MONITORING THE STUDEN KLADENETS RESERVOIR USING AIR AND SPACE IMAGES

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Introduction

The observation and control of the state environment by air and space instrumentation is a subsystem of the monitoring system. The successful operation of the monitoring system depends on the precision of the standard and remote sensing measurements and observations, the GIS-data base and on the systems for prompt data transmission to the management authorities. In the developed countries in the last decade for the environment monitoring more and more local geographic information systems are built which use air and spatial images as the basic source of information [1]. For the territory of Bulgaria, and in particular for study of the dynamics of artificial humid zones, these methods are not much applied yet. As for the artificial humid zone Studen Kladenets reservoir such a local GIS is not yet instructed. This area changes periodically its state, different types of land cover (TLC) appearing on the drained lands. The objective of this study is to establish the changes of the land cover after the reservoir was built, as well as to trace out the water surface dynamics at different benches of water level. To the fulfillment of this goal, GIS data-base is created describing the structure and dynamics of the land cover in this region.

Studied area

Reservoir Studen Kladenets is located in the Mid-Arda region of the East Rhodopian sub region of the Rila-Rhodope massif. In morphographic, respect the region around the reservoir is distinguished by the wide development of the hill type relief within the 200-600 m sea level zone. The reservoir shores are bounded to the north by the rock Kayadjik talus hill. The slopes of the different hills are steep, deforest area and strongly eroded.

The great lithological variety, the multiple and fast alternation with different properties determine the great activity and clearly expressed selectivity of denudation in the examined region. A number of landslide events are related with it. They provide the initial material for the solid runoff of the rivers in the watershed of Studen Kladenets reservoir. The geological pattern of the region is formed by rocks of the polyphase Palaeogenic volcanism and the lava and pyroclastics connected with it [2]. The acid differentiates of this volcanism predominating in the region are a prerequisite for the formation of relatively high single structures situated along the reservoir shores. These are: Saint Ilia, Dambalak, Perperek, Hisar, Studen Kladenets. The reservoir itself is the northern border of a big volcano-tectonic depression – Nanovishka (**Appendix 1**).

Later, during the Miocene and Pliocene, the volcanogenic relief was greatly transformed without being completely changed and at that time, the foundations of the modern hydrographic network and its orientation were laid.

Studen Kladenets reservoir was built up in 1957. It is a hydrotechnical equipment including: gravity dam with height of 71.0 m, full volume of 489 million m^3 of which death storage of 150 million m^3 and lake area of 25.6 km^2, overflow water level bench of 255 m and death storage bench of 208 m. On the reservoir left shore, in its tail, the “Kardjali” lead-zinc plant is located built, in 1955.

The precipitation fallen on the watershed does not wholly flow away. Part of it gets into the earth layers, the other part evaporates. For the watershed, area of the reservoir the runoff coefficient is highest in January, there after to attain its lowest values in September. Then, only about 14% of the precipitation amount flows into the reservoir. The mean yearly runoff coefficient is 0.47 while the runoff coefficient assumed when the reservoir was designed was 0.52.

The reservoir watershed is slightly wooded with completely bare regions at some places featuring fragile, easily erosive soils, which facilitate intensive erosion. On the other hand, the atmospheric and geomorphologic conditions favor greatly the formation of big quantities of solid runoff. This increases the quantity of bottom and floating sediments, which form the mechanic pollution of the reservoir. They determine the mechanical and chemical water composition. The floating sediments of mechanic origin are predominantly gravel, sand and traces of waste from the lead-zinc plant and the ore dressing factories along the valley of the Arda River.

On the reservoir right is the Valchi dol reserve (774.7 ha). Its territory is a representative biom for the Mediterranean zone with respect to ornithofauna. In it, on data of P.Yankov et al. [3] 7 bioms of little spread species are existing, typical for this zone from an altogether 9 for Bulgaria. The region around Studen Kladenets reservoir includes 205 species of birds, including 52 species introduced in the Red Book of Bulgaria and 117 species of European environmental protection importance [3].

Materials and methods

The main information sources used are given on Table 1. The present work integrates two technologies – geographic information systems and remote sensing methods. The processing of the available information passed through several stages, the most important ones being:

1. Creating the foundations of GIS data base by using information from topographic and thematic maps. It the following characteristics: reservoir borders, geology, soil, relief and land cover before the reservoir was built.

2. Construction of a 3D spatial model of the reservoir lake and the adjacent area.

3. Performing a computer visual interpretation of air and space images surveyed during different years. Different types of land cover of the areas freed

of the water – sands, saturated area, humid grassland, wetland vegetation, brush and aborescent formation, arable land and water surface are decoded.

4. Drawing up of thematic maps.
5. Analysis of the area distribution and dynamics of the water surface of the established types of land cover.

Results and discussion

In the region of the Kardjali valley expansion of the Arda, river by the construction of Studen Kladenets reservoir a local technogenic anomaly - an artificial humid zone - has been created. It arises and operates on the basis of a natural landscape which appears to be initial. The main processes running in the natural landscape continue to operate although modified in the anthropogenic one. The transformation of the natural landscape into the anthropogenic one has occurred thanks to the abrupt man's influence on several components of the environment. This has caused a change of the entire complex without the geological fundament.

After barraging the Arda River and the formation of the reservoir lake, the two flooded terraces beneath the town of Kardjali, in the reservoir tail, were eroded. A wide alluvial bed was formed. Depending on the reservoir hydrological regime, its height was either eroded or increased owing to the new silty sediments. The same is valid for the outflow sections of the Varbitsa, Perperek and Kjuchukdere rivers.

Before the reservoir was built, there were 14 types of land cover on the area under investigation (Appendix 2), the sparse wood and shrubs occupying about 50% of it. After it was constructed in the zones of temporary draining, seven types of land cover were established. Their number depends on the duration of the period during which they were not flooded.

The reservoir is distinguished by large fluctuations of the water level, which are determined to a great extent by the agricultural needs and the region hydroclimatic characteristics. From the map of the water, surface change presented in Appendix 3 it is seen that the areas of temporary flooding and draining reach up to 10.77 km^2. On these lands, the hydrological regime changes abruptly and the underground water level raises in the immediate vicinity the reservoir. This causes vegetation change giving rise to water-loving plants. The unfavorable fact here is that flooding and increase underground water level of occur on some of the best agricultural lands in the region. A significant part of them, which after the reservoir was constructed were turned into shallow lands, grows over with wetland vegetation. After the interpretation of the images recording the reservoir state, at water level benches near to the death storage bench, the presence of great turbidity was established in its shallow part reaching the region of the Island. By means of the constructed 3D model, one can judge about the reservoir lake depth increase. This area appears to be a borderline with respect to the propagation of sediment material. The small water volume in this period also suggests greater concentration of sediment particles and increased water turbidity.

When decoding the air and space images surveyed in 1977, 1978 and 1992, two test areas, located in the regions of the Varbitsa river mouth and the village of Shiroko Pole have been picked out (Appendix 3, 4.). These areas are periodically drained and new types of land cover (TLC) appear on them. Let us comment in brief their change.

Shiroko Pole test area

Before the construction of the reservoir, there ware nine TLC (Appendix 4), sparse wood and shrub being spread most (more than 60%, Appendix 2). The water body including the Arda River covered only 9.2%. At the end of October 1977, the section was drained and only 5% of it is now covered by water. The greatest spread was of the saturated area (38%) and wetland vegetation (29%). 26% of the territory under investigation is of interest. It was used for growing tobacco and vegetables. In August 1978, the test area was water flooded (Appendix 4) and only 2.2% of its territory was covered with wetland vegetation. 14 years later, in 1992, also in August, the water area was 81.8 % of its territory. A part of the drained lands (3.8%) is again used for agricultural purposes.

Varbitza test area

This area is situated in the reservoir tail and is very frequently drained (Appendix 3).

Before the reservoir was constructed the main TLC were sparse woods and shrubs occupying more than 50% of its territory (Appendix 4). Very characteristic for this area is the spread of sands, which occupy about 31.6%. In October 1977, sands (43.7%), wetland vegetation and humid grassland (Appendix 2) mainly occupied the reservoir-drained part. Here, too, 18.9% of the area territory was arable land. In August 1978, only 10% of the test area was drained and occupied by wetland vegetation and sands. In August 1992, the drained territory occupied 65%. Most widely, spread was humid grassland and arable land (Appendix 2). Brush and aborescent formation covers the southwest part of the reservoir (Appendix 4).

On data of the carried out investigations of the reservoir bottom sediments in these areas [4], increased concentrations of lead, zinc, copper, arsenic, cadmium, cobalt were sometimes surpassing 2 to 3 times the admissible norms, i.e. the lands freed from the reservoir are not fit for agricultural use.

Conclusions

In the region of the Kardjali valley expansion of the Arda River with the construction of Studen Kladenets reservoir, a local technogenic anomaly, an artificial wet zone, is created.

The main processes, which have run in the natural landscape, continue to operate although modified in the anthropogenic one. After the reservoir construction the TLC in the zones of temporary draining have decreased from 14 (forests and shrubs predominating) to seven types of land cover, sands and humid grassland mainly spread.

The zone in the area next to the Island appears a borderline with respect to the sediment material spread.

In the case of draining part of the lands are used for growing tobacco and vegetables. The identified high concentrations of heavy metals give us a good reason to recommend not using these areas for agricultural practice.

The regime of the flooded terraces beneath the town of Kardjali, in the reservoir tail is abruptly changed. The flooded terraces are eroded, forming a wide alluvial bed.

The created GIS-data base will be kept expanded and supplemented with new information. This will assist the creation of a local geographic information system, which will be used for monitoring Studen Kladenets reservoir.

Summary

The results of an experimental study of the Studen Kladenets reservoir using remote sensing methods and Geographic Information Systems (GIS) technologies are presented in the paper. The purpose of this study is to identify the changes on the earth land cover as a result of the reservoir construction as well as to trace out the dynamics of the water surface at different water level benches. Topographic and subject maps have been used as well as archive air photographs and images from Landsat TM. The foundations of a GIS data-base are land covering following layers: reservoir borders, geology, soil, relief and land cover before building the reservoir. A computer visual interpretation of the air and space images, taken during the different years is made. The following classes have been decoded: water surface, floating sediments of mechanical character and different types of and cover of the areas freed from water – sands, saturated areas, humid grassland, wetland vegetation, brush and aborescent formations, arable land. The data obtained are input in the GIS data-base. A 3D spatial model of the reservoir lake and its adjacent land is made as well as an analysis of the area distribution and the dynamics of the studied types of land cover.

The GIS-data base will allow the formation of a local geographic information system for monitoring of Studen Kladenets reservoir by air and space images.

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МОНИТОРИНГ НА ЯЗ. “СТУДЕН КЛАДЕНЕЦ” С ИЗПОЛЗВАНЕ НА АЕРО И КОСМИЧЕСКИ ИЗОБРАЖЕНИЯ

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(Резюме)

В статията са представени резултатите от експериментално изследване на яз.”Студен кладенец” с използване на дистанционни методи и ГИС технологии. Целта на това изследване е да се установят изменениета на земното покритие, вследствие построяването на язовира, както и да се проследи динамиката на водното огледало при различни коти на водно ниво. Използвани са топографски и тематични карти, архивни аероснимки и изображение от Landsat TM. Създадената основа на ГИС-база данни включва следните слоеве: граници на язовира, геология, почва, релеф и земното покритие преди построяване на язовира. Извършена е компютърно подпомогната визуална интерпретация на аеро и космическите изображения, заснети през различни години. Дешифрирани са следните класове: водно огледало, плаващи наноси от механичен произход и различни типове земно покритие на освободените от водата площи - пясъци, преовлажнени участъци, хигрофитни тревни съобщества, блатна растителност, върби и тополи, ниви. Получените данни са въведени в ГИС-базата данни. Съставен е пространствен модел на язовирната чаша и прилежащата територия и е извършен анализ на площното разпределение и динамиката на изследваните типове земно покритие.

Създадената основа на ГИС-база данни ще позволи да се изгради локална географска информационна система за мониторинг на яз.”Студен кладенец”, чрез аеро и космически изображения.

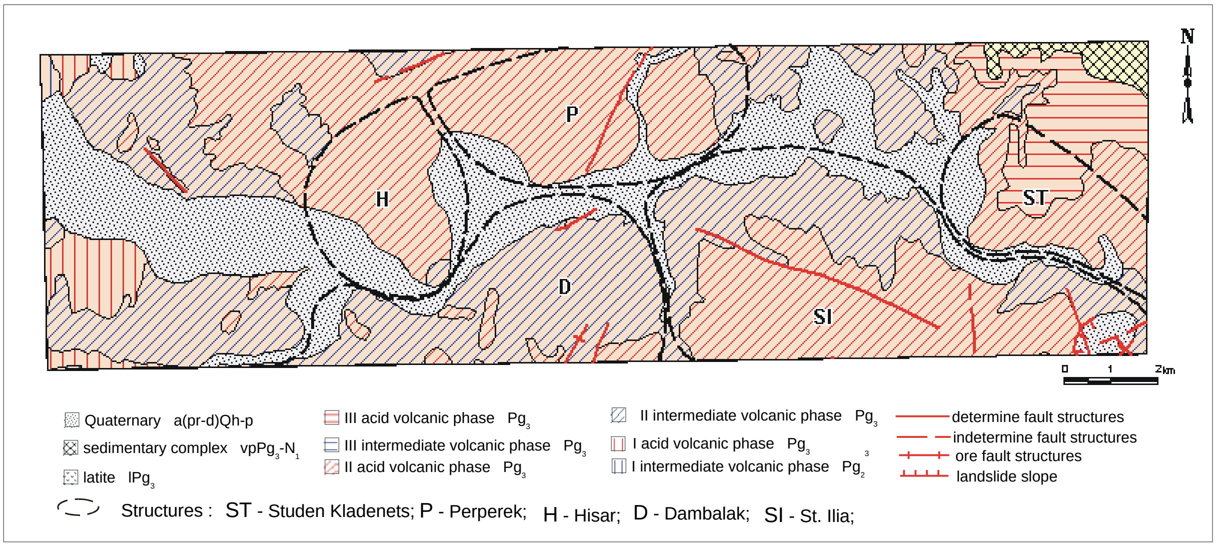
Used materials **Table 1**

Maps	**Scale**	**Images**	**Scale**
Topographic	1:200 000 1:100 000 1: 50 000 1: 25 000	**Air photographs:** MRB, 23.X.1977 г. MRB, 16.VIII. 1978 г. MKF, 23.X. 1977 г. MKF 16.VIII. 1978 г.	1:130 000 1: 70 000 1: 40 000 1: 40 000
Soil and Geology	1:200 000 1:400 000 1:100 000 1: 50 000	**Space:** LANDSAT TM 1992	1:100 000

Appendix 1

The geological map of the study region

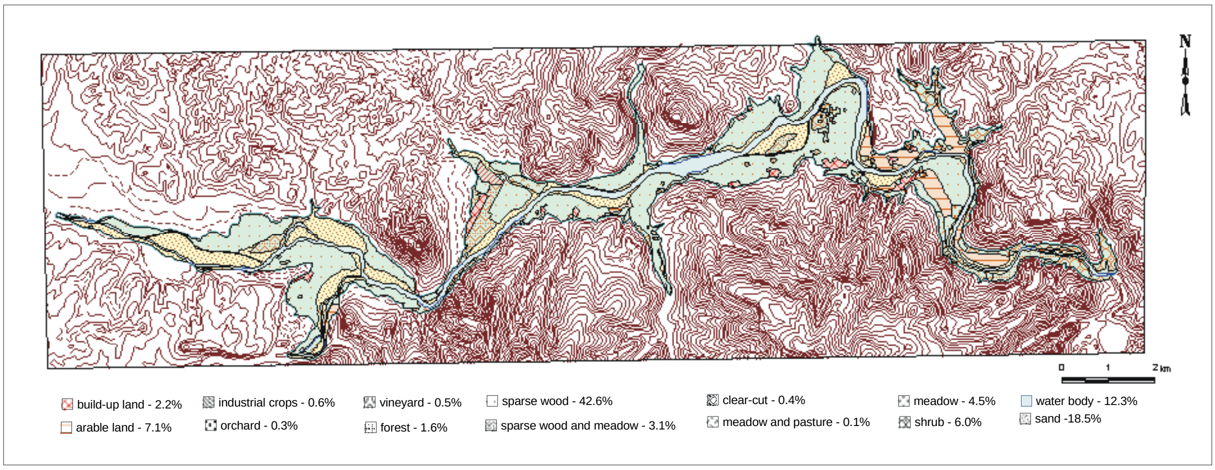
Appendix 1



Appendix 2

Map of the land cover types on the study area before the reservoir was built

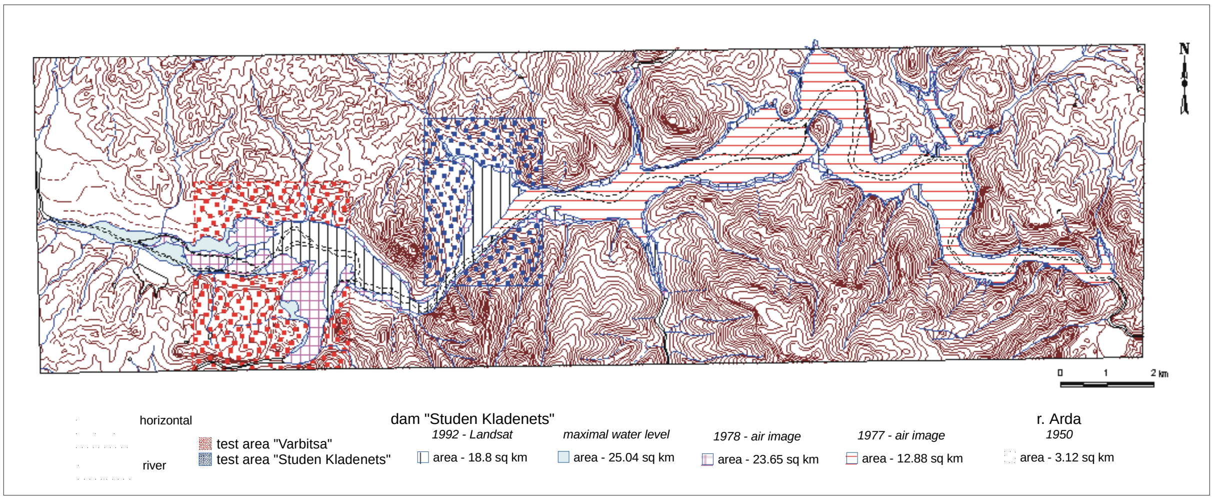
Appendix 2



Appendix 3

Map of the water surface change

Appendix 3



Appendix 4

Map of the land cover types on the test area Shiroko Pole and Varbitsa