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INITIAL RESEARCH USING GIS TO EXAMINE ANTHROPIC MODIFIED ECOSYSTEM

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Abstract

Monitoring the ecosystem evaluated with GIS instruments, measures its spatial and temporal structure and functions at different scales, resulting in information regarding the trend and change in quality due to anthropogenic influence. Observations of ecological indicators make it possible to reveal the types and mechanisms of distribution, changing phenomena, natural resources and their links with the environment. The object of research in this paper was the generalization of data on the appearance and analysis of the territorial state of Negrea village. The aim of our research, using the digital model, is to assess the existing situation and solve ecological problems in the future, already at a qualitatively new level. The preliminary method of the initial information used is based on the digitization of the researched area, being possible to evaluate the digital models of the slope map, the exposure of the slopes, the elevation, the relief depressions, etc., which represent the overall state of the ecosystem. The practical implementation of this methodology has become possible in the last 10-15 years only on the basis of geographical information technologies. The results of the research are presented visually in graphical form.

Key words: ArcGIS, ecosystem, digital models, map projection, soil

INTRODUCTION

The creation and development of geographic information systems (GIS) have provided geography with a new tool for the analysis and application of spatial geographic information. A new science has emerged - geoinformatics, opening an „informational” approach to the study of the natural geosystem. His close relationship with the traditional sciences of the earth is becoming increasingly evident (Albert, 1987).

Koshkarev offers the following definition of GIS: “... a human-machine hardware-software complex that ensures the collection, processing, display and dissemination of spatially coordinated data, the integration of data and knowledge about the territory for their efficient use in scientific solving and applied problems related to inventory, analysis, modelling, forecasting and environmental management and the territorial organization of society” (Лурье, 2000; Верещака and Курбатова, 2002).

We do not have the opportunity to dwell on other GIS definitions, we only cite sources in which you can find other definitions (Berry, 1987; Симонов, 1991; Кошкарев, 1990; Lillesand and Liefer, 1987; MacDonald and Crain, 1985). GIS can include natural, biological, cultural, demographic or economic information and can therefore be tools for the natural sciences,

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social sciences, health sciences and engineering, as well as for business planning.

GIS are a relatively new phenomenon, the ancestors of these systems are geography and cartography. GIS emerged in the 1960^s as a tool for displaying the geography of the Earth and objects located on its surface using computer databases. Traces of the first geographic information system are lost in the bowels of the US Department of Defence, whose employees used GIS to ensure that a rocket flying at an enemy would hit as accurately as possible. True, there is an alternative version - according to him, the first GIS was created in Canada (Albert, 1987; Berry, 1987).

As in the case of the Internet, peaceful applications have not been long in coming. In the early 1970^s, GIS began to be used to display georeferenced data on a monitor screen and to print maps on paper, which greatly facilitated the lives of specialists previously employed in traditional paper mapping. At the same time, the first companies specialized in the development and sale of computer mapping and analysis systems appeared (MacDonald and Crain, 1985).

Today, the two largest GIS companies can follow the path until the 1960^s, although in the beginning they each focused on different aspects of technology. Attention Intergraph Corr. focused on the efficient introduction and storage of spatial data and the preparation for the printing of computer-generated maps, which compete with traditional paper maps in cartographic quality.

Environmental Systems Research Institute (ESRI) - on the development of procedures and functions for data analysis in GIS. Over the years, both companies have virtually equalized the capabilities of their systems. At first, only the largest government organizations, utilities, and corporations could afford to use GIS because of their high cost. GIS ran on mainframes and minicomputers, and a typical workstation with GIS installed cost over $ 100,000 (when all hardware, software, and training costs were included).

However, the GIS market grew rapidly in the 1980^s, largely due to the fact that many journals and professional associations promoted the benefits of geographic information systems. Spatial database management systems also emerged in the 1980^s to link database management systems and computer mapping. In these systems, the user could already, pointing to an object on the map, receive some significant information.

The demand for thematic cartographic information drew attention to the problem of data collection. The result was an integrated environment - remote sensing data, digital terrain model, road map, geological map and all other types of maps coexisted peacefully in a single system. However, the major breakthrough came with the advent of personal computers. GIS quickly adapted to this new, cheaper platform, and the price of systems began to decline as the number of users and organizations that could afford GIS increased. According to Dataquest, the global market for GIS products and services was $ 2.5 billion in 1997, roughly halved by sales in North America and the rest of the world and growing by about 15 % a year (Верещака and Курбатова, 2002).

Gone are the days when the topic was actively discussed whether Russian GIS will survive on the Russian market. Most of the more or less well-known geographic information systems developed in Russia go back to the early 1990s, when the need for GIS had already become apparent and the financial capabilities of our research institutes, universities and city administrations did not allow them to buy systems very expensive foreign (Лурье, 2000).

Despite the fact that the situation later diminished and the import of GIS became quite accessible, the internal development systems managed to occupy their own niche, although small, but quite stable. Currently, among the multifunctional geoinformation systems created by Russian companies, the following are most often mentioned: GeoDraw/GeoGraph (TsGI IG RAS); IngEO (Integral); Panorama (Topographic Service of the RF Armed Forces); Park (Laneco); CSI-MAP (CSI technology); ABRIS Synthesis (Trisoft); ObjectLand (Radom-T).

GIS continues to evolve today. The GIS industry is actively absorbing new trends, changing, evolving and developing, which is an indicator that testifies to the great potential of the industry. Thus, it can be hoped that in the 21st century GIS will continue its dynamic development, offering its users more and more new opportunities. GIS is now a multi-million-dollar industry involving millions of people around the world. GIS is studied in schools, colleges and universities.

This technology is used in almost all spheres of human activity - whether it is the analysis of such global problems as overpopulation, land pollution, reduction of forest land, natural disasters or solving particular problems, such as finding the best route between points, choosing the optimal location for a new office., finding a house after its address, laying a pipe or a power line on the ground, various municipal tasks, such as registration of land ownership (Верещака and Курбатова, 2002).

The intensive use of soil resources in the world in recent decades has led to their accelerated degradation. Taking into account global trends, the rate of degradation and irrecoverable loss of agricultural land, as well as the development of agriculture, the issue of maintaining the quality of agricultural land is becoming a priority strategy of global importance (Măgureanu et al., 2021).

According to the composition and natural fertility, the soils of the Republic of Moldova are among the most valuable resources, characterized by an amazing variety associated with the differentiation of soil profiles, climatic and geological conditions. When optimizing the management of anthropogenic ecological landscapes, it becomes necessary to take into account and evaluate the heterogeneity of the soil and its physical properties (GIS-RSRM, 2008; HGRM, 2011).

The introduction of GIS, opens wide perspectives for the analysis and forecasting of the ecological situation of the researched area. Georeferencing is the process of defining the exact location on the Earth's surface, for which an image or a set of raster data has been created. This positional information is stored in the digital version of the aerial photograph or scanned topographic map. The types of spatial analysis that are used vary depending on the areas of interest (Abler, 1987; Лурье, 2000; Верещака and Курбатова, 2002; Симонов, 1991).

When the GIS application opens the photo (map), it will use the position information to ensure that the photo appears in the correct place on the digital map. Normally, this information consists of a coordinate for the top left pixel of the image, the size of each pixel in the X direction, the size of each pixel in the Y direction, and (optionally) the value with which the image is rotated. With this information, the GIS application can guarantee that raster data is displayed in the correct place. Georeferencing information is often provided in a small, text-like file that accompanies the raster (World File Format).

MATERIAL AND METHOD

Information technology is a process that uses a set of means and methods for collecting, processing and transmitting data to obtain information of a new quality about the state of an object, process or phenomenon. The purpose of information technology is the production of information for its analysis by a person and making a decision on its basis on the implementation of any action.

The main categories of software are system programs, application programs, and software development tools. System programs, first of all, include operating systems that ensure the interaction of all other programs with hardware and the interaction of the user of a personal computer with programs. Utilities or service programs are also included in this category. Application programs include software that is a toolkit of information technology - technologies for working with texts, graphics, tabular data. GIS technologies provide modern, corresponding to today's requirements, convenient and fast, more effective approaches to diagnosing problems and solving problems.

Modern land mapping technologies, which have almost completely replaced traditional mapping methods, ensure the formation of geographic information systems for the purpose of accumulating and processing the necessary information. The geographical reference and the base map serve as a framework for the geographical reference and coordination of all data entering the GIS, the mutual alignment of the information layers and the subsequent analysis using overlapping procedures (Верещака and Курбатова, 2002; Симонов, 1991). For the purpose of mapping, it is promising to create new types of maps, digital and electronic, using automated mapping systems and geoinformation systems (GIS).

The main 3 components of a GIS database are: 1. The database. 2. Database management system and 3. A complex of processing programs that implement the functions of data entry control, regulation, storage, sorting, selection according to the specified conditions, etc. The information about the location of the searched object and their characteristics are taken from the existing topographic maps and remote sensing materials, field research and other background data are also involved.

The editing of the existing electronic maps is performed based on the new plans for individual sections of Negrea locality, made using software and hardware measurement systems. For many types of space operations, the end result is the presentation of data in the form of a map, diagram or graph. A map is a very efficient and informative way to store, present and communicate geographical information (georeferenced).

The total area of the analysed site was 2730 hectares. The resulting data were processed and analysed using geostatistical methods and software packages such as MapInfo and ArcGIS 8.3. GIS - information systems that provide processing, storage, collection, graphical display and dissemination of data, as well as synthesis on their basis of new information about spatially coordinated phenomena (Симонов, 1991). Allows you to transfer objects of the surrounding world to the map, and then analyse them according to certain parameters, then predict based on this data and visualization a wide variety of events and phenomena. Such a modern and powerful technology helps to solve a large volume of tasks using GIS, both planetary and local and private.

RESULTS AND DISCUSSION

Raster data can be obtained in several ways. Two of the most common ways are aerial photography and satellite imagery. To obtain aerial photographs, an airplane flies over an area, with a camera mounted under it. The photos are then imported and georeferenced in a computer. Satellite images are created using satellites moving in Earth orbit and equipped with special, earth-oriented digital cameras. Once the image has been taken, it is sent to the ground using a radio signal that will be picked up by the receiving stations. The process of capturing raster data by plane or satellite is called remote sensing (Gálya et al., 2020).

Raster data can also result from scanning classic maps that exist on paper and are then georeferenced and used as background for viewing in GIS maps or for digitizing vector data. In other cases, raster data can be calculated. Meteorologists could generate a raster, showing the average temperature, amount of precipitation and wind direction, using data collected from weather stations. In these cases, raster analysis techniques such as interpolation are often used.

Sometimes raster data is created from vector data because data owners want to share the data in an easier-to-use format. Each raster layer in a GIS has pixels (cells) of a fixed size that determine the spatial resolution. This becomes obvious when you look at an image on a small scale and then move on to a larger scale.

Several factors determine the spatial resolution of an image. For remote sensing data, the spatial resolution is usually given by the capabilities of the sensor used to take an image. In aerial photographs, pixel sizes corresponding to an area of 50 x 50 cm are not uncommon. Images with a pixel size that cover a small area are called „high resolution" images because they have a high degree of detail in the image. In raster data that is calculated by spatial analysis (such as a precipitation map), the spatial density of the information used to create the raster will usually determine the spatial resolution.

For example, if you want to create a high-resolution map of the average rainfall, you will ideally need several weather stations, located very close to each other. There are a large number of analytical tools that can be run on raster data, and which cannot be used for vector data. For example, raster's can be used to model water flows from the ground surface. This information can be used to calculate, the location of catchment basins and the flow network, depending on the terrain. Raster data are also often used in agriculture and forestry to manage crop production.

For example, in a satellite image of a farmer's land, the areas where the plants grow poorly can be identified and then this information can be the basis for applying a larger amount of fertilizer only to the affected areas. Raster data is also very important for disaster management.

Digital Elevation Pattern Analysis (a kind of raster in which each pixel contains height above sea level), can then be used to identify areas that are susceptible. This can then be used to direct rescue and relief efforts to the area's most in need. GIS maps differ from topographic and thematic maps in that they can be changed dynamically depending on the research. In addition, GIS is a fairly convenient and universal tool for exchanging cartographic information, as this information system was created on a personal computer.

A map provides a visual image of the size and relative position of the described objects; will allow you to obtain qualitative, quantitative characteristics of objects and phenomena; to compare their properties and relationships and dependencies between them and with geographical phenomena; to establish the reasons that contribute to the formation of the characteristic features and characteristics of the individual territories; studies the development models of nature and society, researches changes over time, forecasts and evaluates promising directions for the development of the environment and society. In this way, maps help to communicate information and results more efficiently (HGRM, 2003; HGRM, 2013).

So far, the evolutions of the use of GIS in the field of evaluation and optimization of the state of Negrea locality have not been carried out.

Mapping the results obtained in the study in previous years, describes the territorial state of the given area, taking into account the conditions of natural resources and allows us to obtain indicators for each type of research. To plan or design any researched area, we need to know the characteristics of the soil and use this information together in a single network. The use of descriptive data of the researched area by using spatial information, will improve the situation of the locality. In fact, the GIS application can store several pieces of information, which are associated with places - something where paper maps are not very good. In our case, the use of GIS technologies in land management will allow us not only to store information on land management objects, but also to record various changes, as well as the trend of these changes. This aspect of using GIS is very important. GIS technologies will allow you to solve several land management's tasks in Negrea faster and more efficiently.

The relief of the earth's surface was chosen as the object of the mapping (Fig. 1), which is associated with two circumstances. The first is the hierarchical nature of the relief, which naturally correlates with the scale of the mapping.

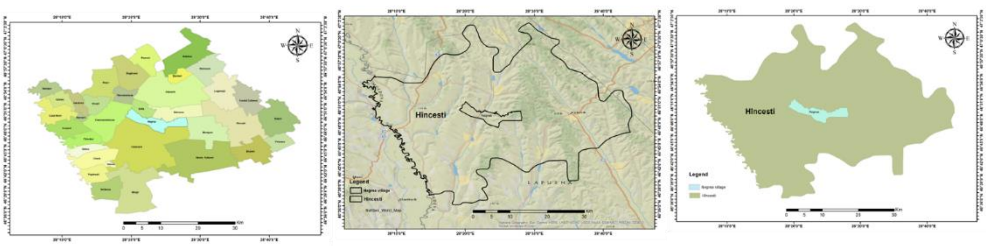

Fig. 1. Extraction of the experimental lot from Hîncești district and representation of the relief (Source: Created by the author)

Generalization and detail when changing the scale of the map allows you to explore landforms of different orders and sizes; studying several levels of relief formation, relief connections with other objects of the natural environment: tectonic structures, river network, soils, vegetation, etc.; to predict the development of geosystems, taking into account the hierarchical relationships of relief features and other natural components; evaluate and consider the role of relief on different scales of human economic activity.

The isolines and the elevation of the Negrea locality (Fig. 2) are built by interpolation - obtaining the values of the functions in intermediate points according to their values specified in individual points.

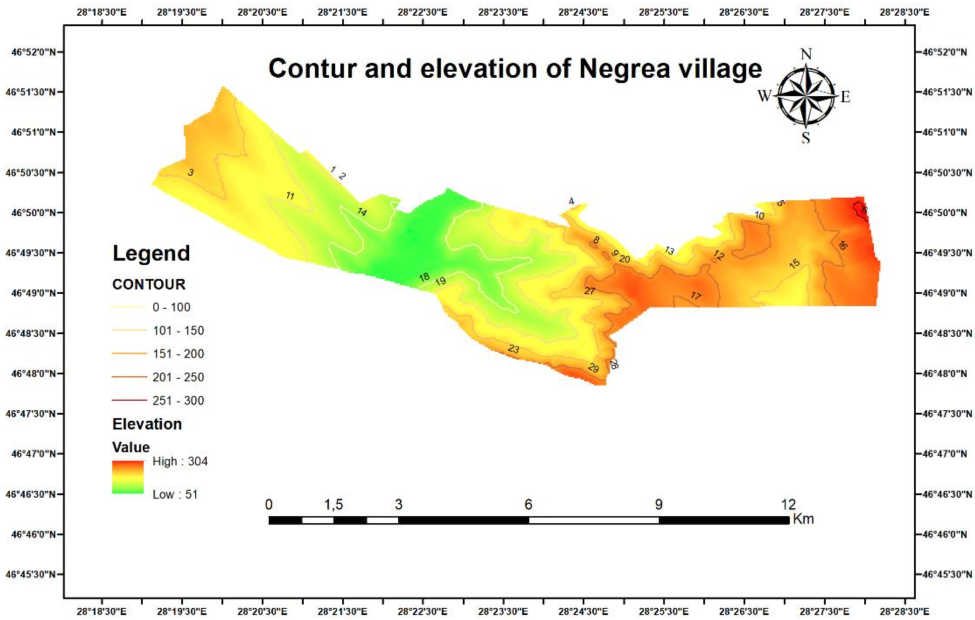

Fig. 2. Contour and elevation of Negrea village
(Source: Created by the author)

The current practical concept of cartography we use now can be formulated as „database-based mapping”. Very important for any GIS application is the possibility to apply symbols for the represented geographical elements. Another common feature of GIS application is the map legend which is represented on the slope map of Negrea village, obtained based on previous research data. The map legend provides a list of the layers that have been loaded into the GIS application (Fig. 3).

The north-western and south-eastern slopes of the peaks from the upper part of Negrea locality (Fig. 4) are mainly characterized by inclination within the limits of 2 - 5˚, which conditions a weak manifestation of soil erosion. The slope of the slopes in the middle and lower part of the receiving basin varies in the limits of 3 - 8˚, which caused the intensification of soil erosion processes on these lands. At the foot of the slopes there are often glazes, consisting of deposits of pedolite, washed from the slopes.

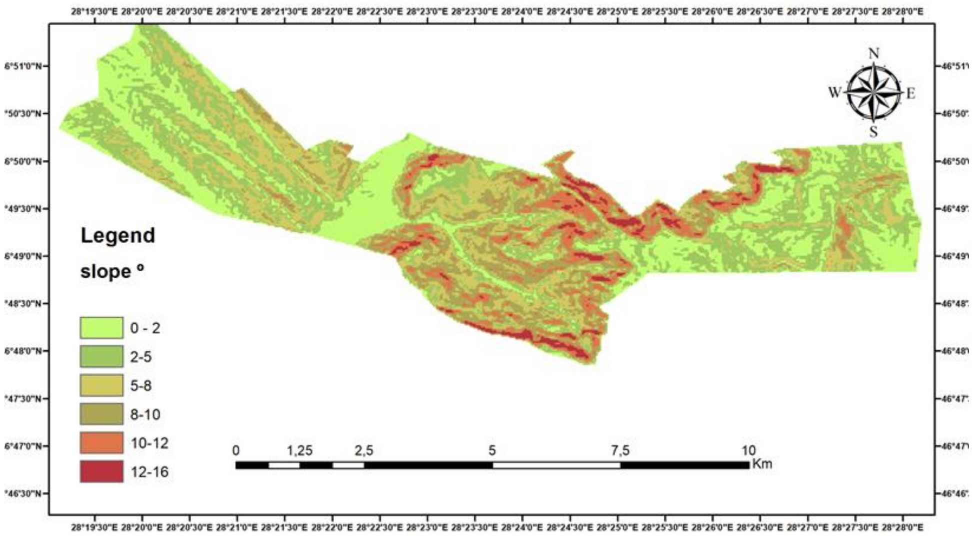

Fig. 3. Slope of Negrea village
(Source: Created by the author)

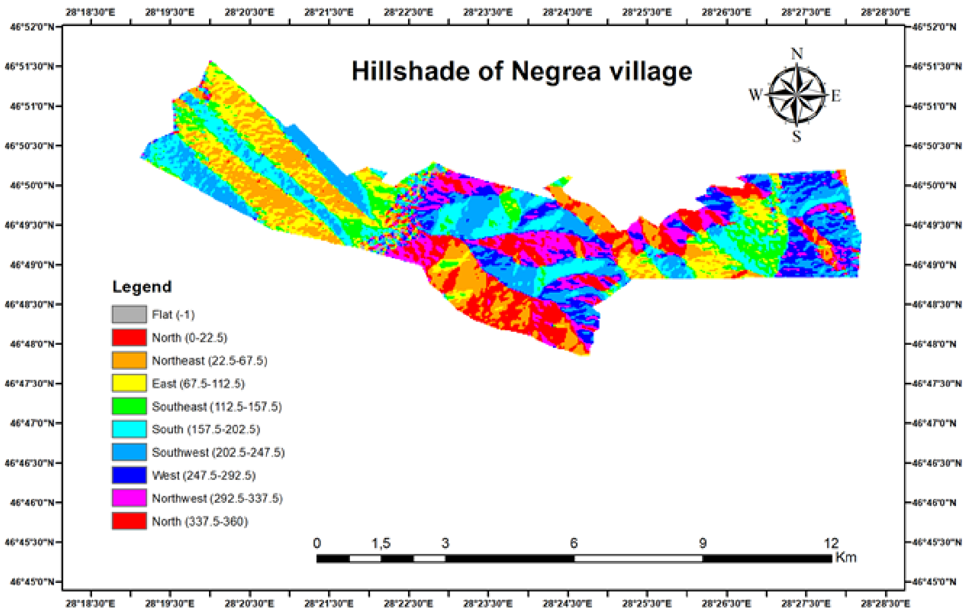

Fig. 4. Aspect of Negrea village
(Source: Created by the author)

The linear erosion on these slopes is manifested by the formation of ditches (Fig. 5). Parallel to the roads, located on the slopes from the hill to the valley, several gaps were formed. They did not form on the agricultural lands on the ravine slopes. The segment of the north-western slope at the bottom of the receiving basin is fragmented by landslides as a result of the stratified structure of the surface rocks, the high inclination (up to 15˚) of the surfaces in this part of the slope and the medium process energy of denudation. The dry valley in the center of Negrea has a width of 20-30 m in the upper part and 50-60 m in the middle part. In this part of the village the slope of the valley varies within 1-2˚. In the lower part of the reception basin, where landslides are spread on the slopes, the valley has evolved into a ravine with strongly fragmented steep walls.

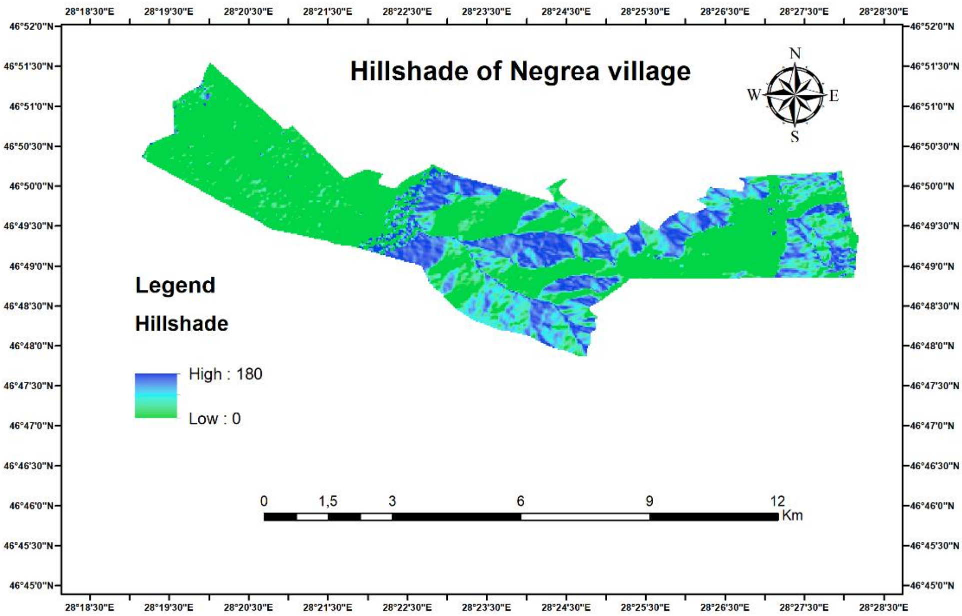

Fig. 5. Hillshade of Negrea village
(Source: Created by the author)

The peak of lengthened form where test/demonstrative fields for environmental sound agricultural practices are situated represents two hills. The indicator (control) of erosion for hills is two surfaces in the form of round plateau, situated at the absolute altitude about 230 m. These indicators of erosion are connected with each other by the crosspiece where the hollow between two hills begins.

The properties of a map projection can influence some of the map design functions. Some projections are good for small areas, others are good for mapping areas with a large extension in the East-West direction, and others are better for mapping areas with a large extension in the North-South direction.

Examples are a scanned map, satellite imagery, some digital elevation models, etc. Thematically, each raster cell (pixel) can describe a certain property or feature of its corresponding geographic area, for example, the steepness of a slope or height above sea level, the type of vegetation or soil, etc.

In terms of organizing storage of objects, such a model is non-topological and provides independent processing separate objects, but in some cases, it imitates topological relations and, if necessary, allows restore them using special ArcGIS programs.

The terrain relief is realized in the form of broken irregular surfaces (TIN), the inflection points of which are the elevation marks of the relief translated from topographic tablets. Local relief elements were also taken into account: embankments, ledges, etc. For this, various inflection lines, cut lines, as well as a contour for replacing elevation values, describing the spatial characteristics of local relief elements, were introduced into the input data set for constructing the resulting TIN.

The use of available software solutions as a model presentation format makes the system open and available for use and quality control. The use of the most relevant information as the initial data, as well as the flexible use of advanced measurement technologies, is a guarantee of the maximum possible correspondence of the model to reality and obtaining adequate and correct results of its use.

GIS has the ability to work with two fundamentally differing data types are vector and raster. In the first model, information about points and lines, as well as polygons, is encoded and stored using a set of X, Y coordinates.

All cartographic information in GIS is systematized and organized in the form of layers. Layers are the initial level in a GIS. When you start working with a GIS, it is always necessary to divide existing data into specific layers. Each layer must contain objects of a specific type, united by some common characteristics. Working in GIS, it is possible to connect or disconnect certain layers, or change the order of their visualization.

The process of creating maps in GIS is more flexible and simpler than in traditional methods of automatic or manual mapping. Begins by creating an attribute database. It is quite possible to use the digitization of conventional paper maps as an initial source of obtaining the initial data.

GIS-based cartographic databases can be scale-independent and continuous, that is, without division into separate regions and sheets. On this basis of such databases, you can create maps (as hard copies or in electronic form) of any scale, for any territory, with the necessary load, with its display and highlighting the required symbols.

At any time, the database can be replenished with data, for example, from other databases or with new data, and the data available in it can be adjusted as necessary.

The maps in Figures 1-5 are representations of the reality of Negrea village.

Lands of Negrea community are situated in temperate zone and are characterized with moderate continental climate, warm and semi humid. The solar period (sunny days) is of 290 – 310 days, duration of insolation varies in limits of 2050 – 2150 hours. The annual average temperature is 9.0 ºC on the semi-horizontal surfaces of the watershed and 9.5 ºC in the lower part of the slopes of watershed. The sum of active temperatures above 10 ºC varies from 3000 ºC at the pick up to 3000 – 3100 ºC at the foot of the slope.

Main anthropological factors of degradation of soil cover are excessive arable activities, cutting of forest protection belts, soil cultivation along slopes, wrong lining of road network, insufficient protection of soil with vegetation cover, big share of technical crops in crop rotation, soil cultivation with heavy machines, non-observance of anti-erosional measures.

Agricultural activities without taking into consideration the soil peculiarities and relief, lead to diminution of soil fertility and its degradation. Intensity of agricultural works during the various periods of time for various categories of land use differs from the quantitative and qualitative points of view and is very various.

Till now the technology of cultivation of cultures on slopes with a various inclination differed a little from the technology used on the horizontal areas with un-eroded lands. For example, cultivation of soils along the slope provokes the loss of 20 – 30 % of downpour precipitations with surface wash off. In case of drop out of 30 mm of precipitations from slopes is loosed about 90 - 150 m^3 of water per hectare. The damage caused to a grain yield makes 1.5 - 2 centimeter/ha.

Concentrated character of wash off also causes the damages to crops. Erosion caused by water streams makes 40 – 50 % from the surface of demonstrative fields. Wash off created by abundant atmosphere precipitations destroyed soil, open the roots of plants. Annual losses of fertile soil constitute tens tones per hectares. As a consequence, annual losses of nitrogen, phosphorus and potassium caused by erosion, exceed in many times the quantity of applied fertilizers. Soil washed off from the slope is accumulated at its basis, in hollows, lakes and rivers.

They are designed to represent not only entities, but also their shape and arrangement in space. Each map projection has both advantages and disadvantages. The best projection for a map depends on the scale of the map and the purposes for which it will be used. For example, a projection may have unacceptable distortions if used to map the entire continent, but it can be an excellent choice for a large (detailed) map of the country.

All these models are mutually convertible. Nevertheless, when obtaining each of them, you must take into account their peculiarities. Environmental problems often require immediate and adequate actions, the effectiveness of which is directly related to the efficiency of processing and presentation of information. With an integrated approach, typical for ecology, one usually has to rely on generalizing characteristics of the environment, as a result of which the volumes of even the minimum sufficient initial information should undoubtedly be large. Otherwise validity of actions and decisions can hardly be achieved. However, the simple accumulation of data is also, unfortunately, not enough. These data should be easily accessible, systematized according to needs. The grouping of data in the desired form, its proper display, comparison and analysis is entirely dependent on the qualifications and erudition of the researcher, his chosen approach to interpreting the accumulated information.

GIS has certain characteristics that rightfully allow us to consider this technology as the main one for the purposes of information processing and management. GIS tools far exceed the capabilities of conventional cartographic systems, although, of course, they include all the basic functions of obtaining high-quality maps and plans. The very concept of GIS contains comprehensive capabilities for collecting, integrating and analyzing any distributed in space or location-specific data. If you need to visualize the available information in the form of a map, graph or diagram, as well as create, supplement or modify a database, integrate it with other databases, the only correct way would be to turn to GIS. In the traditional view, the possible limits of integration of heterogeneous data are artificially limited.

Considered close to ideal, for example, is the possibility of creating a map of the yield of fields by combining data on soils, climate and vegetation. GIS allows you to go much further. To the above dataset, you can add demographic information, information about land ownership, welfare and income of the population, the volume of capital investments and investments, zoning of the territory, the state of the grain market, etc.

As a result, it becomes possible to directly determine the effectiveness of planned or ongoing nature conservation measures, their impact on human life and the agricultural economy. You can go even further and, adding data on the spread of diseases and epidemics, establish whether there is a relationship between the rate of degradation of nature and human health, and determine the possibility of the emergence and spread of new diseases. Ultimately, it is possible to accurately assess all socio-economic aspects of any process, for example, reduction of forest area or soil degradation.

CONCLUSIONS

Raster data is stored as a grid of values. There are many satellites orbiting the earth, and the photos I take are a type of raster data that can be viewed in a GIS. The scale of the map is an important aspect to consider when working with vector data in a GIS. When data is captured, it is usually digitized from existing maps, or by taking information using GPS.

Maps have different scales, so if you import vector data from a map into a GIS environment (for example, by digitizing maps printed on paper), digital vector data will inherit the scale problems of the original map.

In conclusion, it should be noted that further development of approaches to monitoring the studied ecosystem is impossible without a combination of traditional experimental methods on the physical and chemical properties of soils, and at the same time with the use of modern approximation procedures and GIS technologies. The materials presented at the first initiation, demonstrate only new possibilities for the analysis and evaluation of Negrea locality with the use of GIS information in the landscape area.

Variety of relief conditions, rock, climate and hydrology causes the formation of variable and complex soil cover on the territory of test/demonstrative fields for environmentally sound agricultural practices in Negrea community.

In the result of tillage heavy clay loam loess depositions have been mixed with clay loam and loamy sand marine depositions. Recently ploughed layer is composed of derivation of loess and marine depositions and is characterised with clay loam texture for the whole surface of the fields. Average-dense texture and average texture of parental rocks of researched fields contribute to the manifestation of erosion processes.

Using the developed model, ArcGIS tools allow visual assessment of the visibility of objects through precise positioning of the observer in model space, determination of observation parameters, including focal length, observation camera flight, as well as its movement along a given route with setting absolute and relative (in relation to the target) observation.

The deterioration of the ecological situation in intensively developing industrial regions is of great concern to the public and environmental specialists.

For the assessment and forecasting of reserves and the ecological quality of natural resources, geographic information systems are increasingly used as a powerful tool for systematization and comprehensive analysis of a variety of cartographic and applied data.

However, a comprehensive assessment of the ecological state of natural resources and forecasting their changes under the influence of anthropogenic factors is an extremely difficult task.

This is primarily due to the need to take into account all the processes occurring in natural ecosystems, and different stability ecosystems to one or another technogenic impact. The analysis is complicated by the fact that some of the factors affecting the functioning of ecosystems can partially compensate for each other. An additional difficulty is created by the unstable nature of the spatial localization of technogenic pollution caused by the transfer of pollutants through the atmosphere, surface and ground waters.

REFERENCES

1. Albert R., 1987, The National Science Foundation National Center for Geographic Information and Analisis. Int. J. of Geographical Information Systems, Vol. 1. No 4, pp. 302-306;
2. Верещака Т.В., Курбатова И.Е., 2002, Картография XXI века: теория, методы, практика, Том. 2, Эколого-географические исследования по топографическим картам: методологические подходы, Москва, 187 с;
3. Berry J., 1987, Fundamental operations in computer-assisted map analisis. Int. J. of Geographical Information Systems, Vol. 1, pp. 79-143;
4. Симонов А.В., 1991, Агроэкологическая картография. Кишинев. с. 95-121;
5. Gálya B., Nagy A., Juhász Cs., Riczu P., Szabó A., Blaskó L., Tamás J., 2020, Identification of inland-eccess water patches baed on LiDAR and Sentinel 1 Data. Natural Resources and Sustainable Development, vol. 10, no. 2, pp. 188-199, DOI: 10.31924/nrsd.v10i2.054;
6. Кошкарев А.В., 1990, Картография и геоинформатика: пути взаимодействия, Изв. АН СССР, Сер. Геогр, № 1, с. 32;
7. Lillesand T.M., Liefer R.W., 1987, Remote sessing and image interpretation. pp. 25-463;
8. Лурье И.К., 2000, Основы геоинформационного картографирования, Москва, с. 103-129;
9. MacDonald C.L., Crain I.K., 1985, Appied computer graphics in a geographic information system: problems and successes. Computer graphics and application, Vol. 5, No. 10, pp. 29-52;
10. Măgureanu M., Copăcean L., Simon M., Cojocariu L., 2021, Geographic Information Systems in the evaluation of the agricultural potential in the Banat Mountaines. Natural Resources and Sustainable Development, Vol. 11, No. 2, pp. 171-180; DOI: 10.31924/nrsd.v11i2.076;
11. ***, ArcGIS 8.3., ArcSDE® Configuration and Tuning Guide for Microsoft® SQL Server™, (http://www.ciesin.columbia.edu/gisservicecenter/pdf/config_tuning_guide_SQLServer.pdf) Accessed March 12, 2022;
12. ***, Environmental Systems Research Institute (ESRI), Coordinate economic growth strategies with federal funding, (https://www.esri.com/en-us/home) Accessed: March 08, 2022;
13. ***, Intergraph Computer Services (Intergraoh co), (http://www.ingr.ro/ro/pg-despre-noi-MTktMy0y.html) Accessed: March 10, 2022;
14. ***, MapInfo Pro (https://www.precisely.com/product/precisely-mapinfo/mapinfo-pro) Accessed on March 10, 2022;
15. ***, 2003, Hotărârea Guvernului RM (HGRM) nr. 1298 din 28 octombrie 2003 cu privire la crearea Sistemului Informațional Geografic Național;
16. ***, 2008, Concepția Sistemului Informațional „Registrul Solurilor Republicii Moldova" (GIS-RSRM), Chișinău, 34 p;
17. ***, 2011, Hotărârea Guvernului RM (HGRM) nr. 626 din 20 august 2011 cu privire la aprobarea Programului de conservare şi sporire a fertilității solurilor pentru anii 2011-2020;

18. ***, 2013, Hotărârea Guvernului (HGRM) nr. 857 din 31 octombrie 2013 cu privire la Strategia națională de dezvoltare a societății informaționale ―Moldova Digitală 2020.

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