CAUSES AND IMPACTS OF TWENTIETH-CENTURY EXPANSION OF RIPARIAN FOREST IN THE VALLEYS OF POLISH CARPATHIAN RIVERS

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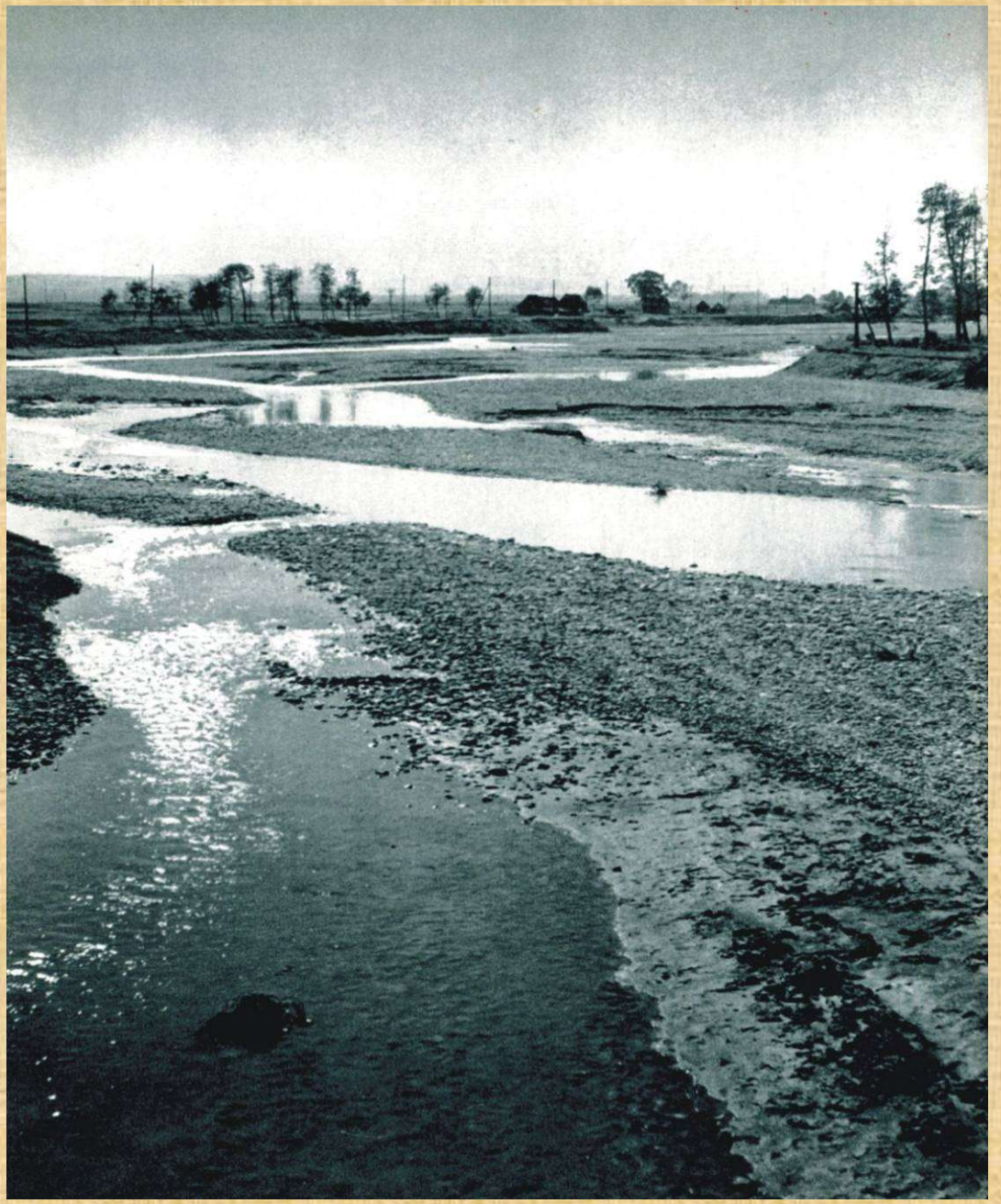
Condition of valley floors in the Polish Carpathians and other mountain areas in Europe:

In the late 19th century:

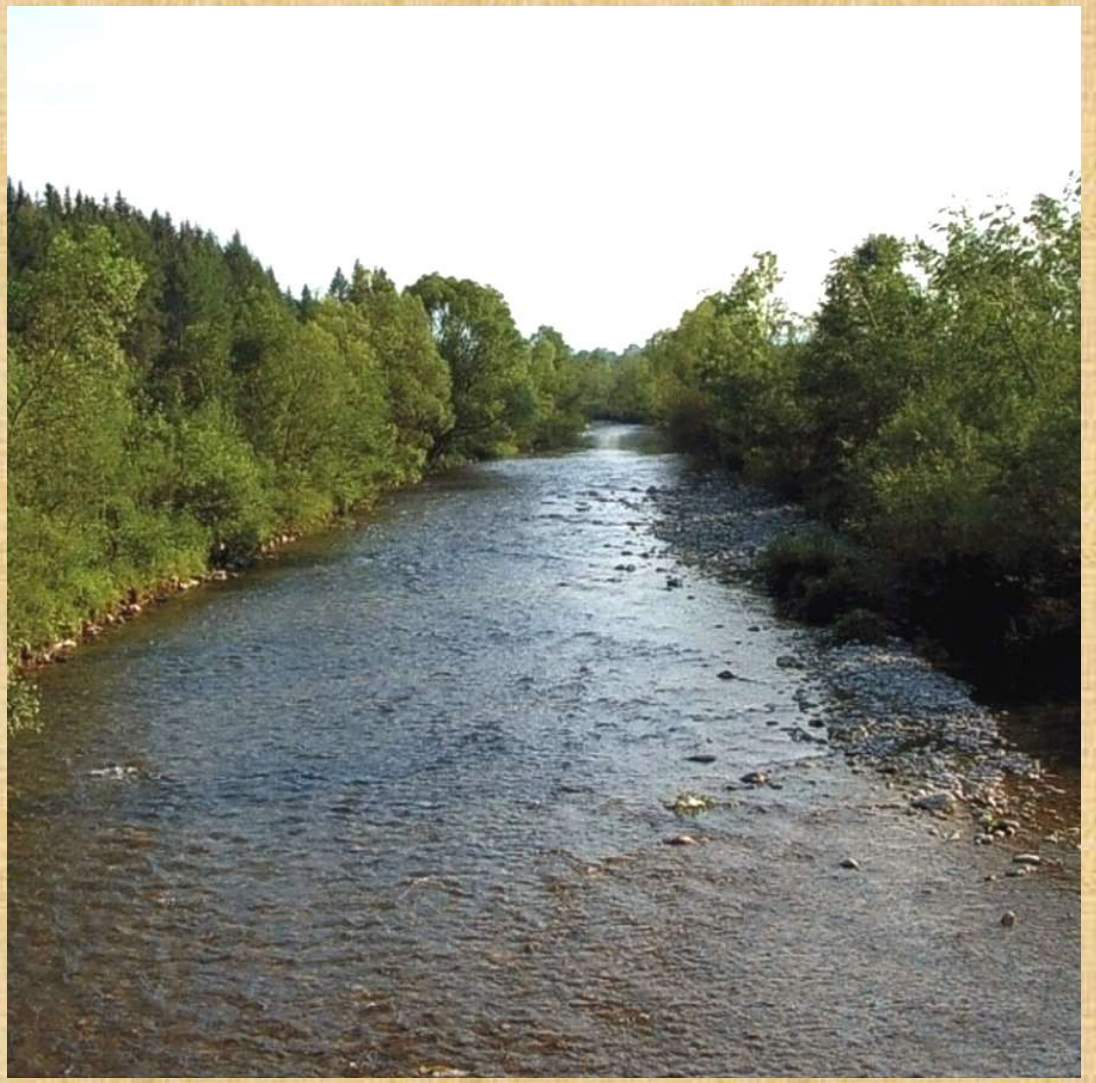
- riparian forest lacking or very scarce
- wide active zones of the rivers (overturned by rapidly migrating, unregulated channels)
- intensive use of riparian areas for grazing and cultivation

In the 20th century (especially in the second half):

- progressive development of forest along river channels
- forest encroachment on mid-channel bars turning them into wooded islands



Czarny Dunajec in the middle course – photo from the mid-twentieth century

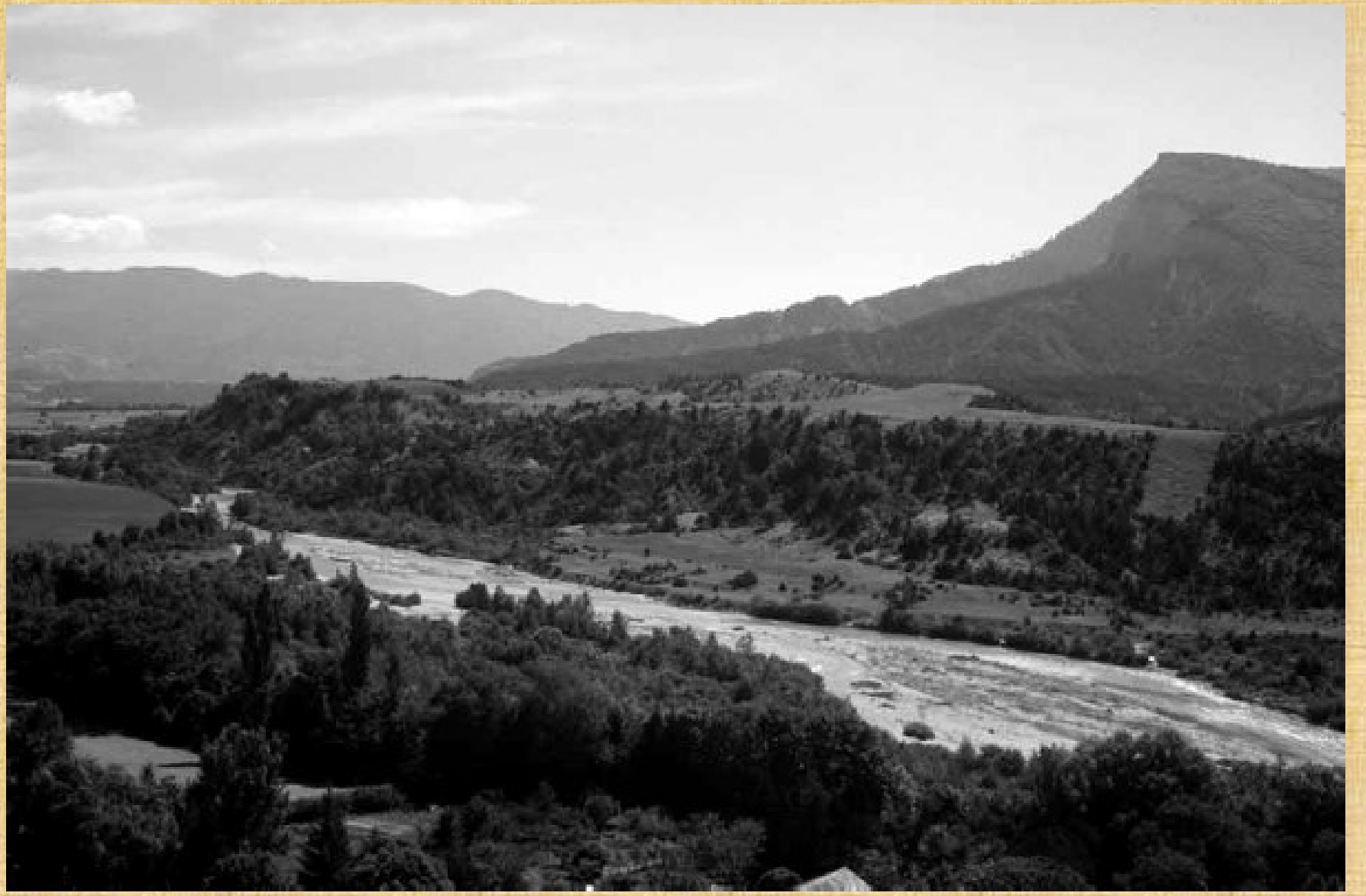


The same reach after channel regulation, present-day situation

Czarny Dunajec River in unmanaged channel section – forest grows on the channel banks

Czarny Dunajec River in unmanaged channel section – forest grows

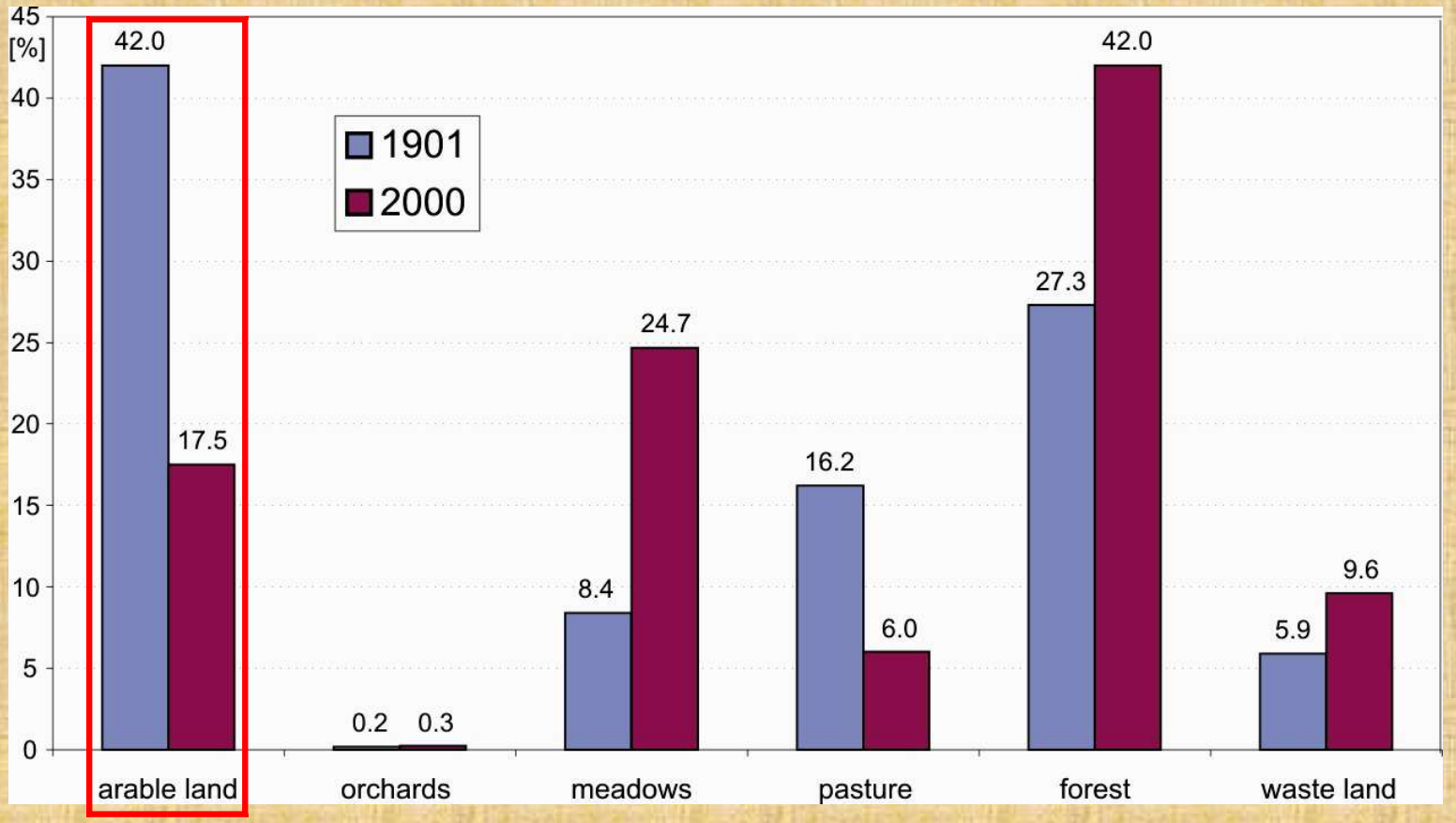
Channel and adjacent hillslopes of the Drome River on the foreland of the Alps, France – photo from around 1900 (Kondolf et al., 2002)



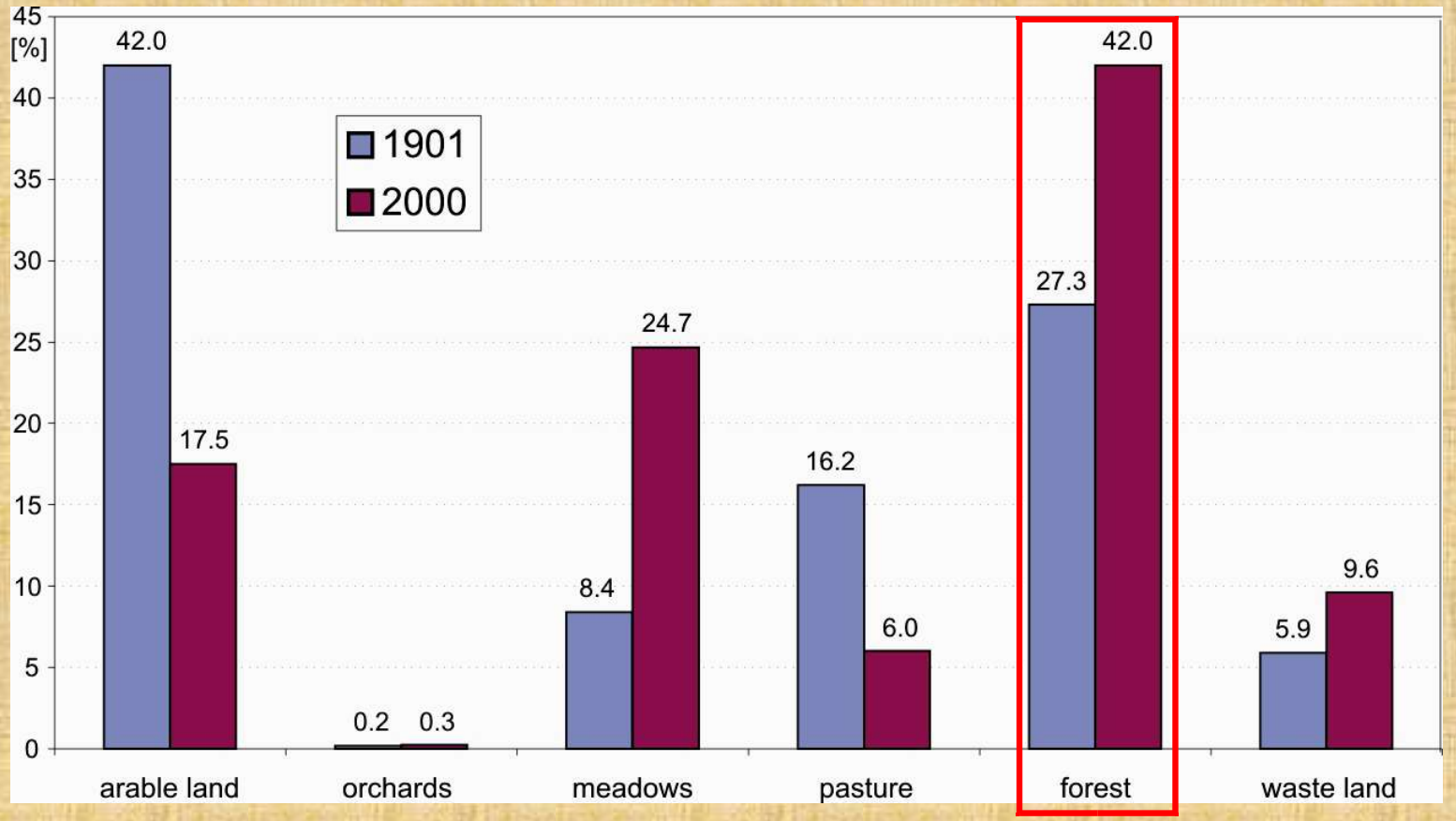
Channel and adjacent hillslopes of the Drome River on the foreland of the Alps, France – present-day situation (Kondolf et al., 2002)

Factors that have contributed to the forest expansion on the valley floors in the Polish Carpathians:

- **reduction of water and sediment dynamics of rivers caused by land use and climatic changes that affected entire catchments**



Twentieth-century land use changes in the upper Dunajec River catchment as an example of environmental changes in the Polish Carpathian catchments



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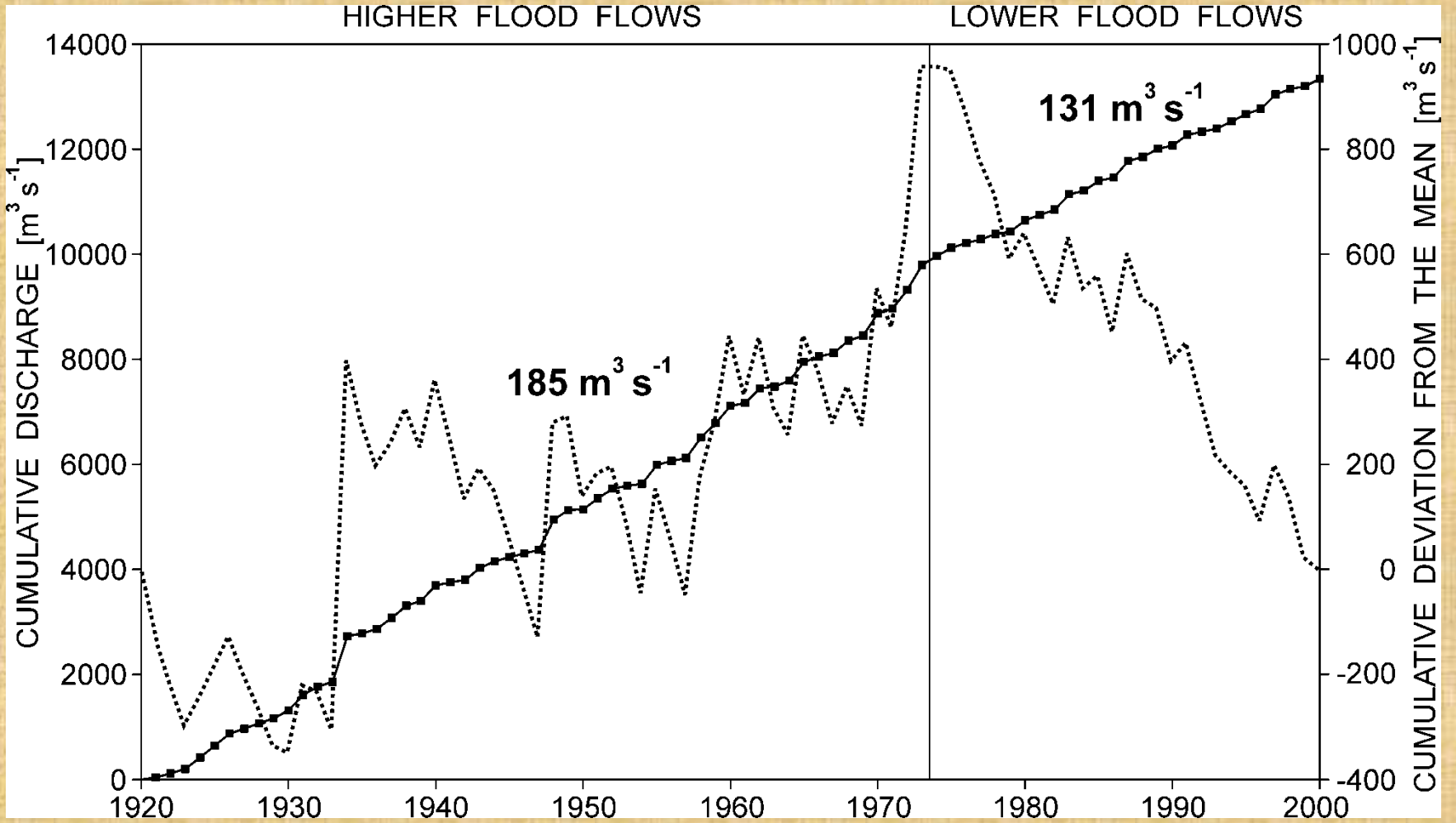

Reduction in maximum annual discharges of the upper Dunajec River since the mid-1970s as shown by the record at the Nowy Targ gauging station

Factors that have contributed to the forest expansion on the valley floors in Polish Carpathians:

1. Reduction of water and sediment dynamics of rivers caused by land use and climatic changes that affected entire catchments

2. Stabilization of river position on the valley floors caused by bank reinforcement in the course of channelization works

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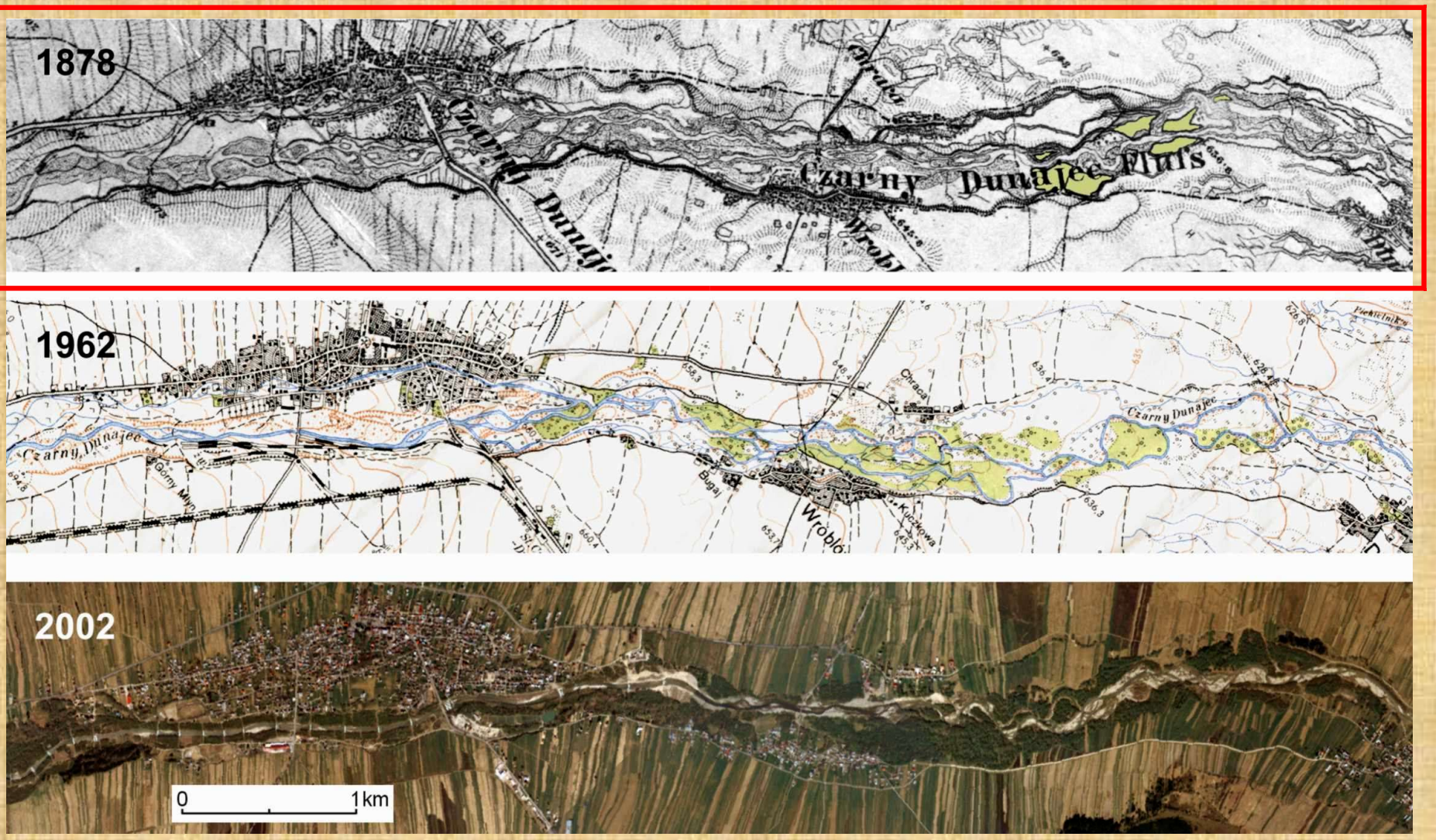
3. Decline in pastoral and agricultural pressure on the riparian areas after new sources of income for the rural communities appeared

Afforestation of the Czarny Dunajec valley

The 20th-century expansion of riparian forest is illustrated by changes in the middle course of the Czarny Dunajec River.

In the second half of the 19th century:

- ***forest present only on few islands in a short river section***
- ***river banks completely deforested***


1878
Czarny Dunajec
Wróblo
1962
Czarny Dunajec
Górny Młyn
Bugaj
Wróblo
Kuczkowa
Czarny Dunajec
2002
0
1 km

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In the mid-20th century:

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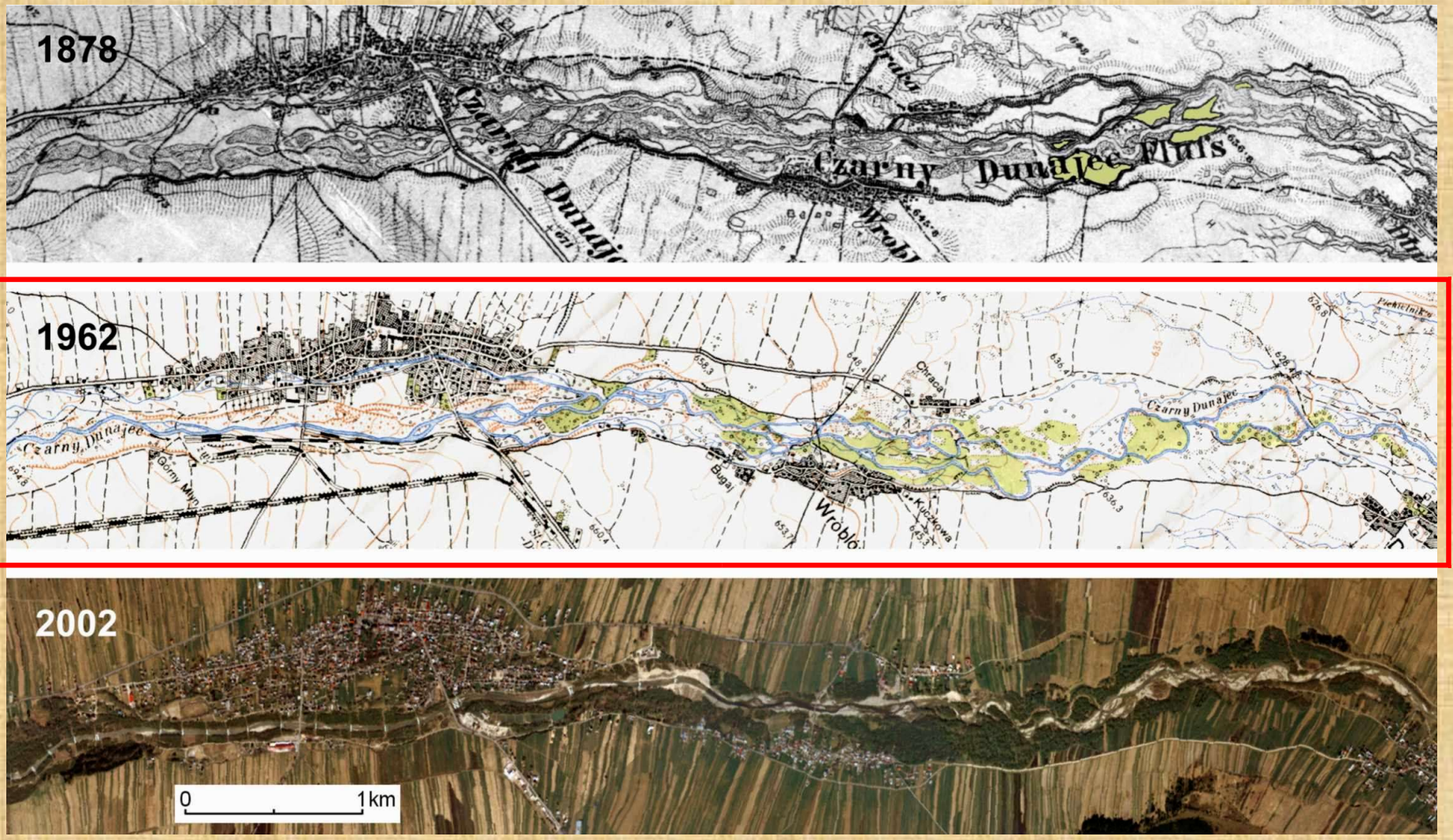
- ***but still absent in the other sections***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Currently:

- forest present along almost the whole length of the river banks
- trees and shrubs cover many emerged surfaces within the multi-thread river sections

The 20th-century expansion of riparian forest is illustrated by changes in the middle course of the Czarny Dunajec River draining the Inner Polish Carpathians.

Effects of the forest development on the valley floors

1. Delivery of considerable quantities of large wood to the channels (mainly during floods)

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2. Increased lateral stability of channel banks and of the network of emerged surfaces and low-flow channels within the active zone of rivers

Czarny Dunajec River in the middle course, present-day situation

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2. Increased lateral stability of channel banks and of the network of emerged surfaces and low-flow channels within the active zone of rivers

3. Increased biocomplexity and biodiversity of riparian and riverine ecosystems

Wooded islands are hot spots of biodiversity from early stage of their development – this pioneer island supports 33 plant species on 13 m^2 of its area.

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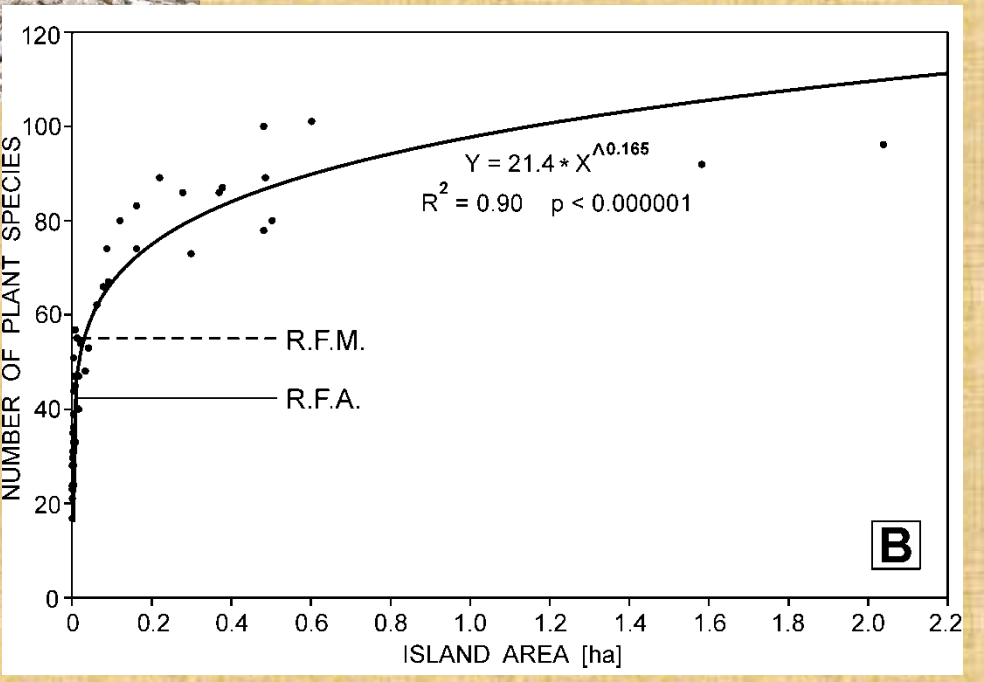
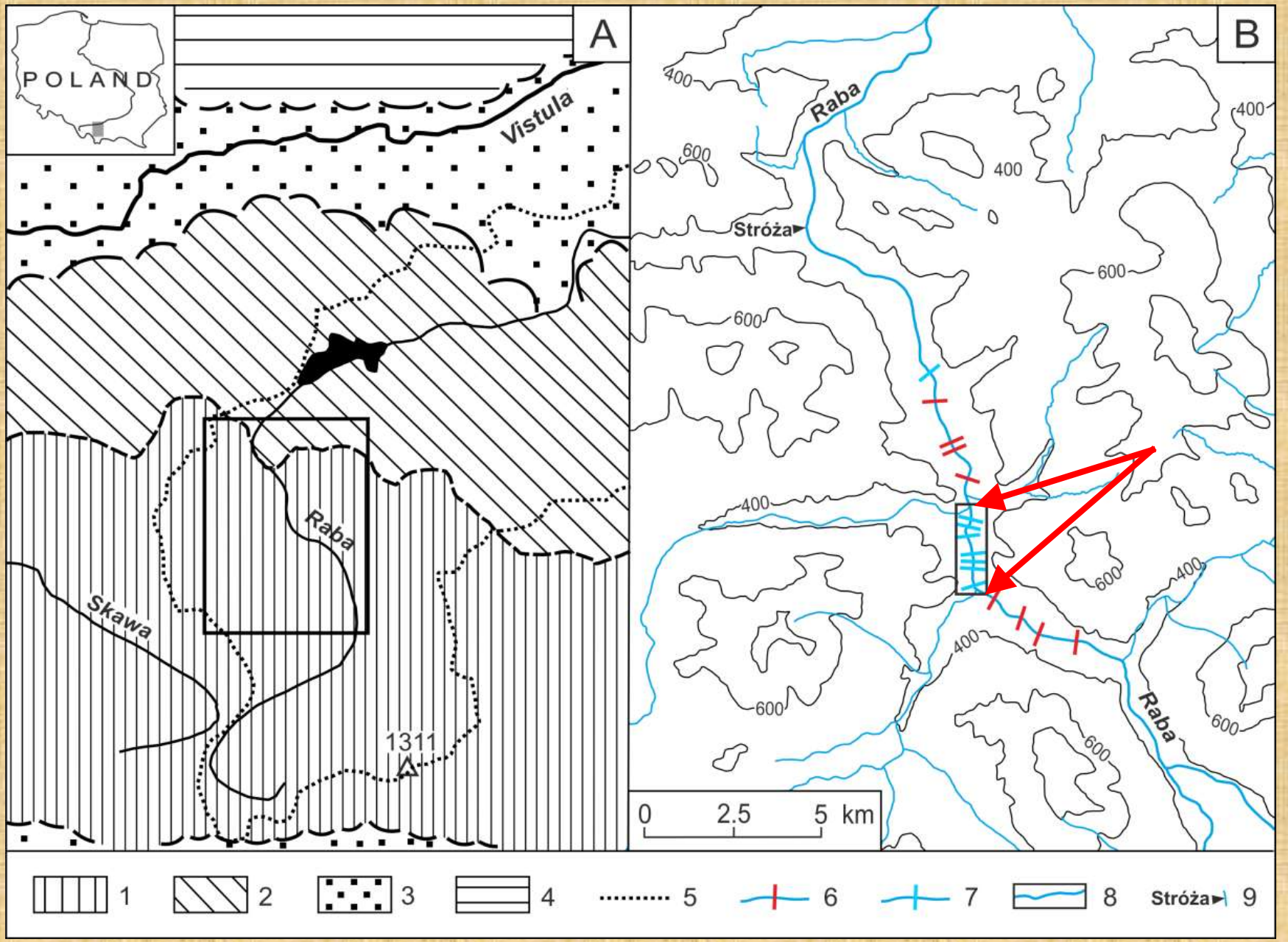


Wooded islands in the Czarny Dunajec River supported between 17 and 101 plant species typical of variable types of habitat: forest, fringe, meadow, ruderal and wetland.

ISLAND DEVELOPMENT IN A MOUNTAIN RIVER SUBJECTED TO RESTORATION: THE RABA RIVER, POLISH CARPATHIANS

Paweł Mikuś[1], Edward Walusiak[1], Bartłomiej Wyżga[1], Maciej Liro[1], Hanna Hajdukiewicz[1], Artur Radecki-Pawlik[2], Joanna Zawiejska[3]

[1] Institute of Nature Conservation, Polish Academy of Sciences, al. Mickiewicza 33, 31-120 Kraków, Poland
[2] Faculty of Civil Engineering, Cracow University of Technology, ul. Warszawska 24, 31-155 Kraków, Poland
[3] Institute of Geography, Pedagogical University of Cracow, ul. Podchorążych 2, 30-084 Kraków, Poland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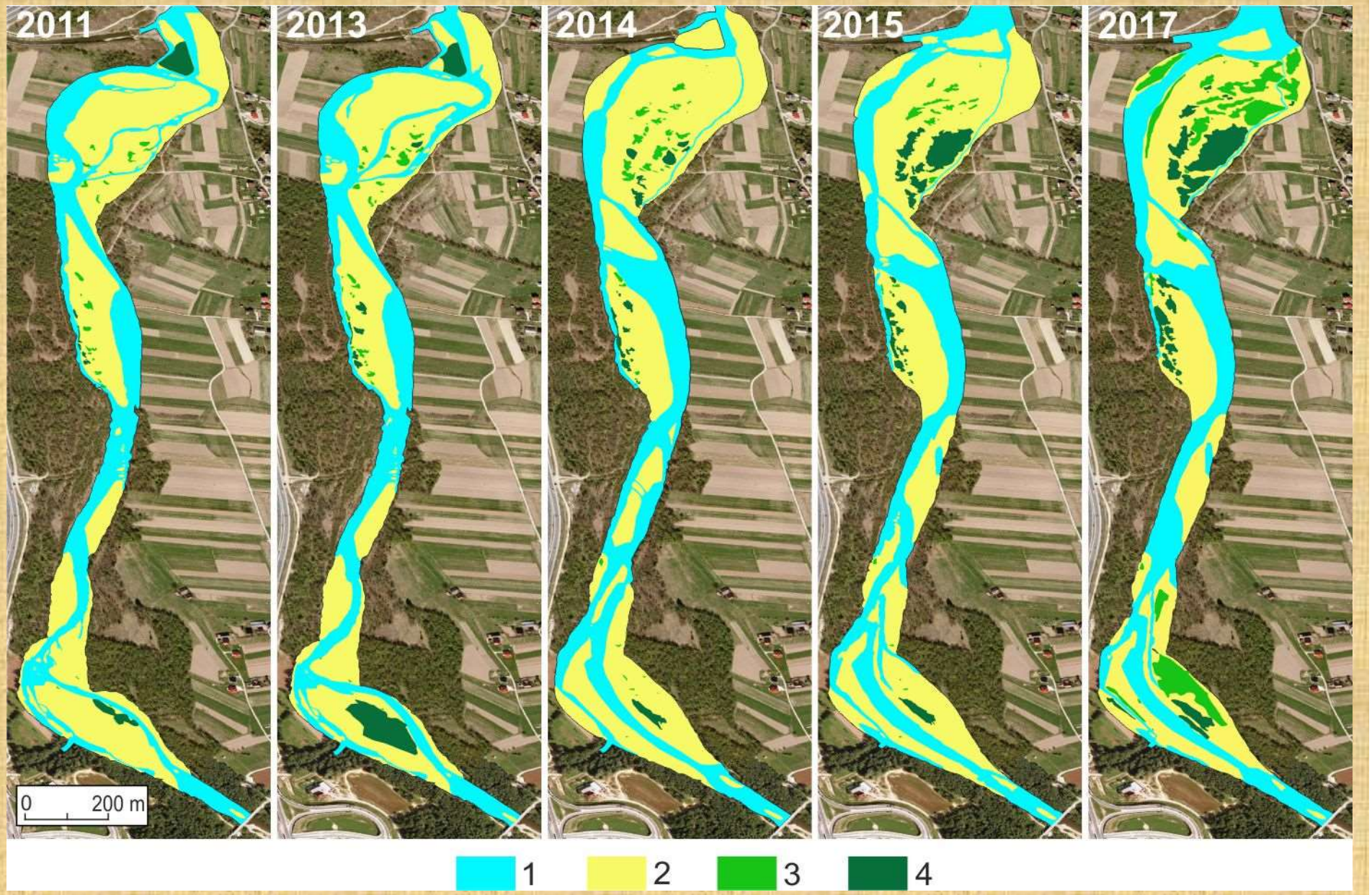
Channel changes in the erodible corridor of the Raba River

2009: resignation from the maintenance of existing bank reinforcements
2010 & 2014: two major floods causing considerable channel widening

Island development in the years 2011-2017



Morphometric parameters of islands recorded in the Raba River between 2011 and 2017

Year	2011	2012	2013	2014	2015	2016	2017
Number of islands: total and (pioneer/building islands)	28 (24/4)	28 (22/6)	40 (33/7)	59 (43/16)	42 (24/18)	42 (24/18)	50 (23/27)
Average island age (year)	2.8	3.6	3.4	2.7	4.0	5.0	5.9
Average island perimeter (m)	54	56	59	55	86	89	148
Average island area (m^2)	139	166	367	162	375	418	893
Total island area (ha)	0.3	0.5	1.5	1.0	1.6	1.7	4.5
Proportion of river area covered by islands (%)	1.4	2.0	6.3	3.5	5.8	6.3	16.4
Total number of plant species on islands	161	198	202	195	158	142	145
Total number of plant species on plots of riparian forest	–	161	–	–	156	142	130
Average number of plant species on islands	52.2	59.4	55.5	28.4	26.6	31.7	38.2
Average number of plant species on plots of riparian forest	–	52.8	–	–	47.2	50.6	48.2
Maximum annual discharge at the Stróża gauging station ($m^3\ s^{-1}$) *	170	61	137	676	173	93	126

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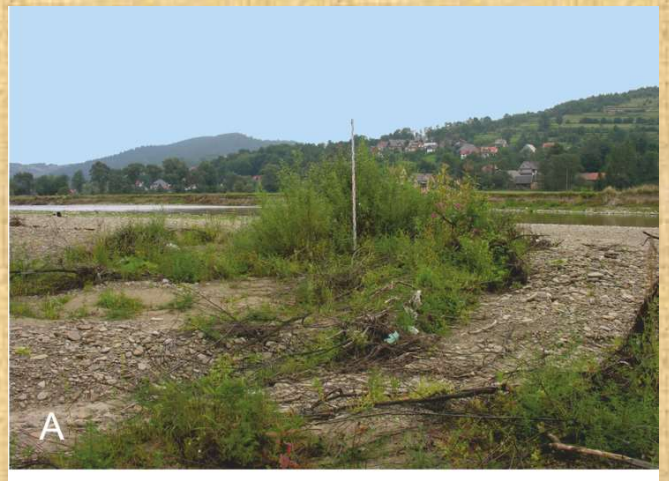
Examples of pioneer islands formed in the erodible corridor of the Raba River

A) Re-sprouting willow driftwood



B) Re-sprouting poplar driftwood

C) Numerous patches of sprouting willow driftwood scattered on a channel bar

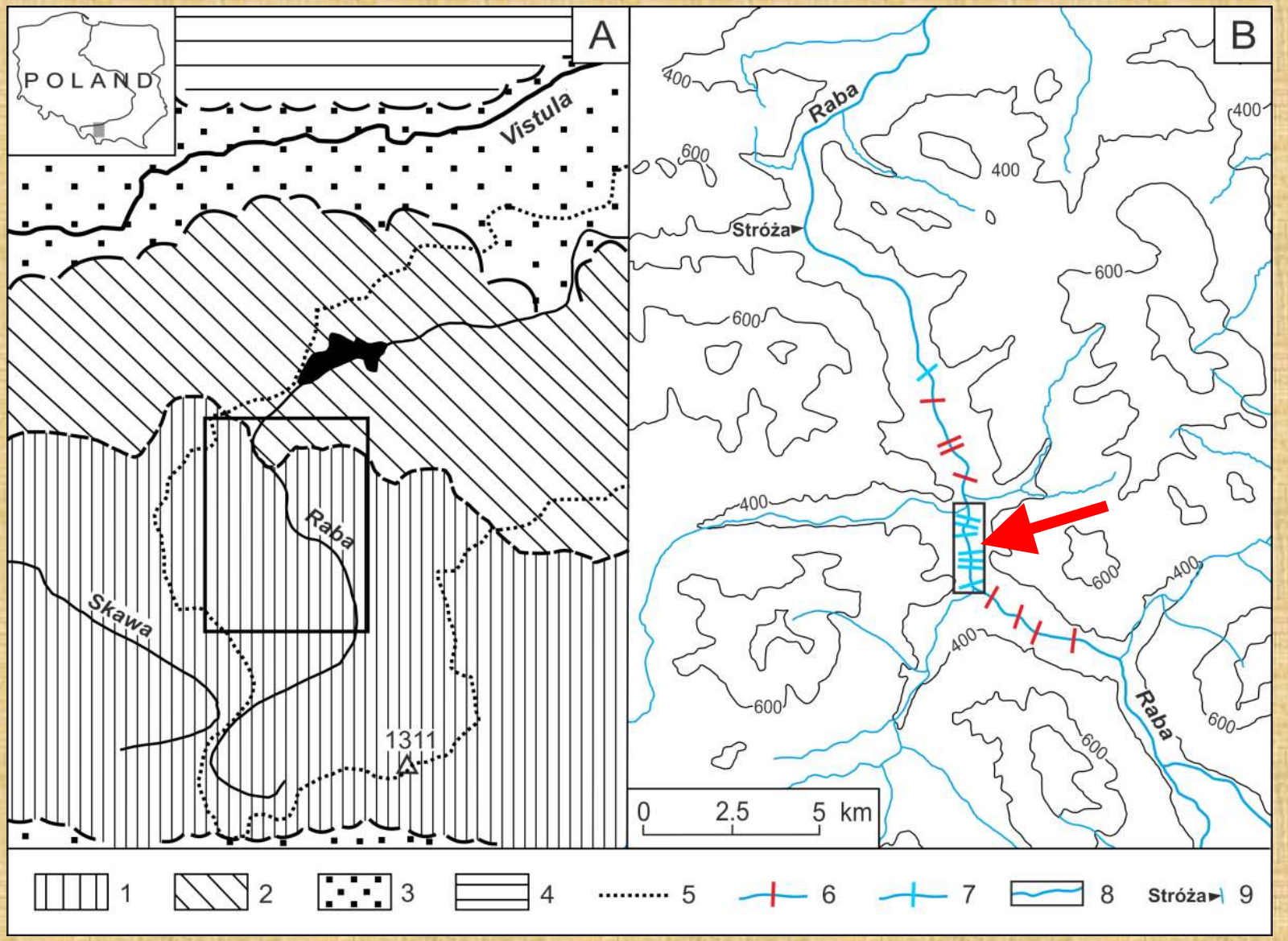
Temporary nature of alder samplings

1,5 m high saplings, developing in the years 2011-2013

Total erosion of all saplings during the flood in 2014

Elongated pioneer islands

Elongated pioneer islands formed along low-flow channel margins as a result of sprouting of willow cuttings


A
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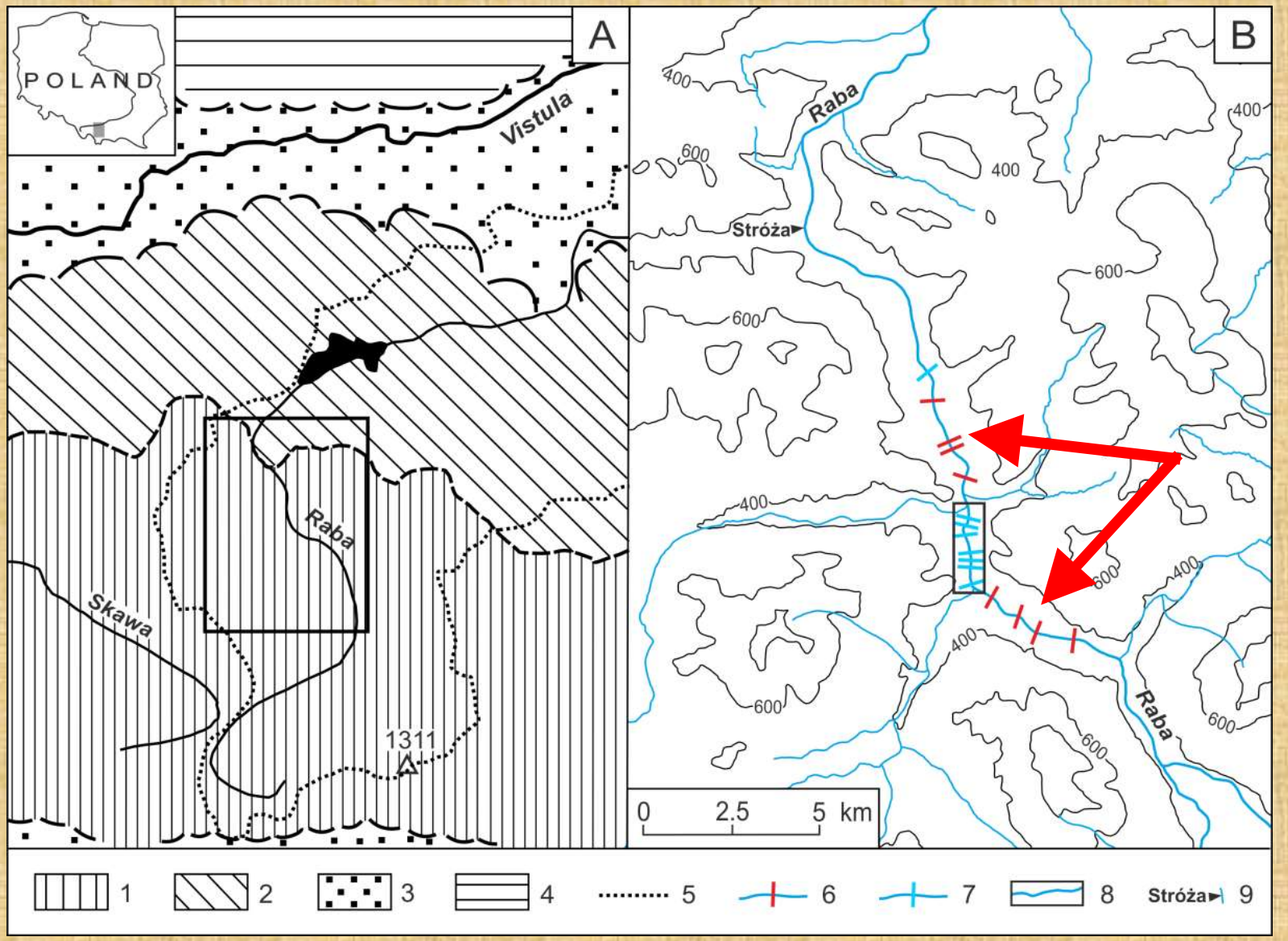
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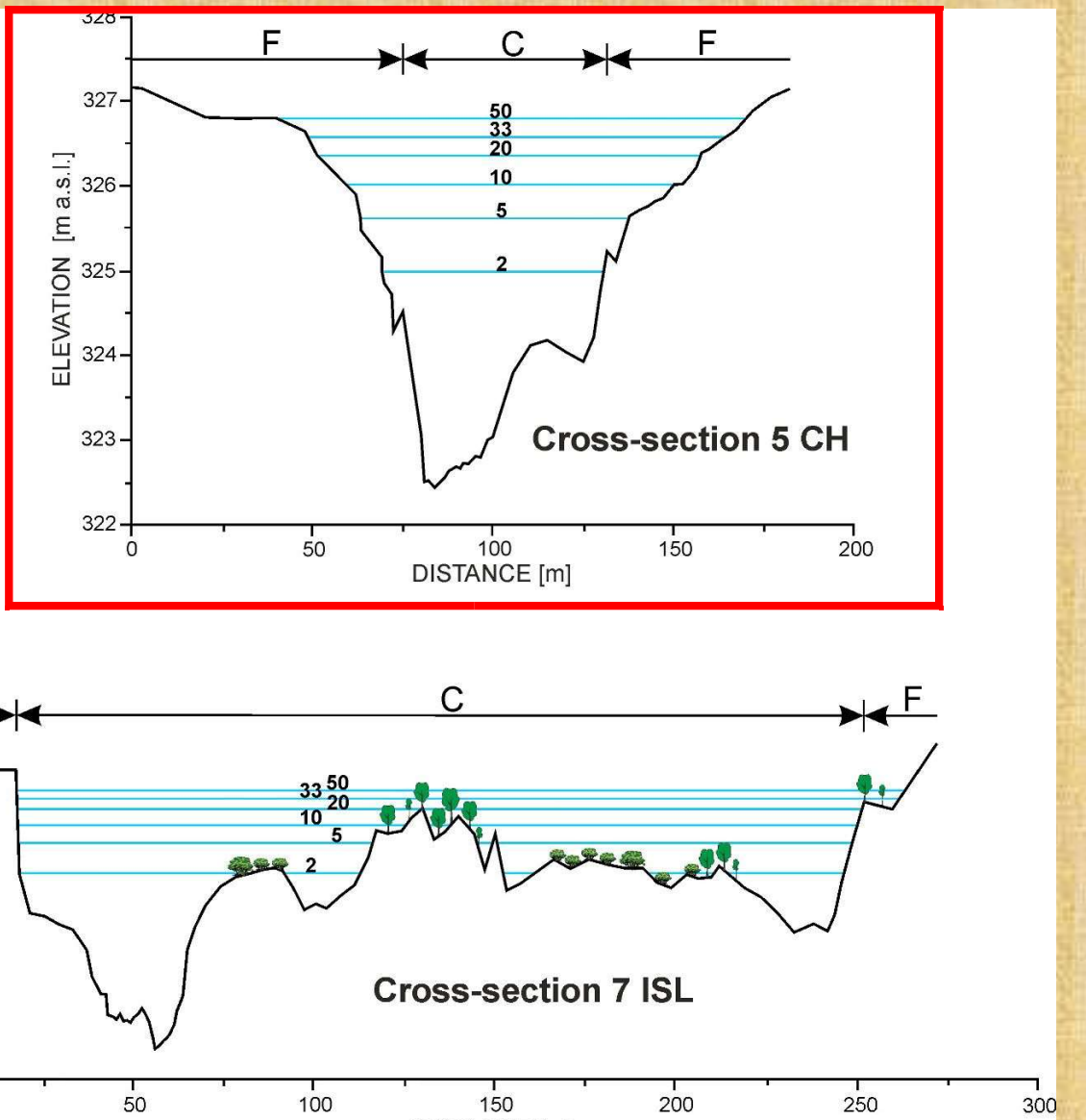
Examples of channelized and unmanaged cross-sections with indicated extent and depth of inundation at flood discharges of given frequency



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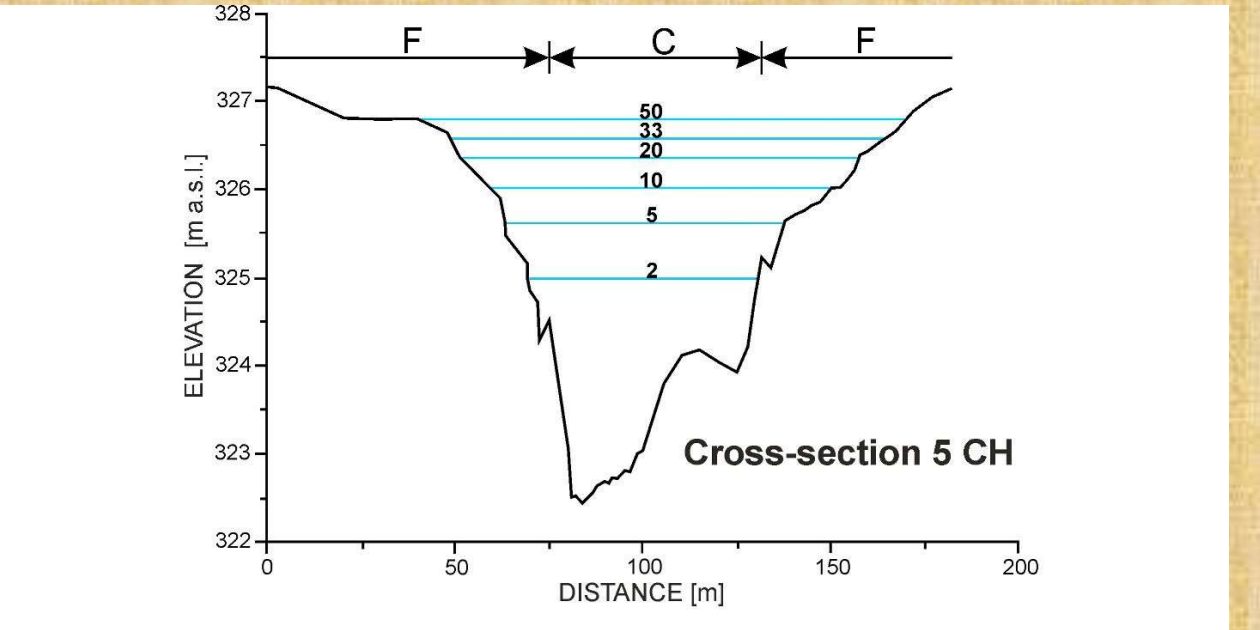
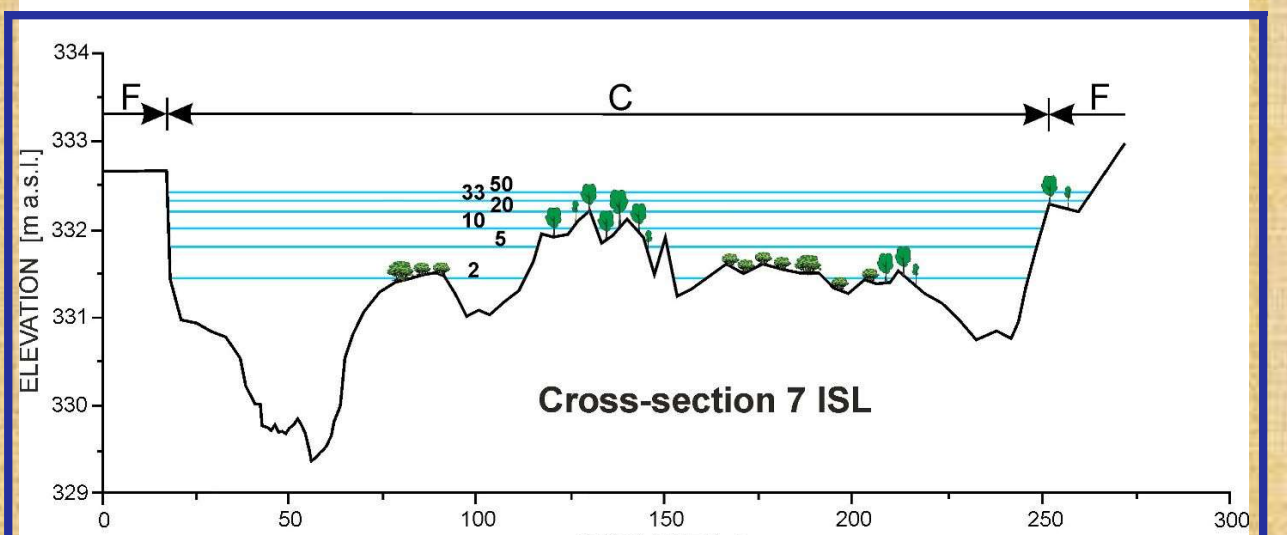
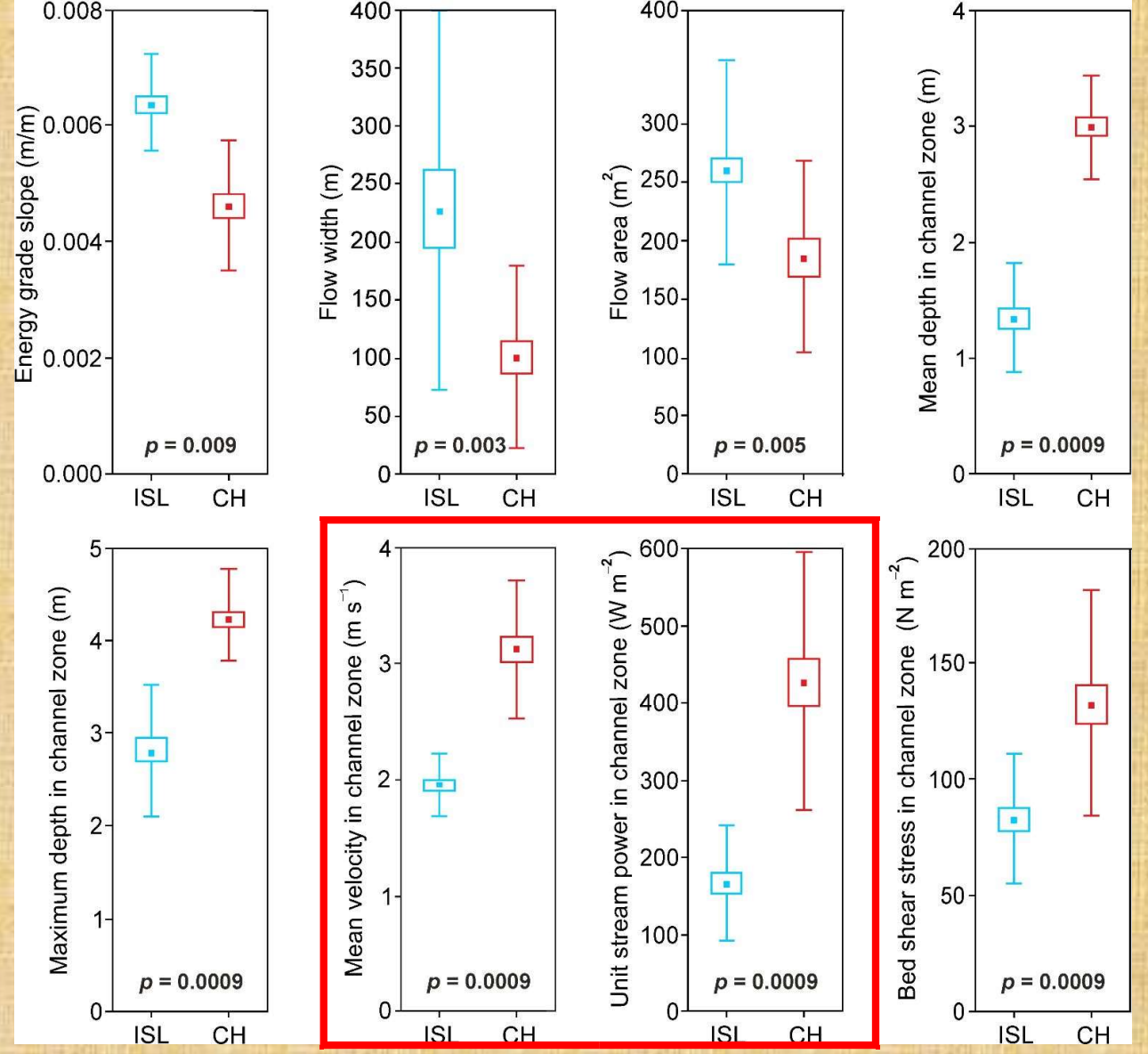
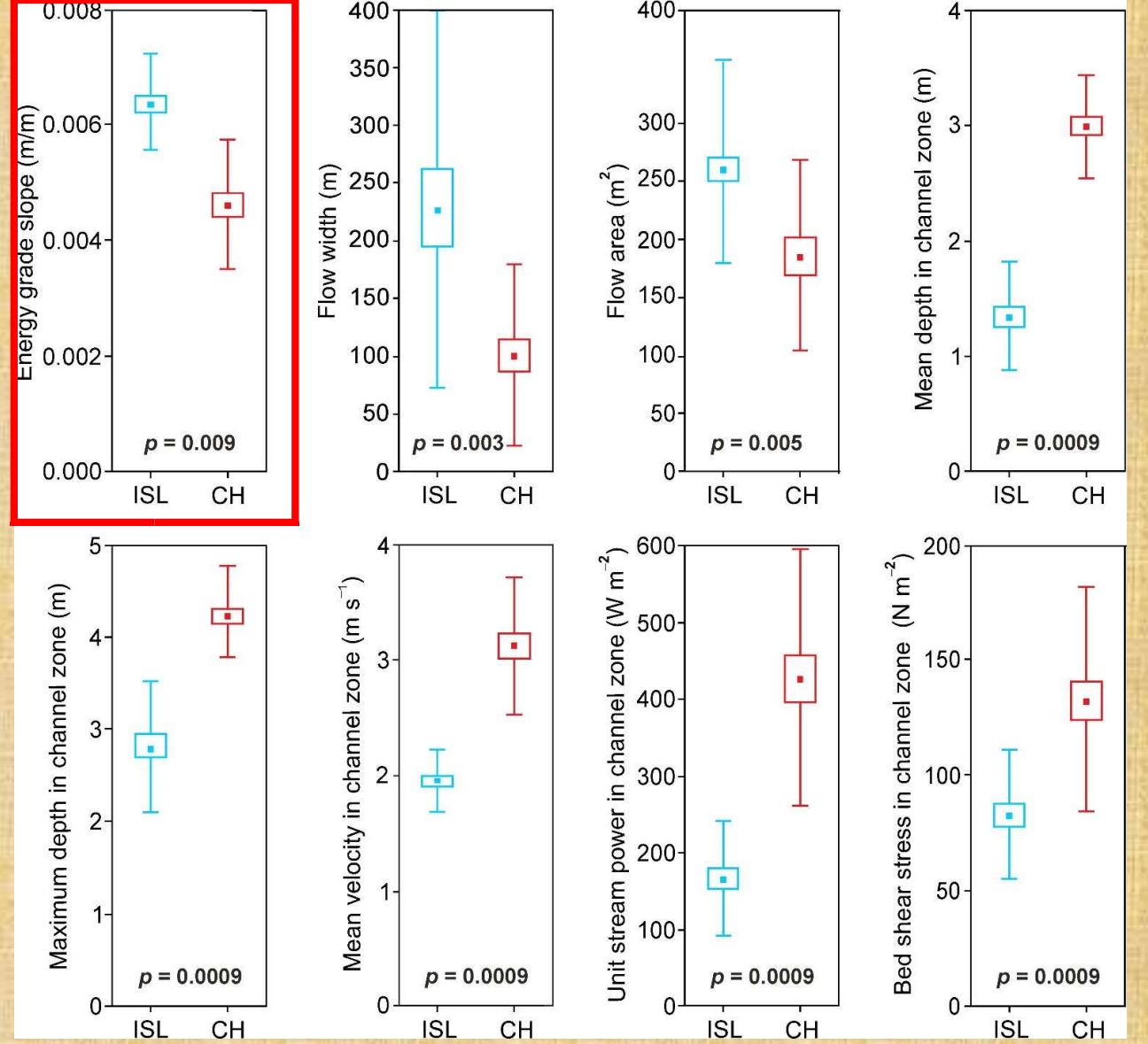






Range and mean value of hydraulic parameters at a 33-year flood in the 8 unmanaged cross-sections of the Raba River with islands (ISL) and the 8 channelized cross-sections without islands (CH)



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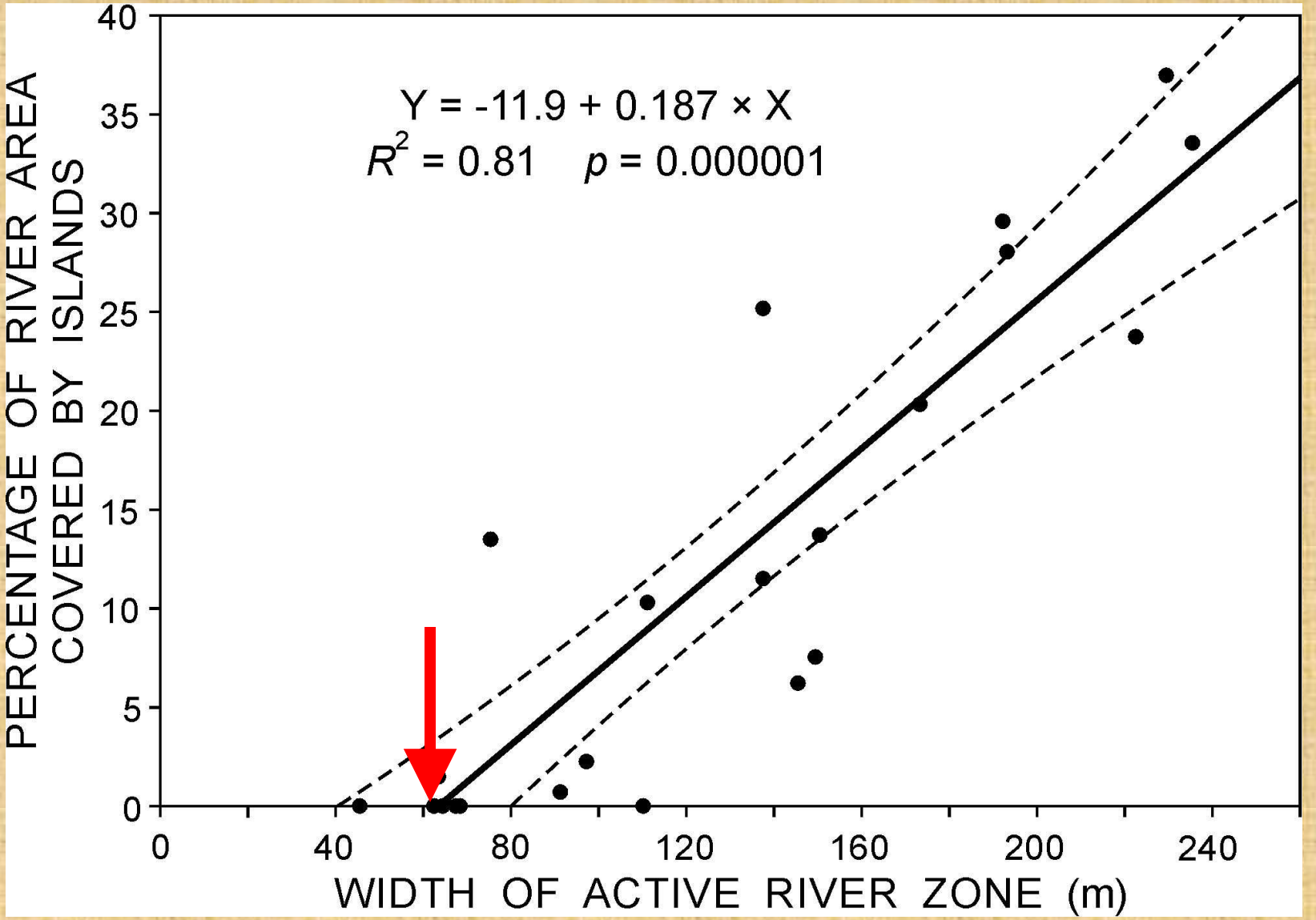
River width determines conditions of island development



Total and average numbers of plant species on islands and plots of riparian forest recorded between 2011 and 2017

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Conclusions

- Observations in the Raba River confirmed the previous findings from the Czarny Dunajec that in a highly dynamic mountain river, islands originate as a result of deposition and re-sprouting of living driftwood of Salicaceae.

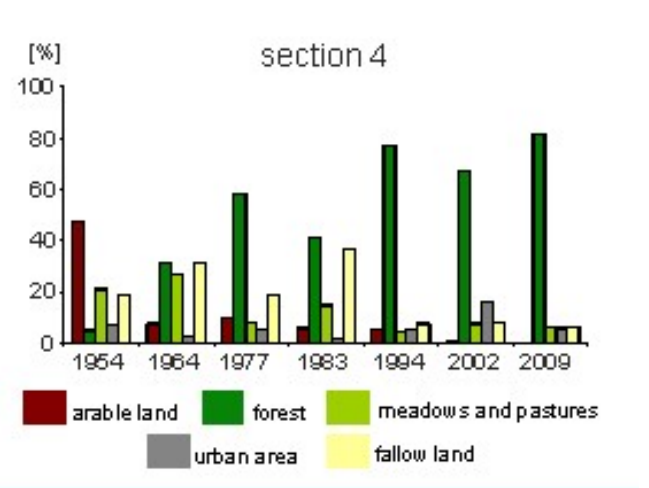
- River width and the associated degree of confinement of flood flows are key controls on the development and persistence of islands as they determine the intensity of flood disturbances.

Conclusions

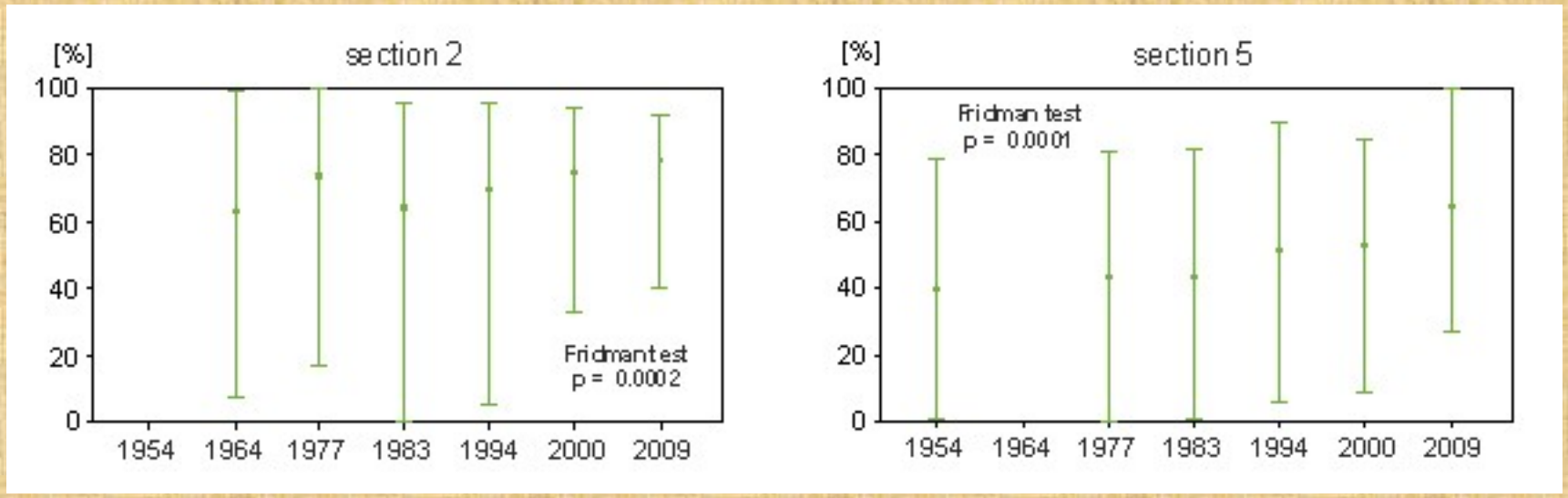
- Hydraulic conditions of flood flows in the widened reach within the erodible river corridor facilitate inception and preservation of islands.

- At early stages of island re-establishment in a widened river, the contribution of islands to the overall species richness of plant communities may be highly varied.

Forested corridor of the Raba River (ca. 40 km south of Kraków) also is protected as NATURA 2000 area



Changes in the proportion of different land use types in the floodplain area between 1954 and 2009 shown for section 4 of the Czarny Dunajec.



Changes in maximum, mean and minimum proportion of wooded channel banks in 100-m segments of sections 2 and 5 of the Czarny Dunajec between 1954 and 2009.