Automated Change Detection from Remote Sensing Data A Case Study at the Pali Cape - Erzeni River Mouth Coastal Sector

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Abstract

Satellite imagery recorded by the multispectral scanner Landsat in the summer of 1992 and 2002 were used to detect changes that have occurred during this period, along the Pali Cape – Erzeni River mouth coastal sector in Albania. The bi-temporal remotely sensed data were analysed with the Multivariate Alteration Detection (MAD) algorithm. The results show that during this time interval a land surface of approximately 36 ha has been eroded from the Erzeni River delta, a land surface of about 33 ha has been created south of the Erzeni River mouth, and in this coastal sector, there has increased the wetland surface. It is indicated also an erosive situation in the Lalzi Bay and in the southwestern part of Pali Cape, although for a more detailed assessment, further field investigations and the use of multi-temporal high spatial resolution satellite or aerial imagery is required. The study demonstrates the applicability of bi-temporal Landsat data to detect changes in the coastal environment.

Key words: *Landsat images, Erzeni river mouth, change detection*

Introduction

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Timely and accurate change detection of Earth's surface features provides the foundation for better understanding relationships and interactions between human and natural phenomena to better manage and use resources (Lu et al. 2004). In general, change detection involves the application of multi-temporal datasets to quantitatively analyse the temporal effects of the phenomenon (Lu et al. 2004).

Continental and oceanic processes converge along the coast to create landscapes typical of rapid change (Keller, 1996). The monitoring of the processes that occur along the coastline is important and open for research. The low Adriatic Coast of Albania (about 230 km from the Buna River mouth to Vlora) is distinguished for its strong dynamics expressed by the large accumulation and seaward advancement of the coastline in several sectors and by the strong and rapid erosion and advancement of the sea in the mainland in several other sectors (Kabo, 1990). These opposite processes lead to large and rapid changes of the coastline configuration.

Satellite remote sensing data are an important and widely available source of information for change detection studies along the Albanian coast (e.g. Bedini, 2007). This study investigated through Landsat images recorded in the summer of 1992 and 2002 the changes that have occurred during this ten-year interval in the coastal sector from Pali Cape to Erzeni River mouth in Albania. Despite the short time interval, the presence of a very dynamic coastline in this sector has led to significant changes. The processing of the bi-temporal remotely sensed data was done using the Multivariate Alteration Detection (MAD) algorithm developed in (Nielsen et al. 1998; Canty and Nielsen, 2006).

Study area

The Pali Cape – Erzeni River mouth coastal sector has a length of more than 10 km and is part of the Lalzi Bay in the northwestern part of the Adriatic Lowland of Albania (Fig. 1). The geology of the region consists of molasse formations and quaternary deposits. In the Pali Cape crop out molasse formations of Messinian age (N_1^{3m}) that consist of sandstones, clays, silts and lenses of sands and gypsum; these are transgressively covered by molasse formations of Pliocene (N_2) that consist of sands, conglomerates, clays and silts. Several syncline and anticline lines strike through this sector: Peza-Shijaku syncline, Kavaja-Shkoza anticline, Kryemedhenjve-Spitalla syncline and Durresi anticline. The quaternary period has played an important role in this sector (Naço et al. 2003).

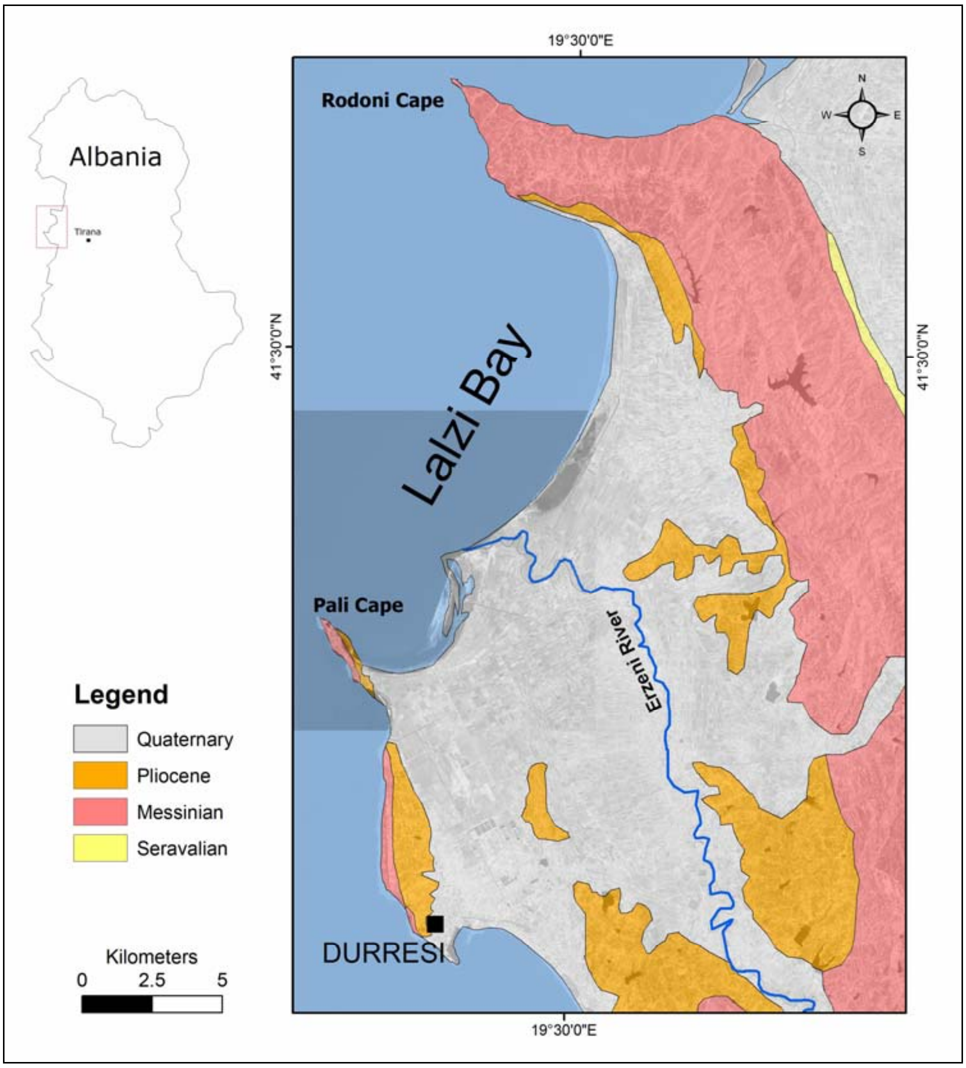


Figure 1. The position of the study area Pali Cape – Erzeni River mouth in a geological sketch map (simplified after ISPGJ, 1983) of the Durresi – Rodoni Cape sector of the Adriatic Lowland of Albania. The shadowed area shows the extent of Landsat image subsets used in this study. Note: The relations between Pliocene deposits and Messinian deposits are transgressive.

The quaternary deposits on the surface are only those of the Holocene age. A key element of the geology and geomorphology of the study area is the Erzeni River that through its sedimentary load has formed the alluvial quaternary deposits. In this field area, Erzeni River flows over its own alluviums. Erzeni River is distinguished for the high solid load (102 kg/s), (Kabo, 1990). In the southwest of the Pali Cape, there is an erosive coastline. Tons of land is grabbed each year from the sea because of wave action and hillslope landslides (photo. 1). Lalzi Bay is an accumulative coastline but it is experiencing disequilibrium moments, where the sea is assaulting the mainland (Naço et al. 2003). Particularly problematic has been the erosion in the Erzeni River mouth where the sea has progressed for hundreds of metres (photo. 2).

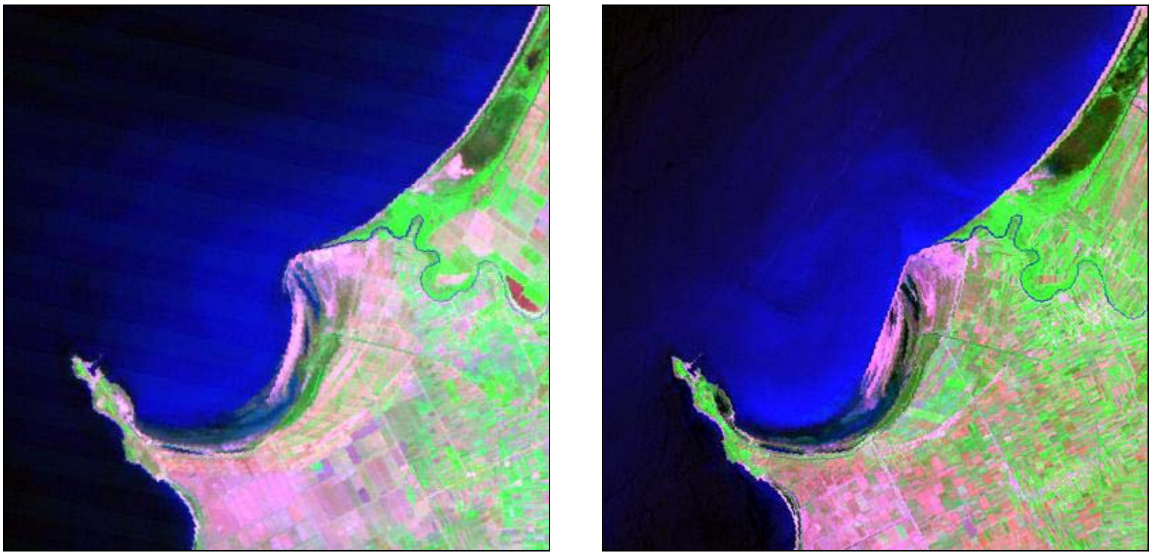
Photo 1. Erosive situation in the southwestern part of the hills of Pali Cape (photo: Naço 2002)

Photo 2. Erosive situation at the Erzeni River delta. (photo: Naço 2002)

Landsat satellite images

The Landsat series of earth observation satellites (Landsat MSS, Landsat TM, Landsat ETM+) provide a unique historical dataset for change detection studies. The TM and ETM+ have seven spectral bands that cover the visible, near infrared, short-wave infrared and thermal infrared regions of the electromagnetic spectrum (Mather, 2004). Pixel size is 28.5 x 28.5 m with the exception of the thermal infrared band that has lower spatial resolutions. The Landsat ETM+ has an additional 15 m spatial resolution panchromatic band. Currently (December, 2007), only Landsat TM is operational, although in October, 2007 it experienced an issue with its onboard batteries. The Landsat Data Continuity Mission (LDCM) scheduled for launch in 2011 is the future of Landsat satellites. It will continue to obtain valuable data and imagery to be used in agriculture, education, business, science, and government (http://ldcm.gsfc.nasa.gov/).

In this study were used two Landsat scenes. The first scene was recorded by the Landsat TM (Landsat 5) multispectral scanner on July 30, 1992, whereas the second scene was recorded by the Landsat ETM+ multispectral scanner (Landsat 7) on June 16, 2002. Both scenes were made available from the Global Land Cover Facility (GLCF) of the Maryland University, USA. These Landsat scenes are part of the NASA's global orthorectified Landsat data set (*see* Tucker et al., 2004). Colour composites of the Landsat scenes are shown in (Fig. 2).



July 1992 **June 2002**

Figure 2. Colour composites (bands 742=RGB) of the Landsat images of 1992 dhe 2002 over the Pali Cape - Erzeni River mouth coastal sector. Images cover an area of 12x12 km.

Image analysis for change detection

Many algorithms and techniques have been proposed for change detection from multi-temporal satellite data. The most used techniques are based on algebraic operations, classification, geographic information systems (GIS) and visual analysis. Recently a new algorithm has been developed for automated change detection from bi-temporal multispectral data, the Multivariate Alteration Detection (MAD), (Nielsen et al. 1998, Canty and Nielsen, 2006). This algorithm was employed in this study to detect changes in the Pali Cape – Erzeni River mouth coastal sector from bi-temporal Landsat data. A brief description of the MAD transformation is based on (Nielsen et al. 1998, Canty and Nielsen, 2006):

We first represent two n-dimensional multispectral images of a scene acquired at times *t*1 and *t*2 by random vectors F resp. G, assumed to be multivariate normally distributed with zero mean. After forming the scalar difference

$$D = a^T \cdot F - b^T \cdot G,$$

the vectors a and b are chosen, analogously to the principal components transformation, so as to maximize the variance of *D*:

$$\mathrm{var}\,(D) \rightarrow \max, \quad (1)$$

with the additional constraints imposed that

$$\mathrm{var}\,(a^T \cdot F) = \mathrm{var}\,(b^T \cdot G) = 1 \quad (2)$$

This means that the resulting difference image *D* will show maximum spread in its pixel intensities. If we assume that the spread is primarily due to actual changes that have taken place in the scene over the interval $t2 - t1$, then this procedure will enhance those changes as much as possible. The determination of the *a* and *b* that satisfy (1) and (2) is equivalent to two coupled, generalized eigenvalue problems. Their solution determines n eigenvalues ρ_i^2 and n pairs of eigenvectors a_i, b_i, i = 1…N and, accordingly, N difference components of the form (1), referred to as MAD variates. The quantities $a_i^T F$ and $b_i^T G$ are called *canonical variates*. The square root of the eigenvalues ρi are the correlations between them. The MAD variates themselves are orthogonal (uncorrelated) and invariant under affine transformations. The MAD transformation can be augmented by subsequent application of the maximum autocorrelation factor (MAF) transformation, in order to improve the spatial coherence of the difference components.

To detect change along the Pali Cape – Erzeni River mouth coastal environment were used the six optical bands from each image (all with 28.5 m nominal spatial resolution). The images were co-registered to each other. The MAD/MAF algorithm (Nielsen et al. 1998, Canty and Nielsen, 2006) was applied to analyze the bi-temporal imagery. The first three MAD/MAF images containing the major information for the changes are shown in Fig. 3.

Figure 3. First three MAD/MAF variates containing the major information for the change.

From the MAD/MAF images can be discerned several features and especially a black spot at the Erzeni River mouth and a high intensity area (white) south of the Erzeni River Mouth. Both these zones have been involved in changes during these time interval; respectively strong erosion at the Erzeni River mouth (the erosion of the Erzeni River delta) and land creation south of the Erzeni River mouth. Comparably smaller changes can be observed in the wetlands north of the Erzeni River and close to Pali Cape. In both cases, the MAD/MAF variates have low pixel intensities, which also by area knowledge corresponds to an increase of the wetlands surfaces. A visual analysis and comparison of the images in (Fig. 2) with MAD/MAF first three variates (Fig. 3) is also very informative. Other changes have also occurred in this coastal environment including the change of the arable land texture the discussion of which is beyond the scope of this study.

To concentrate only in the most important changes each of the first three MAD/MAF variates was threshold by keeping only the pixels with values higher than two standard deviations from the mean and smaller than two standard deviations from the mean. The threshold images were after merged in a colour composite (Fig. 4) which was interpreted jointly with the visual analysis of the Landsat images and knowledge for the study area.

Most important changes indicated by numbers in (Fig. 4) are: 1. the erosion of the Erzeni River delta; 2. the creation of a land surface south of Erzeni River mouth; 3. wetland surface increase; 4. changes in the arable lands; 5. erosion in the southwestern side of the Pali Cape hills. An erosive situation is indicated also in the Lalzi Bay north of the Erzeni River. Other changes could be related to vegetation changes, which may be simply seasonal. Measurements from the analyzed data (Fig. 4) indicate that a land surface of about 36 ha has been eroded at the former Erzeni River delta. A land surface of about 33 ha has been created south of the Erzeni River mouth. An area of about 11 ha north of Erzeni River has been transformed to wetland.

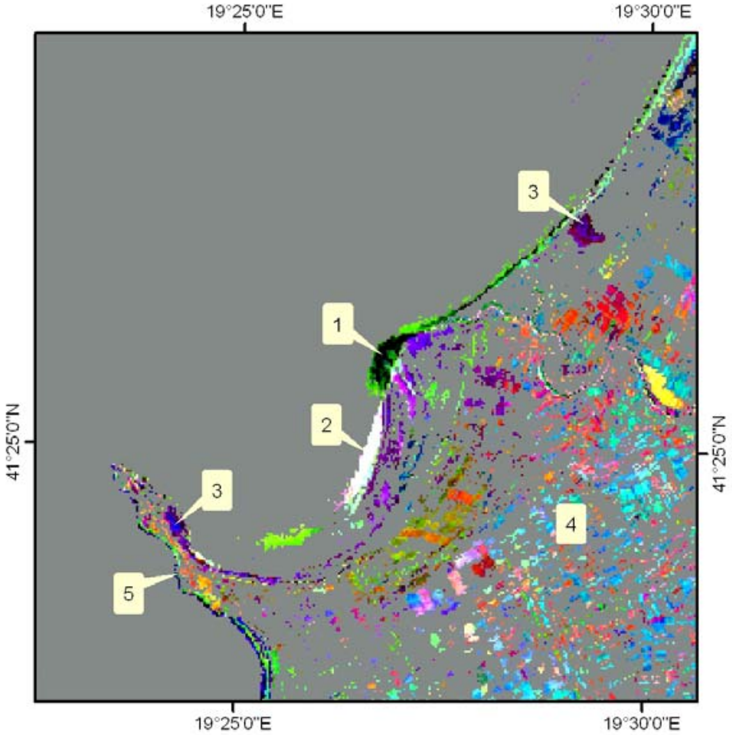


Figure 4. Colour composite of the thresholded first three MAD/MAF variates (MAD/MAF variates 321=RGB). The numbers indicate change areas mentioned in the text.

Discussion

The investigation by bi-temporal Landsat data of the Pali Cape – Erzeni River mouth coastline sector in the Lalzi Bay in the Albanian Adriatic coastline, shows that several important changes have occurred during a short time interval between the years 1992 and 2002. The delta of the Erzeni River has been eroded, whereas a land surface has been created south of the Erzeni River mouth. Results show an increase of the wetland surface and an erosive situation in the southwestern side of the hills of Pali Cape. In an erosive situation is also the sector of Lalzi Bay north of Erzeni River. The erosion of the delta of Erzeni River indicates that the sedimentary material transported from the river to the sea has not been of such quantity to compensate the erosion from wave action. This could be a natural phenomenon but could be also related with uncontrolled riverbed aggregate mining from Erzeni River after the year 1990-ies (Naço et al. 2003). In the other hand an erosive situation has been indicated in the southwestern side of the hills of Pali Cape also in other studies (Naço et al. 2003; Naço and Bedini, 2005), although due to the moderate spatial resolution the results from the analysis of bi-temporal Landsat data for this area should be taken with caution.

Conclusion

This study investigated through bi-temporal Landsat imagery of 1992 and 2002 the changes that have occurred along the Pali Cape – Erzeni River mouth coastline sector. Results show that main changes are: the erosion of Erzeni River delta; the creation of a land surface of about 33 ha south of Erzeni River mouth; wetland surfaces have increased; the southwestern part of the hills of Pali Cape is in an erosive situation; an erosive situation is indicated in the Lalzi Bay north of Erzeni River mouth. The erosion of the delta of Erzeni River may be related to natural causes but also the negative impact of uncontrolled riverbed aggregate mining from Erzeni riverbed must be taken in consideration. The study demonstrates the applicability of bi-temporal Landsat satellite images for the detection of change in dynamic coastal environments.

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