

**COASTLINE CHANGE IN THE SAKARYA RIVER MOUTH (TURKEY)**

V. M. STARODUBTSEV, Doctor of Biology, Professor

*National University of Life and Environmental Sciences of Ukraine**E-mail: vmstarodubtsev@ukr.net*<https://doi.org/10.31548/dopovidi2019.04.001>

**Abstract.** *Changes in the coastline of the mouth area of the Sakarya River (one of the large Turkey Rivers, flowing into the Black Sea) due to the relative imbalance of the processes of water and sediment flow of the river, on the one hand, and processes of coastal erosion by sea currents and waves, on the other, that is especially characteristic for the south and east the Black Sea coast. are revealed. For this, Landsat 4, 5 and 8 satellite images for the period 1985-2018 were used, as well as Google Earth cartographic service. Within the study area about 40 hectares of coastal land were destroyed for this time. And in the mouth area itself, the area of wetlands decreased by 100 hectares due to a decrease in the inflow of river water, as well as intensive economic and recreational activity. Due to the peculiarities of the water masses circulation in the sea, the western part of the coast at the mouth of the Sakarya river more eroded. And the eastern part in recent decades has been actively protected from erosion by special structures, infrastructure and port facilities. To analyze satellite images, we used the ERDAS imagine program, the isodata algorithm.*

**Key words:** *coastline, river mouth, flow regulation, space image*

**Introduction.** Changes in land cover in deltas of rivers with regulated flow have become one of the major environmental problems in the construction of dams and reservoirs. The most rapidly large-scale processes of land cover degradation and desertification appeared in the river deltas of the arid zone, primarily in the Colorado delta [3], and then in the river deltas of Central Asia [10-12] and other regions of the world [14]. The land cover in the river deltas of the more humid regions changed more slowly. There the main driving factor was the reduction of water inflow and sediment due to the construction of dams and an increase in water consumption for

household needs. At the same time, in the deltas of rivers flowing into the seas and oceans, the relative equilibrium between the processes of accumulation of sediment, brought by rivers, and erosion by sea currents and wave activity was broken. From these positions, the situation in the deltas of the Black Sea basin is of interest. Especially on the southern coast of the sea, river deltas are under the active influence of sea currents and waves. Let's consider this situation on the example of the river Sakarya mouth in Turkey.

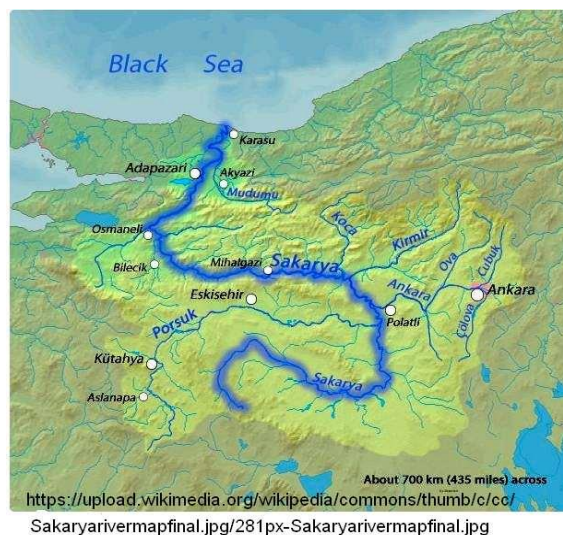
**Characteristics of the object.**

Sakarya is one of the major rivers flowing into the Black Sea from the

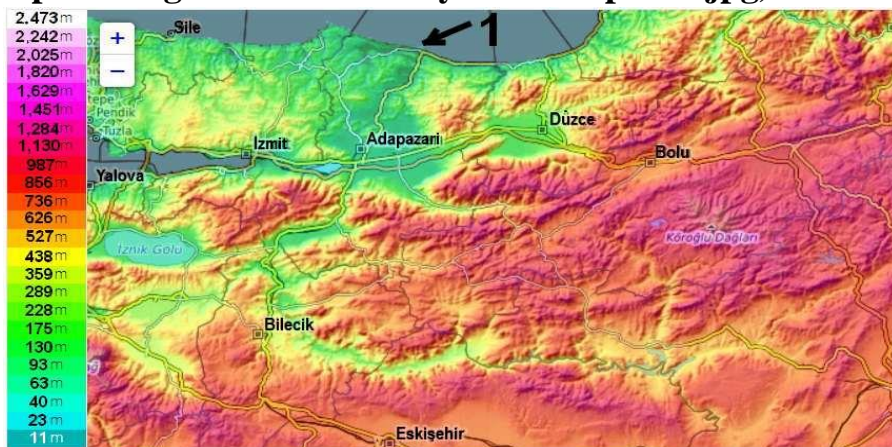
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north-western part of the Asia Minor peninsula (Turkey). The river flows along the Anatolian plateau, cuts through the western extremity of the Pontic Mountains and flows into the Black Sea (Fig. 1, 2). Its length is 824 km, the catchment area is 65,000 km<sup>2</sup>, the average water discharge is about 200 m<sup>3</sup> / s, and the largest tributaries are the Porsuk and Ankara rivers. The river flow exceeded 6 km<sup>3</sup>, and after the flow was regulated by the reservoirs it decreased to 4.75 km<sup>3</sup> [8, 9]. On the main channel of the river, 3 large dams with reservoirs were constructed (Fig. 3) – the Sarıyar (125 km from the

Ankara city) with HPP and with total water capacity 1,910,000,000 m<sup>3</sup>, the Gökçekaya (60 km downstream from Sarıyar), created for irrigation, and the Yenice with HPP (57,600,000 m<sup>3</sup>). At the tributary of the Sakarya was built Akçay Dam with HPP (910,000,000 m<sup>3</sup>). Moreover, many small and middle dams were constructed in the all river basin [8], and new dams are projected. As the result, water flow decreased at about 20%, and sediment – at 45-65% [5, 8, 9]. The process of erosion and deepening of the river bed below the dams was also revealed [2, 5, 8. 9].



**Fig. 1. The Sakarya River basin**  
 (https://en.wikipedia.org/wiki/File:Sakaryarivermapfinal.jpg)



**Fig. 2. Digital map of the topography (1 – the Sakarya River mouth)**

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In the lower reaches, the Sakarya River flows along the accumulative plain and does not form a pronounced delta, falling into the sea in one channel. The Lower Sakarya Basin has a mild climate. Rainfall averages about 770 mm/year and is fairly well distributed throughout the year with the heaviest rains occurring in winter and early spring months. Snowfall is relatively

light and average between 20 to 30 cm/year. The frost-free period ranges from 355 to 360 days [4, 8]. About half of the land cover of the basin is occupied by forests. However, it was observed that the forest was destroyed and converted into agricultural lands by the rural population of the area [1, 13]. In the river basin grown tobacco, wheat, sugar beets.

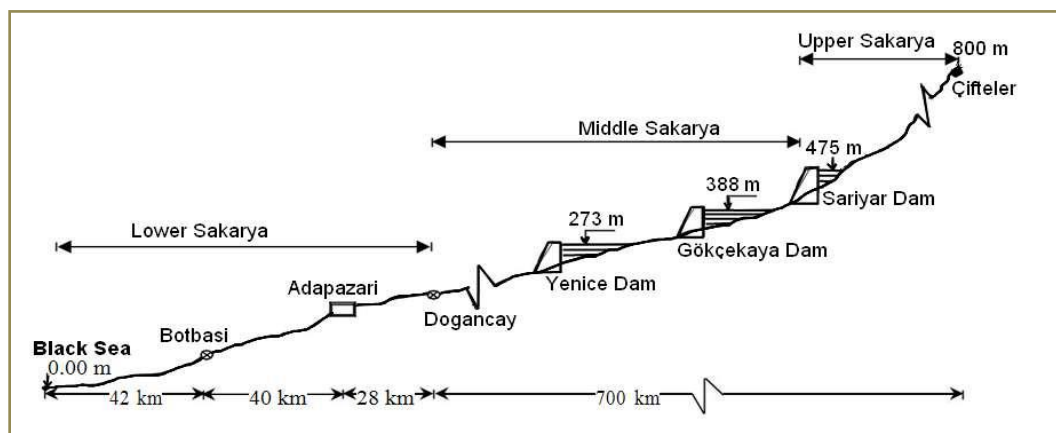


Fig. 3. Dams at the Sakarya River [8]

**Methods of investigation.** For the analysis of changes in the coastline near the mouth of the Sakarya River, satellite images of Landsat 4, 5 and 8 were used. The visualization of the images was performed by the ERDAS imagine program, and the analysis of the land cover of the estuarine region of the river – by the so-called unsupervised classification. In addition, to assess the rate of coastal retreat due to erosion processes, the Google Earth cartographic was used.

**Results and discussion.** For the analysis of changes in the coastline at the Sakarya River mouth, both the decrease in the inflow of water and

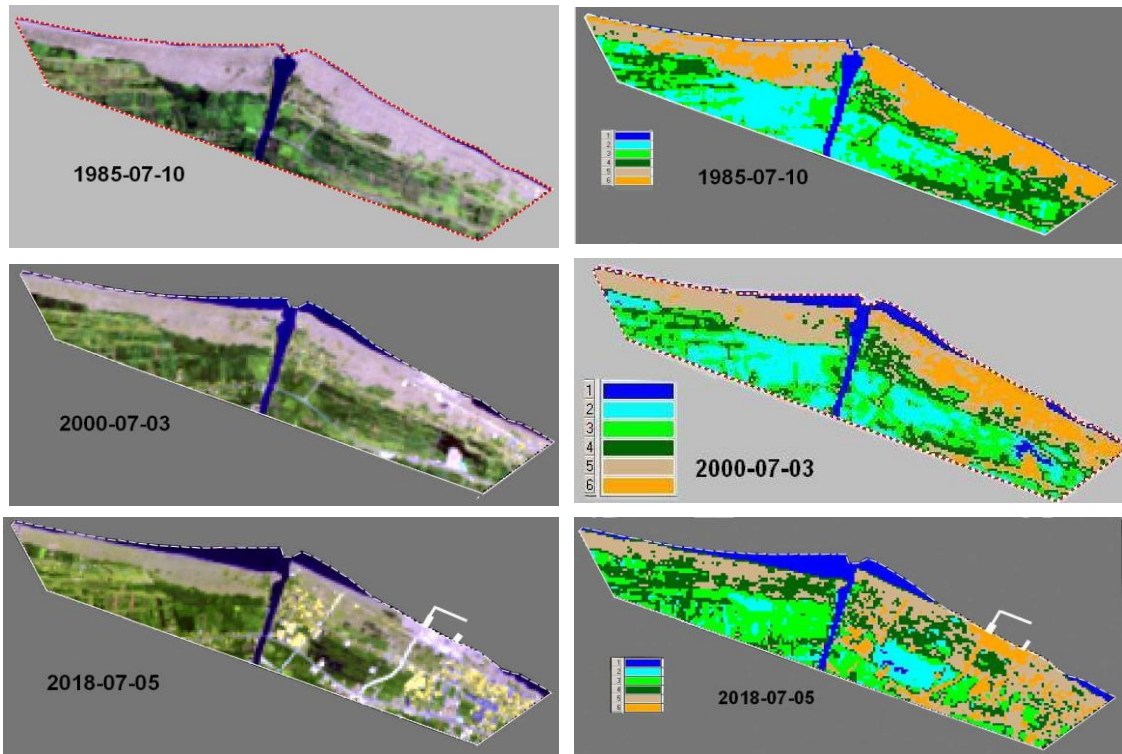
sediment due to flow regulation by reservoirs, and the impact of sea currents and wave activity are briefly considered. As already noted, the water flow in the estuary (delta) decreased by about 20%, and the sediment discharge decreased by 45-65%. At the same time, alongshore currents and waves continued to destroy the coast, unless special defenses and infrastructure were created.

Active currents along the southern coast of the Black Sea are mainly directed from west to east, although local currents with a reverse direction are also observed [6, 7]. Therefore, in the first place, the western parts of the

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relief elements protruding into the sea are eroded. Comparison of satellite images of the Sakarya River mouth for the period 1985–2018 showed that it was the western part of the river mouth

that was washed out more intensively (Fig. 4). And the eastern part of the estuary area was fixed by special structures and the coastline here retreated much slower.



**Fig. 4. Coastline and land cover change at the Sakarya River mouth (left – true color, right – classified images)**

Within the territory investigated by us, the land area decreased by 40 hectares due to the advance of the sea. At the same time, there was a decrease in the area of wetlands by 100 hectares due to the general drying up of the river's around area while the river was regulated. At the same time, there was a decrease in the area of wetlands per 100 hectares due to the total desiccation of the river mouth area when the flow was regulated. The use of the “historical” function of the cartographic service “Google Earth” made it possible to more specifically determine the rate of

retreat of the estuary area shores over the past 15 years (Fig. 5). These data showed that the western part of the coast retreated over these years by 130 m, that is, by 8–9 m / year. And the eastern (fixed) part of the mouth retreated only by 20 m or 1-2 m / year. Consequently, the protection of the coast and infrastructure proved to be quite effective.

**Conclusion.** The analysis of Landsat satellite images and the use of the Google Earth mapping service revealed the changes in the coastline of the mouth area of the Sakarya River

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under the influence of sea currents and waves in the face of decreasing water flows and sediments. Within the study area for the period 1985-2018 about 40 hectares of land were destroyed, and the area of wetlands in the estuary area decreased by 100 hectares. The asymmetry of the manifestation of the banks abrasion was revealed - in the

western part of the mouth of the Sakarya River, the shore retreated in the last 15 years at a speed of 8-9 m / year, and in the eastern part - 1-2 m / year. Strengthening the coast on the east side proved to be quite effective for protecting land and infrastructure from destruction.



**Fig. 5. Coastline change at Google Earth (left) and bank protection in the Sakarya River mouth (right).**

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## ИЗМЕНЕНИЯ БЕРЕГОВОЙ ЛИНИИ В УСТЬЕ РЕКИ САКАРЬЯ (ТУРЦИЯ)

В. М. Стародубцев

**Аннотация.** Выявлены изменения береговой линии устьевой области реки Сакарья (одной из крупных рек Турции, текущих в Черное море) вследствие относительного нарушения баланса процессов притока воды и наносов реки, с одной стороны, и процессов абразии берегов морскими течениями и волнами, с другой, что особенно характерно для южного и восточного побережья Черного моря. Для этого использовались космические снимки Ландсат 4, 5 и 8 за период 1985-2018 г.г., а также картографический сервис Google Earth. В пределах исследованной территории за период 1985-2018 гг. было разрушено 40 га земель побережья. А в самой устьевой области уменьшилась площадь переувлажненных земель на 100 га в связи с уменьшением притока речной воды, а также интенсивной хозяйственной и рекреационной деятельности. В связи с особенностями циркуляции водных масс в море более интенсивно размывалась западная часть побережья в устье реки Сакарья. А восточная часть в последние десятилетия активно защищалась от эрозионных процессов специальными сооружениями, инфраструктурными и портовыми объектами. Для анализа космических снимков использовалась программа ERDAS imagine, алгоритм isodata.

**Ключевые слова:** береговая линия, устье реки, регулирование стока, космический снимок

**ЗМІНИ БЕРЕГОВОЇ ЛІНІЇ В УСТІ РІЧКИ САКАР'Я (ТУРЦІЯ)****В. М. Стародубцев**

***Анотація.** Виявлені зміни берегової лінії гирлової області річки Сакар'я (одної з великих річок Туреччини, що течуть у Чорне море) унаслідок відносного порушення балансу процесів притоку води і наносів річки, з одної сторони, і процесів абразії берегів морськими течіями і хвилями, з другої, що особливо характерно для південного і східного узбережжя Чорного моря. Для цього використовувались космічні знімки Ландсат 4, 5 і 8 за період 1985-2018 рр., а також картографічний сервіс «Планета Земля». В межах дослідженої території за період 1985-2018 рр. було зруйновано 40 га земель узбережжя. А в самій гирловій області зменшилась площа перезволожених земель на 100 га у зв'язку із зменшенням притоку річкової води, а також – інтенсивної господарської і рекреаційної діяльності. У зв'язку з особливостями циркуляції водних мас в морі більш інтенсивно розмивалась західна частина узбережжя в усті річки Сакар'я. А східна частина в останні десятиліття активно захищалась від ерозійних процесів спеціальними спорудами, інфраструктурними та портовими об'єктами. Для аналізу космічних знімків використовувалась програма ERDAS imagine, алгоритм isodata.*

***Ключові слова:** берегова лінія, гирло річки, регулювання стоку, космічний знімок*