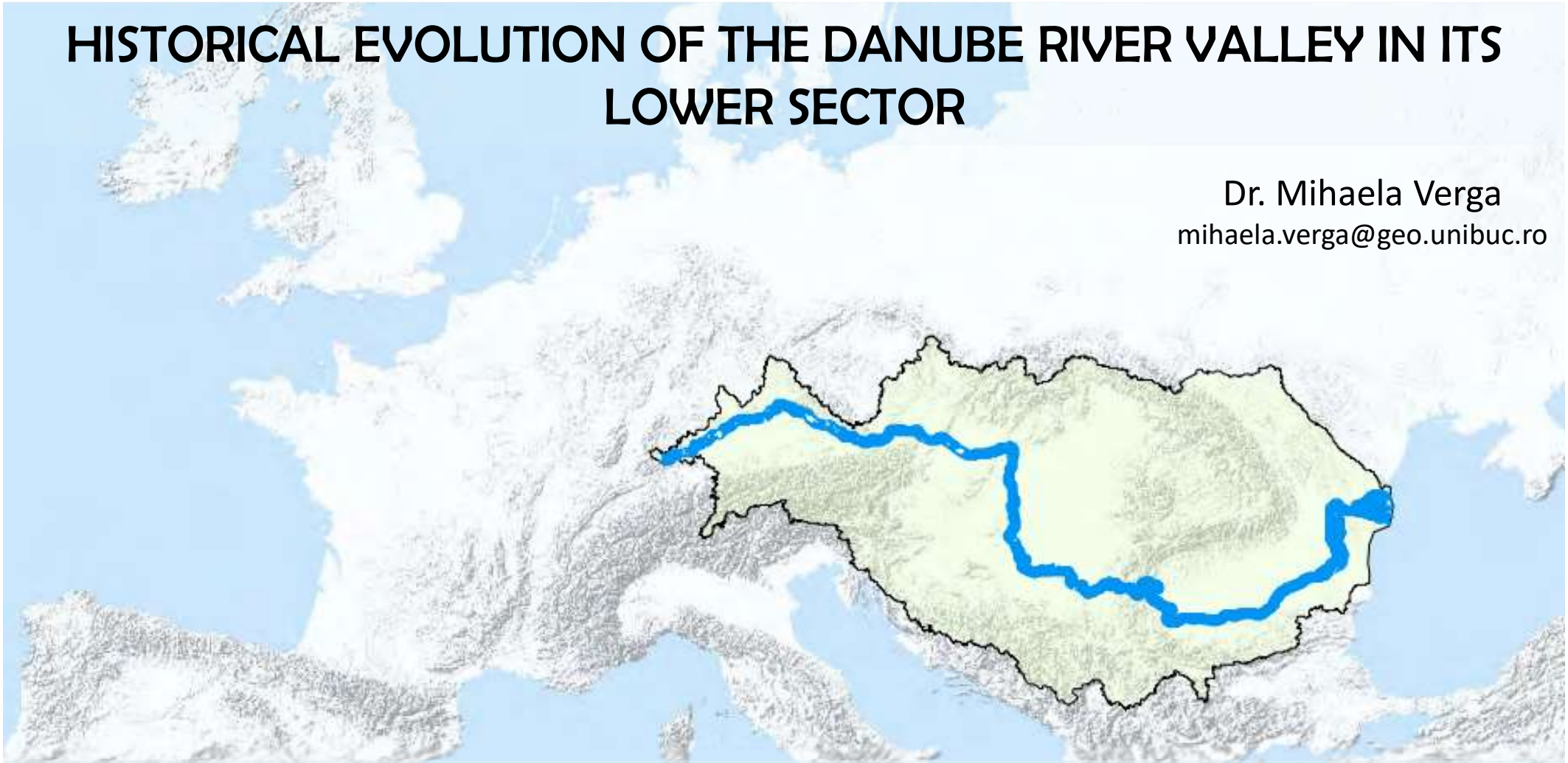
HISTORICAL EVOLUTION OF THE DANUBE RIVER VALLEY IN ITS LOWER SECTOR

Dr. Mihaela Verga
mihaela.verga@geo.unibuc.ro



Workshop

Old Strategies and New Priorities. How Can Historical Research Inform Sustainable Development along the Lower Danube?

29.09 – 03.10.2023, Belene, Bulgaria

DANUBE RIVER

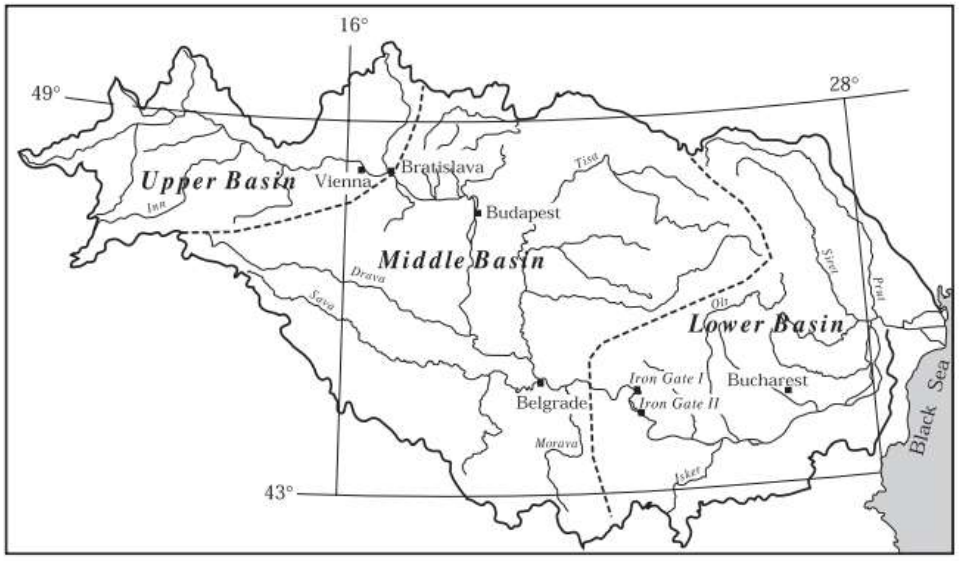
Second-largest in Europe ~2,850 km; average discharge: 6500 m³/s; sediment load: 1500 kg/s

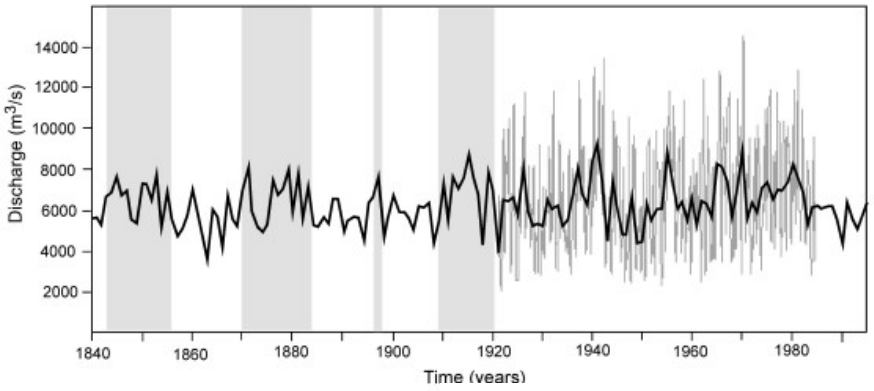
Spring: Black Forest (DE); Outflow: Black Sea – Danube Delta (RO, UA)

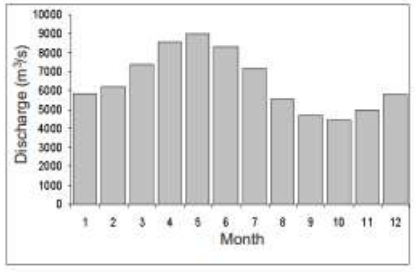
Crosses 10 countries: (DE, AT, SK, HU, HR, RS, BG, RO, MD, UA)

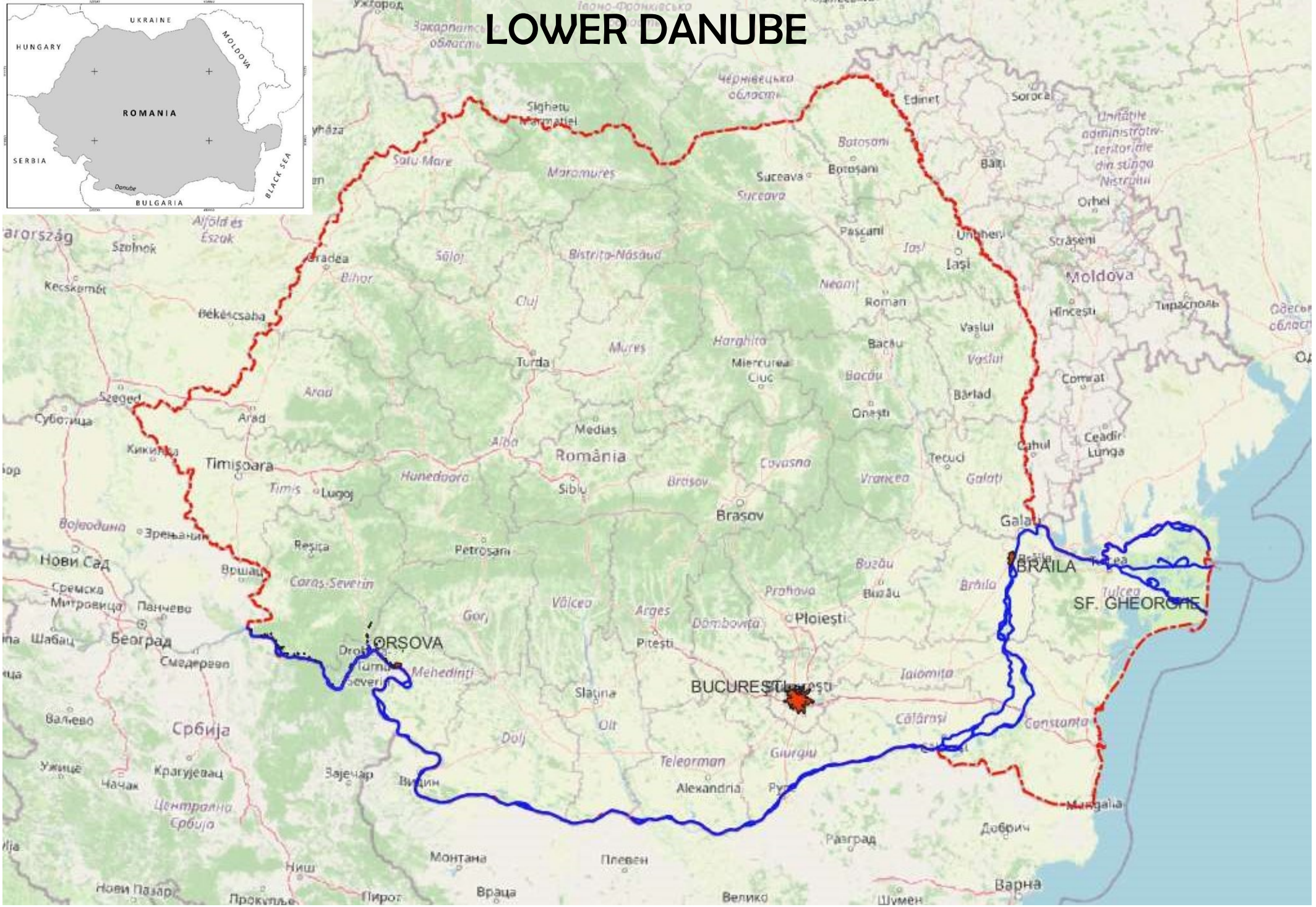
Catchment extends over 19 countries

the "most international" river basin



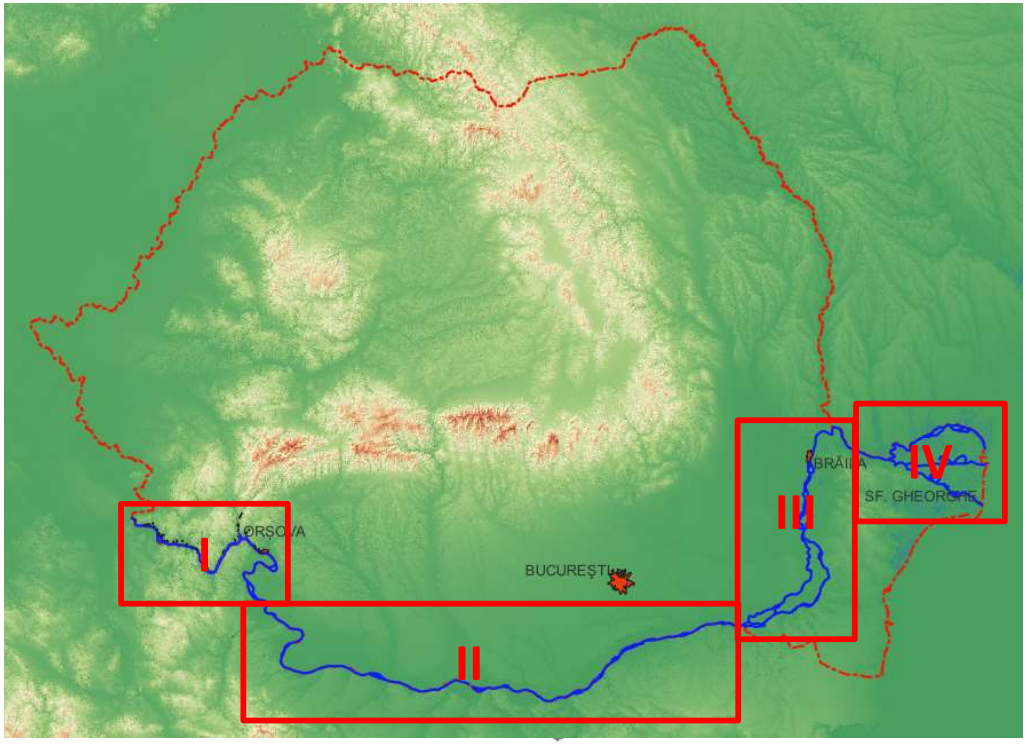






Romania (1075 km length, 29% area)
Serbia (235,5 km, 9,4%), Bulgaria (469,5 km, 5,2%),

Moldova (0,6 km, 1,7%)
Ucraina (53,9 km, 3,8%)



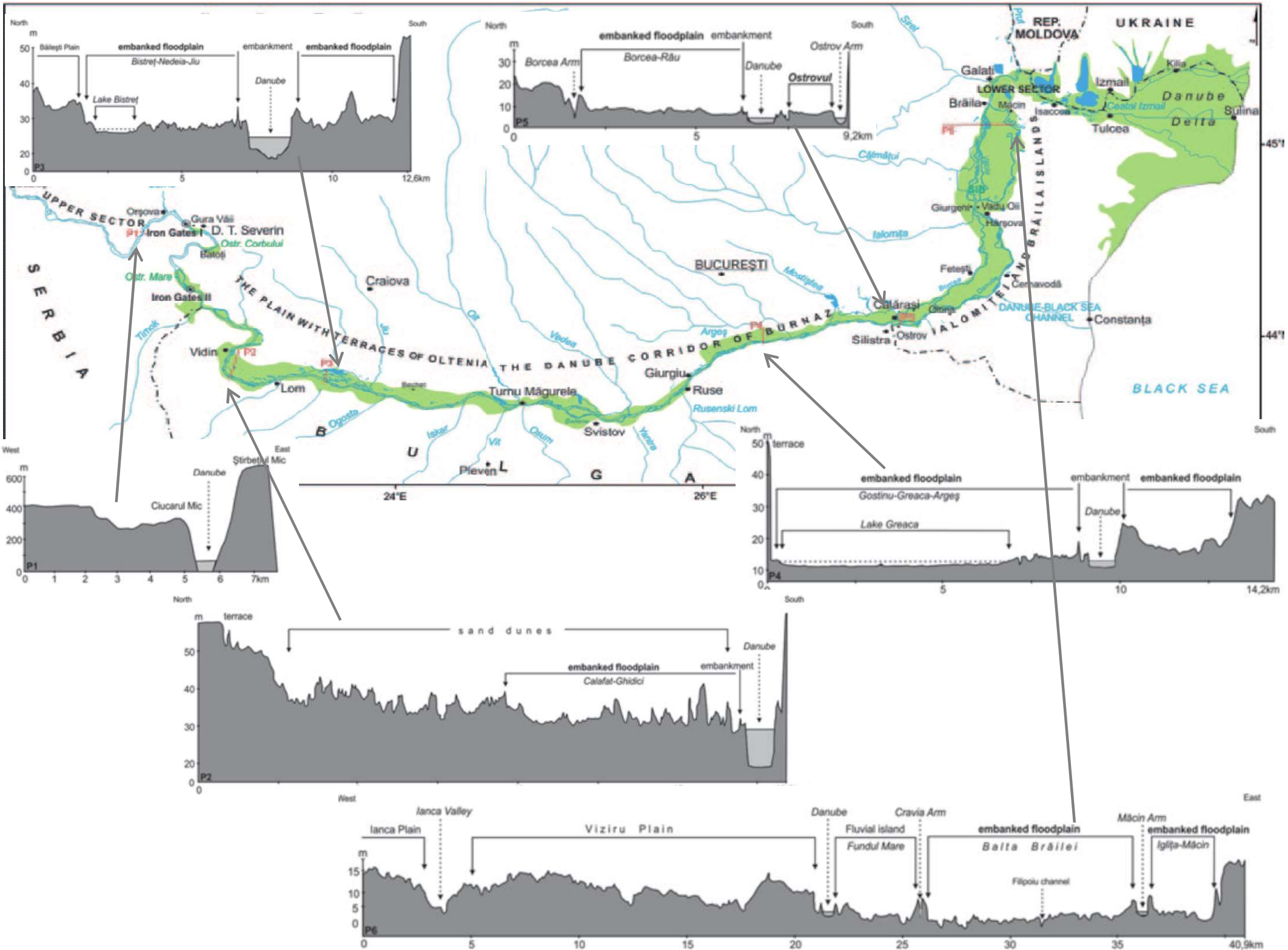
I – Danube Gorges (Iron Gate)

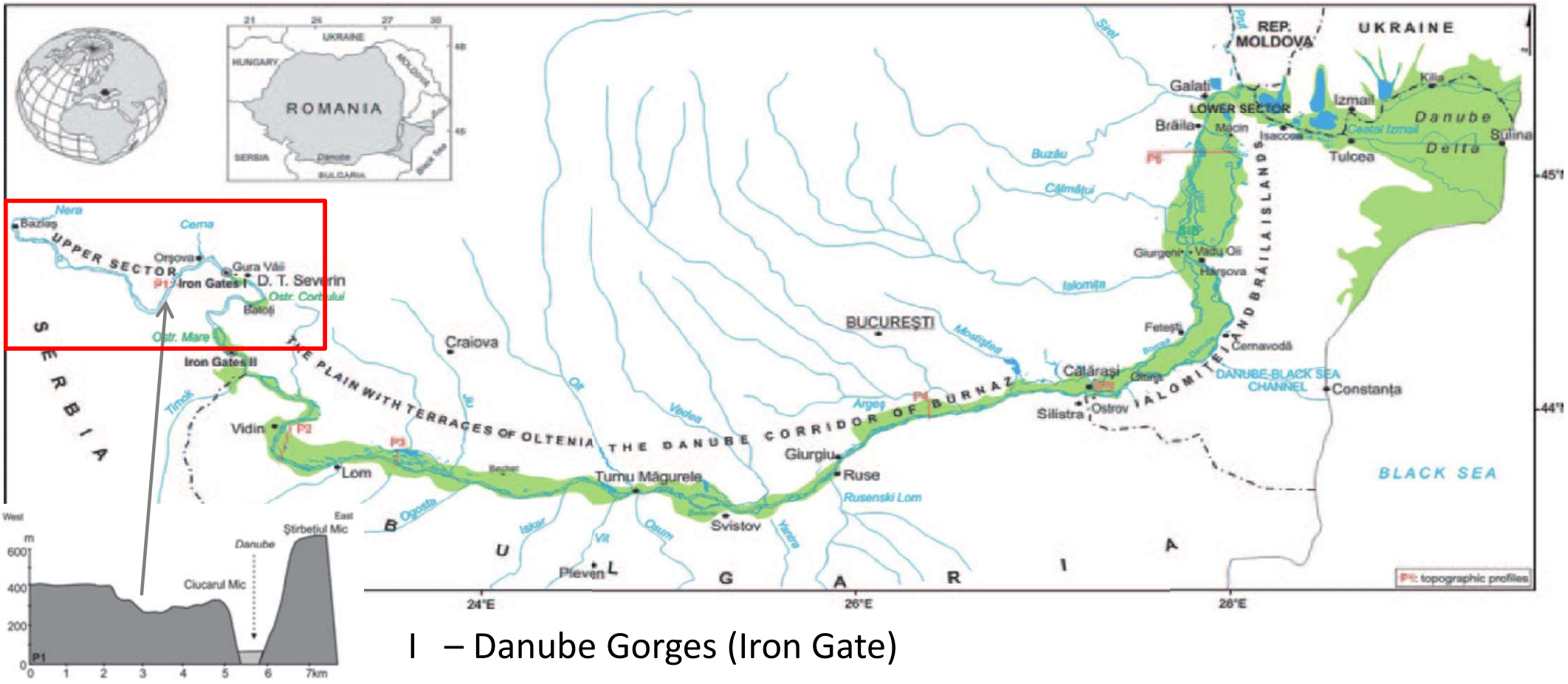
II – Floodplain sector

III – Islands sector

IV – Danube Delta

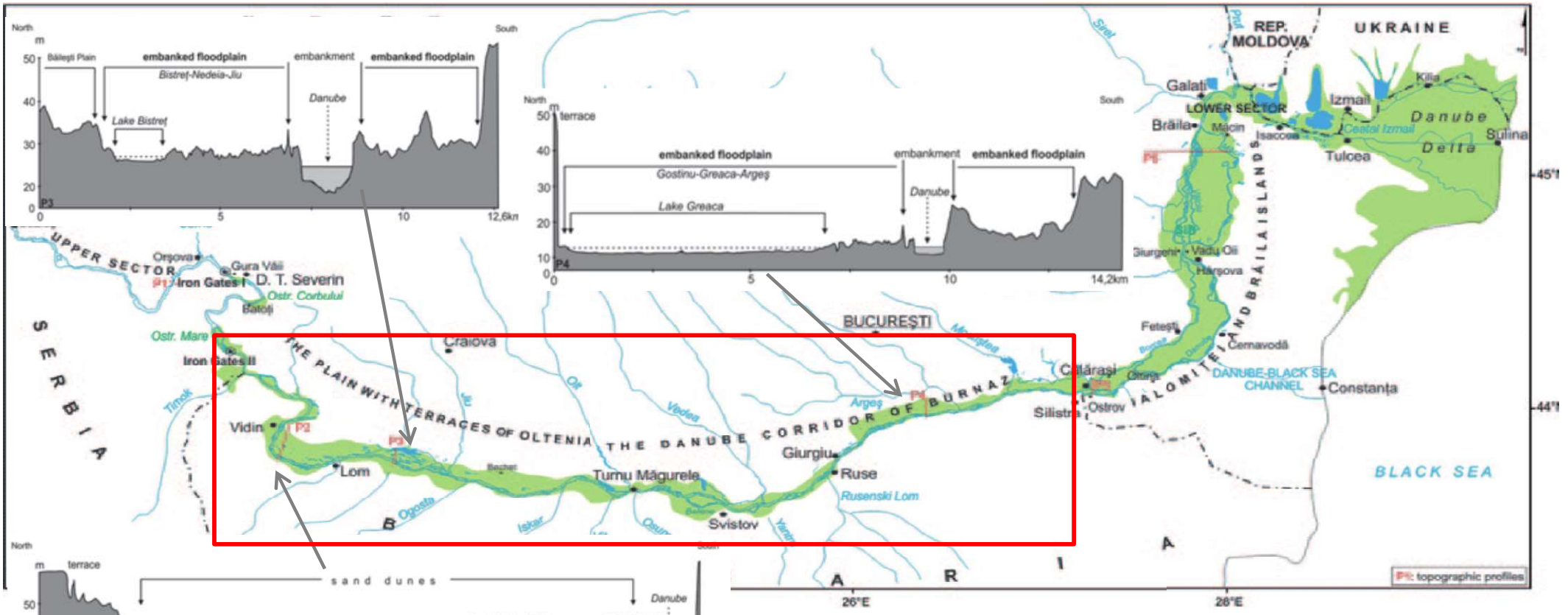
UKRAINE
Siret
Galati
Braila
Buzău
Tulcea
Sulina
St. Gheorghe
Hirsova
Ialomita
Slobozia
D.T. Severin
BUCURESTI
Craiova
Jiu
Olt
Calarasi
Oltenita
Danube - Black Sea Channel
Calafat
Danube
Giurgiu
Bechet
Turnu Magurele
Zimnicea
SERBIA
BULGARIA
BLACK SEA
Legend
Hydrographic Network
Fluvial islet
State administrative limit
Locality
0
50
100 km


UPPER SECTOR
Orşova
Gura Văii
Iron Gates I
D. T. Severin
Ostr. Corbului
Ostr. Mare
Iron Gates II
SERBIA
THE PLAIN WITH TERRACES OF OLTENIA
THE DANUBE CORRIDOR OF BURNAZ
Craiova
BUCUREŞTI
Vidin
Lom
Turnu Măgurele
Giurgiu
Ruse
Svistov
Pleven
BULGARIA
24°E
26°E
Călăraşi
Silistra
Ostrov
Fetești
Cernavodă
DANUBE-BLACK SEA CHANNEL
Constanța
BRĂILA ISLANDS
IALOMIȚA
REP. MOLDOVA
UKRAINE
Galați
LOWER SECTOR
Brăila
Măcin
Isaccea
Izmail
Chilia
Tulcea
Sulina
Danube Delta
BLACK SEA
45°N
44°N
P1
P2
P3
P4
P5
P6
Băileşti Plain
embanked floodplain
Bistreț-Nedeia-Jiu
embankment
Lake Bistreț
Danube
Borcea Arm
Borcea-Râu
Ostrovul
Ostrov Arm
9,2km
Ciucarul Mic
Ştirbeiul Mic
Gostinu-Greaca-Argeş
Lake Greaca
14,2km
terrace
sand dunes
Calafat-Ghidici
Ianca Valley
Ianca Plain
Viziru Plain
Fluvial island
Fundul Mare
Cravia Arm
Măcin Arm
Balta Brăilei
Iglița-Măcin
Filipoiu channel
40,9km

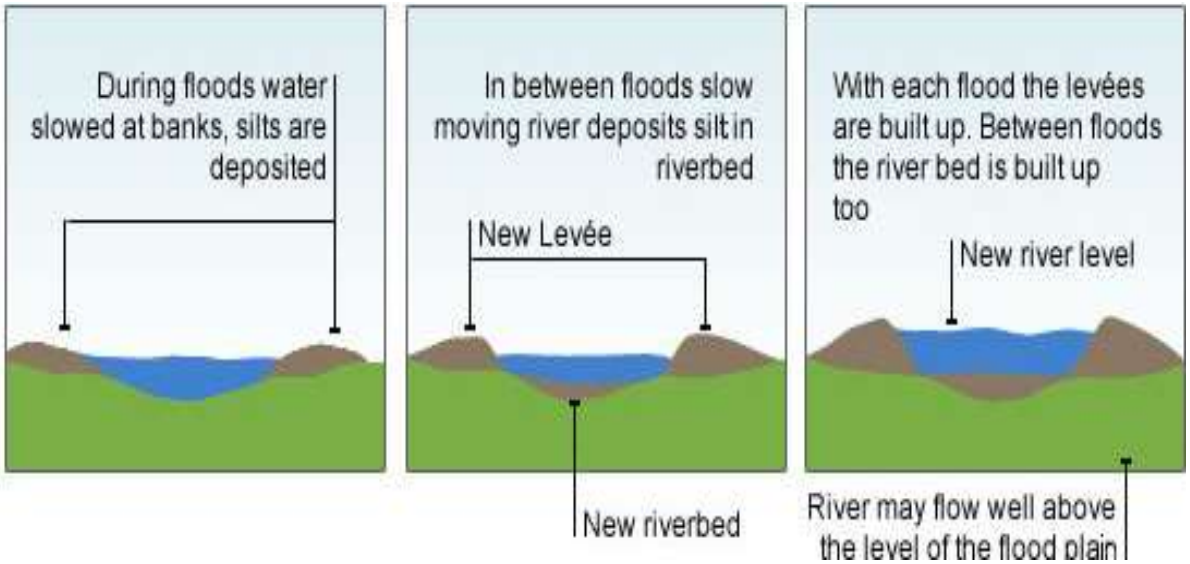


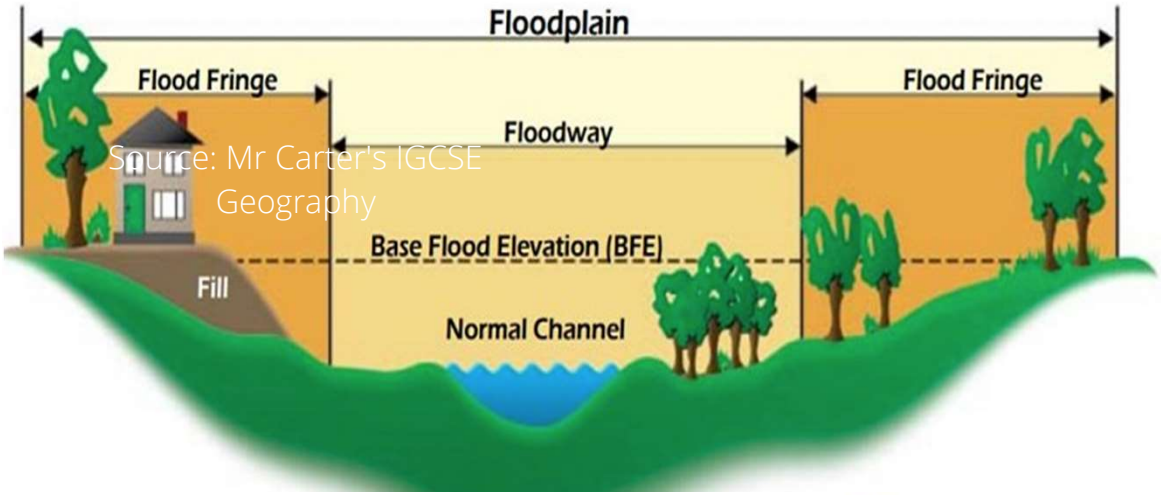
I – Danube Gorges (Iron Gate)

- low-elevation mountains (40 m - 968 m)
- most spectacular landscape
- narrowest sector (180 m)
- a large outdoor geological museum with „exhibits” over 450 million years old
- steep rocky slopes, with up to 200 m amplitude
- complex valley with narrow sectors and depressions
- many cataracts and rapids in the past (max. speed 5 m/s)
- hosts a large biological diversity

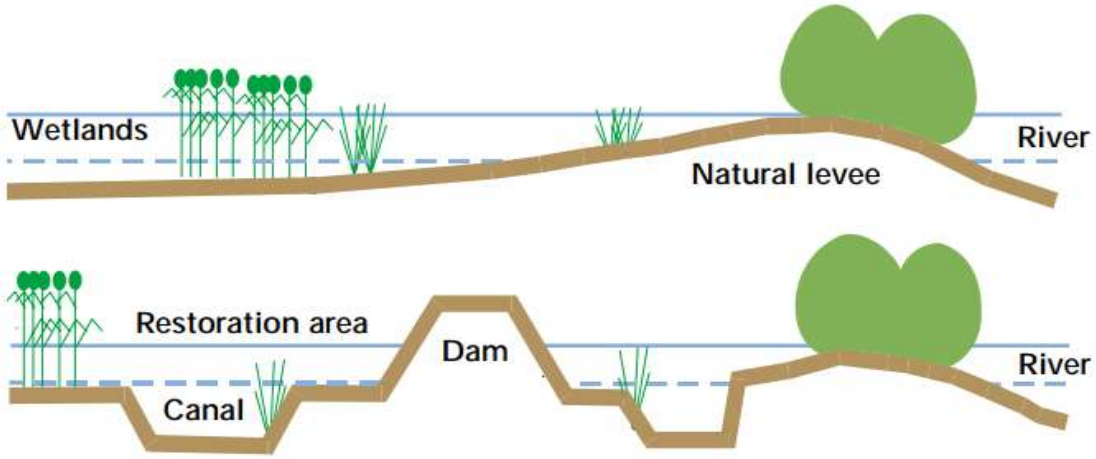


II – Floodplain sector





Source: Mr Carter's IGCSE Geography



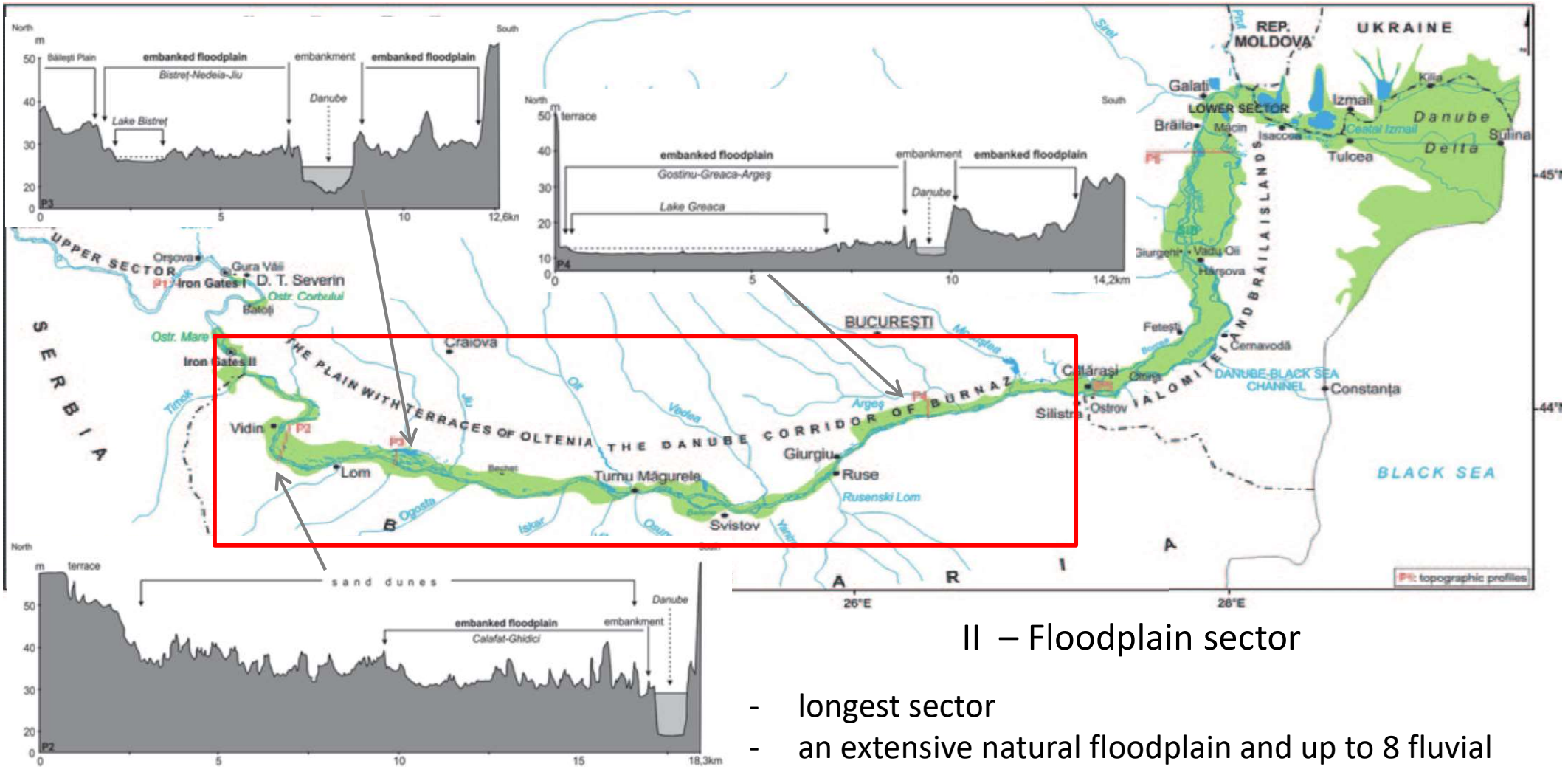
THE IMPORTANCE OF FLOODPLAINS

components: flat areas along rivers or streams, consists in *floodway* (main channel) and *floodfringe* (wetlands, marshes, ponds, lakes, sand banks, secondary channels)

processes: erosion and aggradation (alluviation)

functions:

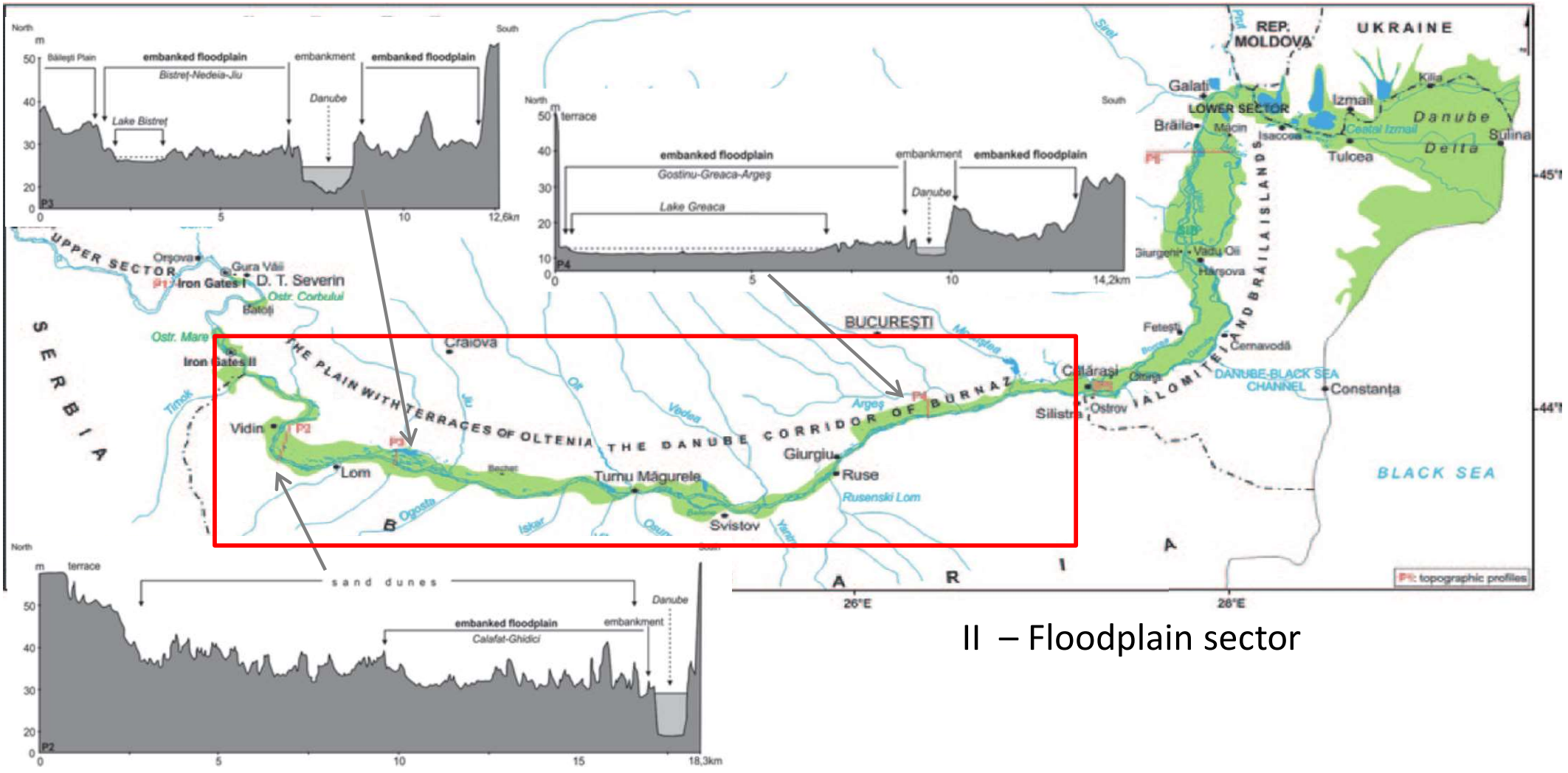
- flood and water flow regulation
- natural filtration
- climate mitigation (moist air, smaller thermic amplitude)
- fertile soils
- habitats – biodiversity



II – Floodplain sector

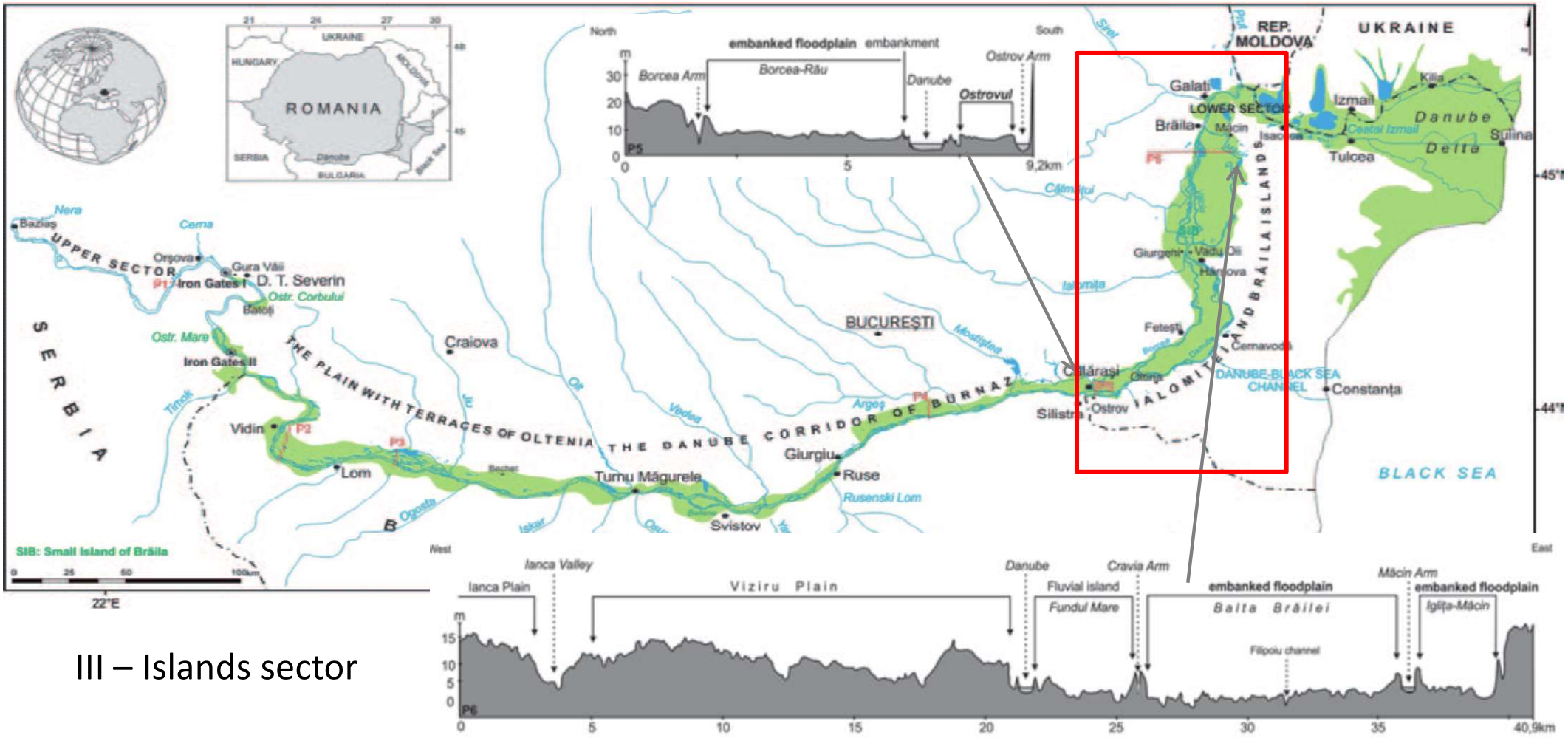
- longest sector
- an extensive natural floodplain and up to 8 fluvial terraces (115-120 m)

- flood basins (lakes, marshes, ponds, secondary courses) - habitat and fauna diversity; previously - storage basins and safety valves during floods
- asymetric valley:
  - floodplain broaden preferentially on the left bank (Romania), between~200 m near Calafat and 10-15 km width
  - on the right bank, in Bulgaria, the floodplain is a narrow fragmented strip, largely embanked before 1945



II – Floodplain sector

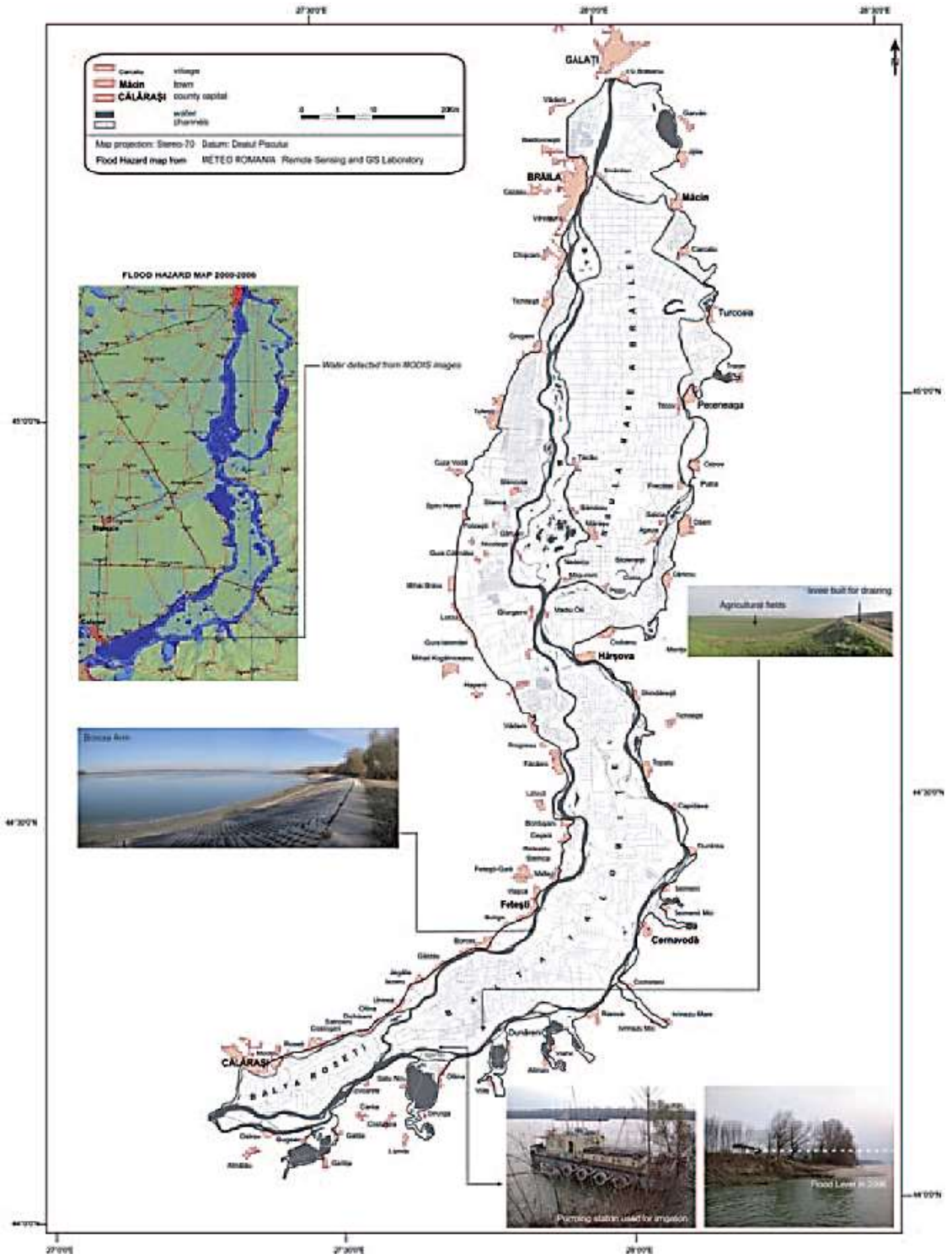
1. highest elevation (up to 4-5 m) – natural levees , overtopped only during exceptional floods. The elevation of the levee corresponds to an average value of discharge in the spring months
2. lowest elevations (even bellow river water level) – lakes, ponds (19.2% of the entire surface between Călăraşi and Brăila in 1880 compared to 2.9% in 2005)
3. intermediate elevations (0-5 m) - floodplain marsh with cattails and reeds

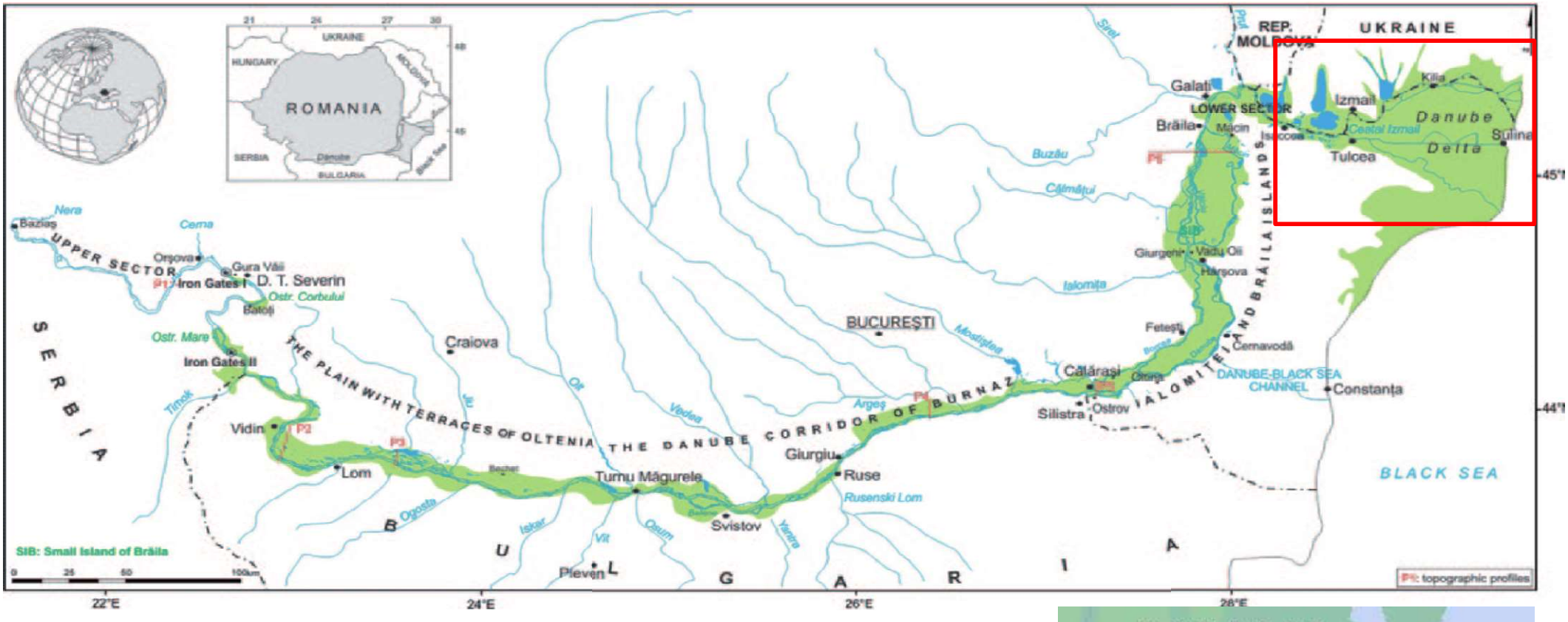


III – Islands sector

III – Islands sector

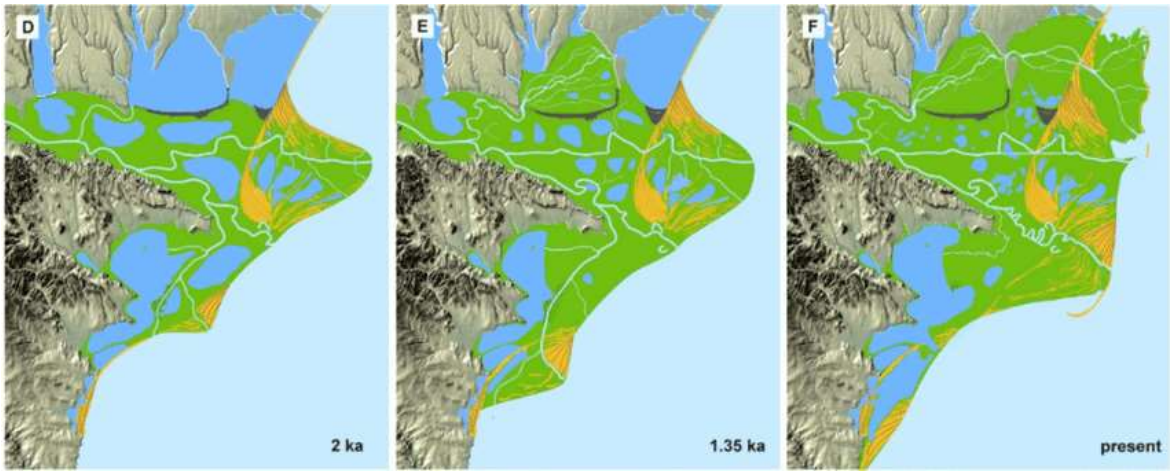
- the widest sector - internal floodplain
- the sequential branching of the river, (decreassing in slope and sediment transport capacity)
- two important acumulative islands (70 – 130 km long, 18 – 30 km width)
- floodplain bottlenecks (alluvial fans)
- asymmetric valley
- the Small Islet of Brăila - the only floodplain area along the lower Danube valley subject to the natural flood regime



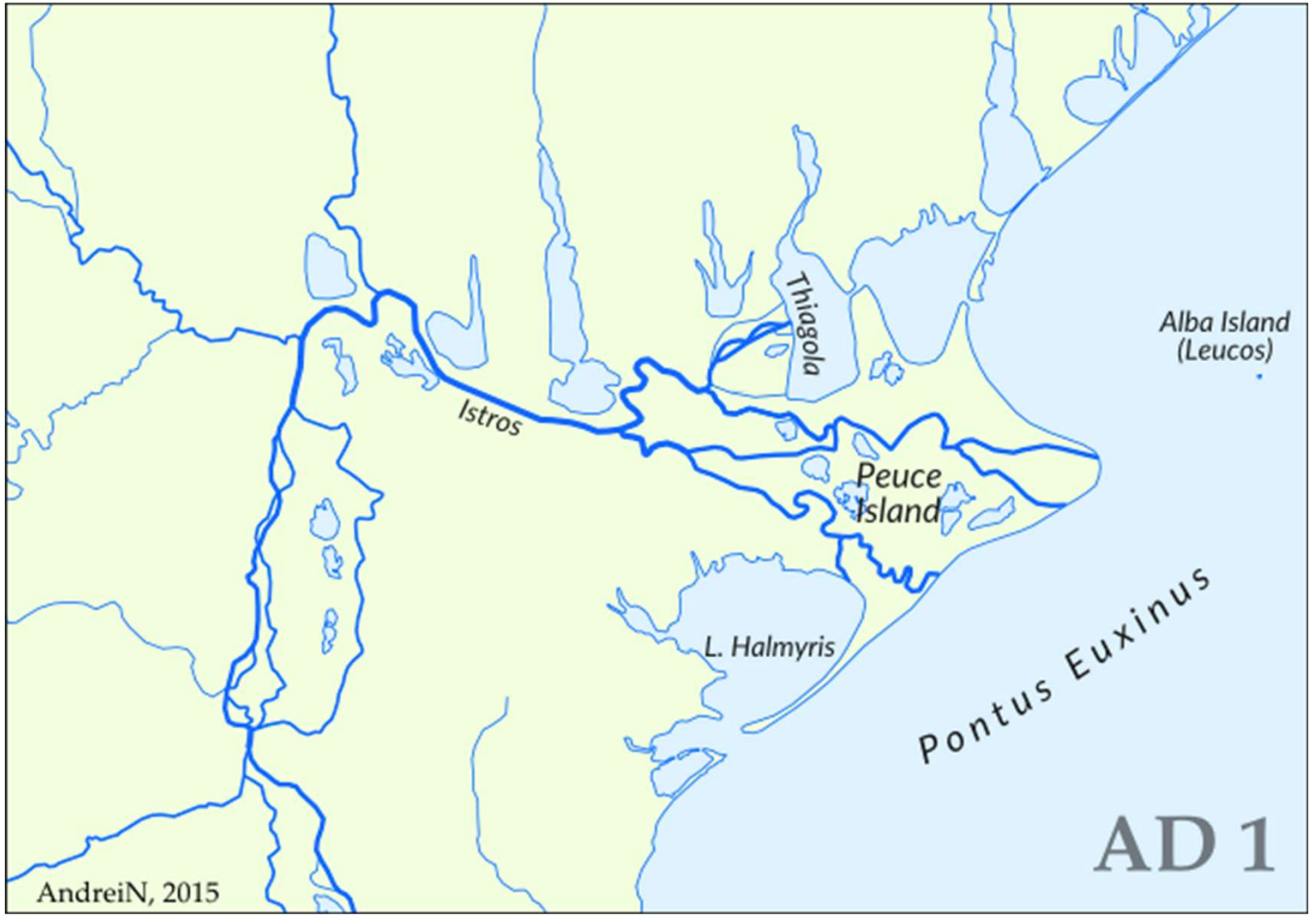


IV – Danube Delta

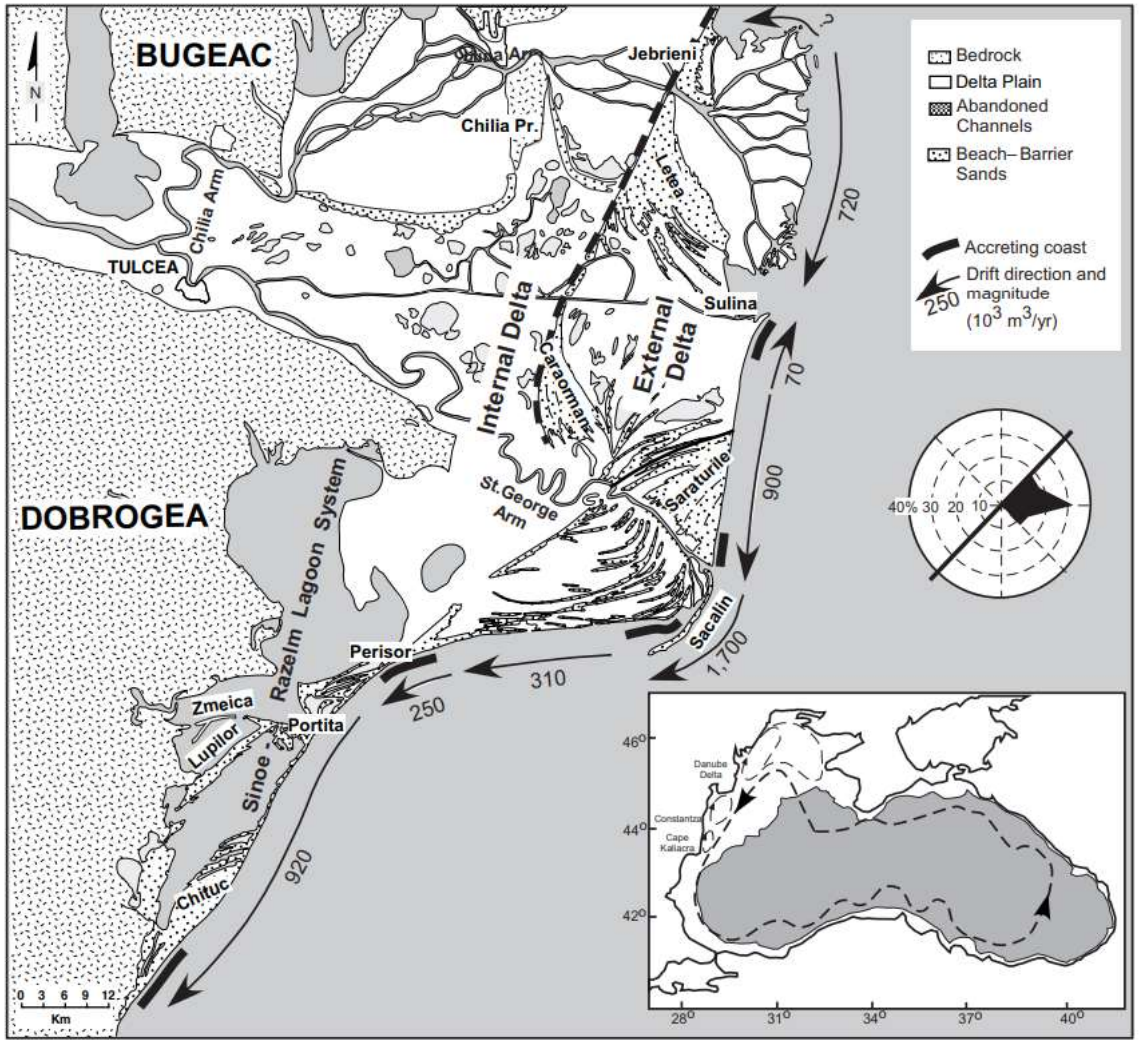
- three main distributaries: Chilia (Kilia), Sulina, and Sf. Gheorghe (St. George)
- the best preserved delta on the continent
- 88% in Romania and 12% in Ukraine
- 80% wetlands and water (swamp, ponds, lakes, rivers and channels)
- 20% alluvial plain (strand plains, dunes, sand banks)
- 20% of the territory below sea level (the average altitude 0.5 m, the max. altitude 12.4m)
- hosts 23 natural ecosystems



Danube Delta natural evolution



Main distributaries of the Danube		
Danube branch	Length (km)	Flow (m^3/s) (1921–1990)
Chilia	120	3800
Sulina	64	1250
Sfântu Gheorghe	70	1500



The internal delta consists of several bay-mouth and lacustrine delta lobes were built inside Danube bay, separated from the Black Sea by a bay-mouth barrier (thick dashed line indicates the probable orientation of the barrier; Panin, 2003)

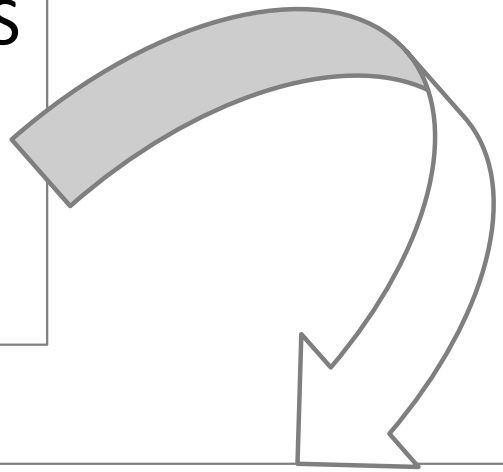
UNESCO World Heritage (1979 - 1992)
Wetland of International Importance – Ramsar Convention (1991)

National Park – IUCN (1993)
Transboundary Biosphere Reserve – (1998)

DAMS AND RESERVOIRS

EMBANKMENT

CHANNELLISATION



reduction of sediments discharge

islets migration

changing the ratio between erosion and accretion

lakes and marshes drainage

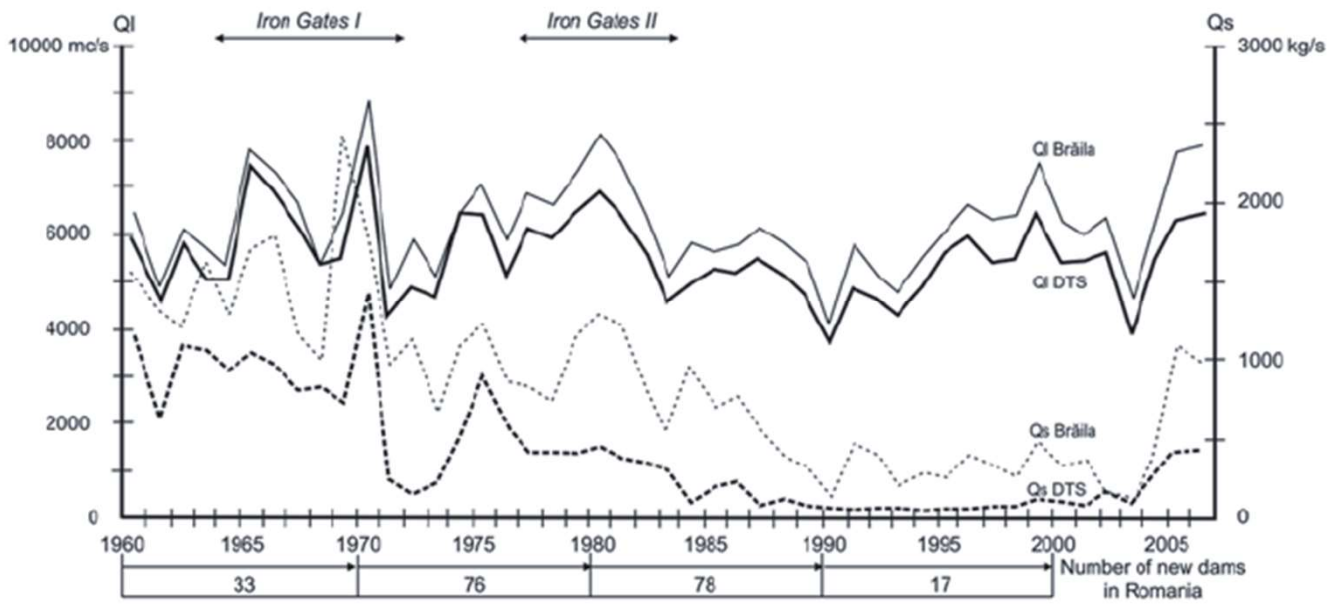
lowering the groundwater level

land use alteration

biodiversity loss

I. DAMS AND RESERVOIRS

Danube basin - hundreds of dams and reservoirs
Romania - 150 dams (up to 22 billion m3)
Bulgaria - 600 small dams



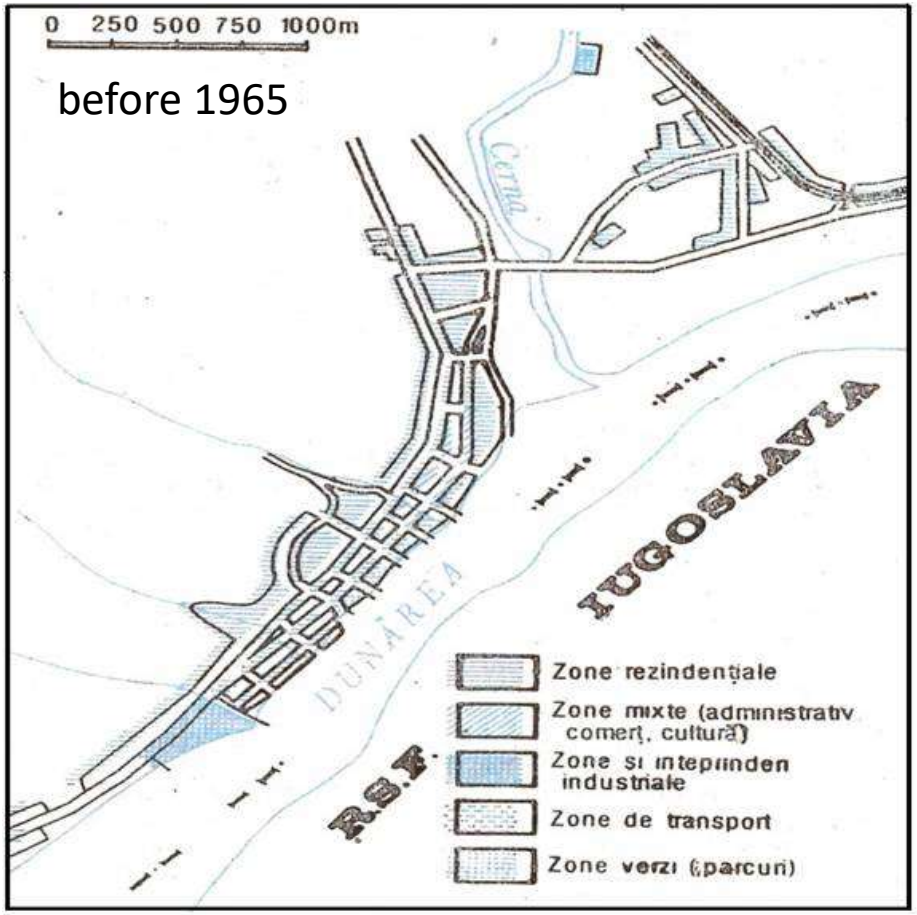
Water (Ql) and sediment (Qs) discharges at the Drobeta Turnu Severin (DTS) and Brăila gauges between 1960 and 2007 (in solid and dashed lines respectively). Note changes in discharge after the Iron Gates dams construction

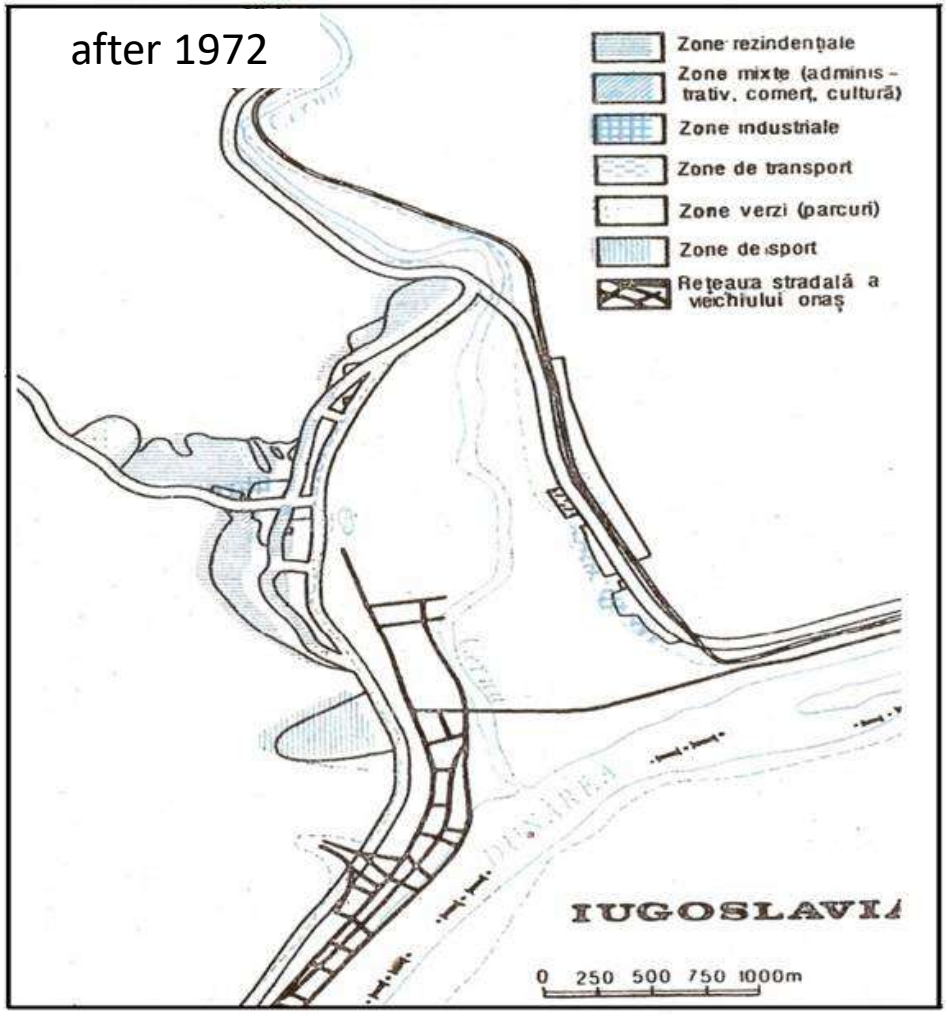
A. considerably ***reduction of*** downstream ***sediment loads*** by trapping sediments within the reservoirs: Danube tributaries are currently contributing~60% less suspended sediment than under pre-dam conditions

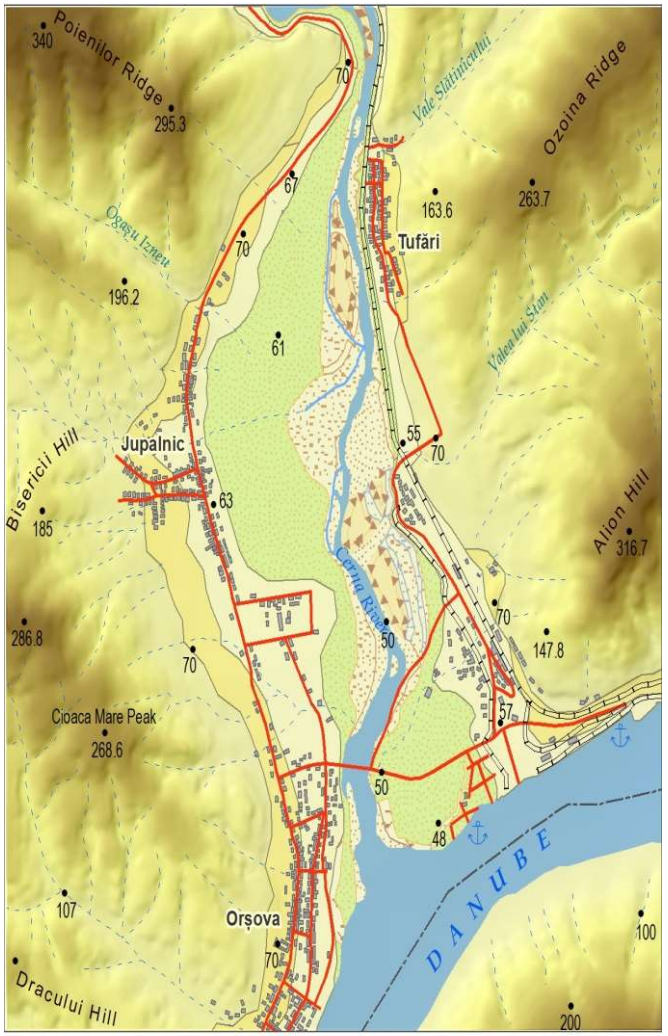
Iron Gates I and II Dams - major contributor to the sediment reduction - by 53% at the entry to the delta (1846 kg/s between 1840 and 1970 and 962 kg/s between 1971 and 2000) (Bondar 2008).

- Iron Gate Dam (1972) - river course radically modified – lacustrine regime
- water level raised up to 50 m
- sediments trapped
- 17 000 inhabitants relocated
- cultural heritage of Ada Kaleh Island lost
- forests flooded
- sturgeons spawning disrupted
- riverbed reconfigured

Orșova city







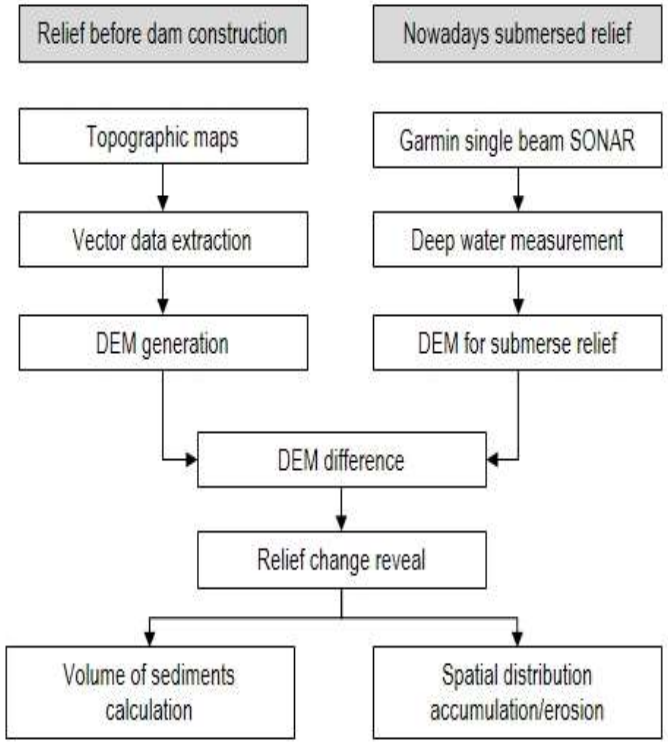
• 70 altitude point (m)
temporary stream
fluvial harbor
railway
road
country boundary
building

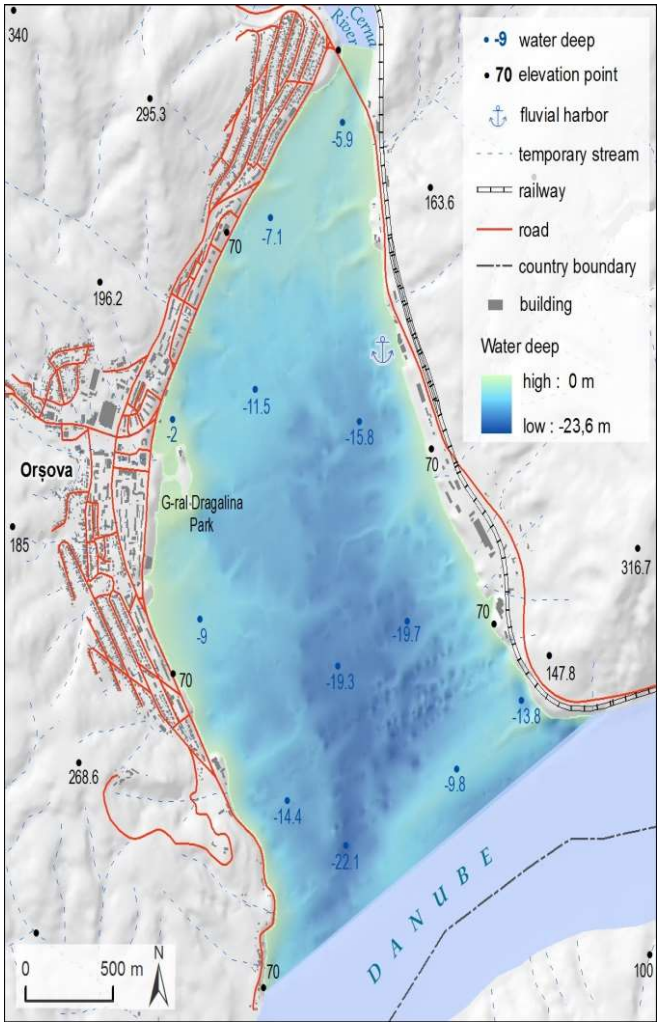
river bed
alluviums
swam
outlier
gravel
floodplain
1st terrace
2th terrace

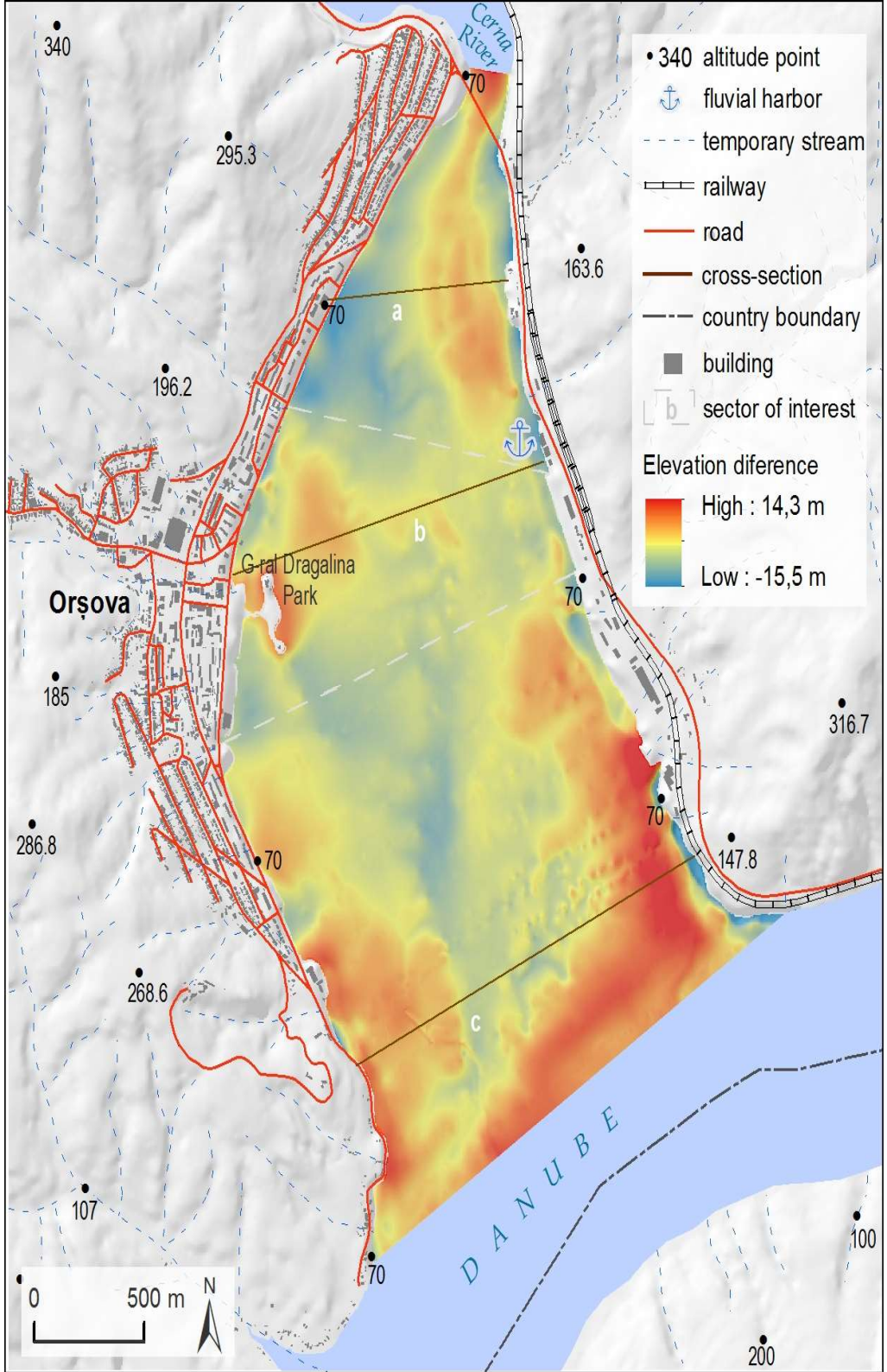
Altitude
High : 353,8 m
Low : 14,3 m

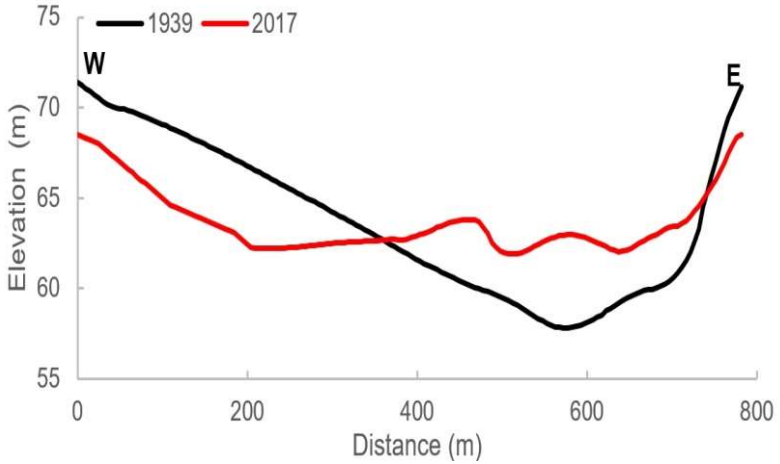
N

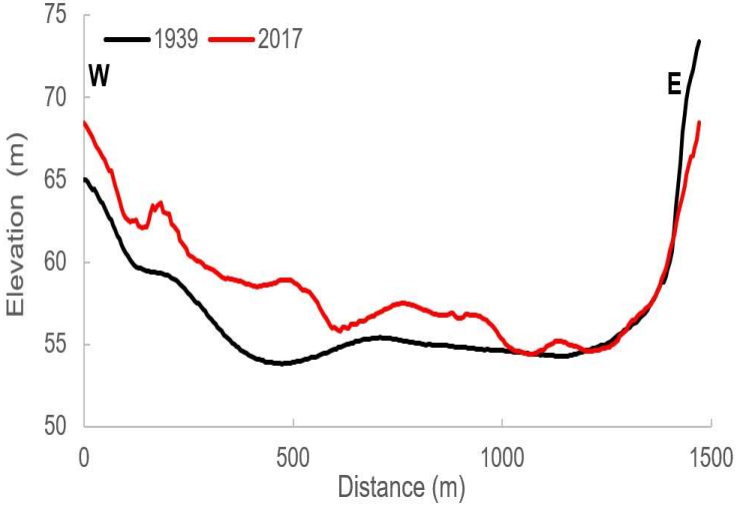
0 500 m

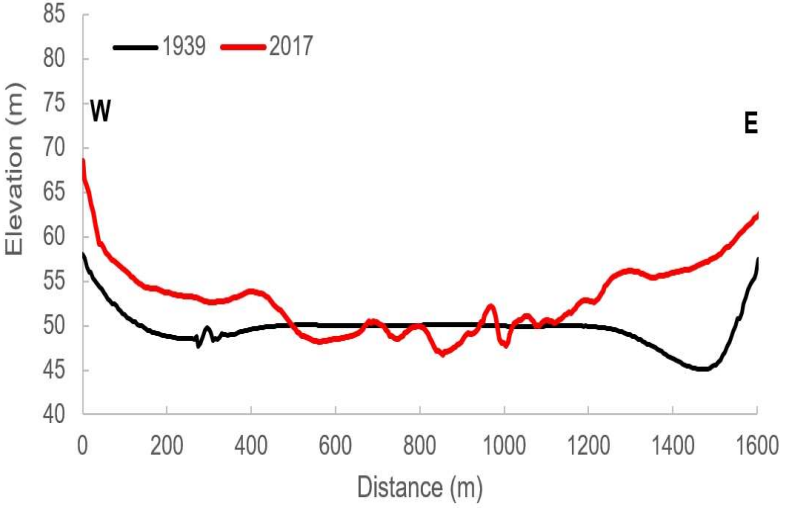




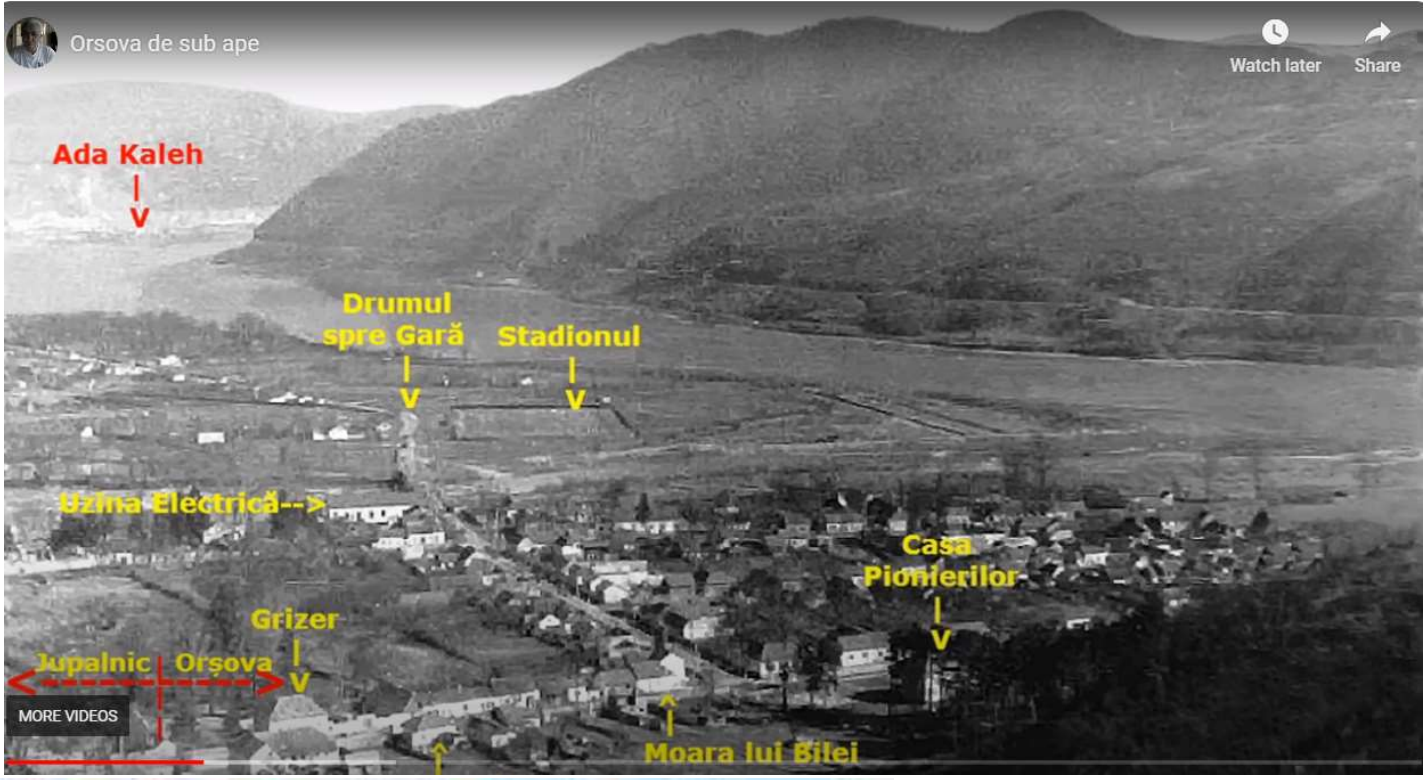

340
295.3
163.6
196.2
185
316.7
286.8
268.6
107
100
200
147.8
70
Cerna River
Orșova
G-ral Dragalina Park
D A N U B E
a
b
c
340 altitude point
fluvial harbor
temporary stream
railway
road
cross-section
country boundary
building
sector of interest
Elevation diference
High : 14,3 m
Low : -15,5 m
0
500 m
N


1939
2017
W
E
Elevation (m)
Distance (m)


1939
2017
W
E
Elevation (m)
Distance (m)


1939
2017
W
E
Elevation (m)
Distance (m)

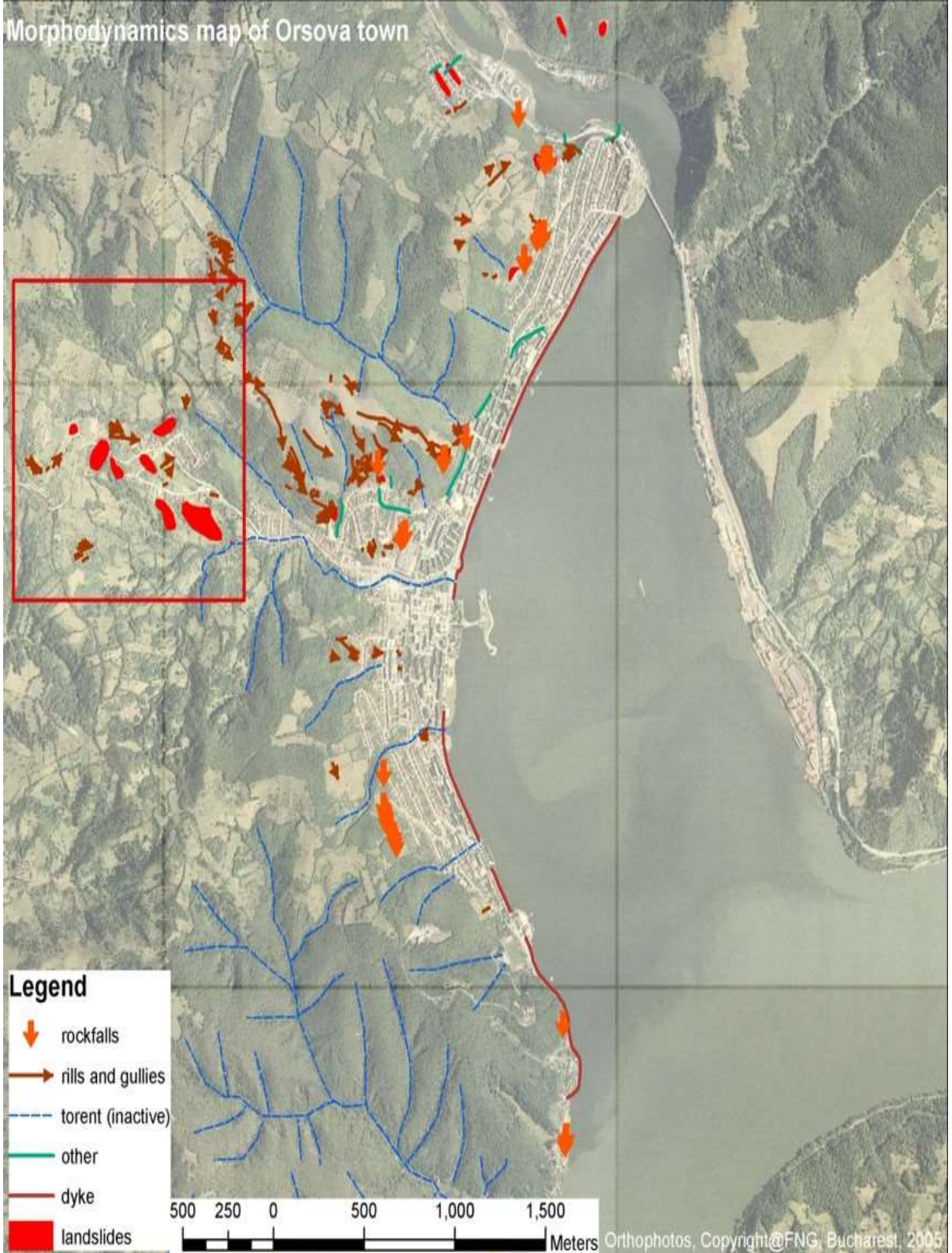
THEN


Orsova de sub ape
Watch later
Share
Ada Kaleh
Drumul spre Gară
Stadionul
Uzina Electrică-->
Casa Pionierilor
Grizer
Jupalnic
Orșova
MORE VIDEOS
Moara lui Bilei

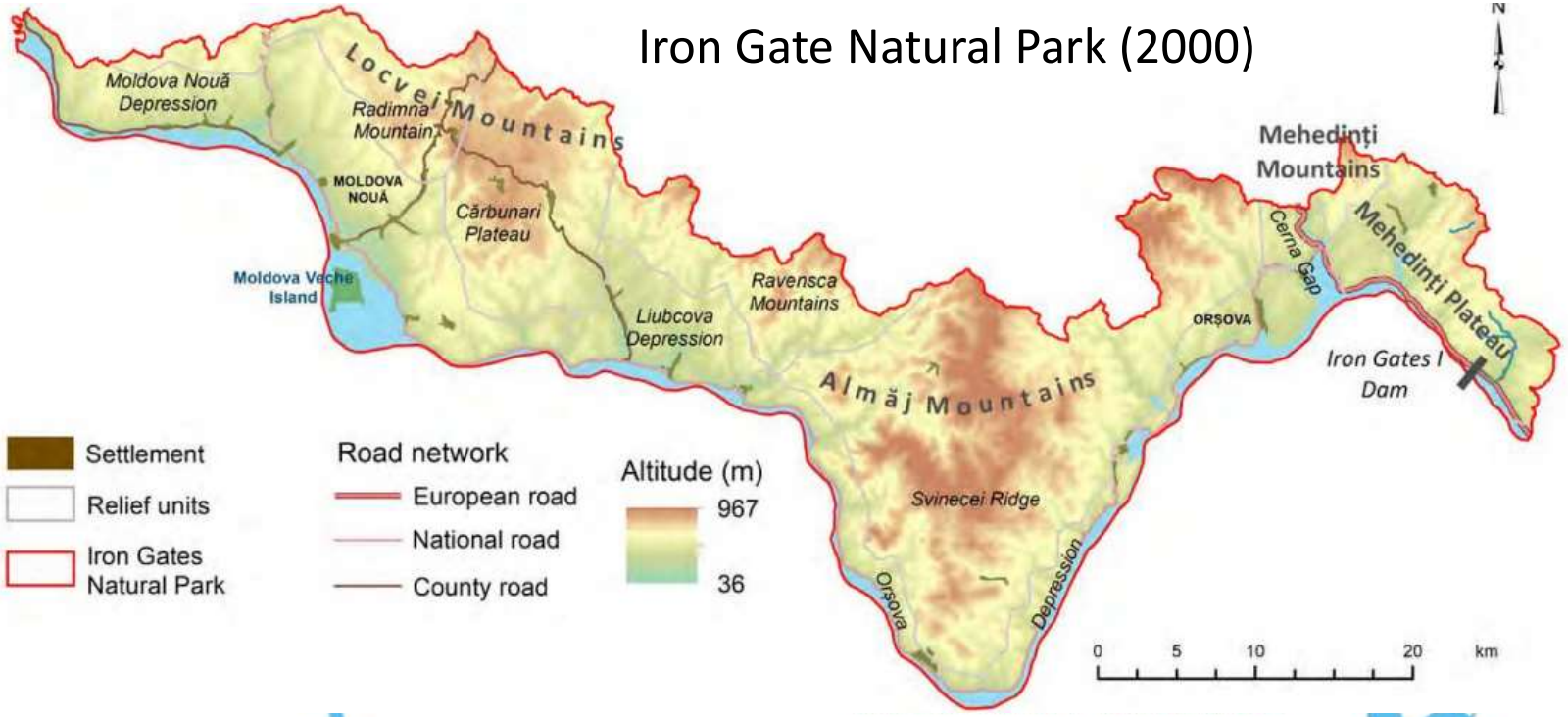
NOW

THEN

NOW

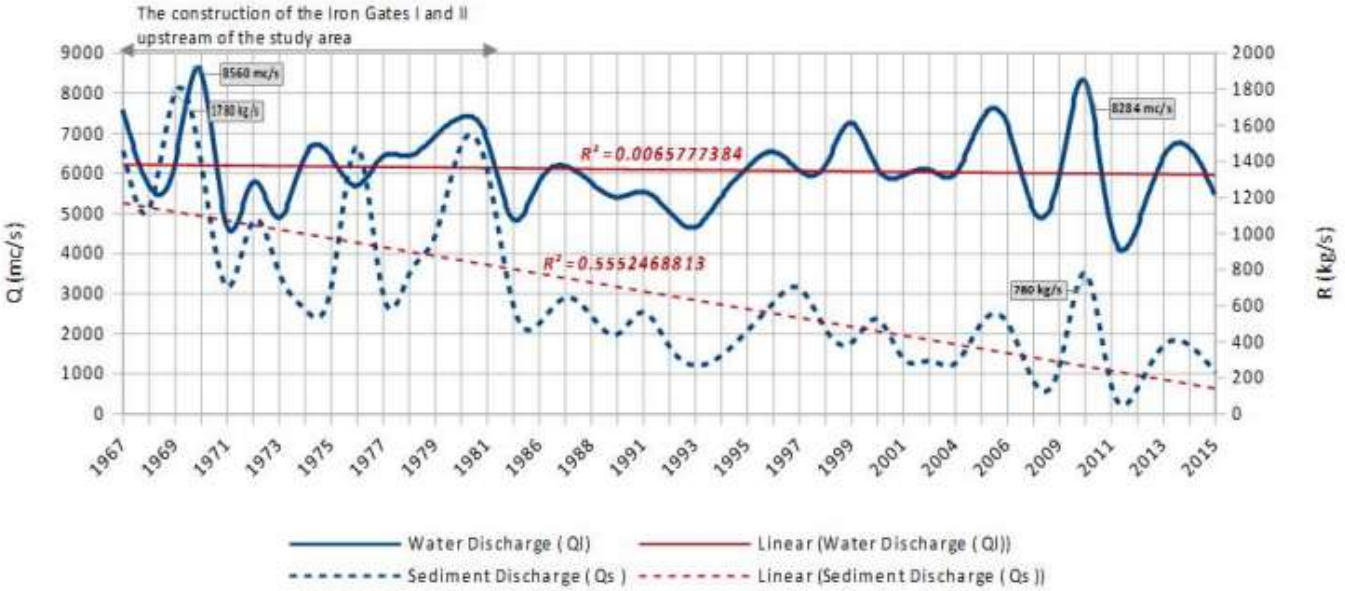

Morphodynamics map of Orsova town
Legend
rockfalls
rills and gullies
torent (inactive)
other
dyke
landslides
500 250 0 500 1,000 1,500
Meters
Orthophotos, Copyright@FNG, Bucharest, 2005

Iron Gate Natural Park (2000)



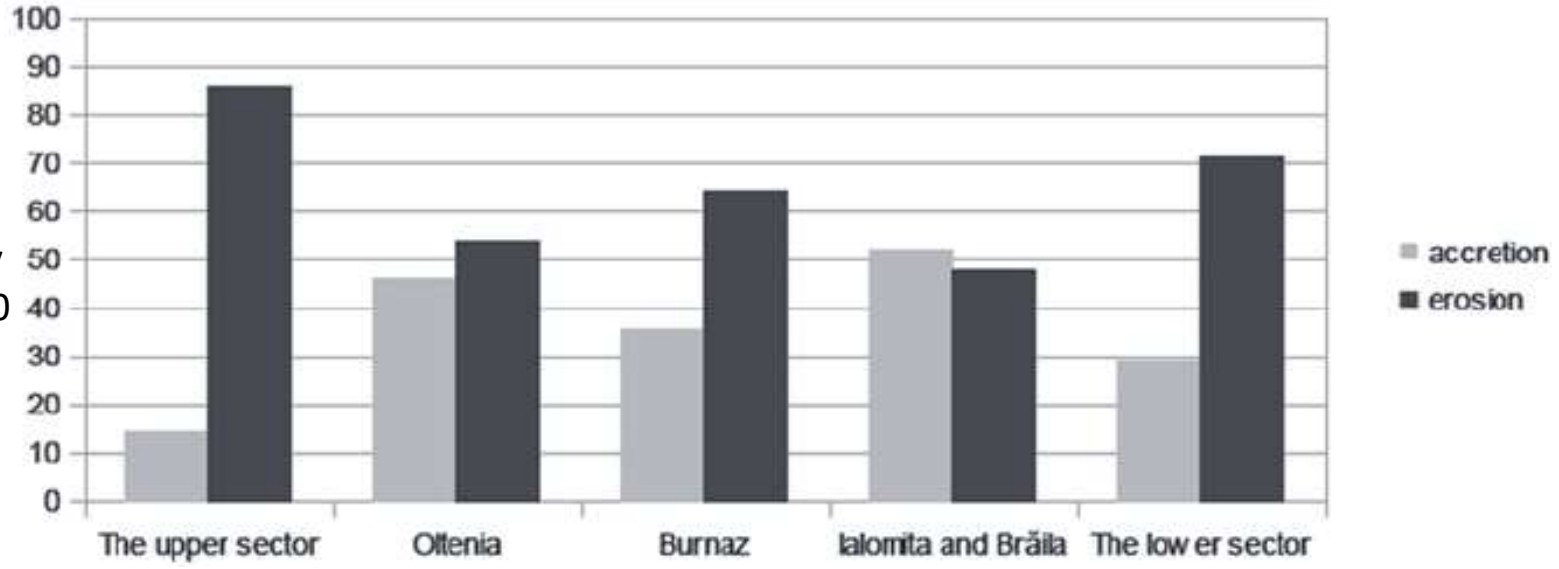
Djerdap National Park (1974)

B. a negative sedimentary balance occurred over the entire lower Danube. This drove an erosional phase in the fluvial regime, resulting in an average loss of 29.2 ha/km.
River bank erosion results in channel bed widening.



Water and sediment discharge at Giurgiu gauge between (1967-2015)

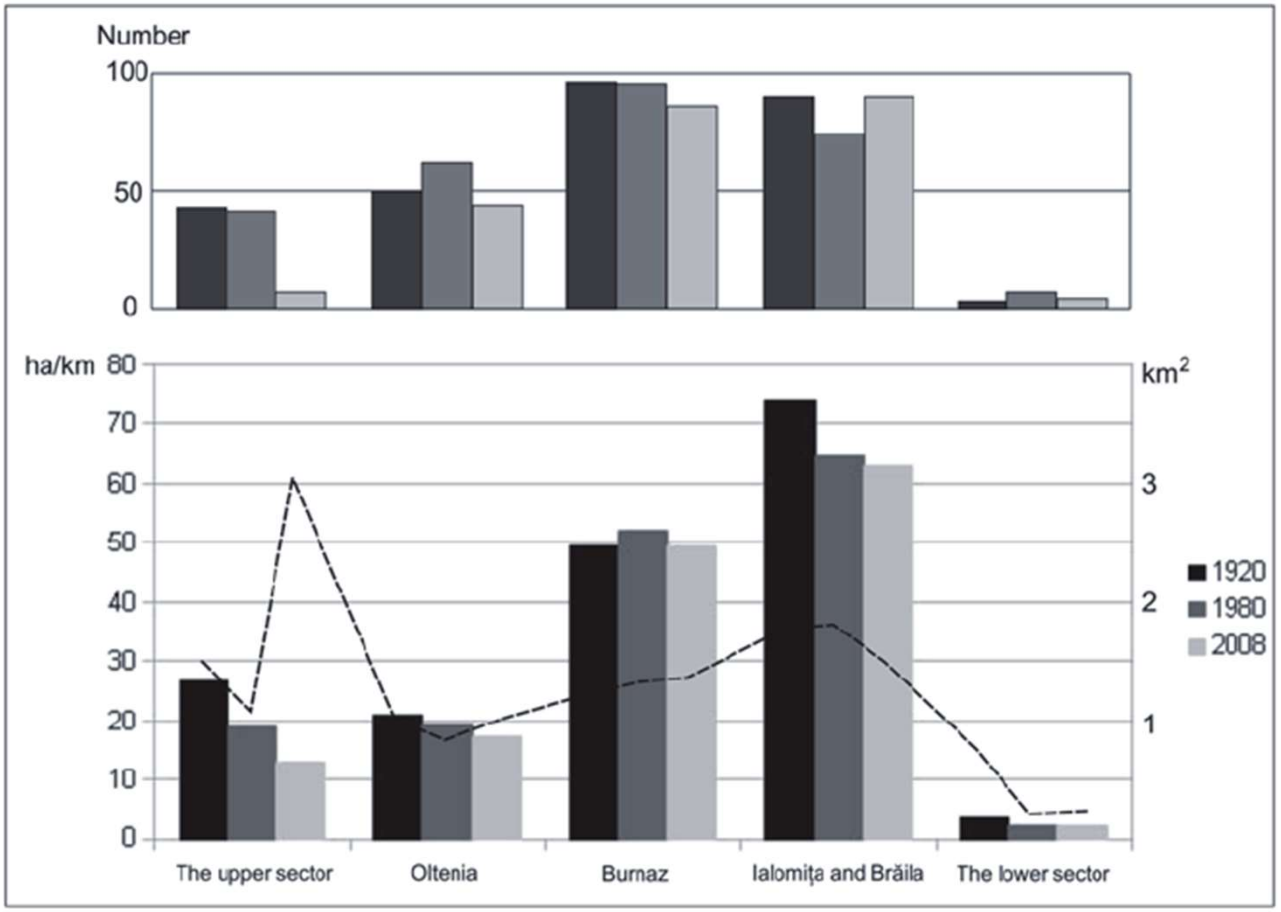
Intensity of accretion and erosion along the Danube by sector (ha/km) between 1920 and 2008



C. Lower sediment transport rates led to riverbed alteration (depth reduction, sandbanks and ***fluvial islets migration***)

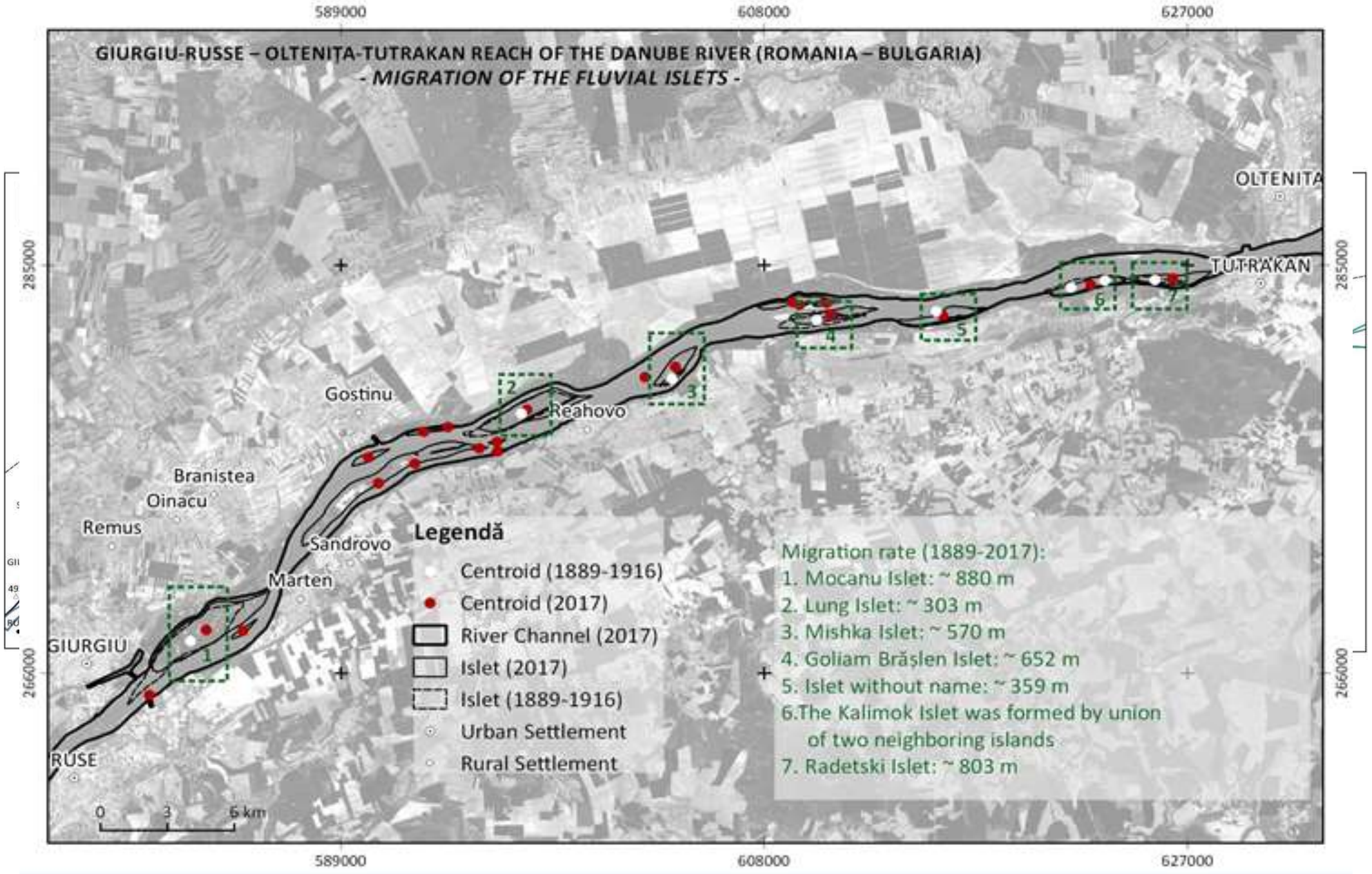
The change from fluvial to lake-like regime led to the disappearance of several islets and the coalescence of other islets in the context of a sharp decrease in number:

- the number of fluvial islets dropped in last three decades by almost 15% (224 in 2008)
- the total surface area decreased constantly, from 379 km2 (1920), to 341 km2 (1980), to 315 km2 (2008)



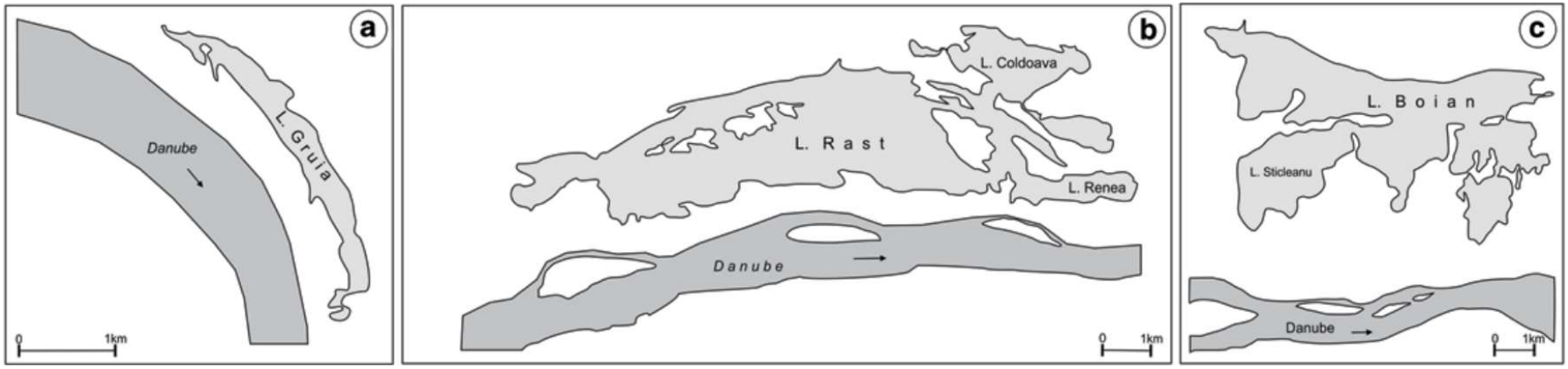
Evolution of the fluvial islet number, density (ha/km) and average surface area (dashed line, in km2)

the largest islets - slightly downstream migration - the average rate 4,5 m/year (max. 6,8 m/year)



EMBANKMENT AND DRAINAGE

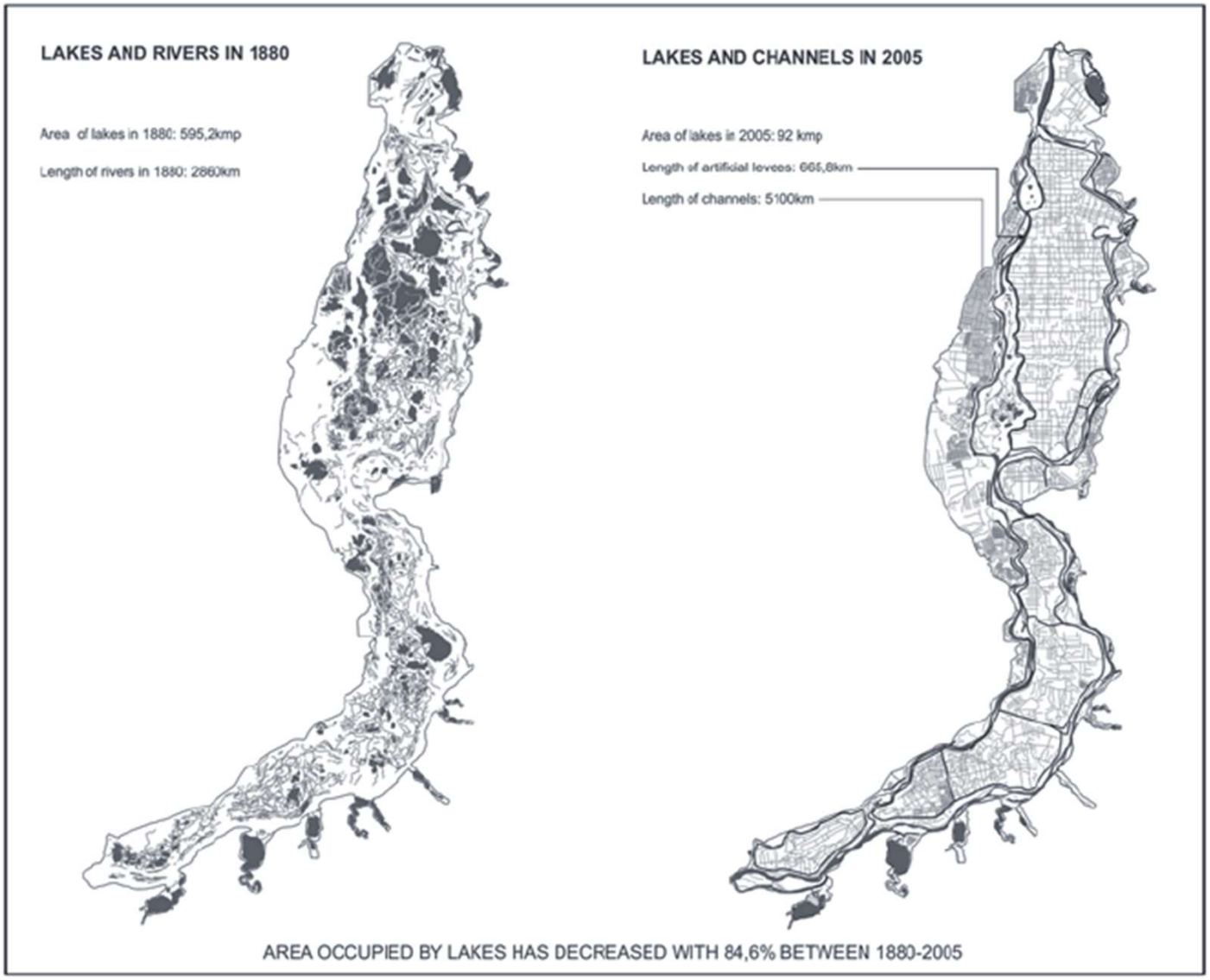
75% of Danube floodplain - currently embanked
the total length of the embankments along the main course - 3520 km (1158 km in Romania)



Morphology of Danube floodplain lakes. a oxbow lakes, b single lakes infre - quently associated in complexes, c lake complexes

before reclamation - 2050 floodplain basins (14% of the floodplain covered by lakes):
three types of lake environments

(1) partly infilled single cut-off oxbow lakes (DT Severin – Calafat),
(2) large single lake basins (Calafat – Giurgiu)
(3) lake complexes become (downstream of Giurgiu)



- during spring floods - the river overflow into lakes (discharge into the marshes - 5–6 m3 /s)
- during summer low water level - the system reversed (discharge rate for the Filipoiu marsh - Balta Brăilei - 450 m3 /s towards the Măcin branch in 1906 (Vidrascu 1915))

water storage in Balta Brăilei - up to 5.5 billion m3 of the total of 24 billion m3 of water stored along the entire floodplain (Antipa 1921).

The use of the Danube floodplain in the early XXth - two different conceptual models:

1. agricultural development (Saligny, Ionescu-Sisești, 1933) – drainage of floodplain
2. fish farms and animal husbandry (Antipa, Vidrașcu, 1921) – preserve the natural flood regime and floodplain features

<u>After 1960</u>, the agricultural model - extensive embankments and drainage works along lower Danube

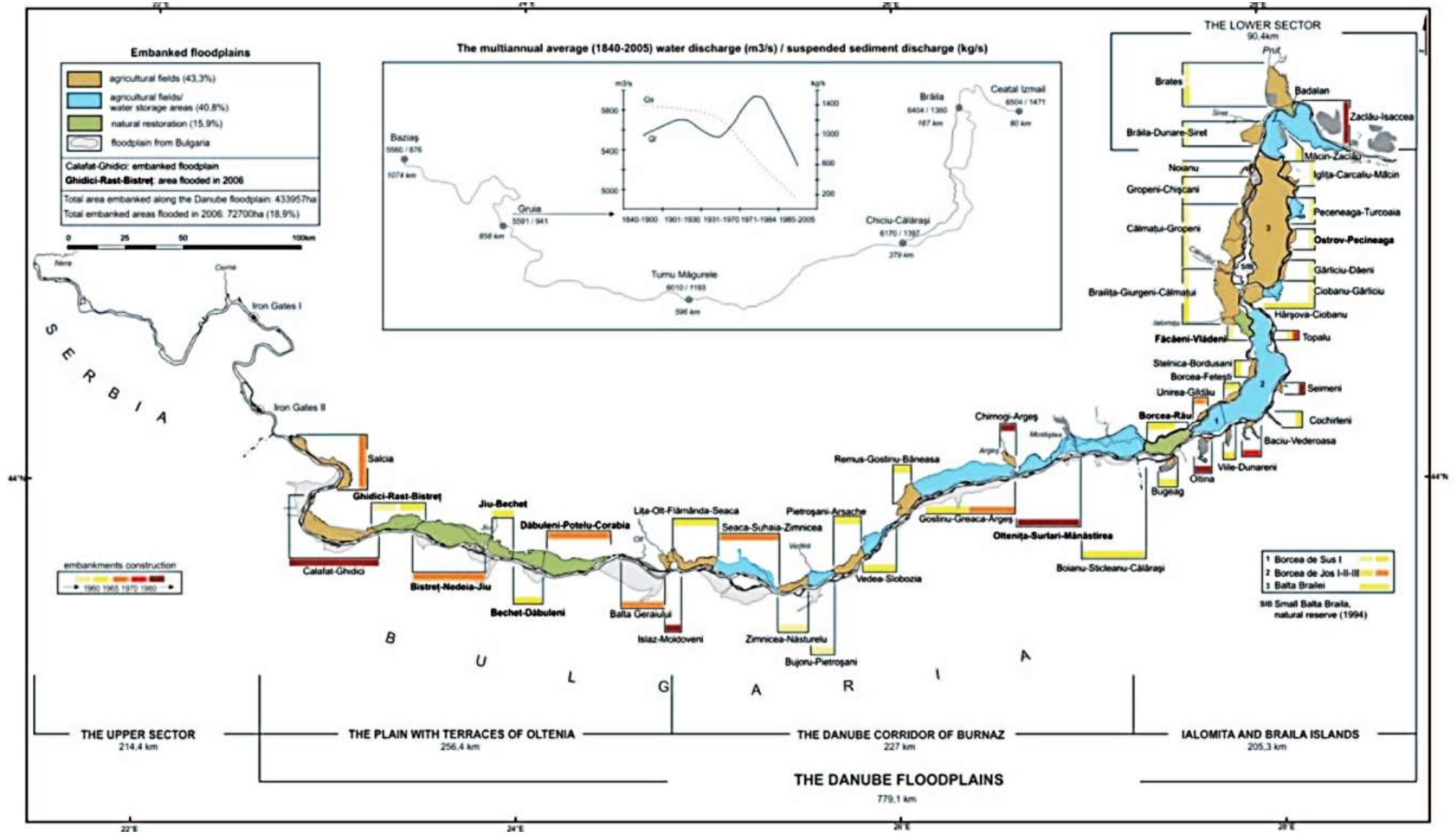
⟶ the natural hydrologic and geomorphic regime was largely eliminated to make way for intensive agriculture.

- a ***narrowing of the channel bed***

<u>After 1990</u> - private ownership:

- the conservative model (agricultural activities)
- ecological model (natural hydrogeomorphic regime)

- 56 embanked enclosures (431,763 ha): 55% on the left bank, 12% on the right bank and 33% on islets
- embankments total length of embankments: 1158 km (619 km on the left bank, 175 km on the right bank and 31 km on islets) (Ioaniţoaia 2007)
- land use of floodplain (2007): arable lands 70.8%, forests 10.3%, fishery 3.5%, reed processing 0.32%, residential 1.49%, transportation 6.7% and unused 5.37%.

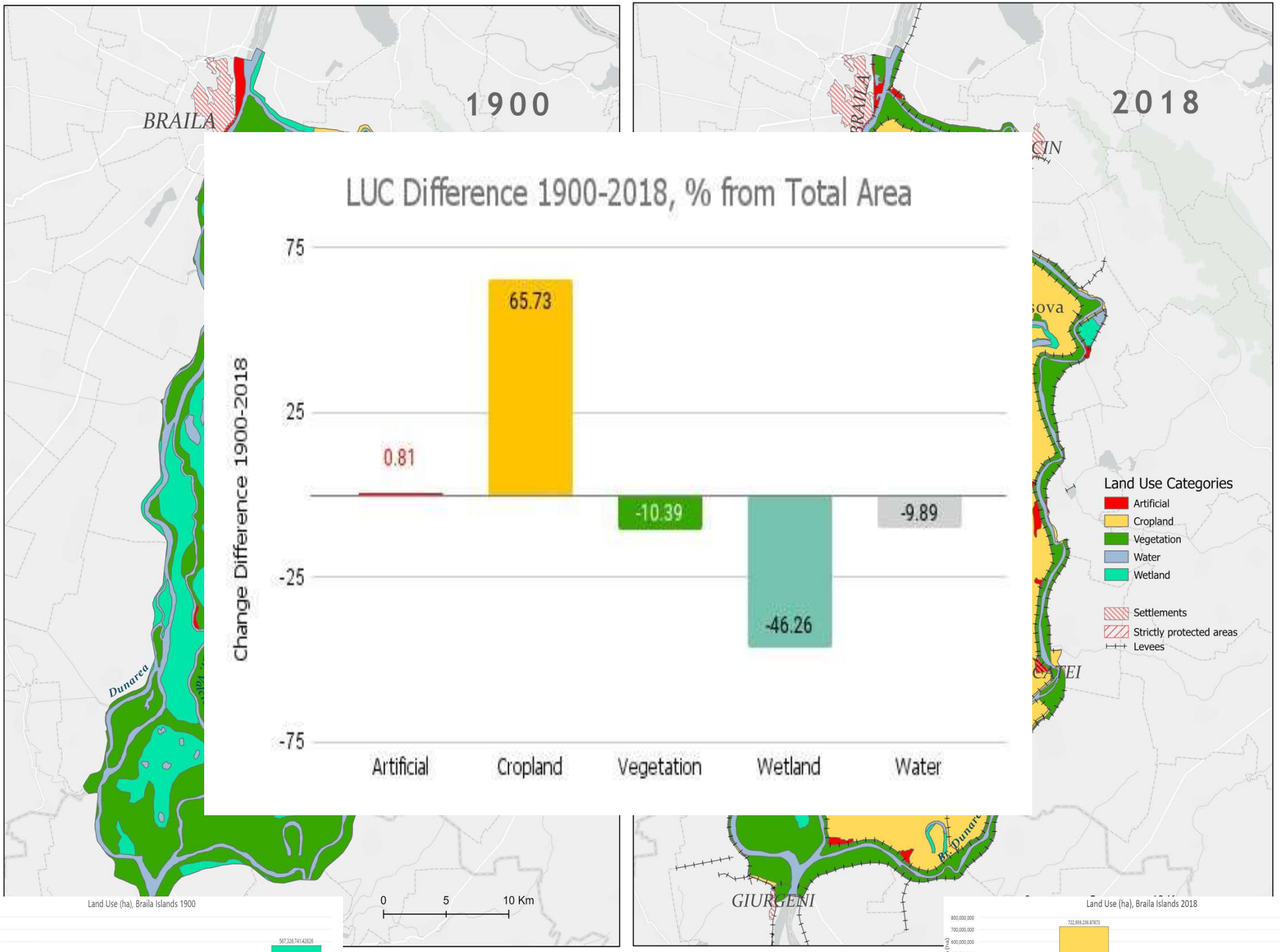


embankments resulted in ***radical changes*** in floodplain ***land use***:

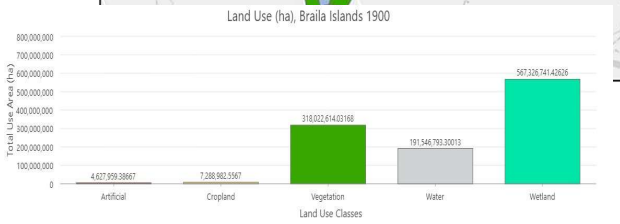
arable land surface (+359%)
forest (–93%)
water bodies (−80.1%)
pastures and grasslands (−85.5%).

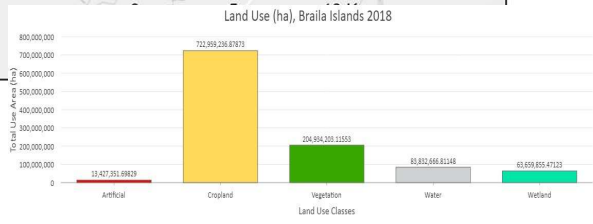
Related to agriculture - water for irrigation - only 45% of Danube's water available

⟶ the extreme pressure - ***major imbalances*** in the overall ***fluvial ecosystem***


1900
2018
BRAILA
Dunarea
GIURGENI
0
5
10 Km
Land Use Categories
Artificial
Cropland
Vegetation
Water
Wetland
Settlements
Strictly protected areas
Levees

LUC Difference 1900-2018, % from Total Area
Change Difference 1900-2018
75
25
-25
-75
0.81
65.73
-10.39
-46.26
-9.89
Artificial
Cropland
Vegetation
Wetland
Water

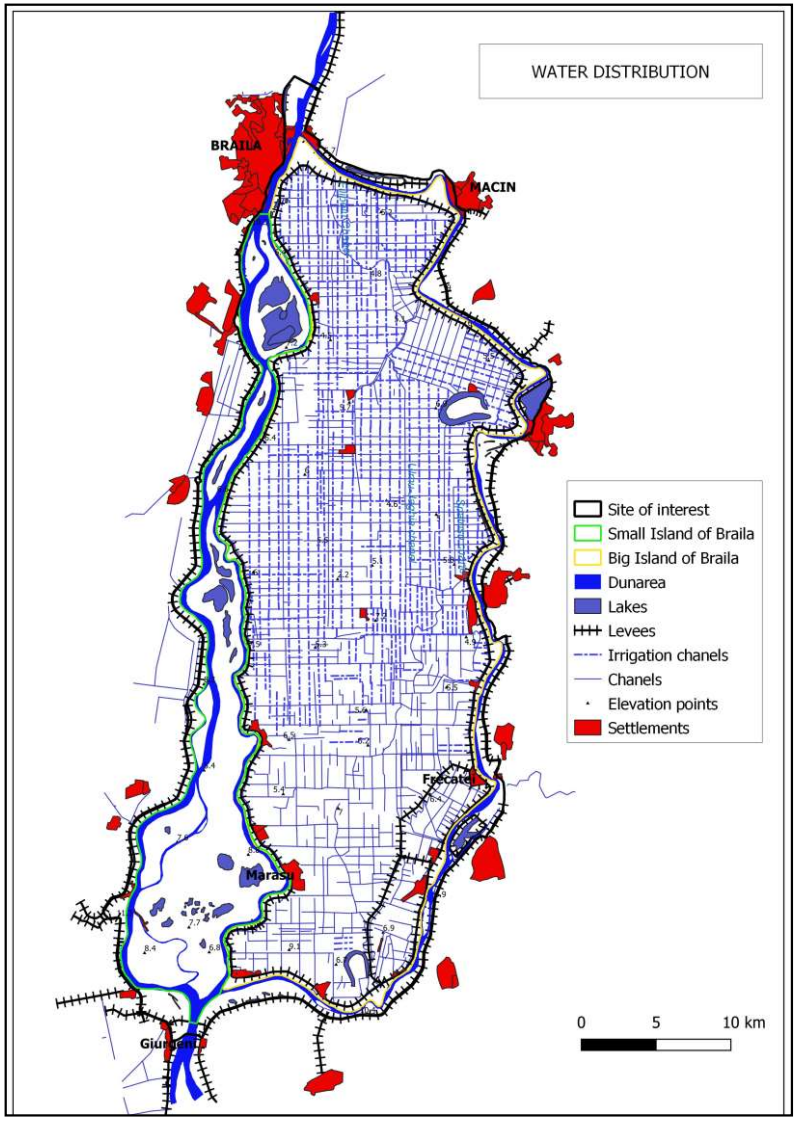

Land Use (ha), Braila Islands 1900
Total Use Area (ha)
4,627,959.38667
7,288,982.5567
318,022,614.03168
191,546,793.30013
567,326,741.42626
Artificial
Cropland
Vegetation
Water
Wetland
Land Use Classes


Land Use (ha), Braila Islands 2018
Total Use Area (ha)
13,427,351.69829
722,959,236.87873
206,994,205.11553
83,832,666.81148
63,659,855.47123
Artificial
Cropland
Vegetation
Water
Wetland
Land Use Classes


Focsani
Delta Dunarii
Galati
Braila
Tulcea
Buzau
Slobozia
Pitesti
Drobeta-Turnu Severin
Slatina
Bucuresti
Balta Ialomitei
Craiova
Calarasi
Constanta
Ghidici - Macesu de Jos
Alexandria
Giurgiu
Oltenita - Calarasi
Bechet - Corabia

CHANELLISATION AND STRAIGHTENING

- 1856 – first flow estimation by the European Danube Commission (EDC) to improve the navigability of the middle branch
- intensive channelization (ex. channel density in Braila and Ialomita increased (0.92 km/km2 to 1.66 km/km2)

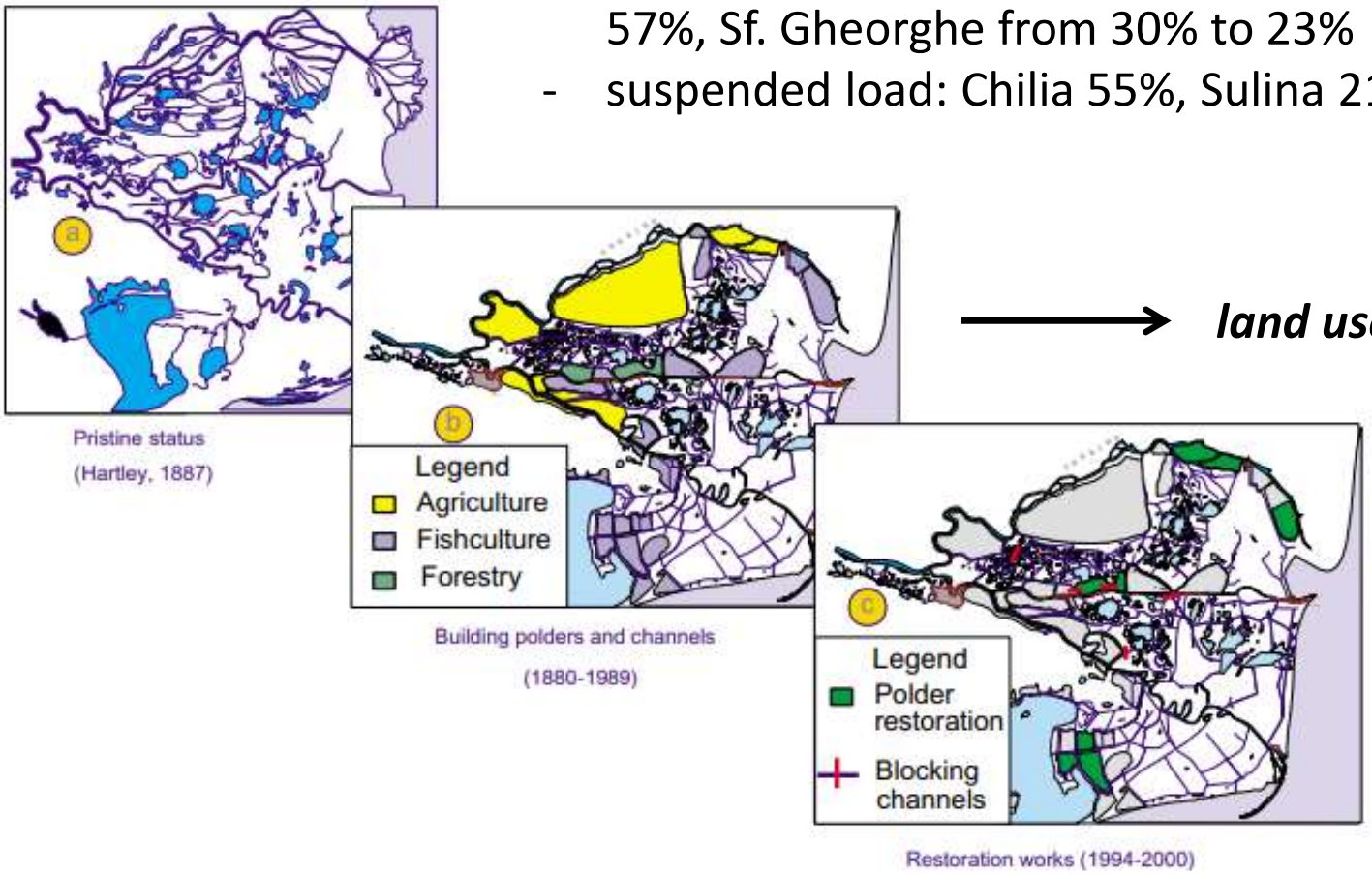


CHANELLISATION AND STRAIGHTENING

- 1856 – first flow estimation by the European Danube Commission (EDC) to improve the navigability of the middle branch
- intensive channelization (ex. channel density in Braila and Ialomita increased (0.92 km/km2 to 1.66 km/km2)

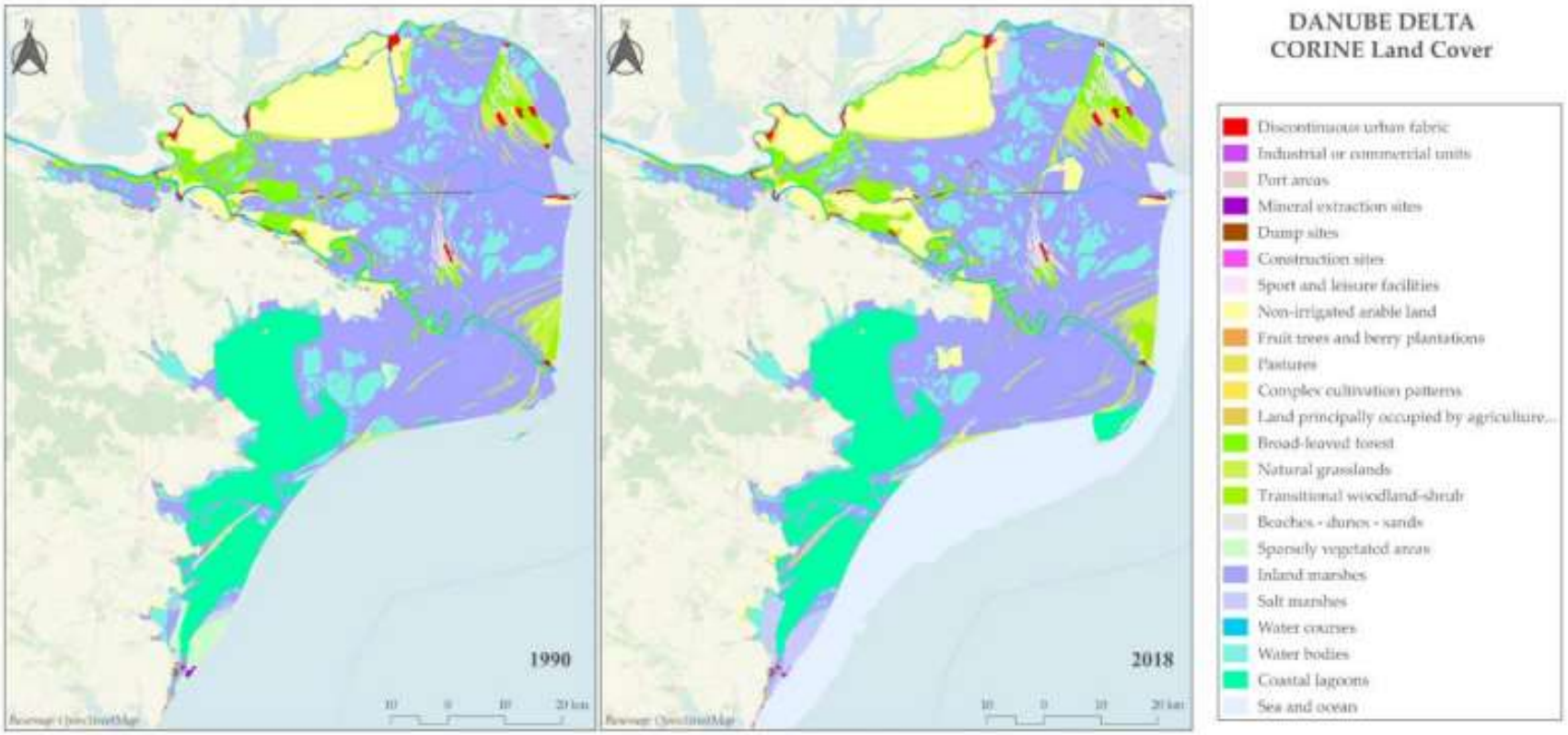
→ ***water and sediment discharge redistributed***

- water discharge: Sulina from 7% to 19%, Chilia from 63% to 57%, Sf. Gheorghe from 30% to 23%
- suspended load: Chilia 55%, Sulina 21%, Sf. Gheorghe 23%

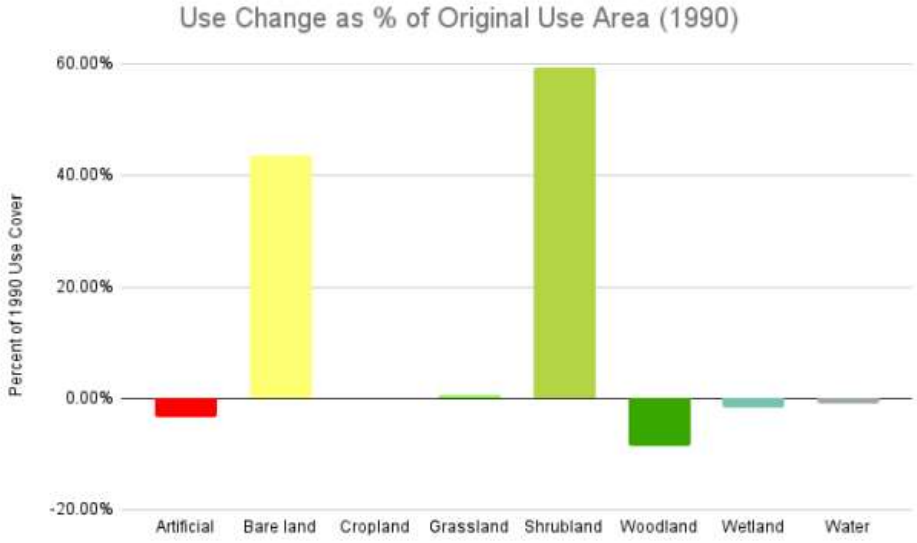


→ ***land use changes***

- 1903-1960 ‘capture fishery period’
- 1960-1970 ‘reed period’
- 1971-1980 ‘fish culture period’
- 1983-1989 - ‘agriculture period’



Danube Delta CORINE Land Cover 1990/2018



CONCLUSIONS

The floodplain improvement system should be based on the local geomorphology of the floodplain and the conservation of large and permanent lakes

The visionary strategy of G. Antipa (rotating agricultural polders, in alternation floodable areas) - the only forward-looking solution for the *economic exploitation* of the Danube floodplain and, simultaneously, for a *better preservation* of the fluvial ecosystem

Restoration can easily be achieved, starting with small embanked areas that were abandoned by farmers because of their economic inefficiency caused by salinization and waterlogging.

The key to returning the floodplain to its natural state is in restoring the collective environmental memory of its people. (Constantinescu et al., 2015)