APPLICATION OF GIS METHODS FOR THE RESEARCH AND MANAGEMENT OF THE ASTRAKHANSKIY BIOSPHERE RESERVE (RUSSIA)

N.S.Kasimov, M.U.Lychagin, E.A.Baldina, I.A.Labutina
Faculty of Geography, Moscow State University, Moscow, Russia, 119899
(7095)9328836

A.K.Gorbunov
Astrakhanskiy zapovednik, nab.r.Tsarev,119, Astrakhan, Russia, 414000

J.de Leeuw
ITC, Enschede, the Netherlands
(3153)874399

Abstract

1. Introduction

GIS technologies as a powerful tool for a management of spatial data are being rapidly spreading into different fields of activities. During the last years International Institute for Aerospace Survey and Earth Sciences (ITC) collaborates with UNESCO in a joint research project which aims to develop a GIS techniques for the management of Biosphere reserves in Indonesia and Kenya.

In 1993 NWO (Dutch Organization for Scientific Research) funded a project to set up a GIS for the Astrakhanskiy Biosphere Reserve in Russia. This project aimed at implementing the GIS to assist the management of the reserve. The project has been carried out by Faculty of Geography of Moscow State University, Astrakhanskiy Biosphere Reserve, ITC and Wageningen Agricultural University. After consultations of the participants it was decided that it should include a research of both ecological and geochemical parts of ecosystems.

Natural reserves in Russia have collected long-term data on different natural components, mainly floristic and faunistic, presented as reports, cronicles, etc. GIS technologies provide a possibility to combine all the information into integral system for the precious geographical locating of observation points, spatial analysis, prediction of changes. Geographic information systems may be especially useful for the research of ecosystems, located in such dynamic areas as river deltas.

1 Study area and background

The great importance of GIS techniques for the research and management of the Astrakhanskiy nature reserve is determined by its location in the Volga delta. This large wetland area (about 20 000 km^2) is highly depend upon the action of both Volga river and Caspian sea. Since 1977 the sea level rises with a rate of about 14 cm/year that poses enormous ecological and economical problems. During this period important changes in flora and fauna have been observed, which have been attributed to the sea level rise. However, the exact spatial extent of these changes was poorly known, since aerospace data were hardly available.

Astrakhanskiy reserve consists of three areas (634 km^2 in total) in the lower course of Volga delta. It represents a unique natural delta landscape with a diverse vegetation and a rich fauna. Being established in 1919, it is the oldest natural reserve in Russia.

The research has been undertaken in the western location of the reserve: Damchik area. This is a flat lowland weakly inclined towards the Caspian sea. Hydrographical network of the area includes a large number of water streams and bodies. Hydrological regime is characterised by well-defined peaks of high water in May-July and low water in August-October. Extremely continental climate conditions are reflected by a hot summer and a cold winter. During the winter water bodies get covered by ice. Vegetation of the area is presented in a large part by aquatic and amphibious plants. The perculiar feature of the reseve vegetation consists in a vast areas of lotus (Nelumbo nucifera Gaertn). The natural reserve territory provides habitats for a large number of bird species. Seasonally flooding areas are of a major importance for the fish spoonihg.

Astrakhanskiy reserve has accumulated quite a lot of data on the present state and dynamics of ecosystems. Permanent staff of the reserve and visiting scientists carry out researchs in different fields: geomorphology, hydrology, meteorology, botany, hydrobiology, ichthyology, ornithology, entomology. A start has been made on the research of contamination. Data of the observations properly describe seasonal and long-term dynamics of natural components in sampling points. On the other hand spatial distribution features as a whole were poorly known. Some thematic maps were created but they could be considered as schemes only.

This is a reason why additional fieldworks appeared to be necessary. These fieldworks have been resulted in the improvement of data on vegetation spatial distribution and hydrographic network as well. Besides that it made possible to create a soilmap of the area.

2 Results and discussion

To create a GIS for this area it appeared to be necessary at the first step to reveal the most important natural components that should be mapped as layers of the GIS. The major problem we were stuck with consisted in the shortcomings of topographic maps for this area caused by hydrological fluctuations and unsufficient content of the maps concerning geographical peculiarities of lowland coastal zone. So that deeply researched natural components of the reserve mostly had not been accurately mapped. This is a reason why it was impossible to use a routine way of GIS creation (on the base of existing maps).

2.1 Remote sensing and cartographical maintenance

Remote sensed materials (aerial and space photographs, digital satellite images) present the most necessary background information for the spatial base of the GIS and for dynamics studies as well. The research of long-term and seasonal dynamics of Volga delta ecosystems required to obtain series of aerial and space data for the last decades. Their acquisition, georeferencing and mutual coordination have been an important stage of the database development.

Significant heterogeneity of primary data sources caused many difficulties in their joint analysis. At the first stage of the GIS elaboration it is necessary to develop a basis for the spatial positioning and georeferencing of all the data. We offer to use a special map, named "base map", as means for coordination of conventional cartographical sources for a GIS. As a base map content it is necessary to use the most physiognomical objects of the territory, which coordinates may be determined with the required accuracy. The compiling of a base map supposes to use both topographic maps and aerospace materials. Hydrographical objects can serve as a main element of base map content "organizing" the mutual coordination of other layers of the GIS.

This approach has been succesfully applied for the northern part of the area. In the southern part it appeared to be impossible to use the coastline as a main element for the base map. Due to hydrological fluctuations the coastline location along the border of hydrophyte vegetation as drawn at topographic maps does not reflect its real position. There is a rather vast area (up to several kilometers width) where it is difficult to say confidently whether it is a land or the sea.

Boundaries between water and vegetated areas can be identified much more precisely. They are quite visible at the aerial and space images. but it is necessary to keep in mind seasonal peculiariaties of vegetation pattern. Quite a vast areas of opened water in summer get covered by abundant vegetation. Integrated analysis of the most recent images of different seasons in a combination with field observations provided to create a vegetation map. This map has been adopted as a base map for the southern part of the reserve.

Computer assissted cartography and geoinformation technologies changed the original comprehension of a map scale. due to potentialities of free scaling or zooming of digital maps. Now it is possible to determine the scale of the base map in terms of its informational capacity or detailness and positional accuracy. In this sense the scale of base map depends upon the detailness and precision of original sources. Main sources of the base map are presented by topographical maps and aerophotoimages. Topographical map of 1:50.000 was the most precise source of information here. but aerophotoimages of scales 1:25.000 - 1:100.000 allow to have more detailes. These facts determined the scale of the base map as 1:50.000-1:100.000. i.e. its detailness corresponds to the scale of 1:50.000 but its precision better meets the requerements of 1:100.000 scale. This scale has been adopted for the most part of thematic layers of the GIS.

2.2.*Vegetation layer*

Vegetation layer appears to be the most important for the GIS. Vegetation in the study area serves as a good indicator for a spatial structure of ecosystems. Plant cover pattern reflects in a large extent the spatial distribution of other landscape components. such as relief. lithology. soil cover.

Vegetation map has been created on the base of aerospace and cartographic layers of the GIS. The preliminary stage included an elaborarion of the map legend draft and pre-fieldwork interpretation of aerospace imagery on the basis of data accumulated in the reserve. Fieldwork (August 1994) included a field interpretation of air photographs and collection of sampling points for the image processing.

Vegetation mapping has been proceeded for the northern and southern parts of the area in different ways. Main vegetation types in the northern part appear to be distinctly separated in aerial photographs. So that vegetation pattern provided by pre-fieldwork map for this area had to be only checked and improved with field observations. Outlines of vegetation units were refined by digitizing from screen.

Perculiar feature of the southern part consists in a well-defined seasonal changeability even of outlines of vegetation units. Only reed outlines are relatively stable in a seasonal aspect. Vegetations peaks from the end of July till the middle of September. Thus we had to use the satellite image from September 5. 1992. as a basic for the vegetation map of the southern part. To avoid accidental features aerial photographs from May. 1989. and satellite image from June. 1991. had been used as well. Application of GIS techniques provided to get classified image. On the next stage the vegetation pattern has been generalized. The final map outlines have been improved by screen digitizing.

As a result the Damchik area vegetation map has been created. Thirty vegetation units reflect not only typical plant associations. but mosaic features of them as well. This is essential for the reserve ecosystems being linked to protective. fodder and nesting properties of birds habitats.

2.3 Hydrographic layer

Hydrographic layer of the GIS has been elaborated on the basis of topographic maps and improved with a help of aerial photographs from May, 1989. According to the hydrological regime water bodies and streams were classified into three groups: running during all the seasons, weakly running and stagnant during low-water, isolating and intermittent during low-water seasons.

2.4 Geomorphology layer

The study area from the geomorphological point of view (Belevich, 1963,1978) could be divided into 3 zones. The northern part of the area is located within the lowermost part of delta and includes main channels, creeks and low river islands with shallow swampy lakes. The sothernmost part of the area occupies so-called avandelta (fore-delta). This is a submerged former delta area, shallow, inclined towards the sea. Due to the abatement of the sea level in 1930th's some islands have been formed here and covered by mainly reed vegetation. Nowadays most of them are flooded but outlines of reed patches have not changed yet. They are still quite visible in satellite images. The middle zone of the area, so called "kultuk" zone, presents a transitional zone from delta to avandelta. Kultuk is a very shallow inlet opened to avandelta. Such inlets are abundant along the sea-side coast of Volga delta. Dryland spots in kultuk zone are presented by sand banks and small islands. This is the most important area from the viewpoint of sedimentation and formation of new delta channels, alluvial islands and lakes.

The most important relief features of the area are displayed at the geomorphology map, which has been created with a use of the "base map", vegetation map and geomorphological schemes for the Volga delta territory.

2.5 Soil layer

Main soil types and features of there spatial distribution were revealed during a fieldwork. Field soil descriptions in 60 points were accompanied by measurements of the depth and mineralization of ground waters. According to FAO classification we determined a few varieties of fluvisols and solonchaks.

Spatial distribution of soils depends on the relief, lithology, vegetation, duration of flooding, depth and mineralization of ground waters. Soil map has been created on the base of vegetation and geomorphological maps, which provided to locate soil units. Each soil unit contains information about pH, granulometrical composition and thickness of the topsoil, concentrations of heavy metals.

2.6 Geochemical layer

The necessity of a geochemical GIS layer for the study area is determined by its position in the lowermost part of Volga basin. This is an accumulation area for many compounds of both natural and technogenic origin. Volga river in the middle and low stream is polluted with industrial and agricultural sewages.

Geochemical layer of the GIS has reflected main features of a spatial distribution of chemical compounds (heavy metals and PAHs) for the natural reserve area and revealed contaminated sites. Application of GIS techniques provides a opportunity to find out relationships between distribution of pollutants and biological subjects, such as plankton etc. A geochemical model is being worked out to predict possible redistribution of pollutants due to the sea level rise.

2.6 Faunistic layers

At present birds and mammals distribution maps are being proceeding. To create them we use both the natural reserve database and the basic layers of the GIS. such as maps of vegetation, hydrography, geomorphology. In some cases classified images and the digital photoplan are being used as well.

The ornithological layer is of a major importance for the Astrakhanskiy reserve. This is an area of nesting and seasonal migration for a large number of rare bird species. The main features of birds distribution and migration will be presented on the base of GIS and field observations data.

3 Perspectives and conclusion

The GIS presents a basis for the management of the biosphere reserve spatial database. Created layers of the GIS are considered as a background for the collection, generalization and spatial analysis of data on many others additional layers.

For the development of the GIS it is necessary first of all to elaborate spatial database of the water depth and bottom sediment lithology. It is desirable also to map a distribution of water temperature and velocity. Integrated analysis of these data in a combination with the basic layers of the GIS will provide an opportunity for the spatial analysis of benthos, plankton and fish species. This should enable to estimate a biological productivity of aquatic ecosystems and to predict its changes due to the sea level fluctuations. This information is of major importance for the analysis of birds and fish habitats. On the next stage for the assessment of contamination influence on biota it could be possible to link biological data to the geochemical layer of the GIS.

The another possibility for the application of GIS techniques consists in mapping of seasonally flooding areas. It could be very useful for the spatial analysis and prognosis of fish spawning, mammals distribution, etc.

The basic layers of the GIS, such as vegetation and hydrography, have a self-dependent importance also. They could be considered as a stage of natural ecosystems monitoring. Geochemical layer is very important for the monitoring of pollutants.

In a future the GIS should be extended to the surroundings of the biosphere reserve and include not only the "core" (the present area of the reserve), but a buffer zone and area of a traditional landuse as well.