Change Detection in Romanian Coastal Zone of the Black Sea

Zăvoianu Florea[a, *], Alexandra Caramizoiu[b]

[a] Faculty of Geodesy, Technical University of Civil Engineering Bucharest, ROMANIA, fzavoian@pcnet.pcnet.ro
[b]Institute of Optoelectronics S.A. Bucharest Romania, alex@ioel.nipne.ro

Abstract: An important aspect in coastal zone management is modeling of the process in coastal zones platforms. In this work we use the SPOT HRV, Landsat TM and SAR image data over the coastal zone of Black Sea. The pre processing and processing of the image data are made with ERDAS 8.7, ARC/INFO and ARC/VIEW systems. To obtain a robust change detection, environmental factors and variables were taken into consideration, such as atmospheric conditions, soil characteristics, vegetation cycles, hydrologic cycles and others. The mean of reducing feature space dimensionality of data uses the Principal Components Analysis to replace the feature set with a derived feature set. We present the influence of accuracy and classification performance based on the confusion matrix, kappa coefficient, the factors that are influencing the accuracy assessment with test data and cross-validation methods, in the Romanian coastal zone from Mangalia to Sulina.

KEY WORDS: Database, change detection, SIG, coastal zone.

1. INTRODUCTION

The environmental policies at the international level are related to such issues as pollution, natural resource management, sustainable development and global climate change. The role of remote sensing data in this context is to define and support information systems for environmental purposes, with the aim to detect air and water pollution, soil degradation, vegetation and environmental change.

The main technique used for land cover detection is the merging of two images from different dates; the resulted overlay indicates the areas that appear to be changed and the nature of change also. In such an analysis the results are dependent of the accuracy of the two images used.

Techniques developed for accuracy assessment must take into consideration the factors that are sources of error in image and the methods used for assessing accuracy in a single image and for a pair of images. Serious erosion processes affect the coast areas. The coast erosion is a natural phenomenon by which the coast line advances into the shore, under the continuous influence of the natural factors. These processes have a variable evolution speed in time and space and form a threat for the human establishments from the coastal areas, and also for the ecosystem. There were theories that stated that the global warming makes the global erosion process to accelerate (Bird, 1985). These theories are supported by the studies over the increase in the retreat speed of the shoreline in different zones in the world. Remote sensing can contribute substantially to the following supervising of the changes and to the monitoring of the important changes in the shore line, through it's excellent capacity to obtain precise and economical in real time information over these phenomena and processes. The following of these kinds of phenomena can be done only with a database of an information geographical system (SIG), which should contain special data (satellite and aerial imagery, maps etc) and also geographical, geological, socio-economical information.

1.1 General characterizations of the Romanian Black Sea shore

Romania is placed in the Northwest side of the Black Sea, with a 243km appearing of the shore. The general orientation of the shore is to the North-South, the northern limit being formed by the Chilia channel (45°12' north and 29°40'east), which makes the shared border with Ukraina and the southern limit with Bulgaria being formed by a conventional line, which passes south of Vama Veche (43°44' north and 28°35'). The open sea limit of the territorial waters is considered to be at a 12-mile distance to the shore line. Genetically and especially morphologically the Romanian Sea shore presents a variety of aspects. Northern sector is an accumulative shore, formed mainly by littoral lines, sandy and in submersibile. Southern sector the shore line is obvious being formed by a high cliff, which is interrupted by parts, which are cut off the sea also by sand areas. To the modification of the actual morphological aspects of the two existing sectors contributes in proportions and combinations, factors of different origins, such as litology, the fluvio-marine accumulations, waves, currents, level fluctuations, seismical activity, winds, precipitations fauna and flora and also human activities.

The northern sector takes 68% from the Romanian shore lying in the eastern extremity of the Danube Delta, between Gura Musura from the secondary delta, Chilia and Capul Midia. The existence of positive eustatism of the Black Sea (0.5cm/year) gave birth to a slight Sea transgression shown by swamps in the river marine movment resulted from the sediments of the delta deposits. At the moment, in the cordon Sulina shore sector there is precise demarcation line because the pre existing sandy aria is submerse under water (-0,80m). The line of the reed shirt is considered to be the shore line. In the area of the Sulina channel behind the dams, the shore had a rapid forward movement, looking overlay like a spur adjacency into the sea. Between Sulina and Sf. Gheorghe there is a sandy belt area almost as a straight line, with a tendency to move towards west. South in the mouth of the Sf. Gheorghe channel is developing the island Sahalin (it appears for the first time on the 1830 and 1857 maps, made by the representatives of the Delta Commission). In the last 40 years it stretched to the south and moved to the west, almost closing the Zatoane - Ciotic zone, transforming it into a lagoon. From Ciotic to Chituc there is a sandy belt area positioned between the sea and the lagoon complex Razelm-Sinoe, pierced by the Portita mouth through which the strong storms often produce ruptures in the littoral belt south to Portita. The littoral belts which border the Danube delta and the Ravel lagoon to the east are formed from instable dunes, with heights varying between 0.20m and 1.50m. These sands are often moved either by the sea waves which cross the belts during storms, or by the strong winds which blow in these parts. Generally the littoral belts have variable widths and are in a continuous change, which show clearly the tendency to move to the west. The southern sector contains 32% from the Romanian shore length and has the structural characteristics of a high cliff. This sector stretches south of Capful Media to the border with Bulgaria, the land configuration being determined by the morphology litology and structure of the deposits which form the Dobrogea Plateau. The shore in this sector has a great stability and undergoes a continuous but slow process of retreat because of the erosion combined with the action of atmospherical and biological factors and also of underground waters which are generating land slides with the aspect of false terraces. The actions used to diminish the erosion and slide processes are to build dams to consolidate the cliffs. Today the zone is caracterized by a diminishing process of the beaches. The aspect of the shore in between Constanta and Vama Veche is given by the complex geological structure. The erosion action of the waves and marine currents determined the apparition of golfs, which better were separated from the sea by littoral belts.

1. 2. Accuracy assessment aspects for change detection

Accuracy is considered to be the degree of closeness of results to the values accepted as true. Some of the accuracy assessment methods are: the variance analysis, minimum accuracy value used as an index of classification accuracy, spatial error and class attribute errors, A probabilistic approach for change detection and land cover classes are abstraction and generalizations of the real world in order to provide discrete values for continues. To obtain a robust change detection, some environmental factors and variables must be taken into consideration, such as atmospheric conditions, soil characteristics, vegetation cycles, hydrologic cycles and others. Most of the environmental features are extremely dynamic; in most of the cases the temporal and geometric resolution of remote sensed data cannot cover the dynamic domain of the environmental parameters evolution. Meteorological aspects and the hydrologic regime of the area along with the agricultural work schedule are important aspects. These aspects are predictable if we have appropriate geomorphologic analysis land cover and soil qualities are assessed for the zone in study. The littoral belts from the south sector are not continuous and are made from fine and medium sands. The retreat of the cliff shore is caused by the marine erosion, which is; - very active in the Aggie,

2. BASIC DATA UTILIZED

The Romanian side of the Sea shore goes over 32 maps at the 1:25 000 scale, designed between 1958 and 1964. These maps were utilized to create the reference situation in our studies. The satellite images that were used for the study are HRV (p) from 23.05.1997 images 98/262 and 98/258. For the interest zone were used two TM images, images 181/029 from 23.06.1997 and the images 181/128 from 23.06.1997. There were also used images SAR from 31 may 1998 orbit 16272/frame 0909 and 09 August, orbit 17274/frame 1891. There were also used aerial photo grams from July 1983, 1984, 1986 and 2002 at the scale 1:6000, other cartographic documents, field determinations, meteorological observations regarding the direction, the size and speed of the waves, ground studies, surface waters, their hydrological regime and vegetation elements, the distribution of human establishments and the traffic infrastructure transportation network, GPS field measurements which were introduced into the data base into separate levels for better analysis.

In order to register the satellite images the digital elevation model of the field was designed, for a band of 50km from the littoral belt. The studies were made within a project having as partners UTCB, IOEL 2001 and CRUTA Bucharest. The morphological modifications of the coastline were evidentiated by the registration of the satellite images over the reference vectorial database.

For the digitization, correction of the vector layers, database formation, coordinates transformation in the Gauss-Kruger projection system the ARC Macro Language (AML) program for loading the database, the automatic vectorisation of the topographical maps generates the derivative thematical vectorial maps, the ARC/INFO and ARC/VIEW software were used. The information maps of the database refer to: human settlements, waters, lakes, roads, land, woods, the coastal line etc. The data collected by map vectorisation are rounded by field measurements of the whole littoral ecosystem, periodically collected, and also by the satellite images which complete the complex analysis of the littoral environment. The ERDAS 8.7 software version installed on a PC station was used to correct the satellites images to generate the "lan grid and GIS" forms to work on them in ARC/INFO mosaics and cutting images HRV-SPOT and TM-Landsat. The preliminary analysis and the interpretation of the image data had the steps:

-geometric and radiometric image processing; and reference images registration, - quantitative analysis, classification and data generalisation, - data conversion, raster to vector and vector to raster, -error analysis of final products.

3. INTERPRETATION OF THE RESULTS

The preliminary analysis of remote sensing data can do little about timely temporal elements, but a judicious discerning radio metrical and geometrical analysis can improve the interpretative proprieties of spectral and spatial data. The geometrical analysis besides correcting the distortions connected to the incoming of the image also contained bringing into the system of the reference a map in Gauss projection, having as reference the Krasovski ellipsoid.

Considered to be a pre-analysis step, the rectification of the satellite images has as a purpose target the geometrical transformation of the images. Usually, this step means: finding the support and control points the calculation of the transformation parameters, the creation of the transformed image in the reference system imposed by one of the known resampling methods. The data administration within a SIG supposes: logical and physical independence, base access to recorded data, with the help of fast algorithms.

3.1. The characterization of the Romanian costal zone

The Romanian coast zone can be divided from the geomorphological point of view, in two main units: the northern unit and the southern unit. In the northern zone prevails the low relief, characteristic to the Danube Delta, with narrow blokes. Transported by the strong currents of that zone, the sands built a barrier in the Sf. Gheorghe zone. These barriers closed the Ravel Lake. The sediments form the modern times are made mainly from quartz sand (70% silicon). Heavy metals do not go over 3%. The transport of sediments that come from the regions north to the Danube Delta have higher silicon content, of almost (90%). The evolution of the delta zone started during the quarternary and was strongly influenced by the modifications into the sea level of that time. The Delta was formed during the period of the sea levels retreat through the alternate developing of the river Danube, each developing it's own deltaic structure. Presently there are three Danube branches active and only Chilia is still developing it's own deltaic structure. The other coast sectors are retracting, being influenced by the decrease in the Danube sediments over the last century. The long term studies shown a decrease of the Black Sea level of almost 2.5mm/year in the Vama Veche region, while other measurements evidentiated rising of the sea level of 1.2 to 1.8 mm/year at Sulina and almost 3.3mm/year at Constanta. The ground in the delta zone is going down with 1.3-2mm/year because of the sediments phenomenon and the zone's tectonics. The tide phenomenon in the Romanian coast is not easily detected because of other fluctuations. The other fluctuations of the Black Sea level are caused by the dynamics in the river's debits that go into the Sea. One of the most important factors that influence the hydrological budget of the Black Sea is the volume of water, which goes through the rivers that form the hydrological pool of the Black Sea. The Danube River has the highest volume during the time between April and June. Another important factor is the winds and waves regime. The average wind speed in the NV region of the BS is between 6.5 and 5m/s. The main directions of the wind are N, V and S a greater weight having the N-V direction. During the summer months the predominant direction is S-SE. The storms have a predominant N direction, with an average wind speed of 9.8m/s, during a period of time of 8 to 22 hours. There is a 50% probability that over one year to have waves higher than 0.2m. The direction in which the waves move is NE-SE. Very close to the shore, the waves regime is controlled by the beach inclination and the largeness of the plankton, which become trimmer close to Sf. Gheorghe channel', mouth and becomes wider to the south direction. The strongest waves activity is expected to be around the Sahalin Island, because of the abrupt edge. The coast dynamic is characterized by the retreat over the entire zone south to Salina, the most important withdrawal being in the Sulina/Sf.Gheorghe sector of almost 20m/year, close to the Rosulet lake, and is caused by a permanent coast current oriented to the south. The retreat of the coast line with almost 10m/year is more obvious along the Sakhalin barrier and south to Ciotca, and also between Portita and Chitiuc. Then the coast line advances immediately south of Sulina where it is accompanied by the presence of some very shallow waters.

4. SOURCES OF ERROR IN CHANGE DETECTION

A first approach to classify errors in environmental change analysis with remote sensed data is dividing the sources of error in instrumental errors and method errors. A more detailed description of errors can include the data acquisition errors, data processing, data analysis and data conversion errors. In the process of error assessment, several errors can occur: positional errors, registration, differences, data entry error for reference data, interpretation and delineation of reference data, reference data and remote sensed data are not simultaneously collected, classification errors. The results are affected by different errors, at different levels and the positional and the thematic information obtained from the two data sets is not of the same precision. From the merging of the two data sets will result an unknown precision of the final product.

4.1 Positioning error

The resulted thematic classification assigned to each identified class a spatial location on the image. During this process a generalization operation is performed. The class boundaries are also affected by misclassification of the marginal pixels. Horizontal accuracy for map products at scales greater than 1:20 000 must be less than 10% of tested points to have a greater error of 0.85cm, measured at the map's scale. For maps at scales 1:20 000 or smaller, the admissible error is 0.51 mm. The horizontal components are defining standard position error in which are contained 90% of point coordinate discrepancies. Another accuracy criterion is the map standard deviation. Standard deviation for tested points must not have a value over the value calculated:

$$d = \sum_{i=1}^{n} \left[\frac{l_i}{n} \right]^{0,5} \quad (1)$$

where: d = standard deviation
l_i = point error
n = number of points

If we assume that two points taken into consideration are independent and their specific accuracy is different, the relative position error can be calculated from the square sum of the two values for the positional accuracy:

4.2 Classification data error

Another source of error is the thematic classification of data. A method to empirically assess the classification accuracy is to select several classes and to compare them with the reference data. Reference data is usually named "ground truth". By comparing the data sets, the percentage of the pixels correctly classified can be estimated. From every class representative pixels are selected and compared to the reference data. A statistical approach of this problem is to select random pixels from the thematic map and to compare them to the reference data. Here, the main impediment is that large classes have the tendency to be represented by a larger number of points and the small classes may be not represented at all. The solution to this problem could be the stratified random sampling, in this case, a set of strata are predefined and the random sampling is carried out in each of these collections. A regular grid can be used or a random selection of pixels in each class, in order to assess the class accuracy. A confusion matrix will result. (Van Genderen, 1982) and (Rosenfield ,1978) have, along with others, determined guidelines for the minimum sample size. The remote sensing characteristics that affect the change assessment accuracy are: temporal, spectral, spatial resolution and look angle. If data used to detect changes are from the sensors with the same IFOV, it is easy to register the two data sets. Geometric rectification algorithms can be used to register the images to a standard map projection.
To obtain robust change detection, some environmental factors and variables must be taken into consideration, such as atmospheric conditions, soil characteristics, vegetation cycles, hydrologic cycles and others. Most of the environmental features are extremely dynamic, and the temporal resolution of remote sensed data cannot cover the dynamic domain of the environmental parameters evolution. Meteorological aspects and the hydrologic regime of the area along with the agricultural work schedule are important aspects when change detection analysis is performed. Depending of the meteorological conditions, the river network of the studied area can suffer changes and thus affect the soil humidity conditions. These aspects are predictible if we have appropriate geomorphologic analysis is and soil quality is assessed for the zone in study.

5. CHANGE DETECTION

In order to obtain environmental changes information, once we selected the appropriate data and classification scheme, special radiometric and geometric corrections must be applied, followed by change detection and classification techniques, creation of thematic products and finally the error assessment. Image normalization reduces the pixel brightness variations. Using simple regression equations between the brightness values of radiometric normalization targets in the base scene and the scene to be normalized can perform image normalization. Ground targets that are spectrally invariant in the two images can be used to normalize multitemporal data sets to a single reference scene. The acceptance criteria for radiometric normalization are (Eckhardt, 1990):

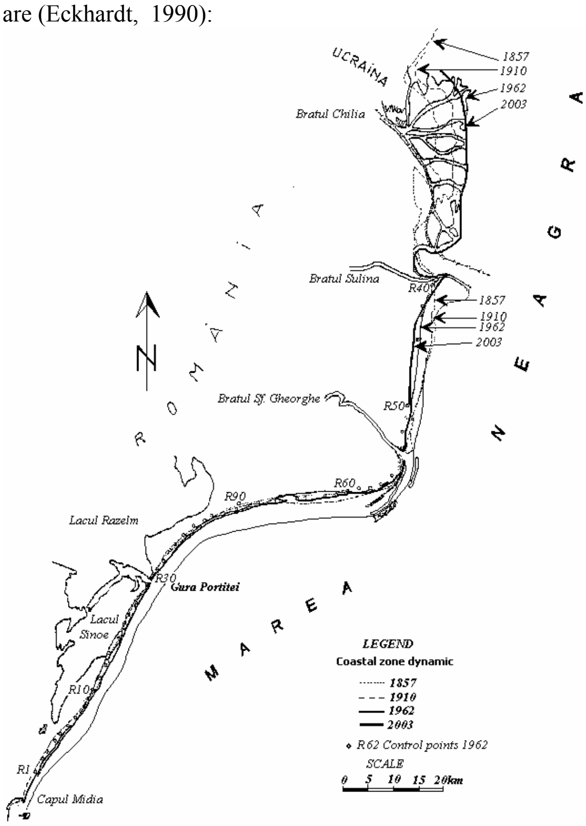

Figure 1. The dynamics of the littoral corridor between year 1857 and 2003.

A good way to perform geocoding is to measure ground control point in the field with GPS and use this data set to calculate the correct rectification. The ground control points are permanent, static features in the field and easily identifiable on the image. The most used algorithms for change detection are (Jensen):

- Change Detection Using Write Function Memory Insertion. This is an analog method for qualitatively assessing the changes in a region and do not provide quantitative information of the changes occurred.
- Multi Date Composite Image Change Detection. Multiple data sets are inregistred to a single database. This composite data set can be used to extract information by unsupervised classification techniques with a result of a class with change and a class with no change.
- Image Algebra Change Detection (Band Rationing and Band Differencing). Subtracting an image from the other one performs image differencing. The result is formed by positive and negative values in areas of radiance change:

$$D_{ijk} = BV_{ijk}(1) - BV_{ijk}(2) + C \quad (2)$$

where: D_{ijk}= change value pixel, $BV_{ijk}(1)$= brightens value at time 1, $BV_{ijk}(2)$= brightens value at time 2, C= constant used to transform the negative or positive results in positive results, i= line number, j=column number, k= band number. The essential aspect of this process is the threshold selection of boundaries between change/no changes zones.

5.1. Spectral Change Vector Analysis

Areas with changes have a different spectral response. The vector describing the direction and the amplitude of the change from image 1 to image 2 is the spectral change vector. The total change/pixel *(CM_{pixel})* in n-dimension spectral space is:

$$CM_{pixel} = \sum_{k=1}^{n} \left[BV_{ijk(date2)} - BV_{ijk(date1)} \right]^2 \quad (3)$$

where: $BV_{ijk(date2),\ ijk(date1)}$ = pixel values for date 1 and date 2 in band k.

5.2. Change detection error matrix

In order to assess the accuracy of the change detection procedures is recommended to generate an error matrix. The columns of an error matrix contain the reference data and the rows represent the results of the remote sensed classified data. The error matrix is a multidimensional table it's cells contain change data from a category to another. The statistical approach of the accuracy assessment consists of different multivariate stastitical analysis. A used measure is KAPPA (Cohen , 1960).

6. CONCLUSIONS

Change detection is an important tool for environmental studies, assessing the accuracy of change detection products is an important step for the integration of remote sensed data to environmental management system as a decision support tool. In assessing environmental changes based on remote sensed data, the major impediment is that the estimate values are difficult to compute due to the complexity of the processes involved and more often the reference data is not available for computing accuracy. A specific attention must be given to different methodologies to detect changes and error matrix construction, as a function of change susceptibility of the studied area.

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