SOME CONCEPTUAL INSIGHTS INTO GIS APPLICATION IN THE STUDIES OF ENVIRONMENTAL PROTECTION

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Abstract: All causes and consequences of environmental problems have a geographical component and they can be modelled using geographic information system as the main tool for dealing with geospatial data with ability to integrate different information and present it on a map. Data visualization of environmental problems, through GIS and geospatial presentations, provides hypothesis and different views, develop alternative ways for solving environmental problems.

Key words: Geographic information system, layer, geospatial, environmental protection, geovisualization

1. The emergence of geographic information systems

The most important challenges in science, industry and society have a geographic component at their basis. A map has always been the main tool for dealing with geospatial data. This remains so, but through the use of computers, introduction of databases and development of geographic information systems (GIS) new opportunities appear.

Using GIS, we can determine why things are how they are depending on their location and what the relation amongst diverse geographic objects is. Using GIS for analysis purposes we can arrive at precise and updated information or even create new information previously unattainable. Having such information can help us in gaining a deeper understanding of geographic space. The results could be a making the best choice and better preparing for future events and opportunities.

The emergence of geographic information systems which allow us to make a detailed spatial display and handle geospatial data rapidly, undoubtedly begins to change the practice of environmental protection.

The most common theory about GIS origins is that it is developed in sparsely populated Canada which by 1950s viewed its own land and resources as being unlimited. The late but inevitable finding that this was not the case, led the Canadian government to initiate a creation of the list of national resources - The Canada Land Inventory, whose “broad objective was to classify lands as to their use capabilities” (ARDA: CLI Report No.1, 1965). The most practical way of dealing with geospatial data is if the data is stored on a map. This data was planned to be used for the plans for land management so the large rural areas could be efficiently exploited. The construction of Canada Geographic Information System (CGIS) led to a rapid handling and analysis of maps and data on which they were based. Contemporary commercial packages have been built on the basis of key conceptual and technical innovations of the CGIS. When the project of the CGIS was launched, there was no previous experience on how to structure georeferenced data within computers and a lot of today basic GIS algorithms had yet to be invented. In 1987, the Department of the Environment in the UK issued a report titled “Handling Geographic Information”, which highlighted the significance of GIS for geospatial analysis and compared it with importance "the inventions of the microscope and telescope were to science, the computer to economics, and the printing press to information dissemination" (as cited in Goodchild, 1991).

2. GIS and the environmental protection

With the advent of industrial revolution, man cause a new damage to natural resources. Factories are being built and they become new sources of pollution of air, water and soil. Due to migration, many cities begin to grow, and the question of how to best balance the needs of the environment with the needs of a growing industrial society only begin to arise later on. This become more and more frequent problem in recent times.

The concept of sustainable development is most often used to describe the way in which man acts towards the environment which should be in accordance with the report “Our Common Future”, which, at the invitation of the United Nations, was compiled by the World Commission on Environment and Development (the so-called Brundtland Commission) in 1987. The definition is as follows: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). This concept implies that both technology and society must be organized so that human activities do not overload the capacity of the biosphere, and so that said biosphere is able to absorb their influence.

Sustainable development planning and management is a comprehensive process that deals with multi-dimensional problems in order to achieve balanced economic development, environmental protection, and social equity and protection. In order for geospatial data to be used for decision-making it is necessary to fulfil several conditions, the main being the availability of data and data analysis tools which would integrate into a complex information system.

Although the creation of GIS-based eco-friendly models is still in progress, it is clear that these techniques will enable the construction of geospatial ecological models with the level of detail previously unthinkable. Also, the ways in which the ecological problems were predicted and explained in traditional ecology change. With the application of significant technical innovations, ever-faster computers, increasingly available satellite images, global positioning systems... the future of ecology preserving techniques looks much safer today than a few decades ago.

The combination of natural and anthropogenic influences increases the complexity of environmental problems, and field systems are far more complex than those that can be modelled or even experimentally studied in the laboratory. Sometimes this complexity excludes the creation of adequately controlled field experiments. One of the characteristics of environmental problems is their uniqueness. Some systems are so unique in their structure or composition that laboratory experiments cannot be used to get insight into them. Uniqueness can also make it difficult to create a controlled experiment, or even make it impossible.

GIS technology is being used more and more all over the world to protect the environment. This system provides an insight into the current state that is obtained by the insertion of layers with data that are considered relevant for a particular subject of study or have in some way affected the preservation of the environment in a given area. Layers that can be significant in the study of the state of the environment are: terrain topography, aquatic areas, green areas and parks, forest cover, nearby habitats of plant and animal species, a layer with built-up areas, a transportation infrastructure, a layer with industrial chimneys, a layer with wind data with information about what are the dominant winds depending on the time of year and its power, speed and the height; a hazardous waste warehouse, sewage network, areas of tailings and deposits from mining... and many others depending on the specificity of the area itself. When all the data are entered, an analysis of the current situation, their mutual relations and the degree of influence of various factors on the environment is carried out.

Techniques of geospatial modelling allow the studying of complex relationships between phenomena. These techniques usually involve the applying a set of statistical algorithms on geospatial data. A wide range of data obtained from various stations, through remote monitoring systems, global positioning systems, maps of all types, annuals, lists, individual research... help in decision-making and go a step further by allowing us to explore alternative scenarios of "what if..." (for example, what if another facility of similar capacity is built next to a refinery, will the amount of dangerous substances then exceed the allowed limits).

By using GIS, it is possible to determine the degree of environmental vulnerability, the reasons for the vulnerability and the possibilities of overcoming them. GIS provides an opportunity to analyse the terrain and determine areas in which, depending on the conditions, pollution and environmental damage have occurred. The reasons for endangering can be varied, for example: discharging untreated wastewater into watercourses, failures on wastewater treatment filters, various types of environmental incidents, noise... Each of the possible causes is entered into a separate layer and then analysed to determine the degree of impact.

One of the crucial things for exploitation of the potential of GIS, and more importantly, avoiding serious errors is a solid understanding of geography by GIS users. Without a strong scientific basis, we cannot be certain that geographic information systems will be used wisely.

3. Some examples of GIS application in environmental protection

The application of GIS in environmental protection implies the handling the raster data (satellite and orthophoto images), polygon, line and point data (e.g. land cover, land use, geology, soil, wells, springs...), network handling (e.g. streams, water supply network, sewage network...), handling relief... These applications can range from simple lists to sophisticated ones that involve the analysis and modelling of spatial data.

The most common pollutant of surface water are suspended sediments both in weight and volume (Howari et al, 2007) but the sewage with additional presence of industrial wastewater is probably the most widespread and most common point sources of pollution of land waters. The main distinction between point and nonpoint sources is that the first one "discharge pollutants into the receiving water bodies at an identifiable single- or multiple-point location" (Novotny, 2003). If the amount of pollutant is high, in some parts of the watercourse there can be total anoxia and the extinction of the living world. If we were to study the state of the pollution of the watercourse and the possibility of its reduction, we would take into consideration the layer with points where waste water is poured into the rivers (in order to see the most critical parts of the river); water level layer (in order to know when it is necessary to prohibit the discharge of wastewaters in case of low water levels in the summer months); a layer with locations where water was sampled to connect with the results of chemical and microbiological findings (so as to present each of the findings with a special layer, for example, a layer with water temperature, smell, pH value, a layer with oxygen level, cyanide...); plant and animal species... With prejudice-free data, interactively through GIS software, using geovisualization (MacEachren, Kraak 2001) which "provides hypotheses and different alternative views" (Kraak 2013), it is possible to solve ecological problems by examining the causative agents and their relations and successfully preventing ecologic disaster.

Coastal waters, into which the wastewater both indirectly and directly flows through the watercourse, still suffer the strongest blow. They are often the "closest to the sources of pollutants" and at the same time "the most physically, chemically and biologically active zones" (Preston, Chester, 2001). The necessary layers would be: the layer with the living sea world; with the marine currents; layer with quantities and types of fish (determined by sonars and various statistical procedures); places where fish are caught (in order to control and prevent extermination)... It would be possible to easily determine the distance from the coast and the ideal place where waste waters would pour into the sea - far enough from the coast (due to bathers); well positioned in relation to marine currents (to dilute as soon as possible); so that they avoid the habitats of plant and animal species...

The drinking water used in Serbia is mostly underground water. Even if the "magnitude of groundwater pollution is much less compared to surface water as the soil acts as a filter retaining a large part of colloidal and soluble pollutants by mechanical trapping, adsorption and chemical reactions" (Goel, 2006), those water resources could be polluted very easily due to negligence, and its purification is almost impossible. In order to prevent the pollution of groundwater, we would need to process: the industrial zone layer; the layer with soil, the layer with a geological data, the borehole layer (to determine areas that would be susceptible to infiltration of polluting liquids, i.e. where, depending on the permeability of the soil, the cracks in the geological base or the present boreholes, it would be possible for polluting substances to reach the groundwater); the layer with the roads that transport the raw materials but also the products of the liquid industry (material that could become a chemical or microbiological pollutant, gasoline, oil or acids). By setting a buffer (an area of interest around the entity) around the roads (e.g. 50 meters around the roads) and overlapping it with the borehole layer, we would find out which boreholes are located at a distance of 50 meters from the road. We would determine the slope of the road and the large curves and their distance from the boreholes. At the critical parts of the road, we would later either ban the transport of dangerous goods or limit the speed to reduce the possibility of overturning the tanker trucks.

By applying a buffer and by placing spatial and non-spatial queries in a GIS database in order to find the desired data, we could determine the corridors that should be used to transport industrial waste. The impact would be: layers with residential parts of the city; layers with areas with protected plant and animal communities; road network; layers with traffic intensity depending on the time of day, month, year; layers with current meteorological conditions and weather forecasts for the coming days; layers with a slope of the terrain... Their combinations would give us the shortest and safest route.

Air pollution is (with pollution of water and land) one of the main concerns in developed countries, but just with a certain time delay also a concern in developing countries, which deal with the same problem which the developed ones had earlier (Mage et al, 1996). Air pollution mainly occurs in the lower layers of the troposphere. It badly affects human health by causing diseases of the respiratory organs and chronic diseases, but also on the environment (soil, forest...). The main source of air pollution in industrial cities is the industry itself, but also the increased use of motorized vehicles in such densely populated areas as well as the use of low-quality fuel for heating and cooking purposes. Seasonal changes and chemical reactions contribute to the concentration of polluted air. There are many factors that cause dispersion of polluted air, including climatic factors and climatic elements (such as relief, temperature, speed and direction of the wind, humidity), but also the local situation (forest protection belts, density and layout of built surfaces, ventilation on the traffic corridors...). Each of these factors and climatic elements could be taken for a special layer, and only imagination can limit the combination of layers, determination of cause-and-effect connections, and the prediction of the occurrences.

Over the last few decades, researchers have confirmed that trees in urban areas improve the quality of life and "fulfils many social functions and psychological needs of citizens, which make urban nature a valuable municipal resource, and a key ingredient for city sustainability" (Chiesura, 2004). GIS would be helpful in selecting locations for raising a forest protection zones that protects residential areas of the city from industrial pollution and traffic as well as from the noise (some of the layers would be the strength and direction of permanent and dominant winds).

The construction of a gas pipeline network and the inclusion of natural gas in industrial processes as a more logical choice from the point of view of environmental protection, economic justification of exploitation and existing resources could also see great benefits from geographic information systems.

We must not forget the impact of possible natural disasters on industrial facilities and their landfills. Earthquakes, floods, forest fires, storm winds, droughts, extremely high and low temperatures, landslides are potential factors and the possibilities of their occurrence should be examined. If an environmental incident or a natural disaster occurs, the emergency response service would arrive to that location shortly with the help of GIS and the global positioning system.

4. Conclusion

Data is an integral element of GIS. Various sources are used to obtain data: different types of maps, lists, terrain surveys, global positioning system, remote sensing and the data obtained by direct research.

Efficient environmental management aims to optimize the use of resources and reduce negative environmental impacts, while maintaining economic growth.

Satellite recording and monitoring are based on the analysis of multispectral and multitemporal satellite images from the same spectral ranges obtained by multi-year recording. Multispectral images allow retrospective testing, which cannot be achieved by any other methodological procedure.

The key trends in GIS are the shift from establishing to generating a hypothesis; from static to dynamic models; from 2D views to 3D views (or even 4D views if time as the fourth dimension is included in the modelling); from simple cartographic displays to complex visualization (animation, multimedia, 3D; due to the advancement of hardware and software solutions, it is now possible to process a much larger amount of data in a shorter time), all in a new medium such as the Internet. Commercial GIS software is being increasingly advanced and used, and helps us to through geo-visualization find the expected and discover the unpredictable.

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