

MULTI-TEMPORAL DATA INTEGRATION FOR THE CHANGEABILITY DETECTION OF THE UNIQUE SŁOWINSKI NATIONAL PARK LANDSCAPE

K. Michalowska^{a,*}, E. Glowienka^b

^a AGH, Dept. of Geology, Environmental Protection and Geotourism, University of Science and Technology Cracow (AGH), 30059 Krakow, Poland - kmichalo@poczta.fm

^b AGH, Dept. of Geoinformation, Photogrammetry and Environmental Remote Sensing, University of Science and Technology Cracow (AGH), 30059 Krakow, Poland - eglo@agh.edu.pl

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ABSTRACT:

Multitemporal aerial photography (1964-2004), Digital Elevation Models (DEM), orthophotomaps, thematic vector layers and satellite images have been integrated for the changes detection of unique environment of the Słowiński National Park (SNP). The Park is situated on the south Baltic Sea coast (the northern Poland). It is known for its moving sand dunes, which migrate with a speed of 3-10 m per year. The project is based on the GIS (Geographical Information System) technology and uses data from various sources and periods. Such an approach made it possible to look at the studies in comprehensive way, taking into consideration almost all factors that contribute to ongoing changes of the SNP environment. The study was focused on analyses of the long-term coast processes, movement of dune zones and the vegetation changes in that area. Multi-temporal data have been performed and integrated using GIS technology for the changes detection of the unique environment of the Park. DEMs derived from aerial photography provided relief data, which were used to indicate selected features changes of the SNP landscape. Differential maps of elevation changes made it possible to recognize areas of elevation gain through the accumulation of sand and areas of elevation loss caused by erosion. There also were computed maps showing horizontal migration of the moving dune, as well as evolution of the dune area and morphology. Based on the classification of the satellite images results and NDVI vegetation index it has been observed vegetation changes over time 1979-2000 of environment in the Park area.

1. INTRODUCTION

The Słowiński National Park (SNP) is situated on the south Baltic Sea coast (the northern Poland). The Park was recognized by UNESCO to be the World Biosphere Reserve. It also is covered by the international RASMAR Convention, which concerns the preservation of aquatic and mud birds habitats. It is the only national park in Poland, which preserves seaside dune ecosystems, as well as lake, peat bog, and forest ones. It is also known for its moving sand dunes, which migrate with a speed of 3-10 m per year. The dunes, big coastal lakes, marshy terrains and swamps occupy major part of the Park area. The exceptionally strong dynamics of geological processes and hardly accessible places cause that any research work in that area is very inconvenient. For that reason, there are not many works, which would be covering the whole Park area at the same time, and those few include (Dzięciołowski 1973, Marsz 1975, Kobendzina 1976, Wojterski et al. 1979, Bednorz 1983, Rotnicki 1987, Rabski 1992, Piotrowska 1997). Research on the subject matter of the impact of eolian processes upon changes in the SNP landscape was undertaken by Miszalski 35 years ago (Misalski 1973). Based on air images from the period of 1951-1968 and on topographic maps, he has carried out the quantitative analysis of dunes and evolved the contemporary development of eolian forms. Modern solutions in the fields of photogrammetry and remote sensing, as well as the use of GIS technology offer wide possibilities of not only the continuation of Misalski's research but also an extension of the research scope. The use of multi-temporal aerial photos and satellite

images makes it possible to investigate the dynamics of changes not only in eolian forms (Mitasova et al., 2006), coastal zones (Sanjeevi 2000, Mitasova et al., 2004, Ricchetti et al., 2004), but also in flora and other elements of the environment (Zanutta et al., 2006, Kim et al., 2006). The project is based on the GIS (Geographic Information System) technology and uses data from various sources and periods. Such an approach made it possible to approach research in a comprehensive way, taking into consideration almost all factors that contribute to the ongoing changes in the SNP environment and landscape. The study was focused on analyses of the long-term (forty years) coastal processes and movement of dune zones in the Słowiński National Park. Moreover, it concerned vegetation changes in the Park.

2. DATA AND METHODS

2.1 Data

The investigation and analyses of variability of eolian forms are possible thanks to multi-temporal aerial photos from the years 1964-2004 (Table 1), as well as satellite images, provided by LANDSAT (Table 2).

The archival aerial photos were scanned with 14- μ m pixel resolution, using the precise *PHOTOSCAN TD* (Intergraph / Zeiss) photogrammetric scanner.

The project makes use of LANDSAT MSS satellite images from 1979 and LANDSAT ETM+ satellite images from 2000,

* Corresponding author.

downloaded from GLCF (Global Land Cover Facility) - University of Maryland server (Table 2).

Year	Scale
1964	1:23 000
1975	1:29 500
1984	1:25 000
1995	1:26 000
2004	1:26 000

Table 1. Date and scale of aerial photos

Sensor	Spectral range	Bands	Pixel resolution	Registration date
LANDSAT MSS	0.50–1.10	4	60	31.05.1979
LANDSAT ETM+	0.45–2.35	6	30	13.06.2000

Table 2. Sensor characteristic

Thematic vector maps (geological, hydrogeological, geomorphological, water ecosystems, soils, forest and non-forest communities, fauna, flora, water resources and other) and tabular descriptive database (the *MS Access* format) concerning particular elements of the SNP environment refer to each vector layer. Also topographic maps of the Park area, scale 1: 10 000, were included in the data set.

2.2 Methods

The aerotriangulation procedure was difficult due to poor quality (both radiometric and geometric) of processed photos (those dating back to 1964, 1975, 1984). Therefore, modern methods of digital image processing, such as filtering, image enhancement, or preliminary colour balancing were applied to upgrade the quality of those photogrammetric materials, and to improve the possibilities of their photointerpretation. The *ImageStation Automatic Triangulation* photogrammetric software was used to perform measurements, necessary for adjustment of the aerotriangulation block. In the first stage, interior and relative orientations were performed for all photo blocks. Main difficulties in the relative orientation stage were related to the identification of Grand Control Points (GCP) because of specific character of the SNP area (70% of its surface area covered by active dunes, lakes and the Baltic Sea). For all aerialtriangulation projects the signa nought was between 4-6 m

The Digital Elevation Models (DEM) were produced using DEPHOS (Mapper Stereo) digital photogrammetric workstation, with 0.9-1.2 m accuracy. DEMs for the whole investigated area from each epoch were converted from vector format to a grid with a 3-metre resolution. DEMs derived from aerial photography provided relief data, which were used to indicate selected features changes of the SNP landscape.

In the next step orthophotomaps (scale 1:5000 and 0.5 m ground resolution) were generated from the aerial photos for each period of time with *ORTHO ENGINE*, the *PCI Geomatica* module.

On the basis of stereoscopic observation of air photos, contour maps of dunes that occur within the SPN area were generated for all year group photos. Contours of particular dune forms were created through digitalisation of dune skeleton lines. To verify the correctness of vectorized dune forms, curvature maps

were prepared, as well as elevation maps of the 0.5 m isolines. Layers showing lines and water course lines were generated on the basis of DTM, with the help of *Geomedia Grid* function, which determines the curvature area in a given point along the slope inclination direction.

The processing of satellite data was done with the use of *ENVI* (Environment for Visualizing Image) *IDRISI* and *PCI Geomatica* software.

In order to minimize the impact of atmosphere on the values of reflection recorded on images, the images were atmospherically corrected, with the use of ATCOR 2 (Richter, 1996), module of *PCI Geomatica*.

Based on the unsupervised classification, colour composite images and orthophotomaps (derived from aerial photos), the supervised classification (The Maximum Likelihood) was performed (Fig.1.). Seven classes of the land cover were defined:

1. Dune 1
2. Dune 2
3. Water
4. Forest complex
5. Meadows and pastures
6. Agricultural
7. Coastal dune forest

Next, Normalized Difference Vegetation Index (NDVI) was completed for LANDSAT temporal data (Fig. 1.).

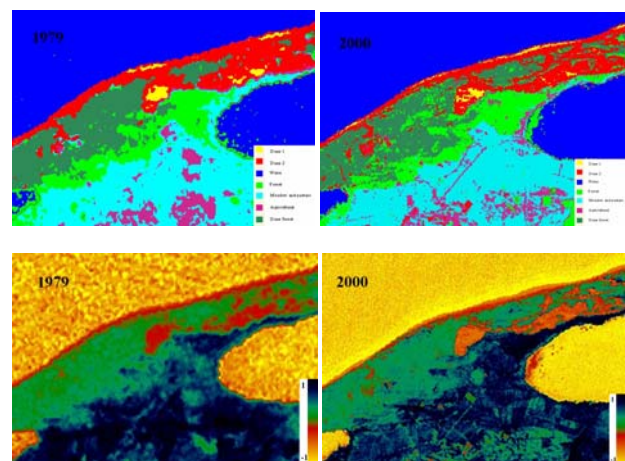


Figure 1. Classification and NDVI results.

3. RESULTS

Multi-temporal aerial photography, DEMs, orthophotomaps, thematic vector layers and satellite images have been integrated for the changes detection of the unique environment of the Słowiński National Park. Full integration of multi-temporal data made it possible to conduct an analysis in GIS environment and to compute maps quantifying the features of landscape changes. All processed images, integrated with thematic vector maps enabled to get complete information about environmental components revealed in raster and vector data.

The differential maps, which had been prepared in GIS environment, made it possible to perform quantitative analysis of horizontal shift of selected dunes, as well as observation of changes in land occupied by them in consecutive time intervals (Fig. 2. and Fig. 3). Based on the observation of the dune's

contour maps it was determined that the biggest migrations of dune forms (mainly within the moving dune belt) took place during last 20 years. The maximum migrations of dunes in the period of 1984 through 2004 amounted even to 320 m.

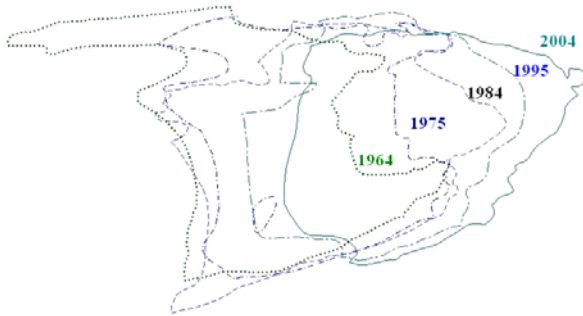


Figure 2. Horizontal migration and evolution of selected moving dune.

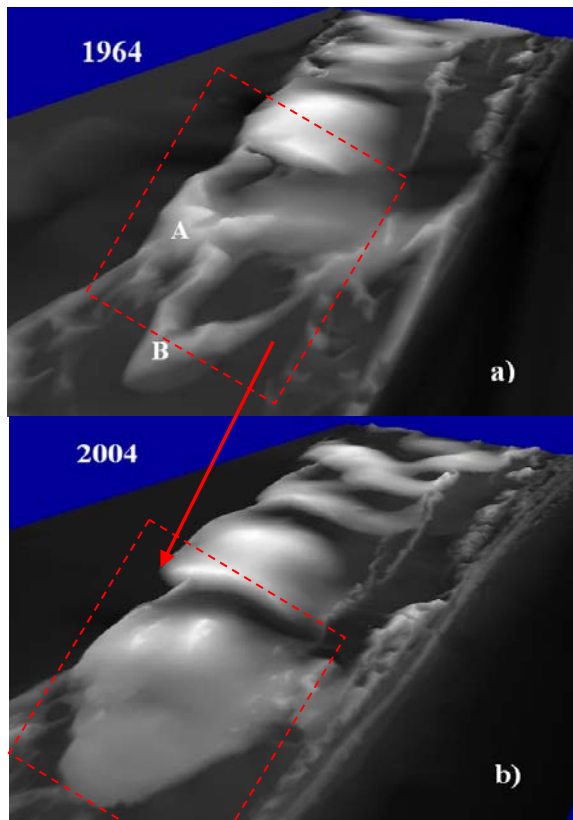


Figure 3. Changes of selected moving dune in the period of time 1964-2004 - 3D view.

The selected dune, which is visible in Figure 3b, was formed through the joining together of two smaller ones (Fig.3a.). The profile analysis (Fig. 4.) shows that during the investigated period of 1964 - 2004, as a result of the operation of eolian processes, the moving dune (A) has reached a much slower dune (B), thus forming a new object of a greater volume.

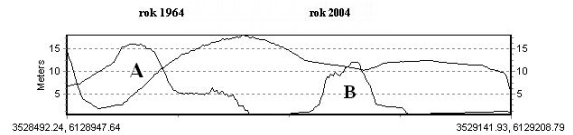


Figure 4. The profile of selected moving dune for two years 1964 and 2004.

The differential maps of elevation changes were developed by subtracting the 1995 DEM elevations from the 2004 DEM elevation values and correspondingly for the remaining DEMs. As a result, this made it possible to recognize areas of elevation gain through the accumulation of sand and areas of elevation loss caused by erosion (Fig.5.).

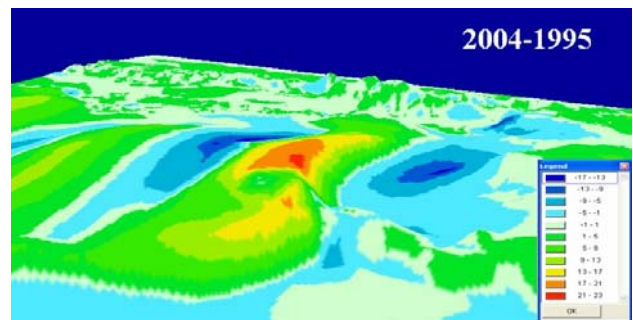


Figure 5. Differential map of elevation between 1995 and 2004

The obtained image comparison results enabled to identify vegetation changes over time 1979 to 2000 in the Park area. Based on the classification results and NDVI vegetation index it has been observed that those elements of the environment, which are classified as *dunes 1* (fields of exposed sand), *dunes 2* (partly covered with plants), and agricultural land are marked by the highest dynamics of their changes. As the analysis shows (Table 3), ca. 40% of agricultural land has been transformed into meadows and pastures. More than 50% of active dune fields have not been changed, whereas 40% of them have been invaded by dune flora. More than 14% of dune fields, which were covered with plants, turned into dune forests. Meadows and pastures have been afforested in 22% and 17%, respectively. On the basis of obtained results, it has been determined that ca. 46 km² of land surface have changed the character of land cover, which constitutes 23.5% of the whole analysed area.

1979	dunes 1	dunes 2	water	forests	meadows	agricultural	dune forest
2000							
dunes 1	53.5	5.7	0.0	0.0	0.1	2.2	0.0
dunes 2	40.2	62.3	0.1	1.0	1.5	15.4	7.0
water	6.0	11.1	99.5	8.8	0.4	1.9	3.2
forests	0.1	4.3	0.3	68.3	21.6	16.7	17.3
meadows	0.0	0.7	0.0	7.9	63.2	39.1	2.2
agricultural	0.1	1.6	0.0	4.9	11.8	22.4	2.6
dune forest	0.1	14.4	0.0	9.2	1.4	2.4	67.7

Table 3. Changes of land cover between 1979 and 2000 [%]

4. CONCLUSIONS

The use of computer techniques, such as GIS, remote sensing and digital photogrammetry that is based on satellite images, as well as aerial photos is fully justified when studying spatial-time changes of the Slowinski National Park landscape. This technology is an ideal tool to investigate inaccessible and legally protected areas. The proposed form of that research work constitutes a complex and unique measure to study the changeability of the Park nature, especially in numerous hardly accessible areas. The results of the project show that digital photogrammetric methods provide enhanced tools for quantification of geomorphology change in dynamic dune systems.

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