ETH zürich

BASEveg:
a tool for Eco-morphodynamic Modelling

VAW (Laboratory of Hydraulics, Hydrology and Glaciology), ETH Zürich

BASEMENT User Meeting 2018

Francesco Caponi, PhD student

FNSNF

VAW Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie

BASEMENT

OUTLINE

1. Vegetation evolution on the Alpine Rhine river
2. The need of *Eco-morphodynamic Modelling*
3. BASEveg
   a) Modelling framework
   b) Alternate bars dynamics
4. Conclusion and Implications

Vegetation evolution on the Alpine Rhine river

First evidences

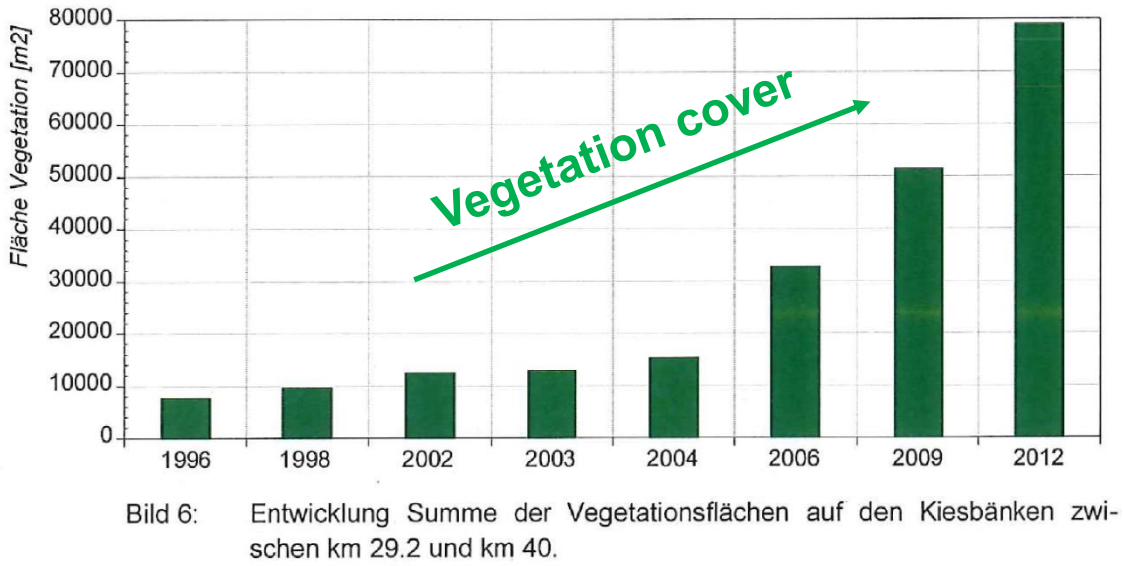
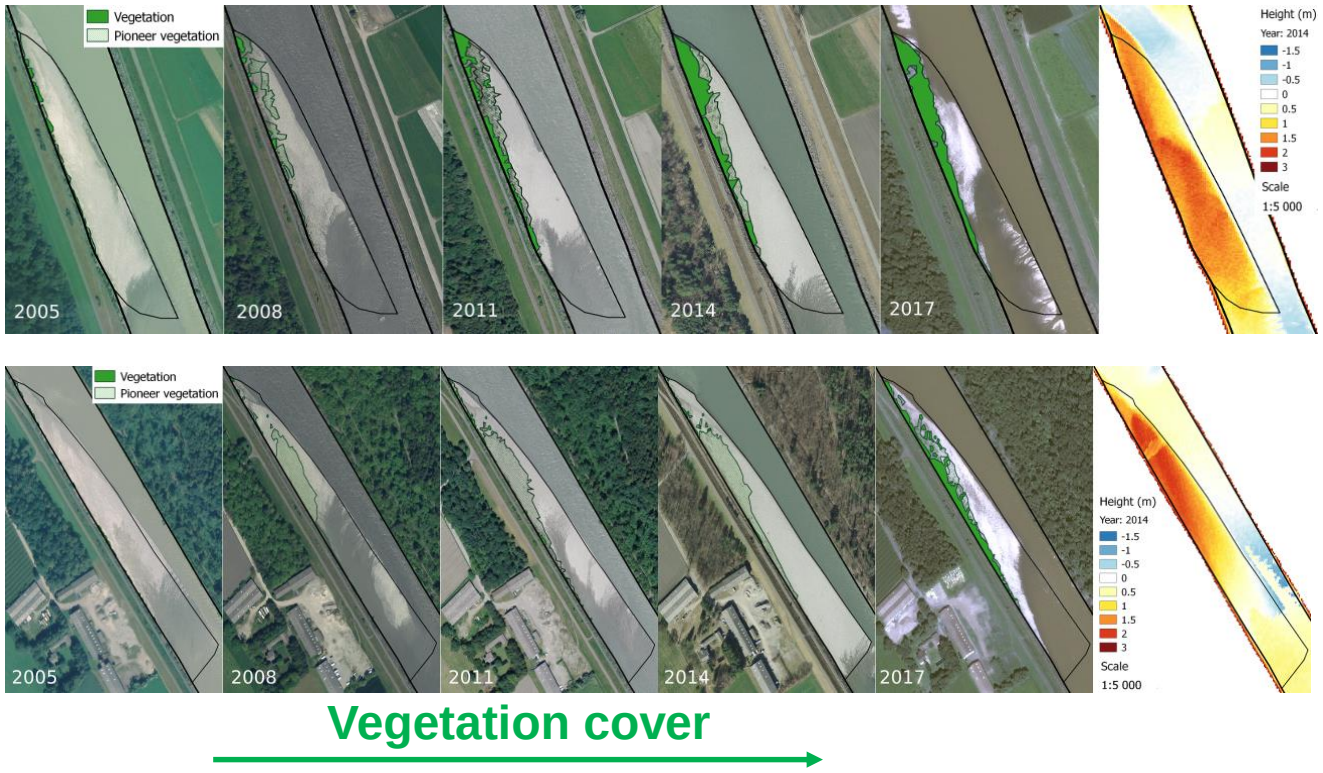


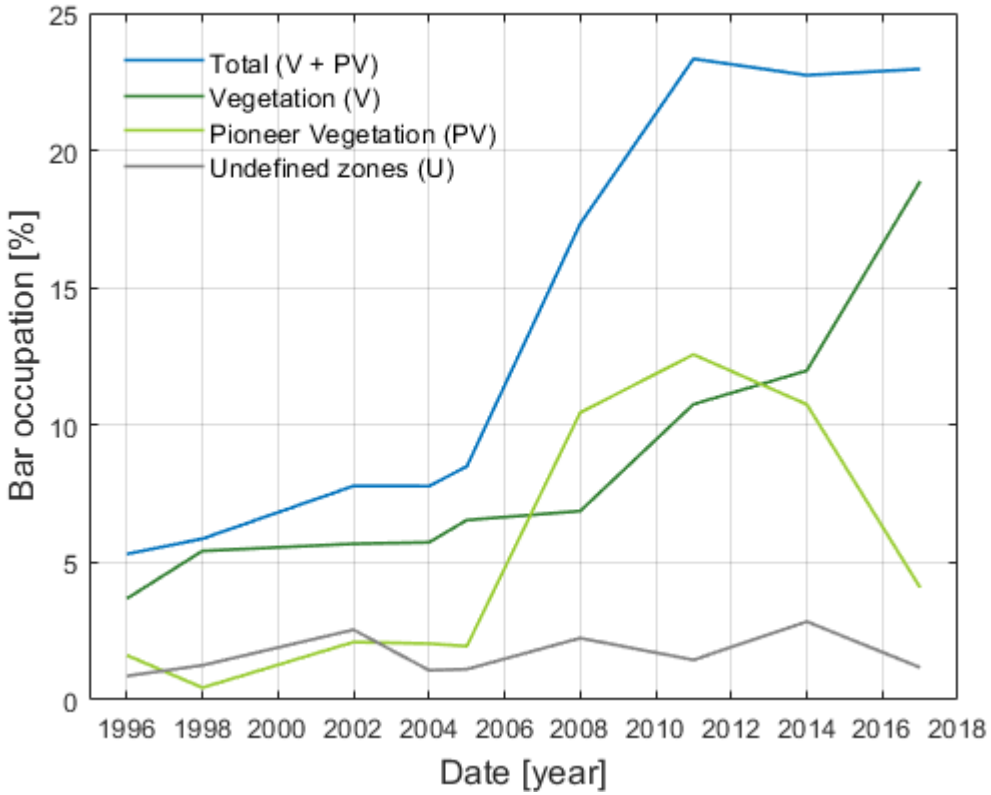
Bild 6: Entwicklung Summe der Vegetationsflächen auf den Kiesbänken zwischen km 29.2 und km 40.

From *«Einfluss von Vegetation auf Kiesbänken auf den Hochwasserspiegel im Alpenrhein», Hunziker, Zarn & Partner*

Vegetation evolution on the Alpine Rhine river

Ongoing research



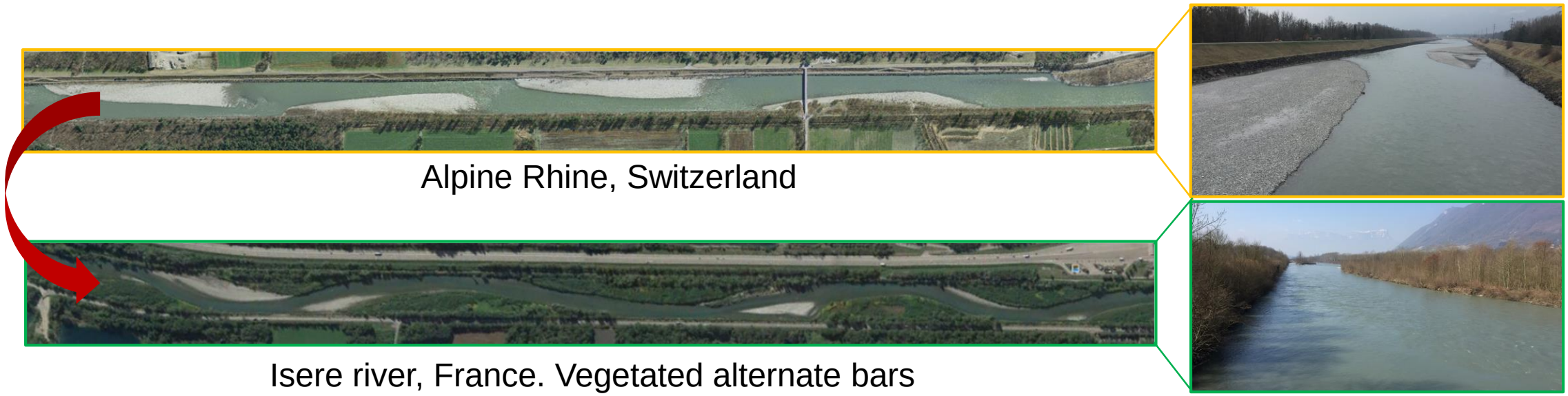


From *'Vegetation pattern evolution on the alternate bars in the Alpine Rhine River: Image analysis and numerical modelling', Master Thesis by Aurelie Koch, ETH*

The need of *Eco-morphodynamics*

an emerging discipline that aims at studying the co-evolution of vegetation and river morphodynamics bridging physical and biological processes

- Are we moving towards a vegetated state in the Alpine Rhine?



Alpine Rhine, Switzerland

Isere river, France. Vegetated alternate bars

1.2 Modelling framework
BASEMENT

- **Hydrodynamics**
  - Depth-average equations for fluid flow
  - Finite volume discretization with Riemann solvers
  - Unstructured grid 2D
- **Sediment transport**
  - Suspended and/or bed load transport
  - Hirano-Exner model
  - Empirical closure relationships

Friction closure relationship:

Manning-Strickler approach

Single grain:
Exner model

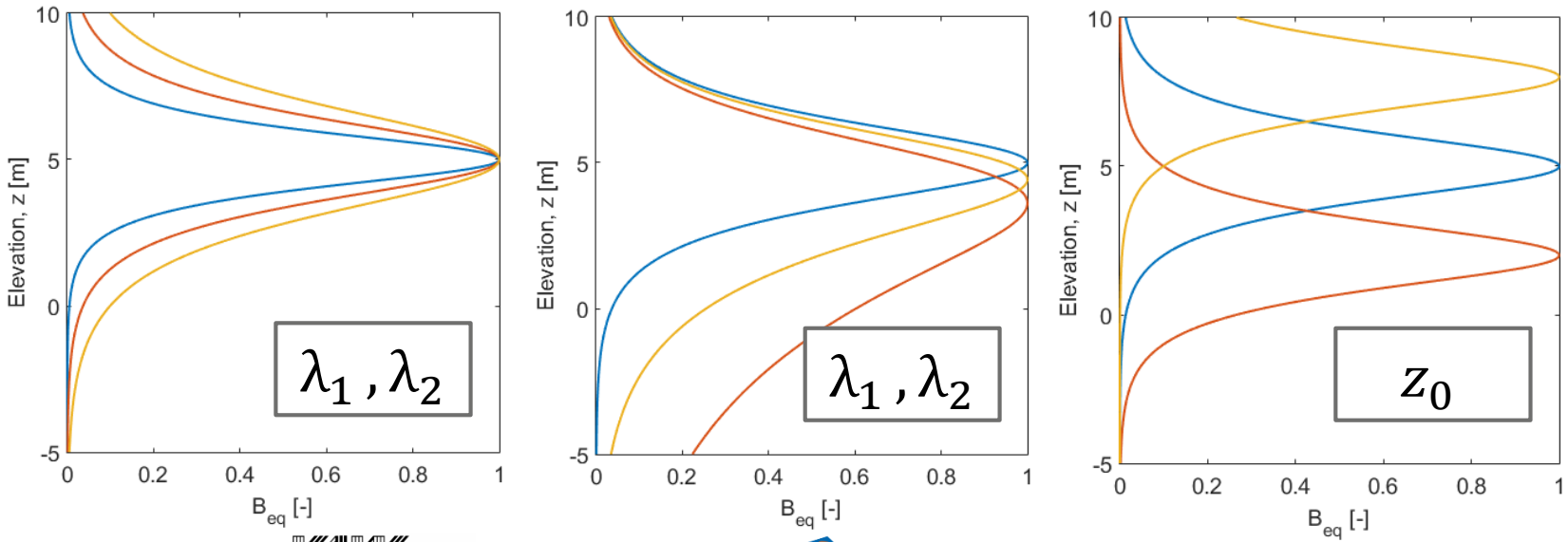
Bed load transport:
MPM-formula

1.2 Modelling framework

Vegetation distribution on elevation gradient

- The vegetation is described by a dimensionless biomass, B, with respect to a reference dimension value, B_{eq}

$$B_{eq}(z) = \frac{\varphi}{\exp[\lambda_1(z - z_0)] + \exp[-\lambda_2(z - z_0)]}$$

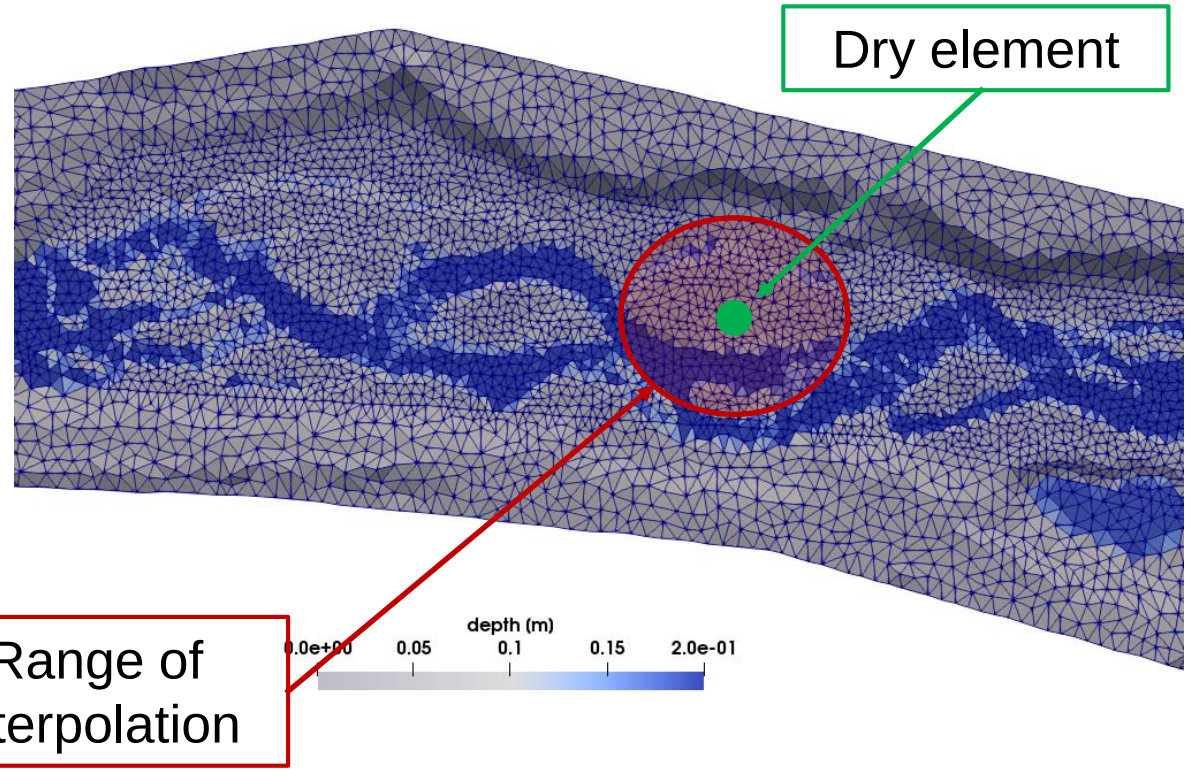


(*Riparia*, 2005)

1.2 Modelling framework

Groundwater modelling

- Elevation of groundwater level (z_0) directly link to water surface elevation
- Elevation of groundwater level (z_0) on dry elements defined by the Inverse Distance Weighted algorithm (IDW)
- Important for complex morphologies (i.e. wandering/braided)

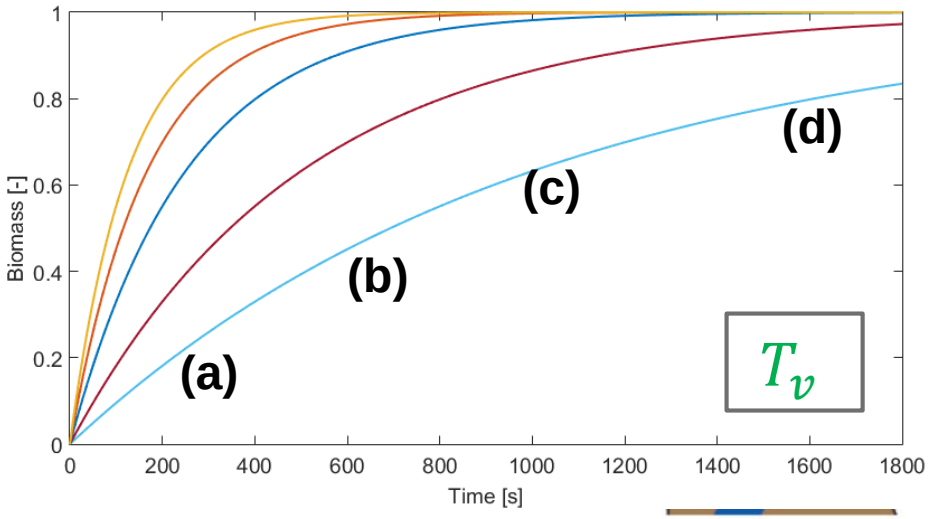


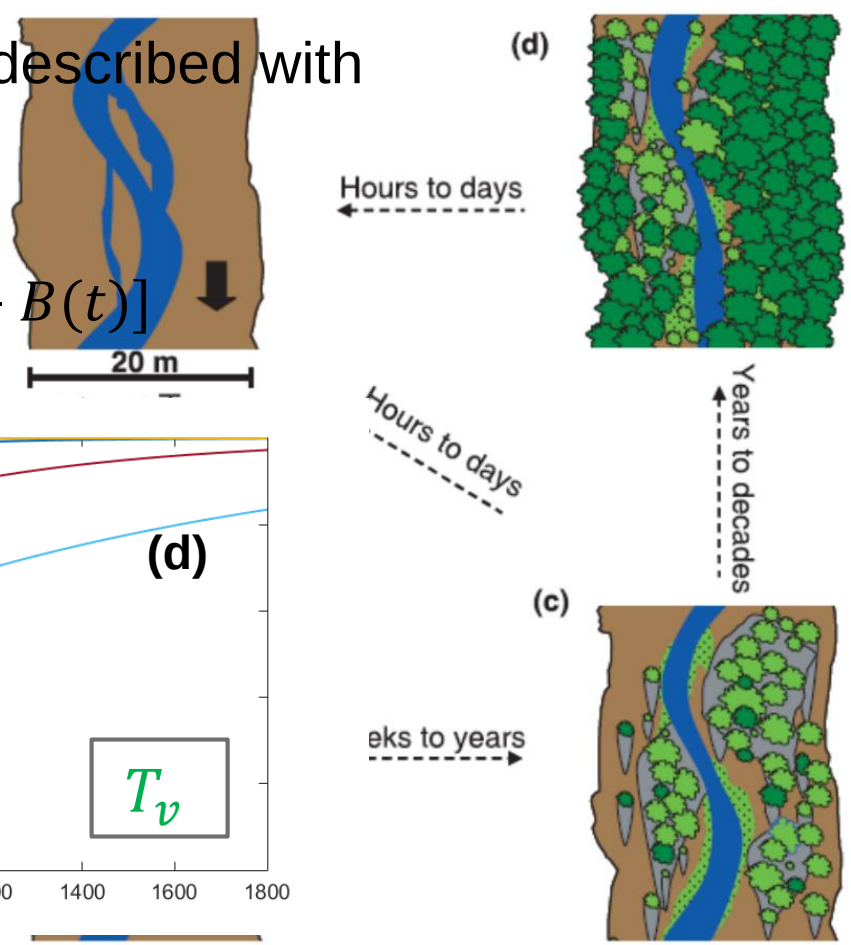
1.2 Modelling framework

Vegetation dynamics

- Vegetation dynamics is described with an exponential function:

$$\frac{dB}{dt} = \frac{3}{T_v}[B_{eq}(z) - B(t)]$$





(Corenblit *et al.*, 2009)

1.2 Modelling framework

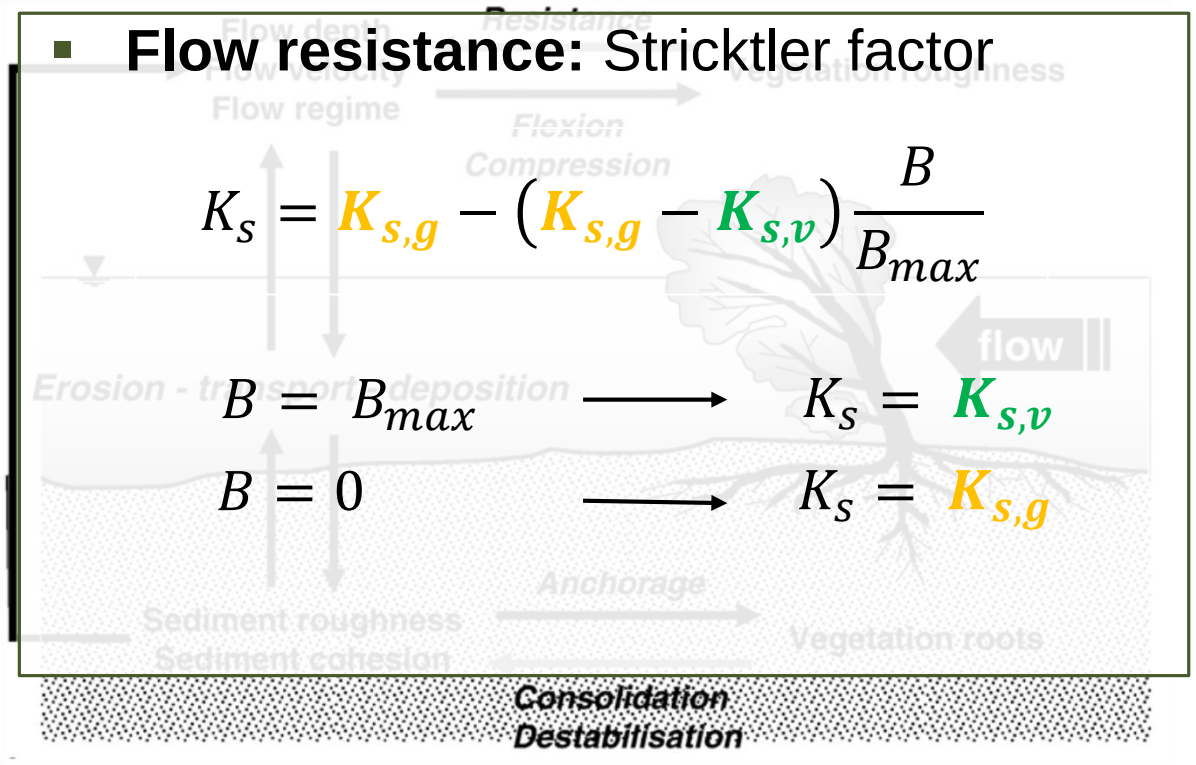
Eco-morphodynamics

- **Flow resistance:** Stricktler factor

$$K_s = K_{s,g} - \left(K_{s,g} - K_{s,v}\right)\frac{B}{B_{max}}$$

$$B = B_{max} \longrightarrow K_s = K_{s,v}$$

$$B = 0 \longrightarrow K_s = K_{s,g}$$



(Corenblit, 2007)

1. **Bottom shear stress** is evaluated as:

$$\tau = \frac{\gamma\, \boldsymbol{u}\, |\boldsymbol{u}|}{K_s^2 h^{1/3}}$$

2. The bed load transport is a function of the **Shields parameter** as:

$$\theta = \frac{\tau_g}{(\rho_s - \rho) g d_s}$$

➢ The MPM formula reads:

$$\boldsymbol{q}_s = \alpha\,(\theta - \theta_{cr})^{3/2}$$

1.2 Modelling framework

Eco-morphodynamics

- **Sediment transport:** shear stress partition

$$\tau = \tau_g + \tau_v$$

  - τ: total shear stress
  - τ_g: exerted on grain
  - τ_v: exerted on vegetation

$$\tau_g = \frac{\gamma \boldsymbol{u} |\boldsymbol{u}|}{K_{s,g}^2 h^{1/3}}$$

- **Soil coehsion:** critical Shields factor

$$\theta_{cr} = \theta_{cr,g} - \left(\theta_{cr,g} - \boldsymbol{\theta_{cr,v}}\right) \frac{B}{B_{max}}$$

(Corenblit, 2007)

1. **Bottom shear stress** is evaluated as:

$$\tau = \frac{\gamma \boldsymbol{u} |\boldsymbol{u}|}{K_s^2 h^{1/3}}$$

2. The bed load transport is a function of the **Shields parameter** as:

$$\theta = \frac{\tau_g}{(\rho_s - \rho) g d_s}$$

➢ The MPM formula reads:

$$\boldsymbol{q_s} = \alpha \, (\theta - \boldsymbol{\theta_{cr}})^{\beta}$$

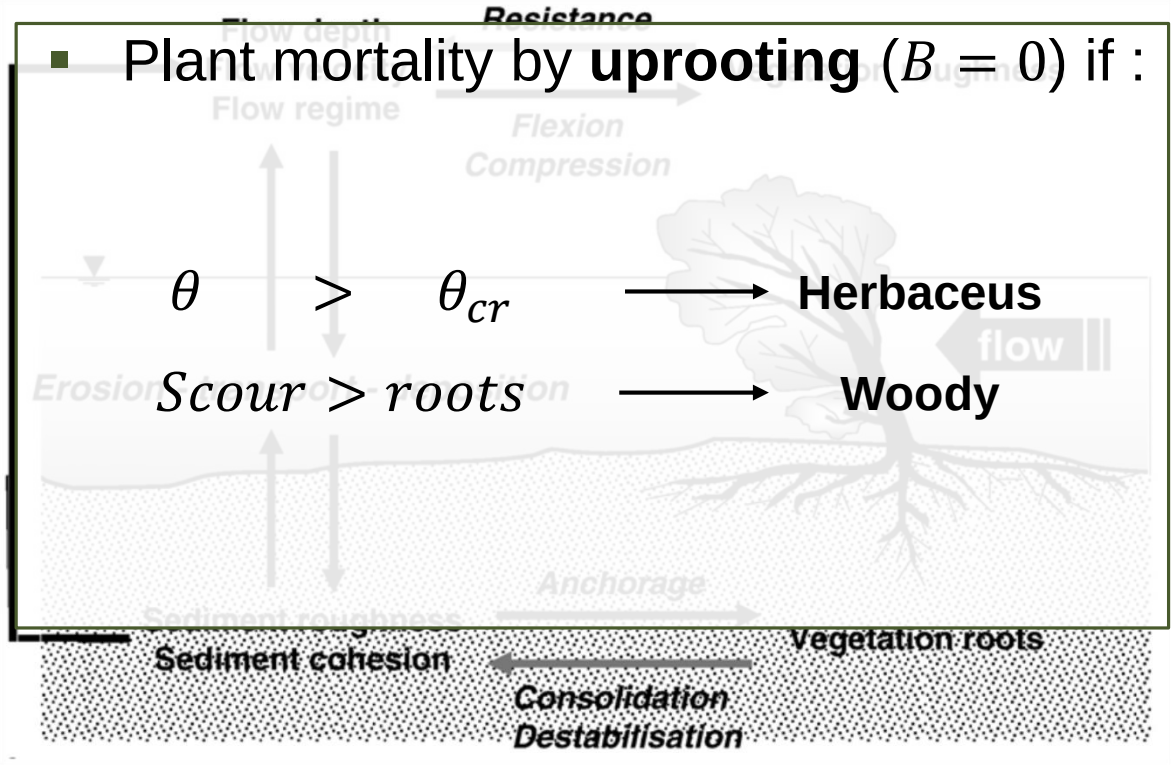
1.2 Modelling framework

Eco-morphodynamics

- Plant mortality by **uprooting** ($B = 0$) if :

$$\theta > \theta_{cr} \longrightarrow \textbf{Herbaceus}$$

$$Scour > roots \longrightarrow \textbf{Woody}$$



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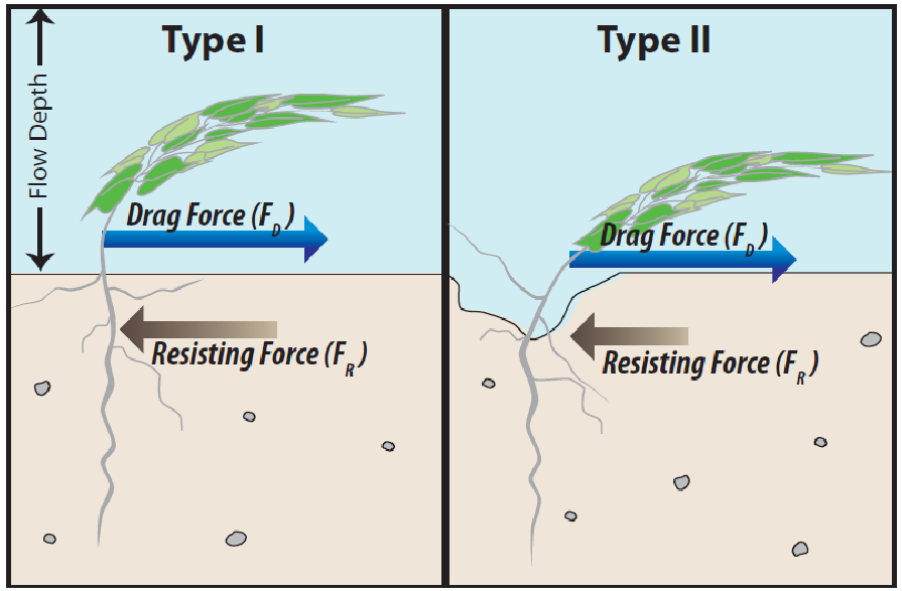


nction of

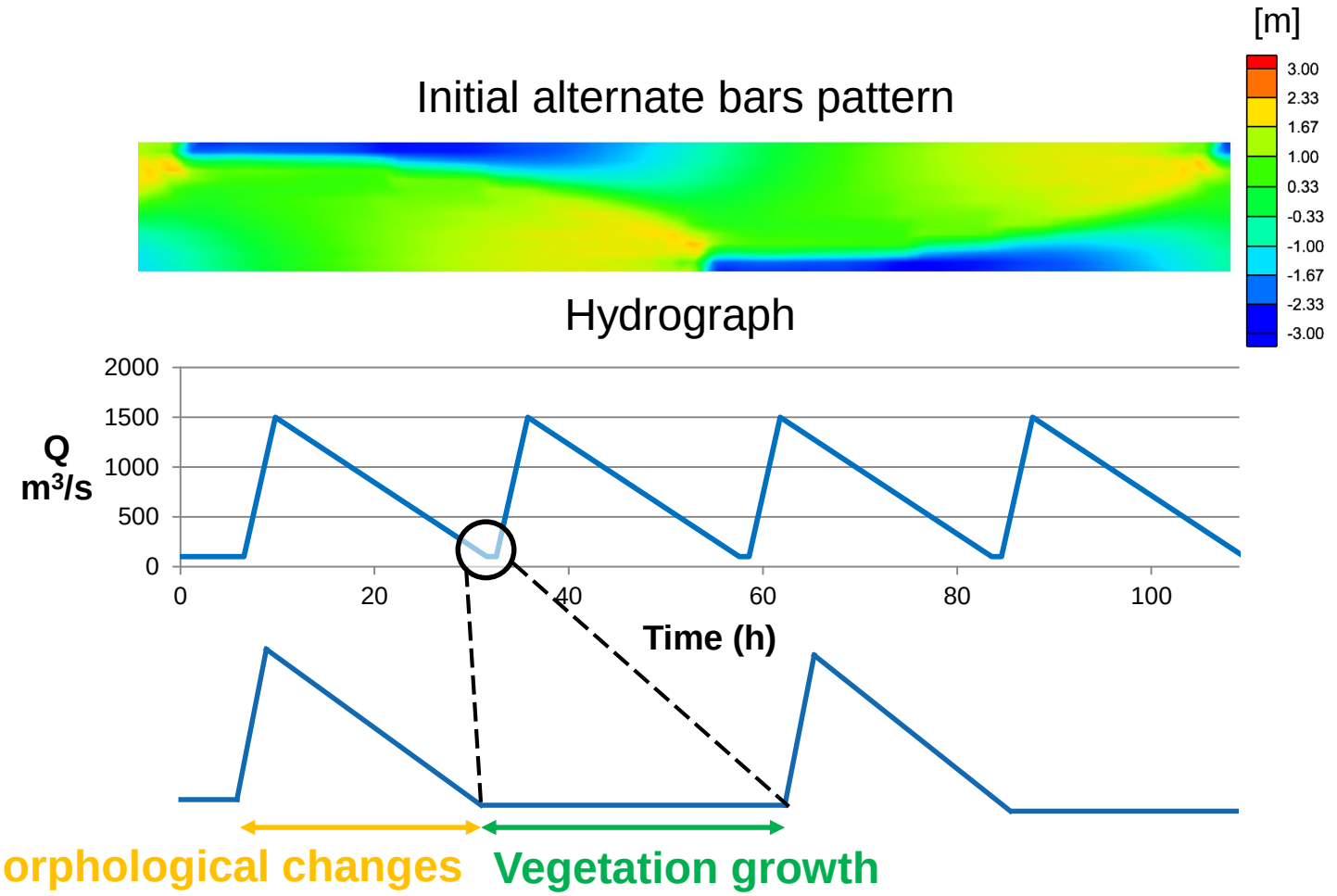
➢ The MPM formula reads:

$$q_s = \alpha \left(\theta - \theta_{cr}\right)^{3/2}$$

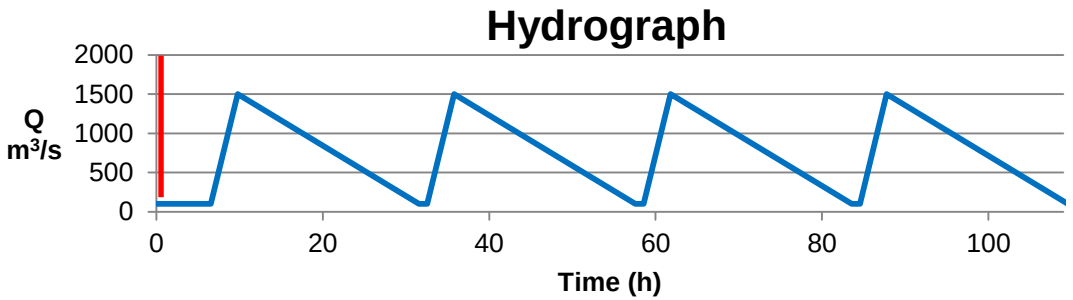
1.3 Alternate bars dynamics

- Straight channel: 20 km
- Width: 120 m
- Slope: 0.0038
- Uniform grain size: 38 mm

- *Peak discharge*
- *Flood frequency*
- *Vegetation types*

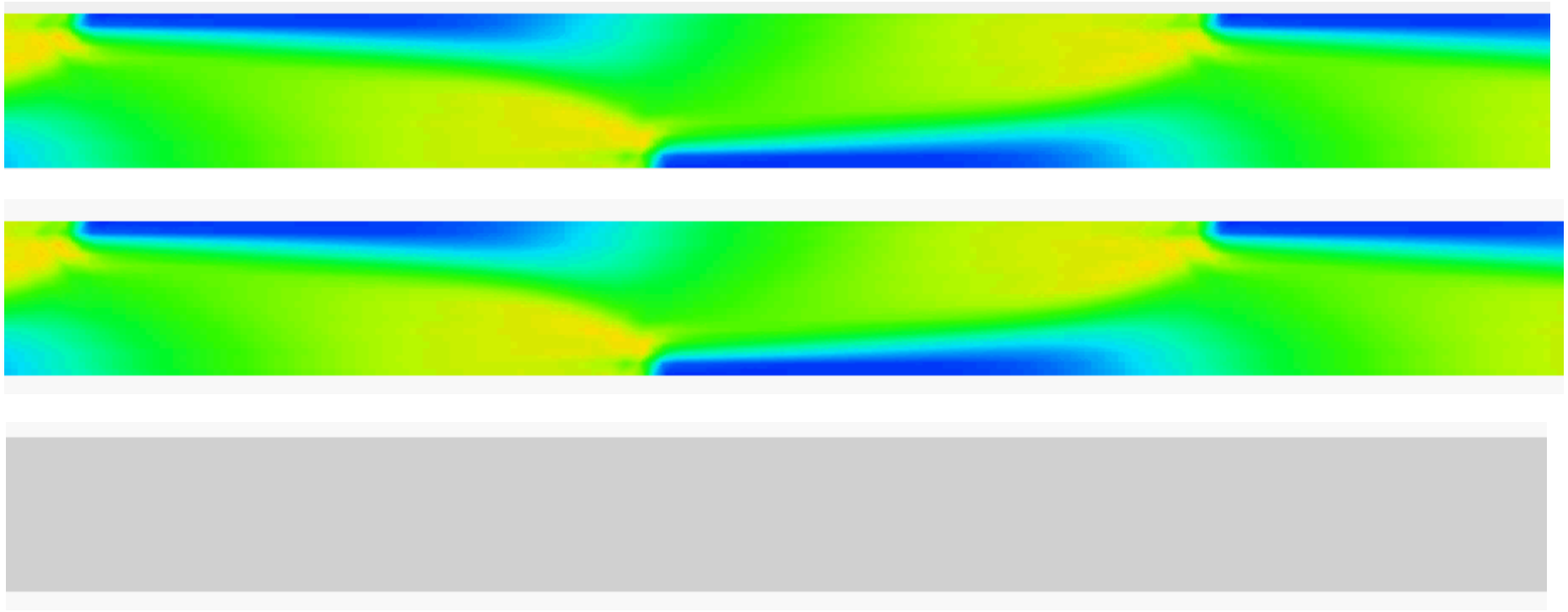


1.3 Alternate bars dynamics



NO! vegetation

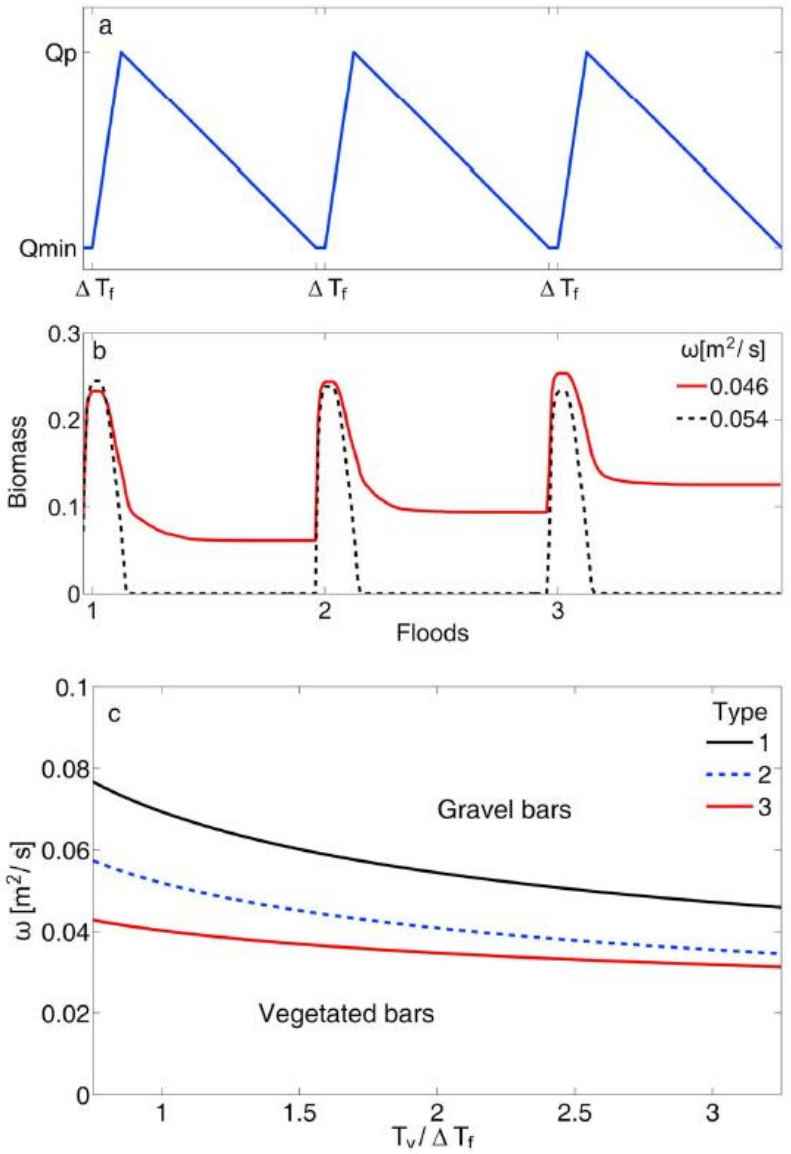
YES! vegetation



1.4 Main results
(Bertoldi, Siviglia, 2014,GRL)

- **Intensity** and **frequency** of floods are needed to avoid complete vegetation encroachment

- The **threshold-like** behavior depends on:
  - Vegetation type
  - Stream power
  - Flood frequency



Conclusion and Implications

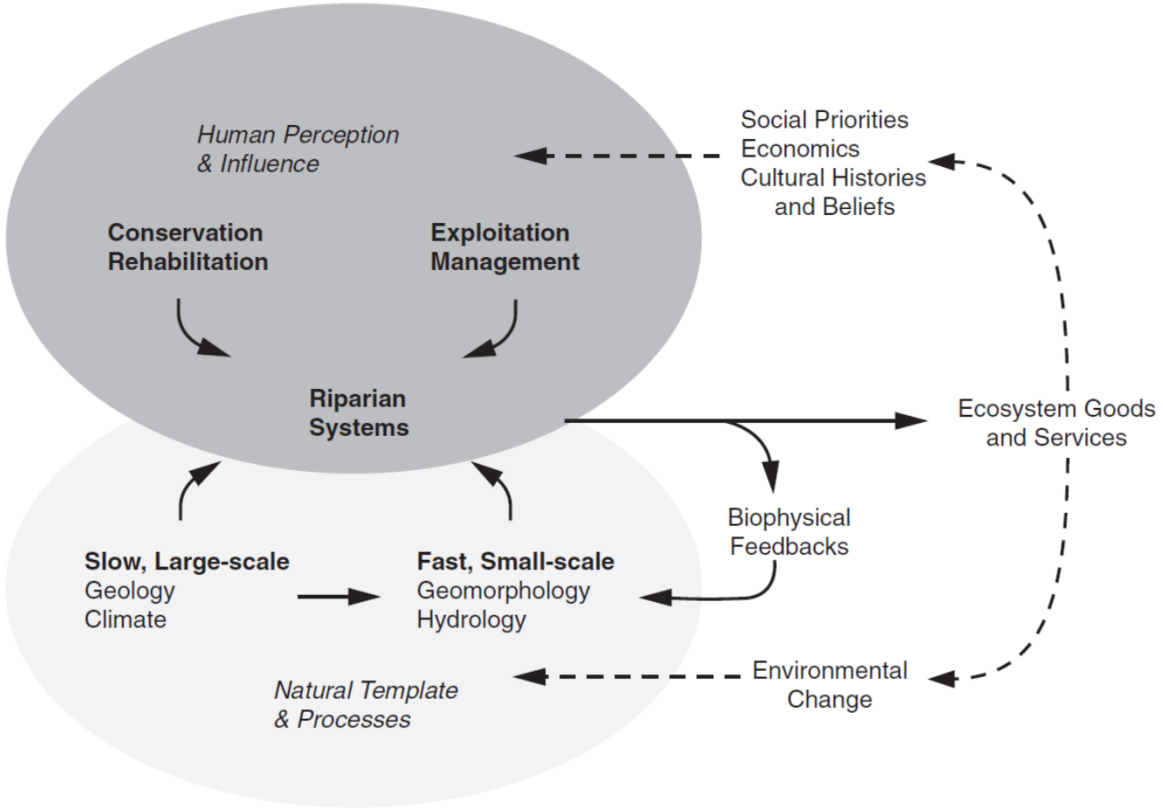
- The inclusion of a **simple model** for vegetation can reproduce the major effects of vegetation on river morphology;
- The model could help to design measures for restoration projects and to assess the effects of a changing environment on river morphodynamics;
- **Ecomorphodynamic modelling require interdisciplinary expertises.**

✓ *BASEveg will be available on the next release v2.8!*

Thank you

Riparian vegetation: a valuable problem
Isère river: clear cut

Riparian vegetation: a valuable problem



(*Riparia*, 2005)

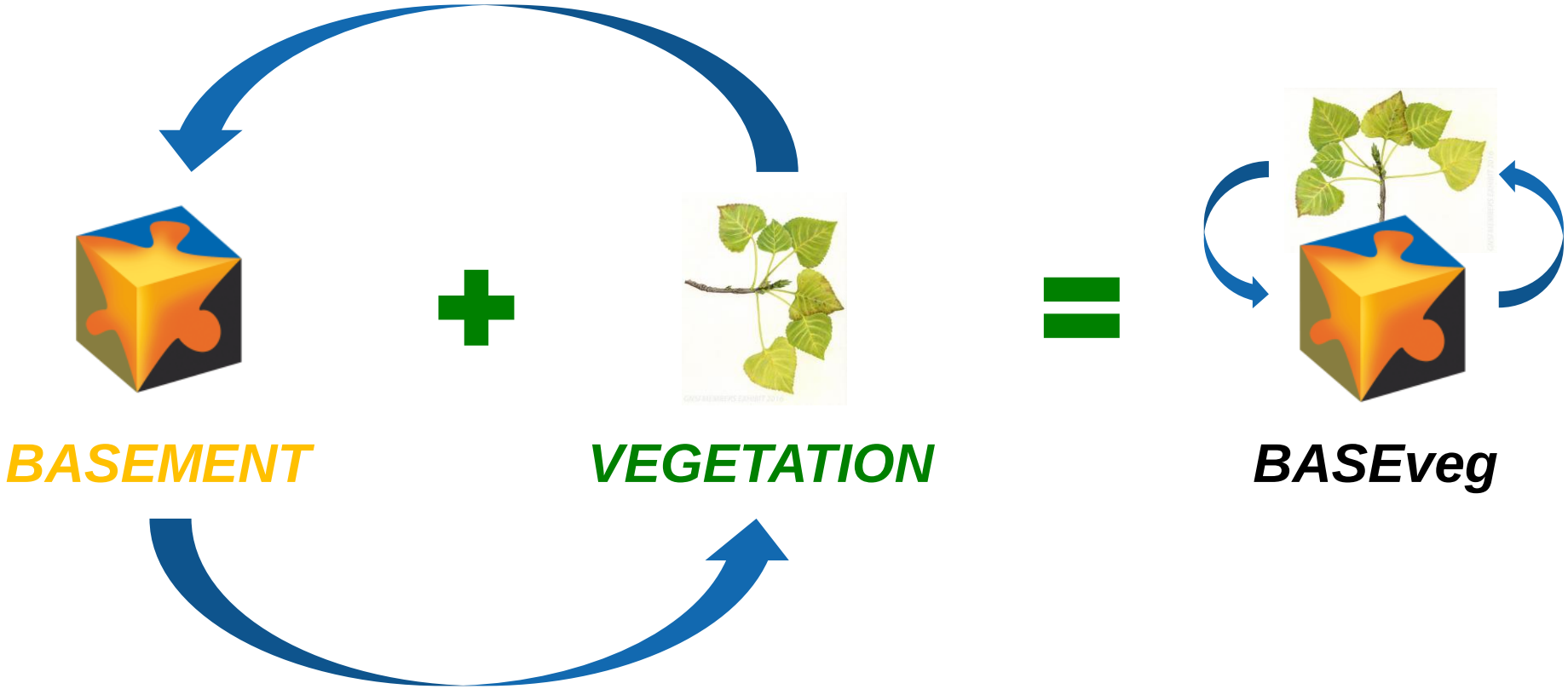
- A ***valuable***…
  - provides ecosystem services (e.g. chemical filter, physical habitat creation)
  - cultural and social benefit
- …***problem***:
  - Flood risk
  - Structures stability (floating woody debris)

Which is the solution for river managers?

1.1 Research questions

- Can we predict the **interplay** between vegetation dynamics and river morphology?

- Is it possible to determine a **threshold behavior** in river system from vegetated state to bare soil configuration?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