

Impact of flow regulation on land cover changes in river deltas of the Black Sea basin

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Deltas play an important economic and social role, especially in connection with water use intensification for power, irrigation, water supply and other purposes. However, excessive use of water resources since the last century has led to a decrease in water and sediment inflow into the deltas and a change in their landscapes.

Monitoring of changes in the environmental state of deltas, long-term and seasonal dynamics of the processes of landscapes flooding or drying, we explore using Landsat satellite imagery and ground-based observations in the deltas of the Black Sea Basin, Central Asia and other regions.

We have proposed a generalized schematic classification of degradation processes in deltas, occurring under the impact of flow regulation and economic activity:

1. Depending on the climate zone such processes occur in deltas:
 - a) Arid and sub-arid zone - desertification, salinization, deflation.
 - b) Sub-humid zone - steppification of hydromorphic soils, poor soil salinity and alkalinity, in some cases - desertification.
 - c) Humid zone - draining and degradation of wetlands and peat soils.
2. Depending on the geomorphology conditions:
 - a) Continental (inland) deltas (Chu, Talas, Tarim, Heihe, etc.): fast and severe desertification and salinization, deflation.
 - b) Continental (inland) deltas, in which transfer of runoff takes place (Tejen, Murgab, etc.) - in the peripheral parts of them: flooding, waterlogging, salinization, desertification, deflation.
 - c) Deltas on the coast of inland water bodies (sea, lake) - (Ili, Syrdarya, etc.): desiccation, desertification, salinization, deflation.
 - d) Deltas in estuaries and narrow bays (Dnieper, Dniester, etc.): desiccation, overgrowing with hydrophytes and hygrophytes, meadow and riparian forests formation, weak salinity.
 - d) Deltas in marine gulfs (Colorado, Euphrates, etc.): sea water intrusion into the delta, salinization, desertification, deflation.
 - e) Deltas on the coast of the seas and oceans (Nile, Yellow, Mississippi, etc.): abrasion of a sea edge of the delta, an intrusion of sea water, draining, desertification, salinization.
3. Depending on land use in deltas:

- a) Rice cultivation: irrigated lands waterlogging and surrounding landscapes salinization (Syrdarya, Amudarya, Mekong, etc.).
 - b) Intermittent irrigation of industrial, cereal crops and forage: drainage and desalination of irrigated lands and salinization and waterlogging of peripheral parts of deltas (Tejen, Murgab).
 - c) Laying-in of fodder (reed and other macrophytic plants) in deltaic wetlands: drainage with water furrows, deltaic lakes dewatering and overgrow, partly – soil degradation and salinization (Ili, Chu, Dniester, Danube).
 - d) Recreational, housing and industrial construction in deltas: drainage of landscapes, new lands inwash (especially at riverine levees), waste water discharge, river water “blooming”, etc (Dnieper, Danube, Don).
4. As a universal process in all types of deltas: subsidence of the earth's surface depending on the intensity of river flow regulation, a predominance of organic matter (peat) in soils, economic activity (especially in the deltas with megacities - Bangkok, Dhaka, Yangon, New Orleans, etc.).
5. Special processes will take place in deltas due to forthcoming sea level rise. Their intensity will depend on deltas topography.

In the Black Sea basin the processes of landscape changes in the deltas of rivers flowing into the deep tide-free sea (Danube, Kizilirmak, Rioni), into the shallow sea (Don, Kuban), as well as into large estuaries (Dnieper, Dniester) are studied (Fig.1).



Fig.1. The Black Sea basin (River basins: 1 – Danube, 2 – Dniester, 3 – Dnieper, 4 – Don, 5 – Kuban, 6 – Rioni, 7 – Yesilirmak, 8 – Kizilirmak).

In the Danube River delta decreased inflow of water and sediment, changed seasonal and long-term hydrological regime as a result of flow regulation and economic activity in the basin. Therefore, in the delta of about 800-900 ha / year water surface is transformed into a land of lakes or wetlands due to siltation of

reservoirs or economic activity. At the same time, the abrasion processes on the sea coast, as well as some renaturalisation of previously cultivated wetlands reduces the area of terrestrial ecosystems at a speed of 400-500 ha / year. Consequently, the overall balance in the delta is formed in the direction of reducing the water surface and increasing the area of terrestrial, hygrophytic and hydrophytic ecosystems (Fig.2).

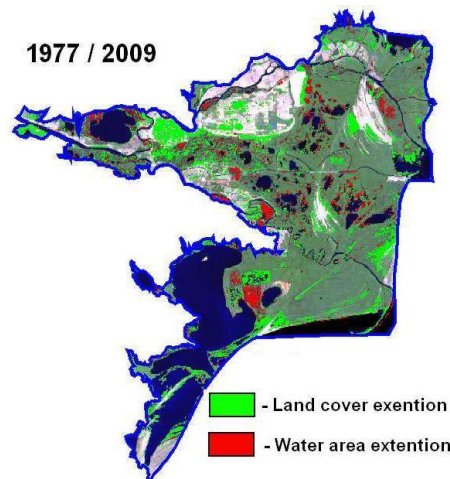


Fig.2. Land cover change detection in the Danube delta.

However, these changes are very dynamic in the years of different water content and manifest themselves differently in various parts of the delta that we study on seven key sections (Fig.3).

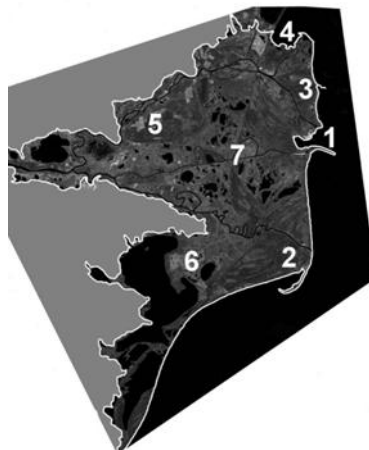


Fig.3. Key sections in the Danube delta.

Key section 1 characterizes land cover changes in the area between the Kiliya and Sulina river canals, section 2 – near the St. George canal, section 3 – near the Bystroe canal, section 4 – near the Ochakov canal, section 5 – agricultural lands, section 6 – area near the Rezim lake, section 7 – near the Sulina canal.

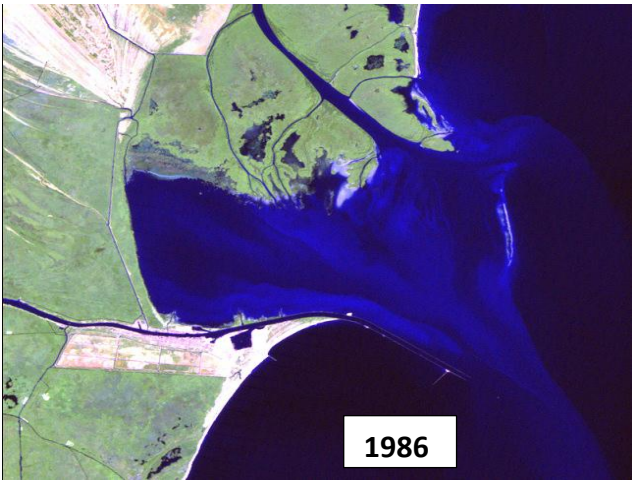


Fig.4. Key section 1.

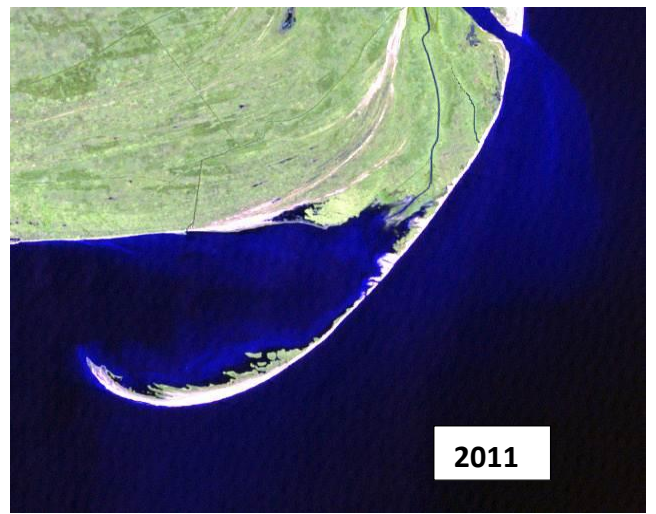
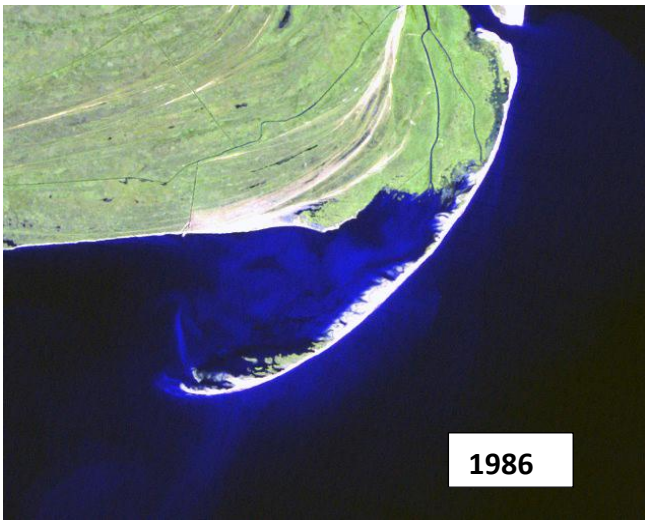


Fig.5. Key section 2.

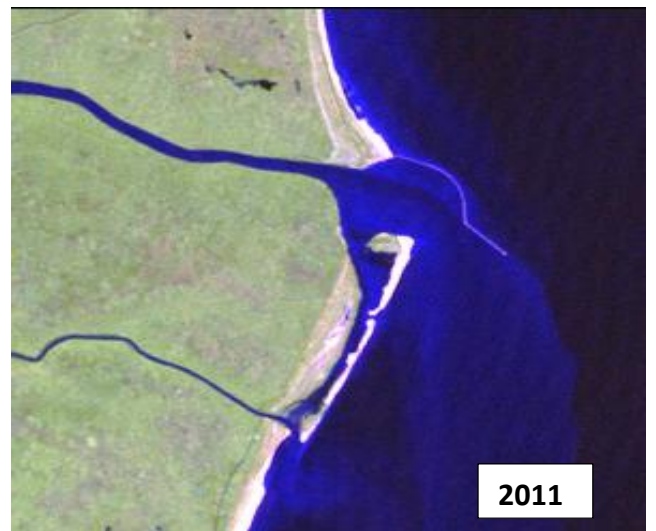
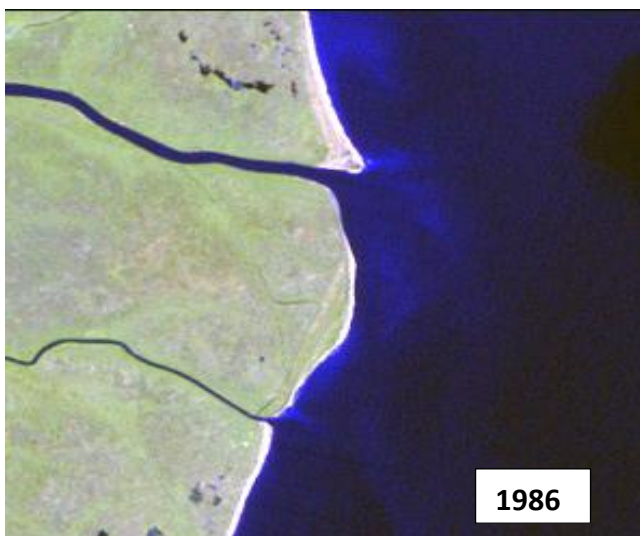


Fig.6. Key section 3.

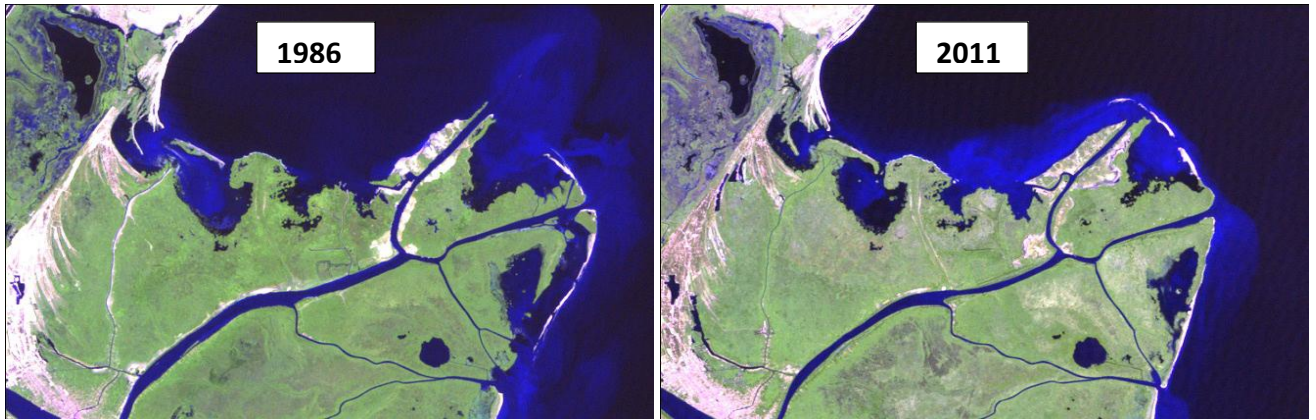


Fig.7. Key section 4.

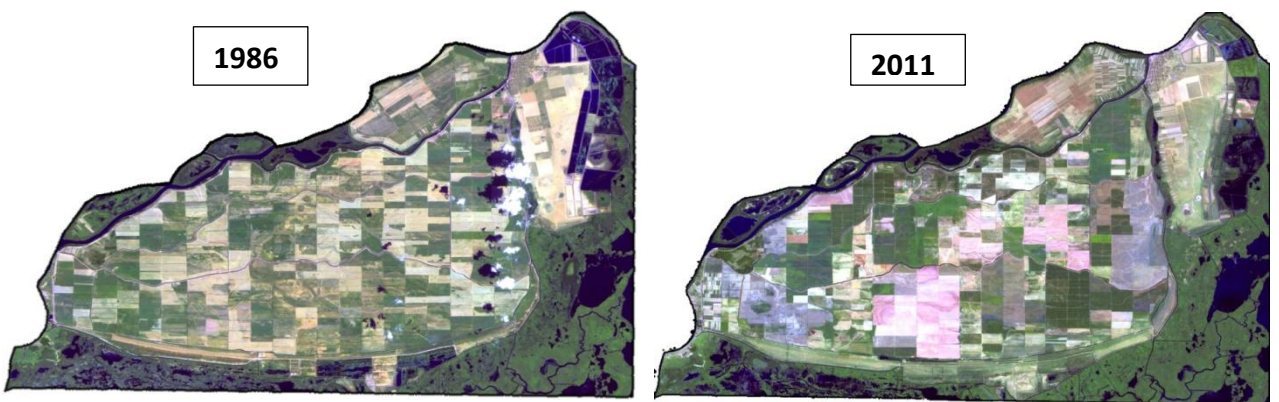


Fig.8. Key section 5.

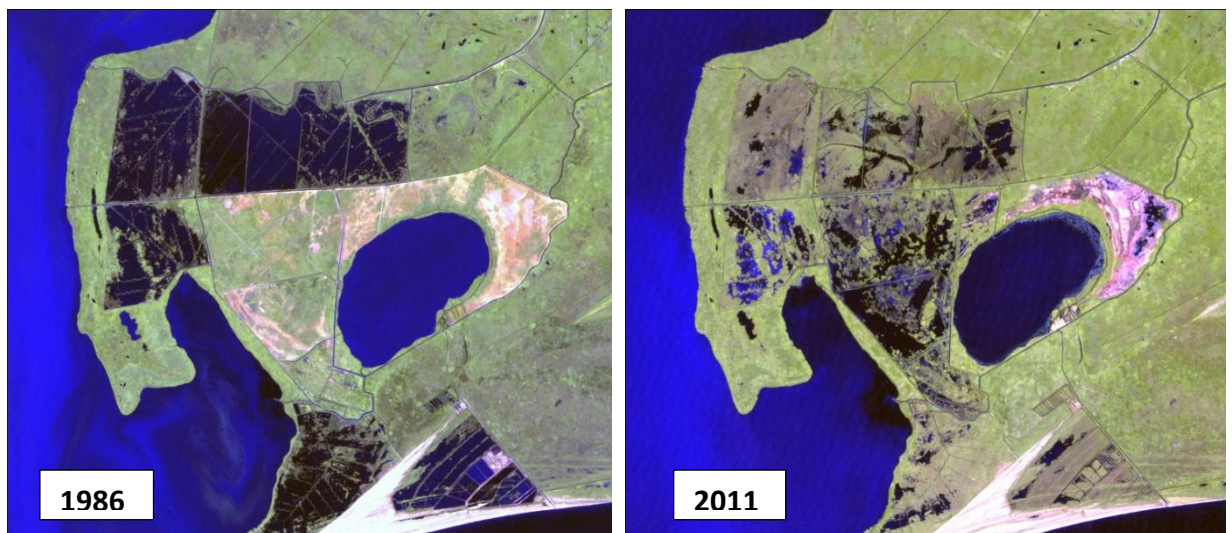


Fig.9. Key section 6.



Fig.10. Key section 7.

Table 1. Land cover changes in key sections of the Danube delta.

Type of surface	1986	2011	Changes, ha
Key section 1.			
Deep water	19885,1	18422,1	-1463,0
Shallow water	599,4	1271,4	+ 673,0
Reedstand and cattail with strips of sandbars and buildings	14167,0	14957,1	+ 790,1
Total key-1 area	34651,6	34651,5	
Key section 2.			
Deep water	10341,5	11454,9	+1113,4
Shallow water (plume)	6527,3	8428,5	+1901,2
Slightly overgrown water area	3150,7	226,2	-2924,5
Overgrown water area	-	226,4	+226,4
Water area (total)	20019,5	20336,0	+316,5
Marsh land strongly watered	383,7	-	-383,7
Marshes with reedstand and cattail	7589,0	5238,0	-2351,0
Dense reedstand and cattail with sands	2564,6	4982,9	+2418,3
Total area	30556,8	30556,9	
Key section 3.			
Deep water	3276,9	3011,7	-265,2
Shallow water	596,2	701,1	+104,9
Overgrown water area	58,4	59,3	+0,9
Sandbars	49,4	78,9	+29,5
Marshes	1961,7	1306,2	-655,5
Dense reedstands and cattail with bushes (riverine levees)	1490,0	2275,4	+785,4
Total area	7432,6	7432,6	
Key section 4			

Deep water	8195,1	9771,5	+1576,4
Shallow water	4526,6	2778,8	-1747,8
Overgrown water area	1367,2	1070,6	-296,6
Marshes strongly watered	4066,8	2262,1	-1804,7
Marshes with reedstand, cattail and sandbars	8171,5	6839,4	-1332,1
Dense reedstands and cattail with trees and bushes (riverine levees)	1317,9	4922,7	+3604,8
Total area	27645,1	27645,1	
Key section 5.			
Water area	5281,2	3815,8	-1465,4
Marshes	13817,3	4632,3	-9185,0
Waterlogged arable land	8080,8	14196,7	+6115,9
Wet fields (forage crops)	12712,9	21290,5	+8577,6
Dry fields (crops)	12164,1	8099,5	-4064,6
Built-up areas	1079,5	1100,5	+21,0
Total area	53135,8	53135,3	
Key section 6.			
Water area	18521,2	16030,9	-2500,3
Water, strongly overgrown with macrophytes	2203,5	2560,6	+357,1
Marshes	6059,1	5679,8	-379,3
Reedstand and cattail with sand plots	13137,5	10707,6	-2429,9
Uplands and drying wetlands	4942,5	9884,5	+4942,0
Total area	44863,7	44863,4	
Key section 7.			
Water of lakes	743,4	672,8	-70,6
Shallow waters (slightly overgrown)	415,5	-	- 415,5
Water, overgrown with macrophytes	861,1	453,2	-407,9
Marshes and water	1403,5	964,9	-438,6
Reedstand and cattail	1715,7	2344,6	+628,9
Uplands at riverine levee	278,6	961,2	+682,6
Total area	5417,8	5396,5	(-27,3)