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COST EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

CONVERGES European Riparian Ecosystems

Seminar on RIPARIAN VEGETATION RESPONSES TO GLOBAL CHANGES

WG 1 Workshop, Madrid (Spain), January 29-30, 2020

Vegetation encroachment as a general response to multiple pressures

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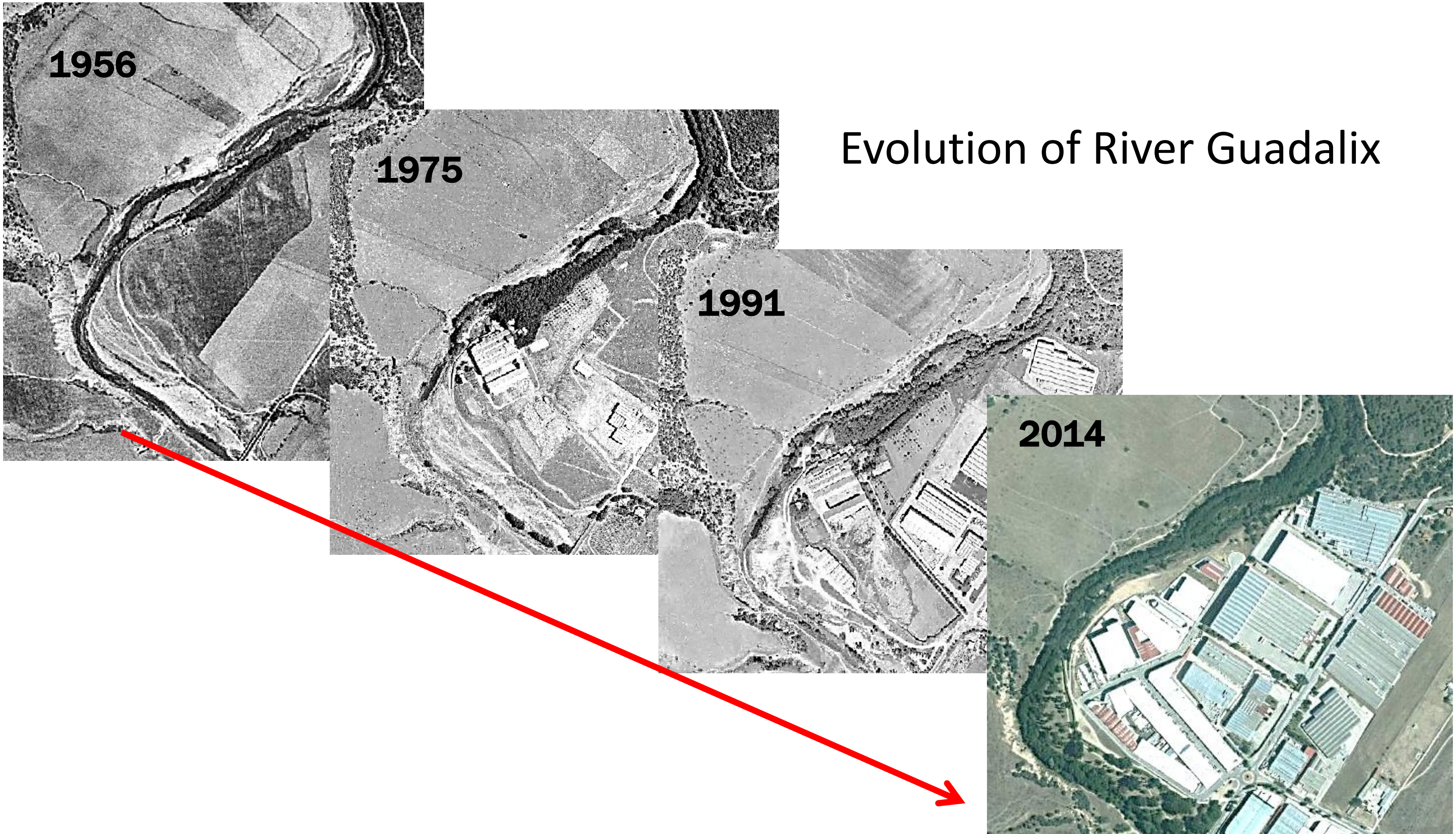
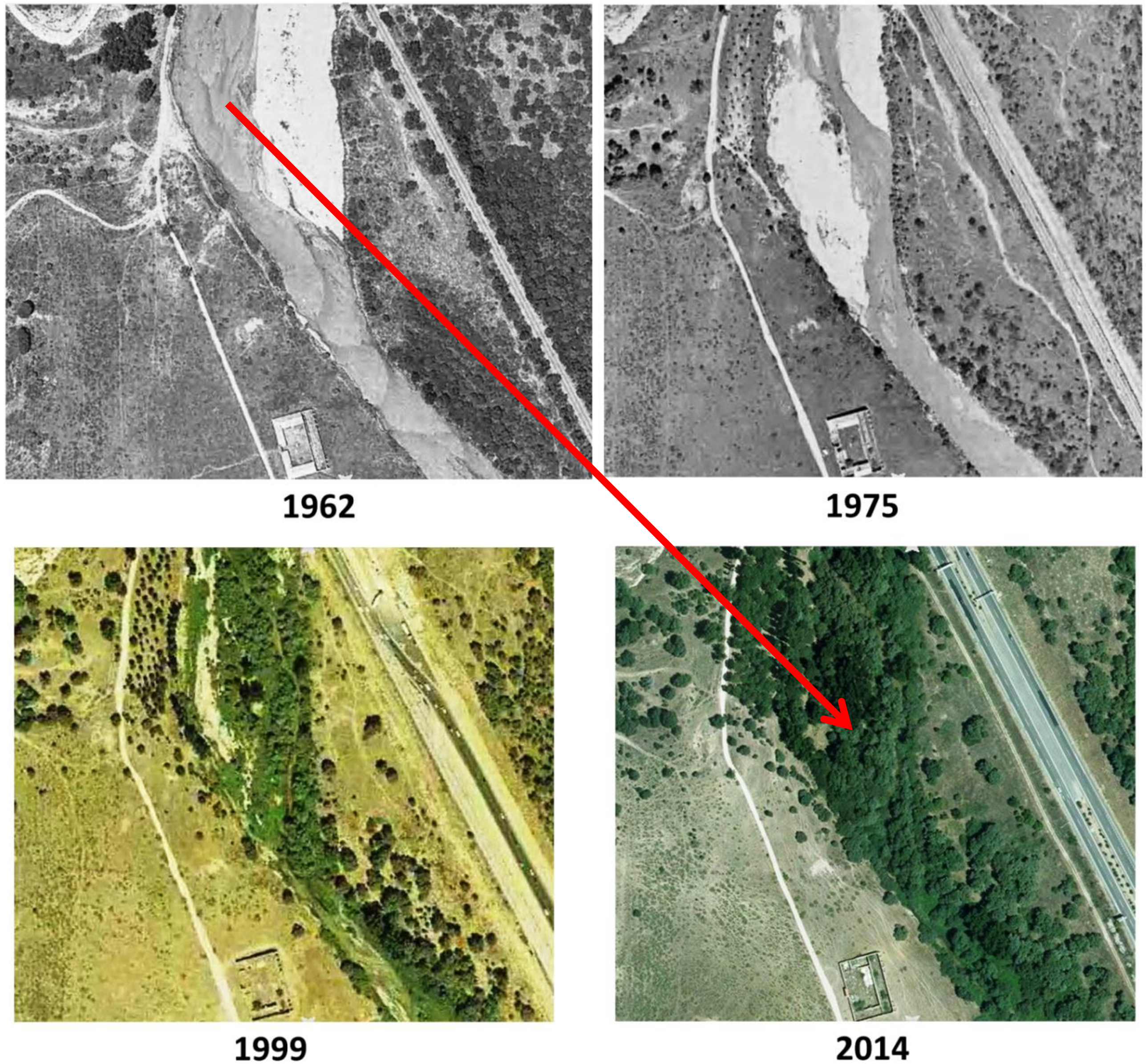
Riparian Vegetation Encroachment in Mediterranean Rivers

Evolution of River Guadalix

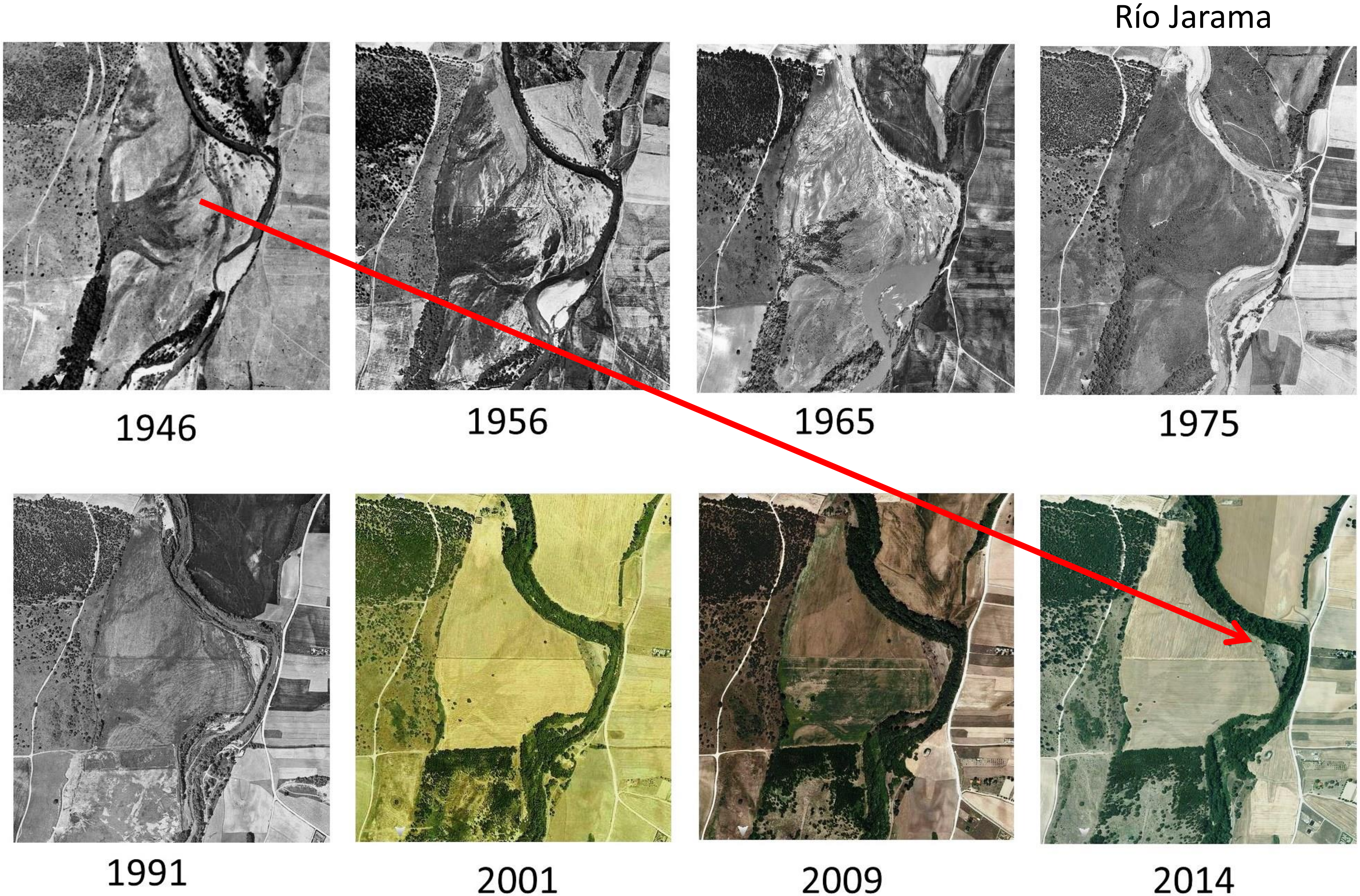


Riparian Vegetation Encroachment in Mediterranean Rivers

Río Guadarrama



Riparian Vegetation Encroachment in Mediterranean Rivers



Riparian Vegetation Encroachment in Mediterranean Rivers

- The **encroachment of riparian vegetation** (ERV) is the invasion of the active channel by woody Riparian Vegetation.
- A widespread process in most of Mediterranean rivers.
- Area and Distribution occupied by Riparian Vegetation is the result of two opposite forces:

1. **Vegetation capacity for recruitment and growth** :
    - new vegetation patches,
    - anchor and expansion of existing patches,
    - ecological succession
2. **Abiotic Controlling Factors** that damage and remove vegetation patches:
    - Flushing Flows,
    - Summer Droughts,
    - Sediments that bury & damage

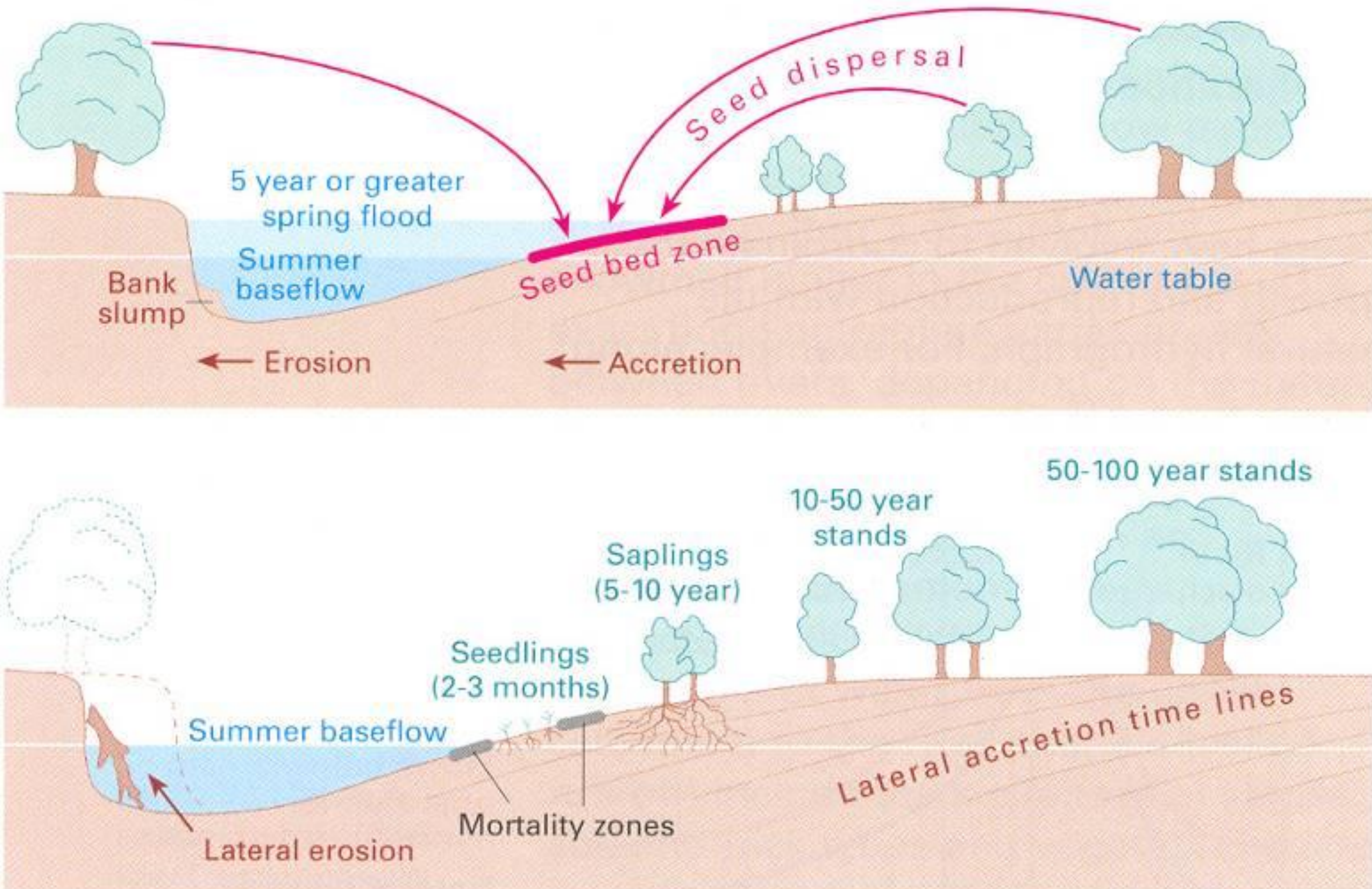
1a. Riparian Vegetation **Recruitment**

Riparian Recruitment needs:

- Bare soil
- Flooded <u>at seedling time</u>
- Slow Flow recession
- Seedling root connected with phreatic water

1a. Riparian Vegetation **Recruitment**

Natural regeneration of riparian vegetation



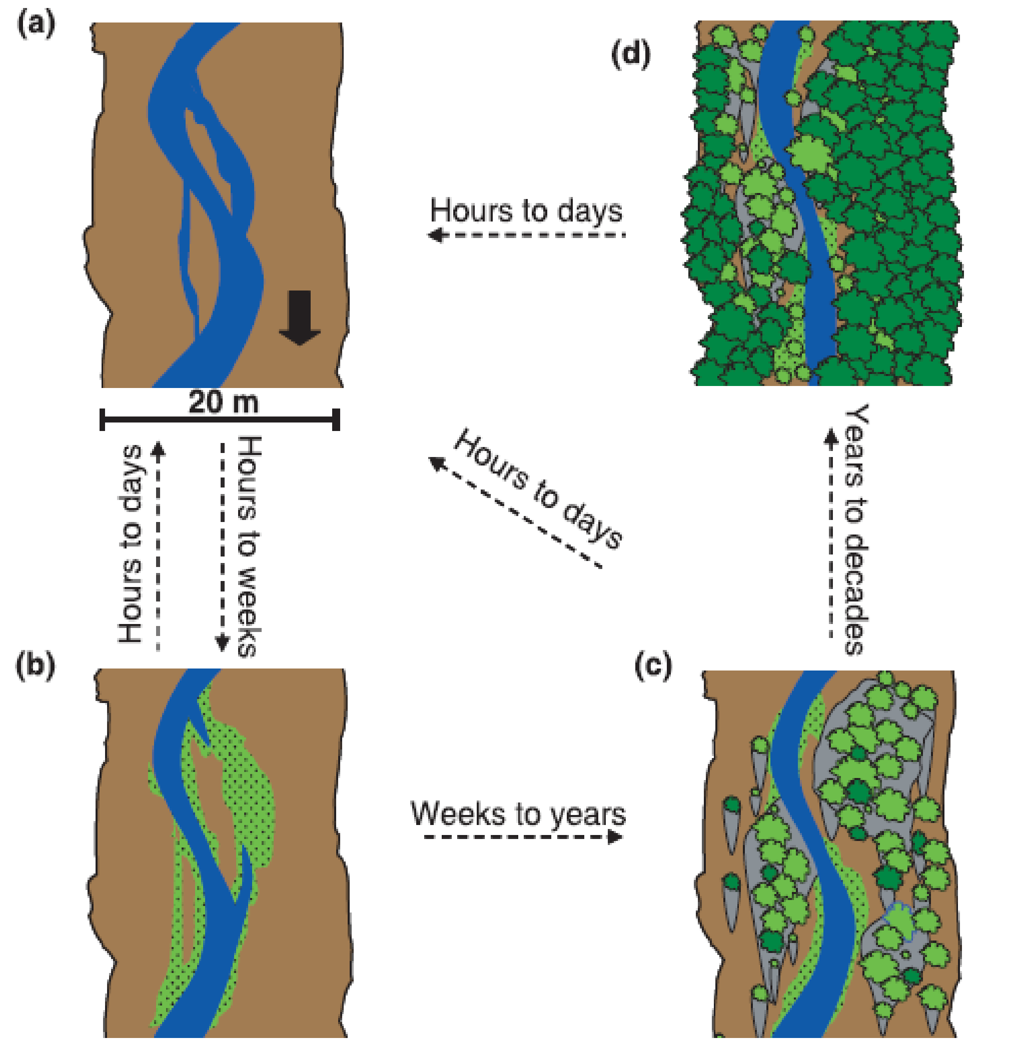
Adapted from *Mahoney & Rood (1998)*

1b. Riparian Vegetation **Growth**

Hughes (2003)

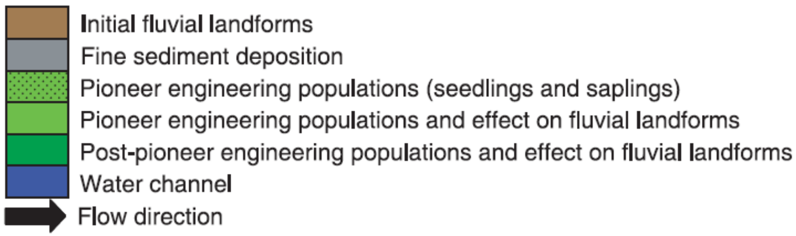
- Soil moisture
- Temperature
- Nutrients

1.c Ecological Succession



- Sequences of Habitat construction induced by **pioneer** plants (a &b) and succession into a **mature riparian forest** (d)

- From stages controlled by **Hydromorphological** processes to stages controlled by **Biological** interactions



Corenblit *et al*. 2009

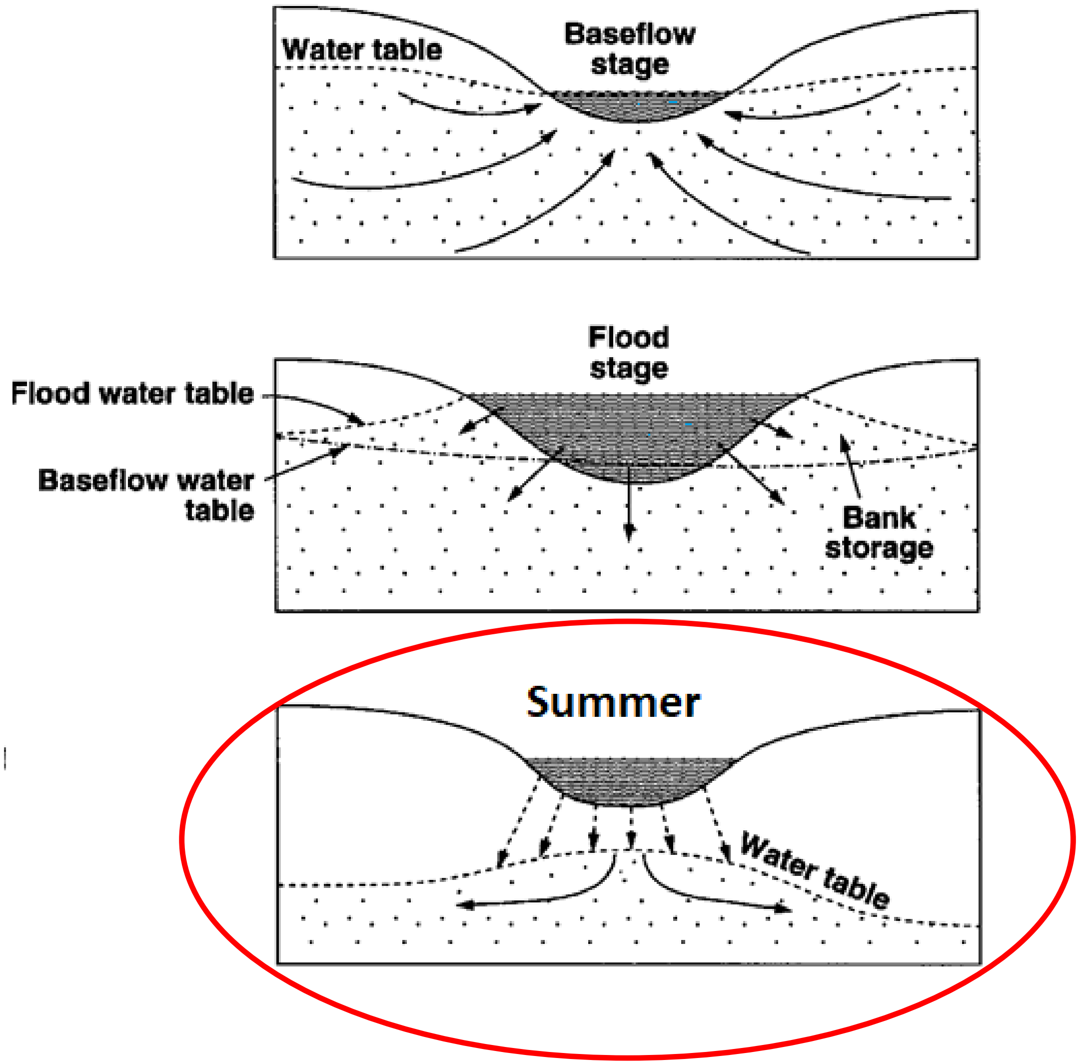
2.a **Abiotic Factors** that control Vegetation

Peak Flows & Floods

- damages
- scours
- unroot trees
- Drag downstream
- Long flood drowning

Río Cinca (Huesca)

2.b Factors controlling vegetation: **Summer Droughts**

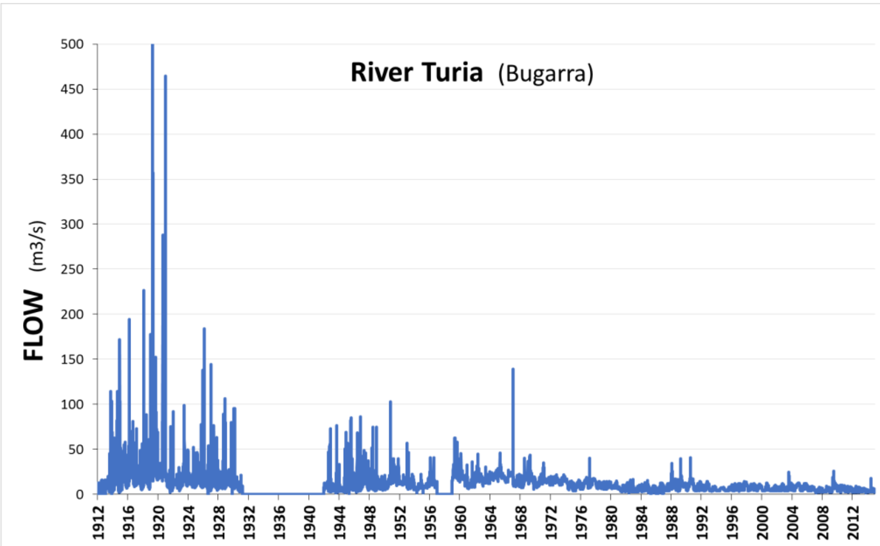


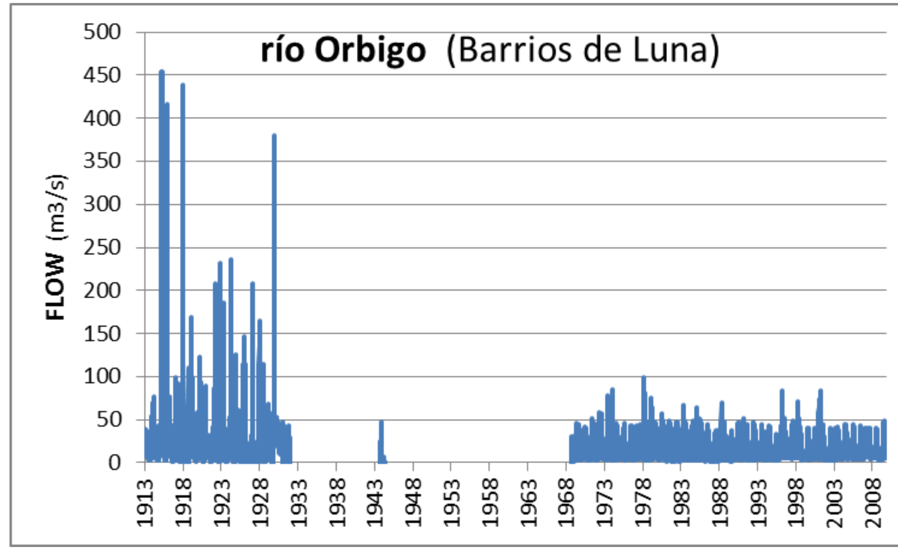
15 July de 2004

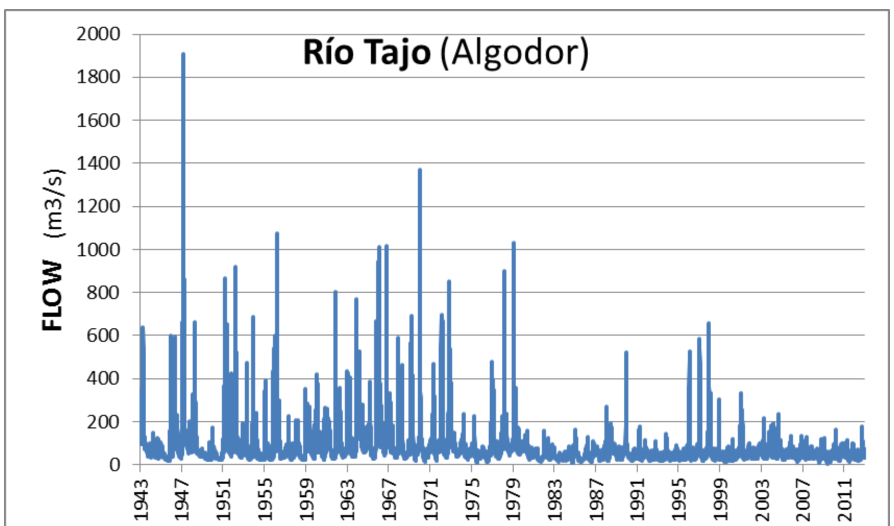
28 September 2004

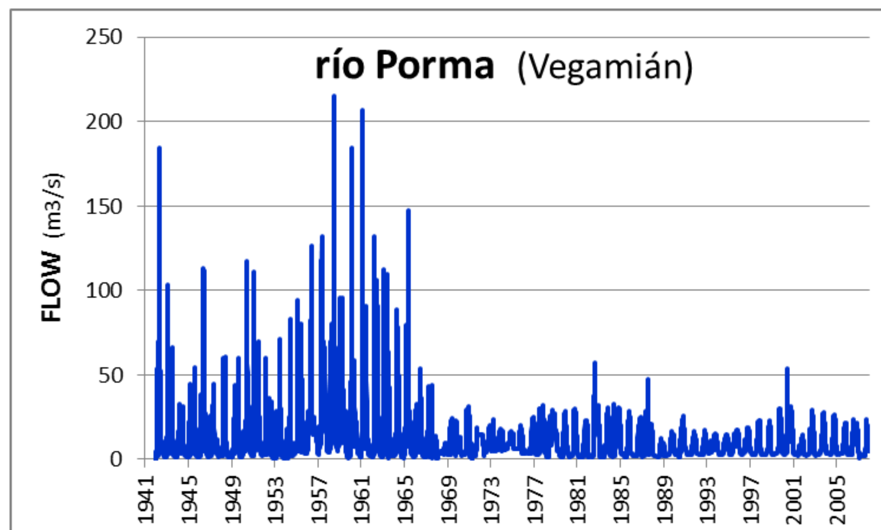
río Jarama

Flood reduction in magnitude and frequency (River Damming)

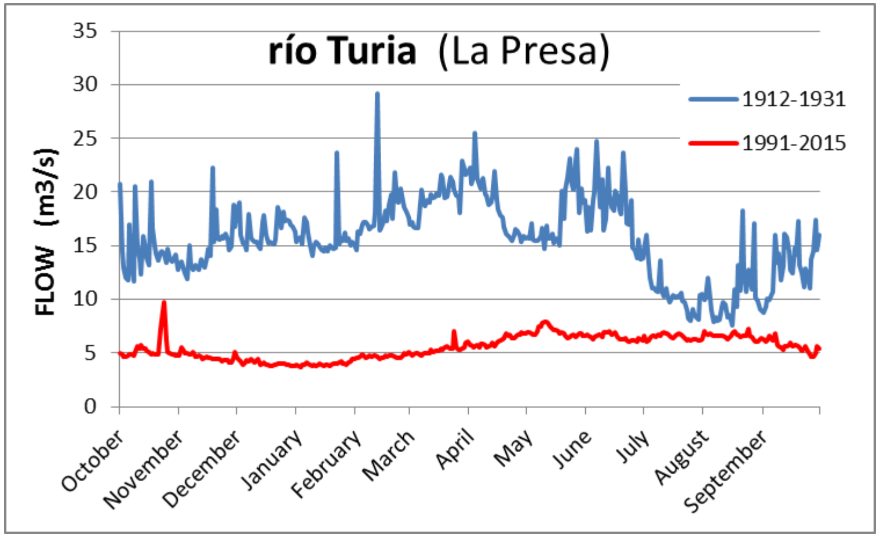


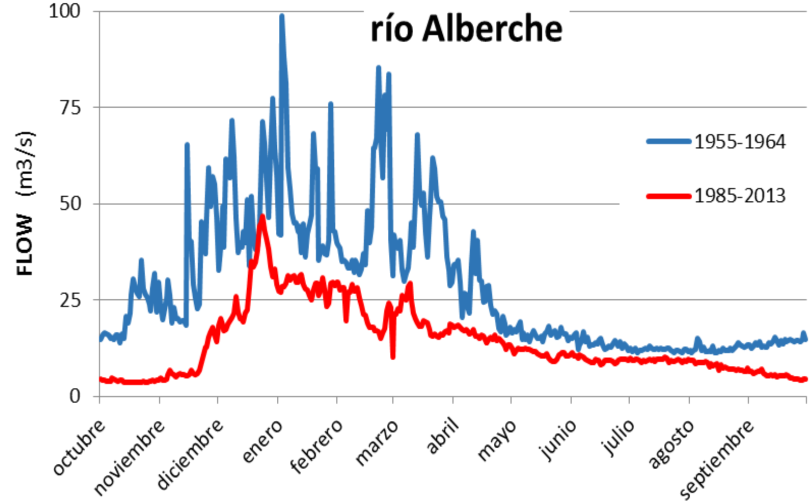


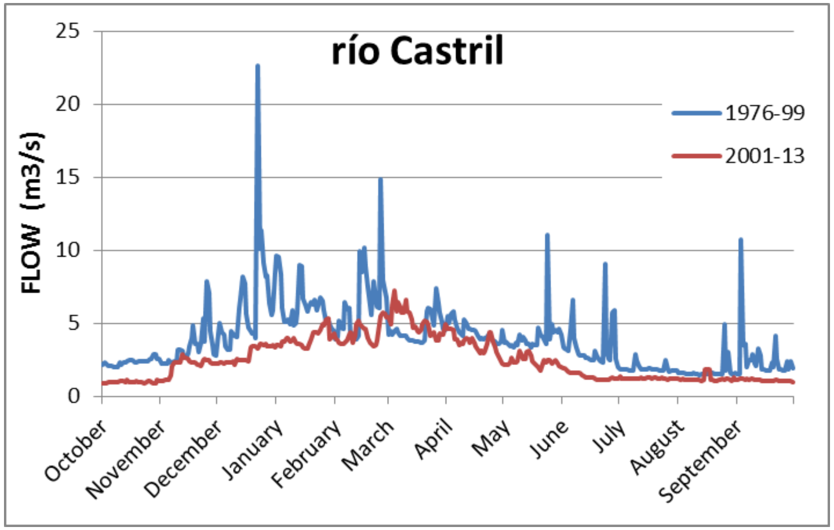


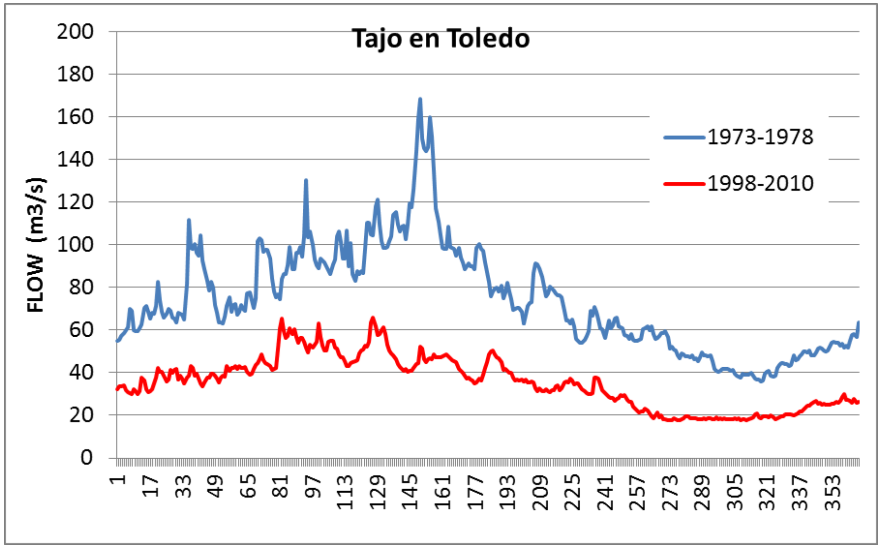


Flow Reduction

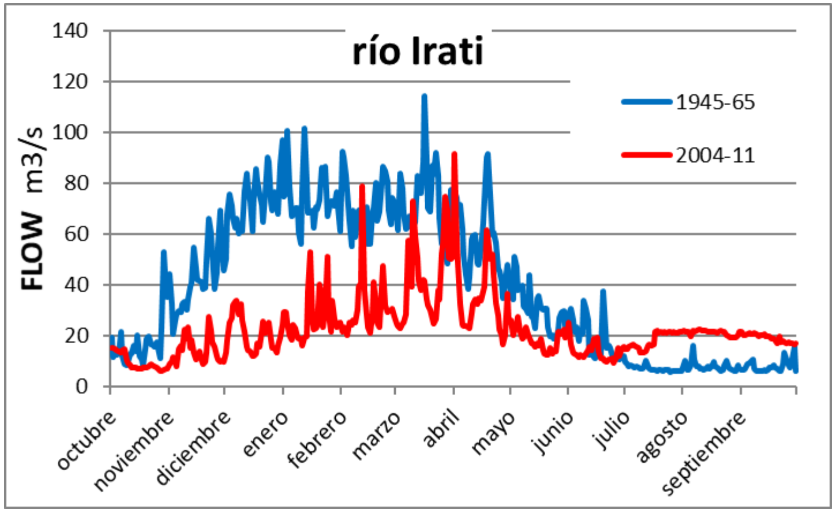


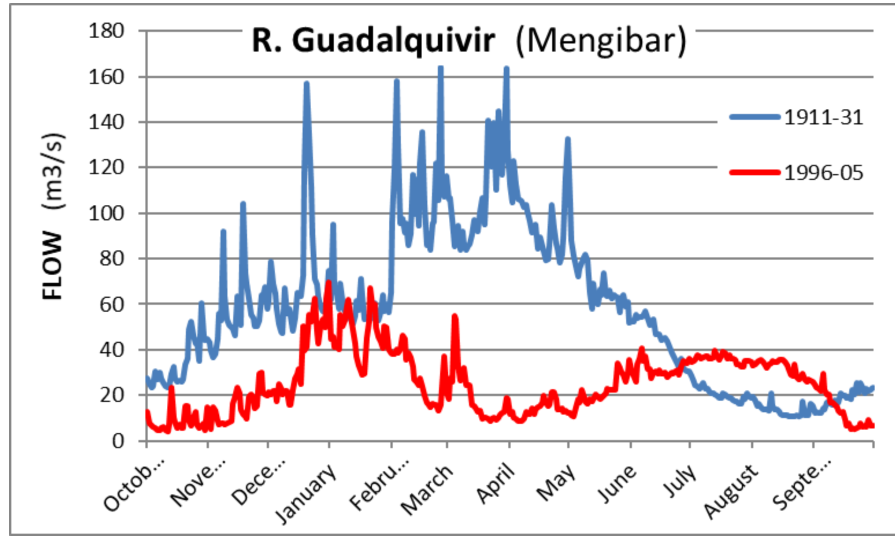


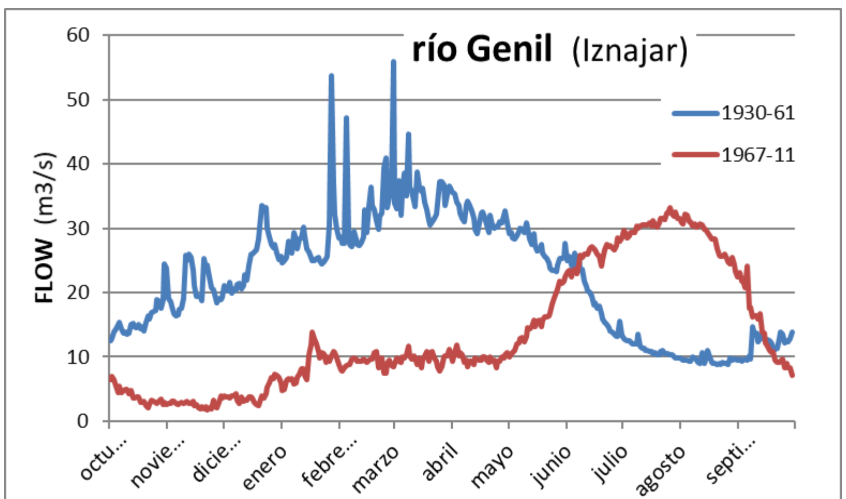


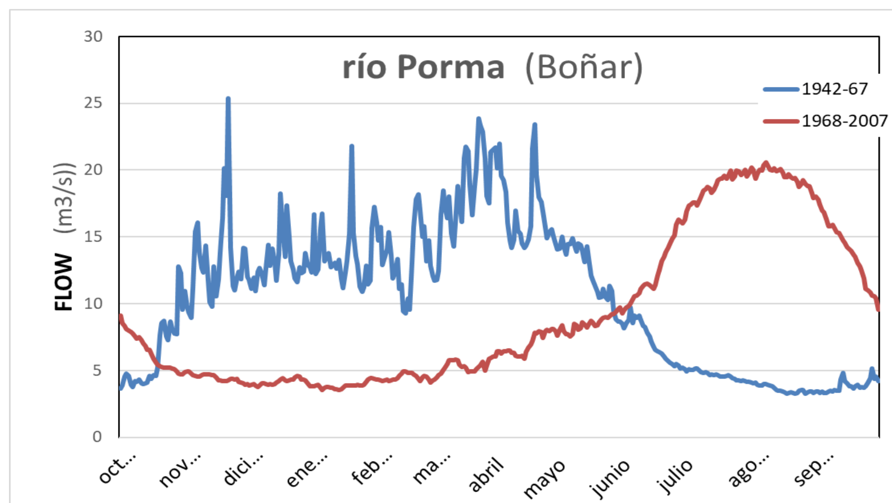


Increase of Summer Flows (drought elimination)



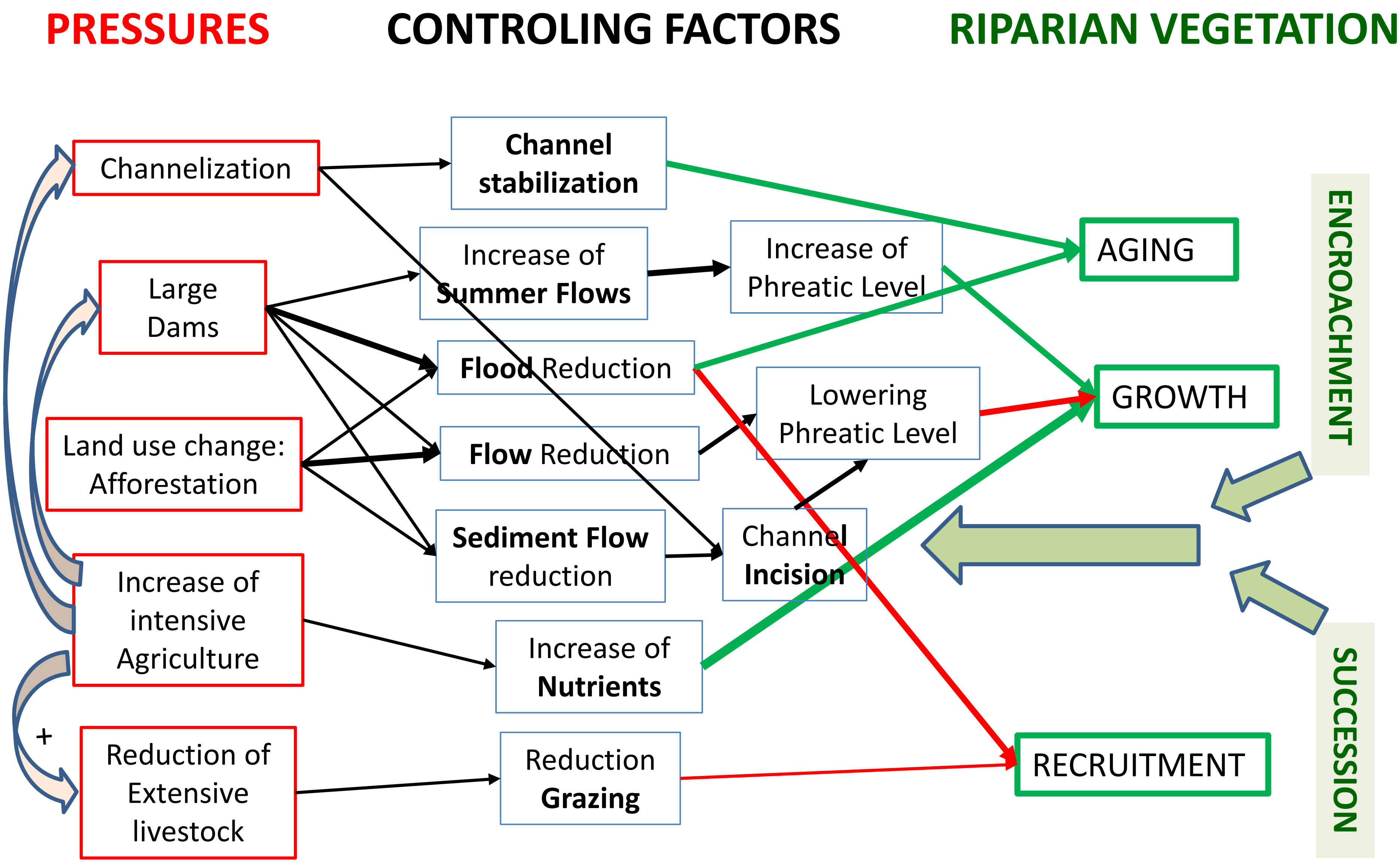






Pressures, Causes and Consequences of Riparian Vegetation Encroachment (RVE)

- Main Pressures responsible for RVE are
  - Flow regulation by Large **Dams** (great demand for water)
  - Changes in **land cover** (increase of forest cover in watersheds)
  - Water **Eutrophication** (farming and sewage discharges)
  - Channelization
  - Decrease of **extensive livestock** (reduction of grazing)
- Main causes of RVE are linked to:
  - Reduction of Floods in magnitude & frequency
  - Increase of Summer Flows
  - Lateral **stabilization** of river channels,
  - Increase of nutrients
- Main consequences of RVE are:
  - Reduction of fluvial dynamism,
  - **Narrowing** of active channels
  - Degradation of aquatic habitats
  - Homogenization of Riparian Corridors



PRESSURES
CONTROLING FACTORS
RIPARIAN VEGETATION
Channelization
Large Dams
Land use change: Afforestation
Increase of intensive Agriculture
+
Reduction of Extensive livestock
Channel stabilization
Increase of Summer Flows
Flood Reduction
Flow Reduction
Sediment Flow reduction
Increase of Nutrients
Reduction Grazing
Increase of Phreatic Level
Lowering Phreatic Level
Channel Incision
AGING
GROWTH
RECRUITMENT
ENCROACHMENT
SUCCESSION

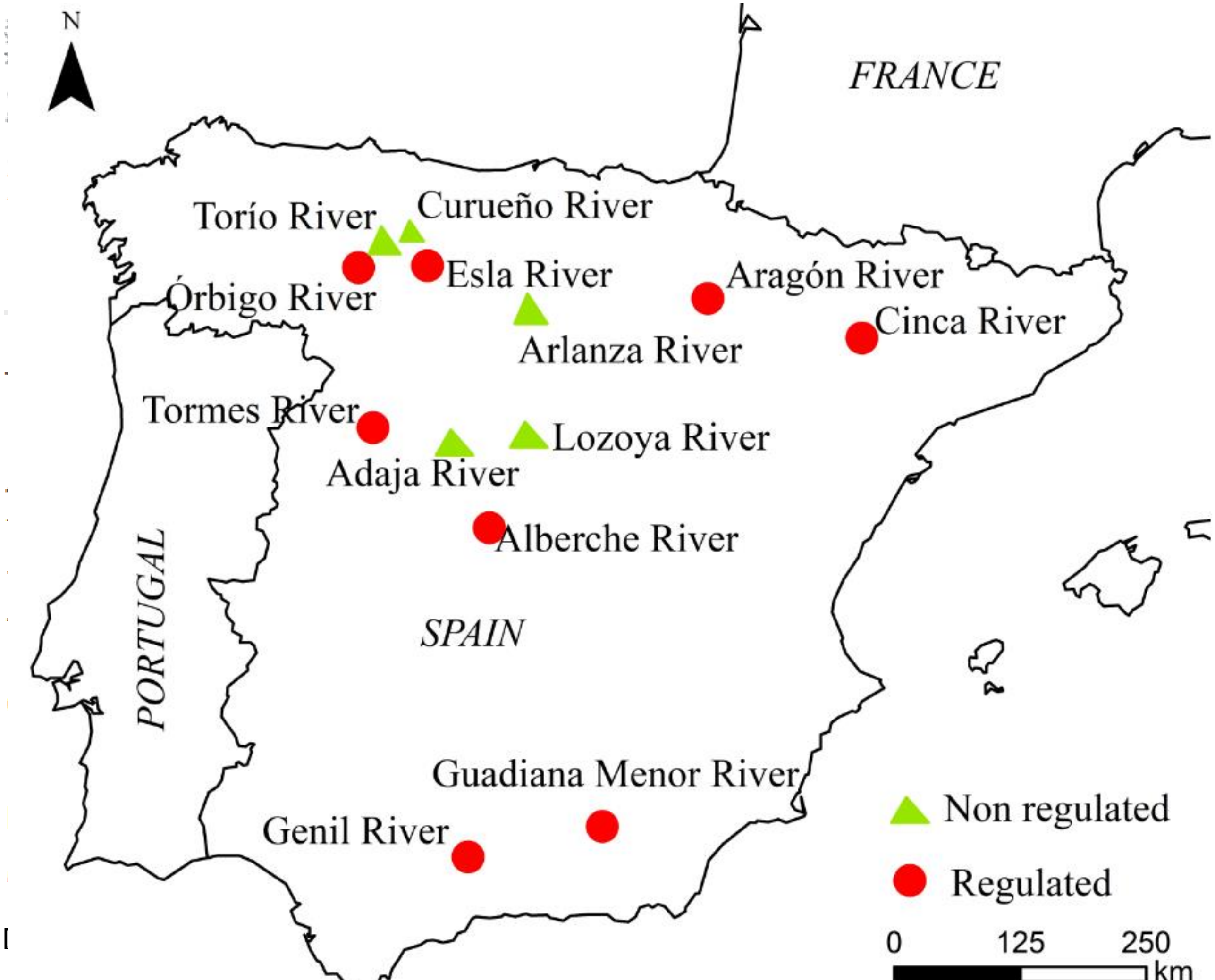
Riparian Vegetation Encroachment
Geomorphic positive Feedback

- Unbalance between Vegetation growth capacity and their natural controls (Floods and Droughts)

- Vegetation Encroachment reduces bare areas and difficult recruitment of pioneer species which leads to late-seral vegetation successional stages

- Once **installed and developed,** riparian vegetation increases riverbanks strength and inhibits fluvial dynamics, promoting single-channel forms, favoring channel narrowing and often channel incision

Case study



https://doi.org/10.1016/j.jher.2019.11.006

Riparian Vegetation Encroachment Ratios in rivers

- 13 **river reaches: 8 regulated & 5 non-regulated**
- 13 associated **long flow data** records (before 1950 until 2015)
- 3 **series of aerial orthophotograph** dated in 1956, 1977 and 2011 or later
- Fluvial features & their evolution were analysed in the reference area (1956):
  - Woody vegetation cover
  - Active channel width
  - Braiding index

Quantification of Encroachment process:

- **Riparian Enc. ratio of change** (REr): increase of riparian vegetation in a period (*m2/m*)
  - $\boldsymbol{REr_{12}} = Veg.Width_2 - Veg.Width_1$ $\quad$ Veg. $Width_1 = \frac{Veg.Area_1}{Length_1}$
- **Annual Encroachment ratio** AREr (*%/y*):
  - $\boldsymbol{AREr_{12}} = 100.\frac{\boldsymbol{REr_{12}}}{(Veg.Width_1).(t_2 - t_1)}$

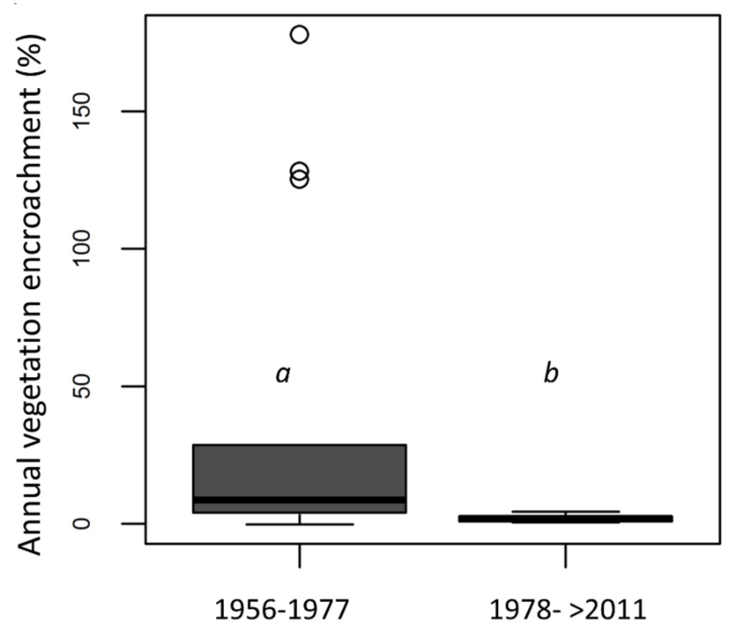
Changes in Riparian Vegetation Canopy

Table 2.- Riparian vegetation area observed in the studied rivers and changes across periods. NV: natural vegetation; TP: tree plantations within the riparian zone. Shadow cells mean that the river is regulated in that period.

River	1956	1977			>2011		
	NV m2/m	NV (m2/m)	TP 77 (m2/m)	□ 56-77 (%)	NV (m2/m)	TP >2011 (m2/m)	□ 77- >2011 (%)
Arlanza	49.3	74.8	40.2	133.1	115.0	133.9	123.9
Curueño	12.0	84.6	0.0	602.9	84.6	91.9	80.9
Lozoya	21.5	43.5	0.0	102.4	43.5	0.0	48.1
Torío	18.0	47.9	60.6	504.1	108.5	117.1	56.7
Adaja	0.3	8.5	0.0	2630.7	8.5	0.0	149.7
Esla	9.8	23.8	352.2	3735.1	376.0	340.5	19.2
Guadiana Menor	36.0	17.4	0.0	120.1	79.3	0.0	80.3
Alberche	69.6	112.3	0.0	61.3	112.3	0.0	29.3
Aragon	96.9	56.4	36.4	-4.3	92.7	25.1	29.6
Cinca	87.4	37.4	261.5	242.2	298.9	210.5	26.6
Genil	43.2	46.5	33.9	86.3	80.5	68.4	31.5
Órbigo	8.7	134.0	62.0	2690.4	241.7	114.7	93.8
Tormes	43.9	63.8	107.7	45.4	63.8	393.9	148.8

Riparian Vegetation Encroachment Ratios

- Nearly all river reaches showed an important **increase in riparian vegetation cover** over time
- Greater annual **Encroachment ratios** were found during the first period (1956 to 1977) than in the second one (1977-2011)
- RVE differences among periods were significant (Wilcoxon test, $p<0.05$).



Changes in Channel Ratios & Braiding index

Table 3.- Average active channel width (ACW: ratio between active channel area and river length) and braiding index values observed in the studied rivers, indicating changes across periods. . Shadow cells mean that the river is regulated in that period.

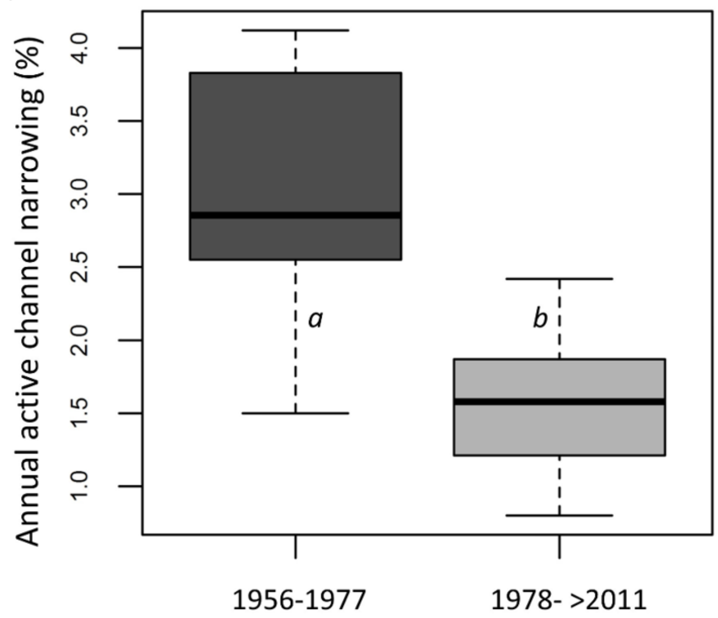
RIVER	ACTIVE CHANNEL WIDTH					BRAIDING INDEX		
	1956	1977		>2011		1956	1977	>2011
	ACW 56 (m²/m)	ACW 77 (m²/m)	Δ ACW 56-77 %	ACW >11 (m²/m)	Δ ACW 77->11 %			
Arlanza	426.3	57.5	86.5	24.2	58.0	1.2	1.4	1.1
Curueño	196.6	86.6	55.9	53.5	38.2	2.6	1.5	1.2
Lozoya	100.6	36.4	63.8	14.9	59.1	1.5	1.3	1.3
Torío	270.1	65.3	75.8	38.4	41.1	1.8	1.3	1.3
Adaja	111.4	56.7	49.1	35.1	38.2	1.2	1.4	1
Esla	533.5	245.0	54.1	43.4	82.3	2.3	1.2	1.3
Guadiana Menor	218.8	37.9	82.7	11.9	68.7	1.4	1.3	1.7
Alberche	197.3	65.1	67.0	45.8	29.7	1.9	1.9	1.1
Aragon	329.5	225.8	31.5	102.5	54.6	1.3	1	1.1
Cinca	782.4	344.4	56.0	100.9	70.7	1.9	1.5	1
Genil	238.6	44.4	81.4	19.7	55.6	1.2	1.2	1
Órbigo	537.8	105.1	80.5	41.3	60.7	3.6	1.6	1.1
Tormes	471.6	218.7	53.6	79.2	63.8	1.5	1.7	1.2

Active Channel Narrowing

- **Active Channel** of all the studied rivers suffer a narrowing process since 1956

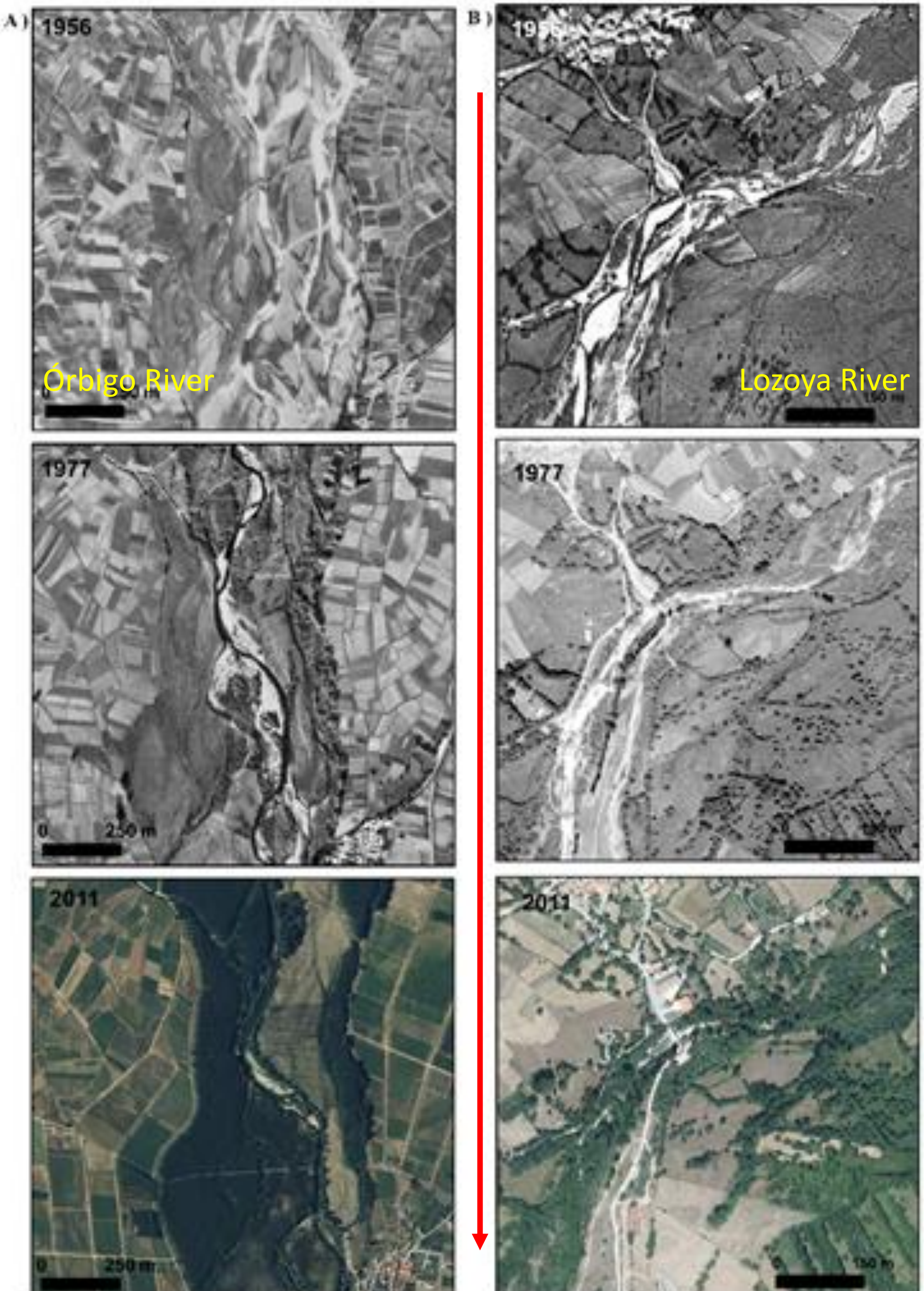
- **Annual decreases in Active Channel width** were much more pronounced during the first period (median value of **3.0** %), than in the second one (median **1.7** %)

- ACN differences among periods were significant (Wilcoxon test, $p<0.05$).



- **Vegetation Encroachment** and **Channel Narrowing** processes underwent in parallel at all the studied rivers.

- However, there was not significant correlation between Encroachment ratios and Narrowing ratios for either periods



Braiding index

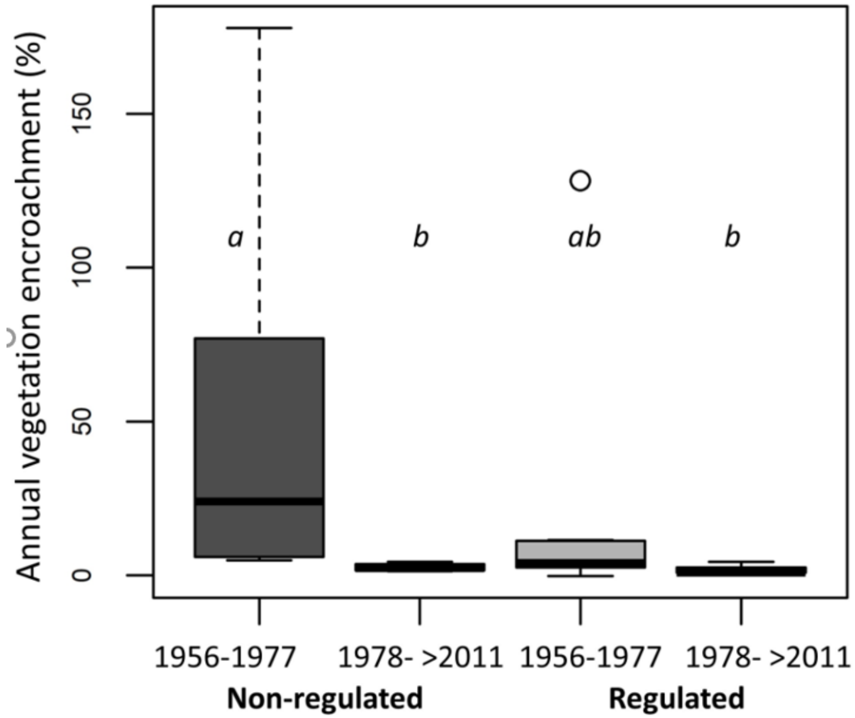
- **braiding index** showed a tendency to decrease in most of rivers,
- change in the braiding index did not show significant differences between periods.

Aerial photographs showing riparian vegetation and channel changes between studied periods:

A. Órbigo River (regulated since 1956);
B. Lozoya River (non-regulated).

Regulated vs Non-Regulates Rivers: Vegetation Encroachment

- Encroachment, during **first period** was more intensive than in second period,
- Encroachment was more intense in the case of the **non-regulated** rivers.
- The median values of annual increases in vegetation during the first period were:
  - ✓ **24.0** % for non-regulated
  - ✓ **3.5** % regulated rivers
- while for the second period:
  - ✓ **2.2** % for non-regulated
  - ✓ **0.8** % regulated rivers



- No significant differences in vegetation encroachment ratios were found between the groups of **non-regulated vs. regulated** within the same period,
- but for non-regulated rivers, differences were significant between periods (Wilcoxon test, $p<0.05$)

CONCLUSIONS

- Our results evidenced a <u>common evolutionary trajectory </u>of all rivers in the long term, with a significant increase in vegetation cover and a significant decrease in active channel width and braiding intensity reduction.
- Measured ratios of bio-geomorphic changes during the two studied periods **did not** show any recognizable pattern based on their <u>flow variables</u>
- Comparisons between <u>regulated</u> and <u>non-regulated</u> rivers **did not** found significant differences in their annual Enchroachment changes
- However, we found significant differences in river changes between time periods suggesting the potential influence of other <u>external drivers acting at broader spatio-temporal scales</u>

Encroachment drivers at multi-scales

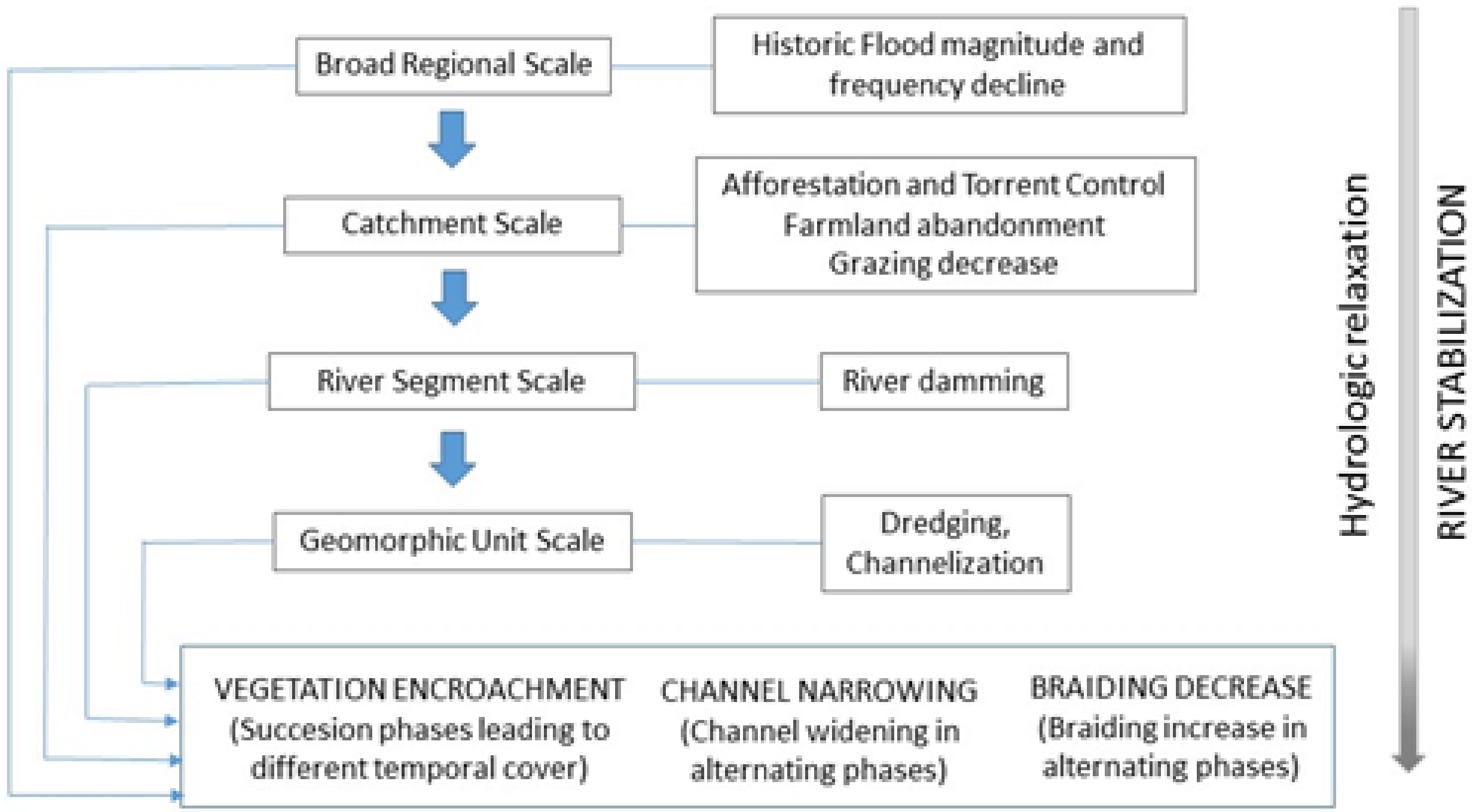
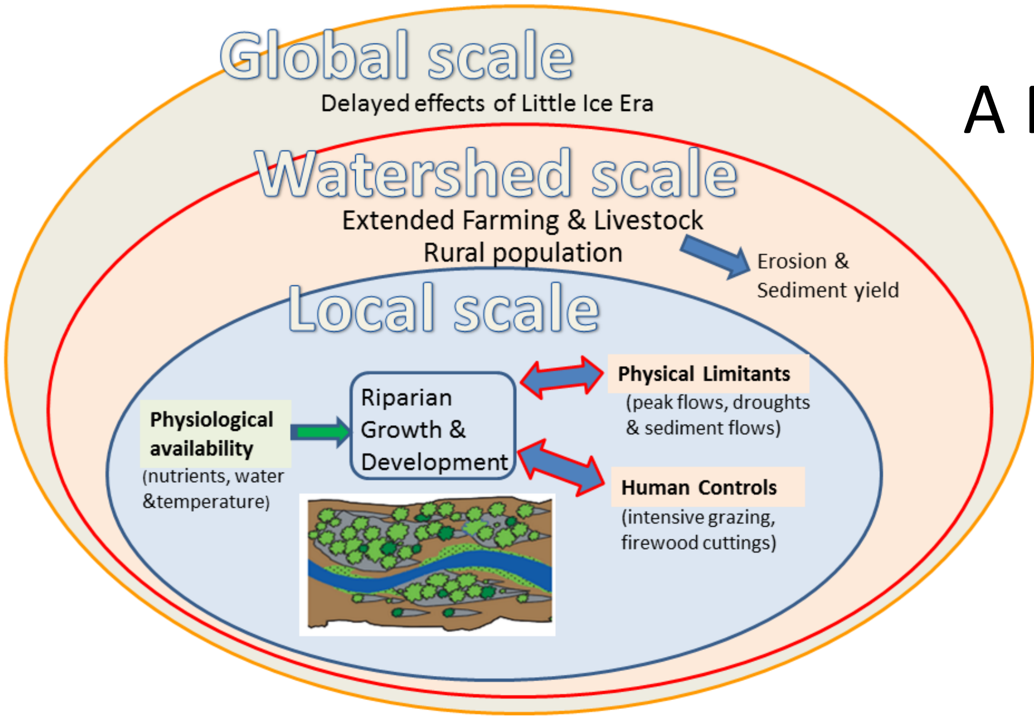


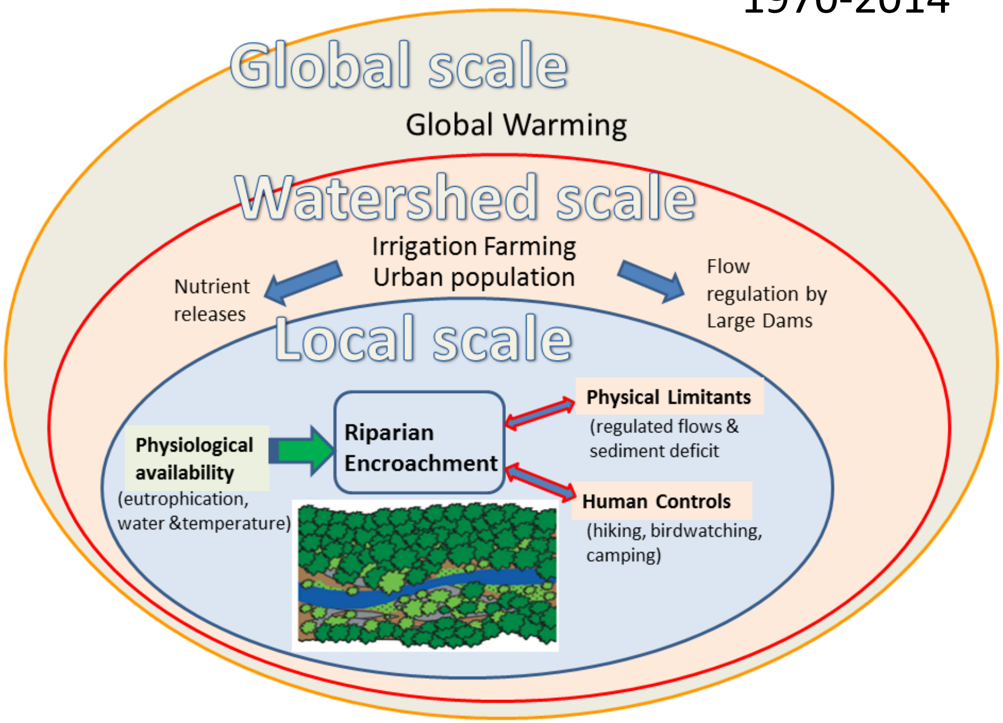
Figura 5.- Multi-scale approach linking spatio-temporal potential drivers of vegetation encroachment and channel changes at long term.

A MORE GENERAL CONTEXT



Before 1956

1970-2014




Thank you for your
attention

Hydrological Changes

% of change for Flow traits along studied rivers between period of years before and after aerial photos were taken

Rivers	Qmean		Max3days		Qsummer		Qrecruit	
	A	B	A	B	A	B	A	B
Arlanza	112.6	-31.0	49.7	6.4	85.7	-35.4	99.0	-17.7
Curueño	NA	-31.5	NA	-46.1	NA	-31.6	NA	-30.1
Lozoya	NA	-7.7	NA	-19.8	NA	-50.0	NA	-21.4
Torío	NA	172.2	NA	325.4	NA	100.0	NA	89.5
Adaja	-14.6	-28.6	-9.5	-48.9	33.3	-25.0	-39.0	-4.3
Alberche	-27.0	-43.1	-60.0	-45.1	-15.3	-33.3	-56.0	-36.2
Aragon	80.9	-38.7	64.1	-31.8	117.0	-43.6	70.9	-36.0
Cinca	65.8	-16.2	80.5	-37.2	52.9	-31.5	19.9	-23.1
Esla	21.0	-11.3	1.4	-53.2	27.6	267.6	12.3	-43.3
Genil	40.8	-33.3	54.8	-44.9	40.4	-38.4	9.5	-34.2
Guadiana Menor	57.0	-15.5	77.2	-32.3	25.7	106.8	72.7	-5.3
Órbigo	25.0	-20.4	-31.9	-14.3	346.2	-3.8	-35.2	-14.4
Tormes	23.4	-43.2	-44.8	4.4	207.6	-60.7	-30.6	-37.5

A = % Change between periods "before 1956" and 1957-1977

B = % Change between periods 1957-1977 and 1978-2015

All the rivers showed hydrological changes since 1956.

Although the ratio of change was very variable across rivers, some general trends could be noted:

1. **Mean & Maximum annual flows** during the period 1956-1977 increased in relation to the period before 1956 (A), followed by a general decline after 1977 (B).

2. Concerning **low flows** (summer), non-regulated rivers showed a tendency of reduction, whereas regulated rivers showed increased minimum flows and average summer flows after dam operation started