REMOTE SENSING MONITORING OF ENVIRONMENTAL CHANGES IN THE DANUBE DELTA AND THE COAST AREA OF THE BLACK SEA

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ABSTRACT:

Danube Romanian Delta contains a wide variety of ecosystems and bird species, being an area of unique ecological and faunal significance. Environmental stress on the delta wetlands has increased markedly in the past 5 decades, caused mainly by man's intervention. Antropic works caused continuous and incontrollable changes, due to their rapid development and superficial knowledge, in both the Danube Delta and in its surrounding areas. The decrease of the beach areas on the Romanian touristic sea coast is one of their direct consequences. Multispectral space images used for this application are taken above the Delta, with several sensors (Landsat-2 MSS, Landsat-5 TM, Landsat-7 ETM+, Spot-2 HRV), at different dates. Usage of analogical topo-hydrological maps, extend the study period. After a multisensor digital analysis including radiometric preliminary processing, geometric rectifications, contrast enhancement of the digital images, digitisation of a series of characteristic linear elements on analogical maps, for change detection it has been applied overlapping technique which allows the geometric correlation of images from the same area, taken at different dates, with identical or different sensor types. Conclusions can be drawn: medium resolution satellite images (Landsat-TM, Landsat ETM+ and Spot-HRV) allow the geometric and radiometric qualitative prerequisites for multisensor and multitemporal environment change studies; the accuracy of change-detection is directly conditioned of preliminary processing, especially geometric rectification; some of these major environment changes are caused by anthropic actions, but also by others natural factors.

1. INTRODUCTION

Although second in Europe and the twenty-third in the world, the Danube Delta contains a wide variety of ecosystems and bird species, making an area of unique ecological and faunal significance.

The newest land of Romania and coastal area of Black Sea proximity are in the mean time areas with obvious natural geomorphologic changes. Environmental stres on delta wetlands have increased markedly in the past 3 - 4 decades, caused by man's intervention, which became more and more actively over the entire hydrographical basin of Danube, inner delta and coastal area.

Romanian and american researchers *(Pringle, Vellidis, Bandacu, Cristofor, 1993)* identified the following main causes:
- the hydrological works made in upper-river, in the nine riverine countries;
- the building of hydroelectrically dams on Danube and its large tributary streams, which radically changed sediment flow with a 50% lower of their volume;
- the hydrological works made in Danube Delta (agricultural and forest polders, dams along the river branches, close or excavation works of some new channels;

Antropic works caused continuous and incontrollable changes, due to superficial knowledge, in both Danube Delta and in its surrounding areas.

Decrease of beach areas of romanian coast is one of their direct consequences.

Morphological changes research of Danube branches and the coastal area of the Black Sea require the use of efficient evaluation methods.

Due to their specific techniques for data recording and analysis, photogrammetry and especially remote sensing are exquisite means in change detection at the level of principal morphohydrological elements and vegetation in the delta's ecosystems.

2. RESEARCH AREAS SELECTION

As study sites there has been selected Delta's representative areas for dynamic changes from the past decades. Were chosen three coastal areas:
- the area of mouth of Sf. Gheorghe branch in Black Sea;
- the area of mouth of Sulina channel in Black Sea;
- the mouth Portița area.

3. DATA SOURCES

For this study have been used space multispectral images taken over delta, as well as other complementary products:

- space images: a Landsat-2 MSS (07.24.1975) image, two Landsat-5 TM (06.24.1984 , 04.17.1993) images, a Landsat-7 ETM+ (05.13.2002) image and two Spot-2-HRV (04.17.1993, 06.11.2001) images;

- topo-hydrological maps of Danube Delta at 1:25,000 and 1:200,000 scales;
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For test areas sub images (windows) with variable size have been created from initial space images.

4. DIGITAL PROCESSING TECHNIQUES OF DATA

4.1 Sfântu Gheorghe Area

In multisensor and multitemporal analysis, in order to compare images coming from different sensors, from different dates, some problems which most be surpassed such as: different resolution of initial data, variation of incidence angle of solar radiation, variation of atmospheric characteristiques and their moisture at ground level.

There are also other factors which perturb value of pixel reflectance, such as the differences between data calibration for detectors of different sensors *(Lillesand, Kiefer, Chipman, 2003).*
Space images used for this application are taken at different dates: Landsat-TM (06.24.1984), Spot-HRV (04.17.1993) and Landsat 7 ETM+ (05.13.2002).

As a result, initial data hve to be normalized, in order to reduce variance of the reflectance values and to adapt it to specific conditions at the moment the image considered as reference image was taken.

4.1.1 Preliminary processing: *Radiometric calibration*:
Multisensor analysis requires that initial data be normalized, in order to reduce variance of the reflectance values and to adapt it to specific conditions at the moment the image considered as reference image. Due to lack of information regarding atmosphere characteristics at dates of space images and bidirectional reflectance values of objects from study areas, I used an atmospheric corrections model which takes into account calibration data of sensor and characteristics Spot-HRV image, chosen as reference image.

Radiometric calibration has been realized for every test area based on 10 invariant or quasi-invariant in time objects: **darker zones** (great lakes water and Black Sea without turbid water), or **brighter zones** (sand of coastal beaches). Landsat- TM and ETM+ images normalization has been done, for every channel, using a nonlinear regression equation:
y (i) = **a** x **x**(i) + **b**, where: **y**(i)-is radiometric value of pixel from reference image; **x**(i)-is correspondent radiometric value of pixel from corrected image. After the normalization process, have been computed the calibration coefficients (**a**) and (**b**) and correlation coefficients (**r**). Landsat TM image had to be further processed using *Destripe TM Data* module from *ERDAS IMAGINE 8.6* in order to correct the "Striping" effect.

Resampling of initial data: for comparing multispectral multisensor data it was necessary to bring the image resolution coming from TM and ETM+ sensors to spatial resolution of image coming from HRV sensor, chosen as reference image. Rectification of an image requires accurate and homogenously distributed ground control points. These are obtained by aerotriangulation, performed on two sets of aerial photos 1:20,000 scaled, acquired in 1990. Their planimetric coordinates have been used to perform resampling process of multispectral images using the nearest neighbour method.

Because of different resolution of the sensors, TM and ETM+ image have been resampled using a factor of 1,5x1,5 *(Barbalata, Noaje, Ionescu, 1997).*

For resampling, have been selected a number of 15 reper points for each image, representing invariant details. Their planimetric coordinates have been used for geometric transformation functions computation for Landsat-TM and Landsat-ETM+ images (using tree-degree polynomials) in order to their overlap on Spot-HRV image dated 04.17.1993.

Because obtained coordinates after transformation were not exactly matched at pixel level, was used a cubic convolution. The resample function included 16 pixels surrounding the processed one, allowing local modeling of image by a polynomial surface. In the final phase, obtained spectral plans perfectly overlapped with the reference image at pixel level.

Transformation accuracy varies according to resampled images. The root-mean-square error corresponding to rectified channels is ±0,827 pixel for Landsat - TM image, ±0,641 pixel for Landsat - ETM+ image and ±0,282 pixel for Spot-HRV image. For resampling was used the module *Resample* of *Idrisi Andes GIS software.*

4.1.2 Color composite images generation: Due to the specificity of available satellite data, coming from different sensors, with different resolutions and number of spectral channels, the application of some complex digital processing strategies was mandatory *(Jensen 1996, Lillesand, Kiefer, Chipman, 2003).*

Multispectral images allow different color combinations, which highlight studied objects. Examining channels histograms for chosen Landsat - TM images (2, 3 and 4) can be seen pixels concentration around 23-90 values for the first one, between 16-110 for the second one, and respectively between 10-204 for the third one. Similarly, Landsat-ETM+ channels (2, 3 and 4) concentrates around 33-103, 12-140, respectively 40-220.
The histograms of Spot-HRV channels cover a small part of sensor range register: XS1 channel has values ranging between 10-125, XS2 channel has values ranging between 25-144 and XS3 has values ranging between 0-187. This limitation of brightness values leads to a low contrast ratio for the original images.

Using the above three channels, three color composite images have been realized, for each sensor, for study area Sfântu Gheorghe. Digital processing has been realized with *Idrisi Andes GIS software*.

4.1.3 Contrast enhancement techniques: For improving the spectral dynamic of images have used three of the most known methods of contrast enhancement for the digital images:
- *the linear contrast enhancement with point saturation:* are used low values of enhancement (2.5-3.5%) with purpose of optimal use of grey level scale of each channel;
- *the nonlinear contrast enhancement:* offered better results by enhancing the contrast for the densest domain of reflectance values from the original image;
- *Intensity Hue Saturation transformations:* IHS version is remarkable for larger color domain and the improvement in color separation.

Experience in image processing field allows choosing the most adequate method for contrast enhancement *((Ionescu, Noaje, 2000, Noaje, 2003).*

Edge enhancement: some of these appear as thin lines on contrastive background (Sf. Gheorghe branch, channels, dams, shore line). Other are represented by the linear contact between neighborhood areas with different brightness. In most of the cases, edges are marked by small differences in brightness, being more difficult to be detected. For image edge enhancement the Laplacian unidirectional and directional filters have been used (having 3 x 3 pixels kernel format) *(Tso, Mather, 2001).*
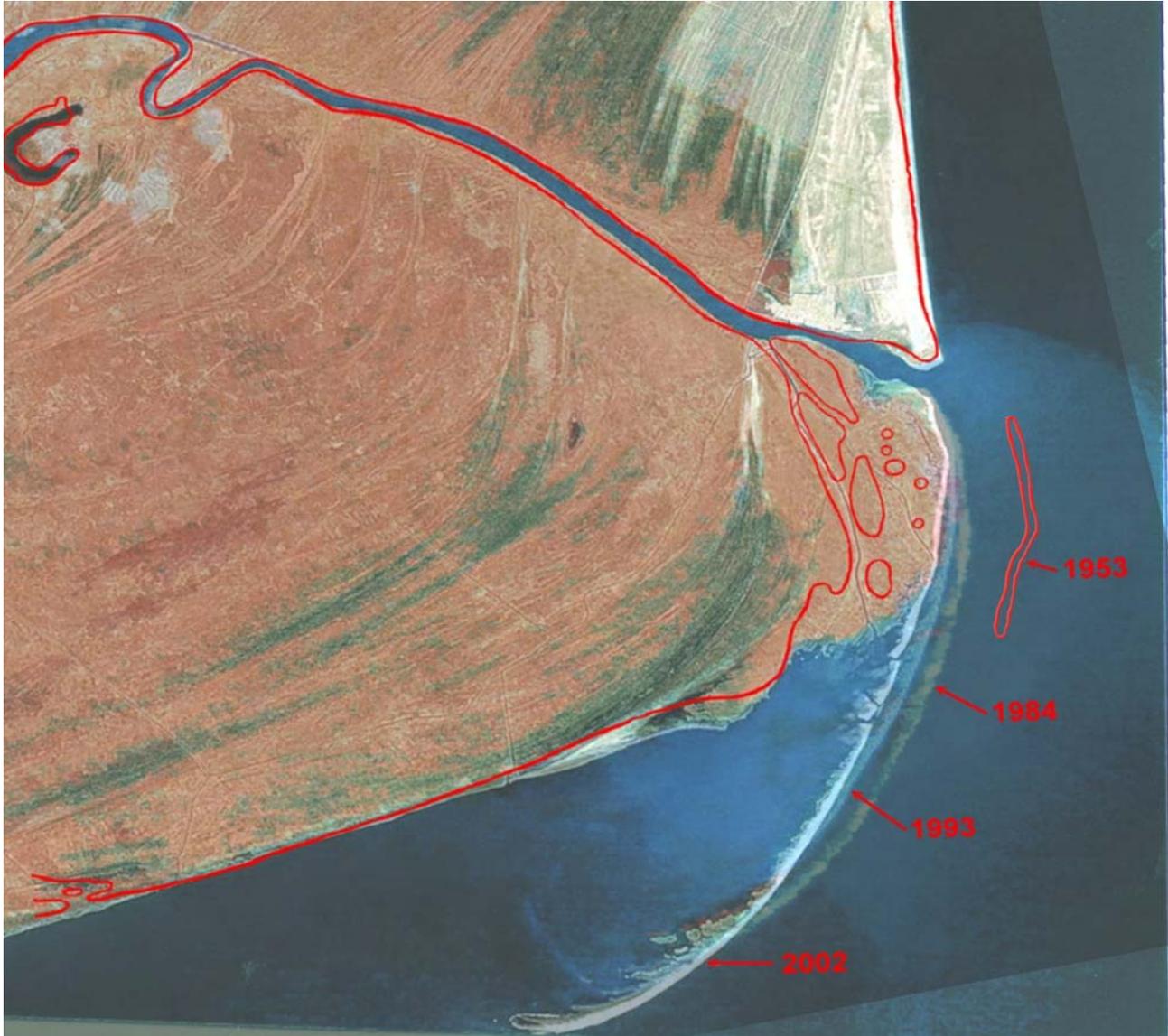

Figure 1. Changes monitoring in Sfântu Gheorghe area during 1953 – 2002

For image refinement modal and median filters have been used. These filtrations allow the accuracy improvment for changes detection *(Jensen and all, 1995).*

4.1.4 Images overlapping: Overlapping is a technique for geometric correlation of same area images, taken at different dates, with same or different sensors types.

This technique facilitated by the format and digital processing of initial data, allows to achieve accurate geometric correspondence between space and aerial images. Furthermore, the overlapping technique allows the usage of analogical cartographic products (maps and plans), extending the study period for a certain area long before the first remote sensing image was taken. For extending study period has used a topo-hydrological map at 1:200.000 scale dated 1953. In this way, the study period allowed by satellite images (18 years) was extended at 49 years. The map was scanned at 600 dpi resolution and converted into digital format, followed by the vectorization of a series of characteristic linear elements (shore-line, Sf. Gheorghe branch banks, islands in the area).
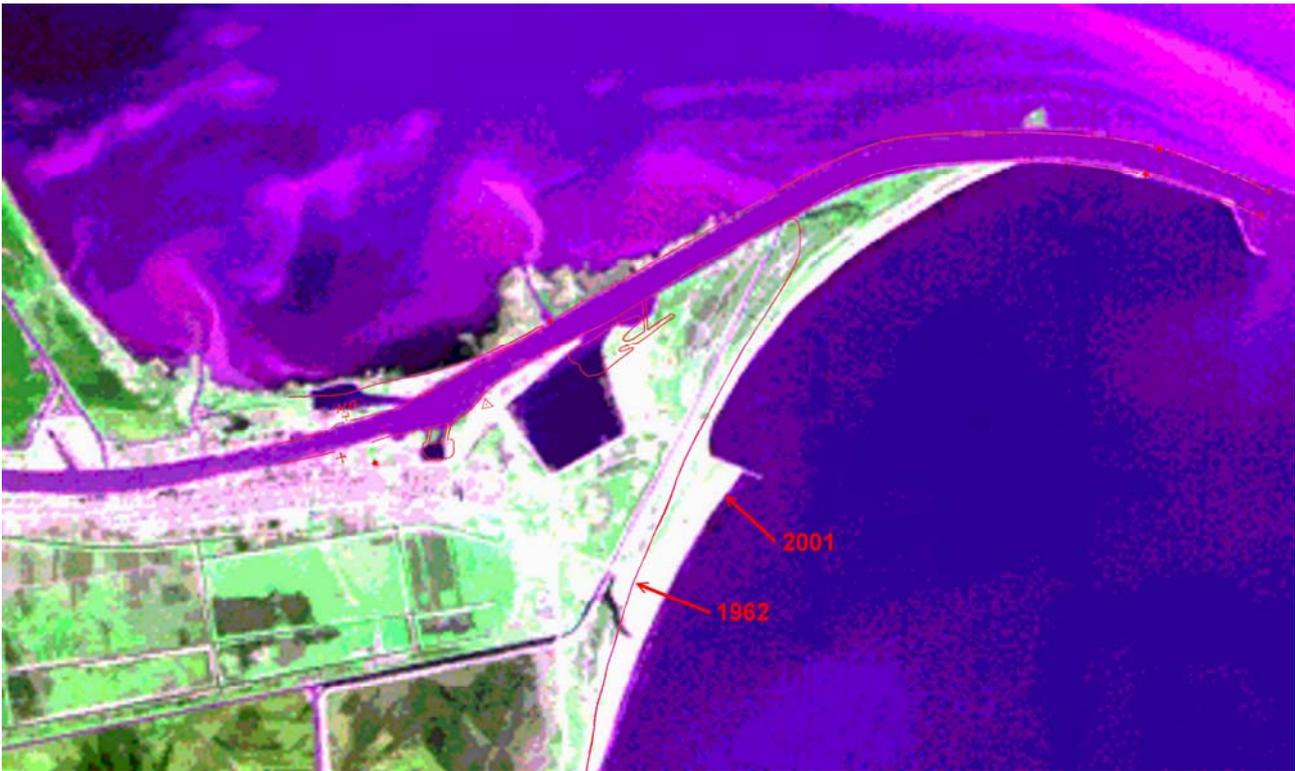
Figure 2. Changes monitoring in Sulina area during 1962 - 2001

These three color composite satellite images and vectorized details from map have been overlapped, using 12 invariable in time details (channels crossing, lakes, Sf. Gheorghe branch banks).

Images have been subject of radiometric correlation process, with *PhotoImpact 11* software, ensuring a reasonable brightness and contrast balance for each image, allowing their simultaneous display (Fig. 1).

4.2 Sulina area

For highlighting changes in the area of mouth of Sulina channel in Black Sea, has used a classic (analogic) product, a topo-hydrological map (L-35-108-C-b map) at 1:25.000 scale dated 1962 and a window of Spot-2 HRV dated 06.11.2001.
In this way the geomorphologic changes which occurred in a 39 year period have been analyzed.

The map has been scanned at 600 dpi resolution and converted in digital format. Then a series of characteristic linear and dot elements have been vectorized such as: Sulina branch banks, Black Sea shore-line in the east of Sulina city and a few ground control points (6 light towers on dams or banks channel and one church from Sulina city), with the purpose of satellite image overlap.

A 3750 × 2246 pixels window centered over the study area has been cropped from Spot-HRV image dated 06.11.2001.
Some of digital processings of the images used for SF. Gheorghe area have been applied to Spot-HRV image (geometric corrections, contrast enhancements, edge enhancement, color composite image realisation).

Multispectral images allow different color combinations, which highlight the studied objects. A principal component analysis of images allowed computing first and second principal component for each image. In order to generate color composite images a Normalized Difference Vegetation Index (NDVI) was further added using *ERDAS IMAGINE 8.6* and *Idrisi Andes* software.

Finally satellite images and vectorized details from map have been overlapped allowing their simultaneous display (Fig. 2).

4.3 Gura Portița area

This area has also a high dynamic of changes. Gura Portița dam and offshore bar configuration north and south of its mouth offers topographic details which can be found on satellite images taken at different dates.

For this area have been used Landsat-MSS and TM satellite channels, taken in near infrared, spectral range in which water reflectance is null (black color). The great difference between vegetation or soils and water reflectance in this electromagnetic spectrum domain allows facile shore-line outlining, being another method for highlighting changes. A window from Landsat 2-MSS 7 channel dated 07.24.1975 and a window from Landsat-5 TM 5 channel dated 04.17.1993 have been used.

The shore-line has been vectorized on the two sub images, followed by simultaneous display, with geomorphologic changes occurred during the 18 years being highlighted (Fig. 3).
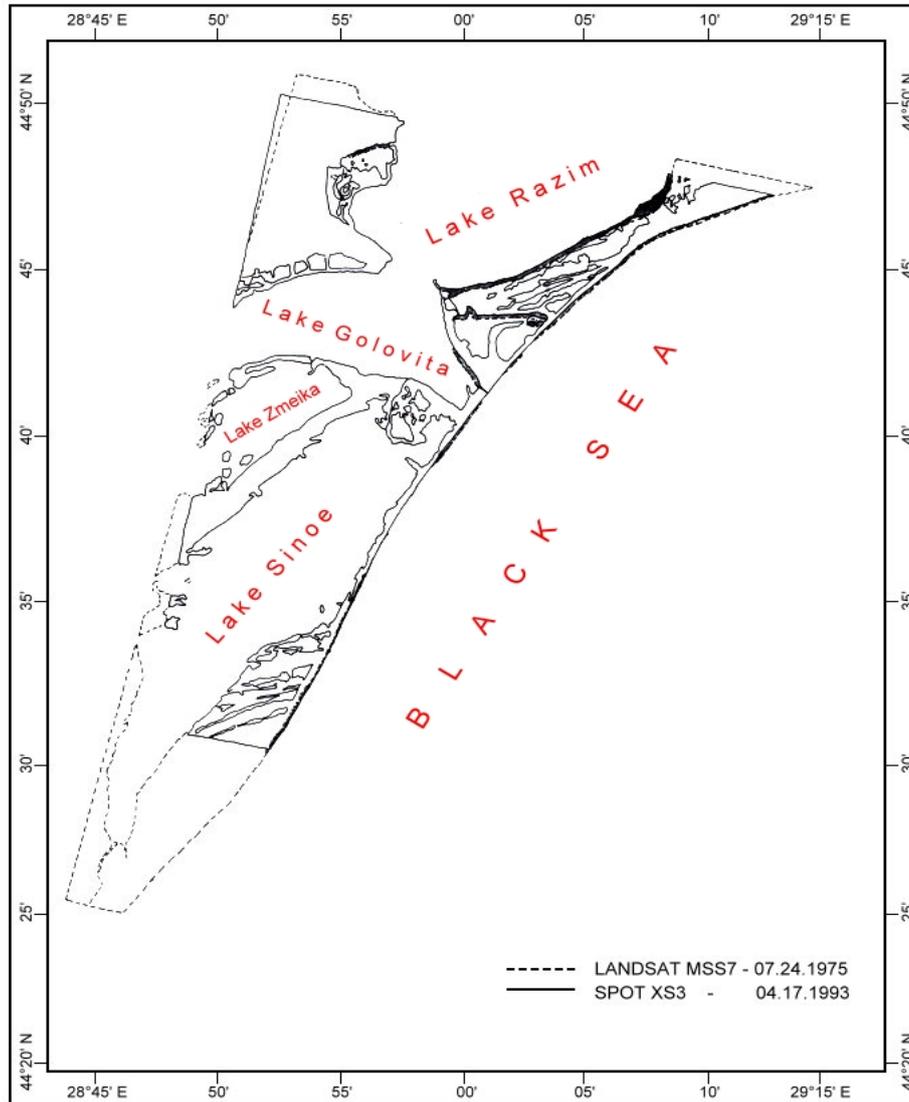
Figure 3. Changes monitoring in Gura Portita area during 1975 – 1993

5. CHANGES ANALYSIS IN RESEARCH AREAS

5.1 Sfântu Gheorghe area

In Fig.1 can be seen sediment flow status changes during the 49 years, with shore-line corresponding change as well as Sacalin island shape and position.

In 1953 Sf. Gheorghe branch was building at its mouth in Black Sea a small estuary, the branch waters being devided into more sub-branches by the nine islands in the area (on one of them there is Sf. Gheorghe light tower). At about 2 km away from these islands, in the open Black Sea, there was Sacalin island with approximately 4 km in length.

Until 1975, estuary is warping, the land enclosing the nine islands, at this contributing both the sediment flow brought by river in sea and north-south stream near Black Sea coast. In this way Sf. Gheoghe light tower is on land now and from the three sub branches there are only two left: the northern (actual Sf. Gheorghe branch) and the southern, was reduced at channel width.

As for Sacalin island the following remarks can be done:

- The island surface has enlarged and it grown toward south, reaching approximatively 16 km;
- The island has moved toward west, reaching the land in northern side, and becoming a peninsula;
- The island arch shape is becoming straighter as the time goes by;
- Sediment flow highlighted in the area between the island and the shore-line points out a colmatage of this marine area, having as a result the link of the peninsula with the shore-line in the future.

5.2 Sulina area

By studying Fig. 2 major geomorphologic changes which occurred during the 39 years can be seen.

Some of these, such as the build of three new port basins and buildings on the left bank of Sulina channel, shape dams mouth Sulina channel modification caused by antropic actions.

Others, such as channel banks and especially Black Sea shoreline in the east part of Sulina city modification are caused by natural factors: storm tides which eroded the channel banks, as well as massive deposits of sediments caused by the north-south stream from Black Sea (approximately 300 m wide), which is favorized by the step forward of channel dams in sea.

5.3 Gura Portița area

In Fig.3 can be seen status changes during the 18 years. Through this breach, fresh water from the Sf. Gheorghe branch arrive in the Razim, Golovița, Zmeica, Sinoie lagoonal complex flows into the Black Sea. The discharge is between 30 and 120 m^3/s.
Changes highlighted with black are caused by fresh water flow as well as by the north-south Black Sea stream action.

6. CONCLUSIONS

Finally, the following conclusions can be drawn:

- In multisensor and multitemporal data analysis, a special attention must be paid to preliminary processing, data comparison being highly influenced by different characteristic of captors and specific season atmospheric conditions at the time the images were taken;

- Medium resolution satellite images (Landsat-TM, Landsat ETM+ and Spot-HRV) allow the geometric and radiometric qualitative prerequisites for multisensor and multitemporal geomorphologic changes studies. For detailed studies for small area, can be used higher resolution images, but for wider areas, results improvement don't justify the high prices and the inconvenience of considerable volumes of data processing;

- Another major inconvenient, no matter what resolution is used, is the very high price of satellite data; this fact narrows the options in choosing the initial data;

- As a best practice, analysis must be done repetitive, for the special areas, with precise changes evaluation which occur in the process steps, with the emphasize of these changes causes, as well as their evolution in the near future. A mandatory condition for rigorous analysis is the purchase of at least medium resolution satellite images.

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