Temporal Satellite Images in The Process of Automatic Efficient Detection of Changes of the Baltic Sea Coastal Zone

Krystyna Michalowska 1, Ewa Glowienka 2, Beata Hejmanowska 3

1 Faculty of Environmental Engineering and Land Surveying, University of Agriculture in Krakow, Poland
2 Faculty of Environmental, Geomatic and Energy Engineering, Kielce University of Technology, Poland
3 Department of Geoinformation, Photogrammetry and Environmental Remote Sensing, AGH University of Science and Technology, Krakow, Poland

E-mail: k.michalowska@ur.krakow.pl

Abstract. The goal of the research was to perform tests aimed at assessing possibilities of using multi-temporal Landsat satellite images for automatic efficient detection of changes (e.g. accumulation and erosion) of the sea coastal zone. The research database was composed of Landsat satellite images, and standardized NDVI vegetation indexes from the years 1998 and 2015, as well as multi-temporal vector maps and aerial orthophotomaps. The result map of Change detection allowed to locate areas, in which diametrical changes in land coverage took place. Satellite images reflecting the condition of the examined area for twenty years enabled outlining changes of Baltic coastal zone, and then determining the rate and extent of transformations of examined part of coast (erosion and accumulation), and also made it possible to trace the migration of dunes. The analysis showed the range of shifting dune displacement in the years 1998-2015 amounts to ca. 180 m. On the examined section of seashore (32 km), the process of erosion and accumulation was detected respectively on the length of 21 km and 10 km along the coast. The changes of accumulation and erosion of the sea coast are easily identifiable and clearly visible. Properly conducted workflow of processing the satellite images have allowed the rapid and efficient detection of changes coastline, dunes and vegetation.
1. Introduction
The application of modern solutions in the fields of digital photogrammetry and remote sensing make it possible to utilize information contained in satellite and aerial images for monitoring the condition of nature in protected areas without a direct interference in natural environment. Data obtained from satellite and aerial ceilings are important sources of information in coastal zone investigations. Examples pertaining to the application of remote sensing methods in investigating changes in sea coastal zone can be found in numerous pieces of world literature, including but not limited in: [1-8]. Especially worthy noticing is the environment research performed on the basis of multi-temporal NDVI (Normalized Difference Vegetation Index) vegetation indexes, which can identify changes in land cover [9-12].
Research works involved the analysis of changes in coastal zone of the southern Baltic Sea and in particular, the migration of dunes and the resultant transformations of land cover. The goal of the research was to perform tests aimed at assessing possibilities of utilising multi-temporal Landsat satellite images, and selected vegetation index (NDVI) for remote detection and to analyse environmental changes in the Baltic Sea coastal zone without having to directly interfere in the natural environment.

1.2 Case Study Area

![Figure 1. Research area of Baltic Sea coastal zone](image)

Research has been made for the coastal zone of 32 km in length along the southern coast of the Baltic Sea. The study area is covered by complete nature protection scheme, and constitutes part of international network of protected areas, such as HELCOMBSPA, World Biosphere Reserve by UNESCO, or wetland RAMSAR. The area is characterized...
by exceptionally strong dynamics of shoreline and land cover. There are moving dunes there, which migrate with a speed of 3-10 m per year.

1.2 Data and methodology

The research database was composed of Landsat satellite images and airborne aerial multi-temporal orthophotomaps, and a vector maps:

- Satellite orthophotomaps (Table 1),
- Aerial orthophotomaps from the years 1995/97 and 2012,
- Vector map of water reservoirs and sand dunes.

| Table 1. Parameters of the satellite orthophotomaps |
|-----------------|-----------------|
| **Satellite**    | Landsat - 5     | Landsat - 8     |
| Sensor           | TM              | OLI             |
| Spatial resolution [m] | 30              | 30              |
| RED band [µm]    | 0.63-0.69       | 0.67-0.67       |
| NIR band [µm]    | 0.76-0.90       | 0.85-0.88       |
| Year of recording | 1998            | 2015            |

Processing of the satellite images was performed using ENVI v. 4.5, and PCI Geomatica v. 2016 programs. The process of integration of vector and raster data (NDVI, Web Map Service, orthophotomaps), as well as the analysis of results were completed in an open-source software. In the study Landsat satellite images were downloaded from USGS servers. Satellite images were subject to a process of preliminary processing (atmospheric correction, scene sub setting). Subsequently, on the basis of spectral channels of the obtained satellite images, Normalized Difference Vegetation Index (1) was created, [13, 14]. For calculation and analysis purposes, channels recorded in visible (RED) and in near infrared (NIR) ranges were selected.

\[ NDVI = \frac{NIR - RED}{NIR + RED} \] (1)

The NDVI images were subjected to automatic ISODATA unsupervised classification. There were five classes obtained, representing various land cover forms, i.e.: water, sand (area of sandy seashore and sand dunes), overgrown dunes, forest, and vegetation (Figure 2). Classification results were then used to generate a map with the use of “Change detection”. Results were subjected to reclassification (Figure 3), in order to delimit areas marked by the following:

- accumulation,
- erosion,
- increased vegetation,
- decreased vegetation,
- no change.
Relevant classes were established by comparing the result of the assumed category with data contained on the vector map of the study area.

Figure 2. Results of automatic ISODATA unsupervised classification

Figure 3. The map of changes for examined area, obtained after reclassification of “Change detection” results
2. Results

Satellite images reflecting the condition of the examined area over twenty years enabled outlining changes of Baltic coastal zone, and consequently determining the rate and extent of transformations of the examined part of the coast (erosion and accumulation), and also made it possible to trace the migration of dunes. Moreover, aerial orthophotomaps from the years 1997 and 2012, and vector maps obtained on the basis of them made it possible to verify the results of the NDVI differential map analysis (Figure 3, Figure 4).

Figure 4. The map of change shows areas, in which diametrical changes in land cover took place. Map displayed on the aerial orthophotomap (year 2012)

The result maps that have been generated made it possible to locate areas, in which diametrical changes in land cover took place, and to determine the nature of processes causing those transformations (Figure 3, Figure 4). On the basis of the analysis of maps, the biggest changes were noticed both within the Baltic Seas coastal zone, and in the belt of moving dunes (Figure 5). Over the section of 32 kilometers of seashore, erosion processes occurred along 14 shore sections of the overall length of 21 km. Accumulation changes were recorded over shorter seashore sections of the overall length of 10 km. Those results coincide with results of studies that were based on multi-temporal aerial orthophotomaps [15]. The range of shifting dune displacement in the years 1998-2015 amounts to ca. 180 m (areas identified as zones of vegetation decline). A process of gradual decreasing of surfaces of water reservoirs as a result of continuous shallowing and covering with plants was also noticed in the examined area (Figure 3, Figure 4). As a result of research, following the processing of satellite and aerial images, a very close correspondence between those types of data was obtained. The analysis proved correspondence between the shoreline locations set out on the basis of both types of data. As a result of research, following the processing of satellite and aerial images, a very close correspondence between those types of data was obtained. The changes of accumulation and erosion of the sea coast are easily identifiable and clearly visible.
3. Conclusions
The correspondence between shore outlines on the NDVI map and vector data obtained on the basis of aerial orthophotomaps demonstrates that the method of computing differences in multi-temporal vegetation indexes is correct, and may be used for determining the extent of transformation of the sea shoreline and water reservoirs as well as changes in dune areas. One can therefore come to a general conclusion that when using different NDVI values, one can easily identify areas, in which essential land cover changes took place. At the same time, change detection results obtained on the basis of automated NDVI image classification allow to qualitatively designate specific transformation objects.

It was found that proper processing of satellite imaging (NDVI, automatic classification) allows to get results that conform with the results obtained on the basis of data with a higher resolution (e.g. aerial photographs). The resulting map can be the basis for remote and quick identification of diametrical changes in land cover.

References
[1] Singh, A., 1989. Review Article Digital change detection techniques using remotely-sensed data. International Journal of Remote Sensing, 10 (6): 989-1003
[2] Berlanga-Robles, C., Ruiz-Luna, A., 2002. Land Use Mapping and Change Detection in the Coastal Zone of Northwest Mexico Using Remote Sensing Techniques. Journal of Coastal Research, 18 (3): 514-522
[3] Marghany, M., 2003. Environmental Applications of Remote Sensing. Morphological automatic extraction of Pan-European coastline from Landsat
ETM+ images. In: Proceedings of the Fifth International Symposium on GIS and Computer Cartography for Coastal Zone Management, S. Bagli and P. Soille (eds.), Genova

[4] Mitasova, H., Overton, M., Harmon, R., 2005. Geospatial analysis of a coastal sand dune field evolution. Jockey's Ridge, North Carolina, Geomorphology, 72 (1–4): 204-221

[5] Kuleli, T., Guneroglu, A., Karsli, F., Dihkan, M., 2011. Automatic detection of shoreline change on coastal Ramsar wetlands of Turkey. Ocean Engineering, 38, (10): 1141-1149

[6] Aedla, R., Dwarakish, G., Venkat Reddy, D., 2015. Automatic Shoreline Detection and Change Detection Analysis of Nethravati-GurpurRivermouth Using Histogram Equalization and Adaptive Thresholding Techniques. Aquatic Procedia, 4: 563-570

[7] Dipson, P., Chithra, S., Amarnath, A., Smitha, S., Harindranathan Nair M., Shahin, A., 2015. Spatial changes of estuary in Ernakulam district, Southern India for last seven decades, using multi-temporal satellite data. Journal of Environmental Management, 148 (15): 134-142

[8] Jangir, B., Satyanarayana, A., Swati, S., Jayaram, C., Chowdary, V., Dadhwal, V. K., 2016. Delineation of spatio-temporal changes of shoreline and geomorphological features of Odisha coast of India using remote sensing and GIS techniques. Natural Hazards, 82 (3): 1437-1455

[9] Fabio, M., 2004. Monitoring forest conditions in a protected Mediterranean coastal area by the analysis of multiyear NDVI data. Remote Sensing of Environment, 89 (4): 423-433

[10] Shalaby, A., Tateishi, R., 2007. Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt. Applied Geography 27: 28-41

[11] Meera Gandhi, G., Parthiban, S., Nagaraj Thummalu, Christy, A., 2015. Vegetation Change Detection Using Remote Sensing and Gis – A Case Study of Vellore District. 3rd International Conference on Recent Trends in Computing 2015 (ICRTC-2015). In: Procedia Computer Science, (57): 1199-1210

[12] El-Hattab, M., 2016. Applying post classification change detection technique to monitor an Egyptian coastal zone (Abu Qir Bay). The Egyptian Journal of Remote Sensing and Space Science, 19 (1): 23-36

[13] Rouse, J., Haas, R., Schell, J., Deering, D., 1973. Monitoring Vegetation Systems in the Great Plains with ERTS. Third ERTS Symposium, NASA: 309-317

[14] Tucker, C., 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment, 8, 127-150

[15] Michalowska, K., Glowienka, E., Pekala, A., 2016. Spatial-temporal detection of changes on the southern coast of the Baltic Sea based on multitemporal aerial photographs. In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLI-B2: 49-53