THE DELTA COASTLINE DYNAMICS FOR THE DANUBE NORTHERN ARM OVER THE PERIOD 1986–2011

YEVGEN GAZYETOV[*], ROMAN SIZO[**],

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The research was implemented in the framework of EnviroGrids international project. Long-term trends in the dynamics of the delta coastline at the Ochakiv Arm (Ukraine) were assessed based on original LANDSAT remote sensing data with spatial resolution of 30 m and time interval of 7 and 4 years. The relevance of original information and advantages of modern GIS-technologies allowed to obtain new information about long-term delta processes. It is established that during 26 years the area of the Danube delta at the Ochakiv Arm, in general, increased by 1.335 sq.km. However, it was found that in different parts of the delta and in different time periods, not only accumulative but also erosion processes were dominant, leading both to the increase of the new land area and to the sea intrusion. Also, long-term changes in the geometric shape of the delta coastline were found. Some assumptions about the causes of the observed morphological changes were made. The information received is important from a scientific point of view as well as for the management and implementation of economic activities in the Danube River Delta.

1. INTRODUCTION

Long-term dynamics of the Black Sea level and continuous deposition of suspended sediments in the river delta form a coastal zone, and in particular, coastline location and type of the delta vegetation coverage. River deltas are known as indicators of natural and anthropogenic drivers of changes in the river runoff and sea level (Mikhailov *et al.*, 2006). Intensive economic activity can have a significant impact on the character and rate of geomorphological changes in deltas (Nikiforov *et al.*, 1963, Mikhailov *et al.*, 1981, Mikhailov *et al.*, 1999, Mikhailov *et al.*, 2010).

LANDSAT satellite data provide objective temporal data, and modern GIS techniques provide a comprehensive set of tools for analysing the changes.

The study-area is located in the south-west of Ukraine near the Romanian border in the Danube River Delta. The location of the coastline in the year 2010, and the main hydrographical objects of the Ochakiv Arm of the Danube are shown in Figure 1: Prirva Arm, Potapovske Arm, lakes and bays in the delta. Figure 1 is based on the aerial imagery web mapping service (Bing 2013). A total area of the studied pilot area was approximately of 62 sq. km.

The Ochakiv is the northernmost arm of the Danube and simultaneously a branch of the Danube's most water-abundant arm – the Kilia Arm. In 2001–2003, the Kilia arm water volume was 52% of the total Danube runoff (*Hydrology of the Danube Delta*, 2004). From the 1950s to 1998, the USSR and Ukraine used branches and canals of the Ochakiv Arm as a main Danube shipping route. However, after 1998, the Bystre Arm was decided to be used instead as a navigation waterway, because the Ochakiv Arm was shallowing and the unreasonable costs required for its dredging.

The main task of this work is to analyse the dynamics of the marine coastline and area of vegetation coverage in the Ochakiv Arm of the Danube using up-to-date GIS and remote sensing technologies.

[*] Researcher, Odessa National I.I. Mechnikov University, 7 Mayakovskogo Lane, Odessa, Ukraine, gazetov@gmail.com.

[**] Researcher, Institute of Biodiversity of Terrestrial and Aquatic Ecosystems, 20 Lenin Str., Melitopol, Ukraine, sizo.roman@gmail.com.

In this paper we made an attempt to evaluate trends of delta-formation processes driven by natural or anthropogenic factors in the study-area over the last 26 years based on remote sensing data.

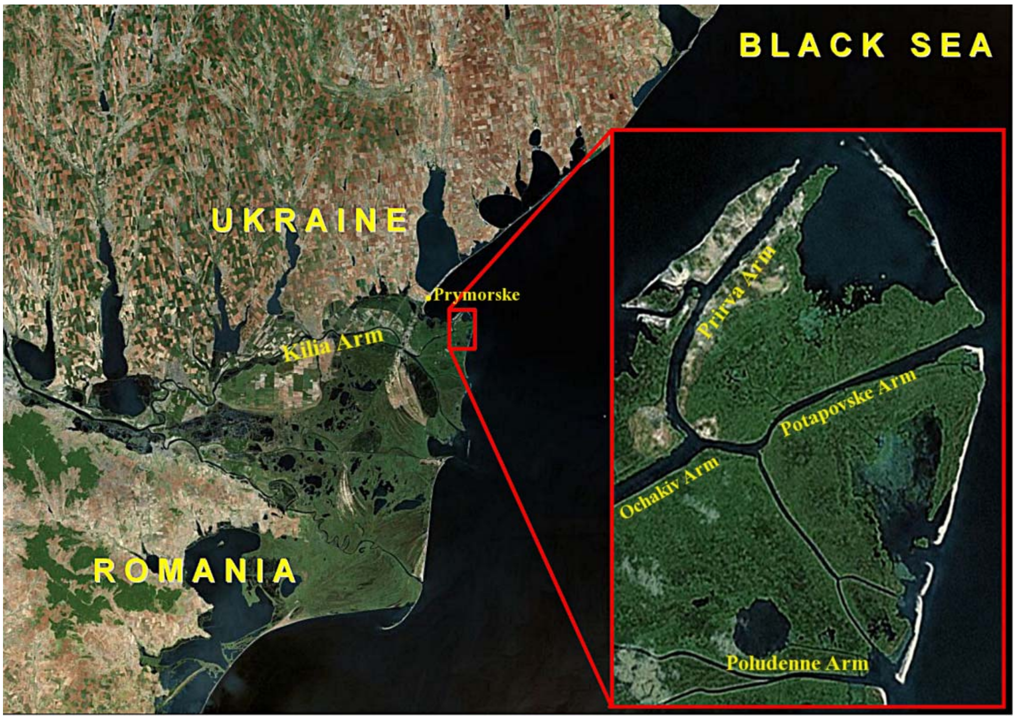

Fig. 1 – Location of the arms in the northern part of the Danube Delta.

2. INPUT DATA AND METHODOLOGY

2.1. Input data

Mapping the Ochakiv Arm coastline was done based on LandSat 5TM space imagery in the spring seasons of 1986, 1993, 2000, 2007 and 2011. The original information is available on open access at a website of the Earth Resources Observation and Science Center (EROS Center 2012). The spatial resolution of original satellite images is 30 m (15 m in panchromatic range).

The sea level is one of the most important factors to form a configuration of the coastline, islands and spits. Sizeable lowland areas of the delta can arise or disappear during short periods of time due to changes in the sea level, synoptic situation and wind tide processes. To minimize the error caused by short-term sea level fluctuations, we chose satellite images taken at dates with similar sea level values. Information on the sea level is based on measurements of the Prymorske hydrometeorological station, 10 km from the studied-area (Fig. 1). Sea levels for the dates of satellite images were kindly provided by the Danube Hydrometeorological Observatory (DHMO).

2.2. Methodology

Multichannel satellite images were processed by ArcGIS 10 and ERDAS IMAGINE 2011.

To identify the distribution of water and of land areas we used a combination of spectral channels LandSat 5TM – “7-5-3” as being most suitable for this purpose (GIS-Lab 2005).

The processing procedure of satellite images includes the merging of channels 7 and 5 and 3 of the image (Stack function of ERDAS IMAGINE 2011) and further the creation of a multichannel image (pseudo-RGB). ERDAS IMAGINE has been selected for the creation of space pseudo-colour images of the Danube River Delta because this software is one of generally accepted leaders for correct processing of the remote sensing information.

Supervised classification, transfer raster to vector and further processing of the vector maps were carried out in ArcGIS 10, which provides a wider range of tools for working with vector objects. The vector version of the maps has been chosen given the need to work with a significant number of small, often “unreal” objects, which appear during the classification of remote sensing data. The authors considered it more convenient to remove such objects or their merger into the larger ones in ArcGIS environment. The interactive supervised classification was done with ArcGIS on the basis of the significant number (30–40) of matching signatures being characteristic of water types of the underlying surface. Everything other than bodies of water was classified as land and/or vegetation. Then, from the whole set of received objects, ‘land’ was extracted using the ‘Extraction’ function of the ‘Spatial Analyst’ module of ArcGIS 10 and consequently processed with other functions of the ‘Spatial Analyst’ to remove occasional objects and make final maps. To accelerate the processing of a great amount of objects, obtained as a result of half-automatic classification, a set of ArcGIS 10 functions was used for the spatial processing of vector maps.

As a result, thw processing of time-dynamic raster images series of vector maps for the coastline of the studied area over the above-mentioned interval of time were composed. To reveal changes in the delta, the maps of the same scale were compared pairwise for the years as follows: 1986–1993, 1993–2000, 2000–2007, 2007–2011, 1986–2011. Also a toolset of the spatial operations module ‘Analysis Tools’ from ArcGIS 10 was used to compare vector maps and calculate the size of changed areas.

Thus, a series of vector maps was produced, showing the dynamics of a form and location of the marine delta coastline of the Ochakiv Arm for the above-mentioned periods (Figs. 2, 3, 4, 5, 6).

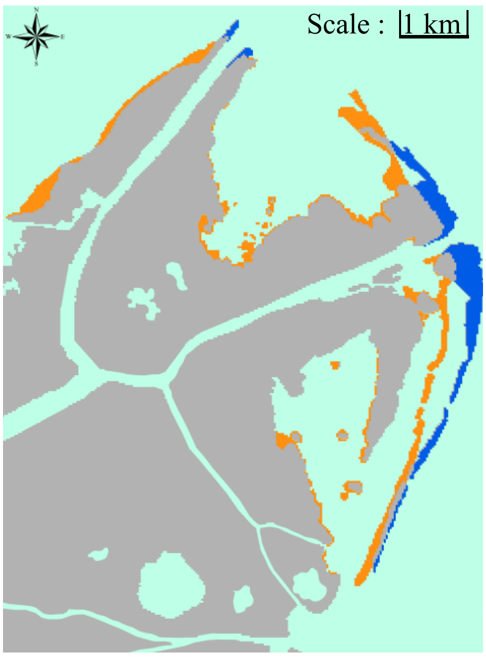

Fig. 2 – Coastline dynamics of the Ochakiv Arm in 1986–1993.

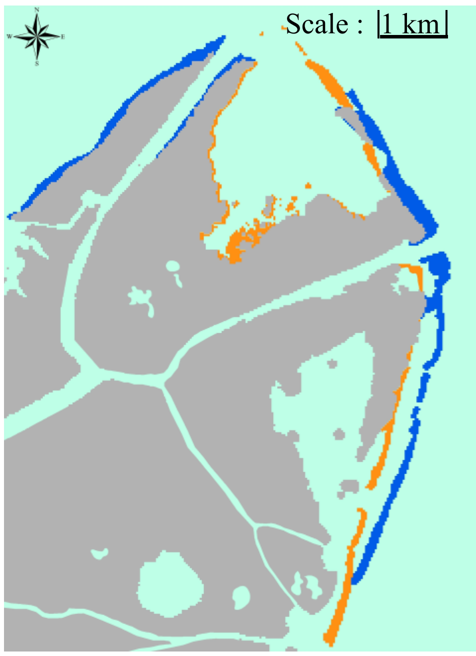

Fig. 3 – Coastline dynamics of the Ochakiv Arm in 1993–2000.

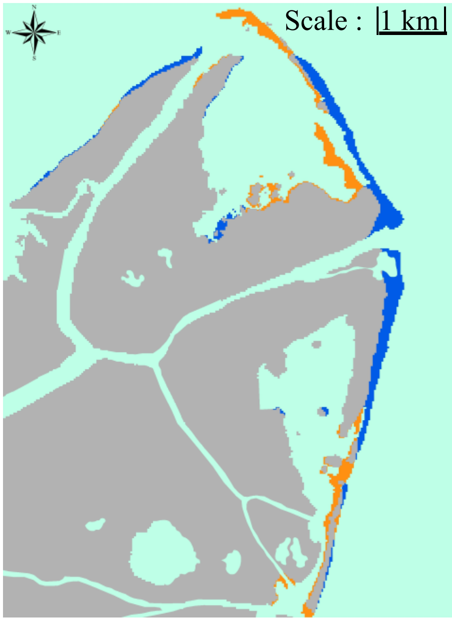

Fig 4 – Coastline dynamics of the Ochakiv Arm in 2000–2007.

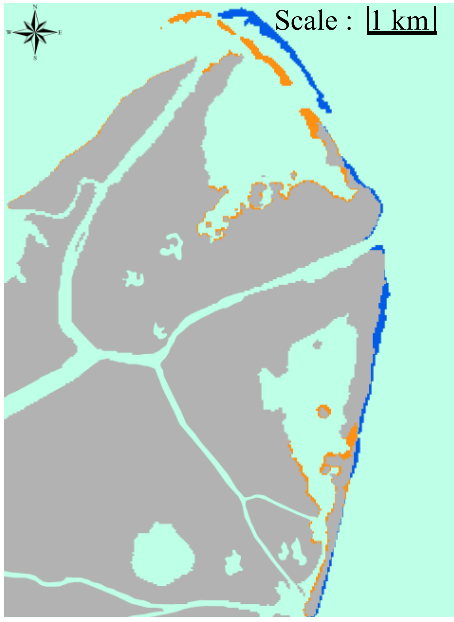

Fig. 5 – Coastline dynamics of the Ochakiv Arm in 2007–2011.

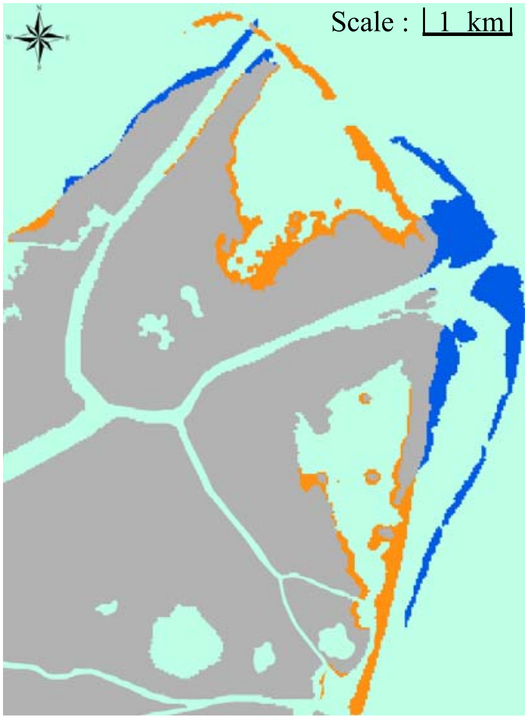

Fig. 6 – Coastline dynamics of the Ochakiv Arm in 1986–2011.

A map legend is identical for all the coastline dynamics maps: grey color indicates location of delta objects in the initial year of each period; blue ones are areas of the sea encroachment for the last year of each period; orange – areas of newly appeared land.

Assessment of reedbeds dynamics was carried out by the method as follows: using the ‘Unsupervised Classification’ function of ERDAS IMAGINE 11 we obtained the classes associated to different types of water surface, and different types of reedbeds and sand. Then, with the ‘Spatial Analyst’ module of ArcGIS 10, the raster was reclassified and three classes obtained: reed, sand and open water. For each of the three classes a size of the area was calculated that showed the reedbeds area dynamics from 1986 to 2011.

3. RESULTS AND DISCUSSIONS

Long-term trends of open water and lands distribution were evaluated with this pilot study of the Ochakiv Arm of the Danube Delta. Additionally, time periods were determined for the prevalence of active delta accumulative processes and formation of new land areas.

Maps of morphological dynamics of the coastal zone based on images of the 1986–2011 period (Fig. 6) revealed the following directions of the Danube delta changes:

- abrasion (sea encroachment) of spits and cones at the Prirva Arm and Potapivske Arm, where a land strip up to 800 m wide has disappeared (at a confluence point of the Potapivske Arm);
- accumulation, formation of new land areas (spits up to 280 m wide) to the west (toward the Continent) of formerly existing ones;
- trend of closure of extensive water areas of the sea near the marine coastline by alluvial spits;
- growth of reedbed areas with newly-formed reed fields as wide as up to 380 m (between the Prirva Arm and Potapivske Arm).

Comparative GIS-analysis of the delta coastline morphology over the last 26 years at the Ochakiv Arm has shown time dynamics as follows (Fig. 7):

The most intensive processes of land formation were recorded during 1986–1993 and 2007–2011 (land formation prevailed over abrasion by 1.7 times). The 1993–2000 and 2000–2007 intervals showed an opposite situation: erosion prevailed over accumulation of sediments and land-forming processes by 1.5 times.

In general, as for the Ochakiv Arm coastal zone in the 1986–2011 period, we can ascertain a balance between accumulation and abrasion activities. Tectonic subsidence of 1.5 mm/year (Shmuratko, 1982) in this region is negligible because for all the investigated interval of time this subsidence equaled about 4 cm in total.

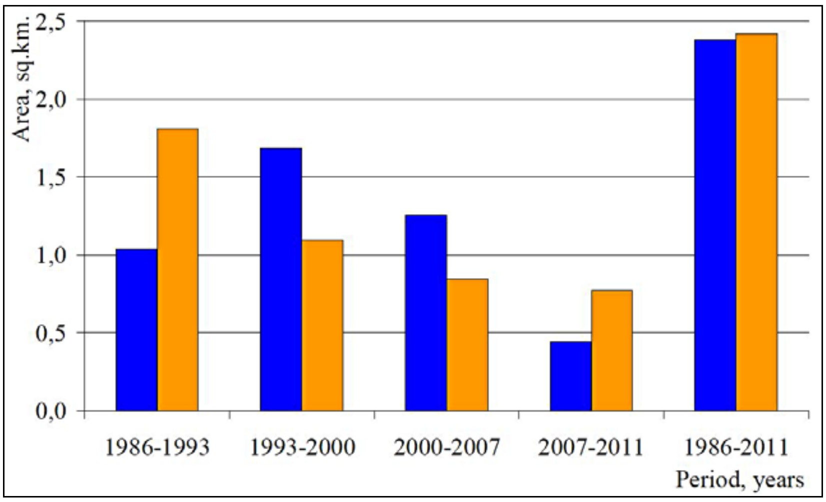

Fig. 7 – Dynamics of changes in the areas of the Ochakiv Arm coastal zone in 1986–2011 (blue – abrasion; orange – accumulation).

4. CONCLUSIONS

The pilot research of long-term changes in the region of the Ochakiv Arm of the Danube River, based on remote sensing services, has shown trends of radical delta changes, straightening of a cone-shape form of the Ochakiv Arm, and development of new closed lagoons in which accelerated overgrowing with reed is observed.

From 1993 to 2011, a general weakening trend of either abrasion or accumulation processes was observed in the study-area. Compared to 1986–1993, the 1993–2011 period demonstrated 2.6 less intensity of abrasion and accumulation processes. One of the reasons is the end of active economic use of the Ochakiv Arm with intensive dredging works (until 1998) aimed at improving a 'Danube-Black Sea' transit shipping route conditions.

The conclusions reached in the course of this pilot research correspond to the results of long-term observations and field studies of hydro-morphological processes in the Danube Delta provided by DHMO experts in co-operation with the Geographic Faculty of the M.V. Lomonosov Moscow State University (*Hydrology of the Danube Delta*, 2004).

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