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Influence of plant traits on biogeomorphic patterns of gravel bed rivers

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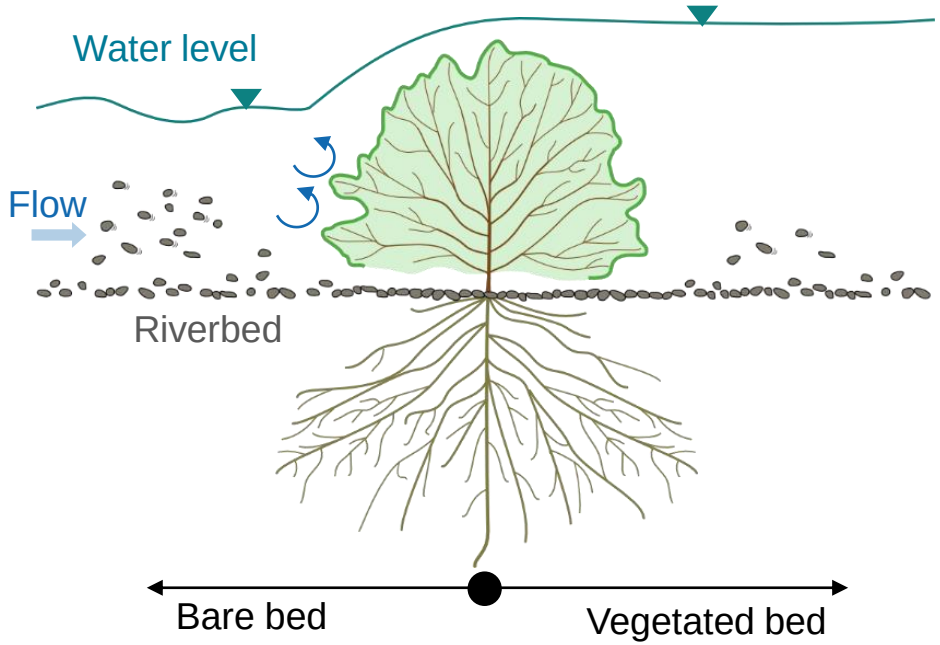
BASEMENT

Feedbacks between vegetation and hydromorphological processes



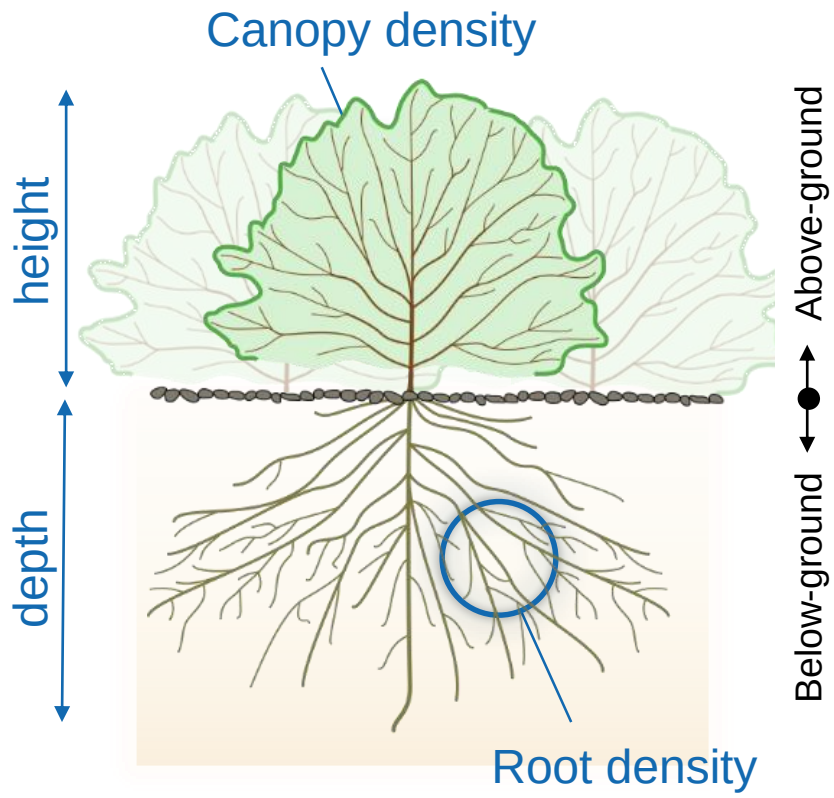
Vegetation influences flow and sediment transport when inundated.

Hydromorphological processes determine disturbances and environmental stresses, but also provide resources for plant growth.

- Plants increase flow resistance and reduce sediment transport, promoting landform construction

- Floods cause mortality by **uprooting and burial**
- Low discharges provide water for plant growth

Plant traits that influence biogeomorphic feedbacks



What are the plant traits that most influence feedbacks?

Canopy density and stem biomechanics;
Plant height;

- Dense and stiff canopy increases **flow resistance**
- Tall trees are resistant to **sediment burial**

Root density distribution;
Rooting depth.

- Dense roots increase **soil cohesion**
- Deep-rooted plants are resistant to **uprooting**
- Fast-root deepening allows for **water uptake** from groundwater from groundwater

Research question

Above- and below-ground traits have specific functions in determining biogeomorphic feedbacks.

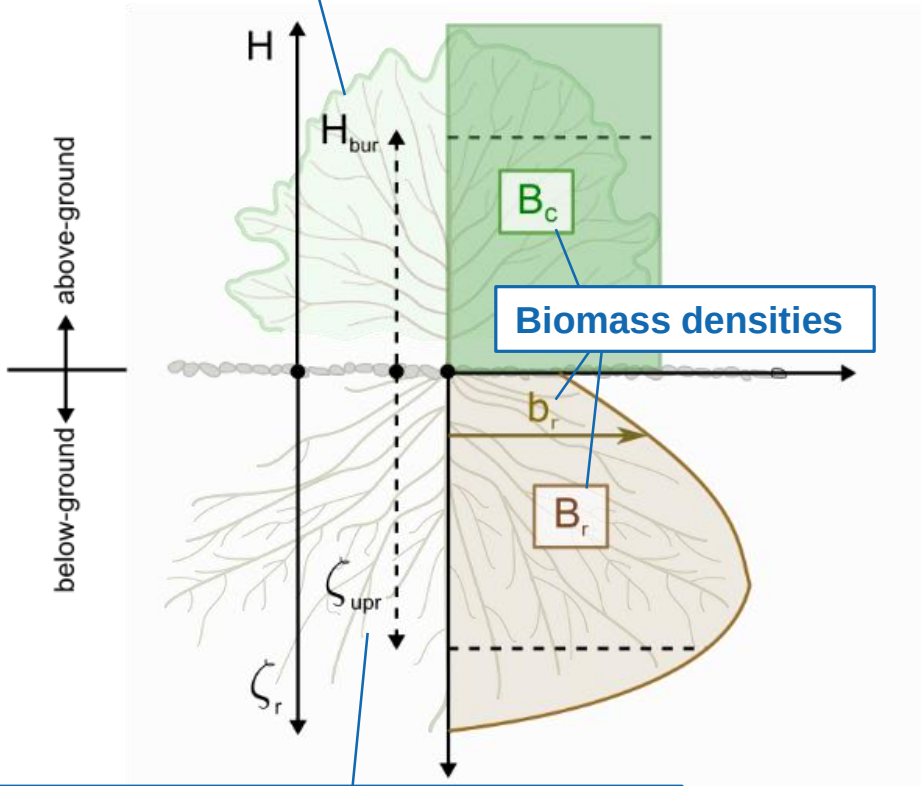
Traits change over time depending on the plant growth strategy.

However, we have limited knowledge on how combinations of traits influence biogeomorphic systems

How do above and below-ground plant traits influence vegetation response to floods?

A novel eco-morphodynamic model

Burial height: max. sediment deposition before mortality



Uprooting depth: max. erosion depth before uprooting occurs

To answer the question, we developed a model that combines:

- a river morphodynamic numerical model (BASEMENT)
- a plant growth model describing how plant traits, and their associated feedbacks, develop in time.

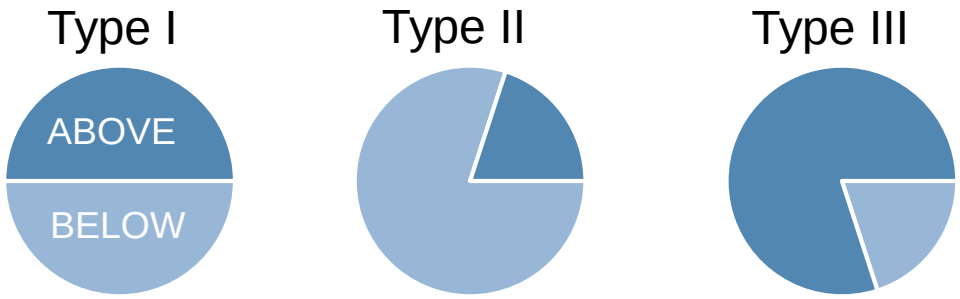
Above-ground vegetation influences:
- Flow resistance
- Sediment transport
- Mortality by burial

Below-ground vegetation influences:
- Soil cohesion
- Plant growth rate by water uptake
- Mortality by uprooting

Numerical simulations

Vegetation types

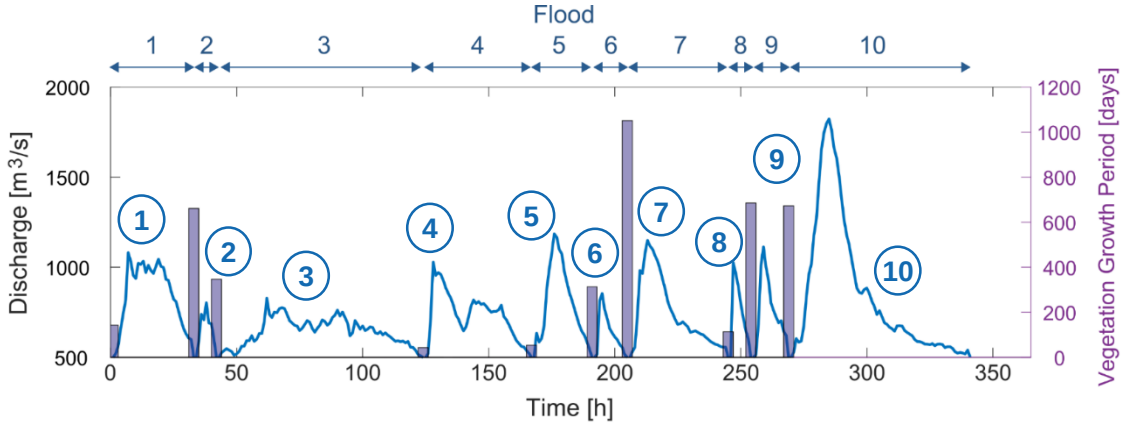
We tested three plant growth strategies, which depend on how plants develop biomass (and relative traits) above and below-ground

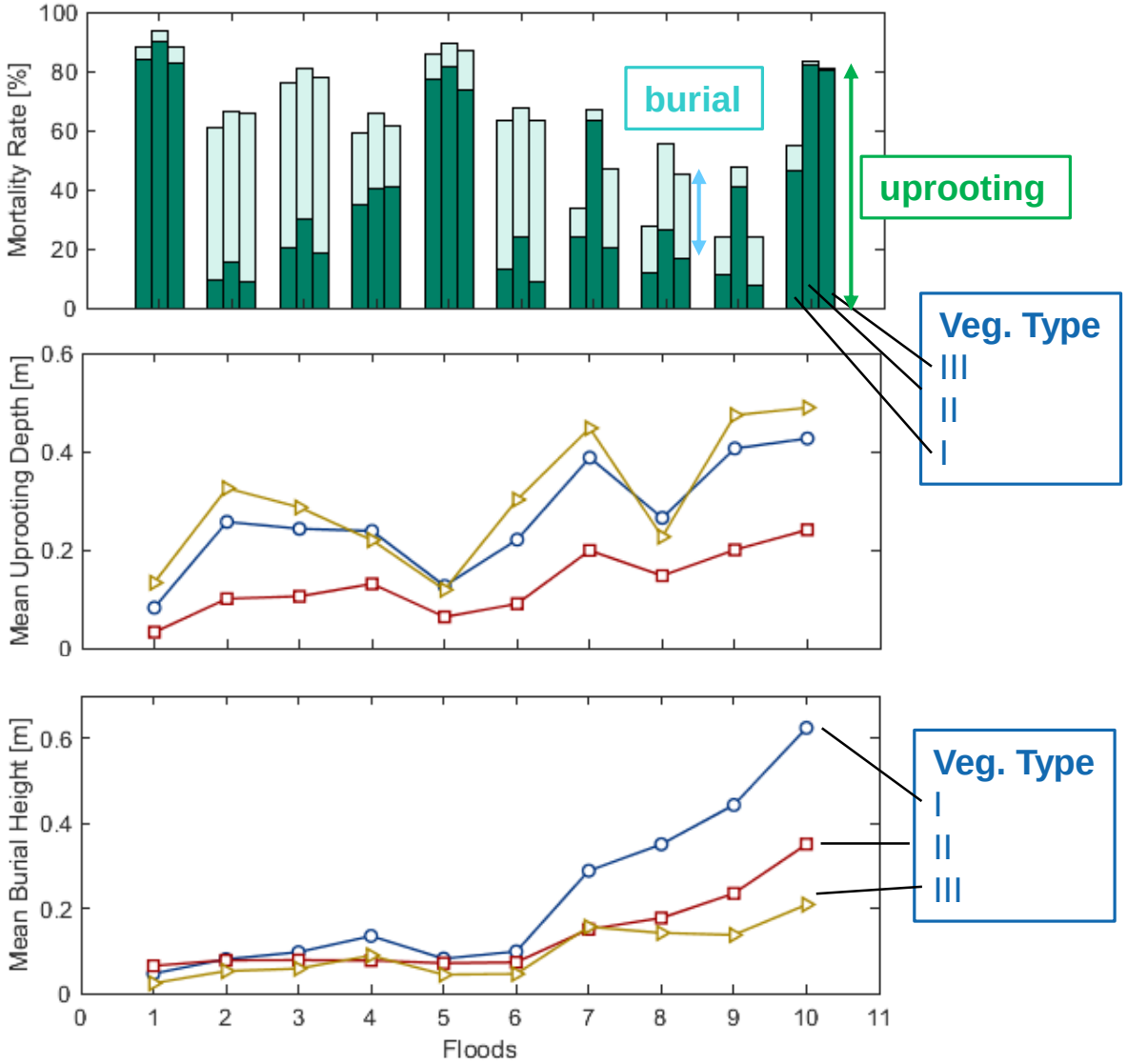


% of biomass allocated

River morphology: alternate bars

Hydrology: alternating series of floods and low discharge periods (about 15 years)





How do plant traits influence vegetation mortality due to floods?

Three phases can be identified:

1. **Until flood 7** → vegetation response (mortality by uprooting or burial) is controlled by hydromorphological processes (i.e. floods)
2. **Flood 7 – 9** → vegetation response depends on plant traits
3. **Flood 10** → vegetation (type I) is able to resist more to flood 10 because it activates biogeomorphic feedbacks

Summary

- We developed a **eco-morphodynamic model** that accounts for both above-and below-ground plant traits and their associated feedbacks
- The application of the model to alternate bars **qualitatively reproduced** the co-evolution of vegetation and bars observed in the Alpine Rhine river
- **Signature of plant traits** in biogeomorphic patterns requires characteristic timescale to emerge, which depends on flood hystory, low discharge periods, and bar morphology
- Our results suggest that vegetation that develops equally above and below-ground might have better chance to establish on bars

This work is currently under review in *Scientific Reports,* write me by email or find me on Research Gate for updates!

- **Related publications**:
  - Caponi, F., & Siviglia, A. (2018). Numerical Modeling of Plant Root Controls on Gravel Bed River Morphodynamics. *Geophysical Research Letters*, 45(17), 9013–9023, https://doi.org/10.1029/2018GL078696
  - Caponi, F., Koch, A., Bertoldi, W., Vetsch, D. F., & Siviglia, A. (2019). When Does Vegetation Establish on Gravel Bars? Observations and Modeling in the Alpine Rhine River. *Frontiers in Environmental Science*, *7*, 1–18. https://doi.org/10.3389/fenvs.2019.00124
  - BASEMENT model website → https://basement.ethz.ch/
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