

MONITORING AND GIS APPROACHES FOR MAPPING ECOLOGICAL DISASTERS IN THE KYZYL-KUM DESERT

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RÉSUMÉ

Cette communication examine la méthodologie de gestion de l'espace et des paysages telle qu'elle est pratiquée en Russie. Différents points de vue sont examinés qui concernent aussi bien la gestion de l'environnement que son organisation pratique. L'expérience acquise dans le fonctionnement des SIG et le développement des bases de données est proposée pour des études géographiques et écologiques en zones désertiques. Les cas de désastres écologiques étudiés dans le désert de Kyzyl-Kum sont présentés.

ABSTRACT

The paper reviews the methodology of space monitoring of landscapes as it is practiced in Russia. Different views are presented concerning environmental monitoring as well as the aspects of its practical organization. Experience gained in the operation of geoinformation systems and development of relevant databases are suggested for geographical and ecological studies of the desert landscapes. Ecological disaster case studies in the Kyzyl-Kum desert are described.

◆ SPACE MONITORING AND GIS FOR THE STUDY OF THE PRESENT-DAY LANDSCAPES

The concept of ecological crisis zones research is being developed now within the frame of the space mapping monitoring. It will ensure the application of genetic series of landscapes as indicators of the natural-anthropogenic processes estimation. The necessity of historical-geographical approach is also being substantiated.

The experience shows that it is useful to conduct the monitoring of the present-day landscapes at system level.

Presently the focus is on a geosystem approach to the study of spatial structure of landscapes, their evolution at different taxonomic levels, as well as the desertification processes that occur under natural and transformed conditions. Within the framework of remote sensing, models for aqua- and geosystems, in particular, in the Aral Sea basin, are being elaborated.

Part and parcel of space monitoring of present-day landscapes, desertification processes occurring in them and nature management is the cartographic monitoring. This includes plotting reference and operational maps based on space photographs, which can be used for the assessment and prediction of areal extent, state and dynamics of objects and phenomena under study with periodicities ranging from several days to decades.

Regional space monitoring of the present-day arid landscapes has the following aims: 1. furnishing regular

scientific research at different taxonomic levels both in spatial and temporal aspects using modern data acquisition and processing techniques; 2. control of environmental changes in regions with different pattern and degree of anthropogenic landscape transformation for the purpose of environment conservation; 3. elaboration of scientifically-based programs of natural resource management, with guidance to the national economic plans, and implementation of rehabilitation measures in the areas of disturbed landscapes.

The space monitoring concept includes sections dealing with classification, methods, structure and programs of investigations. Three main blocks are distinguished in the monitoring structure: the Earth survey, information processing and management. Monitoring is based on a multi-stage system of space, aerial and land-based surveys providing for the regional, local and detailed studies. The information processing block includes data reception and primary processing, systematization and storage as well as the scientific interpretation within the geoinformation system. Management block integrates observation and reporting, control and prediction, and also planning of environment protection measures.

The complex program includes three subprograms of monitoring: the present-day landscapes, nature management and desertification processes. Each of them systematizes the main areas of study and specific scientific and economic tasks, required types of monitoring, and advisable parameters for aerospace and land-based surveys. The possible applications and the expected results of monitoring are defined. For each subprogram a set of study objects is determined as well as their characteristics identified by remote sensing methods. Satellite survey requirements are specified for solving actual monitoring problems at various taxonomic levels.

Among the various geographic information systems (GIS) those based on remote sensing data become more common in the world. This priority can be explained by the utilization of both spectral and textural characteristics, the wide areal coverage (up to global), the possibility of periodic addition and correction of data, in particular for their spatial and temporal analysis, and suitable direct input of data into GIS without special preparation. Such data are indispensable for multi-purpose geographical studies, including those of the present-day landscapes. The techniques of remote sensing are being improved thus widening the application of data in solving a wide variety of problems, for example the determination of integrated anthropogenic-natural systems which is important for ecological studies.

In the absence of the country-wide system the authors organized a regional GIS intended for study of the present-day landscapes; it satisfies our requirements now, but it can be modified in accordance with the future strategy of GIS development. At present its main objective is the operational reproduction of thematic maps like those described in the next section of the article.

◆ SPACE GEOECOLOGICAL MONITORING IN THE PRIARALIYE (THE ARAL SEA REGION)

In the second half of the XX-th century many arid regions of the Earth, including formerly Soviet Middle Asia, experienced the severe deterioration of environment which was caused by a general aridization as well as by extensive land and water use. The objective assessment of the actual state and trends of environment changes requires the comprehensive studies of landscapes, nature management and desertification processes. The practical way of accomplishing the geoeological setting control in the regions of ecological disasters is the organization of aerial-space monitoring.

Monitoring of environment changes in vast regions under ever-increasing pressure of economic activity and intense development of desertification processes involves the application of a complex approach. The combination of ecological, historical and landscape studies at system level is the most efficient in this case. The geosystem landscape approach allows to reveal the regularities of spatial differentiation and development of natural landscapes and their anthropogenic modifications. The ecosystem approach is oriented on the analysis of interactions between landscape systems and human community in the process of economic activity. Historical approach pursues the objectives of a complex analysis of nature and society evolution for the whole period of man's constructive influence over the environment. Such a concept makes it possible to study the spatial organization and time variability of transformed landscape zones of ecological disasters as an integrated regional historical geoeological system.

Space monitoring of present-day landscapes, nature management and desertification in the regions of ecological disasters should provide for the permanent observation of environment changes, revealing the specific causes of landscape deterioration, and for the elaboration of scientifically-based predictions and recommendations on preventing the detrimental effects of desertification, as well as the control of their implementation.

The design of the space monitoring system includes the elaboration of classification, methods, structure and programs of investigations. Monitoring is based on complex surveys - space, aerial and land-based, which ensure the investigations at regional and local levels. Three main blocks are distinguished in the monitoring system: survey of the Earth, information processing, and management. A complex program includes three subprograms of monitoring: landscape, nature management and desertification. For each subprogram a particular set of study objects is defined, their characteristics being determined on the basis of remote sensing methods. Space survey requirements have been developed to solve various tasks of monitoring.

In the 50-ies the intensification of desertification processes in the Aral Sea region and the Kyzyl-Kum desert manifested itself by drying of the vast alluvial-deltaic plains of the Amu-Darya and Syr-Darya rivers as a result of the expansion of sowing area, water consumption for irrigation, regulation and decrease of the river flow followed by the cessation of flooding. However the most severe desertification dates from the 60-ies when the long period of river flow decrease led to the draw down of the Aral Sea level and the drying of the shallow water bodies. If geographical maps of the Kyzyl-Kum desert compiled in the early 60-ies are compared with space photographs taken at different periods of the 70-ies and 80-ies and depicting the state of landscapes for the relevant time it becomes possible to trace the dynamics of landscapes, desertification processes and nature management for the period of intense landscape disturbance and formation of ecological disaster zones.

Complex investigations of the Aral Sea region and the Kyzyl-Kum desert were based on the small-scale black-and-white satellite photos at the scale of 1:2,400,000 taken from the «Salyut» orbital station in 1975-1980 which provide the full coverage of the territory. The use was also made of multi band black-and-white synthesized multispectral images from the «Resurs-F» satellite at the scale of 1:1,000,000 with several times coverage of the study area and at the scale of 1:200,000 for some parts of the area, taken in 1980-1989. Apart from space images numerous publications and cartographic works were analyzed as well as the results of selected land-based studies conducted by the authors.

Complex geographical studies of the Aral Sea region and the Kyzyl-Kum desert within the frame of space monitoring included basic, special and operational mapping of the territory using the space images. The main objective was the interpretation and mapping of present-day landscapes at scales of 1:2,400,000 and 1:1,000,000.

The landscape maps served as a basis for mapping desertification processes, long term dynamics of geoecological setting, natural decrease foci, desertification control measures, at the same scales mainly. Besides, largescale maps of the present-day landscapes and their dynamics were compiled for key sites using the materials of space and aerial surveys for different time periods at the scale of 1: 200,000 and more as well as the author's land-based observation data.

For computerized processing and thematic mapping survey data were digitized and stored in special databases. Thus the operational compilation of various thematic maps by means of computer plotting devices became possible. First of all basic maps of the present-day landscapes were compiled to be used as a reference for future special mapping. The present-day landscape maps reflect the actual landscape differentiation of the territory with the account of their anthropogenic transformation. Natural landscapes of the Central Kysyl - Kum are distinguished at the 1:2,400,000 map together with their anthropogenic modifications formed under the influence of long-practiced irrigation in the Amu-Darya

and Syr-Darya river deltas and valleys, cattle grazing in sandy, solonchak and clay deserts. The landscapes of the Aral Sea dried-off bottom are also distinguished at this map.

The maps of desertification processes compiled on the landscape basis characterize the spatial distribution of detrimental processes which occur in different components of landscapes and cause the destructive changes of the environment. The maps show about 30 processes leading to changes of relief, surface and ground water, soil and vegetation cover. The processes are grouped according to their association with drying of sea bottom and deltaic-alluvial plains, pasture overgrazing, irrigation and post-irrigation desertification. A distinct connection between a particular set of processes and certain landscapes and types of land use has been revealed.

Maps of long term landscape dynamics for the last 30 years reflect the nature and degree of environmental changes under increasing anthropogenic influence. Long term changes of landscape state and structure have been revealed with the help of dynamic and retro indicators while interpreting many -year series of space images and comparing them with geographical maps of study areas compiled in the early 60-ies of this century. The maps show territories where primary landscapes were formed; where one variant of landscape was replaced by another; where landscape structure has changed within the limits of the same variant of landscape; where properties and certain features of landscape structure have changed; where no signs of change were identified.

Maps of geoecological setting were compiled on the basis of previously plotted maps. Geoecological assessment was carried within the limits of distinguished landscape units. For each of them the prevailing type of changes has been determined (natural, natural-anthropogenic, anthropogenic) and the main groups of natural-anthropogenic processes were indicated. The degree of changes of the main landscape components was evaluated by 10-points scale using various classifications. The actual trends of landscape changes - restorative, optimizational, digressional - were revealed.

On the basis of above-listed data and with the use of original geoecological classification of present-day landscapes five main categories of landscapes were distinguished: natural, optimized, compensated, depressed and disturbed, as well as their various combinations.

The results of mapping show the existence of a large ecological disaster zone which embraces most of the Aral Sea region including the dried-off sections of the sea bottom, peripheral parts of the Amu-Darya and Syr-Darya river valleys and ancient alluvial plains that divide them. In the Kyzyl-Kum desert three ecological disaster regions are identified: eolian plains in the northern part of the desert, ancient alluvial and eolian plains in the peripheral parts of the Bukhara oasis, and eolian and clayey plains in the south-eastern part of the Kyzyl-Kum desert.

Within the framework of the complex landscape-based mapping the schematic map showing the distribution and dynamics of plague epizooties among rodents was compiled at the scale 1:4,000,000. The use was made of space survey data obtained in different periods and the evidence of the Uzbek plague-prevention station for 1948-1982. The mapping has revealed the regional features of landscape differentiation and dynamics of natural disease foci under increasing desertification. Statistical processing of long term observation data permitted to determine the typical dynamic series of epizooties in different landscapes. The joint analysis of the results of statistical and cartographical studies allowed to specify the natural and anthropogenic factors of long term migrations of plague epizooties within the territory of the Kyzyl-Kum desert.

The map of desertification control measures was compiled on the basis of the above-discussed maps at

the scale of 1:2,400,000. The recommendations on the implementation of complex measures are based on the existing proposals and regional experience with account of the actual geocological situation. Within the landscape limits different sets of hydro-, phyto-, land and chemical ameliorations, restoration, socio-economic and research measures are presented. The experience of local implementation of effective measures can thus be taken into account and extended on the whole study area by distinguishing the analogous landscapes.

Multipurpose geocological studies including mapping and conceptual modeling of landscape functioning and development represent an integrated series of experimental research works on space monitoring with the aim of environmental control and optimization in Middle Asia.