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Starodubtsev V.M., Faley V.G.

DNIEPER DELTA CHANGES UNDER IMPACT OF ECONOMIC ACTIVITY

National University of Life and Environmental Sciences of Ukraine,
Kiev, Heroiv Oborony 15

Стародубцев В.М., Фалей В.Г.

ИЗМЕНЕНИЯ ДЕЛЬТЫ ДНЕПРА ПОД ВЛИЯНИЕМ ХОЗЯЙСТВЕННОЙ ДЕЯТЕЛЬНОСТИ

Национальный университет биоресурсов и природопользования Украины,
Киев, Героев Обороны 15

Annotation. The changes in the Dnieper Delta landscape in conditions of water shortage were considered. It was marked the increase in processes of its overgrow with coastal-aquatic vegetation and trees and shrubs, as well as the "blooming" of water in estuaries and lakes. The danger of autumn-winter fires was highlighted.

Key words: delta, reservoir, vegetation, landscape, space imagery

Аннотация. Рассмотрены изменения ландшафтов дельты Днепра в условиях маловодья. Отмечено усиление процессов ее зарастания прибрежно-водной и древесно-кустарниковой растительностью, а также «цветения» воды в лиманах и озерах. Подчеркнута опасность осенне-зимних пожаров.

Ключевые слова: дельта, водохранилище, растительность, ландшафт

Introduction.

Regulation of river flows and economic activity in their basins leads to changes in the deltas environment [1]. This process takes on a global character, but manifests itself in different ways depending on the climate of the region, the morphological features of the deltas, sediment transport, characteristic of flow regulation and water use, water salinity, as well as a number of other factors. Processes in deltas are significantly depending on conditions of the confluence of the rivers in the waters bodies (sea, estuaries, and lakes) as well. Therefore, we investigate in the Black Sea basin [2-4] changes in the ecological status of the deltas of rivers flowing into the sea, and into the long estuaries (Dnieper, Dniester).

Object of research.

The Dnieper Delta is formed in a narrow long canyon, and it ends in the Dnieper-Bug estuary on the Black Sea coast. Its area is estimated by different sources from 24-26 to 30-33 thousand ha depending on which part of the water surface of the estuary is included in the delta area and where the top of the delta is determined. Our research is conducted in a contour from the road bridge across the Dnieper River to the estuary in an area of 37.4 thousand ha [4].

Results and discussion.

Flow regulation of the Dnieper began in 1932 with construction of the Dnieper HPP, but it did not affect much on the landscape of the river delta. More significant changes in the water regime of the delta and its ecosystems began in 1956, when large Kakhovka reservoir was filled. It was built for irrigation, energy, water supply and water transport. And then until 1975 the cascade of six reservoirs has been created with a total capacity of 43.8 km^3, useful capacity - 18.5 km^3 and water area - 7,000 km^2 (Fig. 1).

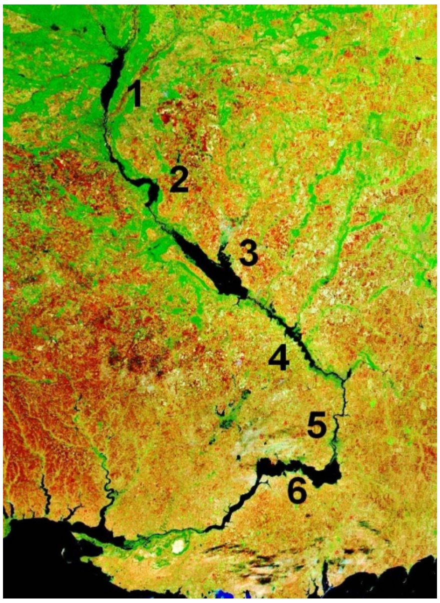

Fig.1. The cascade of reservoirs on the Dnieper River
1 - Kiev, 2 - Kanev, 3 - Kremenchug, 4 – Dneprodzerzhinsk, 5 - Dnieper, 6 - Kakhovka.

In the same period, large channels (North Crimean, Kakhovsky, Dnieper-Donbass, Dnieper-Ingulets) were built, which diverted water from the Dnieper River. They increased consumption of the Dnieper water for municipal, industrial and agricultural water supply. Because of this a flow of water and sediments into the delta reduced, water quality deteriorated, powerful flood spills virtually ceased and they happen now only in wet years. Deep restructuring of landscapes started, accumulative processes and extension of the delta into the Dnieper-Bug estuary significantly weakened [3, 4]. Schematic delta zoning on the basis of terrestrial research and analysis of Landsat satellite imagery for the period 1975-2013 made it possible to identify areas with different overgrow intensity by gigrophytic and hydrophytic vegetation, "blooming" of water, and to allocate anthropogenically modified territories [4]. However, in recent years, it was observed the shortage of water and a decrease in the Dnieper water flows from the Kakhovka reservoir into the delta, reaching in some periods of 300-500 m^3/s (Fig. 2). This has led to an increase of the delta overgrow with coastal-aquatic vegetation and to an extension of trees and shrubs on the “plavni” (wetlands) areas (Table). The area of human settlements and anthropogenically-altered territories markedly increased there and reached in 2015 more than 4 thousand ha. Efforts are being "Bloom" of water in estuaries and deltaic lakes of the delta also increased (Fig. 3).

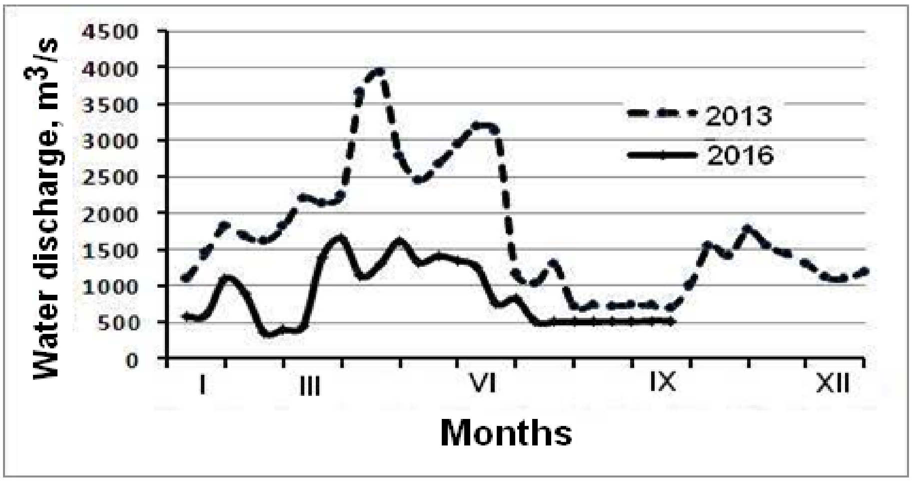

Fig. 2. Water discharge into the delta from the Kakhovka reservoir

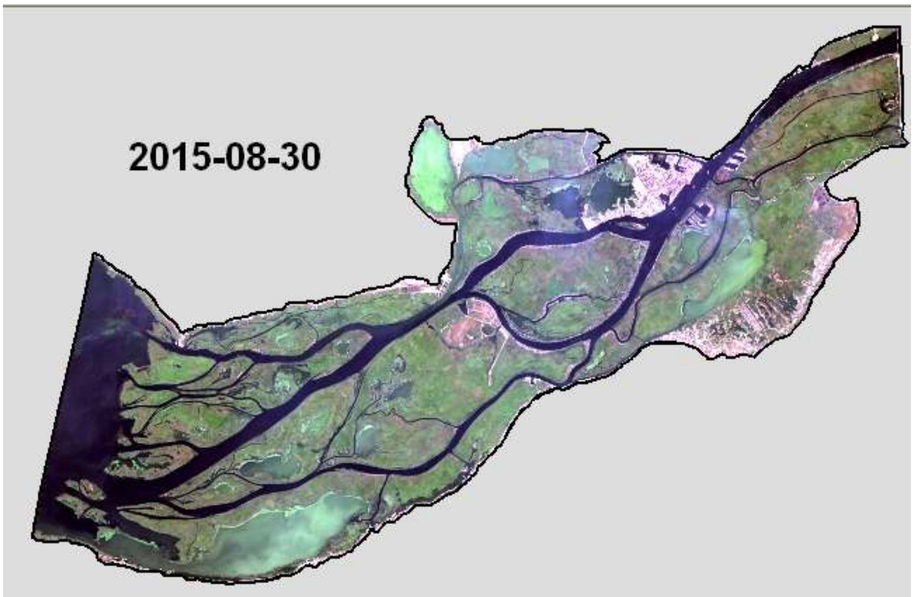

Fig. 3. Delta overgrows and water “bloom” on the Landsat 8 image

Table.

Perennial changes in deltaic grounds

Grounds	Area, ha		
	Dates of satellite imagery		
	13.07.1986	16.08.2010	30.08.2015
Water area	11606	11568	10464
Shallow water	2240	1564	1410
Water overgrown floating vegetation and marshes	4710	1334	1529
Human settlements and anthropogenically-altered area	1865	3181	4239
Wetlands (“plavni”) with shrubs and forest	9053	9510	13920
Wetlands with cattail and reed	7910	10227	5822
Total area	37384	37384	37384

It is important to note that large fires continue in the delta, affecting the entire biota. So, we revealed on satellite images the effects of large fires that occurred in the autumn-winter period 2015-2016 (Fig. 4). The total area of fires was more than 5 thousand ha. Of these, on the area of 2.8 thousand ha vegetation, including trees and shrubs, completely burnt out, and on the area of 2.2 thousand hectares - partly.

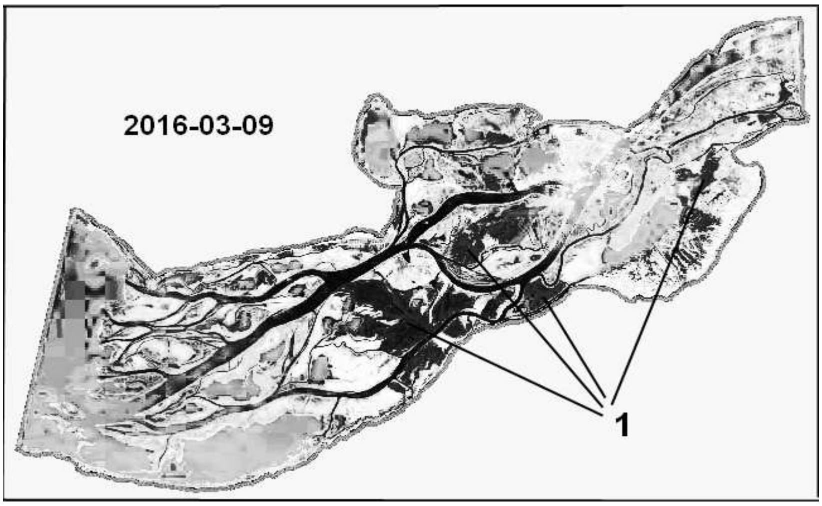

Fig. 4. Traces of fires in the Dnieper delta (1 - areas of burned vegetation)

Conclusions:

1. The Dnieper flow regulation and water shortages have contributed to increasing of delta overgrow with coastal-aquatic vegetation, increase the wetland areas with trees and shrubs, as well as the "blooming" of water in lakes and estuaries.

2. The area of human settlements and anthropogenically-altered areas markedly increased and reached more than 4 thousand in 2015.

3. In conditions of water scarcity the threat of fires in the delta during the autumn-winter period is increasing, the area of burned vegetation can reach more than 5 thousand hectares.

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Starodubtsev V.M., Bogdanets V.A.

DYNAMICS OF THE TSIMLYANSK RESERVOIR COASTLINE

National University of Life and Environmental Sciences of Ukraine,
Kyiv, Heroiv Oborony st., 15

Abstract. The features of the Tsimlyansk reservoir banks reshaping for more than 60 years are considered. There is analysis of the shoreline moving acceleration at the turn of the century as a result of changes in levels of amplitude fluctuations at higher and higher the reservoir elevations, due to the intensification of the water use and the reservoir management and silting. According to Terra and Landsat 2-8 satellites some impact on the shores dynamics is marked for the last five years because of water shortage. Graphical evaluation of the shoreline changes for the period 1977-2015 has been made.

Key words: Tsimlyansk reservoir, coastline, many-year dynamics, remote sensing.

Introduction. The Tsimlyansk Reservoir for many-year flow regulation was created in the middle of the Don River valley in the Volgograd and Rostov regions of Russia (now - Russian Federation). Its filling lasted from December 1951 to May 1953, which is like water facilities and the new natural and man-made system it is functioning since 1952. The reservoir accumulates the Don and Volga rivers water, supplied through the Volga-Don channel. This water inundated floodplains and terraces of the Don Valley and estuarine areas of its tributaries. The reservoir extends from the southwest of the dam at Tsimlyansk city to the north-east at 250 km to the town of Kalach-on-Don, where there is thinning of backwater [9]. The main morphometric characteristics are as follows: normal water level (NWL) - 36 meters of Baltic Sea system (mBS), level of the dead water (level of inactive storage capacity) - 31 mBS, full volume (total storage) - 23.86 km^3, working volume (effective storage) - 11.54 km^3, total water-surface area (at NWL) - 2702 km^2, average width at NWL - 10.4 km, the maximum - 38.0 km, the average depth at NWL - 8.8 m, maximum - 35.0 m, coastline length - 991 km. The total catchment basin above the dam HPP is estimated at 248 800 km^2, and above the town of Kalach-on-Don, where there is thinning of backwater - 221 600 km^2. Therefore, the actual reservoir watershed is 27,200 km^2.

Project of Volga-Don Canal with Tsimlyansk reservoir was created in the postwar years as the most important and ambitious water facilities, that has socio-economic importance. It was assumed, first of all, to provide transit navigation on the Volga-Don waterway for transport and economic connection in such a way the seas of the European part of Russia. The second problem was no less important - irrigation of arid land adjacent to the Tsimlyansk Reservoir and to the highway of the Volga-Don canal. And, of course, it was intended to produce electricity at Tsimlyansk hydroelectric power station (now the Rostov NPP is helping to solve this task).

Intensive creation of reservoirs, which developed in the last century in the former Soviet Union, was accompanied by the intensification of research aimed at assessing and forecasting the impact of these reservoirs on the environment. However, most scientific analysis was followed by the reservoirs construction. Only after that empirical data were accumulated and theoretically comprehended. Nevertheless, large-scale comprehensive study of the influence of reservoirs on the climate, vegetation, surface water and groundwater, "processing" (marginal erosion) the shores of reservoirs were developed at the Institute of Geography of the USSR, Moscow State University, Institute of Water Problems, Giprovodkhoz, Hydroproject, the Research Institute of Hydraulic Engineering and Amelioration, the Hydrometeorological Service of the USSR and many organizations of the former USSR republics. Whole scientific schools were formed under the direction of Vendrov S.L., Avakian A.B. and other prominent scientists. The results of these studies have been summarized in a number of monographs, in particular S.L. Vendrov [2], S.L. Vendrov and K.N. Dyakonov [3], A.B. Avakian et al [4], and later – K.K. Edelstein [14]. A special place among them is the book "The reservoirs and their impact on the environment". [5]. The first studies of the reservoirs impact on soil were associated with the names of V.A. Kovda, A.A. Rode, S.A. Vladychensky and other eminent soil scientists, summarized in our monograph [11] and later - in the brief English-language edition. [15].

Input data. Monitoring of environmental changes in the area of this reservoir initially carried out Tsimlyansk Reservoir Management [9] and Tsimlyanskaya Hydrometeorological Observatory [6, 7]. Already as of 1972 assessment of the SHI estimated forecasts and actual changes in the coastal line of the reservoir as a result of abrasion and accumulation processes has been made [13]. Builov V.V. et al [1] observed the backing-up of groundwater at a distance of 200-300 m in areas of low permeable clay and loam up to 10-12 km at the Tsimlyansky sands massiff. In flooded soils, they noted gleying, prairiefication (meadow features occurrence), carbonate leaching and other changes.

But the most comprehensive long-term study of environmental transformations was undertaken by expedition of the Institute of Water Problems of RAS in 2004-2013, which is used also most of the previously accumulated information [8, 10]. Scientific novelty of the work was associated with the development of the theory of ecologically destabilized environment as a special medium of the biota existence and maintenance of services in the conditions of the water regime transformation on a regional scale. Among the objectives of this study it was also to study the dynamics of the reservoir shoreline and assessment of the forecast convergence that was designed at reservoir creating.

Analysis of the data for the first 20 years of the reservoir operation [13, 10] showed that in 1972 the shoreline displacement rates were generally somewhat lower than forecast. At the same time the average rate of the coast displacement decreased by 1977, except of Primorsky and Vesely posts (Fig. 1), where unstable rock to erosion (mainly loam) were dominated.

It is noted that the abrasion, abrasion and landslip, abrasion-landslide processes reshaping coasts most clearly manifested in the southern, most deep and wide, part of the reservoir. On the flat left bank abrasion processes are much weaker. Special environmental conditions are formed on the sandy coast, which is easily eroded. At the site of hilly sands flat sandbar is formed, and sand carried into the reservoir and partly accumulated in the shallow waters of the flooded river mouths.

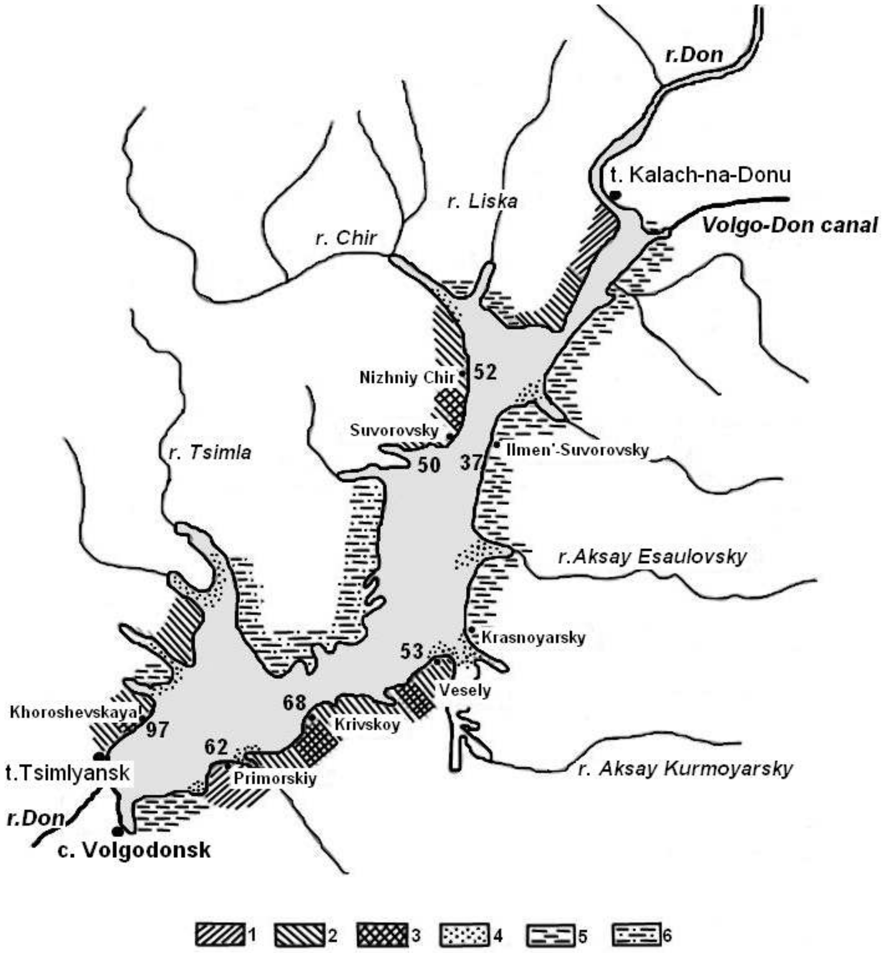

Fig.1. The types of beaches and shoreline displacement to 1972: *1 - abrasion type coast; 2 - abrasion-landslide; 3 - abrasion-landslip; 4 - flooded lower level; 5 – bay-like; 6 - accumulative; 7 – coastline changing is shown by figure [13].*

The acceleration of the Tsimlyansk Reservoir shoreline displacement in recent decades is an important feature of the coast transformation process (Table). This process, of course, linked to the nature of the reservoir operation, the intensification of the water management and its navigational use, as well as sedimentation and the formation of shallow water.

Table. Average Tsimlyansk reservoir observed displacement rate of shoreline on the forecast period. [10]

Name of profile	Average rate of shoreline displacement, m/year		
	1952-1965	1952-1972	1952-2002
Nizhny Chir	1,46	1,42	1,28
Suvorovsky	1,70	1,44	1,81
Khoroshevskaya	2,92	2,61	2,83
Primorskiy	5,56	5,96	6,34
Vesely	1,95	2,09	2,58
Ilmen'-Suvorovsky	1,46	1,40	2,82

Results and discussion. Researchers have rightly linked the acceleration of coastline displacement with the changes of the reservoir level fluctuations amplitude (Fig. 2). But it is very important to clearly understand that the significant decrease in the amplitude of fluctuations is observed at significantly higher levels of the reservoir, and it enhances the erosion of shores. In this regard, it seems to us somewhat premature conclusion about a possible continuation of the active, or even - acceleration, processes of shores transformation in many reservoirs in the multi-year plan, made by researchers with referring to our work [12].

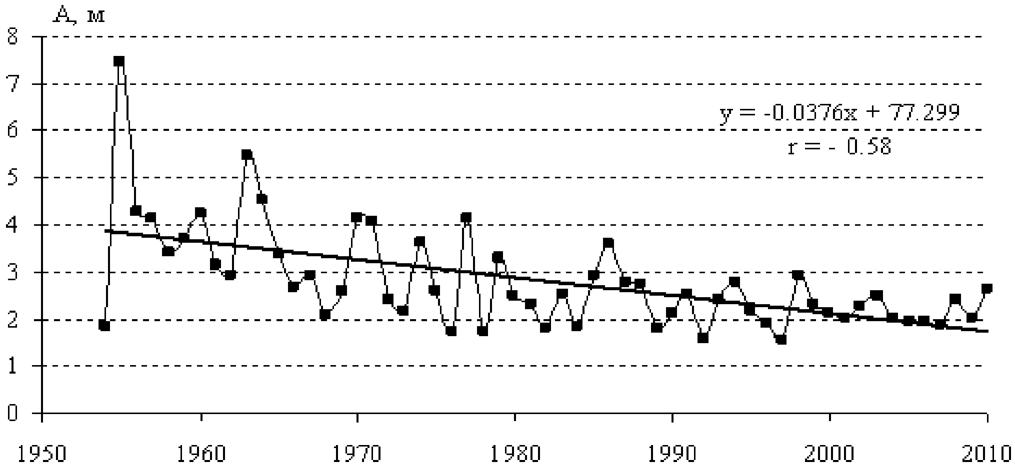

Fig. 2. Change of the amplitude of the reservoir level fluctuations [10].

In assessing the transformation of the reservoir shores and the displacement of its coastline in recent years, one must also consider the outlined since 2011 water scarcity, which is significantly increased by the end of 2015. The Terra satellite image (09.12.2015) clearly reflects the shallows along the coast, especially near the sandy massif on the right bank and along the flat part of the left bank (Fig. 3).

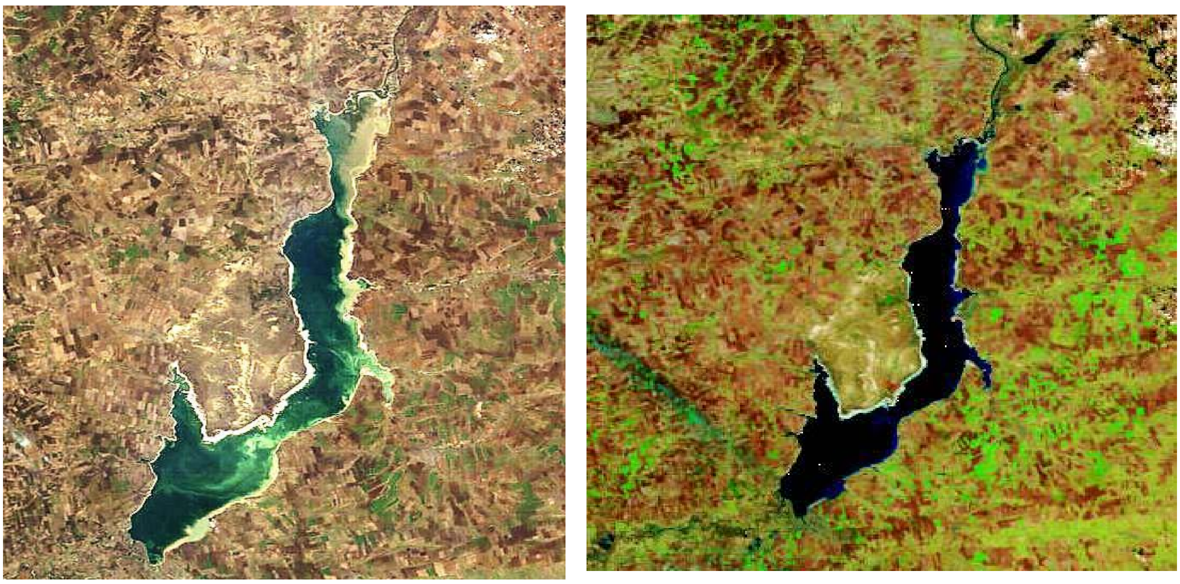

Fig. 3. Tsimlyansk reservoir shallowing (Terra satellite, 9 December 2015): Left - a combination of channels 1-4-3 ("true color"), the right - 7-2-1, reflecting the state of vegetation.

Fig. 4 shows a series of Landsat satellite images for the period 1977 - 2015, reflecting the coast landscape of reservoirs in the visible spectrum ("true color"). Landsat-2 image quality in 1977 is low, but it lets see well enough the coast line of the reservoir.

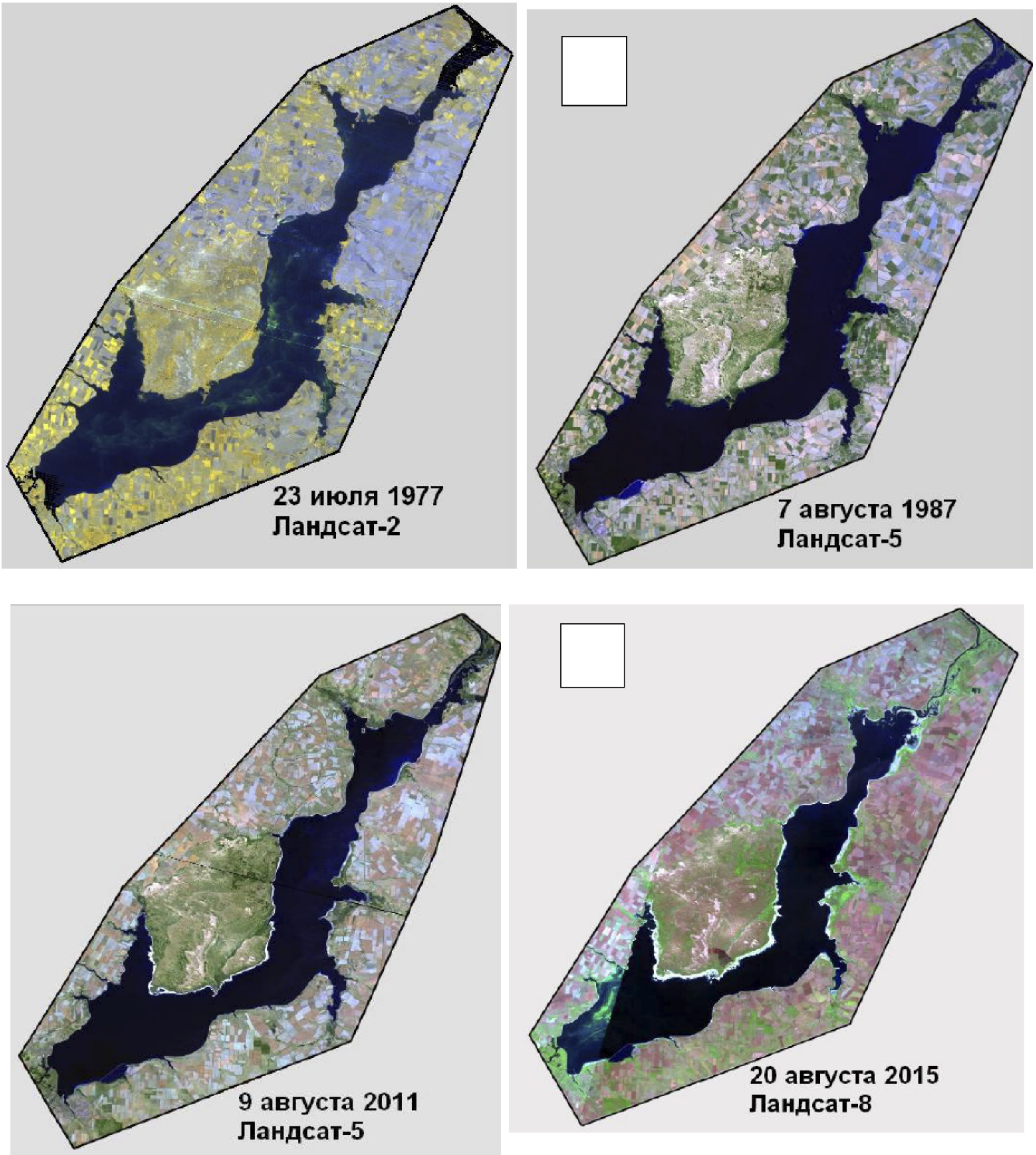

Fig. 4. Tsimlyansk Reservoir coast landscapes: A - 1977 (Landsat-2), 1987 (Landsat-5); B - 2011 (Landsat-5), 2015 (Landsat 8).

The quality of the images Landsat 5 (2011) and Landsat-8 (2015) allows us to trace the formation of shoals because of low water in this period, and drying bays of the rivers flowing into the reservoir. The classification of these satellite images with ERDAS imagine program showed that in a relatively comparable data the water surface area has decreased significantly from 241,623 hectares in 1977 to 218,933 ha in 2011 and to 189 367 ha - in 2015. Naturally, these areas are not strictly linked to the reservoir level marks in those years, therefore a correction is required. We attempted to make an approximate estimation of the reservoir shoreline dynamics on satellite images as well (Fig. 5).

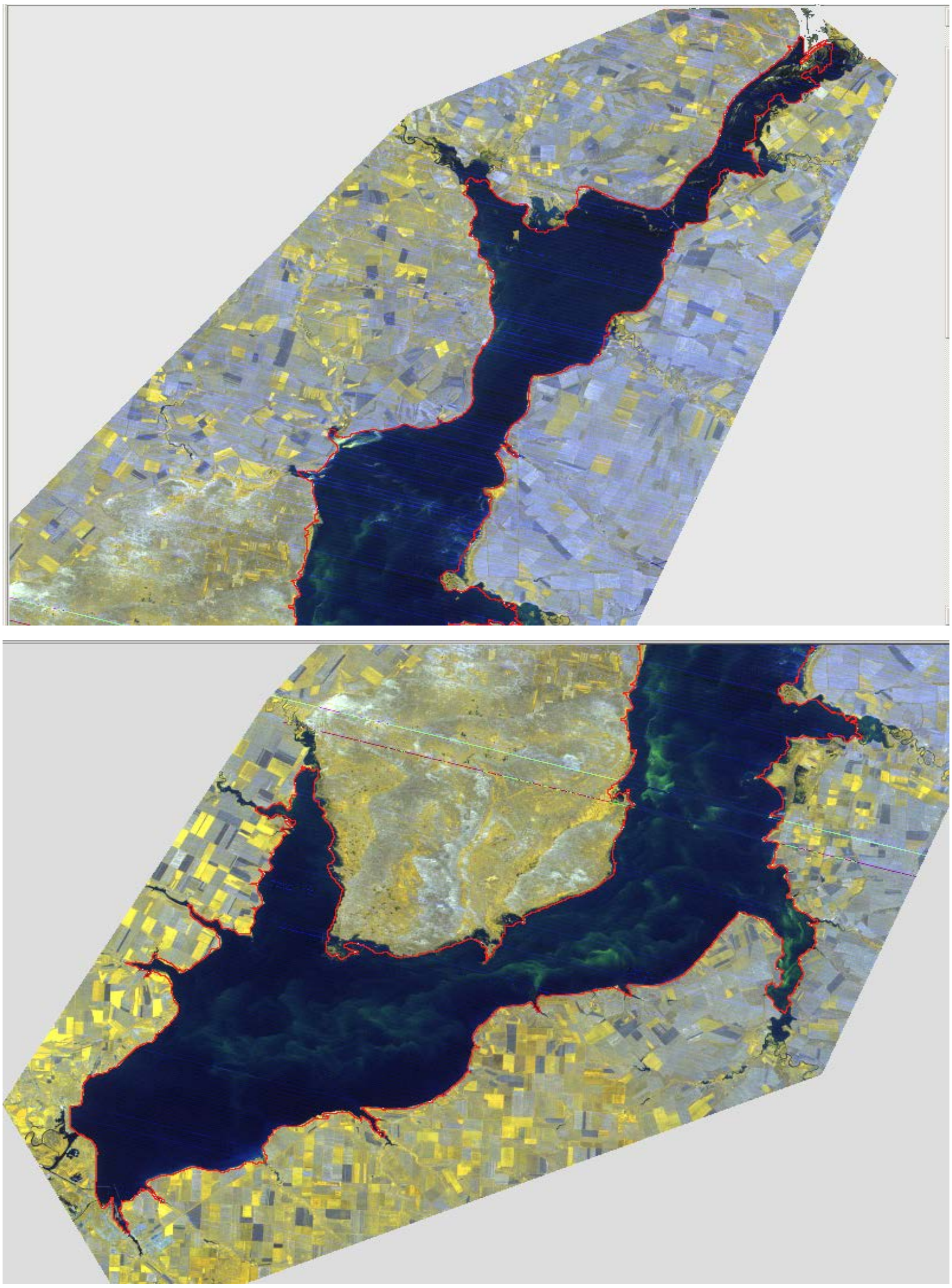

Fig. 5. Change in the Tsimlyansk reservoir shoreline for the 1977-2015 according to the Landsat satellites.

Imposition of coastline in 2015 on the image in 1977 showed the most significant changes, especially in the areas of sediment accumulation in estuaries. The processes of coastal erosion are shown very schematically, taking into account the spatial resolution of Landsat-2 images 60 m. Thus, the proposed scheme of the coast dynamics with Landsat imagery use cannot replace ground-based observations, but can significantly optimize the choice of ground profiles. Thus, the proposed scheme is the coast of the dynamics with Landsat imagery use cannot replace ground-based observations, but can significantly optimize the choice of ground profiles. The accuracy of the observations can be significantly enhanced when using the detailed satellite images with high spatial resolution.

Conclusions.

1. Changes in the water management and navigational use of the Tsimlyansk reservoir in recent decades led to a some strengthening of the coast erosion [10]. This was due to the decrease of the amplitude of water level fluctuations, but on much higher elevations of the reservoir. Therefore, since this substantial change in the regime of reservoir water management the processes of the shores reshaping should be viewed as a new stage, rather than as a natural continuation of these processes, applying to the situation in other reservoirs.

2. Comparison of Landsat satellite images for the period 1977-2015 allowed very roughly identifies sedimentation and extension of small rivers mouths into reservoir to 1 km and medium rivers (river Chir, Tsimla, Aksay.) - up to 2-2.5 km. Displacement of coastline due to high banks abrasion during this period amounted to 0-60 m, only on protrudent in the reservoir areas and on easily washed plots – up to 120 m (between river Don and river Chir, river Tsimla and dam, river Aksai Kurmoyarsky and dam). In the areas on the left bank with low and flat bay-like banks the processes of sediment accumulation and shoreline displacement into reservoir by 60-120 meters dominated. On the coast of sandy massif on the right bank of the reservoir an accumulation of sediment and shoreline displacement ranged from 60 to 300 m. The largest reservoir sedimentation occurred in the area between the Volga-Don Canal and the mouth of the river Donskaya Tsaritsa, where the fragments of delta-like landscapes are formed. Here, the coastline has shifted to 200-500 m.

3. In general, changes in shoreline of the Tsimlyansk reservoir for all the years of its existence was less than projected by the State Hydrological Institute. [10]. However, it does not make less urgent the coastal protection from abrasion processes.

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