reference geo-informational system for environmental monitoring of KryvBas" is based on the methodology outlined above. First, all necessary files and folders were created. Yes, the entire system is in the root folder

"Ecology of KrivBas". Next, in the created folder, you need to create 5 subfolders (subdirectories) with the names "Maps", "Maxi bulleten", "Monthly bulleten", "Projects" and "Zvit". In each of these folders, we create 7 subfolders with corresponding names to the names of Kryvyi Rih districts. For example, "Dolgintsevsky", "Dzerginsky", "Zhovtnevy", etc.

Назва підприємства	Інформація про підприємство	Місце на карті	Проект ГДВ	Звіт про охорону атмосферного повітря			
				1999	2000	2001	2002
КДГМК "Криворіжсталь"	i	M	☑	☑	☑		
Криворізький державний залізорудний комбінат			☑	☑	☑		

Fig. 13. General view of the table "List of enterprises"

In them, we already create the necessary *.doc files with maps consisting of four layers (hidro, forests, squares, industry), and texts with draft standards of maximum permissible emissions (hereinafter abbreviated as GDV), as well as *.xls files with tables statistical data on registered emissions of pollutants from all industrial facilities of the city.

The first district file is created, for example "Sacsagansky". In the "Page Options" dialog box, on the "File" menu, the "Paper Size" tab opens, and the page orientation is selected. Now it is necessary to insert a graphic file with an image of the administrative-territorial division of the district, which was previously scanned and saved on the hard disk. The file is inserted through the following menu "Insert ⇒ Picture ⇒ From file", in the dialog box that appears, you need to find the desired folder and file. The inserted map of the district will act as a background on which the vector map is drawn.

When the boundaries of all districts are ready, names are drawn on the map. When drawing the main hydrographic objects, the stroke technique is used, which was used when drawing linear objects. The method of creating inscriptions of hydrographic objects is the same as when creating inscriptions of city districts. Similarly, layers of forest plantations, neighborhoods and industrial facilities are created (fig. 14).

To create an industrial map of the district, another scanned, specialized map is used as a substrate. The names of industrial enterprises, associations, organizations and institutions are signed, as well as posts of observation and recording of the amount of discharged pollutants.

To work with the "Statistic" folder in MS Excel spreadsheets, a general table template is created: the required boundaries are outlined using the tool "Borders" on the toolbar, set the desired size of cells by dragging their borders using the left mouse button, and set the desired cell format by clicking with the right mouse button on the selected range of cells and selecting the necessary actions from the context menu that appears, and further - from the dialog box. These changes are saved in a file called "Report Template". After entering data on the amount of harmful substances released into the atmosphere by each industrial facility in the city of Kryvyi Rih, save this file by entering the main menu "File ⇒ Save as" and choose a name according to the name of the industrial object There will be many such tables, so they were there for greater convenience systematized and listed in such folders as "daily", "monthly" and subfolders "1999", "2000", "2001"; "January", "March", "September"; "1", "15", "30", etc.

To work with the texts for the "GDV" folder, a new file is created in the text editor MS Word, where the necessary texts scanned and recognized in the FineReader program are inserted using the menu "Insert ⇒ File" - "Draft of the GDV standards of pollutants in the atmosphere". The project contains the following information:

1. General information about the enterprise (name, address, telephone, surname, name and patronymic of the head of the enterprise, the name of the responsible

employee of the environmental protection service, information about the organization that implemented the GDV project).

2. Characteristics of production (structural composition of production).

3. List of pollutants emitted into the atmosphere.

To link the files with information about the industrial facilities of the city and their markers on the maps, a file named "Ecology of Krivy Rig" is created in the root folder "Startfile.doc" is the main active file of this GIS in the text editor MS Word.

A general map of the city is inserted here via the "Insert ⇒ Picture ⇒ From file" menu Kryvyi Rih, where all districts are marked with punches. Each punch is hyperlinked to the corresponding file. The required punch is selected by pressing the Ctrl+K keys or selecting the "Hyperlink" item in the "Insert" menu, further in the box "Overview" is where the necessary file is located, a checkmark is placed opposite the inscription "Use relative path for hyperlink" and click OK.

Next, on the "Drawing" panel, select the "Object selection" tool, select the entire map of Kryvyi Rih (this applies to each district separately), by moving the cursor to the upper left corner and lowering it to the lower right corner, so that all elements are covered by a rectangle. Now the item is selected in the "Actions" menu "Group". In this way, all graphic objects of the map are grouped, which makes them one whole. This allows you to copy an entire map to the clipboard, paste it into another document, or create a map of a specific size, all by simply resizing in the menu "Auto shape format". Now it remains only to save all the changes made in the file and close it. However, grouping map objects into a single whole does not mean that the map will become unedited. To enter additional information, you can place it on the second level (layer) or in the "Actions" menu on the toolbar "Drawing" select the item "Ungroup" and add or remove unnecessary elements from the layer.

4. Positive features of elementary GIS. Summing up, we can say that the proposed method combines the features of a geographic information system and, separately, of an electronic map. Taking into account the attention paid to the solution of regional problems, local history work, as well as in the conditions of a shortage of cartographic support, thanks to the proposed methodology, it is possible to constantly restore and replenish thematic maps both in paper and electronic form.

A positive feature of the proposed method is a certain simplicity of replenishment and linking with the geographical basis of new attributive information. However, this feature can also be considered a disadvantage. For example, if the objects are "opened", that is, capable of editing, then any average PC user can "steal" (copy, print) this software product. In our opinion, this is not the case at all.

Fig. 14. Layers of Saksahansk district: *1) hidro; 2) forest; 3) squares*

The last feature is the most valuable and to some extent can to be regarded as an advantage, because thanks to it an entrepreneur, scientist, university teacher, civil servant can constantly replenish the cartographic and attributive GIS database. In addition, the proposed elementary GIS can become a reliable tool for the production of high-quality demonstration maps for scientific articles, reports, presentations in vector graphics mode.

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[42] The cartographic-geographical aspect of the methodical approach outlined in this section is that the main source of spatial presentation of geographic information is an electronic map that can be scaled in different directions, edited, completed, modified. In addition, the main positive feature of the proposed elementary GIS is the ability to read spatially distributed data from the map, which, according to S.M. Serbenyuk, one of the pioneers of electronic cartography, gives an additional qualitative increase in the perception of any phenomenon or process.

LECTURE 7

TOPIC 7. ANALYTICAL CAPABILITIES OF THE INFORMATION SYSTEM

(MODULE 2)

Plan

1. The main methods and techniques of spatial GIS analysis.

2. Correction of individual layers of the thematic map and topographical basis.

3. Organization of hyperlinks.

4. Work with the buffer.

5. Use of spatial statistics.

1. The main methods and techniques of spatial GIS analysis. The analytical capabilities of modern instrumental GIS packages include several dozen different procedures, which together make up a powerful arsenal of spatio-temporal analysis and modeling. They are divided into the following groups:

- cartometric operations;
- selection operations;
- reclassification;
- cartographic algebra;
- statistical analysis;
- spatial analysis;
- overlay analysis;
- network analysis.

In addition to the above, in packages focused on tasks related to environmental problems, including ecological ones, the following are allocated to a separate group:

- analytical procedures based on a digital terrain model;
- spatial interpolation operations, the task of which is the construction of continuous surfaces based on sets of discrete spatially coordinated data.

Most analytical procedures are based on a raster model of spatial data. their implementation is carried out using cartographic algebra operations. Within the framework of the vector model, analytical procedures are implemented using analytical geometry algorithms.

Cartometric operations, that is, measurements on maps and other geoimages using software, are one of the most common types of analytical operations in GIS. The possibility and accuracy of measurements is largely determined by the data model (vector or raster), measurement methods, and accuracy of data digitization (spatial error for vector objects, raster cell size, etc.). Most often, measuring operations in GIS packages are implemented as special functions and presented as a separate menu item. Such functions include:

- measurement (determination) of point coordinates;
- measurement of distances between two specified coordinates (with or without taking into account the three-dimensional coordinate system);
- measuring the length of a straight or broken line;
- measuring the length of the perimeter of the polyline:
- measuring the area of the landfill;
- measurement of volumes using the surface and cutting plane.

Coordinate measurement. The technology and accuracy of measuring the coordinates of a point (which exists as an object on a digital map or a cursor on the map plane) are determined data model and the used coordinate system. When creating digital maps, as a rule, the following coordinate systems are used.

1. Two-dimensional Cartesian coordinate system - the starting point is the zero point in the lower (or upper) left corner of the map plane, X and Y coordinates can only have positive values. This coordinate system is typically used in raster digital or scanned maps. In most cases, such coordinate systems are created by the user for local projects.

2. Two-dimensional Cartesian coordinate system - the starting point is the zero point, the X and Y coordinates can have both positive and negative values. Two global coordinate systems, built according to this principle, have become widely used - geographical with the zero point at the intersection of the equator and the Greenwich meridian; units of measurement - angular degrees-minutes-seconds; and a

topographic coordinate system with a zero point also at the intersection of the equator and the Greenwich meridian; units of measurement - meters.

3. Three-dimensional spherical coordinate system — the beginning of the X and Y reference from the zero point at the intersection of the equator and the Greenwich meridian, the X and Y coordinates can have both positive and negative values, for coordinate 2, the reference is made from the geometric center of the ellipsoid of rotation[43].

The coordinates of the points in the vector representation are measured and presented to the user in a certain format - hexadecimal degrees, decimal degrees, meters with a specified number of decimal places. For polygonal objects, the extreme values of X and Y coordinates, the coordinates of the geometric center (centroid) of the polygon are determined. The coordinates of the central point of the raster cell are determined in the raster representation of spatial data.

Measuring distances. Most GIS packages include a special "Ruler" or "Roulette" tool that allows you to measure the shortest straight line or along a complex route. Distances can be measured:

- along the shortest straight line with or without taking into account the sphericity of the earth's surface ("by air");

- along a given route using turning points;

- according to the given route, taking into account the unevenness of the terrain ("by land").

As part of raster GIS packages, distance measurement is implemented in the form of an analytical function Distance, which allows you to build maps of fields of equal distance of raster cells relative to one or more objects. The measurement of distances taking into account the unevenness of the relief can be implemented when using a map of the field of equal distances and a digital model of the relief.

Measuring the lengths of lines and perimeters of polygons is in many ways similar to measuring the distances between two or more points. This procedure is usually implemented as a separate function (Object Length, Perimeter), available when building spatial queries or when performing calculation operations in cartographic databases. With the help of this function, it is possible to search for linear objects of a certain length, as well as automatically determine the length or perimeter in the specified measurement units and place the result in the specified field of the database.

Determination of the lengths of lines and perimeters can be performed both with and without taking into account the sphericity of the Earth's surface[44].

Measurement of areas. Measurement of the area of vector and raster polygons is performed using the special function Area. Area measurement can be performed both with and without taking into account the sphericity of the Earth's surface. With the help of this function, it is possible to search for polygons of a given area, as well as automatically determine the area in the given measurement units and place the result in the specified field of the database[45].

Measurement of volumes is performed using digital terrain models. The user must specify the level of the horizontal dissecting plane in the units of the digital terrain model. The simplest volume measurement procedures determine the volumes bounded by the earth's surface from below or above, which are placed below or above the cutting plane. Usually, this method is used to determine water volumes in reservoirs at different levels of filling. Methods of calculating volumes by comparing the levels of two surfaces characterizing geological or soil layers are also quite common[46].

Selection operations help the user to get exactly the information he needs at the moment of working with GIS. The selection of the necessary part of information from one or more cartographic databases is carried out using queries.

Queries are one of the main tools of almost any GIS package, with the help of which the user receives information from the database. As a rule, with the help of various query organization tools, the user formulates requirements for information that must be extracted from the general array of available data and presented in a certain form.

Depending on the nature of the required information, requests can be organized both by location (by coordinates and relative position of objects) and by attributes (identifiers, classifiers and text descriptions stored in the attributive database). Depending on the type of request and the list of parameters involved in the request, its organization is carried out using different sets of tools. During the execution of the request, there is a search for objects that meet the given conditions; objects that have the necessary properties are included in the selection, which can be presented both in the form of a table in a separate screen window, and in the form of a map on which the selected objects are marked with a specially defined color or hatching. To participate in queries, the map layer properties must specify that sampling is allowed.

The selection can be copied to another data file, used to change the graphic variables of the selected objects or the contents of the database fields.

The main location query tool in most GIS software packages is the large arrow on the pictographic menu button. With the help of this tool, map objects are defined and activated during editing. When this tool is held over the object for a certain time (2-5 s), a text message about the object's attributes is displayed on the screen (usually the contents of the first text field or, possibly, setting to another field, or using a combination of field contents are displayed).

The standard tool for requesting the attributes of a single object is the Info (i) button, while a special information window appears on the screen, in which the content of the entire record corresponding to the selected object is displayed.

Similarly, group spatial samples can be organized using the construction of dissecting frames. When selecting objects in a rectangular area, all objects whose center points (for lines and polygons) are inside the frame will be included in the final sample, that dissects Similarly, sampling occurs in the radial area, the radius of the area is usually displayed in the status bar of the program screen. To search for objects that are within the territory of a larger polygon, sampling in the area of an arbitrary shape is used. When pointing to a certain polygon of one layer, all point, linear or polygonal objects of other layers located on its territory are included in the sample.

When organizing spatial samples using different layers, different functions for determining the relative position of spatial objects are used. Spatial position is calculated relative to individual objects, groups of objects, or the entire set of objects of the specified layers. The following functions are available in many GIS packages (fig. 15):

- *fully contains* - the sample includes all objects within which the objects of another layer (a) are completely located;

- *partially contains* — the sample includes all objects within which the central points of objects of another layer (b) are located;

- *completely contained* - the sample includes objects that are completely inside the objects of another layer (c);

- *partially contained* - the sample includes objects whose central points are inside the objects of another layer (d);

- *intersect* - objects of the same or different layers have at least one common point on the boundary (e);

- *are at a certain distance from the border* (line, point) of another object on one or different layers (a buffer zone of the appropriate size is being built) (f).

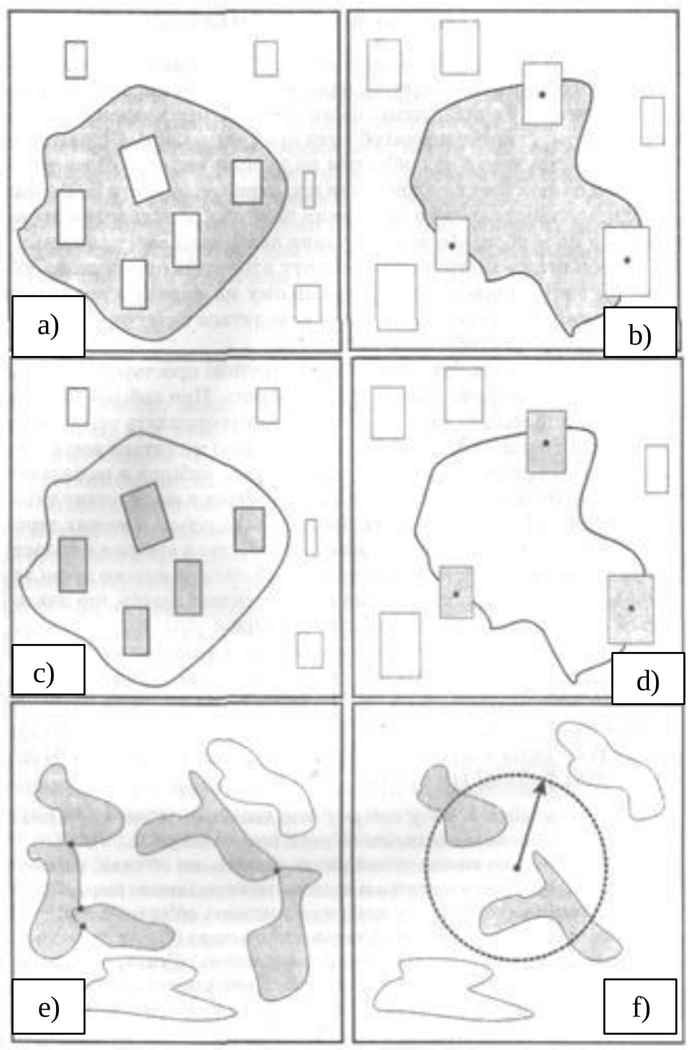

Fig. 15. Methods of organizing spatial samples

Building a query based on the attributes stored in the records of the relational database is performed using special programming languages - universal (ZOC language of structured queries) or a GIS package. Usually, a query is an expression written in a special editor or query construction line; the query text can be saved for reuse. The query uses the field names of the attribute database, operators and functions.

The data to be searched for is determined by the name of the map database file and the name of the field in this database; as a rule, a list of available field names is offered[47].

When constructing query texts in the SQL language, operators and functions of one of the versions of this language for working with DBMS are available to the user. Here, it is possible to search in two or more tables at the same time, linking the fields of different tables. With the help of SQL queries, it is possible to perform a search in remote databases that store data in various file formats, obtain a sample built according to a given condition, and save the received information in the internal format of a specific GIS package.

Reclassification is a widespread operation in practice, the essence of which is to change the content of a raster map either based on the characteristics contained in another map (or maps) from the existing database, or obtained as a result of spatial analysis, or, finally, based on a formulated condition. The operation is used to create new layers of spatial data for a given territory based on an already existing digital cartographic base. By means of reclassification, thematic maps that have an independent scientific or applied value can be constructed, for example, maps of ecological and technological groups of lands, constructed on the basis of a map of the steepness of slopes, or a map assessments of people's living conditions for mountainous areas, constructed by reclassification of the digital terrain model, etc.[48].

Most of the analysis procedures in the GIS environment that are performed with raster spatial data are performed using cartographic algebra operations. Cartographic algebra operations are divided into local operations (int operation), neighborhood operations, or focal operations, area operations, and global operations (map operation). Cartographic algebra operations are implemented using a set of operators that are executed by entering commands written using certain construction rules. In general, these commands have the form: Result = operator (expression), where Result is the resulting map; operator - one of the cartographic operators algebra; an expression is a map, or an operator, or a sequence of operators.

A necessary condition for performing operations with several map layers is the coincidence of the spatial attributes of these layers - the number of rows, the number of columns, the size of raster cells, coordinate systems and map projections used.

Local operations. The class of local operations contains functions that affect map layers "cell by cell", that is, on individual cells of one or several maps. Cell properties change based on the contents of those cells or vertical flow material through these cells. The operations do not depend on the properties of the surrounding cells and for each cell the new value is calculated based on the values in that cell in to one (or more) of the map layers.

The simplest local operations are arithmetic, trigonometric, exponential (exponential) and logarithmic functions applied to the cells of one or more layers of data. Rounding operators, comparison operators, and conditional operators are simple. The same group of operators includes Boolean (logical) operators, map recoding operators according to user-defined algorithms, and random number field generation implemented in GIS packages with advanced analytical capabilities.

Below is a brief description of the operators of this class that are most often used in modern instrumental GIS.

Arithmetic operators:

+ - addition operator;

— - subtraction operator;

* - multiplication operator;

1,0	1,2	1,5	1,9	2,1
1,4	1,3	2,0	2,9	3,3
1,5	1,6	3,2	3,5	3,6
2,0	2,8	3,7	4,8	5,1
2,9	3,2	4,5	5,3	5,5

+

2,2	3,6	4,4	4,0	4,9
2,3	2,8	3,0	3,3	4,5
1,6	0,6	1,2	2,5	3,3
1,3	1,1	2,4	2,7	3,0
0,9	1,0	1,7	2,1	2,5

=

3,2	4,8	5,9	5,9	7,0
3,7	4,1	5,0	6,2	7,8
3,1	2,2	4,4	6,0	6,9
3,3	3,9	6,1	7,5	8,1
3,8	3,2	6,2	7,4	8,0

Fig. 16. An example of a local mapping algebra operation (addition operation)

/ - division operator;

** - exponentiation operator.

Comparison operators:

(>) - "more" operator;

(<) - "less than" operator;

(≥) - operator "greater than or equal to";

(≤) - operator "less than or equal to";

(=) - operator "equals";

(≠) - the "not equal" operator.

Logical operators are Boolean operators, algebra - the branch of mathematics that studies the laws of algebra two values Researched for the first time George Boole, an English mathematician and logician of the 19th century. The general view of the Boolean operation: Logical algebra operators can form complex logical functions based on the laws of commutativity, associativity, and distributivity.

The result of logical operations is a map that contains only logical "1" and/or "0". The most commonly used logical operators are and (logical "and"), or (logical "or"), not (logical "not"), and some others. The spatial interpretation of logical algebra operations is shown in fig. 17.

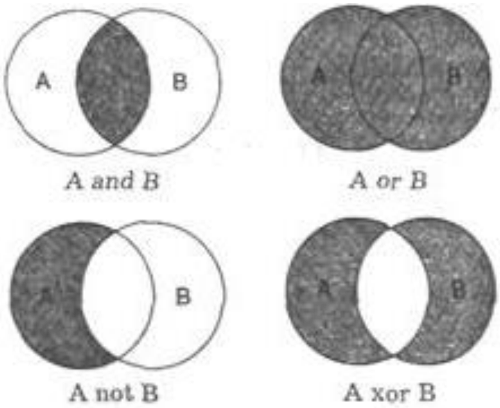

Fig. 17. Spatial interpretation of the operations of logical algebra (darkened areas show areas where the result of the operations is "1", light areas show "0")

Operation A and B has a result of "1" in those locations (cells of the raster) where there are objects A (for example, non-eroded soils) and B (for example, areas with a slope of the earth's surface not exceeding 3°) at the same time.

The operation A or B ("or", which does not exclude) has a result of "1" in those locations where there is object A or object B, including parts of the territory where these objects are present at the same time (for example, for sections of the studied territory with non-eroded soils or with a surface slope of less than 3°), fig. 18.

Commutativity	**Associativity**	**Distributivity**
A and B = B and A	A and (B and C) = (A and B) and C	A and (B or C) = (A and B) or (A and C)
A or B = B or A	A or (B or C) = (A or B) or C	A or (B and C) = (A or B) and (A or C)

Fig. 18. Operators of logical algebra based on the laws of commutativity, associativity, and distributivity

The operation A not B has a result of "1" for a part of object A that does not coincide with object B (for example, for areas with non-eroded soils that have a slope of 3° or more).

Operation A or B has a result of "1" for objects A or B, with the exception of areas where these objects are present at the same time (for example, for areas of the studied territory with non-eroded soils or with a surface slope of less than 3°).

For logical functions without parentheses, the following order of calculations is used:

- calculate negation operations;
- calculate logical multiplication operations;
- calculate logical addition operations.

The order of actions can be changed using round brackets.

Algebraic operations include the operations of converting the contents of raster cells using such algebraic functions as exponent (with selection as an independent operator for calculating the square of a number and the square root of a number), logarithmic (using both decimal and natural logarithms), exponential, integer part number (implemented by discarding the fractional part or by rounding rules), the absolute part of the number, the sign of the number and some others. The same group should include the operations of generating random surfaces subject to a certain law of distribution, including, as a rule, normal, exponential and uniform.

Of the trigonometric operations in GIS, as a rule, the main direct and inverse trigonometric functions are implemented: sine (sin), cosine (cos), tangent (tg), cotangent (ctg) and, accordingly, arcsine (arcsin), arccosine (arccos), arctangent (arctg) and arccotangent (arcctg).

In *neighborhood operations* (focal operations), the content (properties) of a raster cell is mapped to the content (properties) of surrounding cells and changes according to a certain rule, either based on the properties of surrounding cells, or depending on the characteristics of the flow of material from neighboring cells. In this case, for each cell, a new value is calculated based on the information contained in one or more map layers in the cells spatially associated with the data, and stored in the new map layer[49].

Let us consider the above mentioned types of neighborhood operations in more detail. Operations in a sliding (or changing) window. They consist of performing certain operations in a rectangular window that moves along the raster, assigning the result to the central cell of the window at each step.

There are two groups of operations in the sliding window. The first group includes the operations of calculating some statistical parameters from the values of the cells entering the window. For these operations, the size of the square window is defined by the user and is not limited by the total number of cells. This group includes operations performed by such operators as:

- determination of the minimum value in the window (minimum);
- determination of the maximum value in the window (maximum);
- determination of the difference between the largest and smallest values in the window (range);
- determination of the sum of all values in the window (total);
- determination of the average arithmetic value in the window (mode);
- definition of the value that appears in the window most often;
- definition of the value that appears in the window least often:
- determination of the number of unique values in the window and some others.

The second group of operations in the sliding window includes operations in a fixed window with the size of 3x3 cells, which are used to calculate the morphometric characteristics of the topographic surface. A digital relief model is used as the source map in this case. The operations of this group include operations for calculating slopes, exposures, surface curvature and building maps of local current lines.

Distance operations determine the path between the considered (target) and other raster cells. At the same time, the path can be determined in two ways: as the shortest distance between cells or along streamlines using a map of local streamlines. At the same time, in both the first and second cases, costs for overcoming each cell (friction) can be taken into account.

The visibility analysis operation uses a source height map (a digital terrain model) that determines the cells that are in line of sight from the datum.

Zonal operations of cartographic modeling consist of operators that calculate a new value for each cell as a function of the values of the cells that are included in the same area (zone) as the currently considered cell (fig. 19). These operations provide aggregation of cell values within territorial units (areas) of the map in question. For each cell of the considered territorial unit, a statistical value is calculated based on the values of the cells of the original map. This value is assigned to all cells of the resulting map belonging to one (given) territorial unit (zone, range)[50]. The general command format of most zonal operations is as follows: Result = operator (expression, area classes), where Result is the resulting map; the operator is one from zonal operators; expression - a map of the variable with which actions are performed (the area is calculated, the average value, the number of unique values is found, etc.), habitat classes — a map of the spatial distribution of some classes of spatial habitats (soil, vegetation, landscape, administrative or economic units).

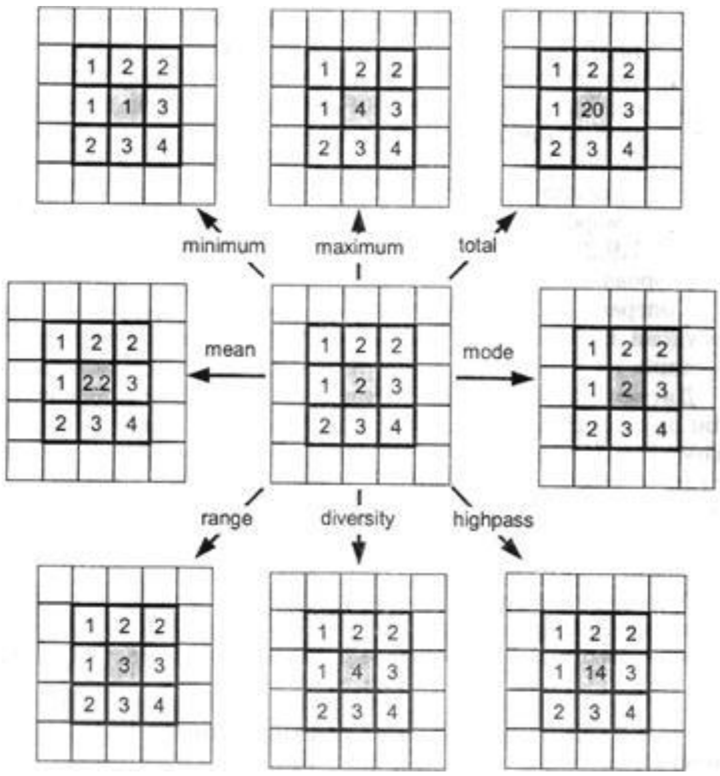

Fig. 19. Operations in a sliding window with a size of 3×3 cells

Global operations are performed when the object class map is represented by one object distributed over the entire area. The result of the global operation is a number - a function of the values of all cells that do not contain missing values. Global includes such operators as:

- calculation of the total area of cells;

- calculation of the sum of the values of all cells;

- calculation of the average value from the values of all cells;

- finding the maximum or minimum values from the values of all cells;

- determination of the area and length of the raster cell and some others.

The general format of a global operation is: Result = operator (expression), where Result is the resulting map; operator - one of the global operators; expression is a variable map. The result of global operations is assigned to all cells of the new map with the same spatial attributes as the original map.

Modern instrumental GIS have various possibilities of statistical analysis. Statistical analysis functions are implemented as their own operators and displayed in the main menu. In a number of packages, including the MapInfo package, which is widely used in Ukraine, statistical analysis functions are implemented using the company's office package (MS Excel), with which they are fully compatible.

The most frequently implemented statistical analysis operations within GIS packages include the following:

- calculation of statistical parameters of the spatial distribution of the variable represented on the map — mean, root mean square;

- deviation, dispersion, minimum and maximum values;

- construction of histograms of the spatial distribution of the variable for the entire territory or part of it in graphical and tabular form with the possibility of specifying the number of intervals and/or the width of the intervals by the user.

In packages with advanced analytical capabilities, the set of statistical analysis operations is significantly expanded, including:

- determination of statistical parameters - mean, root mean square deviation, minimum and maximum values, range of fluctuations of the sample population formed on the basis of the map according to the given mask;

- linear regression of spatial distributions of two variables with construction of a regression graph;

- multiple linear regression of several spatial variables (geoimages);

- linear regression of two logarithmically transformed spatially distributed variables;

- construction of the trend surface of the geoimage using polynomials of the first, second and third order, the parameters of which are determined using the method of least squares;

- calculation of the characteristics of "one-step" spatial autocorrelation - Moran's statistics / for the entire geoimage or its parts specified by the mask map;

- comparison of two spatial distributions and assessment of their correspondence to each other;

- normalization of the spatial distribution of the quantitative variable using the previously calculated arithmetic mean value and root mean square deviation - by subtracting the mean value from the value of each cell and dividing the resulting difference by the root mean square deviation;

- generating the spatial distribution of a random variable subject to linear, normal and lognormal distribution laws.

The methods of spatial analysis can, in fact, include the vast majority of procedures of the analytical block of modern GIS, namely: construction of buffers, analysis of geographic coincidence and inclusion, analysis of proximity and zoning of the territory using Thyssen-Vorony polygons.

Construction of buffers. Point, linear and territorial objects can be used to build new territorial objects, the borders of which are at a certain distance from the original ones. These new territorial objects in GIS technology are called buffers. Buffers can be built around point (drinking water well, concentrated source of pollution, etc.), linear (river, highway or railway route, oil pipeline, etc.) and spatial (territorial) objects (domestic waste dump, reservoirs, forest massif, etc.). (fig. 20).

Around the point object, the buffer will form a circle with a radius defined by the user or calculated according to the specified rule using a set of characteristics.

For linear objects, the buffer forms strips adjacent to them, containing the territory that lies within the defined distance from the linear object. Again, the distance can be specified or calculated. It is possible to set buffers of variable width and distance from the linear object, proportional to some attributes.

For a spatial object, the buffer can be built outside the original spatial object or inside him Buffer sizes can be constant or determined automatically according to some rules.

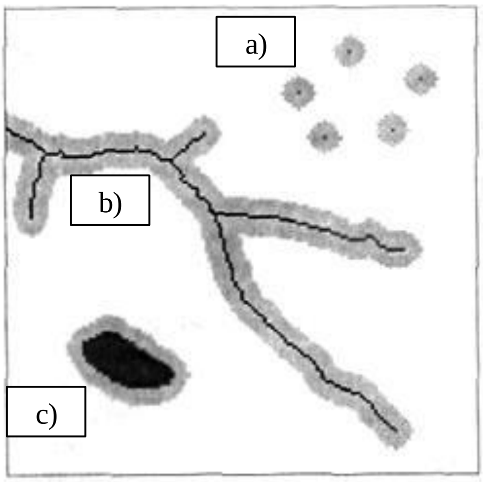

Fig. 20. Buffers around point (a), line (b), and spatial (c) objects

The analysis of geographic coincidence and inclusion consists in determining the mutual placement of point, linear and spatial objects. The options are:

- determination of the location of all point objects (for example, meteorological stations) located within the territorial boundaries

object (for example, administrative region or river basin);

- identification of all linear objects (for example, main pipelines) within the boundaries of a territorial object (for example, an administrative region);

- definition of territorial objects (for example, reservoirs, landfills of household waste, massifs of forest plantations) lying within the boundaries of other territorial objects (for example, the territory of a city, a river basin).

This procedure is often used together with the buffer construction procedure to find objects falling within the buffer zone.

Proximity analysis. The task of this type of geographic analysis is to search for objects located at a certain distance from the initial object. The results of the analysis can be used for further processing. Conceptually, this procedure is similar to building a buffer "on the fly" and does not require the development of a new map - the buffer map.

Proximity analysis involves, for example, searching all buildings containing hazardous materials within 300 m of the fire. This procedure can also be used, for example, to detect all elderly people, as well as other people with chronic respiratory diseases, who fall into the smoke zone and need to be evacuated from the fire, etc.

Territorial zoning with the help of Thyssen-Vorony training grounds. Thyssen-Vorony polygons are polygons built around a network of point objects in such a way that for any position within the polygons, the distance to the central point object is always smaller than to any other object of the network under consideration.

The construction of Thyssen-Vorony polygons (polygons) in practice is one of the main operations that divide the territory under consideration into a set of areas that determine spatial associations and interactions. This type of analysis is widely used for surface segmentation based on user-defined criteria and attributes. As an example, we can cite the task of determining the distribution areas of observation data on a network of meteorological stations unevenly located within the considered territory (fig. 21).

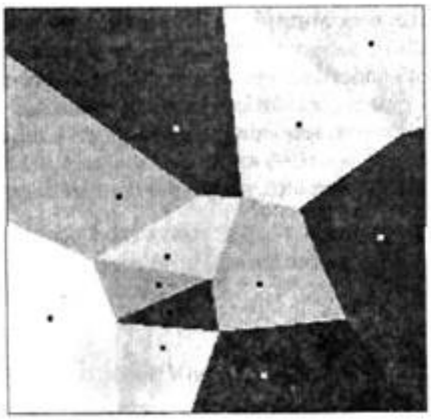

Fig. 21. Thyssen-Vorony polygons constructed for a non-uniform network of point objects

When presenting the analytical capabilities of GIS, overlay operations or overlay analysis are usually called, among others. As a rule, this means the operation of "overlaying" two or more layers on each other, resulting in a graphic composition, or a graphic overlay, of the original layers or one derivative layer containing a composition of spatial objects of the original layers; the topology of this composition and the attributes are arithmetically or logically derived from the topology and attribute values of the source objects in the topological overlay. Different types of spatial objects can be used in compatible overlay operations: point, line and polygonal [51].

However, overlapping of two polygonal layers is most often observed.

Relief analysis. Before proceeding to relief analysis procedures in GIS, which are based on digital relief models, it is necessary to define the concept of "digital relief model" and consider the methods of building digital relief models, because due to the irregularity of the topographic surface and the limitation of available data for its construction, this task is not trivial Under the digital model of the terrain - DEM, although the latter term is not accurate, since its literal translation from the English language is the term "digital terrain model" - in geoinformatics, it is usually understood as a digital representation of a topographic surface in the form of a regular network of cells of a given size or an irregular triangular network. These two forms of presentation of the DEM are nowadays mutually convertible and have practically the same possibilities for presentation and analysis of the terrain.

It is known that in geomorphology and cartography there are slightly different approaches to the interpretation of this concept. The definition of the DEM according to these approaches usually includes the form of input data and the method of calculating the field values at given points. Thus, O.V. Pozdnyakov and I.G. Chervanov (1990) call a digital (more precisely, structural-digital) relief model a model formed by a discrete array of numbers that describes the spatial position of characteristic points of framework lines (thalwegs and watersheds) of the same order. In cartography, the DEM of any geographical field, including relief, is understood as a certain form of presentation of initial data and a method of their structural description. This allows you to calculate (restore) the value of the field in a given area by interpolation and/or extrapolation (Serbeniuk, 1990).

It seems that from the point of view of the analysis of territorial natural or natural-economic complexes and the solution of applied tasks related to the environment by means of GIS technologies, the first definition is better. It interprets the DEM as one of the layers of the GIS information block, which contains digital information about topographic surface markings in the form of a raster or TIM model. In this case, the form of presentation of the initial data on the relief and the method of restoring the values of the topographic surface by raster cells of a given size using the methods of interpolation and extrapolation form the basis of its construction.

Terrain data can be obtained through in-situ measurements, including field surveying, reservoir surveying, remote sensing, and cartometric work. In this regard, significantly different forms of specifying these data are possible:

1) with regular placement of points on rectangular, triangular and hexagonal (hexagonal) grids, obtained during tacheometric surveying or special types of plane leveling, as well as as a result of cartometric works;

2) with irregular presentation of points along structural lines, profiles, centers of areas, local points obtained as a result of instrumental surveying or cartometric works;

3) with an isolinear specification of points placed along the isolines uniformly or taking into account the complexity of their drawing, obtained when digitizing horizontal lines topographic maps.

The form of setting the initial data on the relief, their detail and probability determine the choice of the type of DEM, the method of spatial interpolation within the studied territory, as well as the degree of adequacy of the constructed relief model. The most common type of digital relief model used is a digital representation of the topographic surface in the form of a raster (fig. 22.a). The construction of the DEM in this case consists in the distribution of the available limited set of point data on topographic surface markings in the adjacent cells of the raster, which completely covers the given territory, using spatial interpolation methods. Spatial interpolation of point data is based on the choice of an analytical model of the topographic surface. The task of interpolation here is to construct this function for the entire area based on these data, that is, to specify the algorithm for calculating the function (X, Y) at any point with coordinates X, Y. Due to the impossibility of describing the topographic surface within of the entire territory with one function for spatial interpolation of surfaces with regular placement of reference points usually use methods of local (or piecewise) interpolation. To determine the value of the variable at the considered point (node), not the entire set of available data is used, but the measurement data at points located in some neighborhood of this point. At the same time, polynomial and spline interpolation are used, with the use of bicubic splines in the latter case. In the case of an irregular arrangement of reference points, piecewise polynomial interpolation is used using both orthogonal and non-orthogonal polynomials, Fourier series, analytical spline interpolation (using O-splines), moving weighted averaging and some other methods.

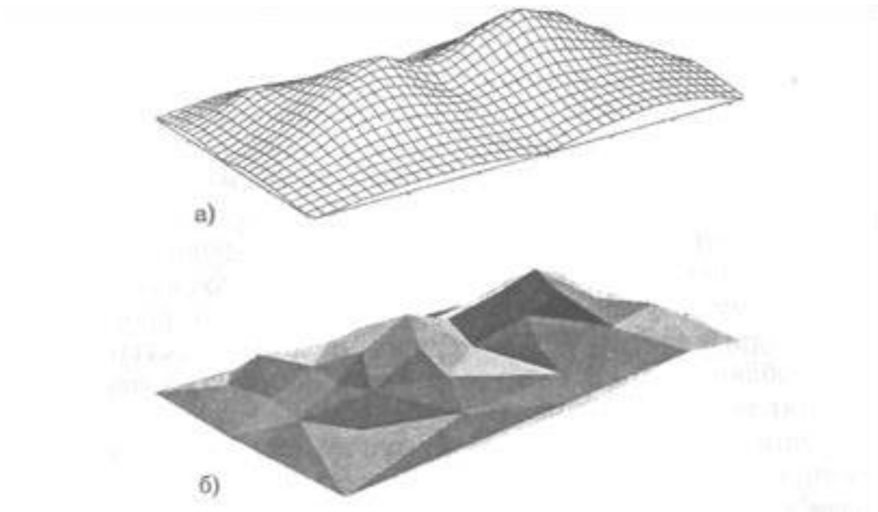

Fig. 22. Digital elevation model in the form of a raster (a) and a triangular irregular network (b)

A number of special algorithms have been developed for network analysis in various GIS packages, the user has the opportunity to create his own algorithms based on a set of network analysis functions. Before starting the analysis, the user must prepare the network - set the starting and ending points for calculating the direction of the flow (movement); set the state of the switches prohibiting movement in the specified direction; set intermediate movement points on edges or joints. On the basis of standard functions (determining the traveled distance, determining the direction of movement, resistance during movement, etc.), the following network analysis algorithms are usually implemented in GIS: determination of the shortest traffic route between two or more points (only the sum of the lengths of the edges is taken into account); determination of the optimal traffic route between two or more points (the length and time of passing edges is taken into account depending on the attribute characterizing the resistance to movement); determination of the maximum or optimal speed of traffic between two or more wheelbarrows (the length and time of passing edges is taken into account depending on the attribute characterizing the resistance to movement, the number of traffic, stops at traffic lights); determination of traffic costs, calculation of road tolls (the length and time of passing edges are taken into account depending on the attribute characterizing traffic resistance); route search for transportation of dangerous materials (attributes of edges and joints that prohibit the corresponding actions are taken into account); determination of the zone of transport reach from the starting point for a certain period of time (the length and time of passage of the ribs are taken into account depending on the attribute characterizing the resistance to movement); determination of pressure or temperature in the water or gas network (the length and diameter of the pipes, the flow capacity of the valves, the pressure or temperature at the outlet from the source, the pressure or temperature at the end user are taken into account); determination of the voltage drop in the electrical network (the length, cross-section and resistance of the ribs, transmission coefficients and resistance at the connections are taken into account).

During the analysis, the network is traced from the starting point to the end point specified by the user. Depending on the set goal, the edges and connections located on the route of movement will be selected and marked accordingly, the distances and costs for overcoming the route will be presented in tabular form (time, fuel, etc.; product or electrical voltage costs); lists of intermediate objects on the route, their status. The route or lists of objects on the route obtained as a result of the analysis can be used to build other analytical procedures.

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[43] Usually, the user has the option of choosing any ellipsoid and a ready-made cartographic or topographic projection, also some GIS packages include functions for creating custom coordinate

systems and projections. When using standard projections and ellipsoids, the user has the opportunity to translate his digital maps from one coordinate system to another.

[44] The measurement of the lengths of the lines in the raster representation is performed through the centers of the cells containing the corresponding identifiers. The measurement is performed vertically, horizontally and diagonally of the cell; the vertical and horizontal distance is equal to the size of the side of the raster cell, the diagonal distance is increased by a factor of 1.44, the resulting lengths are added together. The perimeters of raster polygons are calculated by the sum of the vertical and horizontal sides of adjacent raster cells with the same numerical values.

[45] Areas of raster polygons are calculated by the sum of raster cells with the same numerical values. With the known length of the side of the raster cell, the sum of the cells is recalculated in planar units of measurement.

[46] More complex volume calculation algorithms are implemented in specialized engineering systems for the mining industry or construction. Here you can use cutting planes with a slope or curvature, several cutting planes, planes of a certain shape and size that limit the calculation area (for example, for a separate construction site or a section of the road surface).

[47]The following operators are used for data processing:

- arithmetic operators (addition, subtraction, multiplication, division, exponentiation);

- comparison operators (equal to, not equal to, greater than, less than, less than or equal to, greater than or equal to);

- priority operators (parentheses, nesting of parentheses is allowed, actions in inner parentheses are performed first);

- logical (Boolean) operators for connecting parts of complex queries (logical "and" (and) - both conditions connected by this operator must be fulfilled; logical "or" (or) - one of the conditions related to linked by this operator; logical "not" (not) - none of the related conditions should be fulfilled, etc.);

- the search operator for text lines based on a given search mask (the length of a word or a word fragment, the order of passage of specified symbols in any place of a word or sentence can be determined; all records containing the specified word, letter combination or symbol are included in the sample);

- spatial operators (similarly to queries by location, search operators for inclusions and intersections of spatial objects can be used).

In the data processing process, some GIS packages have additional functions available, for example:

- data format conversion functions (conversion of numerical formats, conversion of numerical data into character data, rounding of numbers, conversion of dates into numbers or character strings, etc.);

- mathematical functions (calculation of square root, exponent, natural logarithm, absolute, minimum and maximum values);

- calendar date processing functions (calculation of the number of days between the specified dates, calculation of the day from the specified date, determination of the year, month, day of the week of the specified date);

- spatial object processing functions (calculation of lengths and perimeters of polygons, calculation of line lengths, calculation of distances between specified points, determination of coordinates of individual points and centroids of polygons).

[48] The use of this procedure is even more widespread for constructing maps of the spatial distribution of characteristics of the components of natural-economic or socio-economic territorial systems or parameters of their mathematical models based on the so-called interpolation with the use of additional information. Maps of the contours of natural or anthropogenic components of natural-economic or socio-economic territorial systems can be additional information. This method of spatial interpolation is used in the absence or extremely limited data of observations or measurements of the spatial variability of the corresponding characteristic. As an example, we can cite the task of building a map of the spatial variability of the anti-erosion resistance of the surface layer of the soil on the basis of a soil map and a table of the ratio of the anti-erosion resistance indicator and genetic varieties of the soil.

[49] Five categories of spatial associations can be considered in neighborhood operations.

First, the new value of the cell can be calculated due to the properties of the cells located within the rectangular window that surrounds the given cell. Such operations are called operations in the variable window.

Second, the new value of the cell can represent the direction of water movement to the neighboring cell on the map of local current lines built on the basis of the digital terrain model.

Thirdly, the new value of the cell can be calculated from the cells placed on the path of movement to this cell from some original one. This path is the shortest distance from the original cell to the given one, taking into account "friction" (cost per unit of path) or without it. Such operations are called remote. Fourth, a new cell value can be calculated based on the contents of cells upstream of the cell in question. These operators use a map of local flow lines to hydrologically model the transport of material within a river basin or part of it.

Fifth, spatial associations can be considered as cells that are within the line of sight of a given cell on a digital terrain model. In this case, focal operations are called visibility analysis.

[50] Operators providing operations of this group usually include operators:

- assigning to each cell of the map the value of the area of the area to which it belongs;
- assignment to each cell of the average value of the cells belonging to this area (class);
- assigning to each cell the number of unique values of the variable within the range;
- assigning to each cell the value that is most often found in this class;
- assigning to each cell the maximum value from the cells of the area to which it belongs;
- assigning to each cell the minimum value from the area to which it belongs;
- assigning to each cell the sum of the values of the cells of the area to which it belongs;
- identification of all continuous groups of cells with the same values and assignment of cells belonging to one continuous group to a new unique value.

[51] For example, the analysis of the cost of laying a cable through several different sections involves the operation of overlaying a cable route map (linear data) on a land use map (polygonal data). At the same time, the length of the section of the route passing through each land use is determined, and depending on the type of section, the cost of laying is determined. Intersections with other underground communications located at different depths, the presence of additional consumers, etc., can also be analyzed.

MODULE 3. MODERN GIS TECHNOLOGIES

LECTURE 8

TOPIC 8. REMOTE SENSING DATA IN INFORMATION SYSTEMS

(MODULE 3)

Plan

1. Types of remote shooting, concepts of aerial photography.

2. Peculiarities of using RSE data in GIS.

3. The main problems of using RSE data in GIS.

4. The role of remote methods in environmental protection.

1. Types of remote sensing, the concept of aerial photography. Remote sensing methods are divided into two main types: passive and active. Passive methods are based on measuring natural thermal or reflected solar radiation. Active methods involve the use of artificial radiation sources (primarily lasers) and the registration of reflected radiation or fluorescence of the objects under study. The physical essence of modern remote sensing is the digital, photographic or graphic registration of ultraviolet, visible, infrared and gamma radiation, radio waves, radioactive processes, as well as geomagnetic, artificial electric and gravitational fields. The structure of the space system for studying natural resources is shown in figure 23.

Signals can be recorded using digital photographic systems, optoelectronic systems and geophysical receivers. Modern types of depending on the type of receiver and the method of registering objects and phenomena are divided into 4 types (tab. 1): visual, photographic, photoelectronic and geophysical.

Visual observations of natural objects from airplanes, helicopters or spacecraft allow to increase the efficiency of performing a number of tasks related to the study of the Earth's natural resources by reducing the amount of information recorded, its preliminary processing and selection before transmission to the Earth.

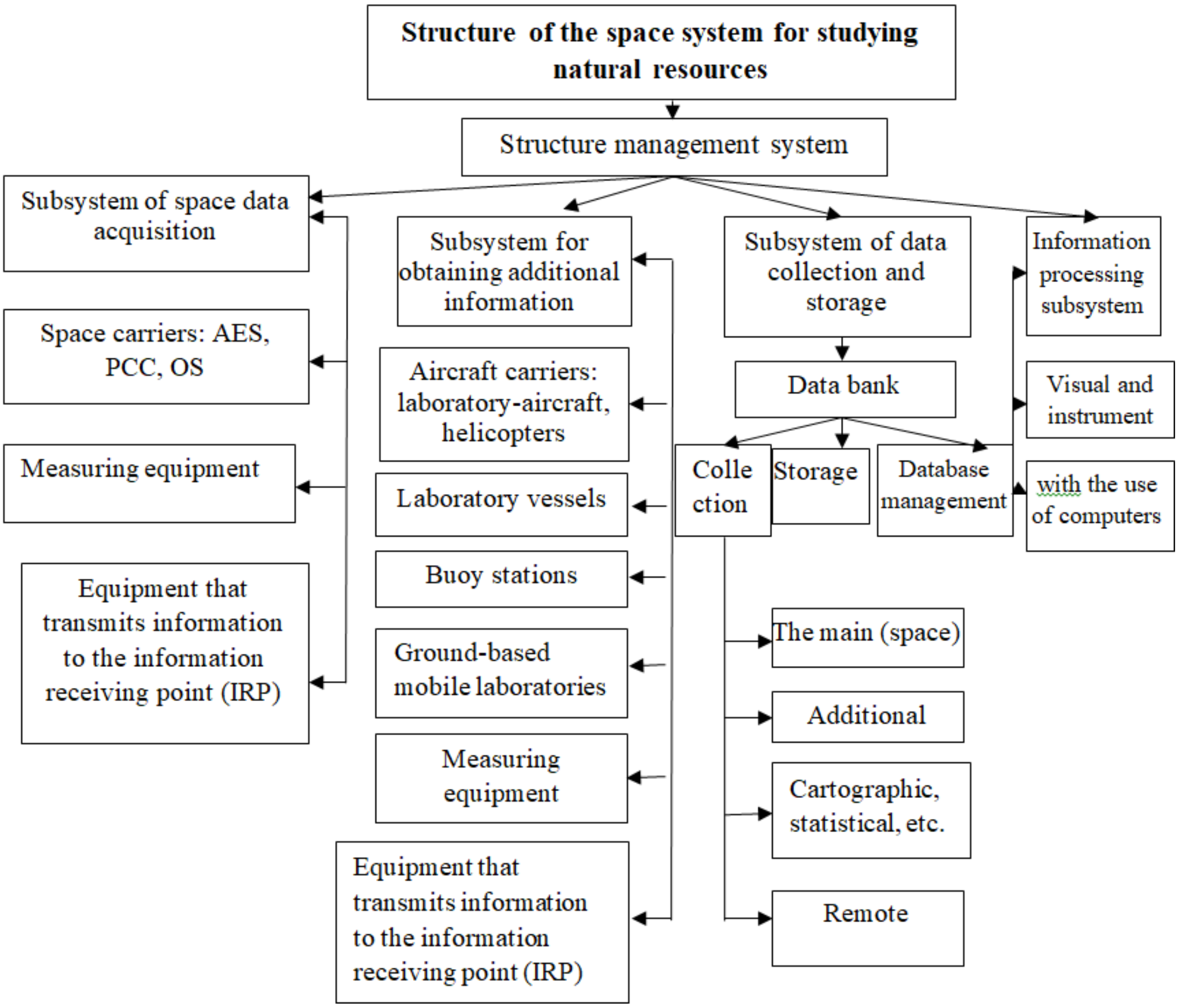

Fig. 23. Structure of the space system for studying natural resources

Photographic aerial surveys are very common because of the visual images that are obtained with the help of this survey. Such images are the most informative and detailed, which is why photographic surveys from aircraft are the most common.

Photoelectronic imagery makes it possible to systematically capture images of the entire Earth's surface over a long period of time.

Geophysical surveying is used for geological research, where the main factor that provides signal formation is rocks, while the influence of other landscape components is close to zero.

Aerial photography, photographing the terrain from the air with a special aerial camera mounted on an airplane, helicopter, airship, artificial Earth satellite or rocket.

The plane of the aerial camera can occupy a predetermined horizontal (scheduled aerial photography is the most common) or inclined (perspective aerial photography) position. In some cases, photography is carried out on a cylindrical surface or with a rotating lens (panoramic aerial photography)[52].

Table 1

Types of satellite imagery

Aerospace methods	Types of shooting	Spectrum area
Visual studies	Visual observations, eye tracking, in-flight image interpretation	**Visible**
Photographic shooting	Black and white, spectroscopic, color, color spectroscopic, infrared, holography	**Visible, infrared (short range)**
Photoelectronic photography	Television, thermal (infrared), radio thermal, radar, ultraviolet spectrometric	**Visible, infrared (thermal) radio range**
Geophysical survey	Magnetic, radiometric, electrical prospecting, gravimetric	**Radio band**

To improve the quality and accuracy of aerial images, aerial lenses with high resolution and low distortion and aerial film with very low sensitivity are used. The aerial camera should be strictly leveled in the plane, the illumination drop across the field of view should be the smallest, the shutter should provide very short exposures (up to 1:1000 seconds) to reduce the blurring of the aerial film at the time of photography.

Photographic materials are classified: by purpose (aerial films, photographic films, etc.); by the color of the photographic image (black and white, spectral and color); by structure (photographic films, photographic plates, photographic paper). All photographic materials have a substrate (base) and a photosensitive or emulsion layer. In aerial photography, substrates made of transparent (triacetate or lavsan) films are used. In phototheodolite photography, thin glass plates are usually used as a substrate for photographic materials. In aerial photography, the following films are used: black and white panchromatic, isopanchromatic and infrared; color spectrophotographic films for conditional color reproduction (spectrophotographic); color films for natural reproduction of terrain objects.

Multi-zone shooting is shooting in narrow spectral ranges when several (up to 6 or more) channels are used simultaneously. Multiband ranges are usually located in different parts of the spectrum. Multi-zone imaging can be classified as photographic if the image is obtained directly on photosensitive materials, and as non-photographic if the image is obtained directly in the form of electrical signals, which are then transmitted via communication channels and/or recorded on magnetic tape. A multi-zone photograph is obtained as a result of photographing with one multi-lens camera or a set of synchronized cameras with different combinations of photographic films and light filters that produce zonal images in different spectral intervals. Multi-zone photography produces a series of images that are not identical in terms of optical density distribution, due to differences in the reflectivity of the objects in different spectral zones [53].

The types of remote sensing described above are passive, or those that capture the natural radiation of the objects being imaged by various means. Active systems include those that allow obtaining more information either due to a wider image capture angle or due to the use of artificial beam or wave radiation.

For example, aerial cameras are equipped with high-quality lenses with different focal lengths from 35 to 1000 mm, which allows for a wider territorial coverage.

With the help of scanners-radiometers, "mosaic" images are formed, consisting of many separate, sequentially obtained image elements. During scanning, the image of the terrain is obtained in the form of a continuous strip, which consists of strips (scans), which in turn consist of individual elements (pixels) [54].

Television equipment is divided into optical, optical-mechanical and photo-television equipment by the means of recording and transmitting video information. In terms of spectral range, photographic and television systems cover the long-wave part of the UV range (0.3-0.4 microns), visible and near-infrared (0.4-0.9 microns). The output of such cameras is a visible image of the object. One of the most effective video recording devices is television cameras.

Active shooting is also possible with the help of laser locators (lidars - short for Light Distance And Ranging), which use monochromatic radiation of the UV and visible ranges. The principle of operation of a lidar is to measure the intensity of laser scattering by atmospheric aerosol. The lidar sends a short pulse of light into the atmosphere and receives a backscatter signal.

Side-view locators are examples of imaging systems that allow for "line-by-line" imaging. Side-view is one of the types of active imaging from a moving carrier carried out in radio or acoustic wave ranges using imaging systems - side-view radar and side-view sonar.

Radar systems are active-type radiometers that perceive the energy reflected from an object when it is irradiated in a certain part of the radio frequency or visible spectrum.

Spectrometers are used to measure the spectral characteristics of the imprint of various natural formations - devices that perceive the energy reflected by an object or the energy emitted by an object simultaneously in several, much narrower than in radiometers, bands of the UV, IR or radio frequency spectrum.

2. Features of remote sensing data application in GIS. Remote sensing data (RS data, syn. aerospace sensing data) (English: remote sensing data, remote sensing data, remote sensing data, aerial data) are data about the Earth's surface and objects located on it or in its subsoil, which are obtained in the process of surveying by any non-contact, i.e. remote methods.

Remote sensing includes data obtained with the help of ground-, air- or space-based imaging equipment that allows to obtain images in one or more parts of the electromagnetic spectrum. The characteristics of such an image depend on many natural conditions and technical factors. The natural conditions include the season of the survey, the illumination of the imaged surface, the state of the atmosphere, etc. The main technical conditions include the type of platform that carries the imaging equipment, the type of sensor (or sensor), the method of controlling the imaging process, the orientation of the optical axis of the imaging device, and the method of image acquisition. The main characteristics of remote sensing are determined by the number and gradations of spectral bands, geometric features of the image obtained (type of projection, distribution of distortions), and resolution of the image (resolution, resolution).

Remote sensing sensors can perceive different parts of the electromagnetic spectrum, both in the visible range and beyond. They provide re-imaging of the same areas of the Earth's surface at a certain time interval, and can also create stereo images. Each remote sensing system is unique and characterized by its own peculiarities. Nevertheless, regardless of the type of sensing elements, the sensors transmit images in the form of a rectangular pixel matrix (abbreviation for "pixel" is an abbreviation for "image element").

So, a pixel is a two-dimensional image element, the smallest of its components, which is obtained as a result of sampling (quantization) of the image (division into further indivisible elements - raster cells). A pixel is characterized by a rectangular shape and dimensions that determine the spatial resolution of an image (or simply spatial resolution), which generally means the size of a portion of the earth's surface covered by a single pixel. The smaller the pixel size, the higher the spatial resolution. Depending on the purpose, equipment, methods and conditions of surveying, remote sensing images can have a pixel size, i.e. resolution, from several centimeters to several kilometers [55].

The amount of electromagnetic energy that falls into one pixel is converted into a number and transmitted to the ground in binary form. The number of binary digits (bits) that encode each pixel is called the radiometric resolution of the image (or simply radiometric resolution). The more bits used per pixel, the higher the radiometric resolution.

For each pixel, several samples are determined - one for each spectral zone. Since each remote sensing system operates in certain spectral bands, in order to select the appropriate sensor, it is necessary to determine not only the required values of spatial and radiometric resolution, but also the spectral band in which the phenomena and objects under study are displayed.

3. Main problems of using remote sensing data in GIS. The most difficult problems related to the use of remote sensing data include their geometric correction and obtaining useful information from the images (decoding).

Regarding the problem of geometric correction of remote sensing, it should be noted that space quantization into pixels creates another level of simplification of the image of ground objects. Objects that are significantly smaller than the pixel size cannot be detected (a case of insufficient spatial resolution), but their presence affects the amount of radiation reaching the sensor, creating the problem of mixed pixels or mixtures, which has already been discussed. Almost always, pixels contain a greater or lesser number of different objects or their parts - the only question is how this mixing will affect the subsequent analysis of the information. When an area with relatively small proportion of small "foreign" objects, it can be assumed that such objects, which are smaller than the spatial resolution of the image in the image, do not affect the analysis results. However, in the case of, for example, urban environments, low-resolution images can significantly distort the results of decryption, as objects of significantly different classes will be mixed in individual pixels.

Another problem is the decryption of remote sensing data, the procedures of which are divided into two groups:

1) procedures for improving the readability of images (e.g., ephemeralization); their purpose is to facilitate the perception of the image by a human analyst. This includes actions such as changing the brightness and contrast of the entire image or its individual parts, smoothing (mainly for noise that creates the effect of shooting through "snowfall), and emphasizing contours and small details;

2) procedures of classification (categorization) of objects. Classification in relation to remote sensing is similar to all other types of classification in GIS in that it usually introduces additional simplification of data in the final product by transferring these data from the scale of relations to more "coarse" scales - interval, ordinal and nominal. Nevertheless, the analytical paradigm requires ensuring that the source data is accessible to the user in order to obtain maximum information, which is why

undecoded images are increasingly becoming part of GIS databases, especially those related to factual geo-environmental information.

All classification (categorization) methods used in remote sensing have the same result - grouping pixels into categories that can be assigned names (or that already have names)[56].

Thus, we can distinguish three main methods of classification and/or categorization in the interpretation of remote sensing data:

1) autonomous classification with subsequent categorization, when special algorithms are used to determine its intervals, which provide the necessary conditions for the distribution of pixels into classes (categories). Some of these algorithms require the user to enter the number of classes, while others are implemented completely independently;

2) classification and categorization by standards, when the operator selects a set of predefined standards, which are determined by existing classification schemes or by the characteristics of the image areas specified by the user, etc;

3) interactive categorization, when the user specifies several pixels (even one) to represent the selected object, and then the program "finds and shows" all other neighboring pixels with similar values.

All of the above methods of classification and/or categorization are automated to some extent, but even offline classification requires the user to have some idea of the image content, not to mention interactive categorization.

In addition to the aforementioned problems with the use of remote sensing, the following can be identified.

First, there are problems arising from the fact that the categories obtained during decryption may be poorly comparable to those previously were created by manual interpretation of images and other map layers and with which actual images are compared in the GIS environment.

Secondly, there are also certain difficulties associated with comparing images of the territory taken at different times under different weather conditions, including from different satellites, problems of correcting geometric and temporal distortions caused by the constant movement of the Earth and the satellite, and some other problems.

However, despite the relative complexity of using remote sensing in GIS, these two once completely separate technologies are now being steadily integrated and the ability to quickly create up-to-date maps significantly "outweighs" all the problems discussed.

4. The role of remote methods in environmental protection. In connection with the aggravation of regional and global environmental problems, there is a need for information support for the study of anthropogenic impact on the environment using aerospace imagery [57].

Data on the sensed object are obtained using the properties of electromagnetic waves emitted, reflected, absorbed or scattered by the sensed objects. The use of remote sensing makes it possible to observe changes in the natural conditions of large regions, environmental disasters and catastrophes. Some of the effects of anthropogenic impacts that are global in nature, such as the reduction of tropical forests and desertification of many regions, require special attention.

Due to the clear recording of environmental features, aerial imagery can play an audit role. For this use of images, it is essential to create a system of image standards for various types of anthropogenic impact on the environment. For example, satellite images were taken of the area of radiation contamination in the vicinity of the Chernobyl nuclear power plant, and then maps of radiation contamination in the region were drawn up.

The system of integrated mapping of natural resources provides for a cartographic study of their anthropogenic dynamics, for which maps based on imagery, maps of landscapes, modern soil use, and maps of anthropogenically altered landscapes or assessments of anthropogenic impact on the landscape created as a result of their analysis are used. The imagery reveals natural or anthropogenic processes that determine the direction or nature of changes in natural resources, records changes over a certain period of time, and identifies trends in their further development under the existing nature of impact.

Peculiarities of anthropogenic impact and natural conditions in different regions are manifested in the specifics of the image pattern on aerial images. This is a good basis for classifying landscapes altered by humans. The images can be used to study a number of catastrophic phenomena caused by anthropogenic impact. These include, for example, sandstorms. When assessing the value of aerial imagery for forest fire protection, it should be noted that forest fires are reliably detected by smoke plumes.

Along with significant practical remote studies of anthropogenic impact on the environment, the theoretical basis is also being developed - the doctrine of the anthroposphere as a human habitat that can be the object of aerospace environmental monitoring. Aerospace imagery makes it possible to monitor, for example, atmospheric dynamics and predict negative phenomena.

Obviously, various forms of anthropogenic impact on the environment occupy a significant part of the Earth's surface. Every year, the area of anthropogenic landscapes is growing faster, and the anthropogenic impact on the environment is increasing. In this regard, it can be assumed that in the near future, aerospace environmental monitoring will become the most developed part of applied remote sensing, even more important and relevant than the study of natural resources.

The peculiarity of remote sensing methods that increase the environmental information content of satellite images is the ability to obtain repeated images of the same area at specified intervals, which allows to objectively track changes in the environmental situation, their dynamics and establish its main trends. In the future, this will make it possible to predict future changes in the environment. The environmental information content of satellite images and their coverage of the entire Earth's surface will make it possible to create a series of environmental maps for all regions of the world. Such maps can provide solutions to a number of global challenges, such as: managing the use and protection of natural resources; making predictive decisions about possible anthropogenic or natural disasters; studying anthropogenic changes and dynamics in natural systems, etc. Such a map can be used as a base map for space-based cartographic monitoring of the biosphere as a whole.

Since the ecological state of different regions of Ukraine and other territories is constantly changing, the National Space Agency and the National Academy of Sciences of Ukraine have established 5 centers of ground stations for receiving and processing information, each of which has a corresponding functional load: in Sevastopol at the Marine Hydrophysical Institute, in Dnipro at the NGO "Orbita in Kharkiv, the Institute of Radio Physics and Electronics of the National Academy of Sciences of Ukraine in Kharkiv, the Center for Aerospace Research of the National Academy of Sciences of Ukraine in Kyiv, and a branch of the Institute of Cybernetics of the National Academy of Sciences of Ukraine in Lviv.

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[52] Typically, aerial photography is performed with a single-lens aerial camera, but sometimes, to increase the area covered in one image, it is performed with a multi-lens aerial camera, and the photography is performed in single aerial images, in a certain direction (route aerial photography) or by area (planar aerial photography). When creating a route, a part of the terrain area photographed in one image should be photographed in another. The ratio of the area covered by two adjacent images to the area covered by each individual image, expressed as a percentage, is called the longitudinal overlap; it is set in accordance with the requirements of further photogrammetric processing (the usual longitudinal overlap is 60%). When taking aerial photos of a large area, the area is photographed by a series of parallel routes that have a transverse overlap (usually 30%).

[53] Natural objects around us have different reflectance spectra. If we divide the entire visible region of electromagnetic radiation into several zones and receive radiation from an object through filters that transmit only a certain part of the entire visible spectrum, the intensity and shape of the received signals will be different. Having images of the earth's surface in this range, it is possible to determine the type of object by measuring the intensity of radiation from different objects. If you use another waveband and measure the intensity of radiation from the same objects in it, then the radiation and reflective characteristics of objects with different physical and biological properties will be more pronounced and will allow you to identify the differences in them. For example, arable land and crops of different crops photographed in several spectral bands will be reflected differently, appearing in the image in completely different colors, shades, and densities. Thus, in the ranges of 0.4 - 0.44 microns, 0.62 - 0.66 microns, it was possible to distinguish between such categories of crops as rye, corn, soybeans, alfalfa, and others, and unplanted soils.

[54] A scan is a sequential line-by-line view of a strip of terrain from a UAS or aircraft. The image is formed as the UAS moves along the flight path by adding individual lines. The scan lines are usually located perpendicular to the direction of flight. Scanning radiometers can be divided by spectral range into visible range scanners (λ = 0.4-0.7 mkm), infrared radiometers (λ = 0.9-1.3; 1.5-1.8; 2-2.5; 3-4; 8-12 mkm), microwave scanning radiometers (λ = 1.55 cm) and multispectral scanning systems equipped with receivers.

[55] Sometimes, especially when characterizing the capabilities of remote sensing equipment, etc. The term "resolution" is sometimes used as a synonym for "distinction". To represent bodies (surfaces) or multilayer combinations of images (digital three-dimensional images), a three-dimensional analog of a pixel is used - the smallest three-dimensional element of a three-dimensional image that carries information, i.e. a kind of "cubic" cell called a voxel (voxel as an abbreviation of "voxel" or "voxel"). In addition, a pixel formed by mixing several adjacent cells with different class values, as well as a pixel that cannot be assigned to any of the classes in a given

set of classes, is called a mixel in digital image processing technology (English: mixel as an abbreviation of "mixed element"). In view of the latter, despite the kinship, interconnection and use of the terms "classification" and "categorization" as synonyms, it is advisable for this manual to distinguish them in a certain meaningful way. According to it, classification should be identified to a greater extent with the substantiation of classification features and the actual creation of universal subject classification schemes, and categorization - with the direct process of distribution and assignment of objects to the categories of the adopted classification scheme. Under such conditions, categorization is close to the concept of "typification by classification features".

56 In view of the latter, despite the fact that the terms "classification" and "categorization" are related, interconnected and used synonymously "classification" and "categorization", we believe that a certain substantive distinction between them is appropriate for this manual. According to it, classification should be identified to a greater extent with the substantiation of classification features and the actual creation of universal subject classification schemes, and categorization - with the direct process of distribution and assignment of objects to the categories of the adopted classification scheme. Under such conditions, categorization is close to the concept of "typification by classification features".

57 The most striking examples are the clear display on aerial images of types of eroded soils, forms of water and wind erosion, the condition of pastures, disturbance of forest vegetation - felling, burning, forest fires; plowed soils, the effects of quarrying and mining, and built-up areas. Aerospace images also show forms of favorable human impact on the environment, as well as activities aimed at restoring lost natural resources or improving unfavorable conditions. Forest belts, irrigation systems, the use of anthropogenic impacts such as erosion control measures, planting of woody and shrubby vegetation on the slopes of ravines, the effects of crop rotations, etc. are clearly visible.

LECTURE 9

TOPIC 9. APPLICATION OF GPS TECHNOLOGIES IN GEOINFORMATICS

Plan

1. Geographic information systems and land management.

2. General scheme and principle of determining the exact coordinates in the GPS system.

3. Working capabilities of GPS for GIS.

4. Application of satellite positioning devices in applied tasks and GIS.

5. Examples of solving specific problems using GPS/GIS.

1. Geographic information systems and land management. Due to the growing value of land and the need for related natural resources, tools such as computerized Geographic Information Systems and resource management systems provide a mechanism for recording, storing and retrieving large amounts of geographic data.

However, unless this vast amount of land-related information is based on a single initial coordinate system, it can be useless because the individual parts do not fit together. Any information that relates to the position of an object in the real world is essentially geographic. It is necessary to define a common geographic basis on which information about the location of objects can be based and to link it to information of different types (i.e., land ownership, natural resources, and political boundaries). GPS is proving to be the most efficient, accurate, and inexpensive means of creating such a framework. Any of the common GPS surveying methods can be used to create and maintain data in a geographically referenced database such as a GIS in a timely manner.

2. The general scheme and principle of determining the exact coordinates in the GPS system. The Global Positioning System or GPS was developed by order of the U.S. Department of Defense and created in 1979. The core of this system consists of 24 space navigation satellites "NAVSTAR". The whole system consists of three blocks (segments):

Space segment is a system of 24 navigational artificial Earth satellites (NES) located in almost circular orbits at an altitude of more than 20 thousand km. The satellites are equipped with radio transmitters and time standards (atomic clocks). The control segment is a network of ground stations for monitoring broadband networks and information processing centers. The main task is to maintain the space segment in working order.

The consumer segment is the owners of GPS receivers on land, water, and in the air. The principle of coordinate determination is based on radio rangefinding. Radio signals, The GPS receiver's antenna receives radio signals. The signal is a special code that carries information about the time of its emission by the satellite transmitter and the satellite's coordinates. After receiving the radio signal, the receiver's processor calculates the time it takes for it to travel from the transmitter to the satellite to the receiver's antenna. This calculates the distance from the GPS receiver to all the cellular networks that are currently in the radio range, and then the coordinates of the receiver itself. The creation of a GPS system allows you to determine the coordinates anywhere in the world, at any time, regardless of weather conditions. The accuracy of coordinate determination (depending on the types and classes of equipment, as well as the measurement methodology) is from 100 m to 1 mm.

The main advantages of GPS technology compared to traditional geodetic methods:

- Mutual visibility between points is not required
- Works in any weather conditions, at any time, anywhere in the world
- Possesses high accuracy of coordinate determination
- Has a much higher speed
- Provides three-dimensional coordinates in plan and height.

3. Working capabilities of GPS for GIS. GPS receivers designed for GIS applications allow you to add a description of the point to the acquired point. Some types of receivers allow you to simply enter a description using the built-in keyboard, while others allow you to select terms from a list of pre-entered dictionaries directly in the field. Some of the data dictionaries have a hierarchical structure. Some of these systems provide offset support, i.e., they allow you to work with the serif method. The offset method allows the user to map an object on the ground if he knows the distance and bearing to the object. The software supplied by GPS manufacturers plays a very important role in the integration of measurement data with the GIS database (tab. 2). All supplied software allows its implementation on IBM-compatible personal computers. Communication between the computer and the GPS receiver is usually carried out via the Rs232 serial port.

Table 2

Classification of GPS receivers

Field of application	**Price** USD	**Brief description**
Positions	500-1000	**Stationary mode only, portable, few channels, 100 m positioning accuracy, no automated data recording system**
Navigation	1000-20000	**Differential mode, accuracy in the meter range, special navigation objects**
GIS	3000-13000	**Differential mode, accuracy in the meter and smaller range, automated data recording, interface with GIS software**
Geodesy/Geodynamics	10000-50000	**Differential mode, dual frequency, centimeter accuracy, automated data acquisition**
Timing	up to 60000	**It is used exclusively for the purpose of time control, the accuracy is within 1 ms**
Military purpose	up to 60000	**Accuracy in a stationary position of 16 m. High accuracy in differential mode. Prohibition for civilian users**

The most well-known receivers on the market are those of the following companies: Garmin International, Lenexa, Kan.; Leica Inc. Navigation and Positioning Division, Torrance, Calif.; Magellan Systems Corp., San Dimas, Calif.; Motorola Inc., Scottsdale, Ariz.; Sokkia Corp., Overland Park, Kan.; Trimble Navigation, Sunnyvale, Calif.

4. Application of satellite positioning devices in applied tasks and GIS. The areas of application of GPS devices can be systematized by the content of the main tasks. Land management tasks, cartography and coordination of construction objects belong to such a group of applications as measurement of the Earth and its surface. Here, not only individual receivers can be used, but also entire computing measuring systems, the accuracy of measurements of which reaches fractions of a centimeter. GPS allows you to "assign" a unique address to literally every square meter of the Earth's surface.

Areas of application of GPS devices in the road sector. Depending on the accuracy of the required data, GPS can be used in the road sector in the following areas: navigation, topography, and geodetic work.

Use of GPS equipment for navigation. Traditionally, the first area is the navigation of moving objects. It corresponds to navigation class GPS receivers that determine the location with an error of at least a few tens of meters. Except for special tasks, this is very high navigation accuracy.

For accurate GIS data collection and mapping, the use of the latest GPS technology combined with powerful data storage and software allows for accurate survey results to be obtained for creating and updating GIS. Topographic GPS devices ensure the accuracy of determining the coordinates of objects in the range from 5 meters to 30 centimeters every second of measurement, even in motion, which allows to significantly increase the number of survey points when creating maps at a scale of 1:2000 and smaller. A special high-precision mode is used for critical work. In addition to three-dimensional coordinates, GPS receivers can also store detailed descriptions of survey objects from pre-prepared dictionaries. The coordinates of objects can be obtained both in the accepted State Systems and in any local coordinate systems.

When a set of GPS devices is equipped with a special radio channel for transmitting corrections, high accuracy of surveying becomes possible in real time. This allows you to solve the problem of bringing objects into the field, perform accurate navigation or search for points. With the help of GIS or an information program, this work can be done visually immediately on the computer screen on electronic maps-substrates.

Use of geodetic class GPS (millimeter-centimeter level of accuracy). A very wide field of application of GPS tools and methods is land surveying in the broadest sense of the word. At present, GPS receivers of this class are widely used in geodesy, geophysics, topography and land cadastre, for field surveying, geodynamic and hydrographic studies.

The most important feature of the vast majority of these problems is the requirement for exceptional accuracy in determining coordinates, points in time and time intervals. Here, the errors are fractions of a meter and fractions of a centimeter at measured distances of tens of kilometers.

The most powerful receivers of the geodetic class are not individual receivers, but entire computing measuring stations and complexes. They are equipped with radio communication lines, external computers, and extensive programs for the so-called desktop processing of data accumulated during field measurements.

5. Examples of solving specific problems using GPS/GIS.

Land cadastre. The main condition of the GIS information system - land cadastre is not only the creation of digital maps, but also their constant updating in accordance with the changes that occur. The most promising solution to this problem is the use of GPS technologies in collecting information. The American company Trimble Navigation, which is a leader in the GPS equipment market, produces various types of receivers for various applications, including GIS. The receivers can be used to collect data in existing GIS systems in order to make operational changes and additions to databases. The coordinates of point objects can be determined in the local system with an accuracy of 10 cm. The software supplied with the Pathfinder family receivers allows converting the output file into the format of the most popular GIS (Arc/info, Mapinfo, Caddy, etc., including standard DXF and DWG formats).

The most promising direction of GPS technologies and their application in GIS can be considered differential positioning - DGPS, which allows to increase the accuracy of navigation determinations up to 0.1 m directly in the field. For the normal functioning of the DGPS system, it is necessary to have base stations on the territory of the country stations broadcasting differential corrections and creating the so-called differential field. In this case, the user of GPS receivers for GIS can obtain the required measurement accuracy without post processing, using only one receiver (50% savings). A radio modem is used to receive differential corrections.

Another area of development of GPS technologies in geodesy, cartography and GIS is digital aerial surveying using GPS receivers to determine the coordinates of the survey camera during the flight. This method of surveying terrain allows you to obtain a digital raster model of the terrain with reference to the local coordinate system almost on the fly.

GPS mapping of objects for crop insurance. RCIS is the largest crop insurer in the United States. It insures more than 110 typical crops: from grapes and strawberries to cotton, grains and even shellfish. In 2007 alone, RCIS (part of the largest company, Wells Fargo & Company) collected $1.7 billion in premiums. The use of GPS there began back in 1997, and as a result, the company was able to become a leader in this market segment. Trimble satellite receivers were used to accurately coordinate and map insured objects. In 2000, the company launched the development of its own software. Currently, more than 30 million acres of grain crops have been entered into the system, for which you can easily display a report on the area of the plot, yields for previous years, print a map and any other information. Trimble Juno ST receivers are used to draw the boundaries of the client's plot directly in the field, which is a compact, fully integrated field computer with Windows Mobile 5.0 software and a GPS receiver with an accuracy of 2-5 meters in real time. In the field, using coordinate definitions, you can determine the area, size and perimeter of the insured area. Information such as site features, type of crop insured, etc. can be entered into the system on the spot. After synchronization with Farmmaps, it is possible to print a map or report, edit, update, or organize the information. In addition to these advantages, a more accurate determination of the area of the plot allows you to more accurately calculate the cost of insurance premiums.

Monitoring nature reserves using GPS. One of the planned tasks within the framework of forest conservation is the localization of "wild" tourist campsites. It is necessary to collect information on where the campsites are located in the forests so that their condition can be monitored regularly. Forestry in the Unita-wasatch-cache National Reserve uses field computers such as Trimble GEOXT and Trimble GEOXH (with a built-in GPS module and Terrasync and GPS Pathfinder Office software, respectively). A database of codes was created that allowed for faster entry of attribute information related to each parking lot under study (number of fires, presence of garbage, etc.). Thanks to these codes, the collected information could be exported to an existing GIS. Information on 450 previously known campsites in Logan County and more than 108 in Stansbury County (in Salt Lake County) was researched and recorded. Once the data was collected, the information was uploaded to a common database and visualized. Now the forestry can enter the necessary filters, quickly find all the data relevant to a specific request, which greatly simplifies the work of managing natural resources. This made it possible to establish the extent to which human activity in parking lots affects the environment.

Use of GPS to assess potential damage to vegetation in the proposed construction area. The proposed work area (San Fernando Valley, Los Angeles, California) is located among historic oak groves. The mapping work was performed using a GPS receiver combined with a Trimble GEOXT field computer. Before the surveys began, special forms were developed to speed up data collection. During six visits, 430 trees were inventoried. For each tree, specific characteristics were indicated: species, diameter, general condition. Collecting the data directly in electronic format made it possible to ensure their simultaneous transfer to a common database, and there - accelerated analysis. This made it possible to determine which trees are more likely to be affected by humans and which are not. The map, which clearly shows both layers - vegetation and proposed construction - allowed the designers and architect to develop alternative schemes to reduce the impact of the work on the ancient groves. In addition to the trees, GEOXT helped collect data on natural features passing through the area of interest: streams, ravines, and other natural formations. All this information is reflected in the final report: the length, width and depth of the ravines, the capacity of the rivers and the flow rate are indicated. The combination of GEOXT measurements and digital photographs allows for georeferencing of the images, and thus, more complete information is obtained as a result of the analysis.

TOPIC 10. USING AERIAL IMAGES IN GIS

Plan

1. **Understand the concept of decryption.**
2. **Aerospace image interpretation as a modern technology.**
3. **General geographic and sectoral interpretation and their features.**
4. **Main techniques and means of aerial image interpretation.**

1. **Understand the concept of decryption**. Decryption means the detection, recognition and characterization of terrain objects depicted in the images. Due to the diverse (complex) content of aerial photographs, specialized interpretation is usually used, i.e., the detection of only those objects that are necessary to solve a specific task. The interpretation is carried out either by simply examining individual contact prints through a magnifying glass or by a broad inspection of the overlays.

Depending on the purpose and tasks to be solved in the course of decryption, there are two types of decryption: topographic and special. Topographic interpretation is performed in order to identify, recognize and determine the characteristics of terrain objects that should be drawn on a plan or map in accordance with the requirements of the current conventional symbols [58] (fig. 24). Specialized, respectively, is aimed at obtaining special (geological, forestry, hydrological, etc.) information (fig. 25).

The effectiveness of decryption, i.e., the disclosure of information contained in aerial images, is determined by the peculiarities of the objects under study and the nature of their transmission during aerial surveys (decryption features), the perfection of the work methodology, the provision of instruments and the qualifications of the decryption performers. The list includes deciphering (demasking) features are distinguished between direct and indirect [59]. When decoding aerial images, objects are recognized primarily by their properties, which are called direct decoding features. These include the shape, size, tone (color) and shadow of the image of objects. Direct decoding features are often not enough for decoding for two reasons. The first is that the objects or their characteristics are not visible on the aerial images (for example, underground structures or the purpose of the structure). The second is that the objects do not have certain stable de-identifying features:

the same feature corresponds to different objects (for example, a rectangular shape can be a residential building, a barn, or an office), and the same object has different de-identifying features (for example, the water surface is depicted in different tones depending on the lighting and turbidity).

In this regard, indirect decoding features are used to indicate the presence or characteristic of an object not depicted in the image or not identified by direct features (for example, a tunnel is recognized by a gap in the railroad image, groundwater outlets in desert areas are emphasized by spots of dense vegetation, elements of a hidden geological structure are decoded by analyzing the plan of the river network, etc. Indirect features are based on the natural relationships existing in nature between the spatial location of individual objects or complexes of objects (landscape components) or between natural objects and the results of human economic activity.

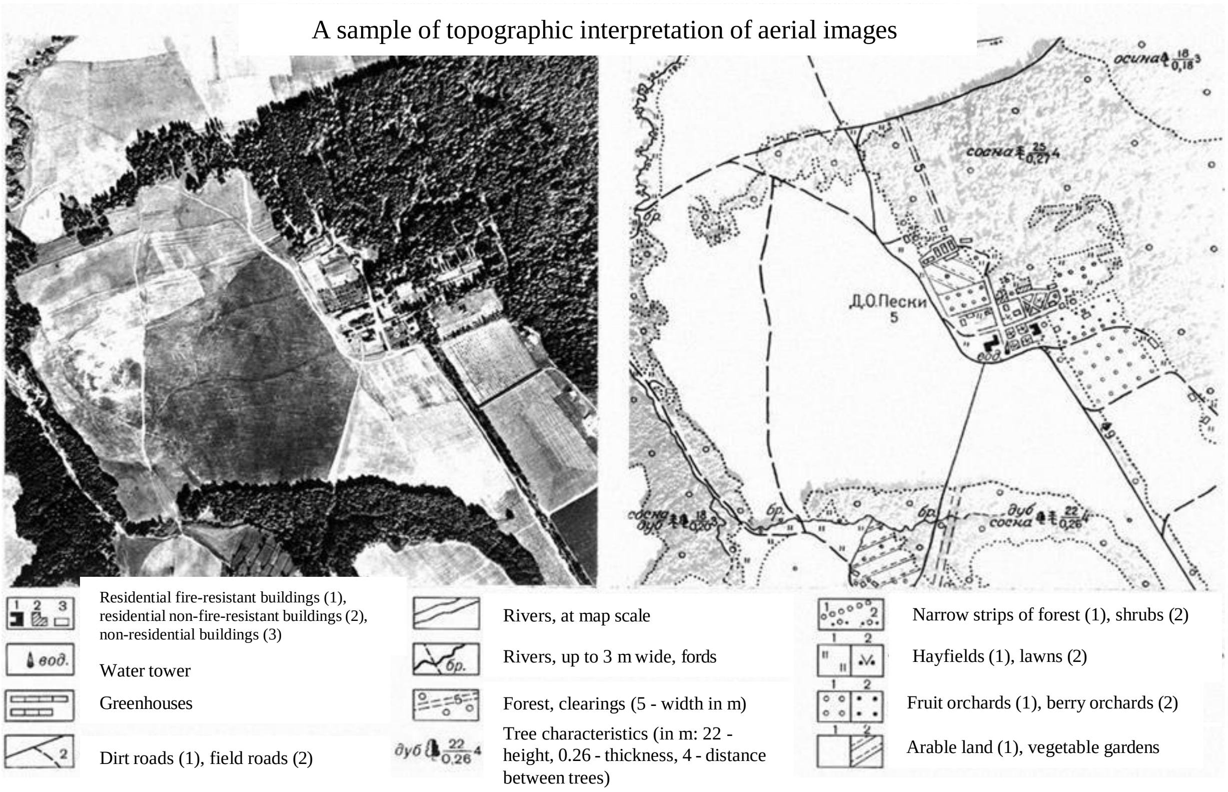

Fig. 24. An aerial image of a plain area: *on the left* - with a normal photo image of the area, *on the right* - with a weakened one, against which the background shows: forests (grainy pattern), arable land at different stages of cultivation (smooth and striped pattern), a dotted pattern of a vacation home with buildings and gardens), etc.

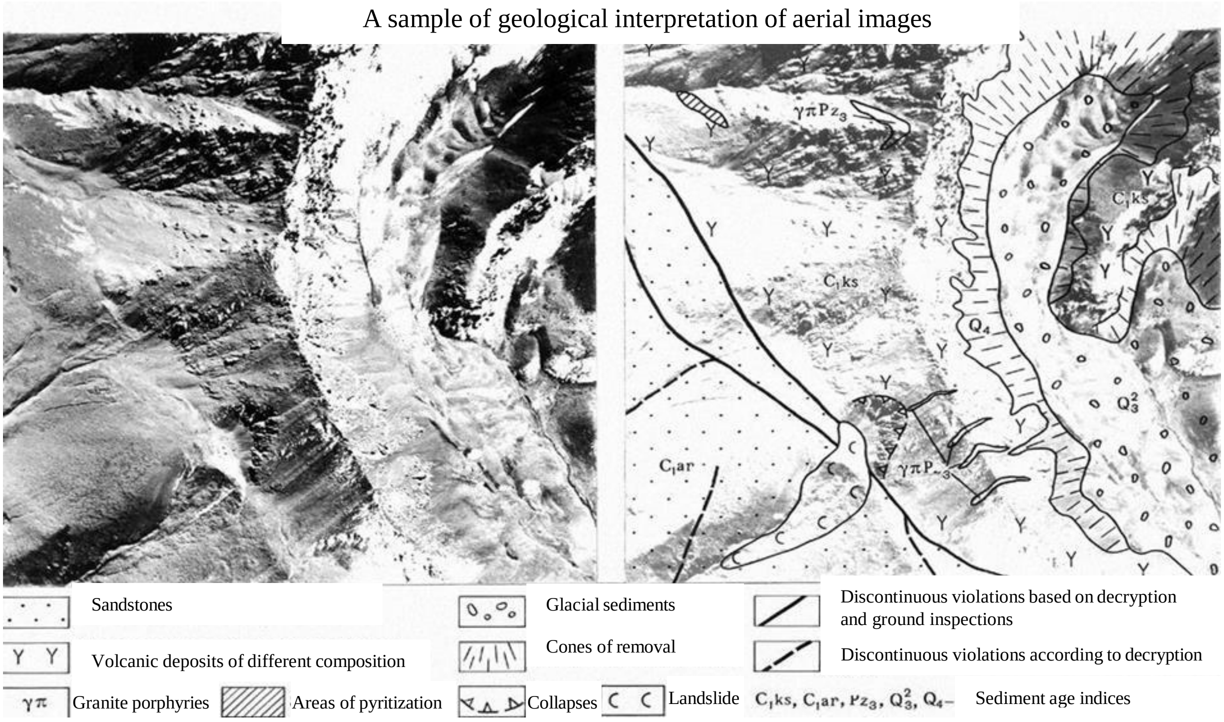

Fig. 25. Aerial image of a mountainous area: *on the left* - with a normal photo image of the area, *on the right* - with a weakened one, against which the background in conventional signs shows: areas of volcanic rocks (a dismembered pattern of ridge slopes), sandstones (a smooth pattern of the plateau), areas of glacial deposits and cones of deposition in the valley, places of collapses and landslides, fault lines, etc.

Those objects (complexes) whose presence and properties indicate the presence and properties of other objects are called indicators, and the method of decoding by indirect features is called indicative.

Often, complex decoding features are also distinguished, which include the combination of direct features of objects that form natural-territorial complexes (landscapes) in a certain pattern. These include: the ratio of areas occupied by different objects; the ratio of the number of different objects; spatial orientation and distribution of different objects; combination and modification of the forms of individual objects, combination and change of tones of different objects according to a certain law. Complex features are associated with the structure of objects or the pattern of an aerial image that reflects the nature of the landscape.

2. Aerospace image interpretation as a modern technology. Aerial image interpretation is one of the methods of studying the terrain based on its image obtained by means of aerial photography. It consists in detecting and recognizing the objects taken, establishing their qualitative and quantitative characteristics, as well as registering the results in graphic (symbols), digital and text forms. Decryption (aerial photographs) has common features inherent in the method as a whole and known differences due to the peculiarities of the fields of science and practice in which it is used along with other research methods.

In order to obtain aerial images with the best possible information capabilities for this type of interpretation (aerial images), it is of great importance to take into account natural conditions (landscape appearance) when taking aerial photographs.

The effectiveness of interpretation (aerial photographs), i.e., the disclosure of information contained in aerial photographs, is determined by the peculiarities of the objects under study and the nature of their transmission during aerial photography (interpretation features), the perfection of the work methodology, equipment and properties of the interpreters. In addition to the above-mentioned direct and indirect features, a number of decoding features include such a complex feature as a pattern or image structure.

In terms of methodology, decryption is characterized by a combination of field and desk work, the scope and sequence of which depends on their purpose and the area under investigation. Field decryption consists of a continuous or selective survey of the territory with the establishment of the necessary information during the direct study of the objects to be decrypted. In hard-to-reach areas, field interpretation is carried out using aerial observations. Desk-based interpretation consists in identifying objects by their interpretive features based on the analysis of aerial images using various instruments, reference and mapping materials, standards (obtained by field interpretation (aerial images) of "key" areas) and geographic interdependencies of objects established in the area ("landscape method"). Although desk-based interpretation is much more cost-effective than field-based interpretation, it does not completely replace it, as some data can only be obtained in the field.

Today, developments are underway to automate interpretation in the following areas:

a) selection of aerial images that have the necessary information and their transformation to improve the image of the objects under study, for which methods of optical, photographic and electronic filtration, holography, laser scanning, etc. are used;

b) object recognition by comparing the encoded shape, size of a given image and photon density of a given image and a reference image with the help of a computer, which can be effective only under standardized conditions of aerial survey and image processing. In this regard, the nearest prospects for automated interpretation are associated with the use of the so-called multi-channel aerial survey, which allows obtaining synchronous images of the terrain in different spectral bands.

The following instruments are used for interpretation: magnifying instruments - magnifying glasses and optical projectors, measuring instruments - parallax rulers and microphotometers, and stereoscopic instruments - field portable and pocket stereoscopes, stereoscopic glasses and camera tabletop stereoscopes, partially with binocular devices and meters (for example, STD stereometer). An interpretoscope is a stationary device designed specifically for the purposes of interpretation. Interpretation is also carried out using universal stereo photogrammetric devices as part of the complex of works on the original map. Depending on the task, interpretation can be performed on aerial image negatives or their copies (on photographic paper, glass or positive film), on photographic schemes mounted along the route or by area, and on accurate photographic plans. Decryption is carried out in through or reflected light with the results of the decryption being drawn (or engraved) in one or more colors on the aerial survey materials themselves or on sheets of transparent plastic applied to them.

The interpreters are subject to special professional requirements in terms of perception of brightness and color contrasts, stereoscopic vision, as well as the ability to effectively recognize and identify objects by their specific image on aerial images. Along with this, the interpreters must know the peculiarities of the nature and economy of the territory in question and have information about the conditions of its aerial survey.

3. General geographical and sectoral decoding and their features. There are general geographic and sectoral interpretation. The former includes topographic and landscape interpretation, and the latter includes the rest of its types.

Topographic interpretation, which is characterized by the greatest use and versatility, has as its objects the hydrographic network, vegetation, soils, lands, relief forms, glacial formations, settlements, buildings and structures, roads, local objects, geodetic points, and borders. Landscape interpretation ends with regional or typological zoning of the area. The main industry-specific types of interpretation are used in the following works geological - for planar geological mapping and mineral prospecting, hydrogeological and engineering geological works; marsh - for exploration of peat deposits; forestry - for inventory and management of forests, forestry and forestry research; agricultural - for creation of land management plans, land records and crops; soil - for mapping and study of soil erosion; geobotanical - in the study of the distribution of plant communities (mainly in steppes and deserts), as well as for indicative purposes; hydrographic - in the study of land waters and catchment areas, in the study of seas regarding the nature of currents, sea ice and the bottom of shoal areas; geocryolithological - in the study of permafrost forms and phenomena, and glaciological - glacial and related formations. Interpretation is also used for meteorological purposes (observation of clouds, snow cover, etc.), in the search for commercial animals (especially seals and fish), in archeology, in socio-economic research (for example, traffic control) and in military affairs when processing aerial reconnaissance materials. In solving many problems, decryption is complex (for example, for land reclamation purposes). In a number of fields of science and practice, along with the decoding of aerial photographs, work is underway to decode space photographs taken from manned spacecraft and orbital stations, as well as from artificial Earth satellites. In the latter case, the acquisition of the images is fully automated; they are delivered to Earth via containers or by television transmission. Thanks to the images from space, it is possible to directly decipher global and regional objects and to decipher the dynamics of natural processes and economic activities over large areas in a short period of time. Decryption is carried out not only for images resulting from photographic surveys from normal heights and from space, but also from various types of photoelectronic surveys.

4. The main methods and tools for decoding aerial photographs. Overlay montage is a large number of contact prints (aerial photographs) laid out along a series of flight and survey routes, combined with longitudinal and transverse overlaps, which gives a photographic image of a large area. Contact prints are mounted on large boards or tables. They are laid along each route in the same sequence as they were obtained during the aerial survey, so that the contours of the situation on adjacent images in the area of longitudinal overlap coincide. It is necessary that the situations in the area of transverse overlap also coincide with the images of adjacent flight routes. The overlap montage is used to determine whether the entire aerial survey area is evenly covered by images, or whether there are no gaps between routes and a specified percentage of longitudinal (60%) and transverse (40%) overlap is maintained. overlaps, and also familiarize themselves with the general orientation of aerial photography of a large area. From the overlay montage, they receive a layout of the individual aerial photographs and their serial number. The reduced photo from the overlay is called the overlay reproduction. In the absence of a reproduction of the overlay, tracings of the entire overlay are often made, on which the outlines and numbers of aerial photographs are circled. Such numbering schemes are necessary for stereoscopic processing of aerial photographs and for the organized storage of a large number of contact prints.

Photoscheme - in aerial photography, a set of mounted contact prints that have not been transformed and reduced to the same scale. The overlapping portions of the images are cut out so that the average portion (working area) of each image is left with a minimum of distortion. The prints are glued to cardboard. A photographic scheme consisting of cut-out central portions of aerial images is called a mosaic. To get an idea of the entire territory covered, a photo map is assembled from several photo schemes, which is usually reduced. This map has the same inaccuracies as the photomaps.

Photomap - a tablet on which topographic symbols are applied over the photographic image of the earth's surface - horizontals, elevations, roads, settlements, etc., as well as the names of rivers, lakes, villages, etc., as on conventional maps. It is compiled at the end of aerial surveying, after photogrammetric processing of aerial images, from transformed images that are brought to an accurate scale and free of distortions. It has a standardized frame design for maps and plans, a nomenclature of trapezoids according to the international rosette, scale, degree grid and its digitization, date of compilation and other information.

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[58] Image decryption in the process of inspecting the terrain in the field is called field decryption. Recognition of objects and contours on photographs without inspecting them in the field is called desktop interpretation. Depending on the topographic study of the mapped area and the adopted work technology, field interpretation is carried out before or after the desk-based interpretation.

[59] Decoding determinants in the form of tabular summaries of direct, indirect and complex decoding features identified by indicators of the internal structure of the landscape in relation to specific geographic areas are constantly published in monographs and individual articles on sectoral decoding. The most detailed is the deciphering determinant compiled for surveying and updating maps at scales of 1:10,000 and 1:25,000, which also provides a classification and list of topographic objects, features of their depiction on maps and their encryption features. This order is accompanied by an album showing the appearance of a topographic object on a regular photo, on an aerial photo, and its image with a symbol on a halftone photo. The decoding determinant should consist of the following components: 1) aerial photographs - standards of the geographic landscape; 2) a summary table of characteristics and encryption features of the standard area; 3) characteristics of general geographic features of the landscape. In recent years, such determinants have been supplemented by optical characteristics of aerial images (SED, spectral density, etc.).

LECTURE 10

TOPIC 11. WORK IN THE INFORMATION SYSTEM "MAPINFO"

Plan

1. Work with toolbars.

2. Opening a table and files.

3. Register the coordinates of a raster image.

4. File structure of the table.

1. Working with the toolbars. The four Mapinfo toolbars contain buttons that represent the most commonly used commands, procedures, and tools. The user can change the size and position of the toolbars with the mouse, as is common in the Windows environment. For example, the user can move the panel around the screen.

To attach a toolbar to the Mapinfo menu bar, you need to move it under the menu bar. The buttons of the toolbar line up below the menu bar. To return the toolbar to the framed display mode (i.e., to make it «floating»), you need to move the toolbar down by pointing the mouse to the area of the toolbar that does not contain buttons. After that, the toolbar will look like it did before we attached it to the menu.

The Command (or Standard) toolbar contains the most commonly used tools from the FILE, EDIT, and WINDOW menu sections. It also contains also contains shortcuts to the DISTRICTS and HELP commands. The Operations toolbar contains tools for selecting objects on the Map, changing the Map window view, and obtaining information.

You can also find buttons for opening some windows faster and showing the distance between objects. There are buttons that allow you to change layer attributes and open the Legends or Statistics windows.

The Pencil case toolbar contains tools and calls commands related to drawing on the map.

The DBMS toolbar contains buttons for commands to access tables in remote databases.

HOME Tab

The **HOME** tab contains commands and command lists for accessing files, windows and tools. The **HOME** tab is available on the ribbon, unless it is minimized.

File Group

The **File** group contains commands and command lists for opening resources, such as workspaces, tables, programs, base maps, web services and connections. Commands for closing resources andsaving workspaces are also included in this group (tab. 3).

Table 3

Commands the File group

Icon	Command	Keyboard Shortcut	Description
	Open	Ctrl+O	The following commands are available from the **Open** command list. **Open Workspace** (Ctrl+Shift+O): Open a workspace **Add Workspace** (Ctrl+Shift+A): Adds a workspace to a current workspace **Table** (Ctrl+O): Opens one or more tables in MapInfo .TAB format, as well as Microsoft Access and Excel, ESRI Shapefiles, raster and grid images, and SQLite and others. **Import**: Opens the **Import File** dialog box for accessing data in MapInfo Interchange Format, AutoCAD and GML. **Universal Data**: Opens external data directly without the need for translation. **Database Table**: Opens a connection to a DBMS server. **Program** (Ctrl+U): Run a MapBasic program or tool. **Aerial**: Adds a Bing Aerial layer to the current Map window. Requires a Bing License Key. **Roads**: Adds a Bing Roads layer to the current Map window. Requires a Bing License Key. **Hybrid**: Adds a Bing Hybrid layer to the current Map window. Requires a Bing License Key. **Mapping (WMS)**: Access layers from a Web Mapping Server (WMS). **Feature (WFS)**: Access layers from a Web Feature Service (WFS).

Continued from tab. 3

Icon	Command	Keyboard Shortcut	Description
			Catalog (CSW): Allows you to locate descriptive information about spatial and non-spatial data. **Open Connections**: Lists any open connections. **Recent Files**: Displays a list of the most recently opened resources, up to 10 items.
	Save Workspace	Ctrl+K	**Save Workspace**: Saves the current session as a workspace. **Save Workspace As**: Saves the session to a new workspace.
	Save Table	Ctrl+S	Save changes made to a table. Available once there are changes made to a table.
	Save Copy As		Saves a table with a new name, projection or format.
	Close DBMS		Closes a DBMS connection. Enabled when a DBMS connection is open.
	Close Table		Closes one or more tables.
	Close All		Closes all the tables and the current workspace.

Clipboard Group

The Clipboard group contains the commands for copying and pasting selections to the clipboard (tab. 4).

Table 4

Commands the Clipboard group

Icon	Command	Keyboard Shortcut	Description
	Copy	Ctrl+C	Copies the selection and puts in on the clipboard.
	Paste	Ctrl+V	Pastes the content of the clipboard. Enabled once you cut or copy a selection.
	Cut	Ctrl+X	Cuts the selection and puts in on the clipboard. Enabled once you make a table selection of an SQL selection.
	Undo	Ctrl+Z	Undo/redo last operation. Enabled after you make an edit.

Window Group The Windows group provides a drop-down list of document windows, tool windows and window commands. Use the scroll bar to move through the list. Click on the down arrow to view the entire list (tab. 5). When you select a window, it moves the icon to the top of the window list for easy access.

Table 5

Commands the Windows group

Icon	Command	Keyboard Shortcut	Description
	Map	F3	Displays a table as a map
	Browser	F4	Display and manipulate data in tabular format.
	Layout	F5	Arrange/annotate windows for printing.
	Legend	Shift+F3	Creates legend frames for the map window.
	3D Map	F11	Displays a map in three dimensions. Enabled when you or one or more tables or activate a map window containing a grid surface layer.
	Prism Map	F10	Creates a prism map using the current Map window.
	Redistricter	Shift+F4	Display and manipulate a table in a redistricter.
	Layers	Ctrl+Shift+ L	Opens the Layers list in a **Layer** or **Explorer** window. Allows you to add and remove layers and set layer properties.
	Tables	Ctrl+Shift+ T	Displays a list of open tables.
	Windows	Ctrl+Shift+ W	Displays a list of open windows that you can sort, search, show or hide.
	Explorer	Ctrl+Shift+ E	Opens the **Explorer** Window. This window contains all the open resources - maps, layers, tables, windows and connections.
	Move To		Allows you to type an address or place to recenter the map.
	Tools	Ctrl+Shift+ U	Allows you to configure the MapBasic tools to run automatically when MapInfo Pro starts.
	MapBasic	Ctrl+Shift+ B	Echoes MapBasic commands. You can also type in commands.
	Connections		Shows a list of open connections.
	Tasks	Ctrl+Shift+ K	Shows tasks.
	Info	Ctrl+Shift+ I	Opens the **Info** window used by the **Info Tool**.
	Ruler		Opens the **Ruler** window.
	Statistics	Ctrl+Shift+ Z	Shows the **Statistics** window.
	Themes	Ctrl+Shift+ G	Shows theme legends for the current map.
	Message		Opens the **Message** window.

Continued from tab. 5

Icon	Command	Keyboard Shortcut	Description
	Clone Window	Ctrl+Shift+ C	Makes a copy of the current document window.
	Redraw Window	Ctrl+D	Redraws the active window.
	Recover Offscreen Windows		Ensures that floating windows are positioned on screen.
	Hide Status Bar		Shows and hides the **Status Bar** at the bottom of the desktop.

Output Group

The Output group contains the commands for setting up and printing window contents (tab. 6).

Table 6

Commands the Output group

Icon	Command	Keyboard Shortcut	Description
	Print	Ctrl+P	Prints window contents
	Create		Creates a PDF of the active document windows
	Save		Saves the active window as a bitmap or metafile
	Page Setup		Sets the page size, orientation and margins.

Tools Group

The Tools group is a command list that expands to display a 3-tab drop-down where you see which MapBasic programs are running, registered or recent. The Options drop-down list allows you to run a program, register and get additional tools, and unload tools (tab. 7).

Table 7

Commands the Tools group

Tab	Description
Running	A list of running programs.
Registered	A list of installed tools and Autoload checkboxes for MapInfo Pro to load them automatically on startup. Click on a tool name to see a description. Buttons display to manage the tool including load, unload, edit registered tool information, and unregister a tool.
Recent	A list of recently used tools.

TABLE Tab

The TABLE tab contains commands and command lists for working with tables. The TABLE tab is available on the ribbon, unless it is minimized. It is also available at the top of floating Map, Browser and Layout windows. The Table tab for a Browser window displays two additional groups of commands (Browser Tools and Sort and Filter).

Contents Group (tab. 8).

Table 8

Commands the Contents group

Icon	Command	Keyboard Shortcut	Description
	New Browser	F4	Creates a new **Browser** window where data from a table is displayed in tabular format.
	Open	Ctrl+O	Opens a variety of resources for including in your layout. See **HOME Tab** on page 28
	Save Table	Ctrl+S	The commands on the Save Table command list are: **Save Table**: Saves changes made to a table. **Save Query** Saves a query **Save Copy As**: Creates a new table from an existing table.
	Revert		Discards edits and uses the last saved table version.
	Close		Closes one or more tables.
	New Table	Ctrl+N	Creates a new table. Opens the **Create Table** dialog box.
	Export		Exports the table to another format.
	Universal Translator		Tool to import and export MapInfo data to and from other popular mapping formats.

Selection Group (tab. 9).

Table 9

Commands the Selection group

Icon	Command	Keyboard Shortcut	Description
	Select		Selects one or more map/layout objects or browser rows. To create a selection query, click on the Launcher button in the lower right corner of the Selection group to open the **Select** dialog box.
	SQL Select		Creates a selection by querying using SQL.
	Invert		Inverts currently selected map/layout objects or browser rows. Available when objects or rows are selected.
	Clear	Ctrl+W	Unselects map/layout objects or browser rows.
	Find	Ctrl+Shift+F	**Find** (Ctrl+Shift+F): Select an item or row and find the item in all windows.
			Find Address: Find an address using a geocoding server. Places a marker on the map. **Mark** (Ctrl+F): Find objects by some criteria and place a marker on the map.

Edit Group (tab. 10).

Table 10

Commands the Edit group

Icon	Command	Keyboard Shortcut	Description
	Update Column		Use to assign values to a column, add a new (temporary) column using data from another table, move values between columns and enter graphics information into columns for descriptive data.
	Append Rows		To attach the rows of one table to another table. The tables should have the same set of columns, in the same order.
	Add New Row	Ctrl+E	Adds a new blank row to the bottom of the active **Browser** window.

Browser Tools Group (tab. 11).

Table 11

Commands the Browser Tools group

Icon	Command	Description
	Info	Displays tabular information about map objects.
	HotLink	Enabled when the Browser references a table containing hotlink data (URL).
	HotLink Options	Opens the Hotlink Options dialog box where you can add, remove and manage the Hotlink properties.
	Pick Fields	Choose which fields display in the active **Browser** window. You can also use **Pick Fields** to temporarily rename a column, creates a new column that will display in the **Browser** window, or edit the expression that defines an existing column.
	Font	Opens the **Text Style** Dialog Box where you select how to display the text in the **Browser** window.
	Gridlines	Show/Hide the Browser gridlines.

Analyze Group (tab. 12).

Table 12

Commands the Analyze group

Icon	Command	Keyboard Shortcut	Description
	Drag Map		Drag the map to another Map or Layout window.
	Hotlink		Launch a file or URL associated with a Browser field or labels/objects in a map.
	Info		Displays tabular information about map objects.
	Statistics	Ctrl+Shift+Z	Displays or hides the Statistics window.
	Redistricter		**New Redistricter Window**:(Shift+F4) Allows you to display and manipulate a table in a district browser. **Set Target**: Sets the selected object's district as the target district. **Assign District**: Permanently assigns selected objects to the target district. **Add District**: Adds a new district to the Districts Browser. **Delete District**: Deletes the current target district from the Districts Browser. **Options**: Sets the district order and grid pattern display.
	Ruler		Opens the Ruler window.

Sort and Filter Group

The Sort and Filter group is enabled when a **Browser** window is active. It provides access to these commands (tab. 13).

Table 13

Commands the Sort and Filter group

Icon	Command	Description
	Filter	**Filter**: Opens the **Filter** dialog box where you can set filter conditions for the column. A filter may consist of up to two conditions where each condition is built from a simple set of operations (such as equals, greater than, and so on) and some set of values. After applying a filter to a column, an icon displays in the column header to let you know that the column has a filter. You can apply as many column filters as the number of columns in the table up to a limit of 100. Each new column filter is appended to the previous filters to produce fewer records in the current view. **Clear Filter**: Clears the filter conditions from the column and refreshes the **Browser** window. This only clears the filter on the right-clicked column; filters and sort on other columns are preserved. The **Clear Filter** command is enabled after you apply a filter condition to a column. The **Filter** and **Clear Filter** commands are also available by right-clicking on a column in the **Browser** window.
	Sort	**Sort Multi-Column**: Opens the **Sort** dialog box where you would make selections to perform a multi-column sort in the **Browser** window. **Sort Ascending**: Sorts the column containing text alphabetically starting from A to Z. This is also available by right-clicking on the column. **Sort Descending**: Sorts the column containing text alphabetically starting from Z to A. This is also available by right-clicking on the column. **Clear Sort**: Removes the sort that was applied to the data in the **Browser** window. This removes the sort from memory, so you cannot reapply the sort after making this selection.
	Clear All	Removes all sort and filters that were applied to the data in the **Browser** window. This removes the sort and filters from memory, so you cannot reapply them again after making this selection.
	Sort On/Off	Turns off a sort, so that you can view data as it appears in the table. After turning a sort off, you can turn it back on to view the sort result.
	Re-Sort	Reapplies the last sort/filter to the data in a **Browser** window. This is useful after making changes to the data or after turning the sort/filter on.

SPATIAL Tab

The **SPATIAL** tab contains commands and command lists for working with tables. It is always available, unless it is minimized. The **SPATIAL** tab is also available at the top of floating **Map** and **Layout** windows.

Clipboard Group (tab. 14).

Table 14

Commands the Clipboard group

Icon	Command	Keyboard Shortcut	Description
	Copy	Ctrl+C	Copies the selection and puts in on the clipboard.
	Paste	Ctrl+V	Pastes the content of the clipboard. Enabled once you cut or copy a selection.
	Cut	Ctrl+X	Cuts the selection and puts in on the clipboard. Enabled once you make a table selection of an SQL selection.
	Undo	Ctrl+Z	Undo/redo last operation. Enabled after you make an edit.

Selection Group (tab. 15).

Table 15

Commands the Selection group

Icon	Command	Keyboard Shortcut	Description
	Select		**Select**: Selects one or more map/layout objects or browser rows. **Radius Selection**: Selects map objects within a circle. **Marquee Selection**: Selects map objects within a rectangle. **Polygon Selection**: Selects map objects within a polygon. **Boundary Selection**: Selects map objects within an area defined by a boundary in another layer (for example, cities within a county).

Continued from tab. 15

Icon	Command	Keyboard Shortcut	Description
	SQL Select		Creates a selection by querying using SQL.
	Invert		Inverts currently selected map/layout objects or browser rows. Available when objects or rows are selected.
	Clear		Unselects map/layout objects or browser rows.
	Find	Ctrl+Shift+F	**Find** (Ctrl+Shift+F): Select an item or row and find the item in all windows. **Find Address**: Find an address using a geocoding server. Places a marker on the map. **Mark** (Ctrl+F): Find objects by some criteria and place a marker on the map.

2. Open a table and files. Just about everything in MapInfo Pro starts with opening a table. You can display the information in your tables in a number of ways in MapInfo Pro, as a table, in a browser, and on a map.

To open a local table (which is a data file on your machine):

1. On the *HOME* tab, on the *File* group, in the *Open* list, click *Table* to open the *Open* dialog box.

Note: If you are at the Quick Start dialog box (the first dialog box you see after starting MapInfo Pro), choose the Open button. The Open dialog box displays.

2. Navigate to the data file you want to open. From the *Files of type* drop-down list, select the type of data you will open.

3. From the *Preferred View* drop-down list, select the view you want of this data.

• **Automatic** –MapInfo Pro chooses the most appropriate view. If the data is mappable (for example, graphic objects are attached to the data), for example, MapInfo Pro opens the table in a Map window. If you have a Map window displayed and the table you want to open is mappable, MapInfo Pro will automatically open the table in the current Mapwindow. If the data is not mappable, MapInfo Pro will attempt to open the table in a Browser window. If the table cannot be mapped or browsed, MapInfo Pro opens the table using the No View option (no data is displayed).

• **Browser -** MapInfo Pro attempts to open the table in a Browser window.

• **Current Mapper** - MapInfo Pro attempts to add your data to the current Map window.

• **New Mapper** - MapInfo Pro attempts to open the table in a new Map window.

• **No View -** MapInfo Pro opens the table making the data available for other uses, but no data is displayed.

Note: When you open a table and select an option in the **Preferred View** drop-down list, MapInfo Pro remembers what you selected and uses the same option the next time you open a table.

4. Select the **Create copy in MapInfo format for read/write** check box to open it in native (.tab) format.

Note: If you do not select the **Create copy** check box, the file opens read-only.

5. To open the file, do one of the following:

• Double click the file you want to open

• Click the file you want to open to highlight it in the list and click **Open**. Using either method, MapInfo Pro opens the data file.

When opening multiple tables, use **Shift**-click to select adjacent tables and **Ctrl-**click to select non-adjacent tables. Note that although a MapInfo Pro table consists of two or more component files (STATES.TAB, STATES.DAT, STATES.MAP, etc.), only the.TAB file appears in the **File Name** box of the **Open** dialog box. It is the only component file you must open. For more about these other MapInfo file types, see **Understanding the Files Associated with MapInfo Pro Tables**.

In MapInfo Pro you can work with a variety of table types. Some data tables are like the example table we just discussed. Further subdividing this class of tables are data tables that contain graphic objects (map objects) and data tables that do not (such as spreadsheets or external database tables). Raster tables are graphic images that you can display in a Map window. These computerized pictures do not have the same table structure of record, field, and index as data tables do, and therefore, will not be discussed in this chapter. For more on raster images, see *Working with Raster Images* in the MapInfo Pro Help System.

A Note about the Preferred View Options Of the five Preferred View options, Automatic and No View will work on all tables, regardless of what kind of data they contain (fig. 26).

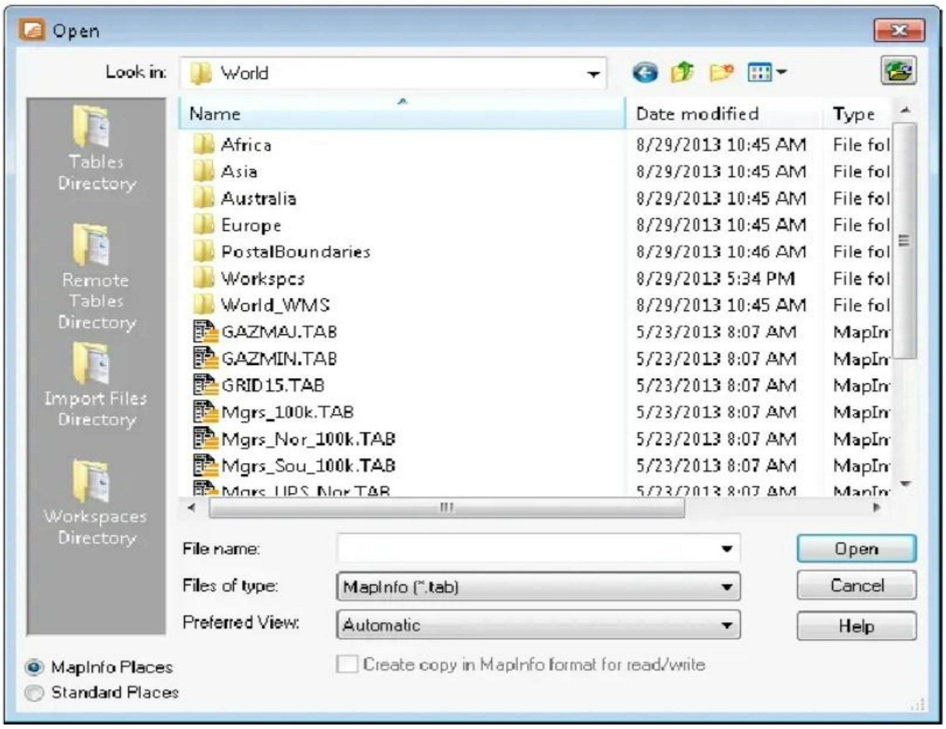


Fig. 26. The dialog window that appears when you start Mapinfo Professional

MapInfo Pro attempts to open the table as specified for **Browser**, **Current Mapper**, and **New Mapper**. If it cannot, it will open the table according to the following rules:

• If **Current Mapper** is selected, and there is no Map window displayed, MapInfo Pro will attempt to open the table in a new Map window.

• If **Current Mapper** or **New Mapper** is selected and the data is not mappable, MapInfo Pro will try to open the table in a Browser window.

• If the table cannot be mapped or browsed, MapInfo Pro will open the table using the **No View** option (no data is displayed).

You can work with several types of tables in Mapinfo Professional. Some data tables are similar to address tables. The main distinction is that there are tables that have graphical objects (map objects) and data tables that do not (spreadsheets or external databases). Raster tables are graphical images that you can view in the Maps window. Such computerized images do not have a tabular data structure in the form of record fields and indexes.

3. Register the coordinates of the raster image. There are a number of ways you can obtain raster image files. If you have a scanner and scanner software, you can use the scanner to create raster image files. MapInfo Pro can read and display the raster image files created with the scanner software. Some graphics software packages let you save or export images into raster file formats, such as TIFF (Tagged Image File Format). So if you can create a TIFF file with your draw or paint package, you can display it in MapInfo Pro. You can also purchase raster images from MapInfo Pro or other commercial vendors. Some data vendors also offer scanning services.

When registering your raster image, you need to know the map coordinates that correspond to your image. If your raster map image shows a graticule (a grid of longitude/latitude lines), you can determine map coordinates by noting the longitude/latitude labels along the graticule. If your map does not show a graticule, you may be able to determine map coordinates by locating prominent map features, for example, the Northwest corner of a region, and then using another MapInfo Pro table as a reference to determine the coordinates of those prominent features.

A raster image is a type of computerized image that consists of row after row of tiny dots (pixels). If youhave a scanner and scanner software, you can create a raster image by scanning a paper map. After you scan a map image and store the image in a file, you can display the file using MapInfo Pro.There are many different raster image file formats. MapInfo Pro can read the following types of raster image files: JPEG, GIF, TIFF, PCX, BMP, TGA (Targa), and BIL (SPOT satellite).

When you register a raster map image, you enter map coordinates (e.g. longitude/latitude degrees), and you indicate which locations on the raster image correspond to those coordinates. You must register each raster image before displaying the image in MapInfo Pro, so that MapInfo Pro can perform geographic calculations, such as distance and area calculations, when displaying the raster map. The first time you open a raster image file in MapInfo Pro, MapInfo Pro will ask you if you want to register it or use it simply for display. Click the Register button to open the **Image Registration** dialog box. By completing this dialog box, you tell MapInfo Pro how to register the raster image and determine the coordinate system for the image. MapInfo Pro stores the raster image's registration information in a table file for future re-use. The next time you run MapInfo Pro, you can re-open the raster table without repeating the registration process. Thus, you only need to register each raster image once. Raster image files provided by MapInfo Pro are already registered. You do not need to perform the registration process when you display the sample raster data included with MapInfo Pro.

Using raster image files, you can bring paper maps, photographs, and other graphic images into MapInfo Pro. For example, if you work with paper maps, you probably want to use those paper maps as the foundation for the maps you create in MapInfo Pro. Once you scan your paper map into a raster image file, you then can display it in a Map window.

Using a raster image as the base layer of your map gives you a detailed backdrop for your other map layers. You can easily change the size, scale, or center point of the displayed image. For example, if you want to enlarge part of the image, use the **Zoom In** command. Keep in mind, however, that as you increase the image's size, the display will become grainier if you exceed a 1-1 pixel ratio. Each pixel in the image becomes more distinct, causing the image to look more like a series of blocks instead of the intended picture.

When you open a raster file you need to register it to identify coordinate point references for the image. Using a vector map as a reference, you identify the coordinates of the vector map and match them with quivalent points on the raster image. This coordinate information allows MapInfo Pro to determine the position, scale and rotation of the image so that you can overlay vector data on top of the image. The coordinate information is stored in a TAB file created during the registration process. The TAB file enables you to re-open the raster file in MapInfo

Pro format. You usually register the image the first time you open it. However, you do not need to register the image if you do not plan to use vector data with it, or if it already contains georegistration information.

Raster images usually fall into one of three categories:

• A fully registered image, containing control points and a projection (for example, GeoTIFF file).

• A partially registered image containing control points, but missing a projection (for example, an image with an associated World file).

• An unregistered image missing control points and a projection.

Once the image is registered, opening it again requires a slightly different procedure. Opening both unregistered and registered images is explained in the next section.

• *Opening a Registered Raster Image*

• *Opening an Unregistered Raster Image*

• *Opening a Georeferenced Raster Image.*

Registering the Coordinates of a Raster Image. Before you can overlay vector data on top of a raster image, you must first register the raster image so that MapInfo Pro can position it properly in a **Map** window. In the **Image Registration** dialog box, you can identify control point coordinates and specify the appropriate projection for the raster image. Control points are the coordinates you identify on the raster image that MapInfo Pro can use later to match up to other layers. It is very important to provide accurate control point information when registering a raster image, so MapInfo Pro can display raster images without distorting or rotating them. Later, when you overlay vector data, MapInfo Pro distorts and rotates the vector data so both layers can line upproperly. Identifying significant control points makes this match up process easier. We suggest you use highway/street intersections and prominent landmarks as control points, as they rarely move. Specifying the correct projection of the raster image is also important for accurate display. Images that do not have known projections, such as unrectified aerial photographs, are less suitable for use with vector data. There are two ways to register a raster image in MapInfo Pro. Each involves specifying the map coordinates of control points on a reference map and matching them with equivalent points on the raster image. To determine map coordinates, you can:

• Identify a point's coordinates from the paper map.

• Determine a raster images control point coordinates on screen and automatically transfer the information to the **Image Registration** dialog box.

Note: If you scanned in the image from a paper map, the map most likely contains a graticule (latitude and longitude grid). You can choose those coordinates for prominent features and enter them in the **Image Registration** dialog box.

To transfer the coordinates automatically from a vector map to a raster image, you need a vector map of the same image. Then, you display the vector map side by side in the **Image Registration** dialog box, which shows a preview of the raster image. Click a prominent feature in the vector map to determine its coordinates and transfer this control point to the **Image Registration** dialog box. To transfer a vector map's coordinates to a raster image:

1. On the **HOME** tab, in the **File** group, on the **Open** list, click **Table** to open the **Open** dialog box. Select the **Raster Image** file format.

2. Choose the raster image file and click **Open**. The **Display/Register** dialog box displays.

3. Click **Register**. The **Image Registration** dialog box displays. A preview of the raster image appears in the lower half of the dialog box.

4. Choose the **Projection** button to specify the image's projection. If you do not set the projection, MapInfo Pro defaults to Longitude/Latitude or to the default table projection set in the Map Window Preferences.

5. To add control points, click the **Add** button to add a control point entry to the **Control Points** list.

6. Click the **Pick from Map** button and select a location in the Map window that matches a location in your raster image. MapInfo Pro updates the Map X and Map Y fields in the **Edit Control Point** dialog box with the new coordinates. Click **OK** to save this entry and close the dialog box.

Note: When the **Pick from Map** button is disabled, you can select locations directly from the open map. If a map is not open, you can select another command (like the **Select** command) and use that command instead of the **Pick from Map** functionality.

7. Highlight the entry in the **Control Points** list and click the matching control point location in the image pane. The **Edit Control Point** dialog box displays showing the control point's location in pixels in the Image X and Image Y fields. Click **OK** to save these entries (fig. 27).

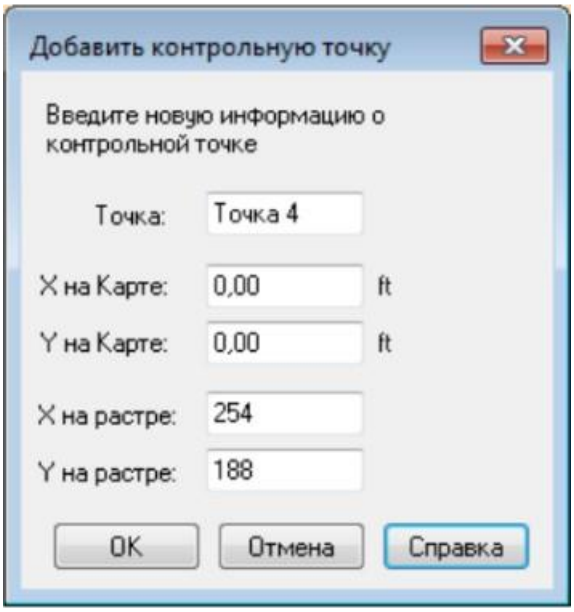


Fig. 27. Window for adding a control point

Note: Remember to type a meaningful description of this location in the **Label** field.

8. Repeat this process until you have identified three or four non-linear points in the preview pane of the **Image Registration** dialog box (fig. 28).

9. After you have defined all of the control points, click **OK** in the **Image Registration** dialog box. The raster image displays in the Map window under the vector layer. Use the Layer Control feature to position the raster map appropriately with your vector layers.

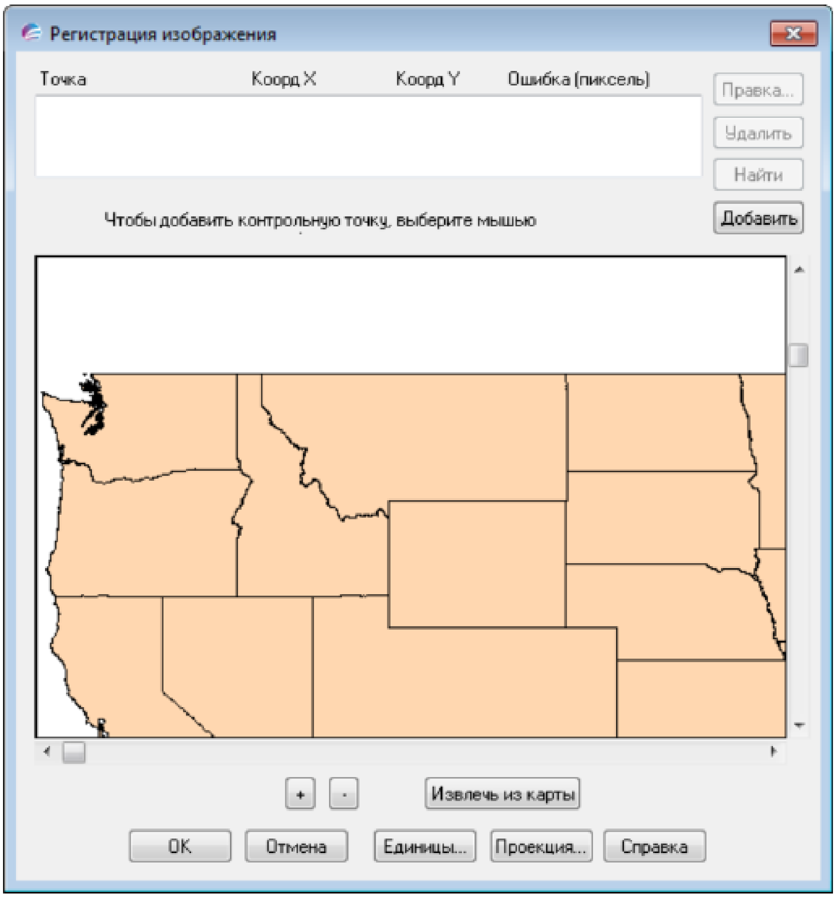


Fig. 28. Registration a raster image

4. The file structure of the table. When you open a data file in Mapinfo, Mapinfo creates a table. This table consists of at least two different files. The first contains the data, and the second contains a description of the data structure:

- <file name>.TAB: This file contains a description of the table's data structure. It is a small text file that describes the format of the file that contains the data.

- <file name>.DAT or <file name>.WKS, .DBF, .XLS: This file contains tabular data. If you are working with dbase/foxbase, ASCII with delimiters, Lotus 1-2-3, Microsoft Access, or Microsoft Excel files, a Mapinfo table will consist of a file with the TAB extension and either a data file or a spreadsheet file. Tables containing raster images store data in component files in BMP, TIF, or GIF formats.

If the records correspond to X and Y coordinates, it means that the table contains graphic objects. In this case, two more files will be included in the table:

- <file name>.MAP: This file describes the graphic objects.

- <file name>.ID: This file contains a list of pointers (indexes) to graphical objects, allowing Mapinfo to quickly find objects on the map.

For Microsoft Access tables, an <file name>.AID file will be created associated with the table (instead of <file name>.ID). This file is a link that connects data to the objects of the Microsoft Access table.

A table can also contain an index file. The index file allows you to search for objects on the map using the FIND command. If you need to find streets, cities, or regions using the FIND command, the corresponding table fields must be indexed. The index is saved in a file:

- <file name>.IND.

LECTURE 11

TOPIC 12. SPECIALIZED GIS FOR FORESTRY

Plan

1. Experience of using GIS in forestry.

2. General characteristics of GIS "Topol".

3. Modern Field-Map technology.

1. Experience of using GIS in forestry. At present, the main component of the forestry information system is a combined relational and geographic information system database for input, storage, processing and output of planning and mapping support materials. The principles of building such a combined database for forestry are developed. A number of works were carried out to introduce new information technologies in forestry, in particular, the following were tested GPS technologies, the use of satellite images for forest fire detection has been tested, and a computer program "Site allocation" computer program is being developed. The following technologies have been developed generation of operational daily summary of forest fires in G1S Geodraw/Geograph.

Standard packages such as ARC GIS allow designing site development technologies (Fig. 29), as well as simplifying and automating some operations related to forestry. With the help of ARC GIS, it is possible to select plots suitable for research according to key parameters (taxation indicators determined during forest management, proximity to roads, hydrological network, species composition of adjacent forest areas). The result is a complete list of plots with the parameters suitable for the study, and the sampling results can be visualized in the form of maps, which makes the information more visual.

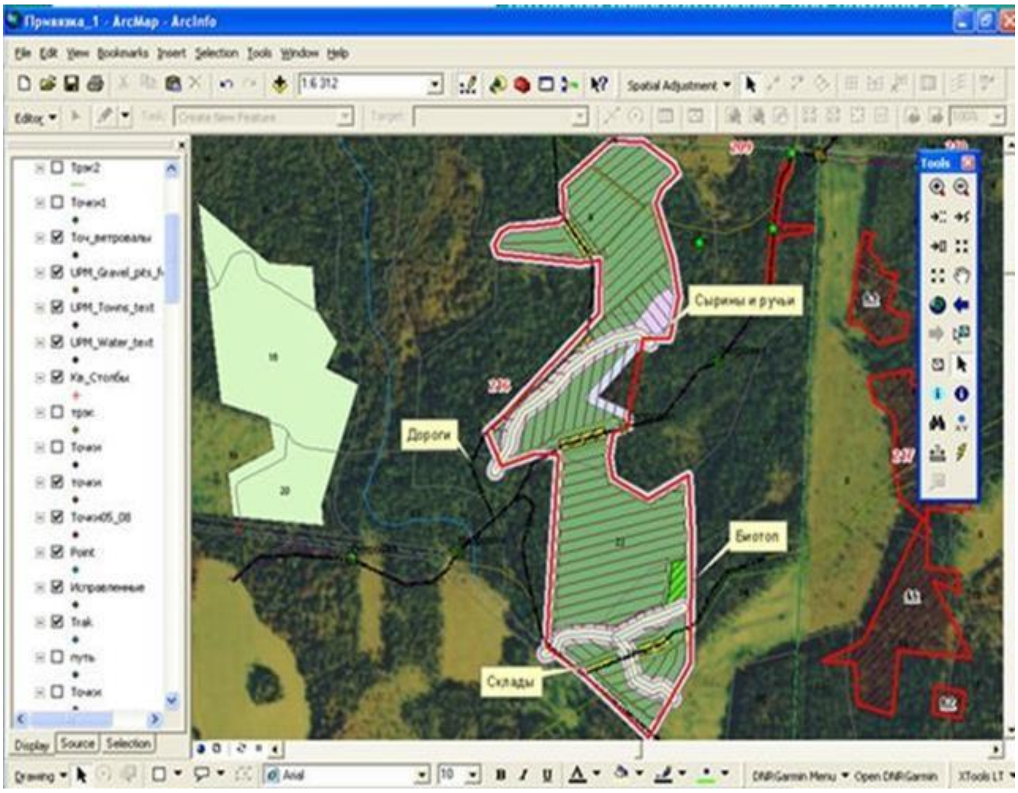


Fig. 29. Design of site development technology in standard packages such as ArcGIS

In addition to standard GIS programs, special GIS programs have been developed to solve specific forestry tasks: LuGIS, Topol, L-tool, Formap, Turbo Taxi, Abris, Lesfond, and others. Since the early 1990s, forestry has been using the Lesfond workstation software package, which is constantly being improved in terms of its main technical characteristics. In particular, to improve it, a data converter for GIS Karta (PANORAMA Design Bureau) was developed to create files in SXF or TXF exchange formats (Fig. 30).

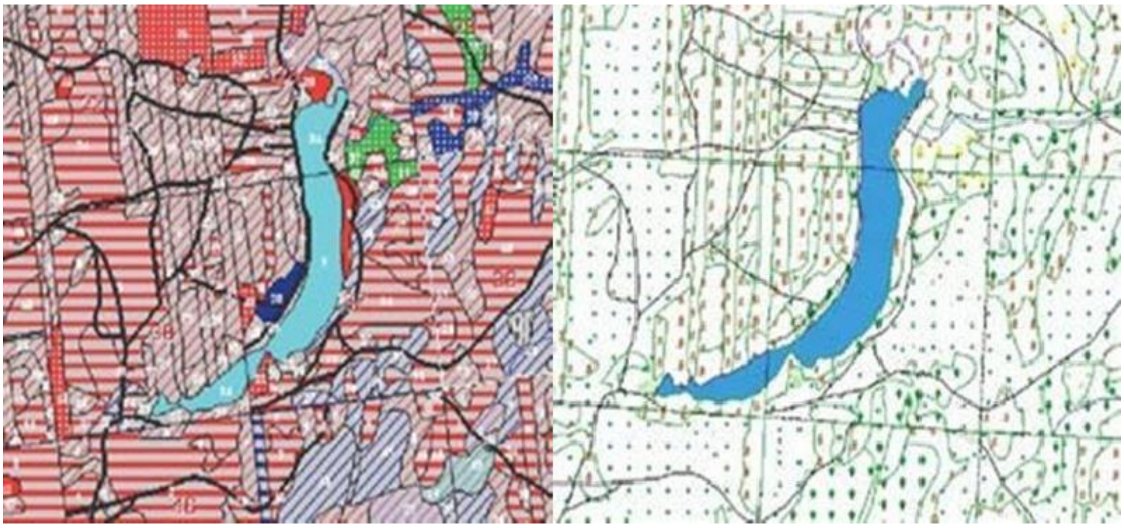


Fig. 30. Map of the forest fund plot: (left) "Lesfond" workstation; (right) GIS "Map"

One of the advantages of this transition is the improvement of the information content of the cartographic material, which is due to the following capabilities of GIS "Map":

- filling the polygon with conventional signs without filling (or with transparent filling) allows visualizing indicators for the main species and age group of the stand (fig. 31);

- creation of thematic maps with polygons coloring and shading allows to display, for example, the type of habitat conditions with the condition of placement under the main map. The information content of the polygon in terms of perception of the electronic map object on the monitor screen can contain up to 7-12 indicators, including

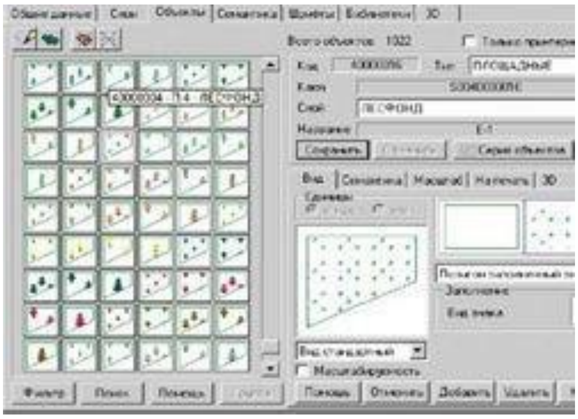
- fill - the color and nature of the fill allow using 2 indicators;

- hatching - the direction, color, type and density of lines allow the use of 4 indicators;

- filling with signs - type, color, design, density of signs allow the use of 4 indicators;

- boundary - line color and type allow you to use only 2 indicators, since using more indicators is difficult when overlaying the boundaries of different polygons.

This informative feature of the electronic map objects representation requires the development of a classifier. An example of such a representation is the identification of forestry objects on an electronic map by species composition and age group (fig. 32), which is an innovation in the field of visualization of forestry information on an electronic map.



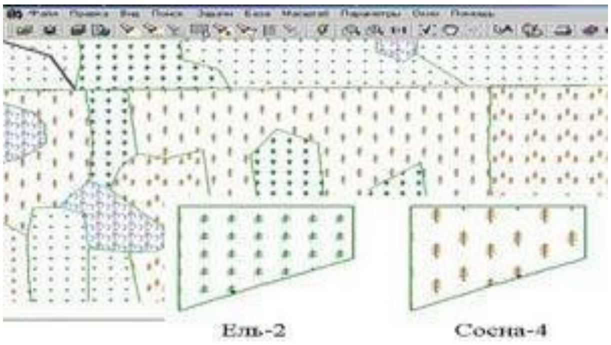


Fig. 31. Visualization of indicators for the main species and stand age group

Fig. 32. Identification of forestry objects on the electronic map by species composition and age group

2. General characteristics of the Topol GIS. GIS "Topol" allows:

- create forest maps - plot, quarterly, regional;
- link any meaningful information to them - taxation descriptions, quarterly summaries, state forest accounting, etc;
- perform a quick search for information within a forestry enterprise or region for queries of any complexity or nesting, by any indicators;
- view maps and related taxation or accounting information in any mode and sequence;
- make current changes to both spatial and taxation information based on the results of business activities;
- obtain summaries by quarters, forestries, forestry enterprises or arbitrarily selected objects, including forestry fund accounting, based on taxation descriptions;
- receive any thematic maps.

Thanks to the efficient operation of the system with raster images, the Topol GIS technology allows creating digital forest maps on a single topographic base for the entire region (district, oblast, state), made using scanned aerial photographs and topographic maps.

With this technology, topo maps at a scale of 1:10,000 are scanned and "stitched" into a single canvas for the entire region in the Gauss-Kruger projection. If the region is too large (more than 6 degrees in longitude), the base is made within 2-3 trapezoids.

The raster (scanned) images of aerial photographs are superimposed on the topographic map of the region created in this way at the reference points. The images are transformed by collinear transformation by 17-30 points.

Next, geodata of district boundaries from geo-journals are entered into text or tabular files, which are then imported into GIS Topol. The draft district boundaries are combined with raster images of topographic maps and gross errors that occurred during multiple rewrites of geo-journals are searched for. To facilitate the search and correction of errors, old forest management plots are scanned and overlaid on the topographic base. However, in the final analysis, the corrected geo-journal materials are used as the basis for the district boundary. From the old forest management plots, after combining all the data as a draft quarterly network. This ensures maximum accuracy of the topographic base creation by using all the source material available to the forestry department.

Only after the topographic base is created, the digitization of the internal situation based on aerial photographs begins.

After all the outliers are identified, the areas are automatically calculated, linked and transferred to the database. After that, it is ready to be used in GIS, including for the production of hard-copy maps.

Viewing taxation. When you select any object, the available characteristics of this object appear in the left part of the database form and in its right part. If the object selected on the left is a plot, it is a taxation description, if a quarter or forestry

- these are tables with various summaries (distribution of stocks by species, areas by bonuses, etc.).

The description of the allotment is presented in forms on several switchable pages: general description, additional description, description of plantations, additional information, notes. There is also a commoditization page for express evaluation of a freight train. To switch pages, just click on their title (visible tab) with the mouse. If the page header is out of the screen view, you can slide it into the visible area using the arrow buttons to the right of the page headers. On top of all pages there is always a visible bar with the area, land category and reserve on the allotment.

3. Modern Field-Map technology.

Field-Map is a system for computer aided field data collection with primary emphasis to forestry. It is a highly flexible system. Its use starts from the level of single tree measurement, through the level of research or inventory plot, up to the landscape level. Field-Map has been designed primarily for the purposes of forest inventory but it has functionality for a number of different field data collection tasks like forestry mapping, attributing forest stands for forest management planning, carbon offset monitoring, landscape mapping, standing volume assessment, measurement of research plots, inventory and monitoring of nature reserves, etc. Field-Map product line combines flexible realtime GIS software with electronic equipment for mapping and dendrometric measurement.

Field-Map system has been originally developed for the purpose of the national forest inventories. Currently it is the only software and hardware solution that is being used in numerous national forest inventories (NFIs). The idea behind Field-Map for NFIs is a continuous development of the software product, which is flexible enough to cover all requirements of various NFI methodologies. Such a solution is significantly more efficient than costly development and maintenance of a specific solution in individual countries. Training of the Field-Map technology for two forest engineers is free of charge with every purchase of Field-Map bundle. New versions of the software are released every year. One year of free technical support including software upgrades is provided with every Field-Map bundle license. Software updates and demo versions can be downloaded from the web pages www.fieldmap.com. Technical support using hot line via e-mail, phone or fax is available to Field-Map customers. Web pages for technical support, on-line help and many scripting examples are www.support.field-map.com. The guarantee period for the software is two years, for the hardware part it is one year (fig. 33).

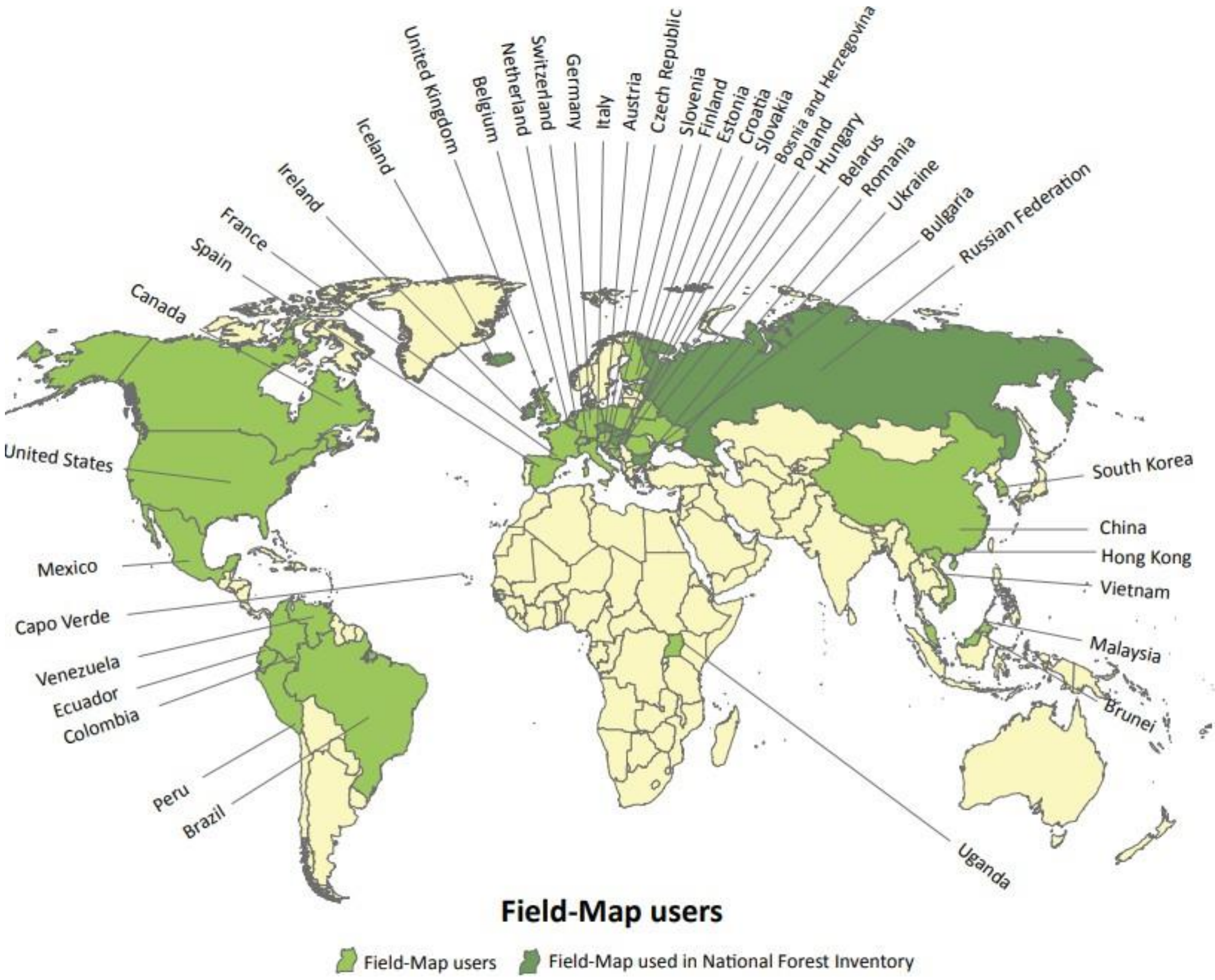


Fig. 33. Field-Map user

Flexible database structure. Field data collection projects such as forestry monitoring, measuring and mapping are based on well defined methodology of field observations. In order to fulfill various requirements of a particular field data collection project Field-Map provides a number of elements that enable complete adjustment of field database. Some features (e.g. special attribute types or multiplot approach) are specific for Field-Map and qualify it for a wide range of different data collection projects up to the most complex ones e.g. national forest inventory projects commonly containing hundreds of attributes in tens or even hundreds of tables.

■ User-defined database structure: user-defined data collection methodology = database structure = Field-Map project. Field-Map project also contains metadata describing the structure and content of the database.

■ Relational hierarchical database = multiple layers arranged in tree-like database structure supporting one-to-many, one-to-one and many-to-one relationships.

■ Multiple layers in each Field-Map project, multiple attributes for each layer.

■ Various attribute types (numeric, alphanumeric, memo, logical, date, time, picture/photo, video, voice memo).

■ Attributes with lookup list for easy and error free input of data particularly useful for keyboard-less field computers (usually about 80% of attribute values are entered using lookup lists).

■ Advanced attributing (height, diameter, counter, line length, lookup lists, conditional lookup lists, quick switch on/off of lookup list items, default values).

■ Multi-plot approach Multiple plots/sites = multiple implementation of the methodology for number of plots/sites Multiple plots in single database (e.g. thousands of plots of a forestry monitoring project) Easy management of multi-plot and multi team projects.

■ Any-time database structure customization without losing existing data.

■ Industry-standard data formats used for data storage (ArcView shape files for map entities, FireBird, MS Access or MSSQL for attributes).

Support for measurement devices.

Field-Map is based on efficient use of electronic or traditional measurement devices such as laser range-finder, electronic compass, GPS or electronic caliper. Field-Map natural and easy combination of measurement devices with the data storage and computing facilities of field computer enables user to obtain maximum effect from the technology (fig. 34). Field-Map supports a broad range of electronic measurement devices. The main equipment, which is usually the most important for forestry mapping and measurement, is a combination of laser rangefinder + electronic inclinometer + electronic compass (RIC). Field-Map fully exploits the potential of RIC to measure distances and vertical and horizontal angles for three dimensional mapping of forest structure. GPS is used by Field-Map both for navigation and mapping. A combined use of GPS and RIC as managed by Field-Map software enables to solve mapping, navigation and measurement tasks in forestry conditions, i.e., under the canopy where GPS commonly does not work well.

Fig. 34. Typical hardware components of Field-Map set

Field-Map is the only software product which fully supports optical scope for remote diameter measurement (fig. 35). Using optical scope mounted on laser range-finder allows measuring tree diameter at any height. Field-Map supports measurement of single diameters and also measurement of whole stem profiles. Additional supported equipment such as electronic calipers for tree diameter measurement or geodetic equipment such as LTI angle encoder or Leica or Sokkia tachymeters might be used. Field-Map can be used on PC compatible computers (MS Windows 95, 98, 2000, XP, Vista, 7, 8, 10), no extra hardware parameters are required. Field-Map requirements do not exceed the requirements of the MS Windows OS itself.

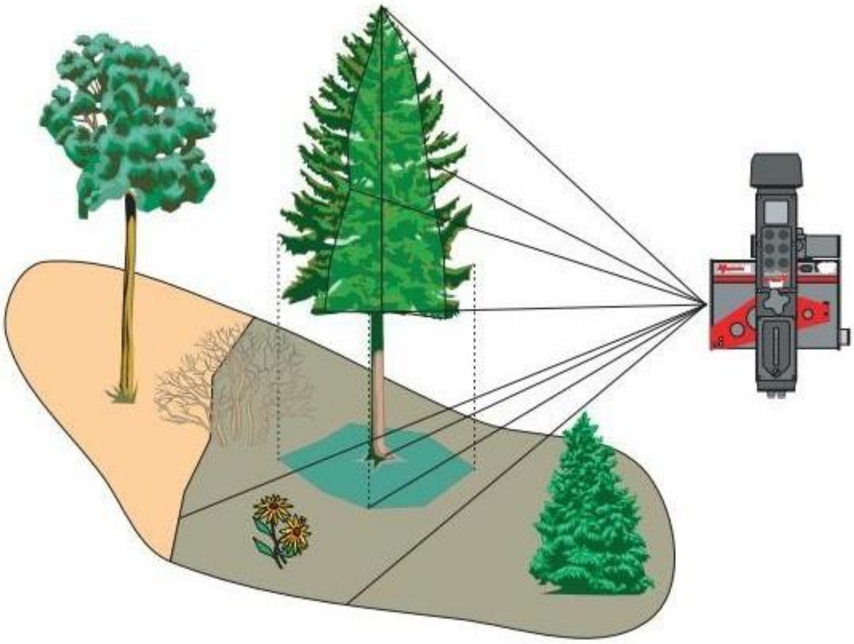


Fig. 35. Typical use of the laser rangefinder + electronic inclinometer + electronic compass for forestry – mapping, tree height measurement, upper tree diameter measurement, stem profile measurement, crown projection mapping, crown profile delineation

Field-Map has been specifically developed for keyboardless field computers that are operated by pen. It can be also used on computers with monochromatic displays. In order to support real-time communication with measurement devices, field computer needs to provide Field-Map with at least one serial port (RS232, USB or Bluetooth). Field-Map communication with external measurement devices is based on standard NMEA0183 protocol and in some cases (Leica and Sokkia tachymeters) on specific protocols. That means that Field-Map can support a broad range of different products, i.e. virtually any GPS on the market. Field-Map settings provide user-friendly tools for connecting measurement devices. User-friendly approach to the use of measurement devices is further emphasized by the Measurement Assistant, which provides user with online animated help during measurement process (fig. 36).

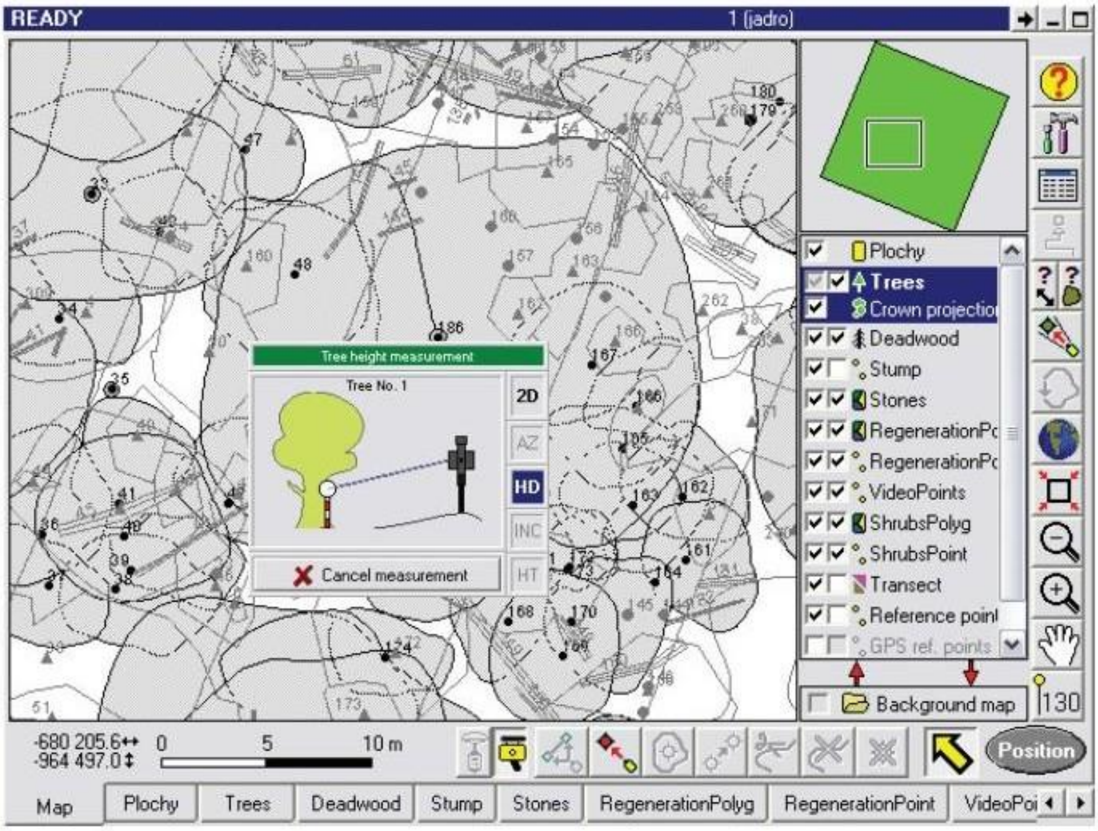


Fig. 36. Field-Map Measurement Assistant provides real-time help during field measurement

Field-Map benefits from the use of electronic measurement devices but it can also be used in conjunction with traditional measurement devices such as mechanical compasses, measurement tapes, hypsometers etc. In such a case the readings from the devices are entered to the computer by the operator.

Mapping. Field mapping and visualization of point/line/ polygon layers represents an important part of Field-Map functionality. Field-Map has all functionality for creating and editing of digital maps in the field including attributing and advanced GIS functionality. Mapping can be based on local Carthesian coordinate system or a selected map projection. The first approach is often used when mapping the interior of monitoring plots. In such a case the centre [0,0,0] is located in the plot centre and coordinates of other objects are related to this centre. The second approach benefits from Field-Map ability to support virtually any map projection worldwide. Parameters of map projections are predefined in Field-Map as well as parameters of geotransformation of WGS1984 geographic system into the projection. Geotransformation parameters as well as map projection parameters are user-defined and can be adjusted if necessary. Thus it is for instance possible to use different sets of geotransformation parameters for different parts of the country in order to increase accuracy. Map projection functionality of Field-Map enables using all measurement devices and obtaining final maps in projected co-ordinates directly on the screen of field computer during fieldwork. Real-time creating and visualization of the produced map right in the field increases productivity and quality of the result. Field-Map provides many useful features for visualization of field maps such as user-defined point and line symbols and labels that can be of fixed-size or scalable. During mapping Field-Map shows the actual position of the measurement equipment as well as e.g. traces of laser measurements. Zooming to user-defined or predefined scale, panning and showing the entire map are standard Field-Map features. Together with edited layers Field-Map can present on the screen of field computer background maps with showing context. Field-Map supports many different raster and vector formats (ECW, TIFF, MrSID, ESRI Grid, Imagine, ERDAS GIS, Band Interleaved By Line, Band Interleaved By Pixel, Band Sequential, Sun Raster, IMPELL Bitmap, SVF, GIF, BMP, JPEG/JFIF, Shapefiles, Digital Exchange Format, MicroStation Design File, Autocad drawing database, ArcInfo coverage) and WMS.

Field-Map works with point, line, polygon layers and special layer types such as trees, deadwood and transects. Additional layer types are derived from the basic ones and have additional features that are relevant for forestry projects. Mapping procedure is user-friendly and straightforward. New points or lines can be added via pen sketching on the screen of field computer, passing measurement data from measurement devices or by direct entering of known co-ordinates. Points and lines can be moved or deleted. Free line editing using dragand-move of selected line segment by cursor is useful for on-screen digitizing. Advanced mapping functions allow copying points and lines between layers, creating grids, buffers, parallel or offset lines, smoothed lines and closed traversing. Field-Map supports building of polygonal layers and has all necessary functions for it. Automatic line snapping and functions for cleaning and building topologically correct polygons give possibility of work with lines and centroids/label points of future polygons during fieldwork. When polygon boundary mapping is finished then Field-Map can build polygonal layers and transfer attribute values to polygons. Efficiency of building polygons by Field-Map is further increased by the possibility of involvement of lines from different layers during data processing. Thus it is not necessary to duplicate lines in different layers. During mapping of monitoring plots Field-Map benefits from its "continuous positioning". That means that equipment operator can freely move in order to, e.g., find the best view for mapping of new entity. Using a system of temporary reference points allows rapid georeferencing by shooting with laser to a reference point. It is not necessary to measure all entities from the center of the plot. During mapping in dense forest with understorey Field-Map benefits from automatic re-calculation of slope distances to horizontal distances. Prior to field mapping it is possible to lock individual attributes or whole layers (limited attributing, limited pen mapping, limited mapping). Thus it is possible to effectively manage the way of editing of data during fieldwork.

A fully functional Field-Map with a set of field equipment was tested at the Ukrainian Research Institute of Forestry and Agroforestry named after G.M. Vysotsky (Kharkiv) to determine the prospects for using this advanced technology in forestry, nature conservation, landscape research and for decoding remote sensing data. Preliminary research results have shown that Field-Map technology offers a very wide range of applications. It can be used by forest surveyors (tax assessors), nature conservationists, environmental and forestry inspectors, land surveyors, geographers, landscape architects, GIS specialists, and remote sensing specialists.

TOPIC 13. SPECIALIZED GIS FOR ENVIRONMENTAL PROTECTION (MODULE 3)

Plan

1. Ecological maps - the basis of environmental GIS.

2. Using GIS in planning and development of ecological network.

3. GIS concept of environmental monitoring and environmental safety.

1. Ecological maps - the basis of environmental GIS.

The purpose of creating environmental maps is to provide governing bodies, educational, scientific, design, and production organizations, public green movements, and individuals with up-to-date spatial information about the environmental state of the environment and the factors that affect it. Environmental mapping is an important generalizing stage of environmental research. Just like in geography or geology, depending on the specific purpose of the research, its detail, scope, and the area under study, environmental maps can also be of different scales and purposes: regional overview (1:5,000,000 - 1:1,000,000), small-scale (1:300,000 - 1:500,000), medium-scale (1:100,000 - 1:200,000), large-scale (1:25,000 - 1:50,000), and detailed (over 1:20,000). Depending on the subject matter, these maps can be of a geo-ecological, bio-ecological or techno-ecological nature, contain medical and environmental, radio-ecological information or some other specific environmental characteristics, and reproduce specific recreational, environmental or ecological and economic features of the territory.

In other words, modern environmental maps, like the modern science of ecology, are characterized by an extremely wide range of information depicted about natural and anthropogenic objects and processes, as well as the peculiarities of the spatial distribution of the effects of the interaction of natural and anthropogenic factors.

Environmental mapping, as well as environmental research in general, always begins with environmental monitoring. This term is understood as a system of observations, assessment, and control over the state of the environment in order to develop measures for its protection, rational use of natural resources, and prevention of critical situations harmful or dangerous to human health; observations of the existence of living organisms and their groups (communities), as well as natural processes, objects and their complexes, and natural and anthropogenic processes.

Depending on the spatial and temporal parameters of the processes and objects under control, or on the purpose and objectives of monitoring, the latter may have several levels, classes or types: local, regional, global (by the scale of observation), bioecological (sanitary), geoecological (natural and economic) and biosphere. The following types of monitoring are distinguished by their target area: basic (in untouched areas of the biosphere), impact (observation of natural phenomena in particularly dangerous areas caused by anthropogenic activity), background, chemical, physical and biological, remote (satellite or from airplanes or helicopters) or ground-based, geophysical, radioecological, etc.

Life requires environmental assessments of territories, environmental assessments of facilities, environmental studies and environmental mapping of areas where current environmental conditions are stressed or approaching critical. In these cases, environmental monitoring of a certain type, scale and time interval is carried out by representatives of other institutions on a contractual basis or under other conditions at the request of the client organizations.

When preparing environmental maps, it is important to clearly define and distinguish between positive and negative environmental impact factors.

Environmental maps are divided into four groups:

1) basic maps of natural conditions and resources with data on their anthropogenic changes and ecological status;

2) maps of pollution and violations of the environment and its components

3) operational maps of air pollution, water resources and disasters that have occurred;

4) assessment and forecast maps of changes in the environmental situation.

The set of environmental maps of an administrative district (region), as a rule, at a scale of 1:200,000 - 1:500,000, should include:

1) maps that characterize the peculiarities of the territory's nature and its natural potential (the main map is a landscape map that reproduces exogenous processes)

2) maps characterizing the peculiarities of the territory use and types of anthropogenic disturbances related to it (the main map is the map of anthropogenic landscape changes);

3) maps of nature protection and restoration;

4) maps and diagrams showing the dynamics of natural and anthropogenic processes (changes in the structure of agricultural land, sown areas, yields, livestock productivity, changes in the use of mineral resources, etc;)

5) a generalized map of geo-ecological zoning of the territory with information on the reasons for the formation of current environmental conditions.

Any environmental map has two components: natural and man-made. The natural component (landscape, geological or tectonic structure, etc.) is usually shown on these maps with a colored background. The anthropogenic component may be of a background nature (areas under intensive pesticide treatment, irrigated or drained areas, deforestation areas, etc.) Such a background anthropogenic component is shown using the same methodology as used, for example, in the preparation of geochemical, geophysical and other similar maps. Namely, when compiling them, it is necessary to have a grid of observation points or sampling points, observation routes. These data are processed by interpolating areas between points or routes, resulting in the allocation of areas between the isolines of a particular pollutant. The second method of displaying the anthropogenic component on environmental maps is discrete (point). Finally, environmental maps can combine both background and discrete components of the anthropogenic component. The first block is a topographic base at a scale of 1:500,000 or 1:25,000 (in the case of a map of a large city such as Dnipro). These maps contain the relief and hydrographic grid. They show residential areas, industrial and sanitary protection zones, highways, streets and bypass roads, bus and electric transport routes, recreation areas (parks, beaches, etc.), social and medical infrastructure (hospitals, hospitals, sanatoriums, boarding houses, kindergartens, schools), stationary state and departmental air, surface and groundwater pollution control points, weather stations, environmental infrastructure facilities (sedimentation tanks, sewage treatment plants, waste treatment plants, etc.). The second block consists of maps showing the sources of pollution with the numbers of enterprises and the types of pollution they emit. Forecast environmental maps are of particular importance. They reflect the changes that can occur in geocomplexes and ecosystems under certain conditions, taking into account the long-term effects of various pollution and disturbances on the environment, depending on their intensity and time of action. Predictive environmental maps are maps of stability and disturbance of geocomplexes, maximum permissible loads on the environment, etc. A promising modern trend in environmental mapping is the conversion of mapping products into digital form using a PC. This, in particular, makes it possible to create a display movie based on a series of environmental maps. A smooth, dynamic sequence of maps on a PC display screen reproduces the spatial and temporal course of natural and anthropogenic processes and phenomena. This technique makes it possible to quickly display different map variants (in terms of content and design), build three-dimensional images, transform images, etc.

2. Use of GIS in planning and development of the ecological network. Modern geographic information systems (GIS) technologies offer wide opportunities for automating the processing of research results of territorial objects. One of the first examples in Ukraine of the use of GIS technologies for the development of nature reserves is the «EcoNetwork» program developed with the support of the Regional Ecological Center "REC-Kyiv". The main task of this system is to summarize the results of scientific research conducted at different times in the Mykolaiv region to design a regional ecological network.

The «EcoNetwork» program is a database of geographical and biological objects in Mykolaiv Oblast. The database structure allows storing information about territorial objects, animal species, plant species and plant communities. The description of each territorial object includes the following characteristics: name of the object, protection status of the object (territory of the nature reserve fund, IBA-territory, etc.), status in the ecological network (natural core, eco-corridor), category of the object according to the Law of Ukraine "On the Nature Reserve Fund of Ukraine" (nature reserve, landscape reserve, etc.), degree of anthropogenic transformation of the territory, description of the geographical location of the object, description of the ecological value of the object details of decisions on granting special protection status to the territory, postal address of the site administration or institution (organization) under which the site is located, area of the site, list of administrative districts where the site is located, list of geographical coordinates of the site perimeter, list of owners, users of land within the site, photos, drawings, diagrams of the site. An example of the data entry dialog is shown in figure 37.

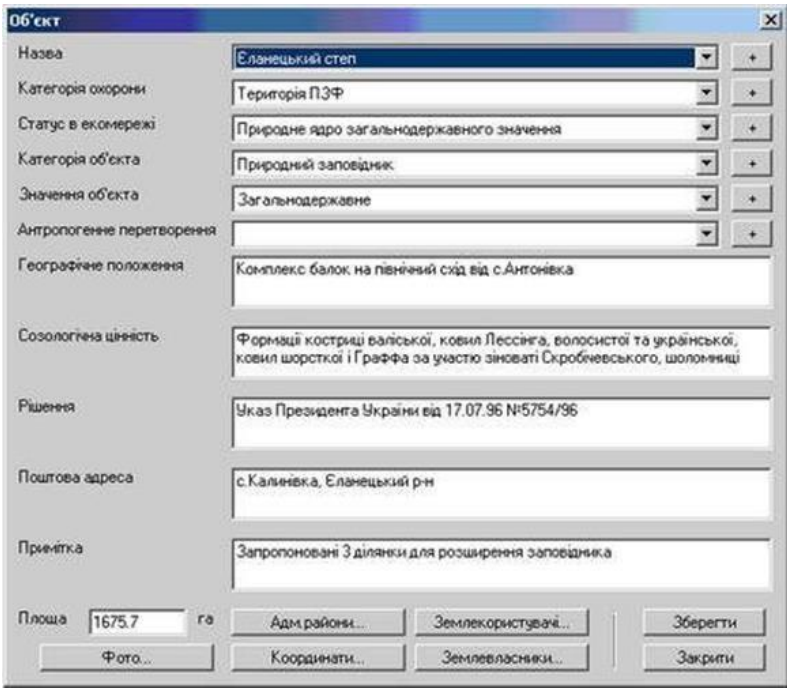


Fig. 37. Dialog for entering information about an object

Information on animal species includes taxonomic characteristics (species, genus, order), data on the special protection status of the species (categories of species protection according to the International Union for Conservation of Nature's Red List, European Red List, Red Data Book of Ukraine, regional Red List; whether the species is subject to special protection under the Bonn and Bern Conventions); geographical coordinates and a brief description of the areas where the species was recorded; administrative district; photographs, drawings. The structure of the data on plant species differs only by replacing the "genus" column with the "family" column. For plant communities, the name of the community, geographical coordinates of the location, its brief description and administrative location, and photographs are entered. The number of descriptions of the location of any object is not limited.

The «EcoNetwork» program allows you to systematize data according to the following selection criteria: all sites that have a given category of protection; all sites that have a given status in the ecological network; all sites that meet a given degree of anthropogenic transformation; all sites whose area is within a given interval; all sites located in a given administrative region; all objects that are under the jurisdiction of selected landowners or land users; species of animals, plants, plant communities that belong to a certain taxon; have a selected protection status; are located within the specified administrative district or on the territory of an object for which information is available in the database.

You can get information in the form of a map, an information window, or a text file. On the map, the territorial object is represented by a polygon, and the locations of animals, plants and plant communities are represented by symbols. The list of elements displayed on the map is generated automatically and appears in a separate window when the map is opened. To get a report, you need to select an element (object, plant species, etc.), specify the type of sampling criterion (e.g., object protection category) and the value for this type (e.g., IBA-territory), after which the sampling result appears simultaneously on the map and in the list (Fig. 38).

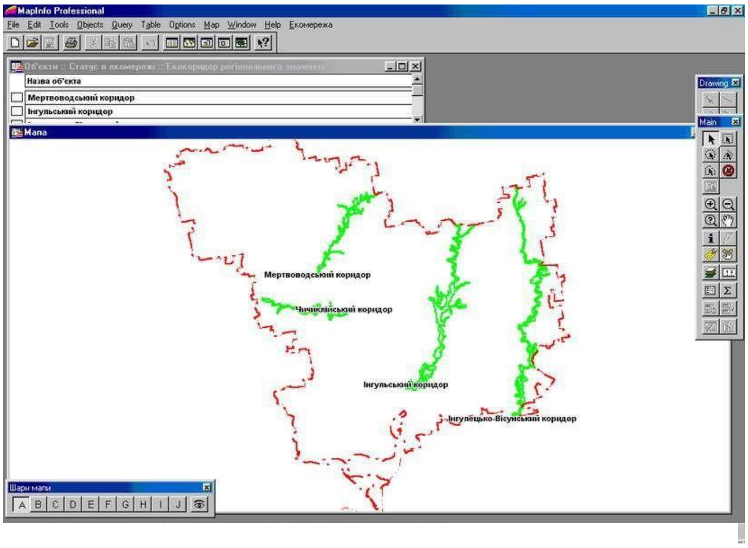


Fig. 38. The result of the GIS «EcoNetwork»

A separate button displays all the information about the object selected in the map window or in the list window. All data about the object can be saved to a text file for further work. Hardware requirements are determined by MapInfo and your operating system. GIS capacity "The amount of space available on a hard disk drive (HDD) depends mainly on the number of photos included in the database. Each photo takes about 100 KB (jpg files of up to 800x600 resolution are used). The base maps of the GIS "«EcoNetwork»" cover 15 MB, the program part - 0.3 MB; 2 MB are occupied by data tables. Capabilities of the program "EcoNetwork" for processing scientific research materials has led to the successful application of this development in solving a wide range of environmental issues. The program has received high marks at the regional and national levels. At the request of the State Department of Ecology and Natural Resources in Mykolaiv Oblast, the system continues to be updated with information.

3. GIS concept of environmental monitoring and environmental safety. The purpose of the geographic information computer system of environmental security (GIS CSES) is to create safe living conditions for the population and restore of the environment. It includes several different scales and can be adapted to Ukraine or any other state at a scale of 1:1,000,000, to oil and gas, energy, transport, construction, forestry, chemical, instrumentation and machine building, agriculture or other industries or a region at a scale of 1: 500,000, to an administrative region at a scale of 1:200 000, administrative districts, recreational areas, national parks at a scale of 1:50 000, industrial hubs, nuclear power plants, thermal power plants, oil and gas pipelines, oil terminals, other industrial facilities, and urban areas at a scale of 1:10 000.

The system is based on an environmental information bank consisting of 10 databases covering all components of the ecosystem. The computer simulates the ecological state of all components of natural and anthropogenic ecosystems, predicting their changes naturally and under the influence of anthropogenic load. Depending on the planned scenario of the interaction between nature, economy and society, the necessary environmental restrictions on economic activity in the territory, industry or enterprise are set. The system is a new information technology that allows for controlled monitoring and automated management of the environmental safety of the territory of the state, region, industry, oblast, district, city, and enterprise.

Scientific result: natural and mathematical models of the impact of man-made objects on natural geo-ecosystems (landscapes) were created, taking into account transboundary and regional transfers of pollutants.

Practical output: the technology of environmental audit of the territory of an administrative district has been developed, which can be used for the Autonomous Republic of Crimea, 24 administrative regions, 480 districts, and any city in Ukraine. After patenting, this technology can be sold abroad.

Research methodology. To solve the tasks, a test site was chosen on the territory that fully includes the Galician district within the administrative boundaries (Fig. 39).

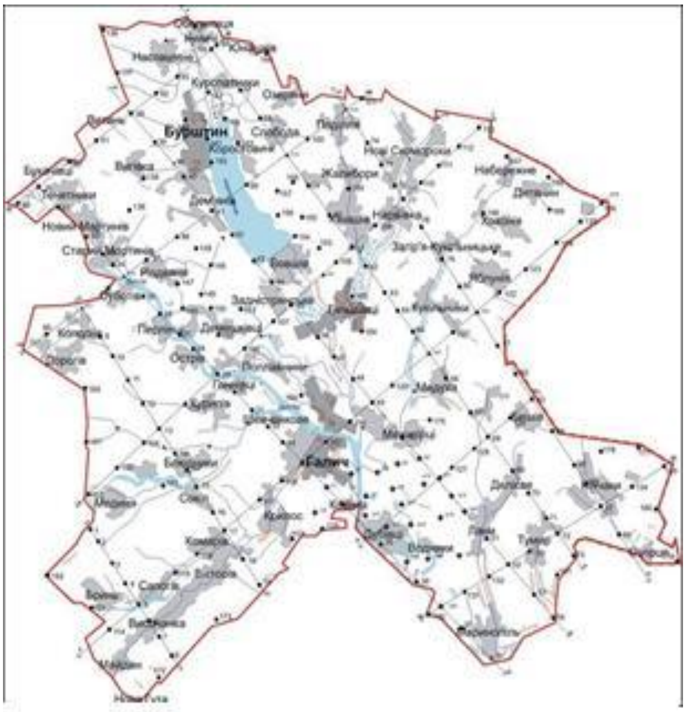


Fig. 39. Regular network of sampling points

A network of 220 observation points was set up on an area of about 722 km^2, which more or less evenly covers the entire test site. The working scale of the field research is 1:50 000. Geographical coordinates and absolute heights (altitudes) of the observation points were determined using GIS MAP INFO from a topographic map of 1:100 000 scale. In field expeditionary conditions at 220 geo-ecological sites, samples were collected: soils - 348; groundwater - 192; surface water - 54; atmospheric air - 192; snow and rain - 192; bottom sediments - 54; total - 1032 samples. A total of 1032 samples were analyzed by atomic absorption, X-ray fluorescence and chromatographic methods for the content of chemical elements and substances: Hg, As, Cd, Pb, Ni, Cu, Zn, Cr, V, Sr, Fe, Al, Cl-, SO-4, N ammonium, BOD_5, oil products, phenols, DDT, O_2, CO_2, CO, NO_x, SO_x, acetone. A total of 7010 analyzes were performed. 40 elemental geochemical maps were created (fig. 40, 41).

4 component environmental and techno-geochemical maps and the resulting (integral) map of the current environmental situation with the allocation of 24 geo-ecological bands and 6 environmental states were constructed.

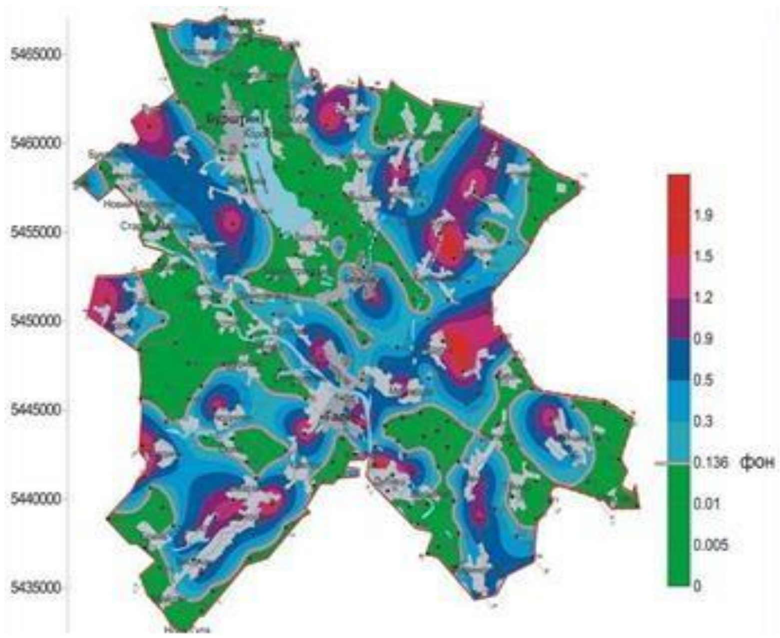


Fig. 40. Example of a map of cadmium content in soils

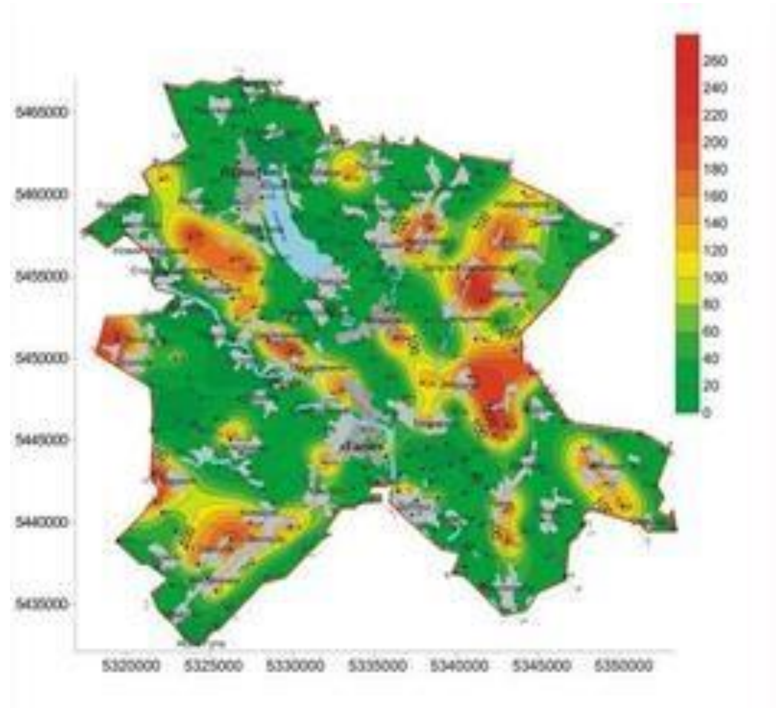


Fig. 41. Distribution of soil samples by the content of pollutants exceeding the background

Scientific results: - Variational and statistical processing of databases by the regression method revealed a close relationship (correlation coefficients of 0.71-0.85) between Cu, Pb, Zn, Cd, Ni; Hg and As; Fe and Al in the range of their content from

0 to the geochemical background, which indicates the natural paragenesis of these elements in soils. Above the background values, the dispersion increases sharply, indicating the anthropogenic nature of the anomalies;

- a new calculation and graphical method for determining the geochemical background is proposed, which, unlike the existing ones, greatly simplifies this procedure.

Practical results:

- close connections between the mentioned elements allow to calculate the content of other elements based on the content of one indicator element, reduce the number of analyzes by 3-5 times, thereby reducing the cost of environmental audit;

- the spatial distribution of contamination in the soil from Burshtyn TPP allows us to identify uncontaminated areas where we can grow, after obtaining an agro-ecological certificate from the Ministry of Ecology and Natural Resources of Ukraine, environmentally friendly plant products, which are 3 times more expensive than conventional ones on international markets.

Topic 14. SPECIALIZED GIS IN THE AGRICULTURAL SECTOR (MODULE 3)

Plan

1. Use of electronic maps and GIS in agronomy.

2. Features of application of remote sensing results in agricultural GIS.

3. Application of information technologies in the system of precision agriculture.

4. Specialized geographic information system for management of erosion processes.

1. Use of electronic maps and GIS in agronomy.

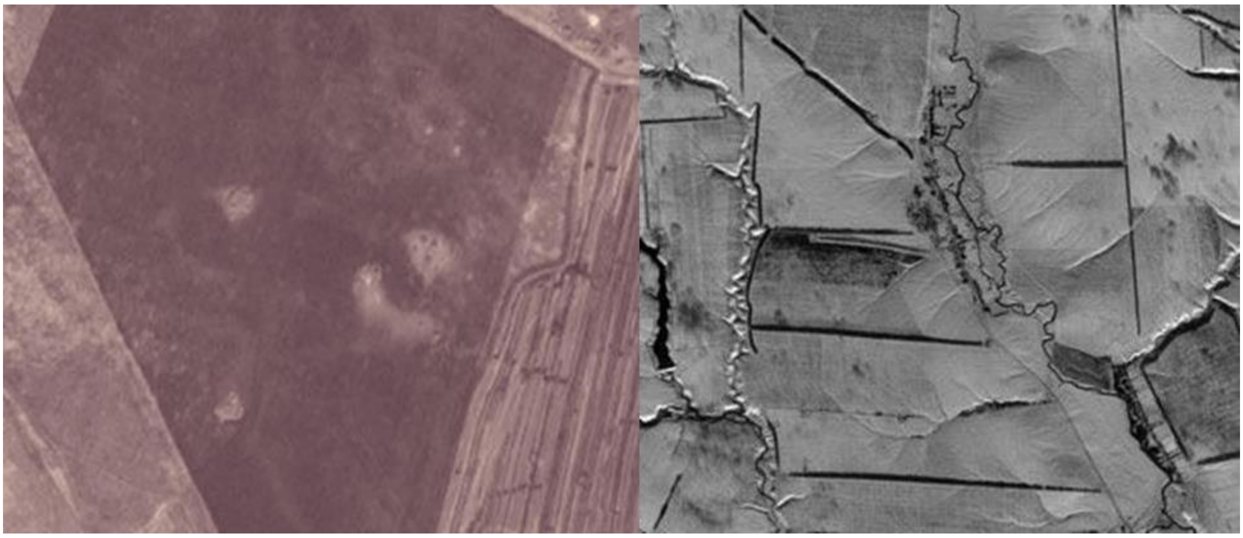
Poor accounting of the necessary factors affecting the efficiency of agricultural production leads to unproductive costs, reduced yields and product quality, and breakdowns of expensive equipment. Each land plot has both relatively stable and dynamic, variable agronomic factors. The former include the conditions of the terrain, soil, and hydrogeology. The latter include the current climatic and phytosanitary conditions. PANORAMA-AGRO GIS is designed to provide information support for the management of an agricultural enterprise, taking into account both factors. In addition, this program has a built-in farm machinery monitoring unit that provides automated collection of information on agrotechnical activities and allows you to assess the quality of mechanized work.

Agrotechnological planning includes the following types of work:

- analysis of the potential production capabilities of the farms (personnel and land resources) and their current and potential efficiency;
- measuring fields by driving around the contour with high-precision GPS equipment;
- drawing up the structure of sown areas and crop rotations in the format of a vector electronic map;
- calculation of the need for machinery and equipment;
- economic analysis at minimum and maximum yield levels that are consistently possible for specific conditions.

Electronic field maps have a common projection and a single coordinate system. As a result, accurate geographical referencing of soil contours is performed, combining soil contours with their corresponding relief forms. The georeferencing begins with the hydrography network, gully and ravine network, and is often supplemented by the road network and other objects that are well distinguished on the soil map and mapping base [60].

Using satellite imagery, the presence of elementary soil structure (or "soil pattern") is checked for each contour highlighted on the soil map. The components of the soil structure have different image tones and create a kind of image pattern, which can be used to calculate the composition of the components. The component composition is determined based on the territory's belonging to the soil-geographical zoning area and the cause of the soil structure (erosion, salinity, etc.) (fig. 42). To do this, the shapes, sizes of the soil structure components, its affiliation to the mezorelief, the genesis of the soil-forming rocks and other information contained in the literature and reports of previous studies are analyzed [61].



a *b*

Fig. 42. Fragments of satellite images used to create an electronic map of fields: *a - Cartosat image (2.5 m resolution). Salt marsh complexes (light plumes) are clearly visible, which spoil the quality of the land and require chemical reclamation; b - Ikonos satellite image (1m resolution). The water-erosion network is clearly visible*

As a result, the electronic map of fields contains all the necessary information for making design decisions on the placement of crops, differentiation of cultivation technologies at different levels of production intensification, optimal organization of the territory taking into account landscape connections, i.e. formation of a system of agriculture and agrotechnologies. This information is also necessary and often sufficient for designing livestock production, solving social and environmental problems, i.e. for developing an on-farm land management project (agricultural production project) (fig. 43).

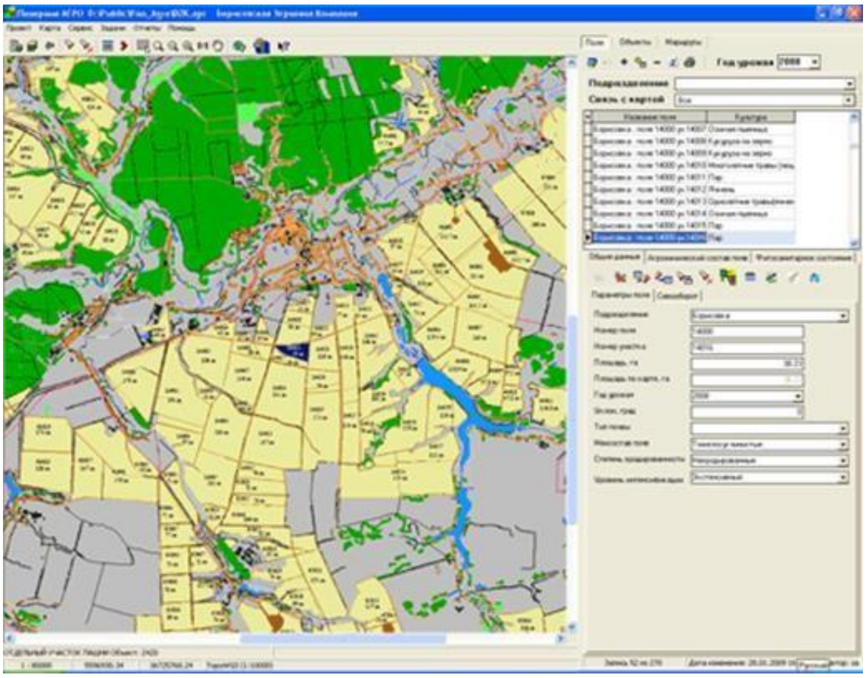


Fig. 43. A fragment of the electronic field map and attribute database in the GIS "Panorama-AGRO"

Farm specialists are offered a convenient mechanism not only for accumulating data, but also for maintaining field history with reference to the year of harvest. Analysis tools allow you to perform spatial and logical queries on data, generate samples and reports. Accumulation of data with data accumulation with reference to the year of harvest provides a retrospective analysis of information, and three-dimensional graphics tools provide its visual representation (fig. 44).

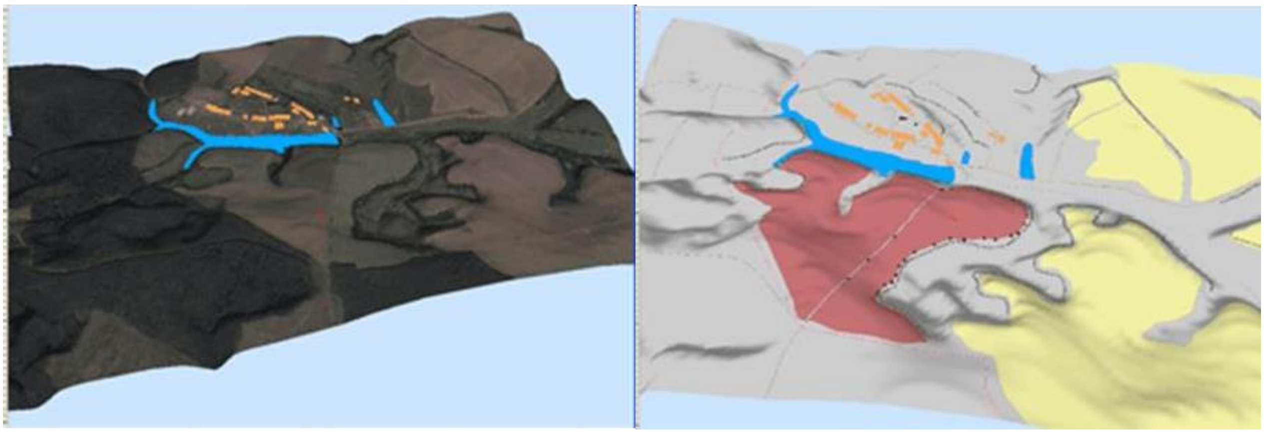


Fig. 44. Fragments of three-dimensional models of electronic field maps

2. Features of application of remote sensing results in agricultural GIS. Remote sensing of soils, vegetation, and water bodies (as areas of remote sensing) can be carried out by measuring reflected or emitted solar radiation. Reflectance spectra depend on the chemical and mineralogical properties of reflective surfaces (e.g., soil cover), as well as on external (relative to the object) meteorological conditions. For example, the granulometric composition of the soil affects the relationship between the amount and magnitude of reflected radiation.

The basic principle of the remote soil survey method is to use data on the amount and distribution of radiation spectrum bands to obtain information on the physical and chemical properties of the soil [62]. The interpretation of aerial images for soil mapping is divided into *genetic and contour*. Genetic interpretation makes it possible to determine the soil content of a contour. Contour interpretation ensures accurate delineation of boundaries between different soils (fig. 45). For soil interpretation, you can use direct interpretive features (tone, color, size and shape of contours, surface image pattern, and, in case of multi-zone images, the spectral appearance of the object).

Fig. 45. Fragment of a satellite image with overlaid soil contours on the territory of the village of Verkhniy Luzhok, Skole district, Lviv region

However, it should always be remembered that soil as an integral natural object is often not directly visible on images. Only in the case of plowing and the absence of crops does the soil surface become visible on the images and its individual properties (humus content, moisture, carbonation, salinity, particle size distribution of the top layer, etc.) However, the soil surface alone is not enough to identify individual soil units. Therefore, indirect features play a very important role in soil interpretation: landforms, vegetation, geological structure, results of human activity, and landscape components. For the interpretation of soils of forested areas, alluvial, meadow, and marsh soils, the greatest effect is obtained by using spectral-zone imagery.

Aerospace imagery information opens up new opportunities in the field of agricultural monitoring [63]. To solve the problems of agricultural monitoring by means of remote sensing, the technical means of the Center for Remote Sensing and Data Processing (Dunayivtsi) - remote sensing data reception centers - are involved[64]. The Center worked to identify the main soil types in Khmelnytskyi region using medium resolution remote sensing data, and to forecast winter wheat yields in the oblast, rayon and individual farms. The method of spectral processing was applied using Terra (Modis 500 m) images close to hyperspectral.

Based on the classification data, the following were created: vector soil layers, thematic maps that allow assessing the typical composition of the main soil types on a regional scale, calculating the percentage of decoded soils, and conducting ground surveys at 17 test sites. The results were used to create soil maps of the test plots and to create a database of soil spectrograms. Using GPS, the test plots were accurately georeferenced and a digital elevation model was built. A flooding model of the test plots was created to predict soil erosion.

To verify the results obtained using remote sensing data, ground surveys were conducted on the following: the condition of crops at all stages of plant development; reserves of productive moisture in the soil; the state of weed infestation in the fields; plant biomass per hectare at all stages of crop development; biological crop yields on each test field; and economic crop yields.

Space-based research on the test plots provided data that affect the dynamics of plant development: NDVI at all stages of plant development; air and soil temperature.

After the expert classification of Terra satellite images (Modis 500m), winter wheat crops were identified and their area was calculated. Using formulas developed in 2005, neural networks were used to calculate the following: biomass of grain crops at all stages of plant development; yield at the the last phase of plant development.

For a more accurate calculation of the biomass of grain crops, all data on biomass and NDVI for 2005-2006 were combined at all stages of plant development. Based on the combined data, new formulas were derived using a neural network that more accurately reflect the dependence of NDVI on time and on the biomass of cereals crops whose varieties were studied. To determine the accuracy of biomass calculations using neural networks, the absolute and relative errors for all phases of grain crop development were calculated. Thus, the data on winter wheat yields on each test field obtained from space-based and ground-based studies were compared. The absolute error was 11%.

3. Application of information technologies in the precision farming system. One of the main ways to solve agricultural problems is spatial and temporal optimization of conditions for plants. Modern agriculture is mainly focused on spatial optimization. Its task is to implement technological measures in accordance with the needs of plants and the phytosanitary situation, the condition of crops in each elementary area of the field, which requires detailed cartograms with data on the supply of nutrients, weed density, plant condition, biological yield, etc. These tasks are successfully handled by modern information technologies, the development of which has led to the emergence of a new trend in the agricultural sector - precision farming [65]. The introduction of equipment control devices based on space navigation systems played a decisive role in this. Currently, the devices used in agriculture related to space navigation systems are divided into two groups: parallel driving systems and autopilots. In the first case, the system consists of a GPS (Global Positioning System) signal receiver mounted on the tractor, a controller, and a direction indicator - a screen that displays the coincidence or deviation of the tractor's trajectory from a predetermined one. The control system allows you to memorize the course and directs the tractor strictly parallel to the line recorded during the first pass of the unit. The second variant of control systems is the autopilot, which consists of an electro-hydraulic tractor control system that provides autopiloting of the machine in the field. The tractor driver assists the tractor control process only at turns, which allows him to focus on the technological process and physically get less tired. The GPS system is universal. The receiver and terminal can be used on other specially prepared tractors and self-propelled machines. In addition, this system allows you to work at night and in poor visibility, due to rain or fog, which often happens during spring, summer or autumn field work [66].

Precision farming is a system of mutually agreed measures aimed at creating optimal and equivalent conditions for plant development by differentiated application of technological materials (seeds, fertilizers, pesticides, etc.) in accordance with the unique characteristics of each elementary field. The concept of "site-specific farming" is close to it. Precision farming involves: 1) detailed mapping of the field according to the main agrotechnical parameters; 2) coordinate linking of machine and tractor units to the field; 3) precise implementation of technological measures in accordance with the characteristics of the elementary sections of the field.

The main components of the STS are a geographic information system (GIS), a differentiated global positioning system (DGPS) and variable rate technology (VRT). A geographic information system in agriculture is designed to collect and process data on agro-technological parameters of elementary field plots. The information can be collected by taking samples in the field (for example, to determine agrochemical parameters), followed by processing the analysis results and linking them to the coordinates of the sampling sites. Optical devices with non-contact sensors have been created, with the help of which in the infrared The fields are photographed using radiation from airplanes or satellites. The information with the characteristics of the parameters is accumulated in the Data Base and used to draw up thematic maps of yield, nutrient content, application rates of technological materials, etc.

Differentiated global positioning system is a radio navigation satellite system specially adjusted to determine the location of stationary and mobile objects in three world coordinates (longitude, latitude, altitude) with an accuracy of tens of centimeters. It is an improved version of the Global Positioning System (GPS), the accuracy of which is measured in tens of meters [67].

Variable Rate Technology (VRT) is the application of variable rates (doses) of technological materials with the help of special equipment in accordance with the characteristics of each elementary field. The basis of VRT is high-precision agricultural machinery, the functional properties of which are determined by the widespread use of electronic devices (computers, microprocessors, sensors) [68].

Precision agriculture includes many elements, but they can be divided into three main stages: Gathering information about the farm, field, crop, region; Analyzing information and making decisions; Implementing decisions - conducting agrotechnological operations.

The first stage is quite advanced in terms of hardware and software. Soil automatic samplers equipped with GPS receivers and on-board computers are actively used abroad; geographic information systems (GIS) for drawing up spatially-oriented electronic field maps; yield maps of threshed crops obtained immediately after harvesting; remote sensing methods, such as aerial photography and satellite images.

The second stage is currently the least developed, but there are a number of software products on the market designed to analyze the collected information and make production decisions. These are mainly programs for calculating fertilizer doses with elements of geographic information systems (GIS). For example, these are SSToolBox ©, Agro-Map ©, Agromanager ©, LISSOZ ©, Urozhayagro ©, ADEPTIS ©, as well as FieldRover II ©, MapInfo © and AgroView ©.

The stage of agro-technological operations, like the first stage, is developing dynamically. Here, the most advanced operations are liquid and solid mineral fertilizer application, as well as grain sowing. Fertilization using precision farming technology is carried out in a differentiated manner, i.e., relatively speaking, we apply as much fertilizer per square meter as is needed here (in this elementary area of the field). The application is carried out in two modes - off-line and on-line. The off-line mode involves the preliminary preparation of a task map on a stationary computer, which contains spatially referenced fertilizer doses for each elementary field section using GPS. To do this, the field data necessary for calculating fertilizer doses (spatially referenced) is collected. The dose is calculated for each elementary area of the field, thereby creating a task map (in a special program). The task map is then transferred on a chip card (data carrier) to the on-board computer of agricultural machinery equipped with a GPS receiver, and the specified operation is performed. The tractor equipped with an on-board computer, moving across the field, uses GPS to determine its location. It reads the fertilizer dose corresponding to the location from the chip card and sends a corresponding signal to the controller of the fertilizer distributor (or sprayer). The controller, having received the signal, sets the required dose on the fertilizer distributor.

The real-time mode (on-line) allows you to determine the agricultural needs for the operation in advance, and the fertilizer dose is determined directly during the operation. Agricultural needs, in this case, are the quantitative dependence of the fertilizer dose on the readings of the sensor installed on the agricultural machinery that performs operation [69]. In the on-line mode, the on-board computer receives data from the sensor, compares it with the defined and stored agricultural needs, and sends a signal to the controller in the same way as in the off-line mode. Currently, various sensors are being actively developed that allow the use of on-line mode. These are optical sensors that determine the nitrogen content of leaves and weediness of crops; mechanical sensors that estimate biomass; electromagnetic sensors, etc.

In 2000, Ukraine adopted the Program for the Development and Implementation of Technical Means for Precision Farming Technologies, which yielded the first results, including mobile machines for mechanical soil sampling, electronic and mechanical devices for changing fertilizer doses, a machine for differential tillage, a radio system for determining the coordinates of units using a base radio station, etc.

4. Specialized geographic information system for managing erosion processes. To predict erosion, calculations of the average runoff over characteristic terrain profiles are widely used using the Universal Soil Loss Equation (USLE). For spatial modeling of erosion at the local level of detail, raster terrain models with a step from 5 to 1 m are used. In the practice of designing anti-erosion measures in Ukraine, not complex models are used, but calculation formulas by C.E. Mirtshulava, G.I. Shwebs, USLE. The most complex and important is the local level of optimization of soil protection.

Its essence lies in achieving, by the cheapest means, management conditions under which the erosion hazard index, determined by the ratio of the predicted and critical water flow rates, does not exceed the value of 1. In the developed model, the relief is taken into account in the form of an information layer of flow lines in the Marinfo according to certain rules, which made it possible to build a discrete hierarchical information model for automatic identification of its erosion parameters. The computer program converts the input information on individual drainage lines into a spatial information network that allows calculating at arbitrary points: the area of elementary catchments on slopes with any width of the closing channel; average weighted slopes; slope exposures; transformation of water flow by boundaries; the erosion hazard index of land; directions of erosion-safe drainage, etc. Fig. 46 shows a discrete information network of 3 hierarchical levels, which allows to automatically determine erosion factors of the relief at any point of the studied territory [70].

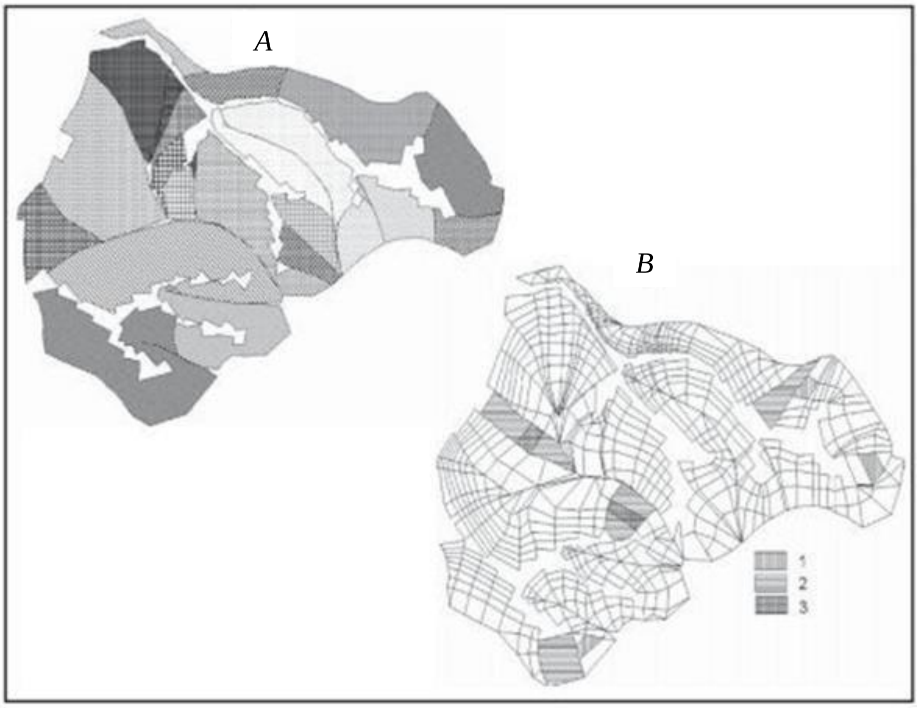


Fig. 46. Information network for spatial identification of erosion parameters of the relief: *A - 1st level (watershed areas); B - 2nd and 3rd levels of identification; 1 - elementary information cells (3rd level of identification); 2 - elementary slopes (2nd level of identification); 3 - elementary information cells within elementary slopes*

To take into account the spatial differentiation of water flow, the computer program automatically draws an elementary catchment with any predefined width of the closing channel, determines the points of intersection of the flow lines that limit this catchment with the boundaries, and calculates water flows taking into account the transformation of the flow by these boundaries. A shows the result of automatic detection of elementary catchments and their parts separated by boundaries. In this example, the width of the closing channel of the catchments is 3 m, so they look like lines. In fig. 47 B shows the result of the land erosion hazard assessment. The assessment was made by independently calculating the erosion hazard index at 150,000 random spatial sampling points of uniform density. Thanks to an efficient information network, the speed of calculations on a computer of average capabilities is approximately 1000 points per second.

Simultaneously with the spatially differentiated assessment, a generalized assessment of the erosion hazard of land is carried out, which is presented in the legend (fig. 47 B) in the form of a distribution of land by erosion hazard categories. The legend, as well as the map of land erosion hazard assessment itself, was calculated in the main computer program and imported into MapInfo in its final form, as shown in fig. 47 B.

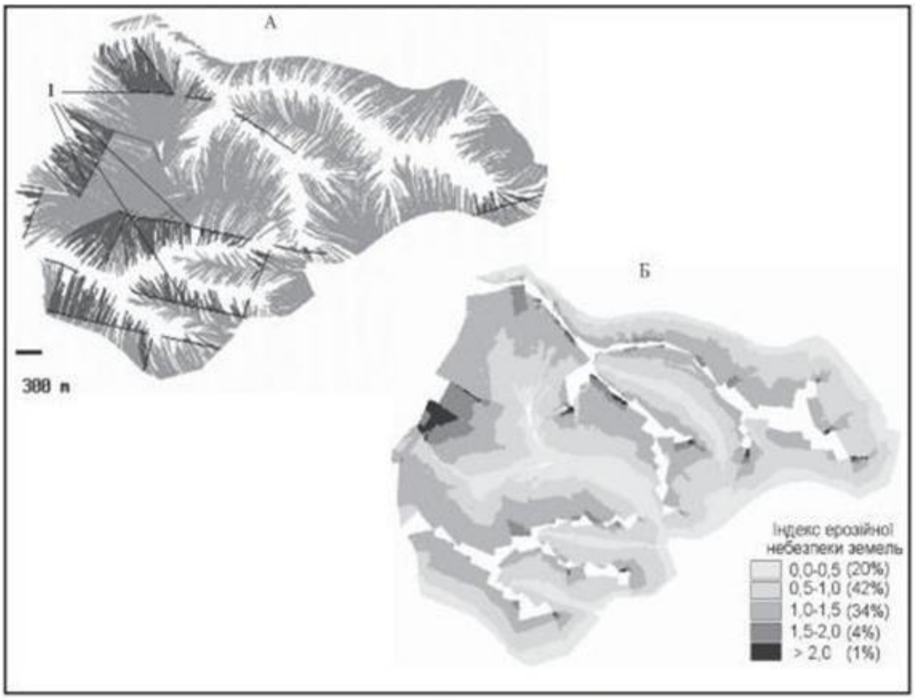


Fig. 47. The result of an automated land erosion hazard assessment:

A - differentiated determination of elementary catchment areas taking into account runoff transformation by boundaries: l - boundaries; B - land erosion hazard assessment

Economic efficiency from the implementation of the development will be achieved through the optimal use of natural capabilities of land protection from erosion, saving time for calculating their erosion hazard and funds for erosion protection measures of excessive protection (up to 30% of their total cost).

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[60] Electronic maps as the basis of GIS can be used in agronomy to create field maps and initially enter information into the system. Each layer of an electronic map is linked to an attribute database that contains information on each contour relevant to the map layer. For example, the database of the soil microstructure map contains the following information: contour number; soil combination index; full name of the soil combination; soil composition; genetic characteristics of soil-forming rocks and their particle size distribution; contour area.

[61] The boundaries of soil structure elements are adjusted to the actual boundaries of forms and relief elements. By mutually overlaying thematic layers of the electronic field map, a comprehensive map of agroecological groups and land types, i.e. elementary areas of the agro-landscape (homogeneous areas), each of which is provided with a database of all parameters, is formed.

[62] The principles and methods of soil interpretation were originally developed for aerial photographs used for soil mapping at large and medium scales. The emergence of satellite imagery made it possible to use them in the preparation and correction of medium-, small-, and overview-scale soil maps.

[63] Bilan I.I., Pakshyn M.Y., Skubko O.V. (State Research and Production Center for Aerospace Information, Remote Sensing and Environmental Monitoring, CPSI and CNP, Dunaivtsi) (http://www.pryroda.gov.ua/ua/index.php?newsid=730).

[64] For image processing, we used the Demo version of the Erdas Imagine software product, ArcGIS, provided by ECOMM Co.

[65] To implement precision farming technology, modern agricultural machinery controlled by an on-board computer and capable of differentiated agricultural operations, precision positioning devices (GPS receivers), technical systems that help to detect field heterogeneity (automatic samplers, various sensors and measuring systems, harvesting machines with automatic crop accounting, remote sensing devices for agricultural crops, etc.) The core of precision farming technology is software that.

[66] Studies show that, due to the increased accuracy of work, working time is reduced by an average of 7%, fuel consumption is reduced, and mineral fertilizers and plant protection products are used rationally. Also, thanks to these devices, there are no untreated herbicide strips on the fields. For large farms and agricultural service companies, it is important that such a system provides information about the work being done and records the coordinates of agricultural machinery every second.

[67] The widespread use of GPS to determine the coordinates of machine and tractor units is constrained by the high cost of technical and information means, the lack of a developed network of differential correction stations, and possible errors caused by lightning discharges and magnetic storms.

[68] Sprayers are equipped with devices for electronic control of the working solution supply pesticides, seeders - for adjusting the seeding rate and seeding depth, fertilizer machines - for adjusting fertilizer doses, tillage machines - for adjusting the depth of tillage. The work process is controlled and monitored from a tractor equipped with a multi-channel microprocessor or computer, and unified sensors are installed on agricultural machines. The control panel receives information about the speed of the machine, the amount of work performed, fuel consumption and stocks of technological materials, etc. If it is not possible to implement a precision farming system according to the classical scheme, alternative approaches are used. For example, radio systems consisting of a base radio station located in a room and transceivers installed on field units are used to determine the coordinates of the MTA. Ukrainian scientists have developed a new concept and methodology for implementing a precision farming system based on determining the location in the field and in a local curved coordinate system. Using digital video cameras equipped with the machines, they take pictures of the fields, which are used to draw up an agrotechnological map of tasks in coordinates that indicate the number of the machine's pass and its distance from the edge of the field. The map can be saved to the on-board computer.

[69] We use an optical sensor Hydro-N-Sensor manufactured by Yara ©, which determines the chlorophyll content of leaves and biomass in the infrared and red light range. Based on these data, as well as data on the variety and phenophase of the plant, the dose of nitrogen fertilizers is

determined. To use the N-sensor (Hydro-N-Sensor), you also need a portable N-tester device that determines the same parameters. The results of the operation (doses and coordinates, treated area, time and name of the performer) are recorded on a chip card.

[70] The 1st step is to determine whether the point belongs to a certain 1st level identification area. At the 2nd step, a system of 2nd level identification areas bounded by adjacent drainage lines is automatically defined within this level and the point is determined to which one it belongs. The 3rd step checks whether the point belongs to one of the elementary slope areas bounded by segments of adjacent drainage lines and horizontals within the 2nd hierarchical level. After that, the height of the point, its exposure, and distances to runoff lines are calculated; the position of the runoff line from the point to the watershed is determined parametrically. At the same time, the point belongs to a certain soil polygon, a certain crop rotation field, and thus all quantitative parameters of erosion factors are determined.

LECTURE 12

TOPIC 15. PROSPECTS FOR THE USE OF INFORMATION SYSTEMS

(Module 3)

Plan

1. Characterization of conceptual directions of GIS development.

2. World experience in the use of GIS/RSE technologies in various industries.

3. Prospects for the use of GIS/RSE/GPS in agriculture.

1. Characterization of conceptual directions of GIS development.

Modern GIS technologies are combined with another powerful system for obtaining and presenting geographic information - remote sensing data from space, airplanes and any other aircraft. Space data in today's world is becoming increasingly diverse and accurate. The ability to obtain and restore it is becoming easier and more accessible. Dozens of orbital systems transmit high-precision satellite images of any territory of our planet. Archives and databases of digital images covering a vast area of the globe have been created. Their relative accessibility for the consumer (quick search, ordering and receiving via the Internet), surveying of any territory at the request of the consumer, the possibility of further processing and analysis of photos from space using various software tools, integration with GIS packages and GIS systems, turn the GIS-RS tandem into a new powerful tool for geographic analysis. This is the first and most realistic direction of modern GIS development.

The second direction of GIS development is the joint and widespread use of high-precision global location data of a particular object obtained with the help of GPS systems (USA). This system is already widely used in maritime navigation, aeronautics, geodesy, military and other areas of human activity. Its use in conjunction with GIS and remote sensing will form a powerful triad of highly accurate, up-to-date (up to real time), constantly updated, objective and densely saturated territorial information that can be used almost anywhere. Examples of successful joint use of these systems by NATO troops during combat operations in the military conflicts in Iraq and Yugoslavia prove that the time for widespread use of this trend in other areas of practice is not far off.

The third direction of GIS development is related to the development of telecommunications, primarily the international Internet and the massive use of global international information resources. There are several promising ways in this direction. The first path will be determined by the development of corporate networks of the largest enterprises and management structures that have exclusive access to the Internet. This way will most likely determine the development of technological problems of GIS when working in corporate networks. Dissemination of proven technologies and solving the problems of small and medium-sized enterprises and firms will give a powerful impetus to their mass use. The second way depends on the development of the Internet itself, which is spreading around the world at a tremendous pace, attracting tens of thousands of new users every year. This way leads to a new and yet unexplored road, where traditional GIS from usually closed and expensive systems, existing for separate teams and solving separate tasks, will eventually acquire new qualities, unite and turn into powerful integrated and interactive systems for global use. At the same time, such GIS will become: geographically distributed; - modularly expandable; - shared; - constantly and easily accessible. Therefore, it is possible to assume that new types, classes and even generations of geographic information systems based on the capabilities of the Internet, television and telecommunications will emerge on the basis of modern GIS.

Based on the information currently available and following the current trends in the development of geographic information systems and technologies, it is already possible to outline some features of future geographic information systems:

- GIS-TV - (GIS-TV). These systems are likely to become a new class of GIS, combining the capabilities of modern television, as well as traditional and specialized GIS and the Internet. Certain prerequisites for the emergence of some features of such systems have already appeared and are used on television channels. GIS-TV has great potential in the sphere of organization of distance educational television, where the functions and capabilities of GIS systems and GIS technologies can be used. It would be possible to organize and broadcast various programs and lessons based on spatial ideology.

- GIS^2 - (GIS about GIS or "GIS in a square"). This new type of geographic information systems is likely to be able to study and analyze not the territorial information itself, but a significant mass of already existing and geographically distributed GIS created and used in various areas of human activity. GIS^2 can and should become certain navigators through the spaces of GIS systems, and possibly other information resources.

- GLOB-GIS - (Global GIS). Ultimately, on the basis of the systems we have listed and the Internet, a single telecommunication Global Geographic Information System may emerge, with tens of millions of users worldwide.

The combination of GIS - remote sensing - GPS - Internet capabilities will form a powerful quartet of spatial information, new technologies, communication channels and services that will be implemented both in the Global GIS, which has various unique capabilities, and in separate specialized GIS of various types and classes.

All the trends, prospects, directions and ways of development described above will ultimately lead to the fact that geography and geoinformatics in the XXI century will be a single complex of sciences based on spatial ideology and using the most advanced technologies for processing a huge amount of any spatial information.

2. World experience in the use of GIS/RSE technologies in various industries. The American Forests project under the Urban Forests program has shown the importance of forest plantations for urban environments. Using remote sensing and other GIS methods included in the CITYGREEN software, a direct correlation was found between the decline in tree numbers and the increase in stormwater runoff and air pollution. The urban environment poses a difficult task for processing remote sensing data. However, using special algorithms, it was found that 37% of trees were lost in urban areas of Puget Sound, which intercepted 34 million cubic meters of water and 16 thousand tons of ozone-depleting pollutants. The project also helped identify where to plant trees to improve the urban environment. The development has been brought to a real management system that can help any city manager.

The use of space-based information opens up new perspectives in the work of large non-governmental environmental organizations (NGOs). Space imagery is the fastest and most inexpensive way to obtain timely and accurate information about the state of terrestrial ecosystems. The spatial resolution of modern scanning systems allows for both large-scale rapid analysis of the ecological state of large areas and detailed analysis of individual objects. The time resolution of the imagery allows for monitoring observations. Today, space-based information is used by NGOs to solve a number of problems:

- Targeted landscape mapping and identification of conditionally undisturbed areas of forest, steppe, marsh and other ecosystems;

- Identification of areas of severe anthropogenic disturbance: large-scale construction, land reclamation, deforestation, pollution, heat pollution, forest fires, and mineral development;

- monitoring of anthropogenic impacts. In general, environmental monitoring is divided into:

- monitoring of industrial aerosol and smoke pollution and its consequences;

- monitoring of environmental disturbances caused by agricultural development - erosion processes, deflation and dust storms, pollution of water bodies in the process of land cultivation and exploitation;

- monitoring of environmental disturbances caused by reclamation measures - quality of reclamation, condition of irrigated/drained reclamation lands, areas of altered salinity regime around reclamation facilities;

- monitoring of anthropogenic disturbances of peat and marshlands;

- monitoring of hydrosphere objects - "blooming" of water bodies, reformation of channel and shoal structure as a result of construction and operation of engineering communications;

- monitoring of snow cover pollution in the areas affected by industrial enterprises and transport communications;

- monitoring of oil and gas production areas and product pipeline routes.

The main method of processing satellite images is expert and/or automatic interpretation, which results in the creation of an electronic map that serves as the basis for a GIS. Such GIS, which includes information obtained during fieldwork, long-term observations, and expert assessments, allows organizing data, conducting comparative analyses, preparing reviews, and planning campaigns. Foreign NGOs widely use GIS methods for environmental purposes. The large-scale work carried out by Greenpeace USA in Alaska is well known, as well as the GIS created by the Australian branch of Greenpeace. A number of environmental organizations, such as ECOLOGY CENTER, INC, are constantly developing new thematic maps of environmentally significant regions and providing them to users in ARC/INFO format. The creation of geographic information systems was one of the stages in the preparation of materials on the territories included in the UNESCO World Natural Heritage in Russia. GIS development work was carried out by NABU (Germany) for the Fenoscandia Green Belt nomination in 1996-98 and by the Association of Small Peoples of the Coastal Region Research Center for the Bykin River Valley cluster of the Central Sikhote-Alin nomination in 1995-98. Greenpeace Russia has been working on GIS applications since 1996, when a GIS department was organized as part of the Mapping Intact Forests of the Republic of Karelia program. The main activities of the department are processing satellite data and creating GIS for various Greenpeace projects. The most interesting results were obtained when using GIS technologies in forestry projects.

3. Prospects for the use of GIS/RSE/GPS in agriculture. More than 15 years of global experience in the use of remote sensing-GIS in agriculture confirms that space imagery not only makes it possible to improve the collection of agricultural statistics, increase the accuracy, uniformity, objectivity and frequency of observations, but also allows for significant improvement of methods of operational control of crops and crop forecasting [71]. SPOT IMAGE Corporation has initiated a program to review the condition of agricultural fields and modern farming methods. It provides remote sensing data and easy-to-use software tools via the Internet that are affordable for Midwestern farmers. With their help, farmers can monitor the condition of their fields and apply expensive fertilizers in a timely and selective manner. This is beneficial to producers and brings environmental benefits to the whole society [72]. Numerous data sources (digital yield maps, satellite data, soil and nitrate maps, cultivation and crop rotation) are combined in GIS and processed to produce a map of the actual state of the crops at the current moment. Operational maps of crop conditions are the basis for a decision support system. The expert user works with it interactively to obtain the results of the survey in price terms, with the addition of information on profit and loss. Differences in crop condition are classified into three classes: permanent, temporary and mixed, depending on the combination of crop condition and weather conditions.

Many years of experience in the diverse practical use of remote sensing have been accumulated in the United States. Here, in all states, research and practical work is carried out by the Agricultural Service, the Natural Resources Conservation and Stabilization Service, the Bureau of Reclamation, the Bureau of Land Management and others [73]. The U.S. Department of Agriculture has a special department, the Foreign Agricultural Service (FAS USDA), which monitors agricultural producing countries that actively use satellite information. The results of the analysis are published every two weeks in a special commercial bulletin World Agricultural Statistical Production Estimation.

Kazakhstan currently has considerable experience in using space monitoring to assess the condition of agricultural land (the National System of Space Monitoring of Agriculture project). Initially, low-resolution satellite information was used, and later multispectral images of medium resolution from the RESURS satellite (MSU-SC scanner) were analyzed. With the help of a special technical assistance program of the European Community (TACIS, ISEAM project), the European technology for analyzing agricultural production was introduced [74].

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71 In many countries of the world (Canada, the USA, EU countries, India, Japan, China, etc.), governmental, including information and marketing services widely use remote sensing of agricultural land in their activities. For example, the MARS system (Remote Sensing Agricultural Monitoring), which serves the countries of the European Community, allows determining the area of crops and crop yields, starting from the country level and down to individual farms. The results of the analysis are used to optimize agricultural production management, including to control production volumes under government support programs for agricultural producers.

72 Galaxy PrecisionAg Services Ltd. uses satellite images from the Spot, provides information on the distribution of crop quality with a spatial resolution sufficient for farm management.

73 For example, at testing grounds in South Dakota and Arizona, ground surveys and aerial photography, and even more so satellite data, are widely used for agricultural production needs: in assessing yields and pasture productivity, establishing a link between fertility and moisture, topography, and mapping soil and vegetation cover.

74 The coincidence between the ground survey data of one of the regions of the republic and the data from the interpretation of medium-resolution satellite information (RESURS/MSU-SC and TERRA/MODIS) was more than 95%. The analysis of 5% of the discrepancies showed that they were related to the lack of cloudless information and differences in the calendar dates of major agricultural operations in different regions. The following year, during the growing season, space-based monitoring of agricultural land was carried out in five more regions, which included an assessment of sown areas and a forecast of grain yields based on data obtained from NOAA, MODIS and Meteor-3M satellites.

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5. http://www.slovnyk.net

QUESTIONS FOR SELF-CONTROL

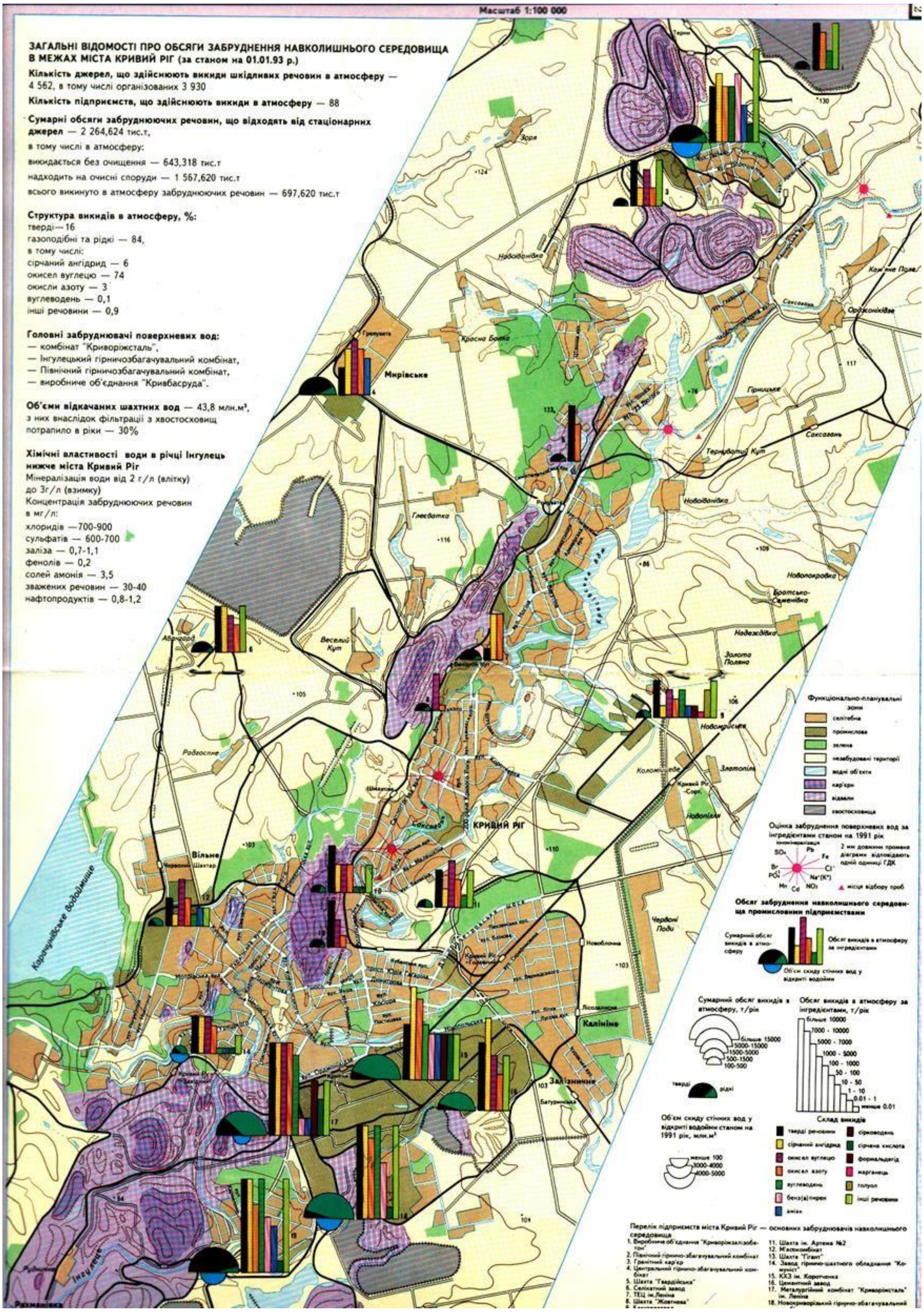
1. The concept of information system and geoinformatics, definition of the subject of study.
2. Definition of the subject of study of geoinformatics.
3. Retrospective of the development of geoinformatics.
4. The place of geoinformatics among other sciences.
5. Connection of GIS modeling with thematic cartography.
6. Tools and methods of thematic mapping in GIS.
7. Modern GIS: approaches to classification.
8. GIS as a tool for creating electronic thematic atlases.
9. Functional capabilities of modern GIS.
10. Practical application of GIS technologies.
11. Spatial information and geographic data in GIS.
12. Attribute data in GIS.
13. Models and databases in GIS.
14. Data entry in GIS.
15. Presentation of information in GIS.
16. Practical application of the methodology of elementary GIS.
17. Development of elementary GIS for environmental monitoring.
18. The main methods and techniques of spatial GIS analysis.
19. Correction of individual layers of the thematic map and topographic base in elementary GIS.
20. Organization of hyperlinks in elementary GIS.
21. Working with buffer in elementary GIS.
22. Using spatial statistics.
23. Types of remote sensing, the concept of aerial photography.
24. Features of remote sensing data application in GIS.
25. The role of remote methods in environmental protection.
26. Geographic information systems and resource management.

27. General scheme and principle of determining the exact coordinates in the GPS system.
28. Working capabilities of GPS for GIS.
29. Application of satellite positioning devices in GIS.
30. Examples of solving specific problems using GPS/GIS.
31. Decoding of aerospace images as a modern technology.
32. The main methods and means of decoding aerial photographs.
33. Working with toolbars in GIS Mapinfo.
34. Opening tables and files in GIS Mapinfo.
35. Registering the coordinates of a raster image in Mapinfo GIS.
36. File structure of the table in GIS Mapinfo.
37. Experience of using GIS in forestry.
38. Modern technology of Field-Map.
39. Environmental maps - the basis of environmental GIS.
40. Using GIS in planning and development of ecological network.
41. GIS concept of environmental monitoring and environmental safety.
42. The use of electronic maps and GIS in agronomy.
43. Features of application of remote sensing results in agricultural GIS.
44. Application of information technologies in the system of precision agriculture.
45. Specialized geographic information system of erosion processes management.
46. Characterization of conceptual directions of GIS technologies development.
47. World experience in the use of GIS/remote sensing/GPS technologies in various industries.

APPENDICES

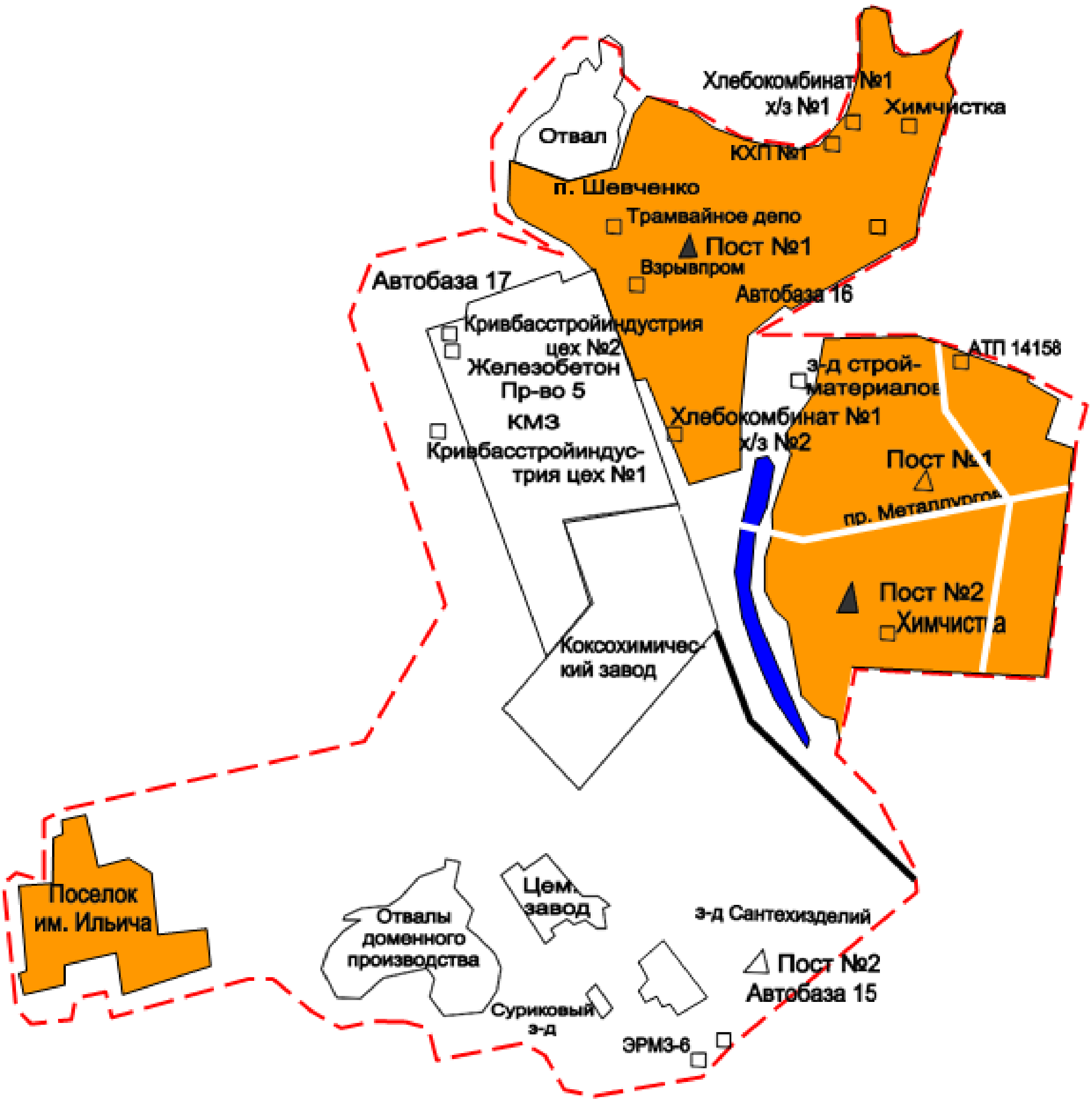
(Examples of practically existing electronic cartographic works and applied GIS)

APPENDIX 1. Environmental map of Kryvyi Rih



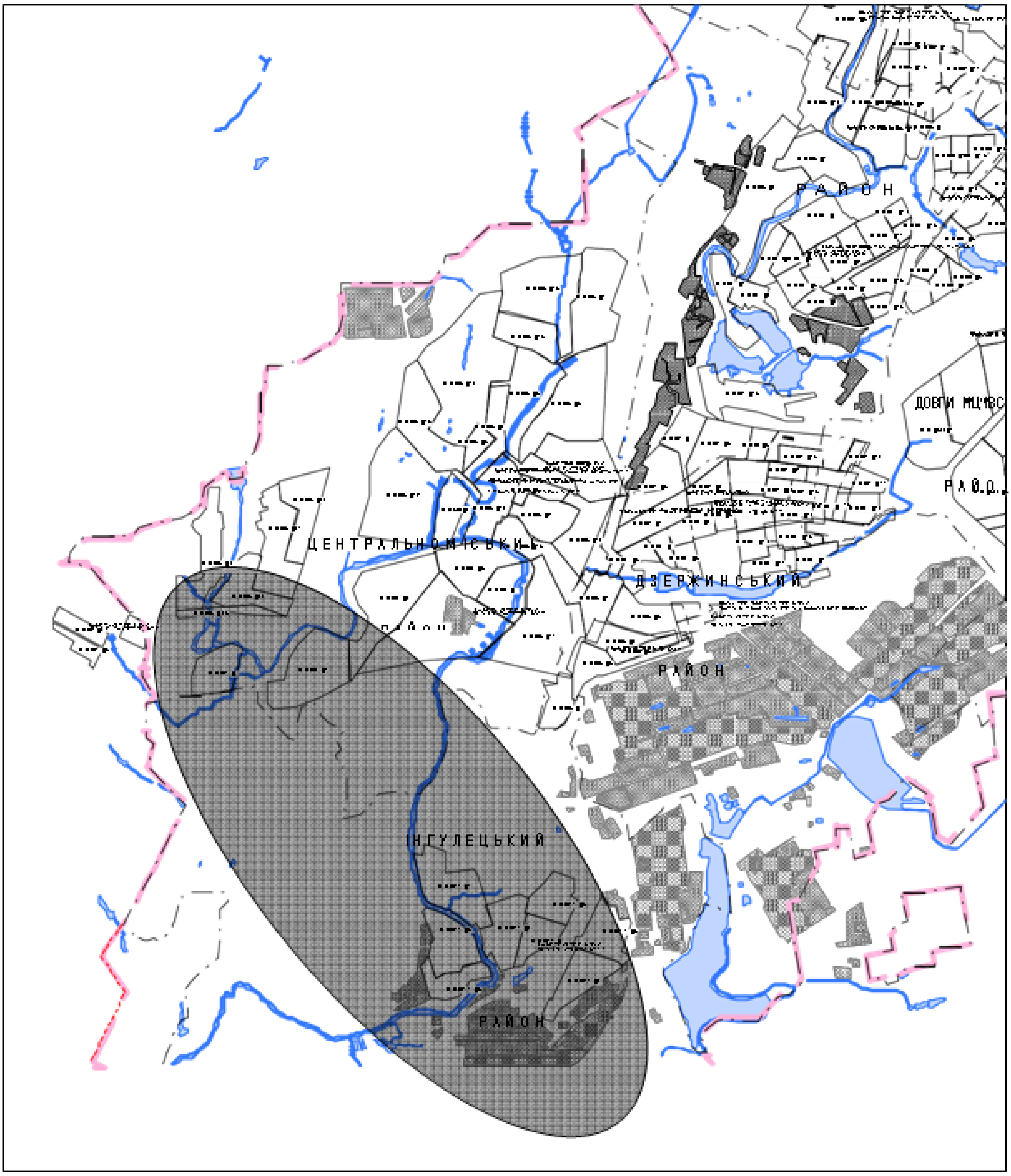
(Ecological Atlas of Dnipropetrovska oblast.) Edited by L.I. Zelenska. - Kyiv - Dnipropetrovs'k: Mapa LTD, 1995. - 24 c.

APPENDIX 2. Practically functioning elementary GIS "Environmental Monitoring of Kryvbas", made in MS Word



A fragment of the electronic map in the GIS "Environmental Monitoring of Kryvbas", made in MS Word. (Sonko S.P., Putilov V.V., Prymachenko M.I., Rozumovsky O.O. Geographic information system of environmental monitoring of Kryvbas in MS Office environment. Development.- Kryvyi Rih, KEI KNEU, 2001.- 24 MB).

APPENDIX 3. Study of environmentally related morbidity using GIS technologies



Localization of oncopathogenic anomaly in the territory of the Southern mining and industrial district of Kryvyi Rih (Shiyan D.V. Territorial features of morbidity of the population of Kryvyi Rih as the center of the Old Industrial Region. Kharkiv KNU. - 2010. - 18 p.; Sonko S.P., Shiyan D.V. Socio-geographical study of morbidity in the old industrial regions (on the example of Kryvbas). Bulletin of the Donetsk Institute of Social Education. Series Geography. Volume III. 8/2012. 126 p. - Donetsk, Donetsk Institute of Social Education. - P.89-93.)

Educational electronic edition

VYNOHRADENKO S. O.

LAND RESOURCES INFORMATION SYSTEM

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