The role of hydromorphological information to improve ecological status and provide sustainable hydropower

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ISPRA – Italian National Institute for Environmental Protection and Research

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Seminar on measurement and data processing techniques for hydro-morphological assessment of regulated rivers, lakes and reservoirs. Trondheim, 9th January 2018

Italian National Institute for Environmental Protection and Research (ISPRA)

- National Research Institute + National Environment Agency
- National coordinator of Regional EA federation
- National Geological Survey
- National node of European Environmental Agency

- Support policies implementation in all environmental fields:

✓Produce standards + methodologies for monitoring + evaluation of env. status, flood hazard etc…

✓Make methodologies applicable

✓Training activity

The National River Science group

ISPRA in charge to develop applied research in river hydromorphology (e.g. methods) to analyse and diagnose the impacts of pressures on river hymo processes.

Networking with (the brightest) Italian fluvial scientist since 2007.

Massimo Rinaldi

me

Francesco Comiti

Nicola Surian

Paolo Vezza

Barbara Belletti

Guido Zolezzi

Simone Bizzi

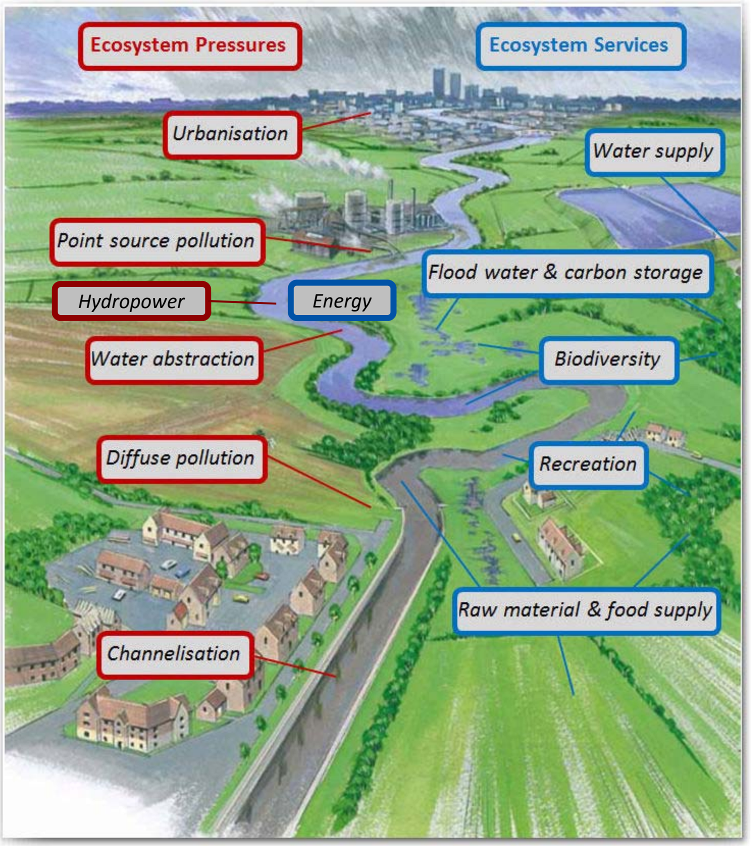
Hymo information supports WFD, FD, RES…

Integration of objectives in anthropized contexts is THE challenge

To evaluate and prioritize optimal measures we need to understand how a river works, how it reacts to pressures at the different scales.

The Water Framework Directive (WFD)

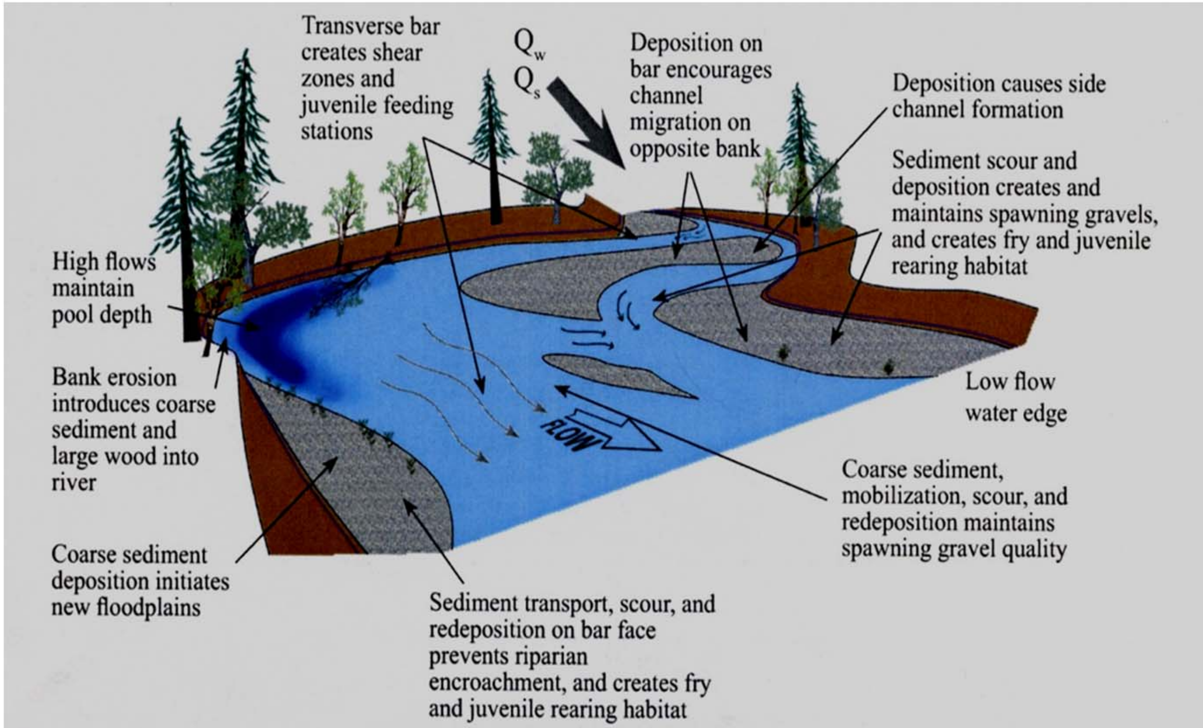
WFD aims to achieve the good status of all EU water bodies (WBs), their associated aquatic ecosystems and the services they provide, which sustain society.



Hydromorphology ensures ecological integrity

Good hydromorphological processes are essential to create and maintain habitats and ensure ecosystem integrity, e.g. good ecological status.

Hymo assessment is crucial in order to inform a sustainable and effective management of WBs and so to comply with WFD



Characterization is not assessment

How does my river work?

Description of the current situation in a river system,
from catchment to geomorphic units to understand how it functions.

Tracking changes is not yet assessment

What’s wrong? Why has this transition taken place?

We can track changes over time but not yet sufficient to assess its status: we need to put those information into a spatial and temporal context!

River systems are complex

Bioscience 1996

The Natural Flow Regime

A paradigm for river conservation and restoration

N. LeRoy Poff, J. David Allan, Mark B. Bain, James R. Karr, Karen L. Prestegaard, Brian D. Richter, Richard E. Sparks, and Julie C. Stromberg

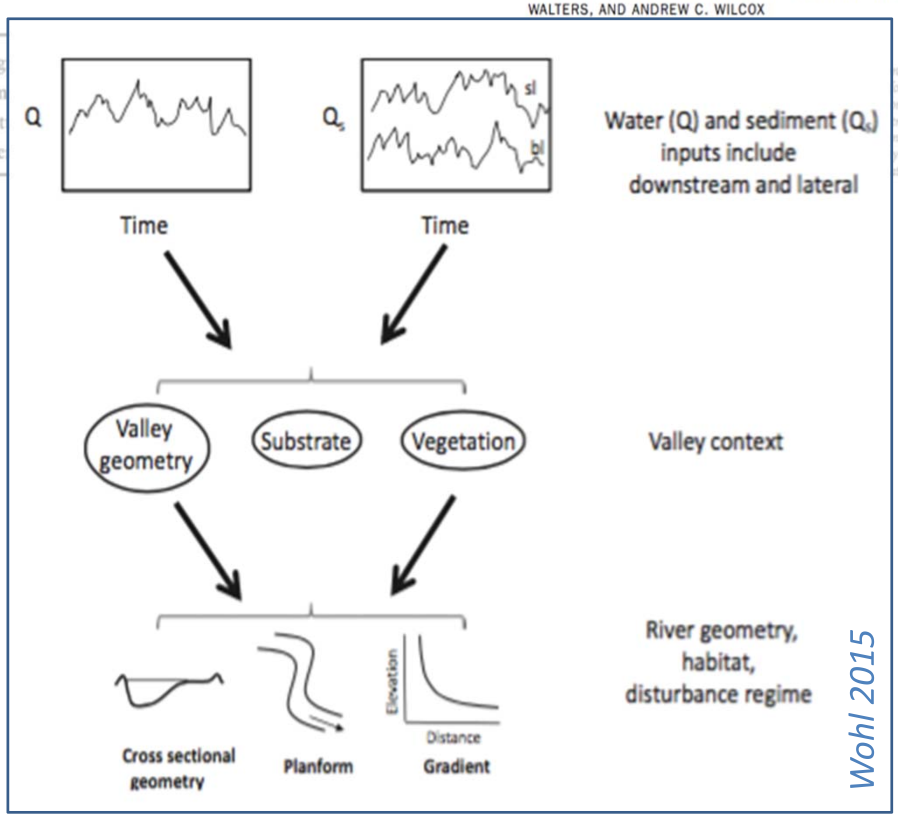
Humans have long been fascinated by the dynamism of free-flowing waters. Yet we have expended great effort to tame rivers for transportation, water supply, flood control, agriculture, and power generation. It is now recognized that harnessing of streams and rivers comes at great cost: Many

The ecological integ
of river ecosystem
depends on their nat
dynamic characte

Bioscience 2015

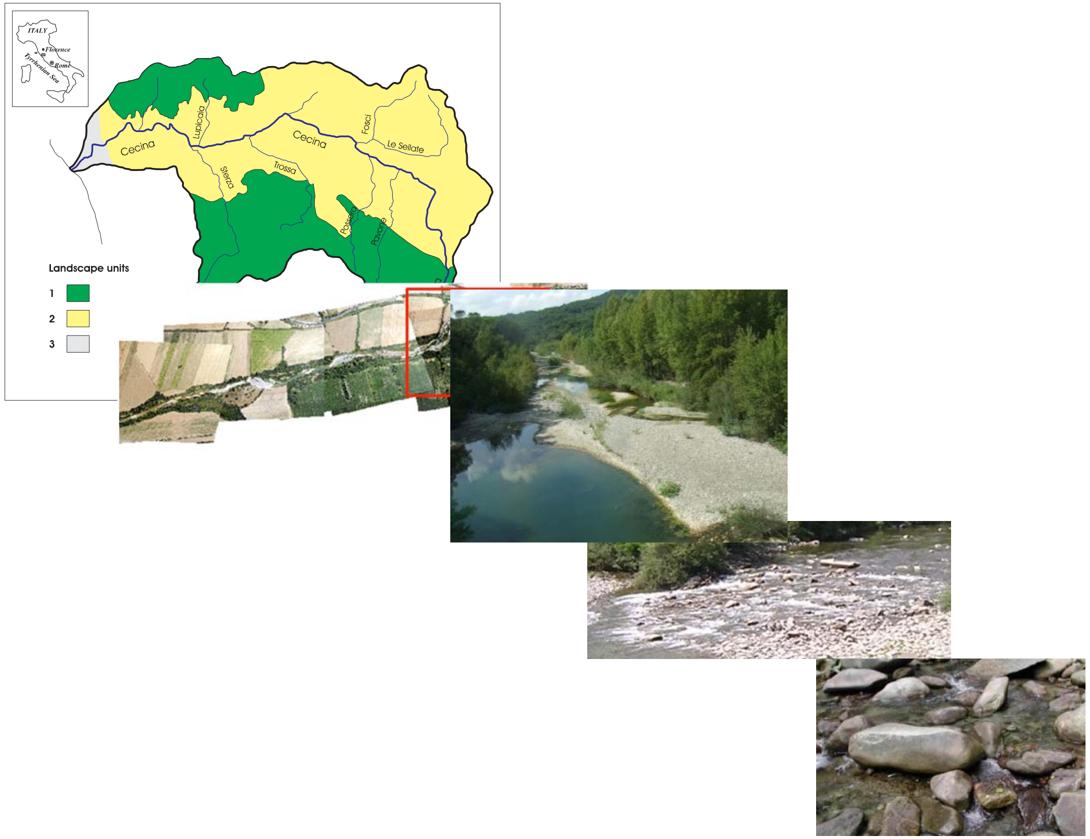
The Natural Sediment Regime in Rivers: Broadening the Foundation for Ecosystem Management

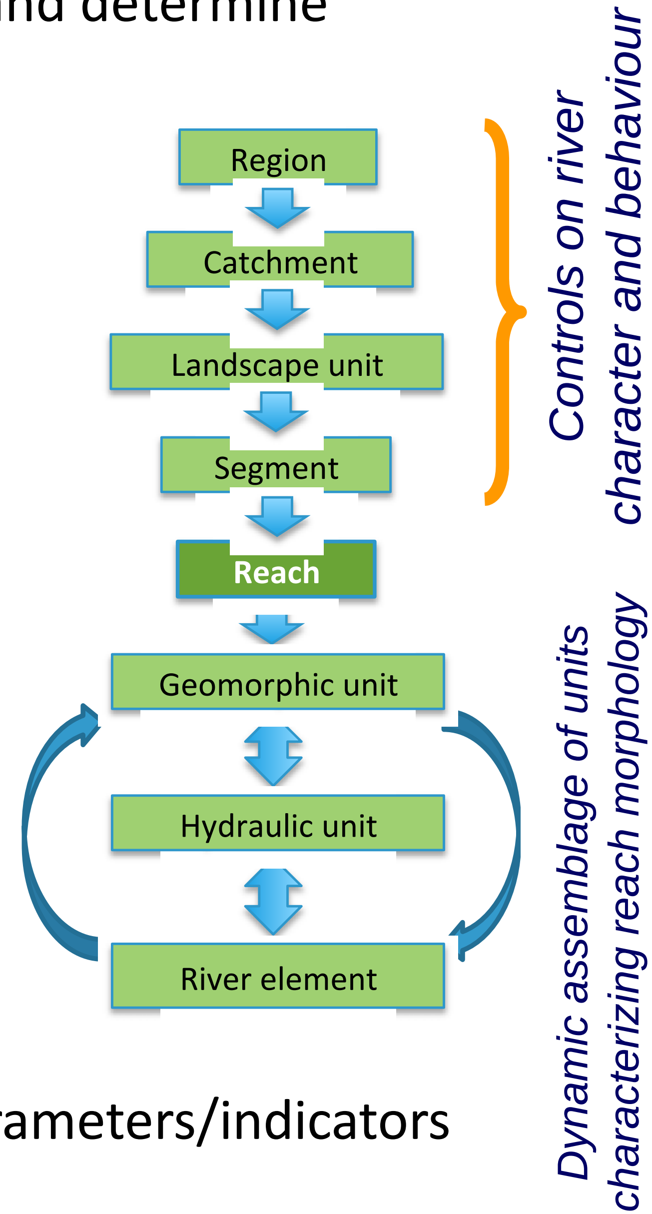
ELLEN WOHL, BRIAN P. BLEDSOE, ROBERT B. JACOBSON, N. LEROY POFF, SARA L. RATHBURN, DAVID M. WALTERS, AND ANDREW C. WILCOX



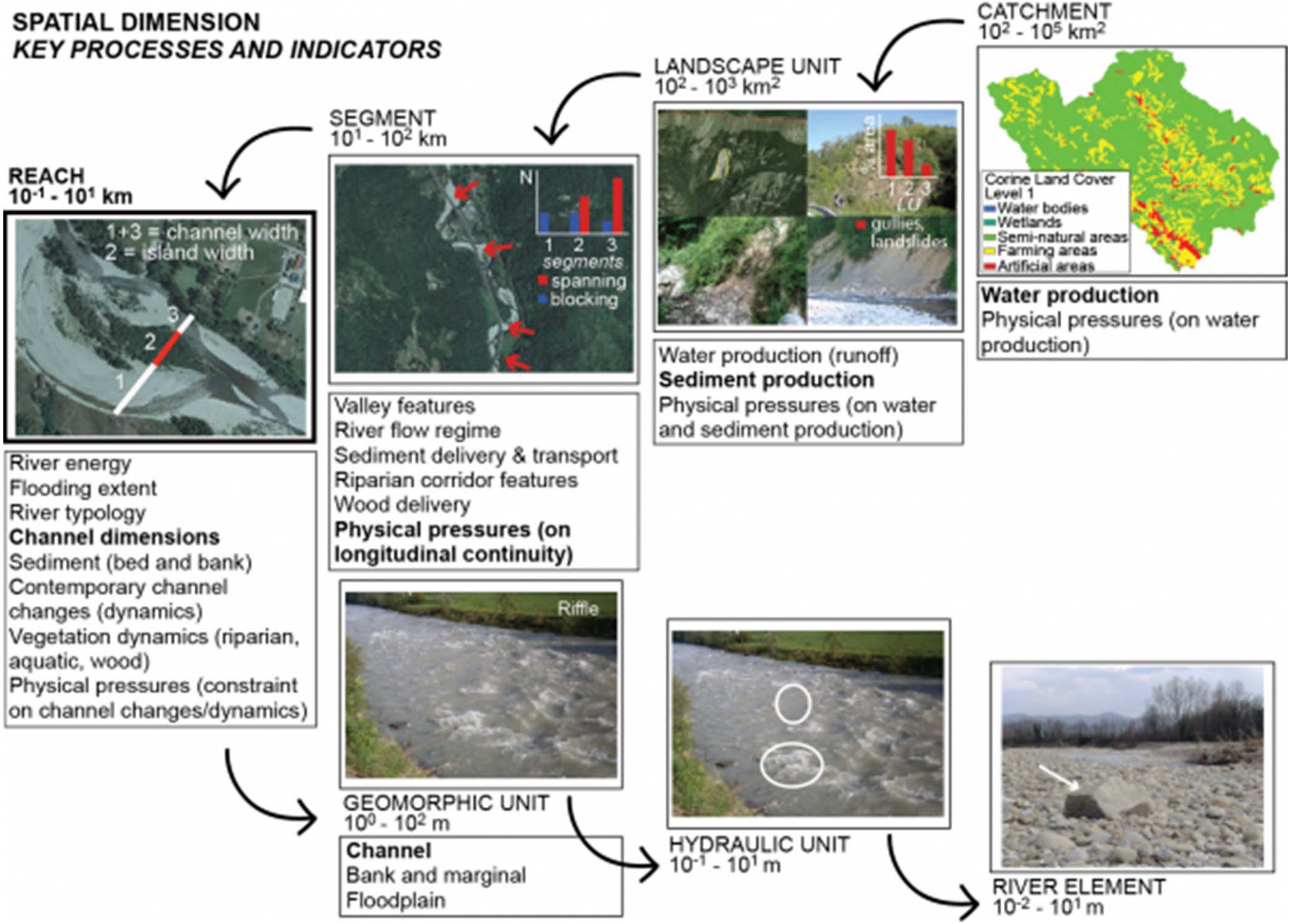
Rivers are hierarchical systems

Processes and forms at larger scales dominate and determine those at smaller scales.





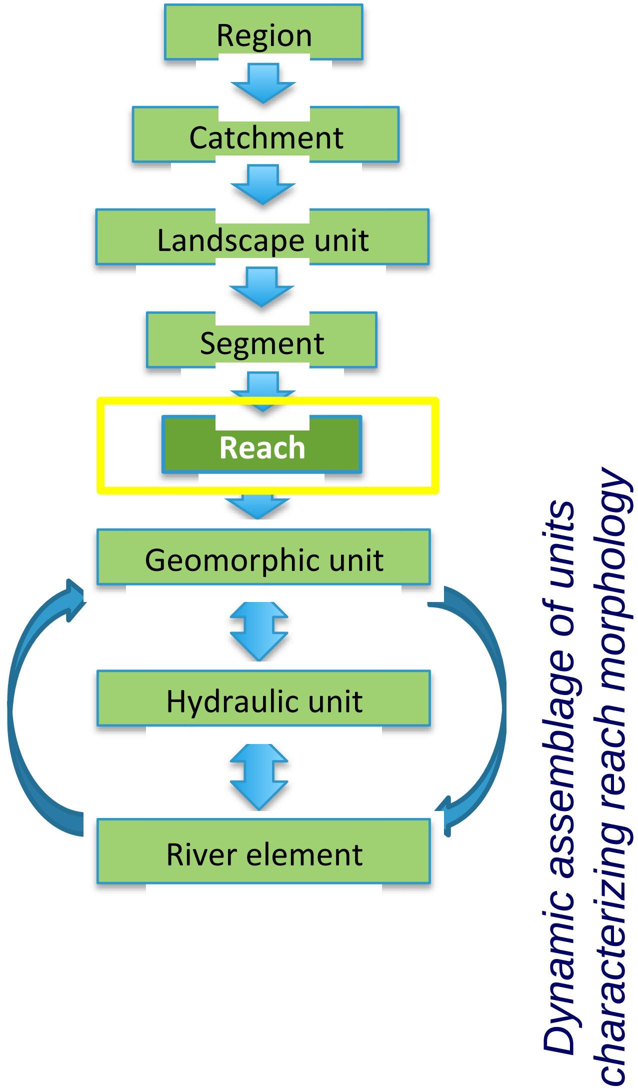
Each scale can be characterized by a set of parameters/indicators


SPATIAL DIMENSION
KEY PROCESSES AND INDICATORS
CATCHMENT
10^2 - 10^5 km^2
Corine Land Cover
Level 1
Water bodies
Wetlands
Semi-natural areas
Farming areas
Artificial areas
Water production
Physical pressures (on water production)
LANDSCAPE UNIT
10^2 - 10^3 km^2
% area
1 2 3
LU
gullies, landslides
Water production (runoff)
Sediment production
Physical pressures (on water and sediment production)
SEGMENT
10^1 - 10^2 km
N
1 2 3
segments
spanning
blocking
Valley features
River flow regime
Sediment delivery & transport
Riparian corridor features
Wood delivery
Physical pressures (on longitudinal continuity)
REACH
10^-1 - 10^1 km
1+3 = channel width
2 = island width
1
2
3
River energy
Flooding extent
River typology
Channel dimensions
Sediment (bed and bank)
Contemporary channel changes (dynamics)
Vegetation dynamics (riparian, aquatic, wood)
Physical pressures (constraint on channel changes/dynamics)
Riffle
GEOMORPHIC UNIT
10^0 - 10^2 m
Channel
Bank and marginal
Floodplain
HYDRAULIC UNIT
10^-1 - 10^1 m
RIVER ELEMENT
10^-2 - 10^1 m

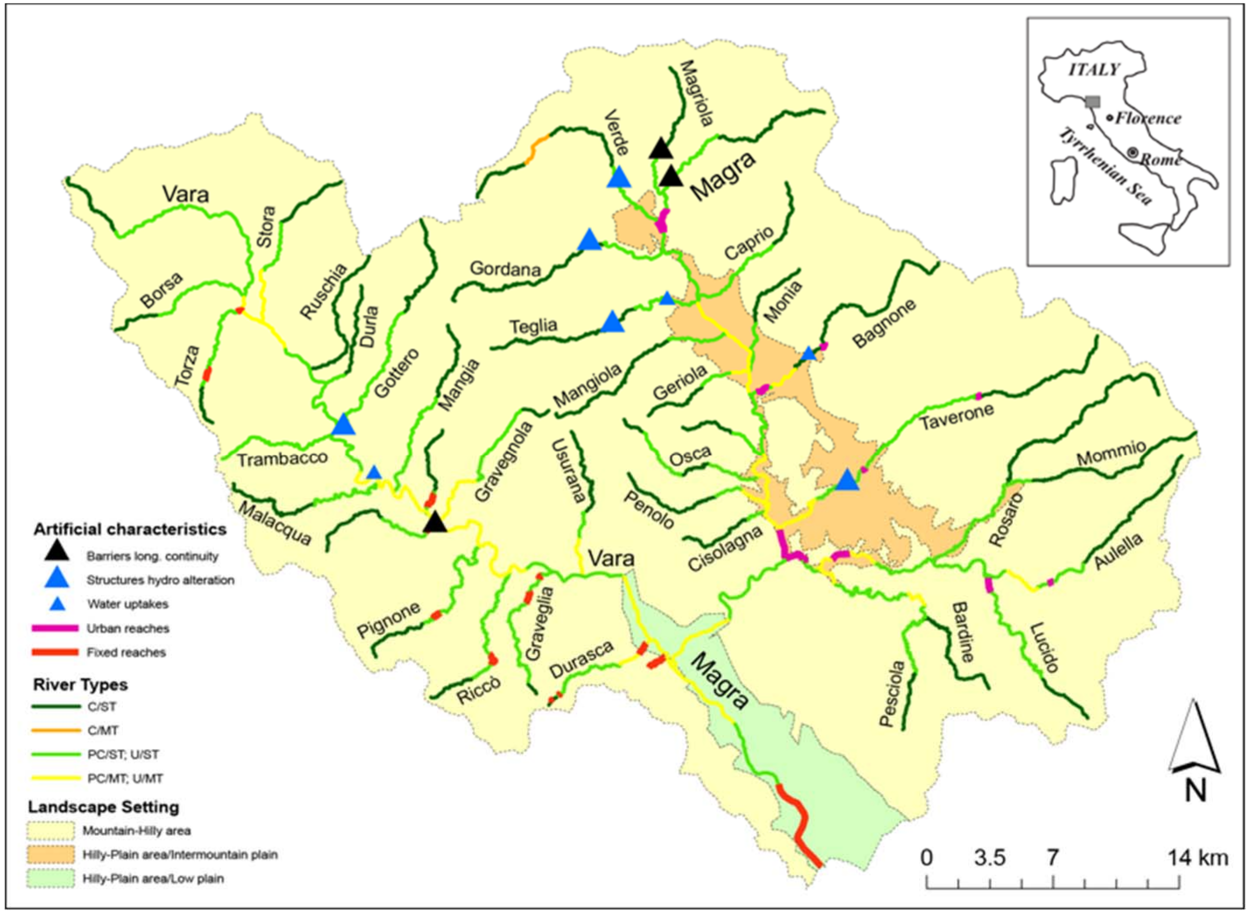
Reach is the key spatial scale for assessment

At the reach scale, the river has sufficiently uniform boundary conditions to maintain a consistent set of process-form interaction

River types have similar character and behaviour and similar response to pressures

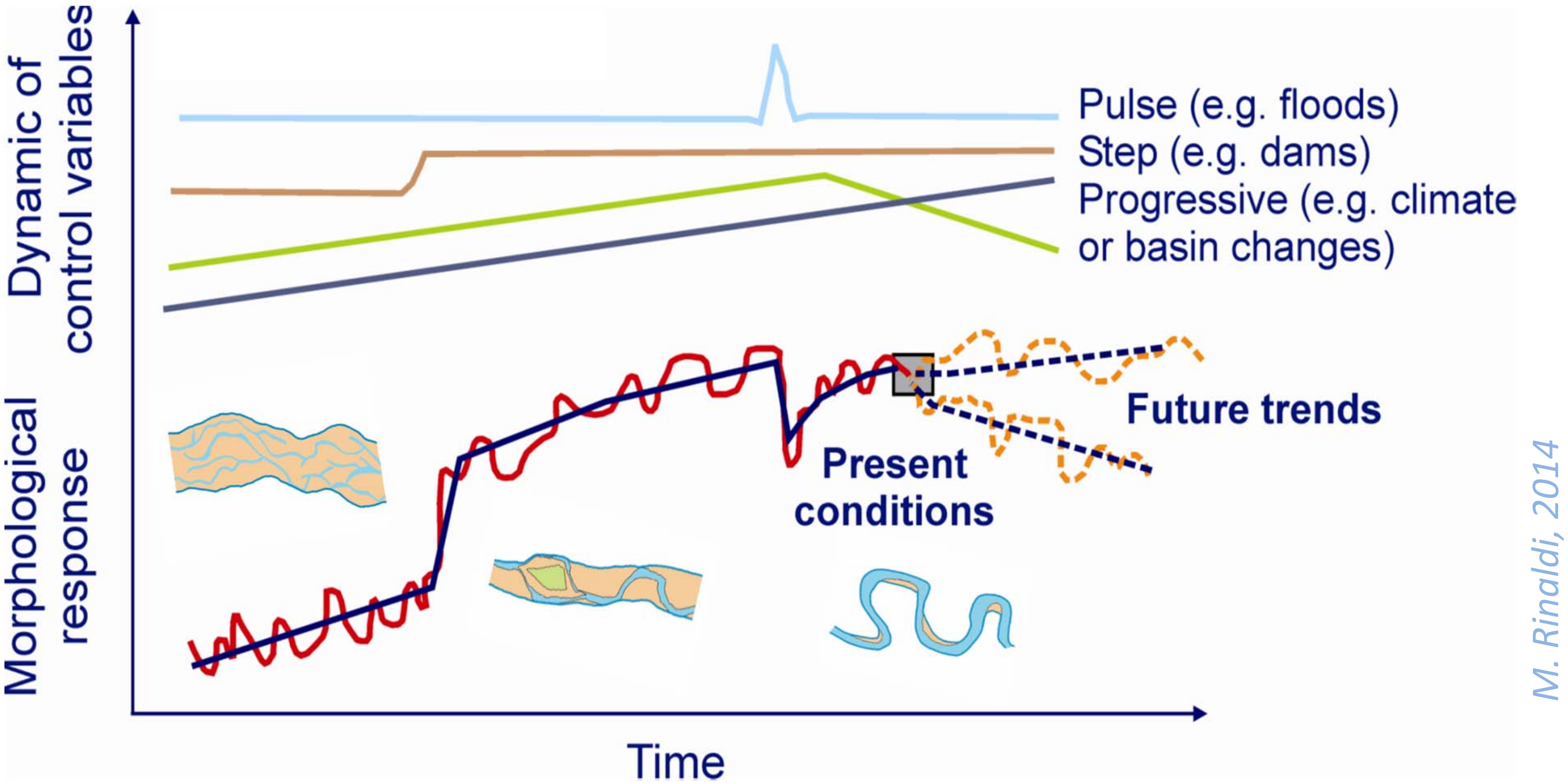


Hymo info has to be placed in a catchment context



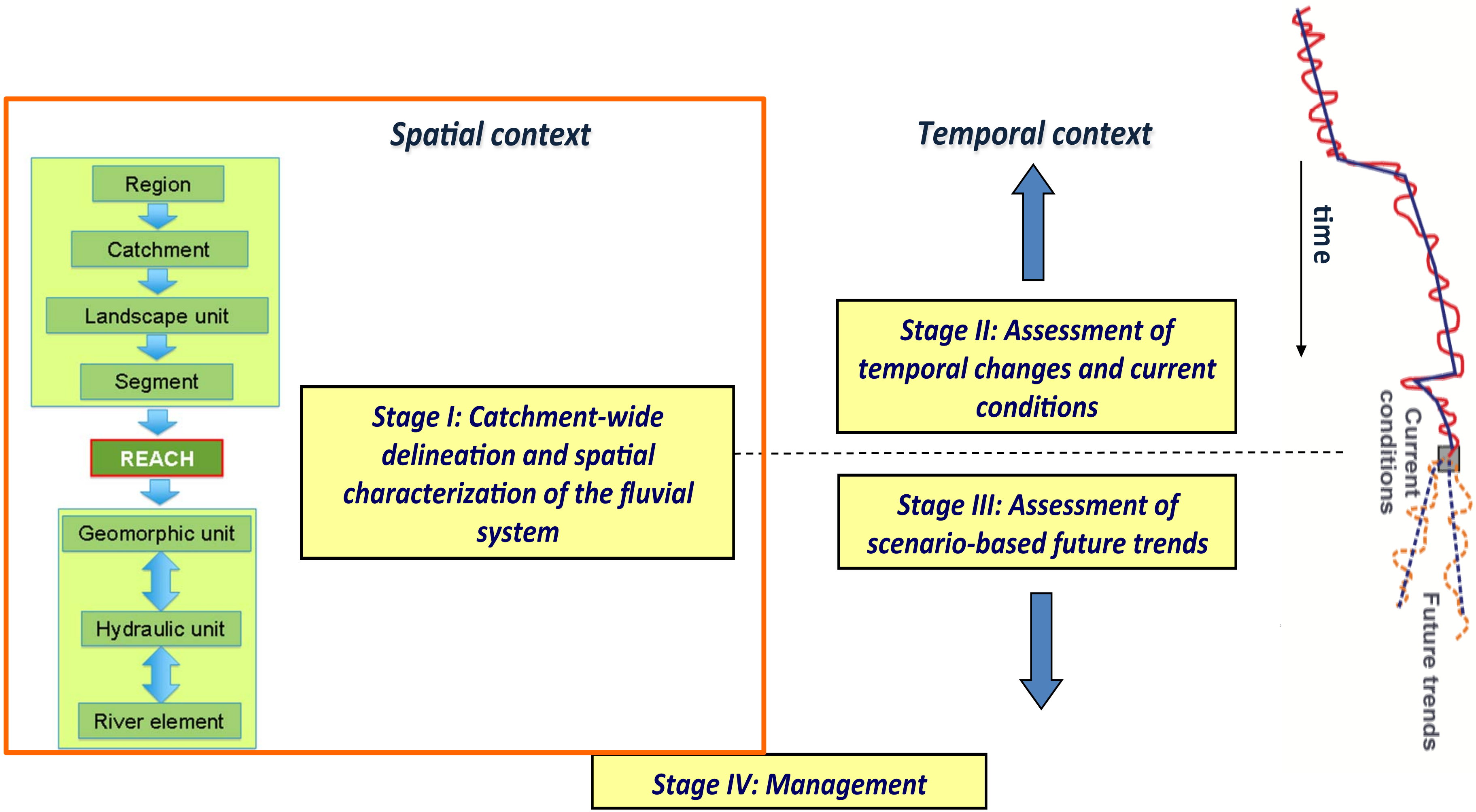
Evaluation of limiting factors and pressures on future changes and on potential of recovery

Hymo info has to be placed in a temporal context



Rivers evolve in a temporal trajectory adjusting their morphology in response to changes in driving variables
Past evolution informs assessment of current conditions and prediction of future changes

Diagnosis of present conditions and evaluation of future scenarios require a multiscale hymo assessment framework.



Characterizing

Date 20 / 04 / 2016 Operators J. Smith
Catchment Reform Stream/river Reform River
Upstream limit confluence Reform branch Downstream limit nearby Willington
Segment code 4 Reach Code 4_3 Reach length (m) 2.4 km

DELINEATION OF SPATIAL UNITS

1. Physiographic setting

Physiographic context P *M*=Mountains, *H*=Hills, *P*=Plain Landscape unit High plain

2. Confinement

Confinement degree (%) 10- 90 >90, 10-90, ≤10
Confinement index >n 1-1.5, 1.5-*n*, >*n* *(n=5 single-thread or anabranching; n=2 braided or wandering)*
Confinement class PC *PC*=Partly confined, *U*=Unconfined

3. Channel morphology

Aerial photo or satellite image Aerial Flight Reform Region 2007 (name, year)
Sinuosity index 1-1.05, 1.05-1.5, >1.5 *(applied only to single-thread channels)*
Braiding index ~ 1.3 1-1.5, >1.5 Anabranching index 1 1-1.5, >1.5
River Type (*BRT*, Basic River Typology) W *ST*=Straight, *S*=Sinuous, *M*=Meandering, *W*= Wandering, *B*= Braided, *A*= Anabranching

4. Other elements for reach delineation

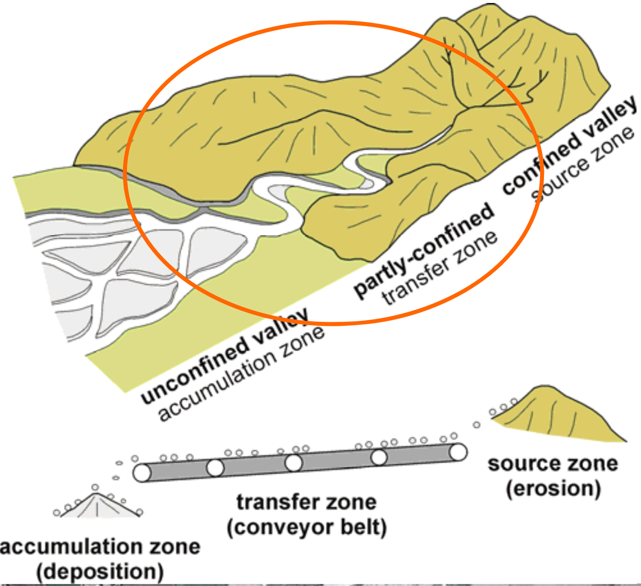
Upstream Tributary Downstream
change in geomorphic units, bed slope discontinuity, tributary, dam, artificial elements, change in confinement and/or size of the floodplain, changes in grain size, other (specify)

FURTHER CHARACTERIZATION

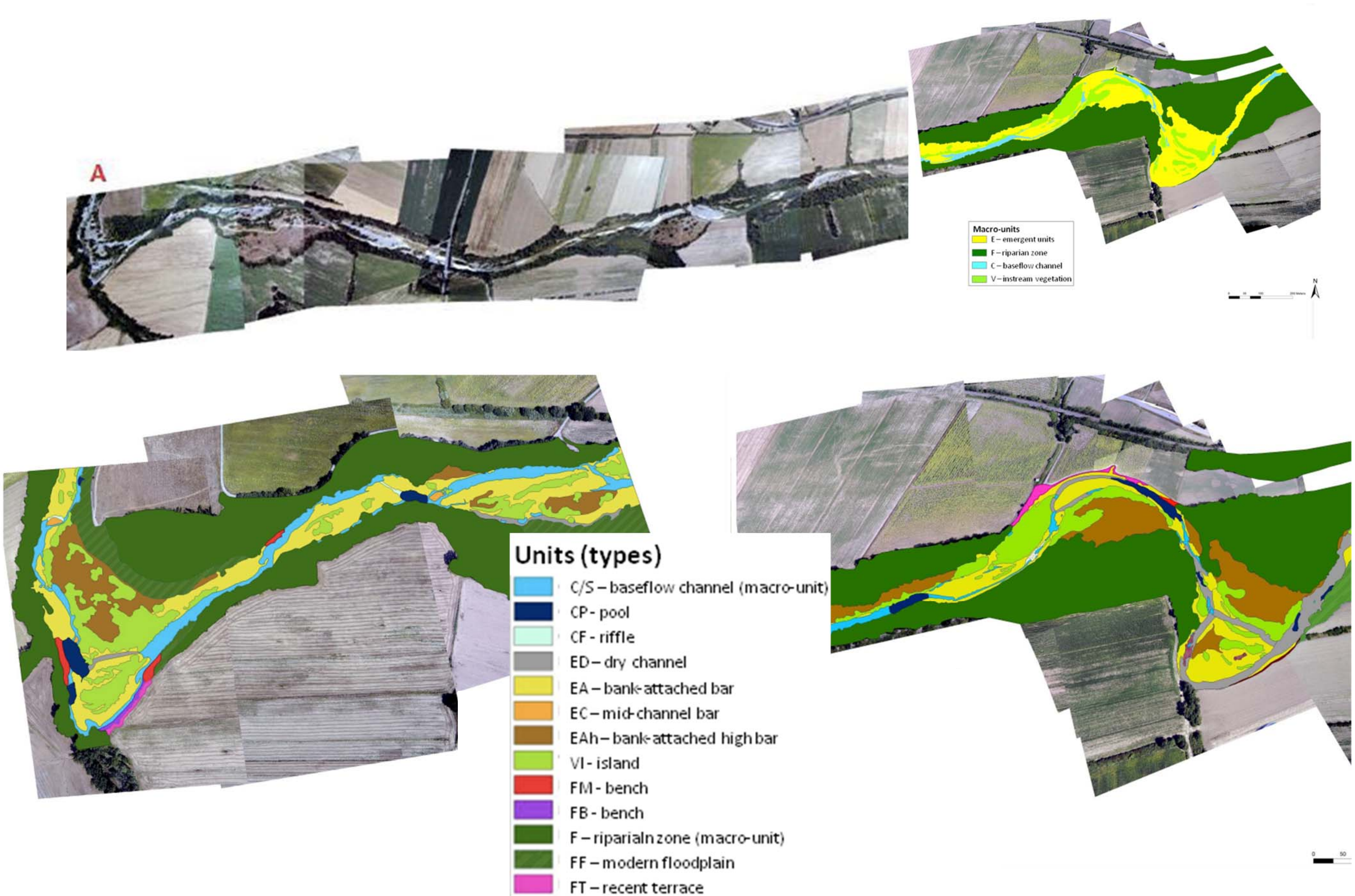
Drainage area (at the downstream limit) (km^2) 760
Mean bed slope, *S* 0.0033 Mean channel width, *W* (m) 42
Bed sediment (dominant) G-C *C*=Clay, *Si*=Silt, *Sa*=Sand, *G*=Gravel, *C*=Cobbles, *B*=Boulders
Bed configuration *BR*=bedrock, *C*=Cascade, *SP*=Step Pool, *PB*=Plane bed, *RP*=Riffle Pool, *DR*=Dune *A*= Artificial, *NC*= not classified (high depth or strong alteration)
River Type (*ERT*, Extended River Typology) *from 0 to 22 (GF= Groundwater-Fed)*
Unit stream power ($\omega=\gamma QS/W$) (when available) >10 ≤10, >10 W m^{-1} Energy setting *LE*=Low Ener

Additional available data / information

Sediment size, D_{50} (mm) 35 Unit Ba(SU) *Be*=Bed, *Ba*=Bar (*SU*=surface layer, *SUB*=sublayer)
Discharges E *M*=measured, *E*=estimated, *NA*=not available
Gauging station (if *M*) Mean annual discharge (m^3/s) 24 $Q_{1.5}$ or Q_2 (m^3/s) 235
Maximum discharges (indicate year and Q when known) Intense flood in 2009

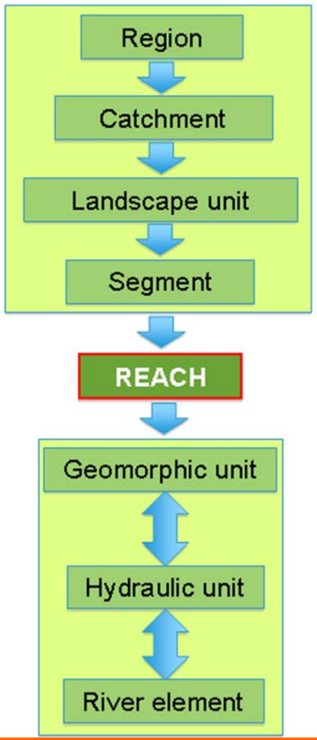


Characterizing



Diagnosis of present conditions and evaluation of future scenarios require a multiscale hymo assessment framework.

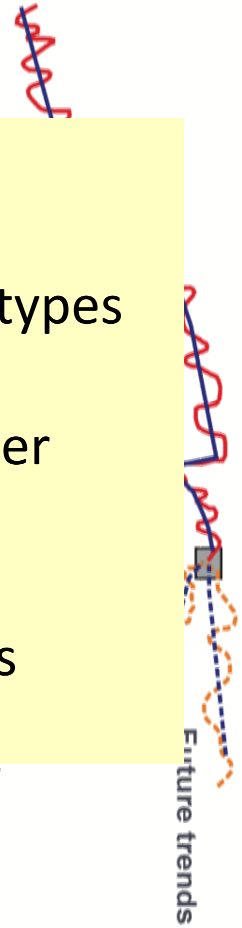
Spatial context



Stage I: Catchment-wide delineation and spatial characterization of the fluvial system

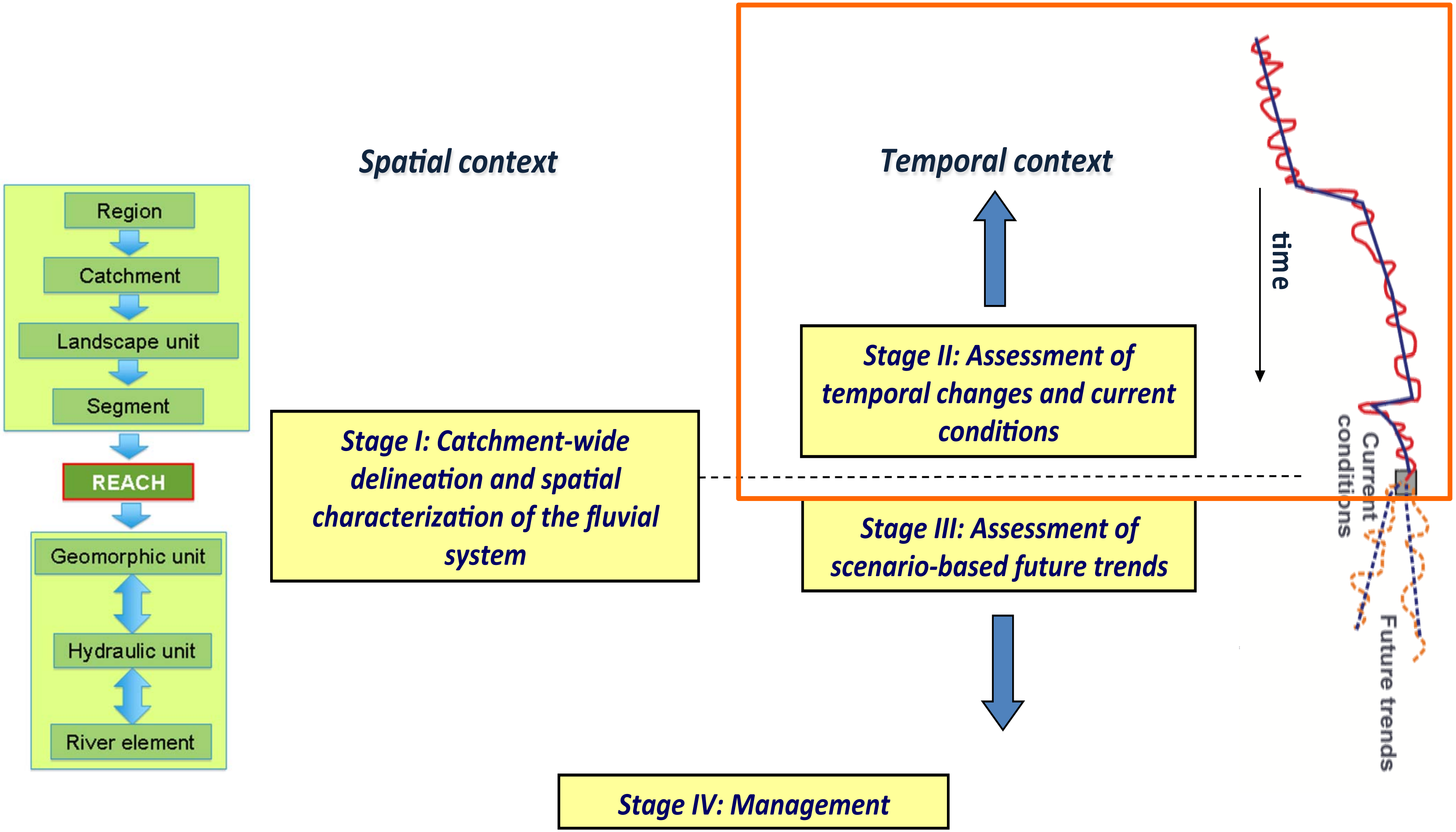
In WFD

- Delineation of river types
- Identification of water bodies
- Analysis of pressures

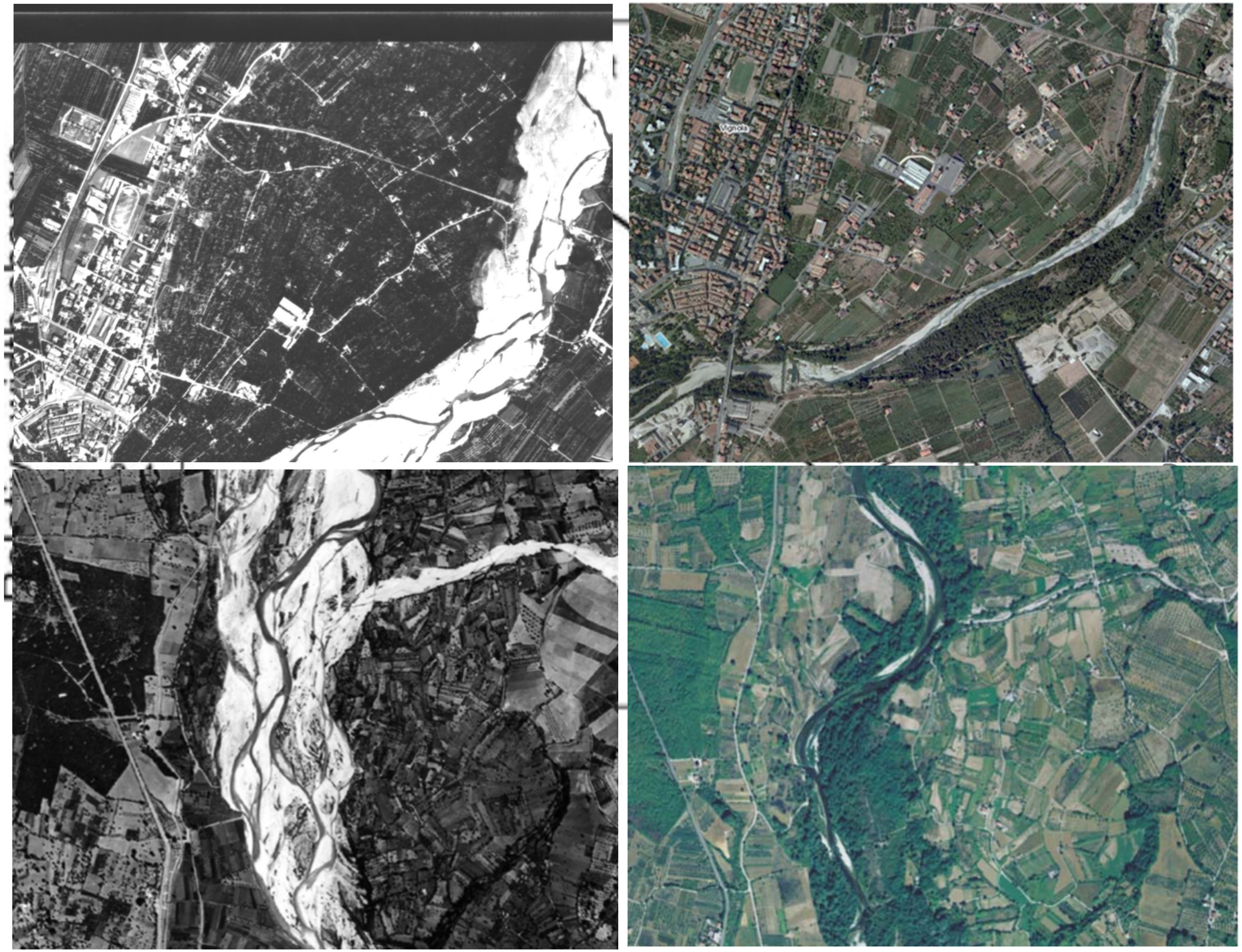


Stage IV: Management

Diagnosis of present conditions and evaluation of future scenarios require a multiscale hymo assessment framework.

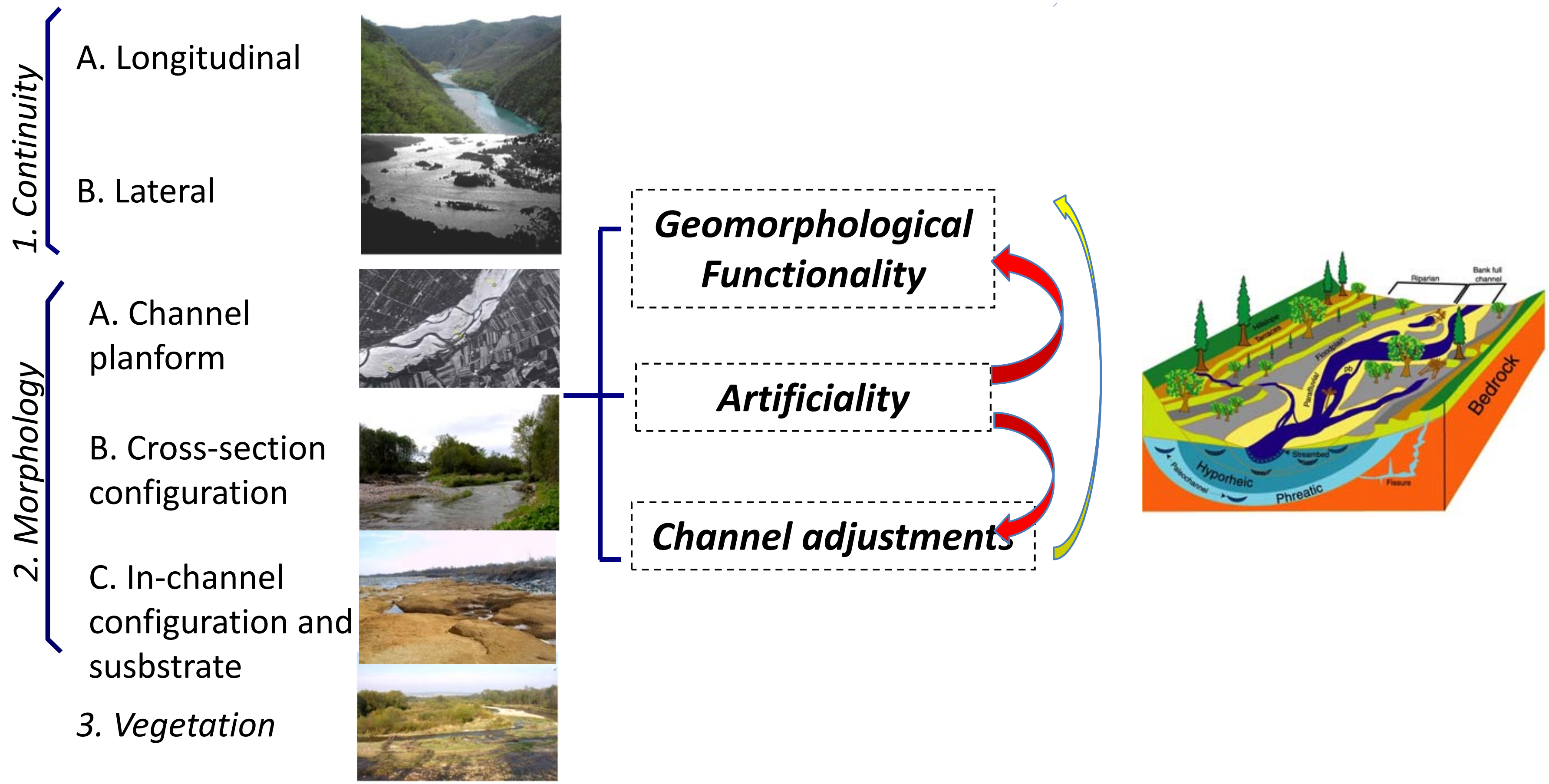


Past and recent evolution of rivers



WFD hymo assessment: the MQI

Assessment is based on understanding the relationship between pressures (artificiality) and responses (functionality) in the light of temporal long term channel changes.



Rinaldi M., Surian N., Comiti F., Bussettini M. (2013) – *A method for the assessment and analysis of the hydromorphological condition of Italian streams: the Morphological Quality Index (MQI).* Geomorphology, 180-181, 96-108.

Indicators

Functionality	
Continuity	
F1	*Longitudinal continuity in sediment and wood flux*
F2	*Presence of modern floodplain*
F3	*Hillslopes – stream connection*
F4	*Processes of bank retreat*
F5	*Presence of a potentially erodible corridor*
Morphology	
Channel pattern	
F6	*Bed configuration – valley slope*
F7	*Forms and processes typical of the channel pattern*
F8	*Presence of typical fluvial forms in the alluvial plain*
Cross-section configuration	
F9	*Variability of the cross-section*
Bed substrate	
F10	*Structure of the channel bed*
F11	*Presence of in-channel large wood*
Vegetation	
F12	*Width of functional formations in the fluvial corridor*
F13	*Linear extension of functional vegetation*

Artificiality	
Upstream alteration of longitudinal continuity	
A1	*Upstream alteration of channel-forming discharges*
A2	*Upstream interception of sediment transport*
Alteration of longitudinal continuity in the reach	
A3	*Alteration of channel-forming discharge in the reach*
A4	*Interception of sediment transport in the reach*
A5	*Crossing structures*
Alteration of lateral continuity	
A6	*Bank protections*
A7	*Artificial levees*
Alteration of channel morphology and/or substrate	
A8	*Artificial changes of river course*
A9	*Other structures of alteration of channel profile and/or substrate*
Interventions of removal	
A10	*Sediment removal*
A11	*Wood removal*
A12	*Vegetation cutting*

Channel adjustments	
CA1	*Adjustments in channel pattern*
CA2	*Adjustments in channel width*
CA3	*Bed-level adjustments*

Some indicators are applied/not applied in specific cases
e.g. F3,F6 are applied only to C

The Morphological Quality Index (MQI)

The Morphological Quality Index (MQI)

Artificiality

A10	Sediment removal
A	Absence of recent (last 20 years) and past (last 100 years) significant sediment removal activities
B1	Sediment removal activity in the past (last 100 years) but absent during last 20 years
B2	Recent sediment removal activity (last 20 years) but absent in the past (last 100 years)
C	Sediment removal activity either in the past (last 100 years) and during last 20 years

The Morphological Quality Index (MQI)

Channel adjustments

CA3	Bed-level adjustments
A	Negligible bed-level changes (≤0.5 m)
B	Limited to moderate bed-level changes (0.5÷3 m)
C1	Intense bed-level changes (>3 m)
C2	Very intense bed-level changes (>6 m)

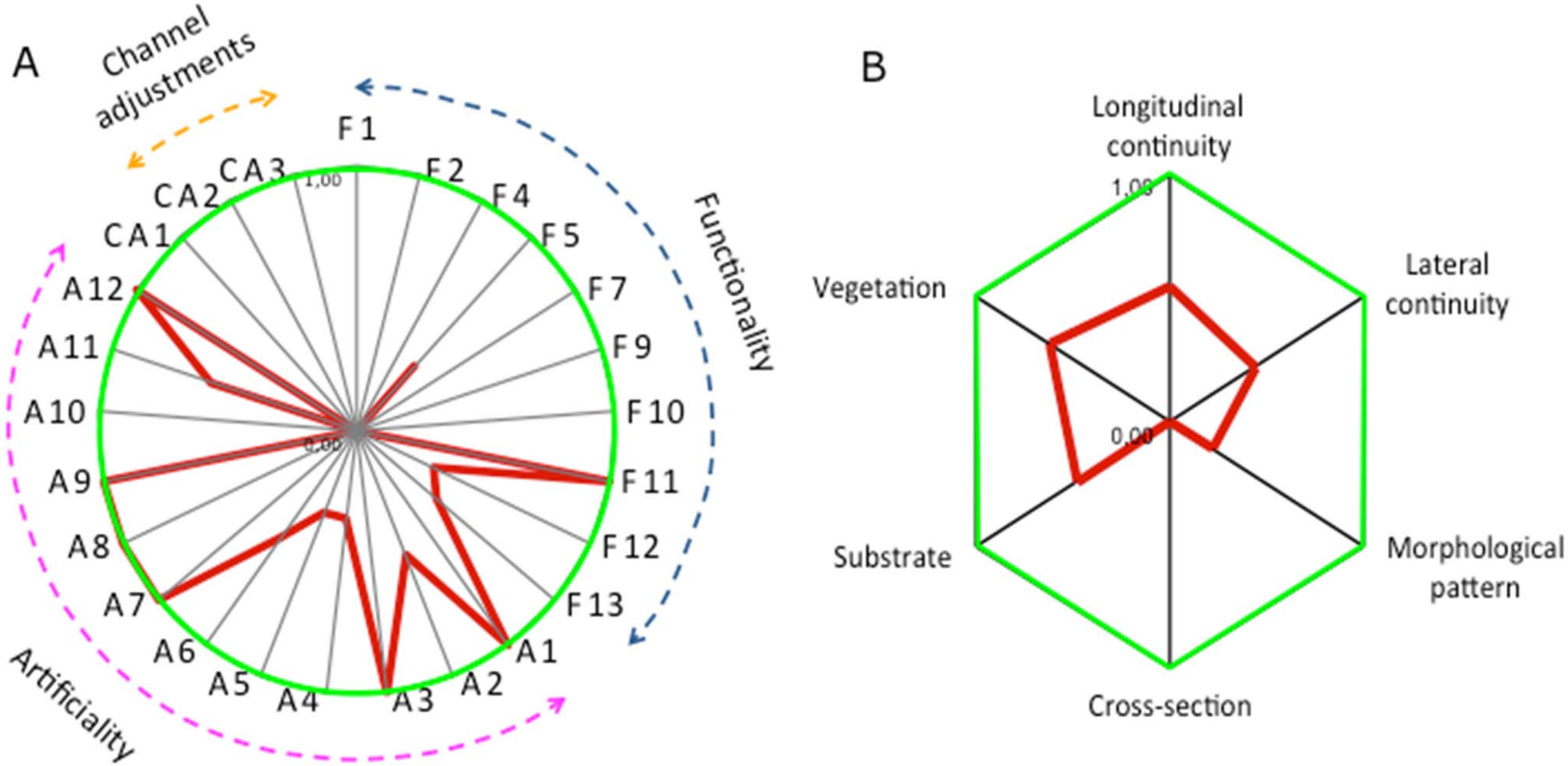
The Morphological Quality Index (MQI)

Geomorphological functionality

F2	**Presence of a modern floodplain**
A	Presence of a continuous (>66% of the reach) and wide modern floodplain
B1	Presence of a discontinuous (10÷66%) but wide modern floodplain or >66% but narrow
B2	Presence of a discontinuous (10÷66%) and narrow modern floodplain
C	Absence of a modern floodplain or negligible presence (≤10% of any width)

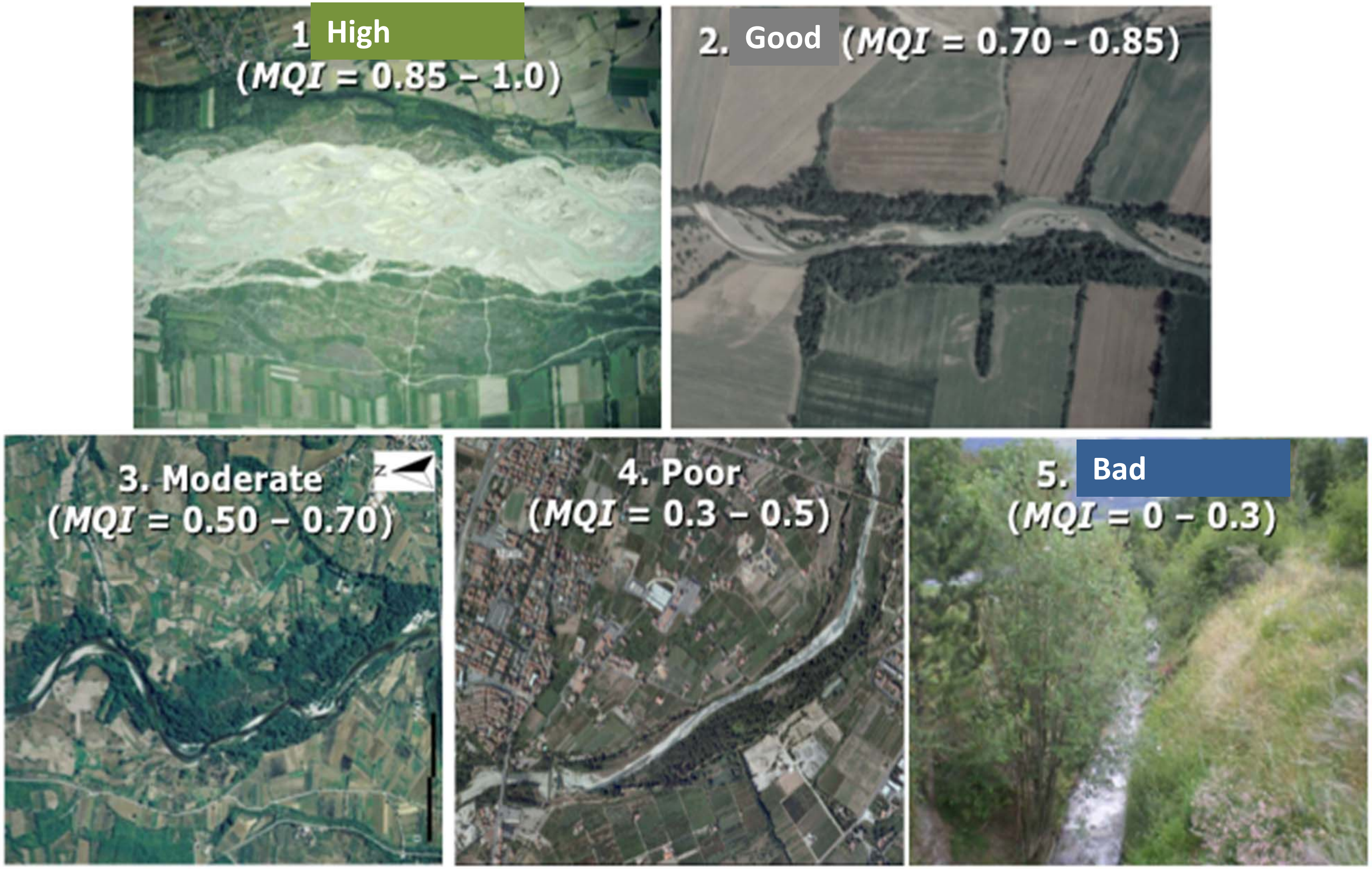
The Morphological Quality Index (MQI)

Synthesis and visualization of results

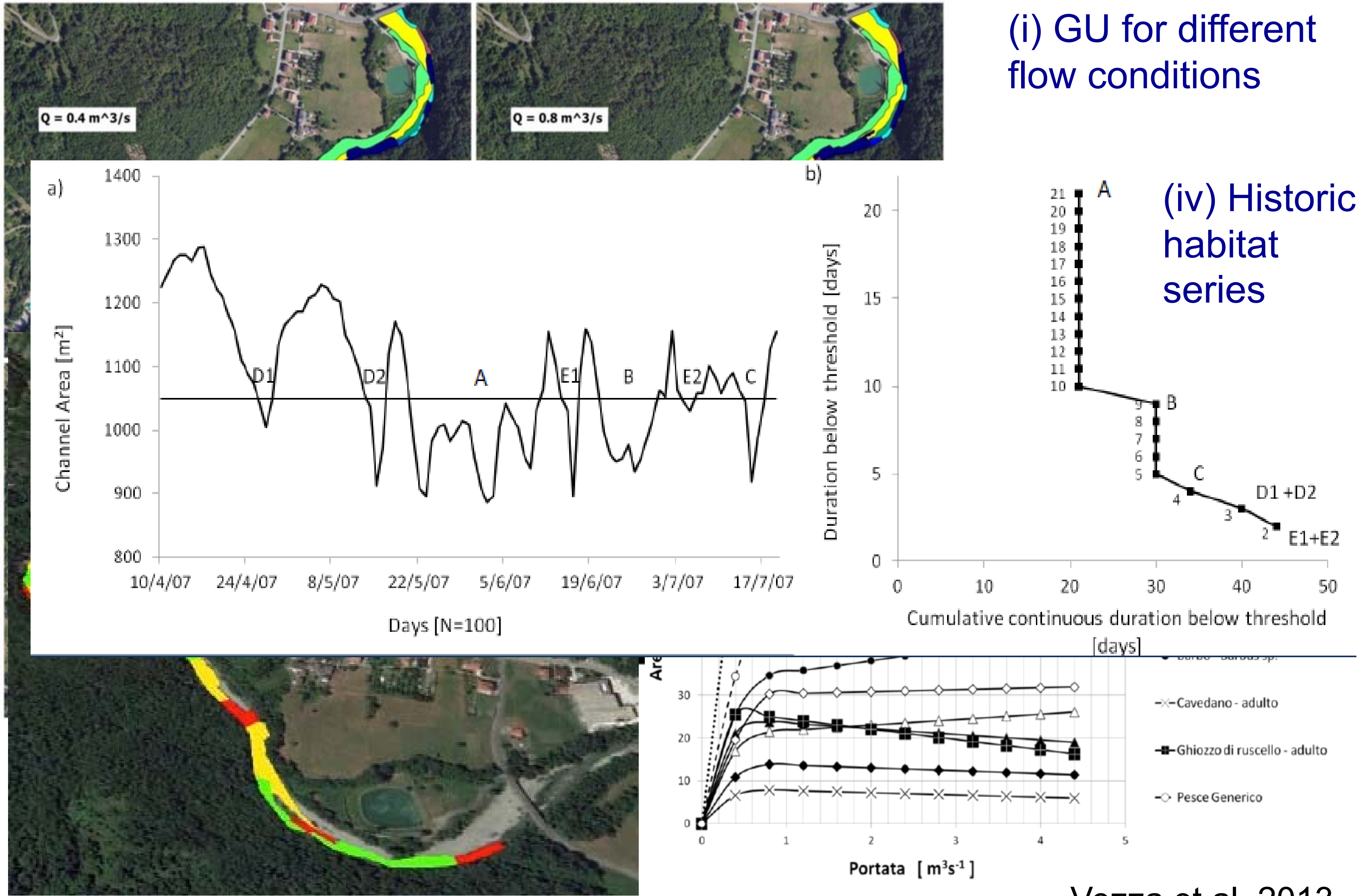


The Morphological Quality Index (MQI)

Scoring system



Hymo information for habitat integrity and e-flows evaluation



(i) GU for different flow conditions

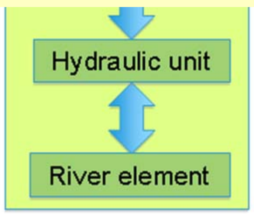
(iv) Historic habitat series

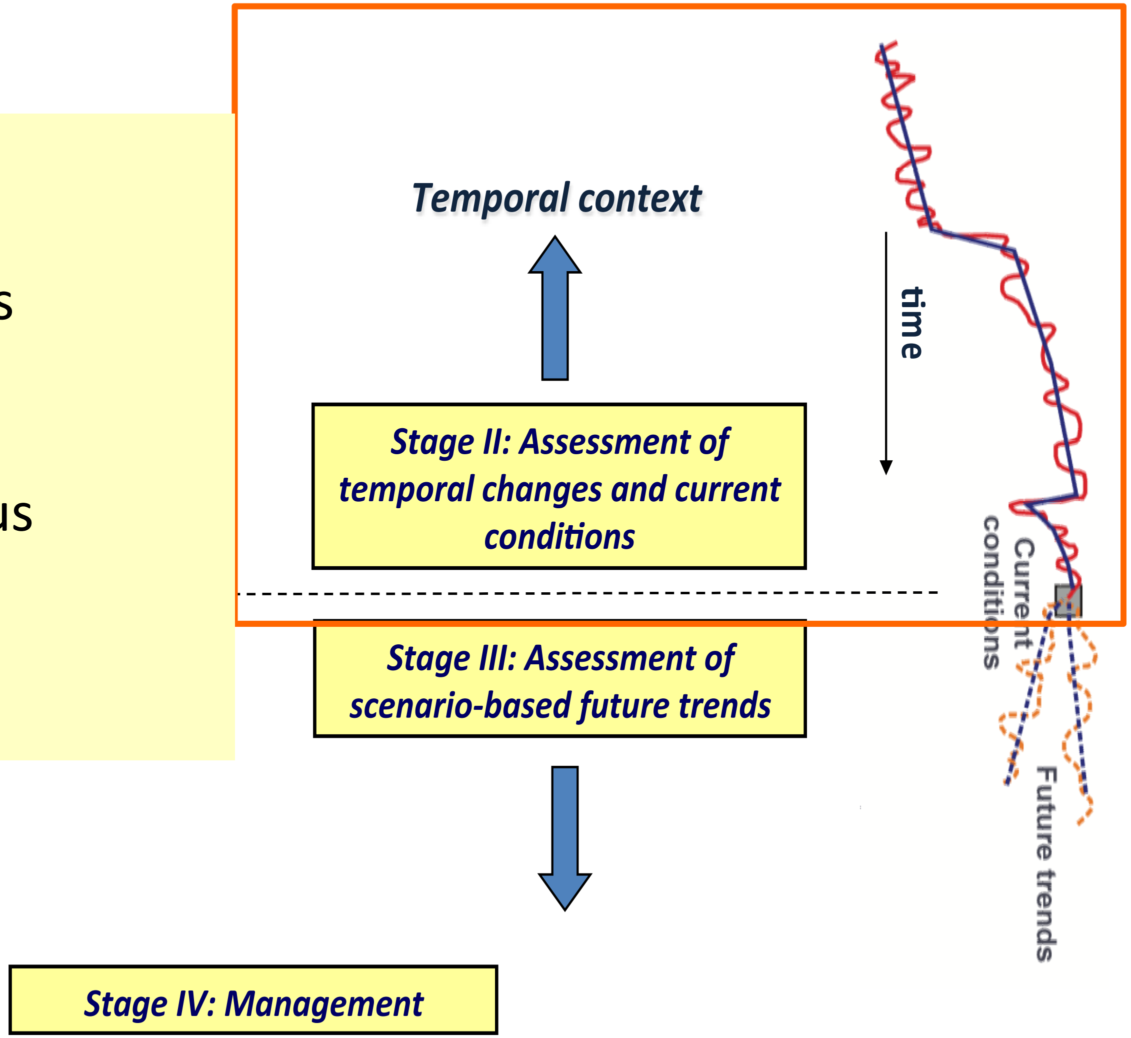
Vezza et al, 2013

Diagnosis of present conditions and evaluation of future scenarios require a multiscale hymo assessment framework.

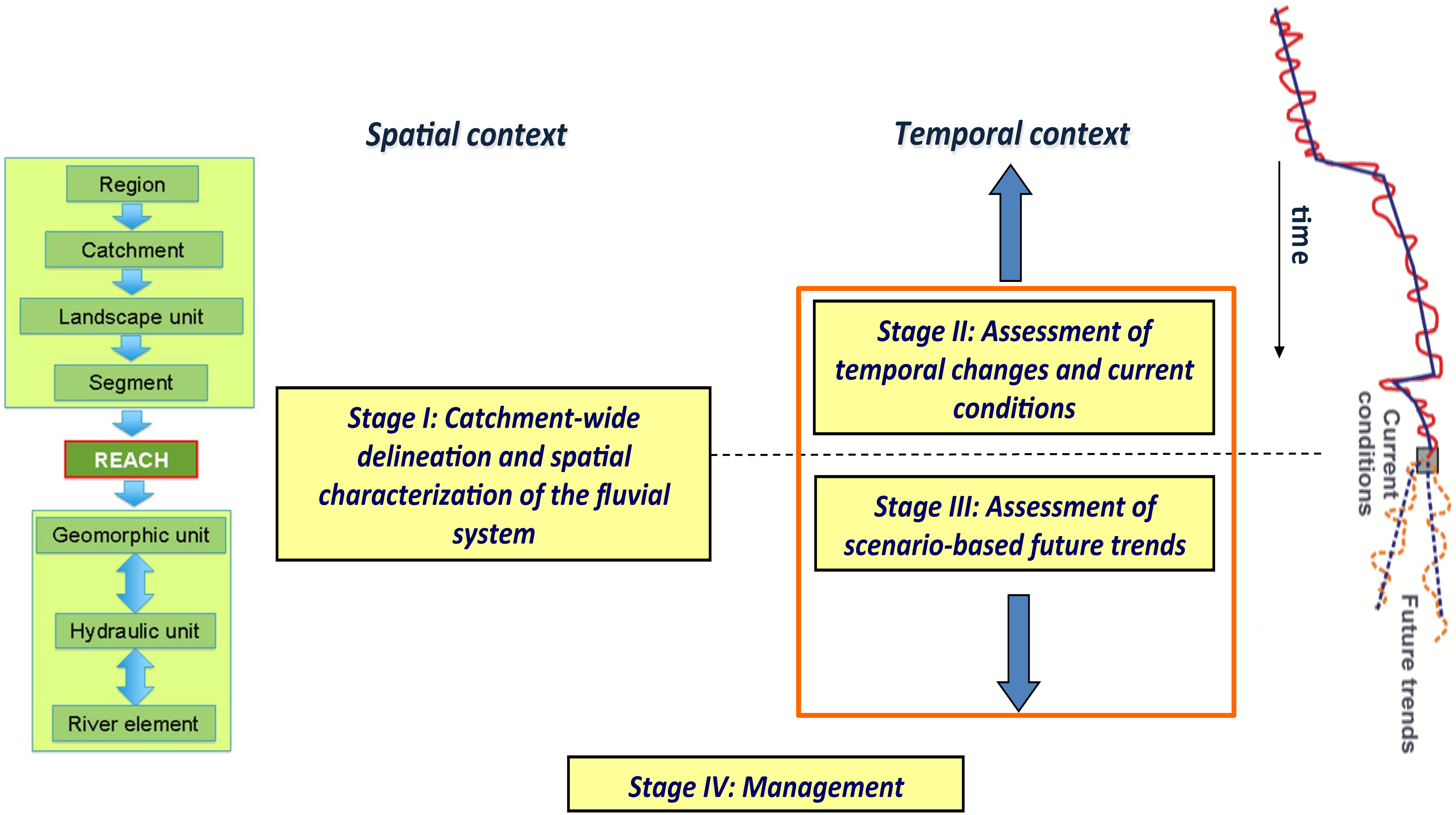
In WFD

- Pressure/Impacts analysis
- Assessment of hydromorphological status
- Identification of HMWB

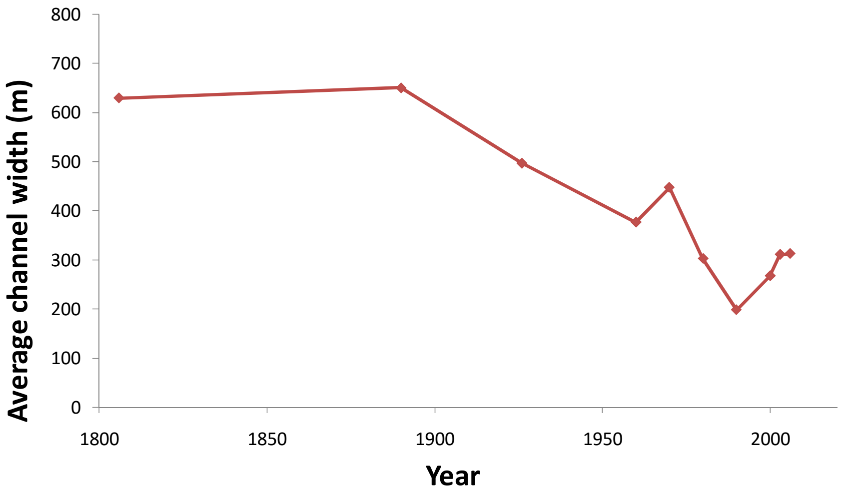


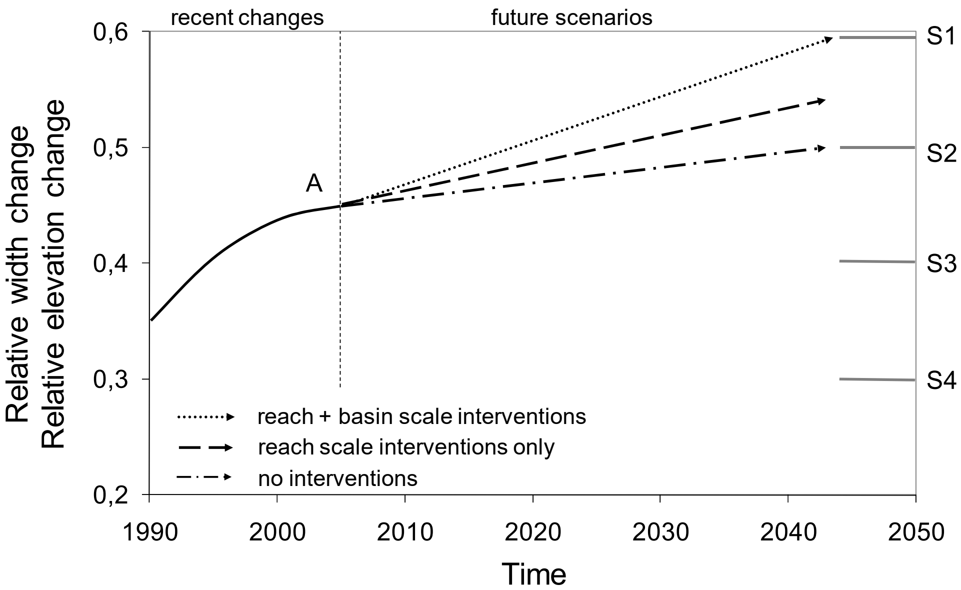


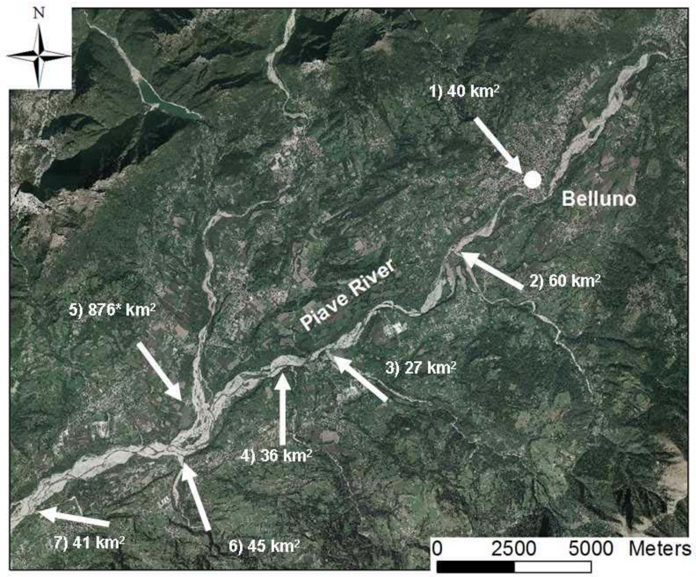
Diagnosis of present conditions and evaluation of future scenarios require a multiscale hymo assessment framework.



What if? Hymo info to evaluate future scenarios



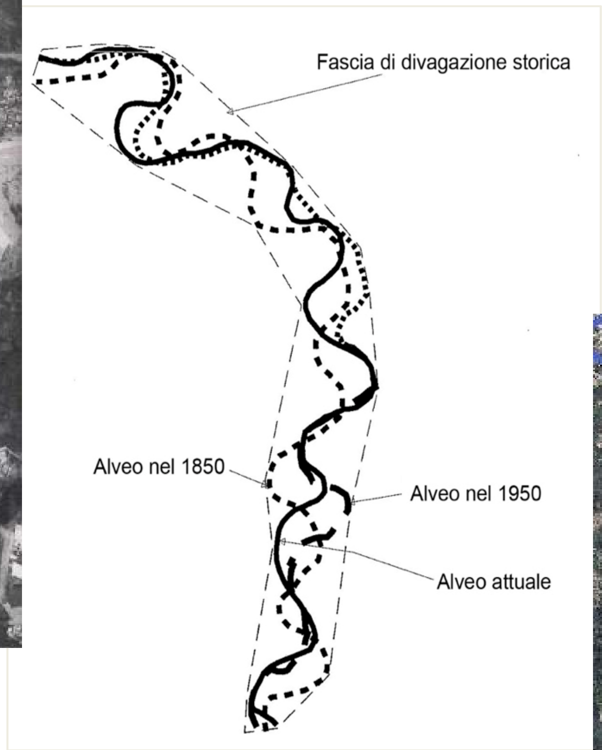




Piave river, upper reach. Surian, 2009

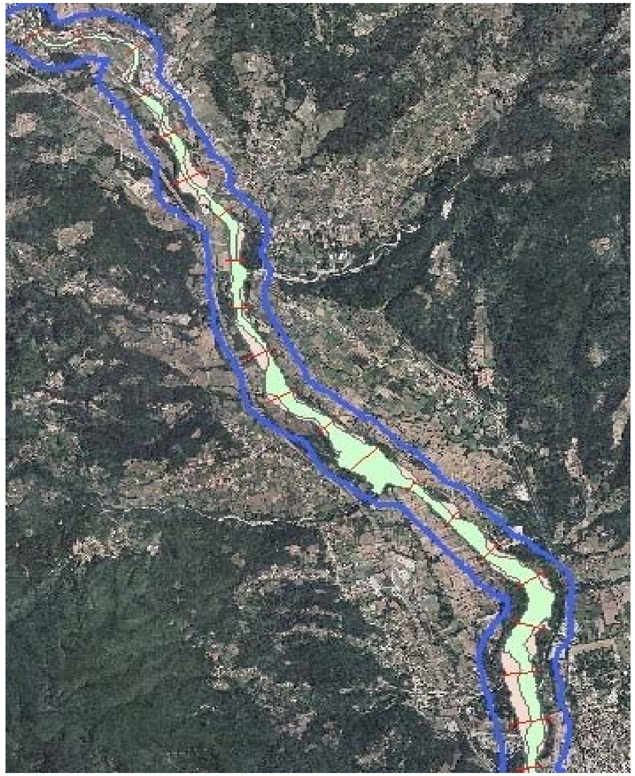
Hymo information to identify flood hazard areas

current

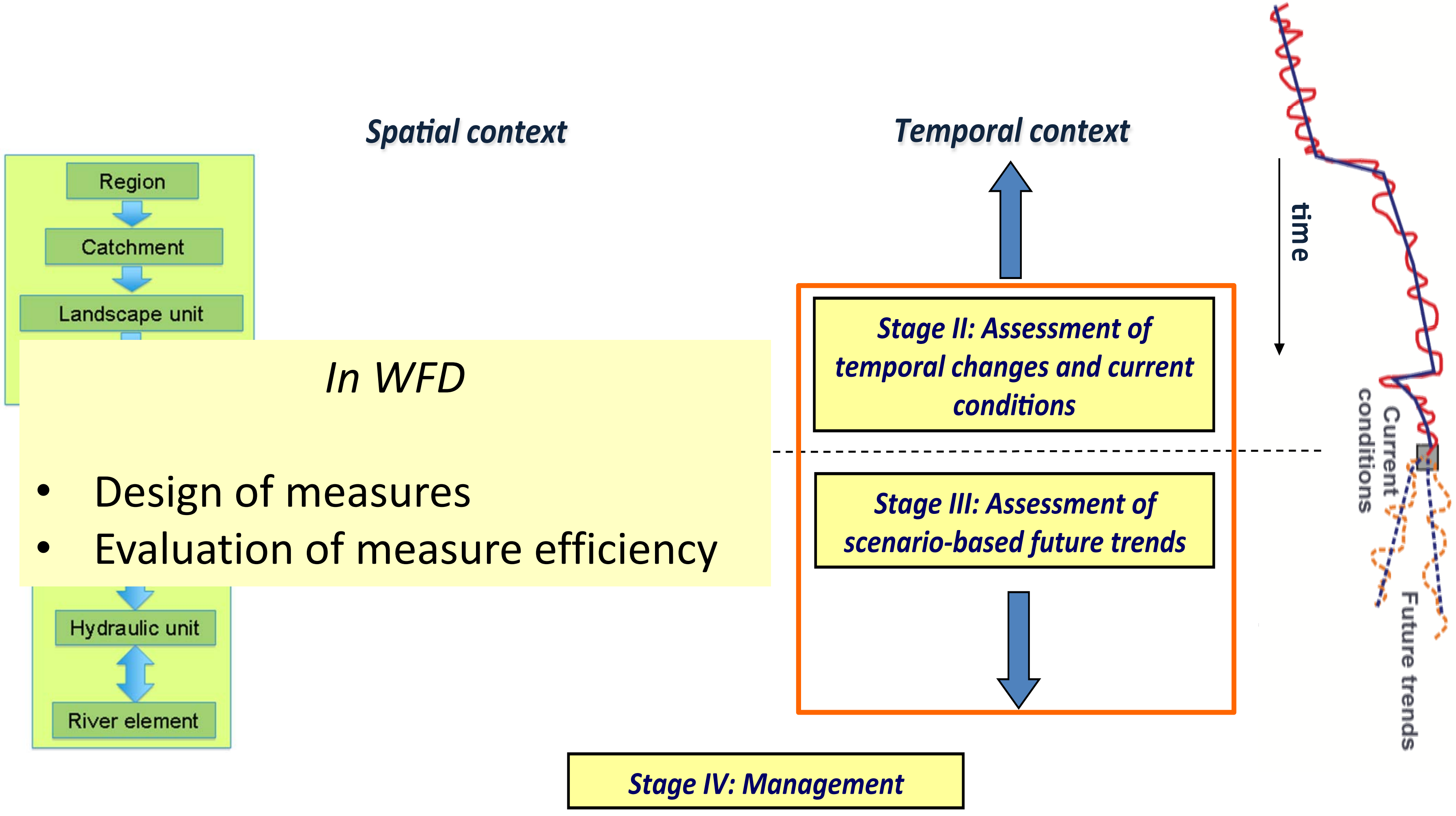


past

Future!



Diagnosis of present conditions and evaluation of future scenarios require a multiscale hymo assessment framework.



How can we use hymo info for WFD and HP,….

We need a common approach envisaging characterization, assessment of current conditions and future scenarios.

These approaches already exist!

(e.g. River Styles, MQI, IDRAIM)

Such methods drive us to know what to monitor at the different scales both for characterization and assessment:

- Spatial scales of segmentation
- Type specific indicators
- Historical analysis

The data needs for these methods can be satisfied by a combined use "traditional" data and remote sensed information.

RS gives opportunity on HOW to monitor in a more cost-effective way

Thank you

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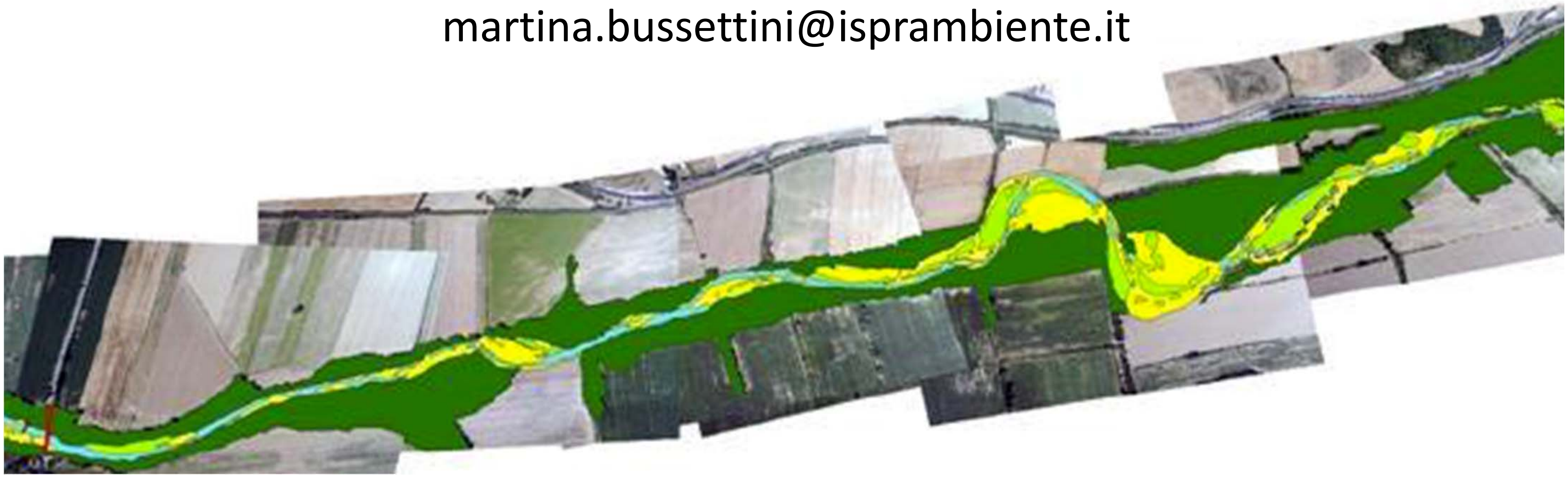
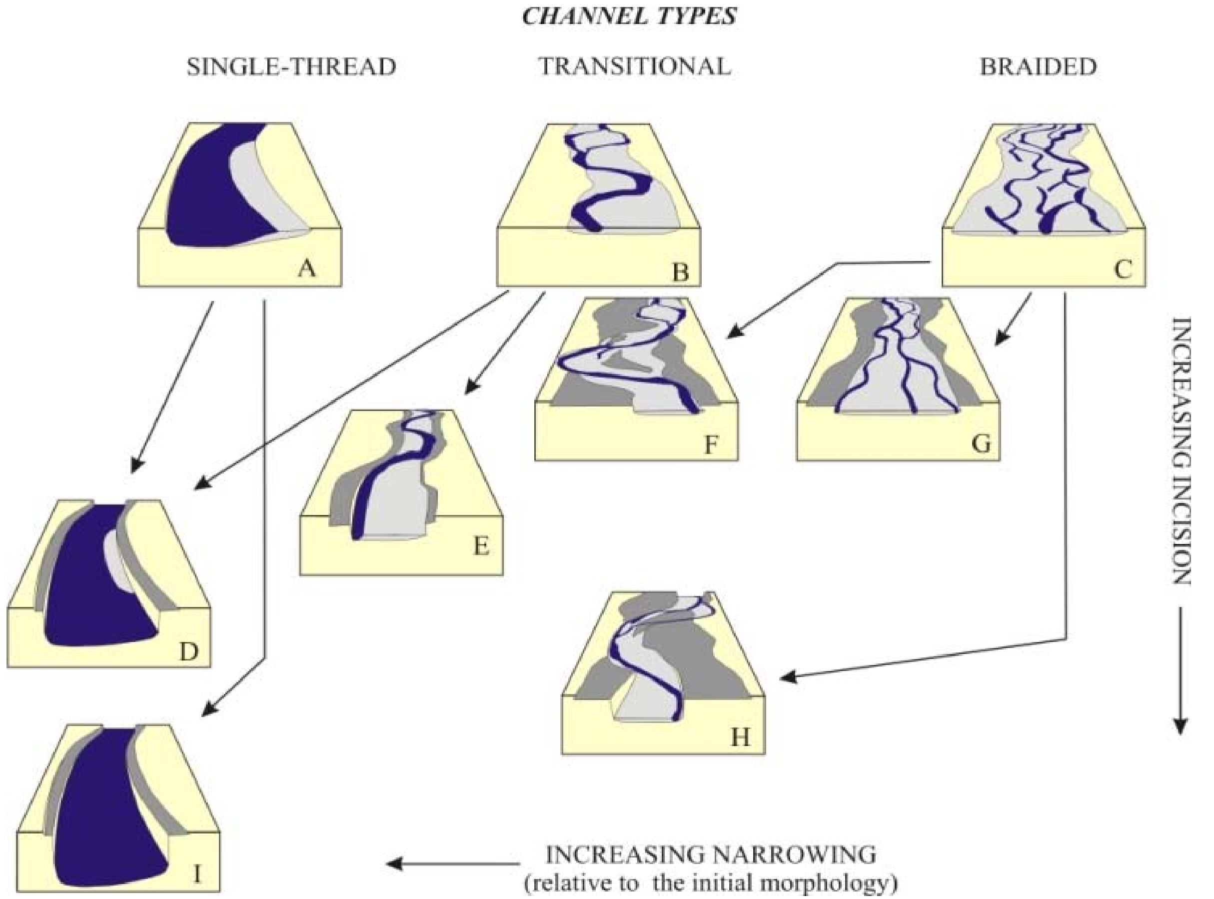


Past and recent evolution of Italian rivers

Past and recent evolution of river systems can be explained by conceptual models developed by quantitative geomorphological analysis.



Surian e Rinaldi, 2003

WFD hymo assessment

It must analyze the relationship between processes and related features

Are the features we observe consistent with the typical character and behaviour of that type?