Growing
ideas
through
networks

MONITORING AND ASSESSMENT OF RIPARIAN VEGETATION IN EUROPEAN COUNTRIES

WG 1, Madrid, 10-11 July 2018

A hierarchical hydromorphological framework for developing multi-scale riparian vegetation characterization and assessment

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CONVERGES
European Riparian Ecosystems

CONTENT

1. Hierarchical hydromorphological context: Spatial scales

2. Hydromorphological characterization of river reaches

3. Riparian vegetation (RV) in the context of the WFD

4. Forms and Processes affecting Riparian vegetation

5. Towards a process-based hierachical characterization / assessment of RV across European regions

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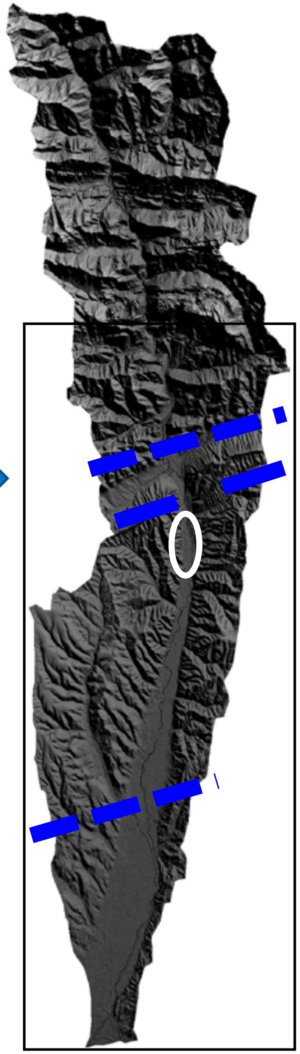
SPATIAL SCALES

River reach

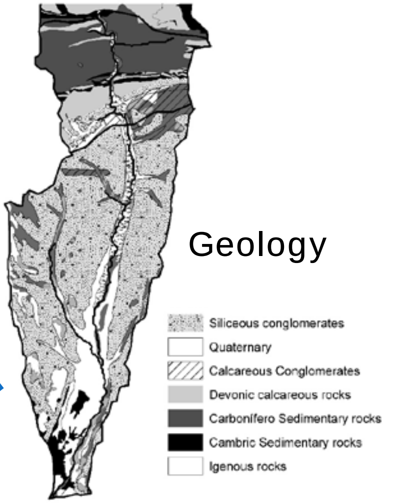
River reach

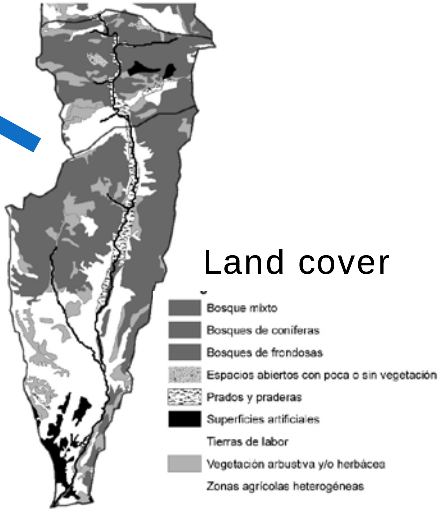
River segment

Catchment



Landscape unit





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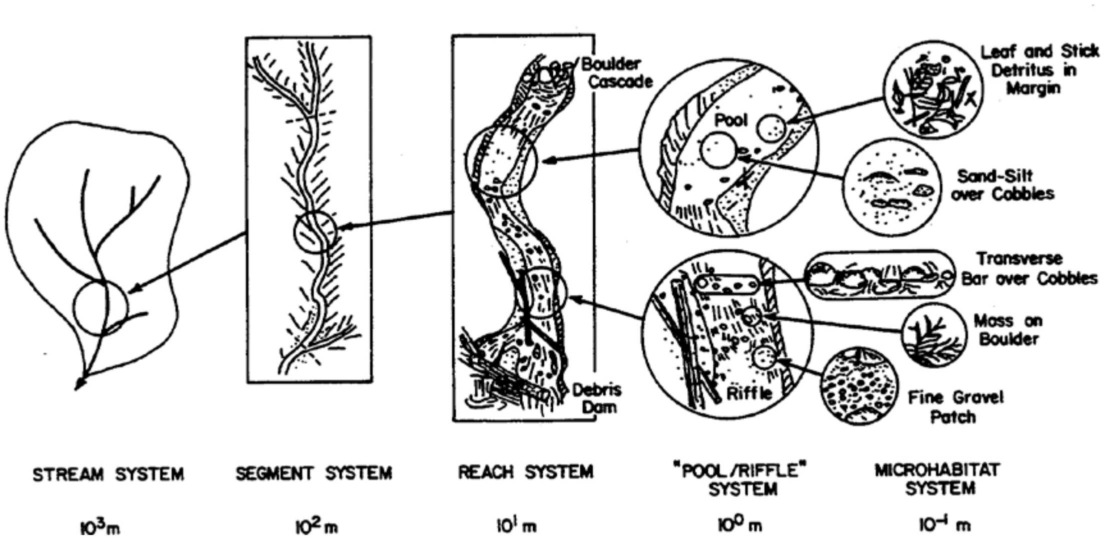
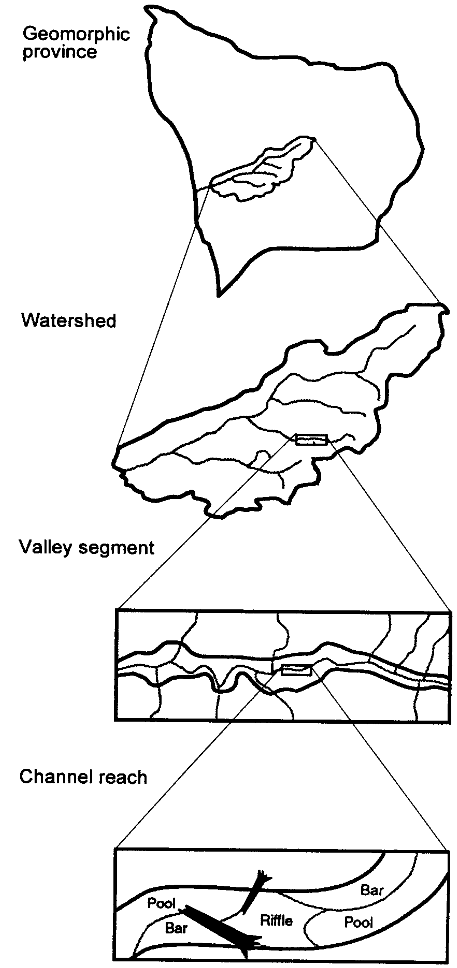
SPATIAL SCALES

No new ideas …



(Frissell et al., 1986)



(Montgomery & Buffington, 1998)

SPATIAL SCALES

Biogeographic Region
↓
Catchment
↓
Landscape unit
↓
River segment
↓
RIVER REACH
↓
Geomorphic units
↓
Hydraulic Unit
↓
River element

River reach

River reach

REFORM

RESTORING RIVERS FOR EFFECTIVE CATCHMENT MANAGEMENT

Understanding Processes ⟷ Forms
Human impacts ⟷ Geomorphic responses

SEVENTH FRAMEWORK PROGRAMME

SPATIAL SCALES

PROCESSES / FEATURES

FORMS / INDICATORS

CONTROLS ON RIVER BEHAVIOUR (confinement; gradient; delivery of water, sediment, plant propagules, wood to river reaches)

Precipitation
Temperature,
Relief, Geology,
Land Cover,
Land Use

Biogeographic Region

Catchment

Landscape unit

River segment

RIVER REACH

Geomorphic units

Hydraulic Unit

River element

Rapid/Delayed Runoff,
Coarse /Fine
Sediment delivery,
Woody debris,

RIVER/ FLOODPLAIN TYPE, DYNAMICS, SENSITIVITY

VALLEY FEATURES,
WATER AND
SEDIMENT FLOWS,

Flow regime,
Channel width,
River planform,
Particle size,
Floodplain shape

DYNAMIC SUITE OF RIVER AND FLOODPLAIN FEATURES (physical habitats)

Flooding,
River adjustments,
Erosion,
Sedimentation,
Recruitment,
Succesion

Bed forms,
Flow velocity,
Shear stress,
Species and
age diversity

cost
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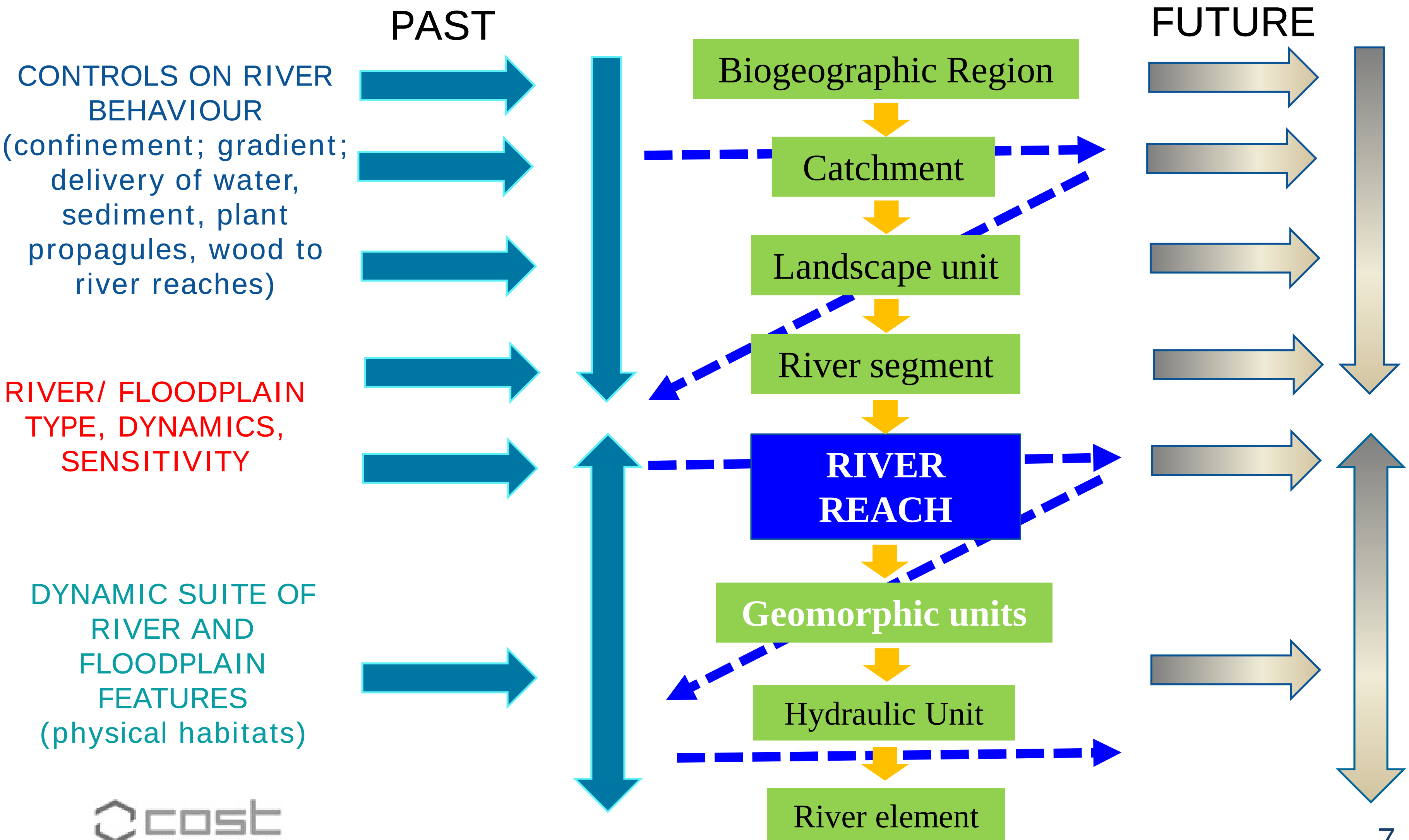
(Gurnell et al., 2014)

TEMPORAL SCALES



(Gurnell et al., 2014)

2. HYDROMORPHOLOGICAL CHARACTERIZATION OF RIVER REACHES

SPATIAL UNIT	KEY PROCESSES / FEATURES	INDICATORS	RELEVANCE AND MANAGEMENT IMPLICATIONS
CATCHMENT	WATER PRODUCTION	Catchment area (km2)	Rules the magnitude of hydrological processes at broad scale. Effective catchment area may be altered by large water transfers, causing significant unbalance between the current flow regime and the natural dimensions of the channels
		Specific annual runoff (mm/km^2)	Indicative of the general hydrologic response of the catchment. When compared with annual precipitation over time, may reflect the influence of global warming or land cover changes (i.e., hydrologic decline with decreasing runoff; e.g., García Ruiz et al., 2011)
		Geology (% WFD classes)	Represents a permanent physical control of hydrological processes at broad scale (Grant et al., 2003)
		Land cover (% CORINE level 1 classes)	As Geology, it represents a main physical control of hydrological processes but may exhibit significant changes over time due to global changes or human interventions (e.g., García-Ruiz and Lana-Renault, 2011)
LANDSCAPE UNIT	**Runoff** production /retention	Exposed aquifers, permanent snow-ice cover (% area)	Represent permanent physical controls of hydrologic response of the area, being indicative of high storage capacity of precipitation determining delayed runoff
		Rock permeability (% classes)	Reflect hydrologic behaviour of lithology influencing general patterns of runoff
		Rapid runoff production areas (% area based on land cover, land use types)	Generate overland flow. Their increase may partly explain a rise of magnitude and frequency of floods and soil erosion rates . They may be associated to urban areas, bare soils, agriculture intensification or natural erodible soils under high gradients (e.g., Chin, 2006).
		Delayed runoff production areas (% area based on geology and land cover)	Influence the flow regime type, determining relative magnitude of base flows. Their increase may partly explain a hydrologic decline and reduction of sediment supply to the channels, causing shifts in river planform, channel dimensions and riparian corridor features (Morán-Tejeda et al., 2012)
	Fine sediment production	Soil erosion rates (t,ha^{-1}, year^{-1})	Drive the magnitude of wash load entering the river network, which has strong influence on river character and behaviour (Brierley and Fryirs, 2005)
	Coarse sediment production	Coarse sediment potential source areas (% area with unstable slopes, gullies, etc.)	Coarse sediments largely influence channel morphology and behaviour. Their supply is frequently restricted by afforestation of hillslopes, check-dams on gullies and dams and gravel mining on the river networks, causing sediment deficit and strong river changes (e.g., Liébault and Piégay, 2002; Rinaldi, 2003).

(González del Tánago et al. 2016a)

2. HYDROMORPHOLOGICAL CHARACTERIZATION OF RIVER REACHES

SPATIAL UNITS	PROCESSES / FEATURES	INDICATORS	RELEVANCE AND MANAGEMENT IMPLICATIONS
RIVER SEGMENT	RIVER FLOW REGIME	**Flow regime type** *	A major control on the functions of river ecosystems (Poff et al., 1997), whose magnitude and temporal characteristics are frequently altered by flow regulation by dams and reservoirs, and major water abstractions.
		Average annual flow ($m^3 s^{-1}$), Baseflow index (%)	Indicates magnitude of discharge and importance of baseflow contribution
		Magnitude of **maximum annual flows** of geomorphic interest (e.g.,1.5, 2, 10 year floods) ($m^3 s^{-1}$)	Peak flows of relatively short recurrence intervals (i.e., bankfull discharge, effective discharge) have strong influence on channel size, are a key criterion used in river assessment and design (Shields et al., 2003) and are frequently reduced by dam implementation and flow regulation (Graf, 2006)
		Timing of maximum flows (Julian day)	An important property of the natural flow regime, that is crucial for riparian vegetation recruitment, the life cycles of many aquatic and riparian organisms, and the control of invasive species (Stromberg et al., 2007)
		Magnitude of 1-day, 7-days and 30-days minimum flows ($m^3 s^{-1}$)	Indicates duration of soil moisture stress for plants, low oxygen and high water chemical concentrations, dehydration in animals (Richter et al., 1996), and is frequently altered by flow regulation, particularly in association with irrigation.
		Timing of **minimum flow** period (Julian period)	A further important property of the natural flow regime, with similar relevance to the timing of maximum flows
	SEDIMENT DELIVERY AND TRANSPORT REGIME	Eroded **soil delivery** (t year km^{-2})	Indicates the potential supply of finer sediments from areas close to the river that influence the rivers wash load.
		Suspended sediment transport (mg l^{-1}, t $year^{-1}$ km^{-2})	The wash and suspended sediment load transported by the river determines water turbidity, which impacts on aquatic organisms, and contributes to channel adjustments and physical habitat clogging. Suspended load dominated systems have limited capacity to rework their boundaries and are highly exposed to aggradation and vegetation encroachment (e.g., Dean and Schmidt, 2011)
		Bed load transport (t $year^{-1}$ km^{-2})	The bedload transported by the river is a main component of channel planform and bedform dynamics. It is frequently altered by the trapping effect of reservoirs (e.g., Vericat and Batalla, 2006) and gravel mining (e.g., Rinaldi, 2003)
		Sediment budget (Sediment Outputs – Inputs within the segment: > 0: Loss, degradation; =0: Balanced; <0: Gain, storage)	The deficit or surplus of sediment within the segment may lead, respectively, to bed incision and/or bank erosion or to bed and/or bank aggradation (e.g., Simon and Rinaldi, 2006; Schmidt and Wilcock, 2008; Grabowski and Gurnell, 2015). It may assess the impacts of land use changes affecting the sediment regime between tributaries
	VALLEY FEATURES	**Valley confinement** (Confined, Partly confined, Unconfined)	Primary control on river channel adjustments and characteristics including the potential river channel planform types that may be present (Brierley and Fryirs, 2005; Rinaldi et al., 2015b)
		Valley gradient (m m^{-1}, %)	Controls the maximum feasible channel slope, and then influences river flow energy and potential to transport sediment
		Valley width (m), River confinement (or entrenchment) index	Indicate the maximum lateral extent of potential fluvial processes (i.e., flooding, alluvial forest development), and the degree to which the river is confined within its valley (e.g., Polvi et al., 2011).
	RIPARIAN CORRIDOR size, functions and wood delivery potential	**Size of riparian corridor** (average width, m)	Refers to envelope enclosing all apparently functioning riparian (woodland) vegetation. Indicative of spatial extent / magnitude of hydromorphological interactions with vegetation, and potential riparian buffer functions as filters, sediment sinks and sources (Sparovek et al., 2002)
		Longitudinal **continuity / fragmentation** of riparian vegetation along river edge (% of river length)	Refers to extent to which riparian (woodland) vegetation extends along the river channel edges. Indicates the degree to which riparian functions, including wood delivery, are maintained along the segment. Fragmentation and disruption of continuity is frequently associated with agriculture or urban development (e.g., Fernandes et al., 2011).
		River channel edges bordered by mature trees	Indicates potential for the recruitment of large wood to the river
		Dominant riparian **plant associations**	Supports diagnosis of the naturalness of the riparian vegetation and the presence of exotic or invasive species.
	Disruption of LONGITUDINAL CONTINUITY	Number of major **blocking structures** (dams, large weirs, etc, can be separated into high or intermediate impact according to their size and functioning)	Indicates the frequency and intensity of major interruptions to water flow and sediment transport and barriers to fish migration. The intensity of their impact is proportional to the height of the structural barrier and the way of the reservoir management. Prioritization for their removal to enhance river connectivity has been deeply studied by O´Hanley (2011).

(González del Tánago et al. 2016a)

2. HYDROMORPHOLOGICAL CHARACTERIZATION OF RIVER REACHES

SPATIAL UNIT	PROCESSES /FEATURES	INDICATORS
RIVER REACH	CHANNEL TYPES and dimensions	River **channel and floodplain types** **
		Planform properties (Sinuosity index, braiding index, anastomosing index) ***
		Channel dimensions Channel bankfull width, depth (m)
		Channel slope ($m\ m^{-1}$, %)
		Bed and bank **sediment size** (descriptive category , or D_{50}, cm)
		Geomorphic units: abundance and type of channel and floodplain units
	FLOODING extent	% of floodplain accessible by flood water, **floodplain inundation frequency**
	River energy and CHANNEL ADJUSTMENTS	Specific **stream power** at 'bankfull' discharge ($W\ m^{-2}$)
		Extent of eroding/aggrading banks (% active channel length)
		Lateral bank movement (m year^{-1})
		Number, extent of bare gravel bars, and vegetated gravel bars / benches / islands
		Bed incision / aggradation rates (m, cm y^{-1})
	RIPARIAN VEGETATION succession and encroachment	Proportion of riparian corridor under **riparian vegetation (% coverage)**
		Age structure of dominant plant associations (% old, mature, young forest, Salicacea recruitment)
		Riparian **vegetation patchiness** (form index) and average size of patches (m^2)
		Lateral functional zones (% area of riparian corridor)
	AQUATIC VEGETATION	Aquatic **plant coverage** (% river channel bed) Number of aquatic plant **morphotypes**
		Aquatic plant dependent geomorphic units (absent, occasional, present, abundant)
	LARGE WOOD	**Large wood** and fallen trees in channel and riparian corridor (absent, occasional, present, abundant)
		Wood budget (good, moderate, degraded, severely degraded)
		Large wood and riparian tree dependent geomorphic units (absent, occasional, frequent, abundant)
	CONSTRAINTS on channel adjustments and lateral and vertical connectivity	% channel length with **bank revetments,** embankments, **artificial levees**
		Average width of erodible corridor (m, channels widths)
		Number and size of channel blocking structures (stated at segment unit scale)
		% channel bed reinforced % paved or **sealed floodplain**
		% channel and floodplain affected by **gravel extraction** or dredging
		Intensity of riparian **forest management** and wood removal

(González del Tánago et al. 2016a)

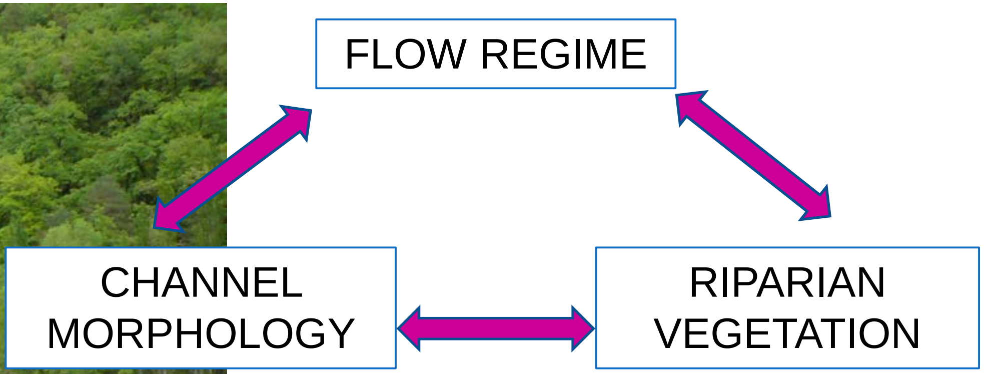
- The WFD requires **periodical assessments** of *ecological status* of water bodies

- The *ecological status* must be based on the status of **quality elements**:

    1. **Biological** elements (aquatic flora, invertebrate fauna, fish fauna)
    2. **Physico-chemical** and **chemical** elements (general and specific pollutants)
    3. **Hydromorphological** elements
        - 3.1. Hydrological regime (water flow, connection to groundwater)
        - 3.2. River continuity
        - 3.3. Morphological conditions
            - 3.3.1. River depth and width variation
            - 3.3.2. Structure and substrate of the river bed
            - **3.3.3. Structure of the riparian zone**

3. RIPARIAN VEGETATION IN THE CONTEXT OF THE WATER FRAMEWORK DIRECTIVE (WFD)

- As a third attribute of "morphological conditions", **RV has little influence on the Hydromorphological status** of river systems
- Frequently **underestimated** or not properly assessed by hydromorphologists
- RV must be up-graded to the **same level as flow regime and channel morphology**



Understanding Processes ⟷ Forms

Human impacts ⟷ Vegetation responses

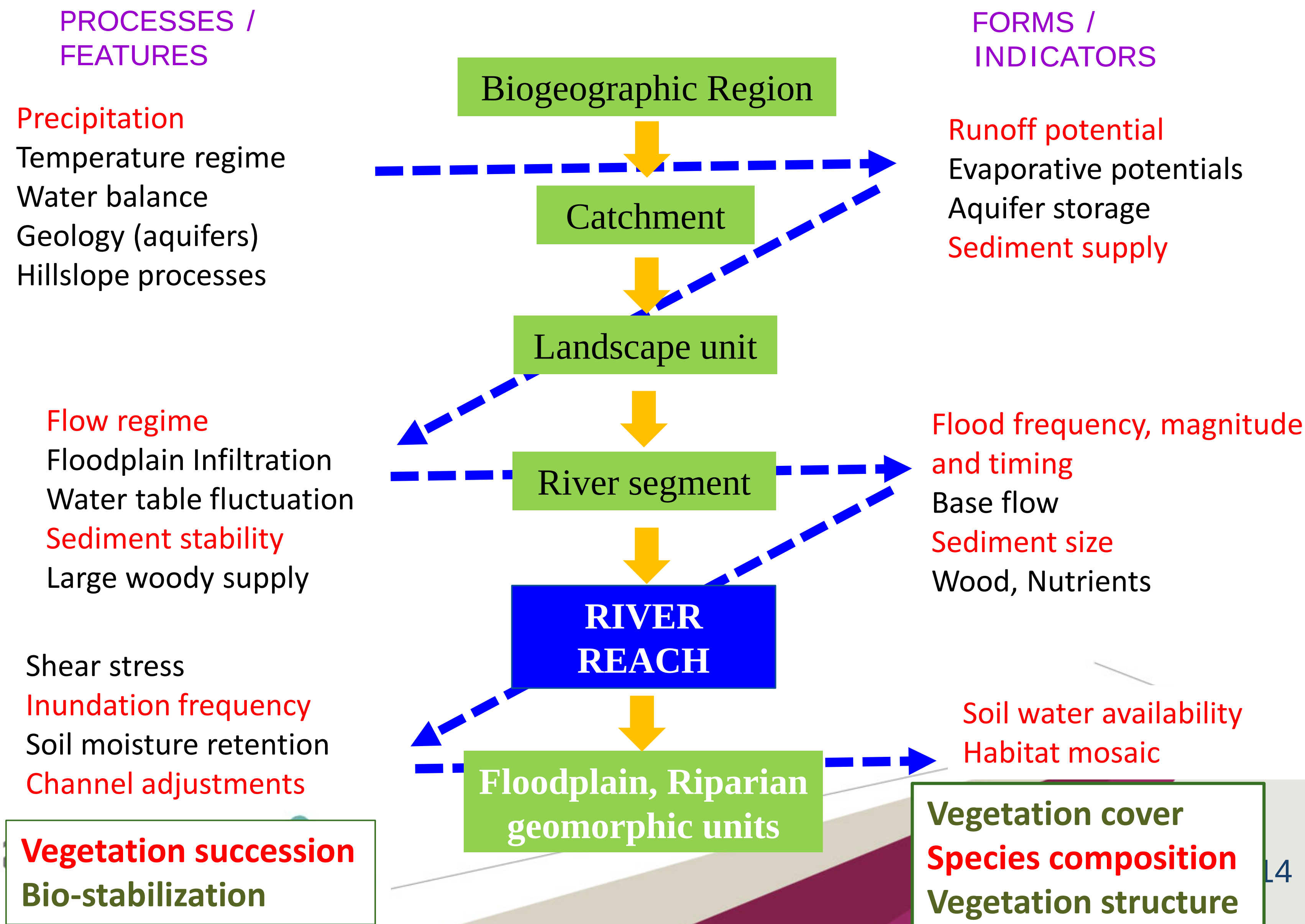
DISPERSION, ESTABLISHMENT, GROWTH, SURVIVAL, MORTALITY

Vegetation succession
Bio-stabilization

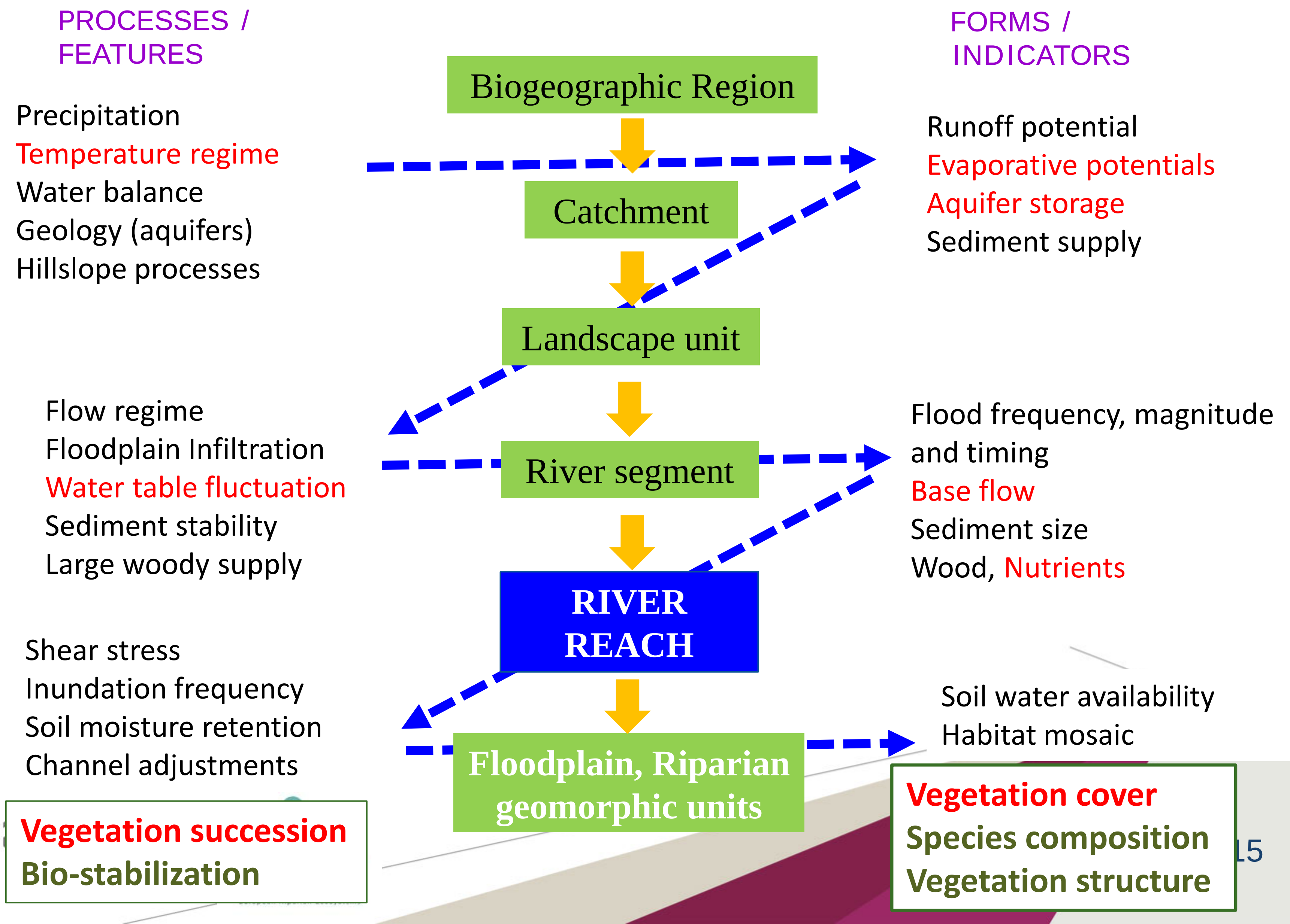
Vegetation cover
Species composition
Vegetation structure

4.FORMS AND PROCESSES AFFECTING RIPARIAN VEGETATION

DISPERSION, ESTABLISHMENT, GROWTH, SURVIVAL, MORTALITY

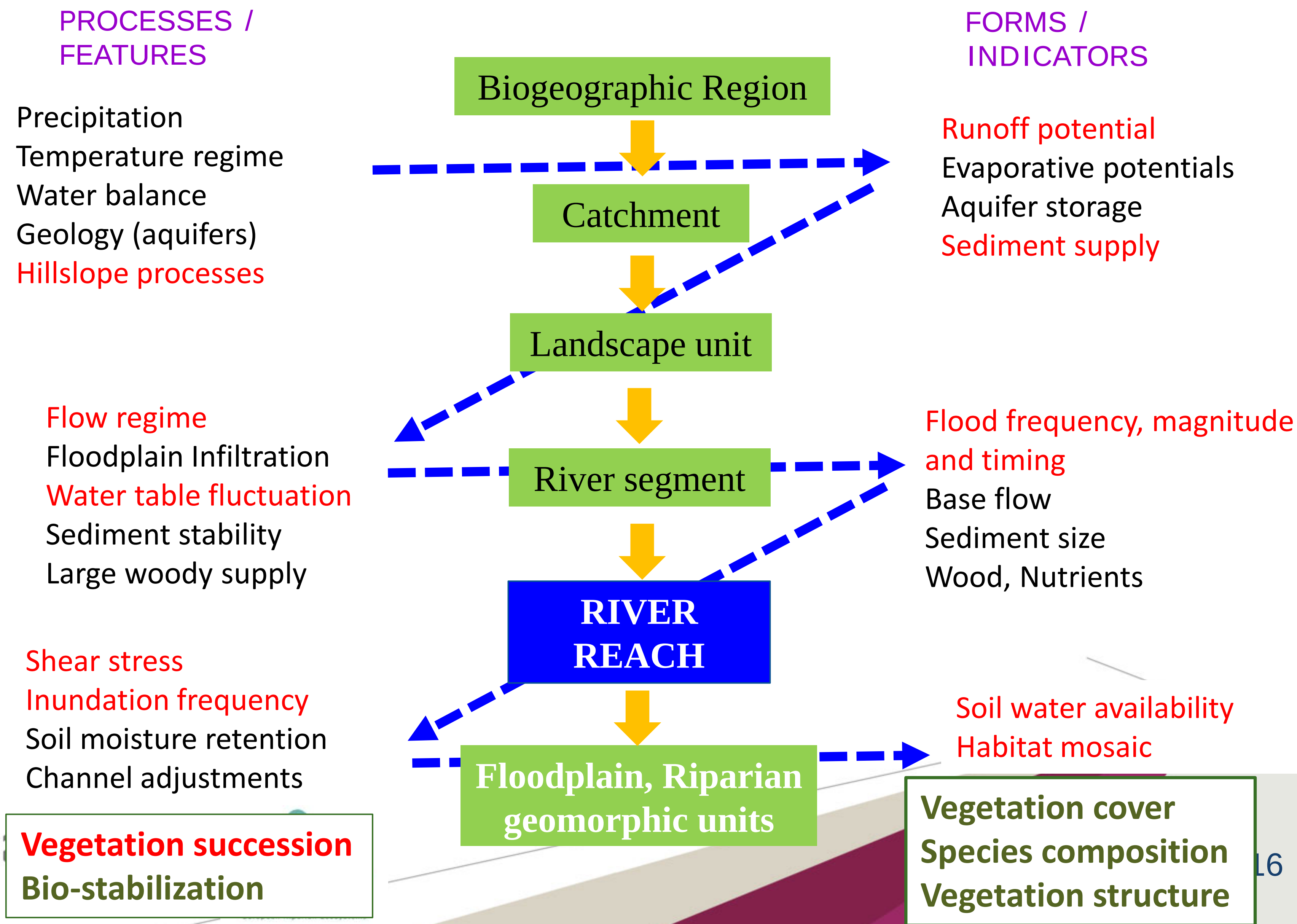


DISPERSION, ESTABLISHMENT, GROWTH, SURVIVAL, MORTALITY



4.FORMS AND PROCESSES AFFECTING RIPARIAN VEGETATION

DISPERSION, ESTABLISHMENT, GROWTH, SURVIVAL, MORTALITY

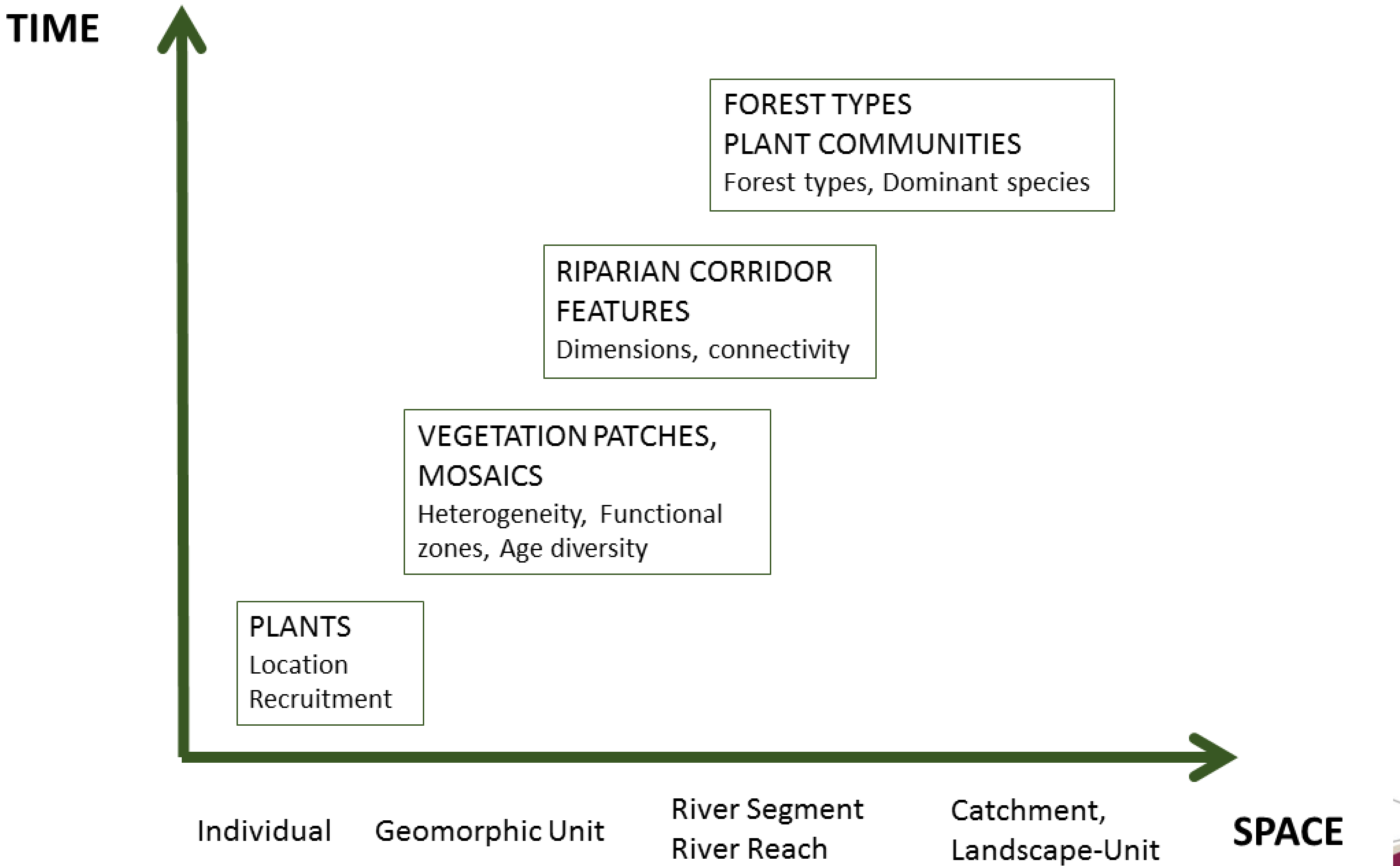


Understanding the dynamic **reciprocal interactions of vegetation with hydromorphology**

CHARACTERIZING / ASSESSING THE STATUS OF RIPARIAN VEGETATION:

1. Specify **vegetation units** and spatial and temporal **scales**
2. Identify **main processes** and **proper indicators** and metrics
3. Characterize **current** condtions: *What we have*
4. Characterize **past** conditions: *What we had*
5. Infere "**natural**" conditions according to typologies: *What we could have*
6. Define "**reference**" conditions (reference sites, reference periods ….): *Targets*
7. Quantify **deviations** from references: *Quality assessments*
8. Consider **future** scenarios: *Management options*

MULTI-SCALE VEGETATION UNITS



5. TOWARDS A MULTI-SCALE RIPARIAN VEGETATION CHARACTERIZATION

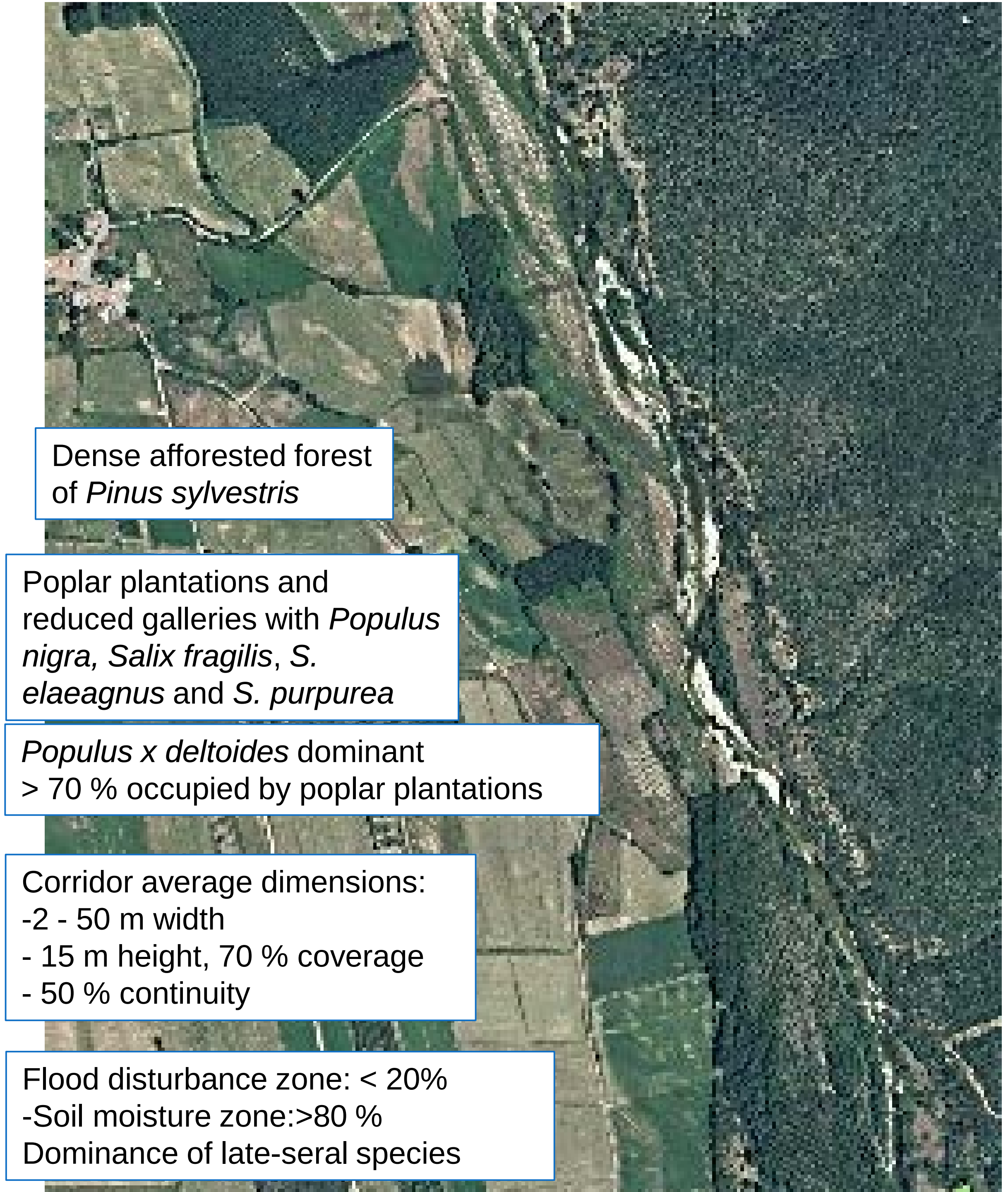
SPATIAL UNIT	VEGETATION UNITS	INDICATORS	PRESSURES / IMPACTS
REGION:			
CATCHMENT			
LANDSCAPE UNIT			
RIVER SEGMENT			
RIVER REACH RIPARIAN AND FLOODPLAIN GEOMORPHIC UNITS			
CHANNEL GEOMORPHIC UNIT RIVER ELEMENT			

IN PREPARATION

RIVER PORMA (NW SPAIN)

Current conditions: 2014, regulated

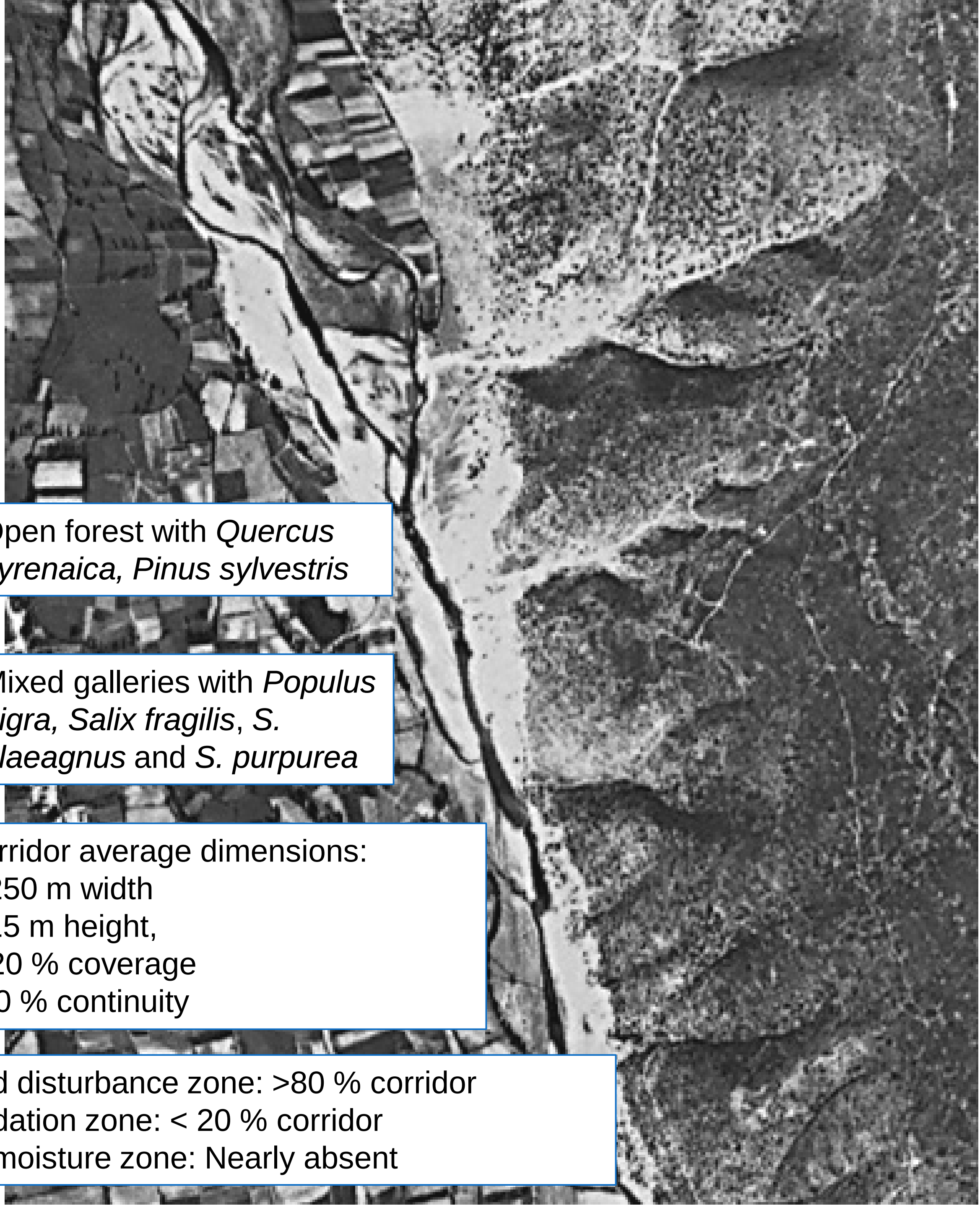
SPATIAL UNIT	VEGETATION INDICATORS CURRENT CONDITIONS
Region:	Vegetation Types • Vegetation Type
Watershed	Vegetation Forms • Dominant species
Landscape unit	• Changes in species composition/abundance • % Alien species • Valley floor occupation
River segment	• Corridor narrowing/widening • Changes in coverage • Fragmentation • Transversal homogeneity (no different lateral zones) • % no native species • Vegetation encroachment



RIVER PORMA (NW SPAIN)

Past conditions: 1956, non-regulated

SPATIAL UNIT	VEGETATION INDICATORS PAST (REFERENCE) PERIOD
Region:	Vegetation Types • Vegetation Type
Watershed	Vegetation Forms • Dominant species
Landscape unit	Riparian / Floodplain vegetation Associations • Dominant species • Diversity
River segment	Corridor features: • Dimensions (average width) • Height and Coverage • Longitudinal connectivity Transversal zonation (lateral zones) • Average width • Species composition • Vegetation coverage



Open forest with *Quercus pyrenaica, Pinus sylvestris*

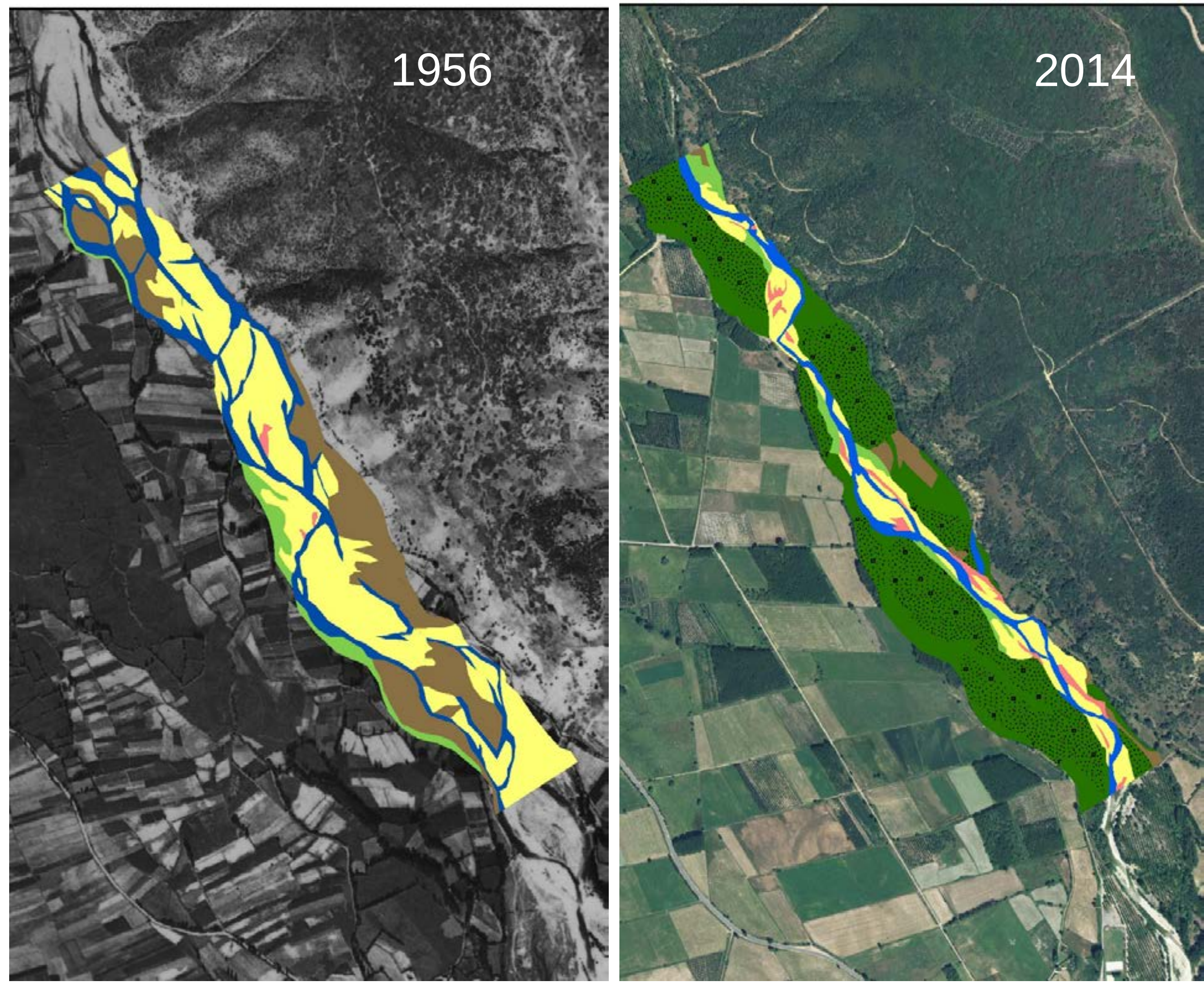
Mixed galleries with *Populus nigra, Salix fragilis*, *S. elaeagnus* and *S. purpurea*

Corridor average dimensions:
- 250 m width
- 15 m height,
- 20 % coverage
- 50 % continuity

Flood disturbance zone: >80 % corridor
Inundation zone: < 20 % corridor
Soil moisture zone: Nearly absent

RIVER PORMA (NW SPAIN)

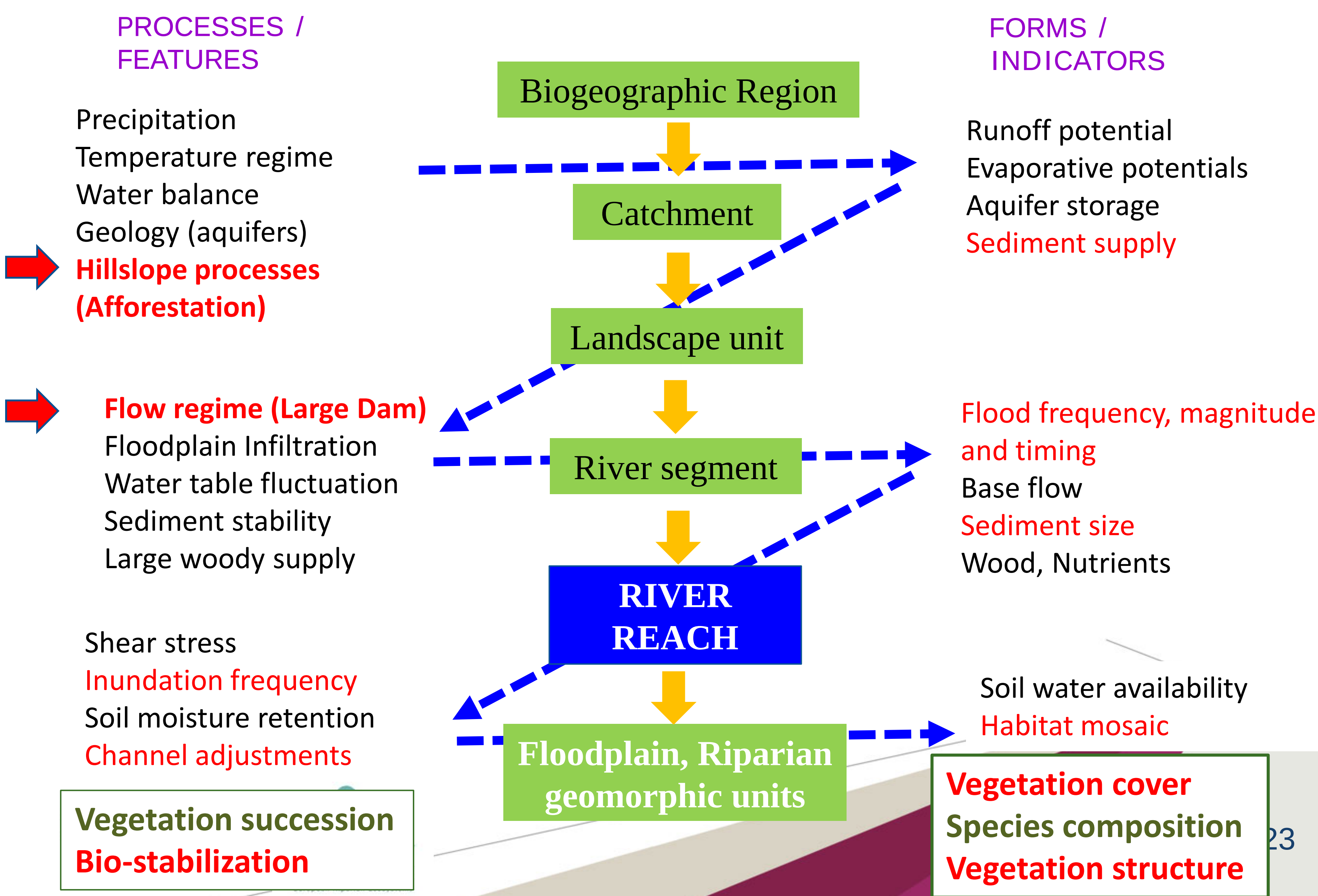
Deviations from reference



- Riparian vegetation assessment (*what we have, what we should have*)

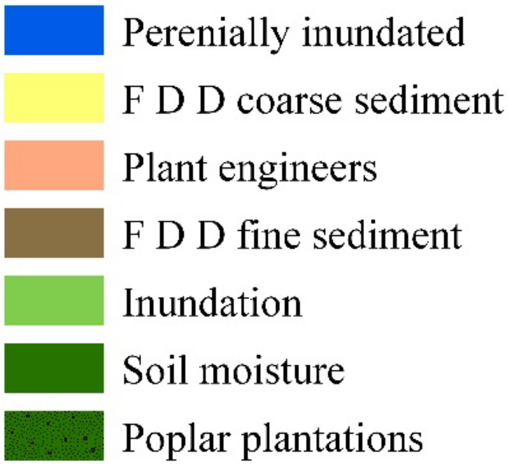
(González del Tánago et al. 2016b)

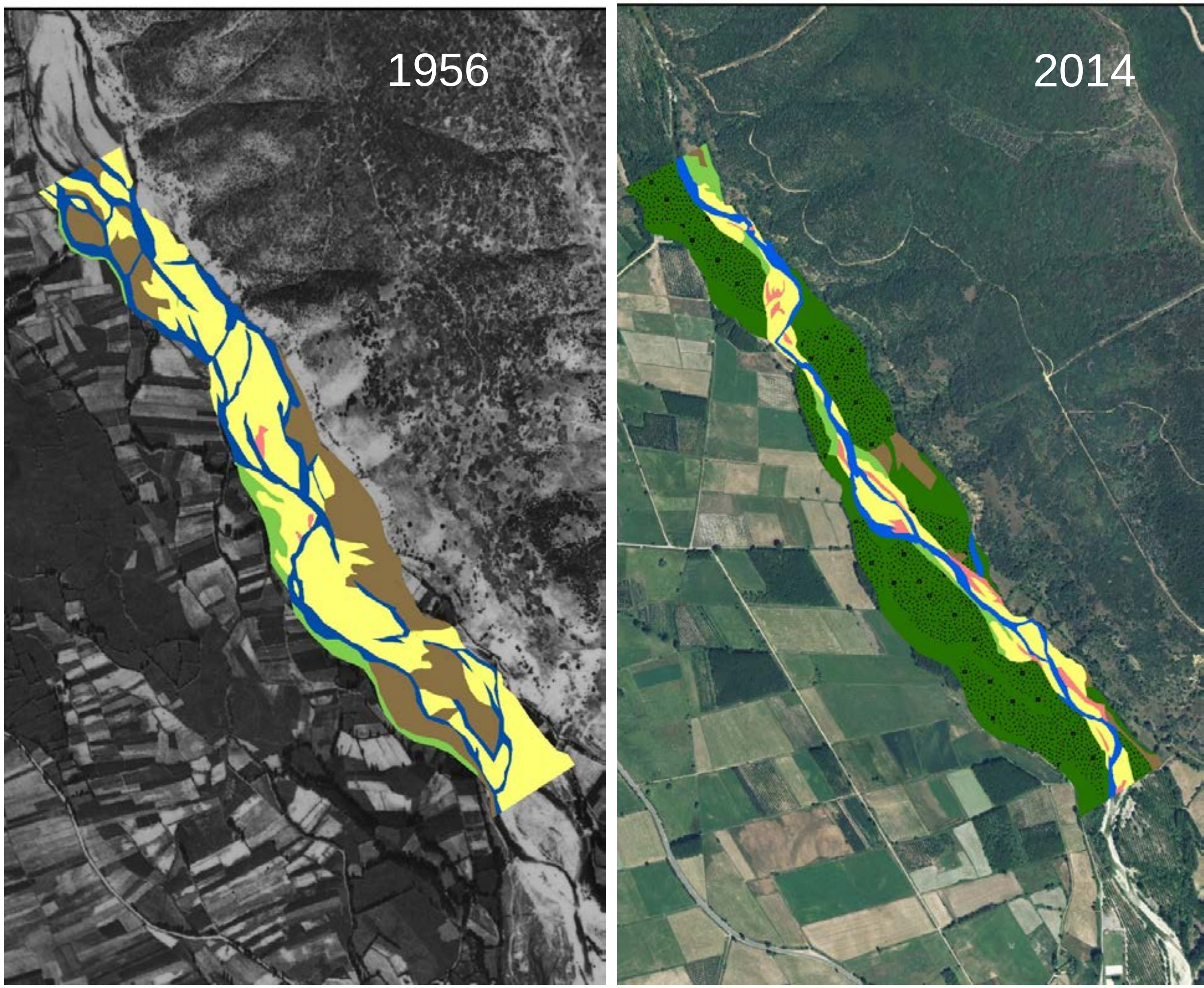
DISPERSION, ESTABLISHMENT, GROWTH, SURVIVAL, MORTALITY



RIVER PORMA (NW SPAIN)

Deviations from reference





- Riparian vegetation assessment (*what we have, what we should have*)
- Predicting **future trajectories** (*what we will likely have under potential scenarios*)
- **Management options**

CONCLUSIONS

- **Riparian vegetation** (RV) is a dynamic component of rivers and should be characterized according to the **reciprocal interactions that it maitains** with water-flow and sediments

- RV status at **reach scale** is determined by different hydromorphological processess and features that are acting at **different spatial and temporal scales**

- A **multi-scale hierarchical approach results very useful to understand** current RV status and its evolution from the past, and **to predict** future conditions under potential scenarios

- **Homogeneous** multi-scale **vegetation units, indicators and metrics** should be the **first step** defining proper RV characterization and assessment **across European regions**

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