DETECTION OF ENVIRONMENTAL CHANGES CAUSED BY A HYDROELECTRIC STATION CONSTRUCTION ON THE DANUBE RIVER USING LANDSAT DATA

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ABSTRACT

A joint Hungarian-Czechoslovakian hydroelectric project, called GNHS (Gabcikovo-Nagymaros Hydroelectric System) has started at the end of the 70's. The project based mainly on political decisions, neglecting sound impact studies on the possible environmental and ecological consequences. As a result of increased overall protection, Hungarian government banned all the works on the Hungarian side in 1990, but Slovakians continued it. The questions of the GNHS project recently has became a main political issue between the two countries.

The purpose of the paper is to assess the environmental changes caused by the construction using multitemporal satellite image analysis. Two Landsat MSS images (taken on April and July 1976) were used to provide generalized land cover, providing the basis for change detection. The images were individually classified for water, forest, agricultural vegetation and non-vegetation. Crossing the two classification maps resulted five categories: improved results for water and forest, agricultural crops, pasture and bare surfaces.

A Landsat TM image taken on March 8, 1990 was used to characterize the recent situation. The area containing the potential changes was outlined visually, then it was classified for the following categories: water, forest, bare surface, pasture and construction site.

Comparing classifications obtained for 1976 and 1990 a change map was produced, showing the decrease of arable lands, pastures and forests. All together at least 39.9 km^2 area has been changed (8.1 km^2 forest, 26.6 km^2 arable land, 5.2 km^2 pasture) as a direct consequence of the construction.

KEYWORDS: environment, multitemporal, change-detection, Landsat, MSS, TM

1. THE GABCIKOVO-NAGYMAROS HYDROELECTRIC SYSTEM

A joint Hungarian-Czechoslovakian project, called Gabcikovo-Nagymaros Hydroelectric System (GNHS) has started on the Danube river at the end of the 70's to produce energy using two stations: the upper in Slovakian, the lower on Hungarian area. The upper stage is being constructed within a region characterized with two larger, and a number of smaller islands, formed from the sediments deposited by the river. This area is fairly complex, including forested regions with protected habitats as well as pastures and highly productive farm lands.

The GNHS project based mainly on political decisions, neglecting sound impact studies on the possible environmental and ecological consequences. At the second half of the 80's environmental movements in the two concerned countries has raised, claiming to stop the construction. Main ecological and environmental concerns were as follows: serious degradation of forests and good quality arable lands along the river, due to the decreasing level of water table, and contamination of a huge drinking water resource of the gravel deposit because of stagnant water in the constructed reservoir. As a result of protests, Hungarian government banned all the works on the the Hungarian side in 1990, but Slovakians didn't. However, to turn the Slovakian part operational according to the original plans, the system would require a new channel, starting from the bordering region of the Danube, to provide water to the reservoir.

The questions of the GNHS project recently has became a main political issue between the two countries. The latest decisions (May, 1992) of the concerned parties are as follows: Czechoslovakia decided to build this new channel on her area (diverting the Danube arbitrarily), while Hungary, confirming her previous decision concluded to denounce the 1977 Interstate Treaty related to the construction of the GNHS.

2. AIMS

The purpose of the work is to assess the environmental changes on the upper part of the project, caused by the construction. Although more drastic changes could be anticipated only if the system would be operational, the construction itself has already destroyed significant areas of good quality arable lands, pastures and forests. It will be possible to use the land cover map derived for the pre-construction status in future change detection studies as well.

3. MATERIALS AND METHODS

3.1 Data characteristics

Satellite imagery provide an excellent opportunity to assess environmental changes within this 15 years time frame on an area covering two countries. (It would cause serious difficulties to acquire archive aerial photography for the area outside Hungary.) According to preliminary studies two Landsat MSS images (pixel size 60*80 m) taken in the spring and summer of 1976 were necessary to characterize the pre-construction status. A single Landsat TM image (pixel size 30*30 m) taken in 1990 was used to map the present situation.

Some difficulties in data processing were expected due to the different geometrical resolution of Landsat MSS and TM images. Although we could use MSS data depicting the present status as well, TM imagery was preferred because of its better spectral information content (Anuta, 1984). All the Landsat images used in the study (Table 1) were recorded at the ESA/Fucino station.

Table 1
Landsat data sets

date	type	used bands	data quality
Apr 1 1976	MSS	all four	a bit hazy
July 18 1976	MSS	all four	small clouds
March 8 1990	TM	2,3,4,5	excellent

In addition to 17 years old topographic maps at scale 1:50.000, a set of good quality CIR aerial photography taken in Aug 1991 at scale 1:30.000 were also available as reference materials. All the reference information were used qualitatively, i.e. no quantitative estimation of accuracy have been done.

3.2 Methods

Minimum distance classification was applied for all three images with iterative, supervised training (Swain, 1987). In the course of training, most of the categories needed more than one training area. Having the single-date classifications, a two stage

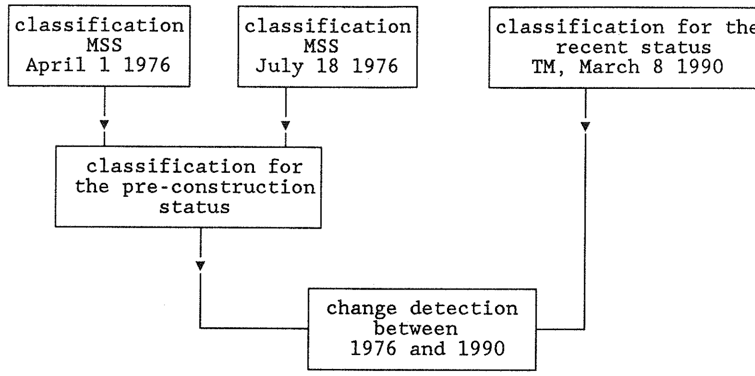

Figure 1. Flow chart of the image analysis

multidate image analysis was used to achieve the change map (Figure 1). Instead of a multitemporal classification, two class maps were compared to produce a new classification using a carefully designed cross-classification table (Singh, 1989).

Comparing class maps resulted for the spring and summer 1976, a land cover map was derived for the pre-construction period. Comparing land cover maps for 1976 and 1990 similarly, the change map was created.

All the class maps have been smoothed because of problems arising from slight misregistration and the difference between the MSS and TM resolution. A minimum area reclassification filter was used to achieve this goal (Davis and Peet, 1977).

4. DATA PROCESSING

Data processing have been done using facilities at the FÖMI Remote Sensing Centre. A MICROVAX-2 system with in-house developed software was used for geometric registration and image enhancement. The Remote Sensing Package, developed also in our laboratory (Hajós et. al, 1987, Büttner et. al, 1989) on a Numelec Pericolor workstation was used for interactive image analysis. An Optronics Colormation C-4500 was applied for filmwriting.

4.1 Geometric registration

To carry out multitemporal data processing, the images covering an 50 * 85 km area should be registered geometrically. Using the TM image as a reference, the MSS images were registered to this by means of ground control points (Dalia, 1983). Altogether 55 GCPs were digitized and about 40 were used in each case to achieve a 50 meter RMS registration accuracy. MSS images were resampled to 60 * 60 m pixel size, to facilitate easy visual comparison with TM data. Registration to map projection hasn't been done, but the boundaries of the 1:50.000 scale map-sheets in Gauss-Krüger projection were overlaid on the hardcopies produced on the filmwriter.

4.2 Classification for 1976

Spring image
The image taken at early spring shows deciduous forests leafless. Green vegetation (winter cereals and pastures) appears red on the standard color composite (MSS1=blue, MSS2=green, MSS4=red). Surfaces with no vegetation cover are shown with different shades of gray and blue. The image was classified for the following categories: water, forest, agricultural vegetation and bare surface. Some of the smaller branches of the Danube are not visible, because of the resolution of MSS. The most serious weakness of the category set is the similarity of a forest and a bare-surface sub-category.

Summer image
On the mid-summer image the same classes were defined as on the spring one. For that time cereals were ripened and partially harvested. Spring crops, like maize, sunflower and sugarbeet, but also pastures are in full green canopy. The weakness of this classification is the similarity of one of the forest and agricultural crop sub-category.

Cross-classification
Crossing the above two classification maps a new classification was created with 16 categories. Examining the spatial distribution of the new classes and applying some logical rules the cross-classification table was constructed with the following five categories: water, forest, arable land, pasture and bare surface (Table 2).

Some explanations concerning Table 2:

+ water → non-water and non-water → water transitions: small number of pixels, explained mainly by misregistration; always the non-water category was kept;
+ forest → agricultural vegetation: because of the weakness of July forest classification, arable land was decided;
+ forest → bare surface: because of the weakness of April forest classification probable spring cereals, therefore arable land was decided;
+ agricultural vegetation → forest: this is vegetation on both date; due to the weakness of July forest classification pasture was decided;
+ agricultural vegetation on both date: this is pasture;
+ agricultural vegetation → bare surface: winter crops, ie. arable land.
+ bare surface → agricultural vegetation: spring crops, ie. arable land.
+ bare surface → forest: because of the weakness of the July forest class, arable land was decided (spring crops);
+ bare surface on both date: settlements, narrow sand and gravel surfaces, and probably some non-representative crops with short vegetation period (e.g. peas).

Table 2
Cross-classification table to derive land-cover for 1976

April 1 classif.	July 18 classification water	forest	agr.veget.	bare surface
water	water	forest	arable land	bare surface
forest	forest	forest	forest	arable land
agr.veget.	arable land	pasture	pasture	arable land
bare surf.	bare surface	arable land	arable	bare surface

The resulted class map was filtered with the following minimum connected pixel number limits: two for water and five pixels for the other categories.

4.3 Classification for 1990

TM image classification was accomplished with four bands using five categories: the same classes as were used for each MSS images, supplemented with a new category, called construction site. In spite of the early spring acquisition date, forests could excellently be separated. The agricultural vegetation category in this case also represents winter crops and pastures, similarly to the April 1976 MSS image. Another data set, taken in summer would have needed to make the separation. Construction areas (earthworks, concrete surfaces), were fairly distinctive, because of their extreme brightness in all spectral bands. There were however some spectral mixing with bright alluvial soils.

We could overcome these two classification problems with confining the classification to the region of potential changes. This area was outlined on the TM color composite tracing the dikes on both sides of the river and the northern coastline of the industrial channel. Within this region there were no misclassified construction site pixels, and because of the lack of agriculture all the agricultural vegetation could be considered pasture.

To minimize problems arising from the better resolution of TM data in the comparison with MSS classification, TM data were averaged using a 2*2 window to yield 60 * 60 meter pixel size. The classification was accomplished with the reduced data set. The classification map, representing the recent situation was smoothed with similar parameters as the MSS classification.

4.4 Change detection

Comparing the 1976 and 1990 classification maps changes could be derived. In this case the cross-classification table consists of 25 entries. The table was designed to reflect only those changes which have taken place without doubt, as the consequence of the construction (Table 3).

Some explanations concerning Table 3:

+ classes of the 1976 classification changed into water (inundation) or construction got their category name as of the 1976 class assignment;
+ the bare surface pixels within the area of potential changes were mainly arable land in 1976, therefore "arable" appears in two lines of the table;
+ only transitions, inevitably explained are used to give a reliable lower bound for the estimation of changes (Table 4).

Color coded change map were produced with categories present in Table 4 using TM 5 band in black-and-white as a background.

5. CONCLUSIONS

Computer assisted multidate Landsat image analysis was used to assess environmental changes over a 14 years time span caused by the construction of the Gabcikovo-Nagymaros Hydroelectric System. Two MSS images were used to map the pre-construction status, which was compared to the actual situation derived from TM data. Image processing methodologies were successfully applied to overcome difficulties arising from the inherent differences between MSS and TM sensors. Area estimations for destroyed forest, arable lands and pastures could be considered as lower bounds for the actually existing changes. Much larger damages are anticipated if the system will be operational.

Table 3
Cross-classification table aiming at the change detection

1976 classes	1990 classes: water	forest	bare surf.	pasture	construction
water	nc	?	-	-	?
forest	76:forest	nc	?	-	76:forest
arable land	76:arable	?	-	-	76:arable
bare surf.	?	?	nc	-	76:arable
pasture	76:pasture	?	?	nc	76:pasture

Remarks:
nc: no change
- : there are no significant number of pixels in this class
? : these transitions need further evaluation

Table 4
Estimated changes in km² between 1976 and 1990

change class	Hungary	Czechoslovakia	together
forest cutting	1.62	6.50	8.12
destroyed arable land	2.03	24.57	26.60
destroyed pasture	1.03	4.19	5.22
altogether	4.68	35.26	39.94

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