UNIVERSITY OF TRENTO

EGU General Assembly 2022

Intermediate hydro-morphodynamic disturbances amplify riparian vegetation dynamics

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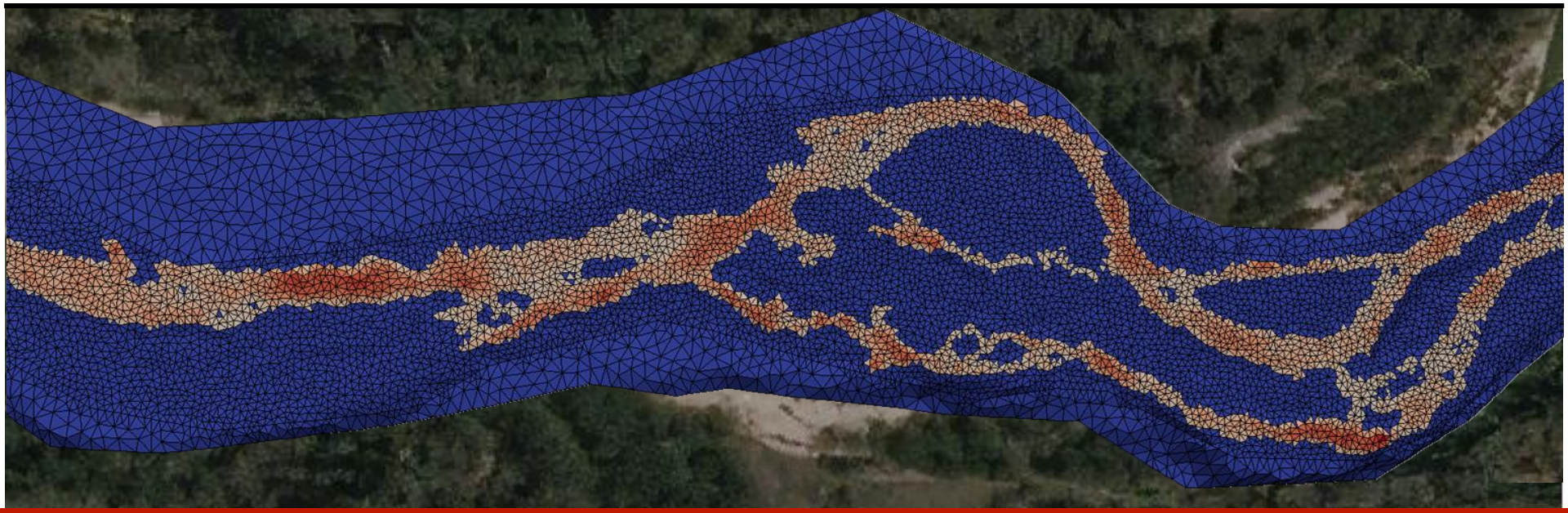


Goal & outline

Eco-morpho-hydro paradigm: Riparian vegetation, flow field and sediment transport are interconnected by non-linear complex relations, which remain, nowadays, still not well quantified

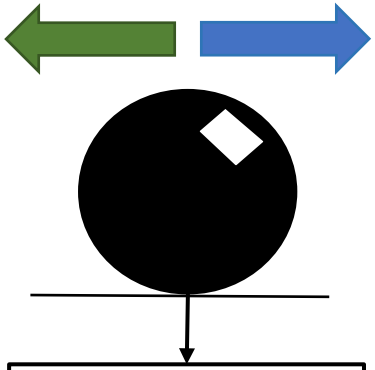
Goal: Quantify and investigate the presence of chaotic behaviour in our ecosystem by means of a ecomorphodynamic model

Outline:

- Introduction
- Numerical model & set up
- Results & conclusion

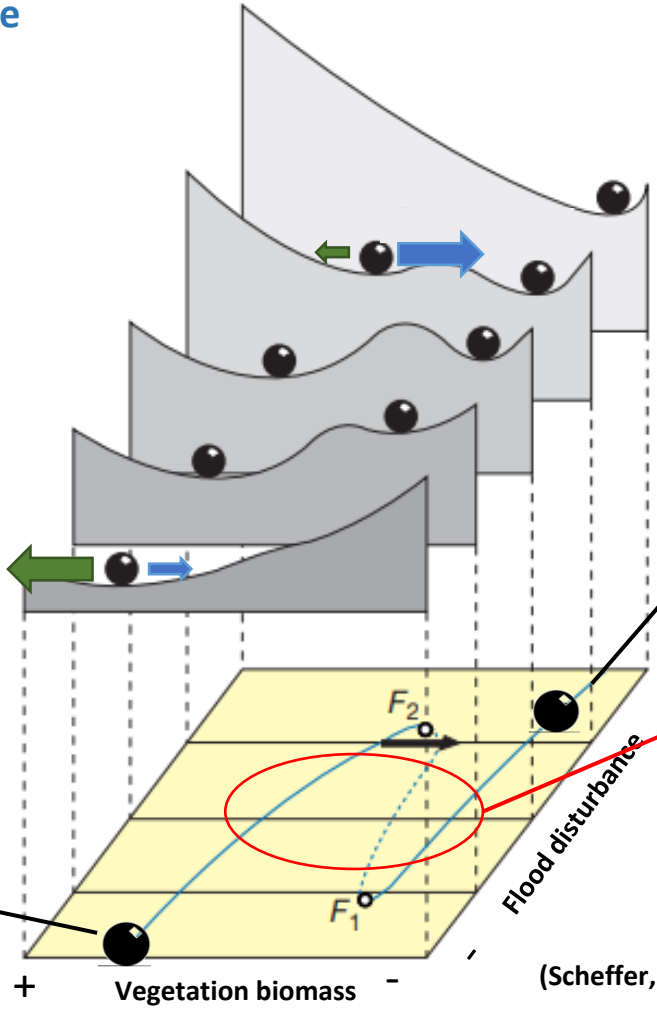
Ecosystem dynamics

Plants resistance Flood disturbance



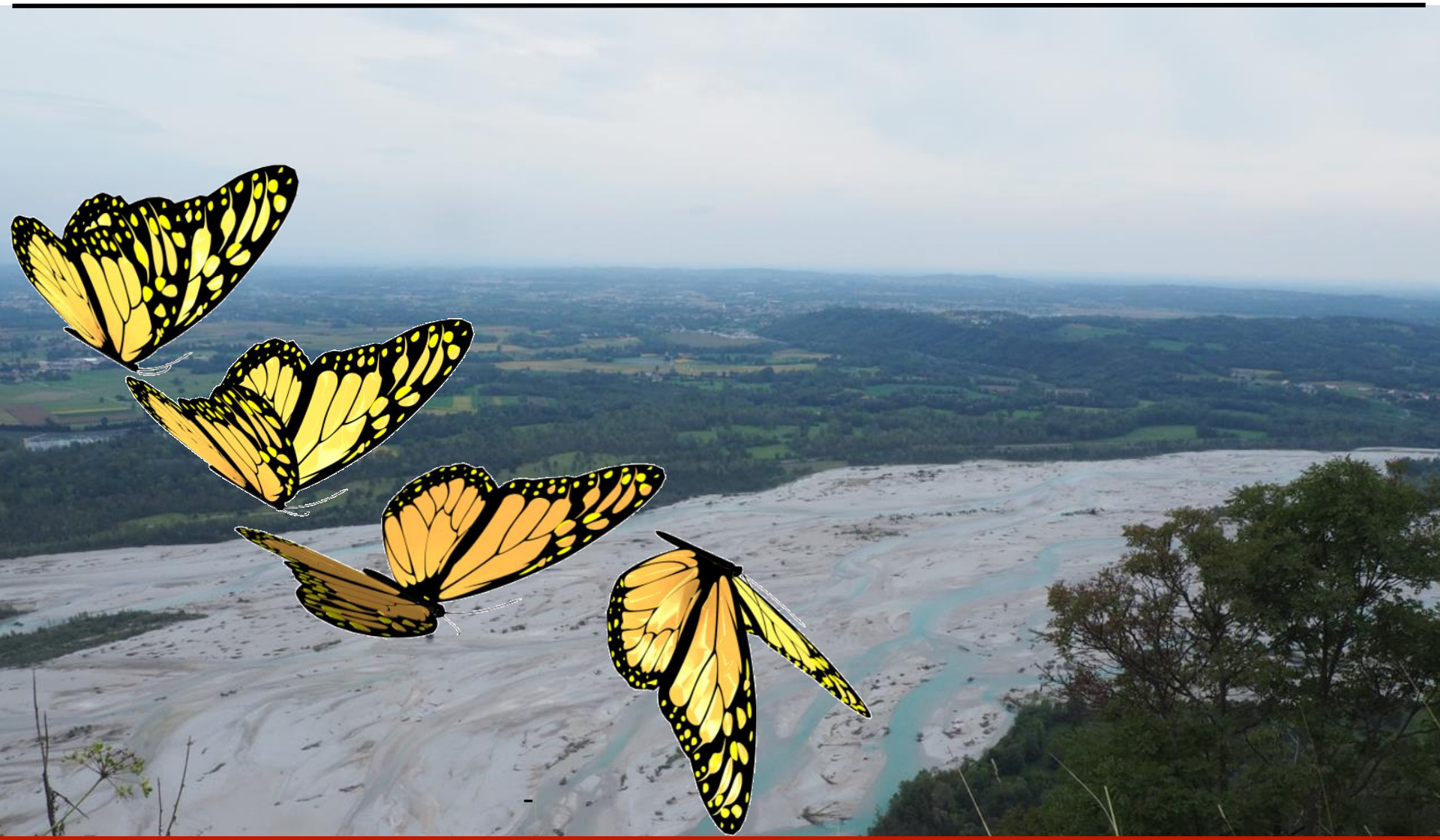
Bare soil

Ecological phase



(Scheffer,2001)

Chaotic ecosystems



Numerical model

Hydrodynamics

GVF equation

$$\frac{dh}{dx} = \frac{S_0 - S_f}{1 - Fr^2}$$

Morphodynamics

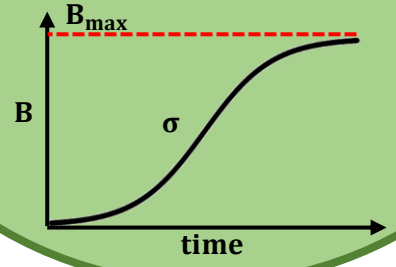
Exner equation

$$(1-p)\frac{\partial z_b}{\partial t} + \frac{\partial q_b}{\partial x} = 0$$

Vegetation growth

Logistic equation

$$\frac{dB}{dt} = \sigma B\left[1 - \frac{B}{B_{max}}\right]$$

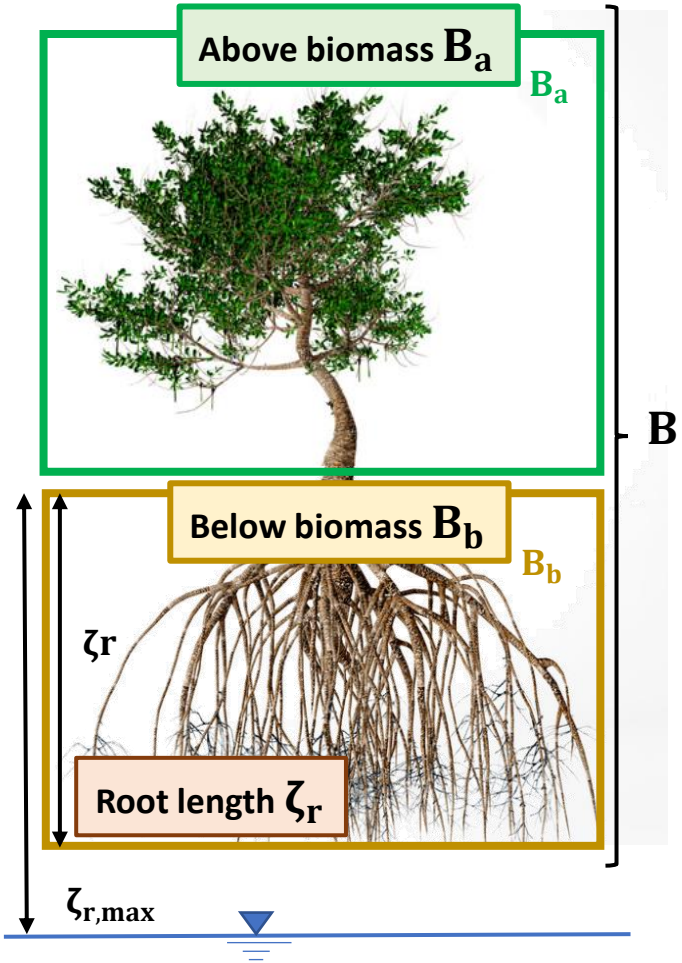


B_{max} = carrying capacity [-]
B=total biomass [-]
h=water depth [L]
Fr=Froude number [-]
S_0 = bed slope [-]
S_f= friction slope [-]
x=stream coordinate [L]

σ = growth rate [1/T]
t=time [T]
z_b= bed level [L]
q_b = sediment discharge per unit width [L^2T^{-1}]
p= porosity of sediment [-]

Numerical model

Vegetation growth



Biomass growth

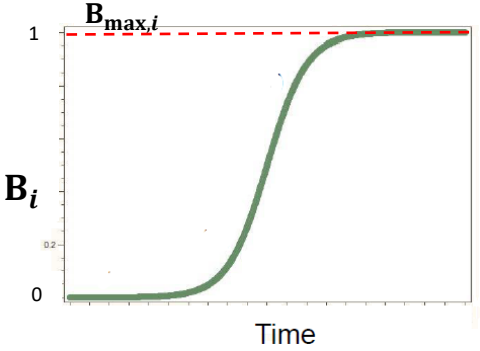
$$\frac{dB_i}{dt} = \sigma B_i\left[1 - \frac{B_i}{B_{max,i}}\right]$$

i =a, b

$$B = B_a + B_b$$

Logistic equation

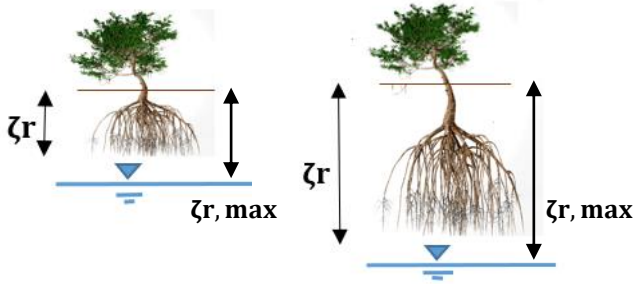
- $B_{max,i}$: carrying capacity (maximum total biomass value)
- B_i: biomass (below or above)
- σ is the growth rate and its constant



Root length

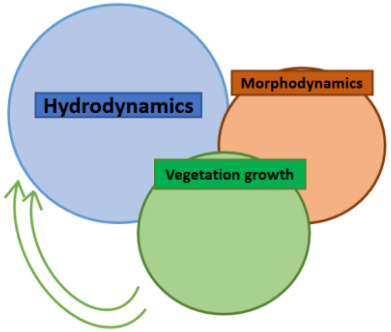
$$\zeta_r = B_b \frac{\zeta_{r,max}}{B_{max,b}}$$

- ζ_r: root length
- $\zeta_{r,max}$: distance between the riverbed surface and the water table level
- $B_{max,b}$: carrying capacity (maximum below biomass value B_b)



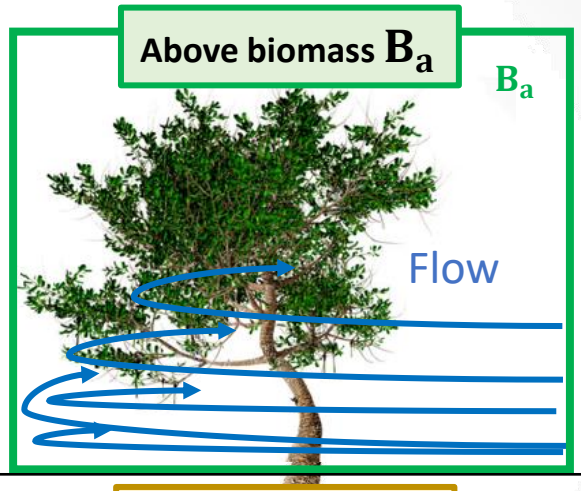
Numerical model

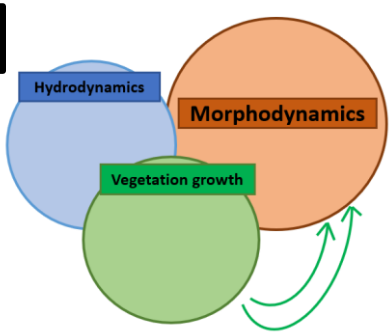
Feedback vegetation & hydromorphodynamic processes



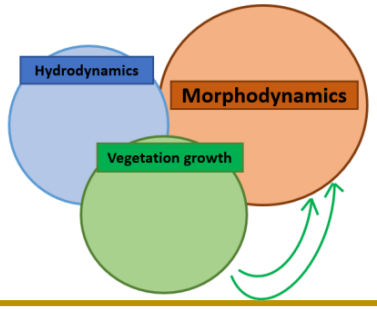
Increase of flow resistance

Increase of the roughness



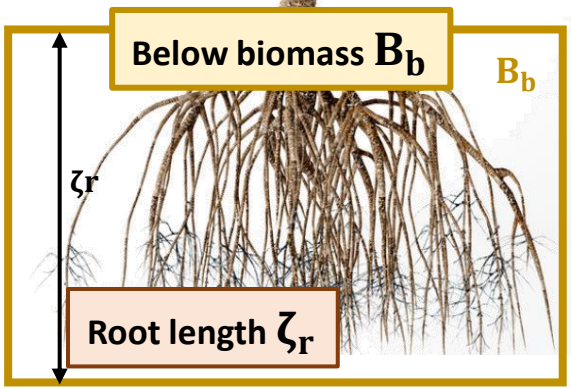


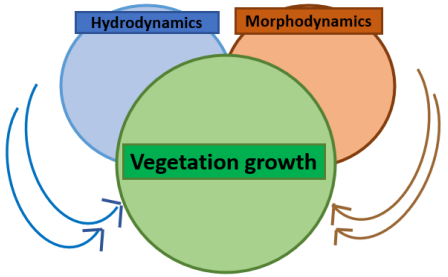
Decrease of shear stresses of the bed surface



Increase of soil cohesion

Increase of the critical Shields parameter





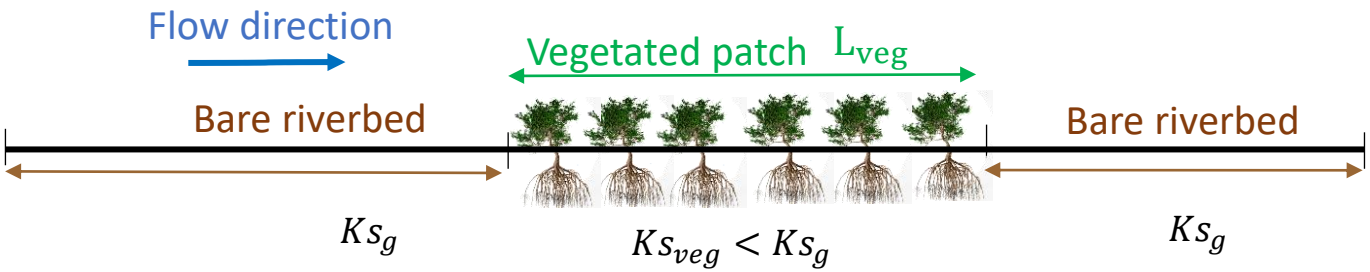
Uprooting mechanism

Uprooting mechanism occurs when the flow is able to excavate a given fraction of ζ_r

Model set up

1D model

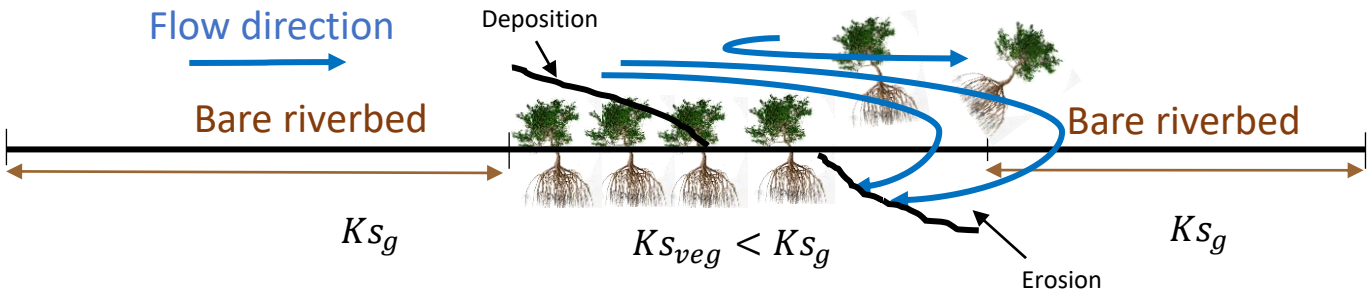
time=0



Model set up

1D model

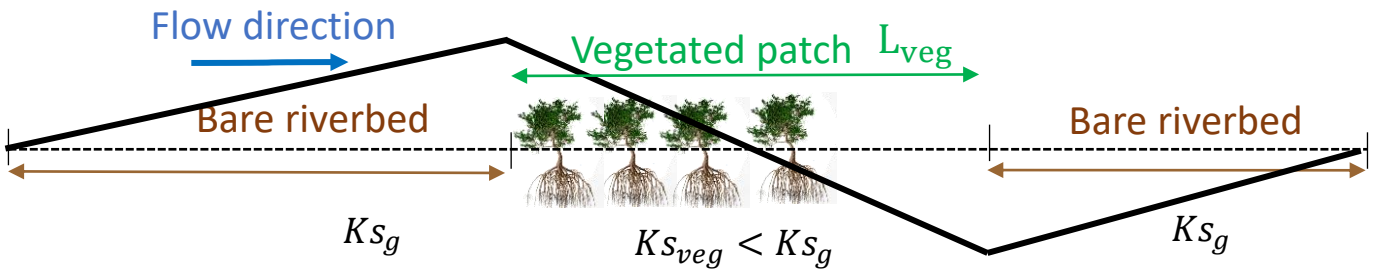
time>0



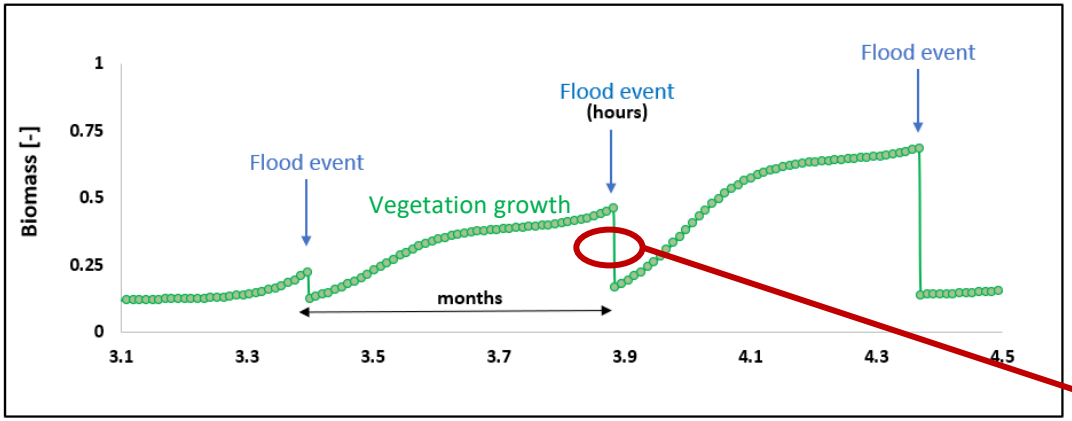
Model set up

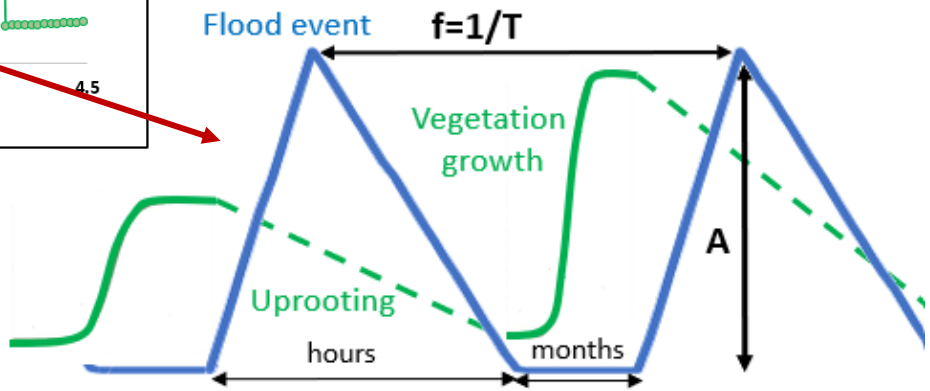
1D model

time>0

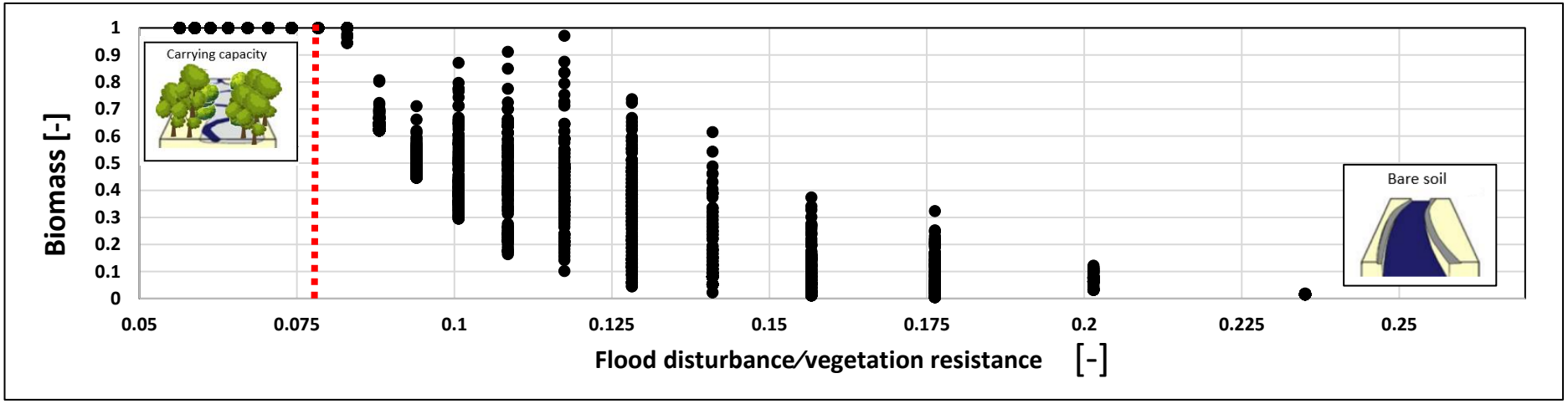


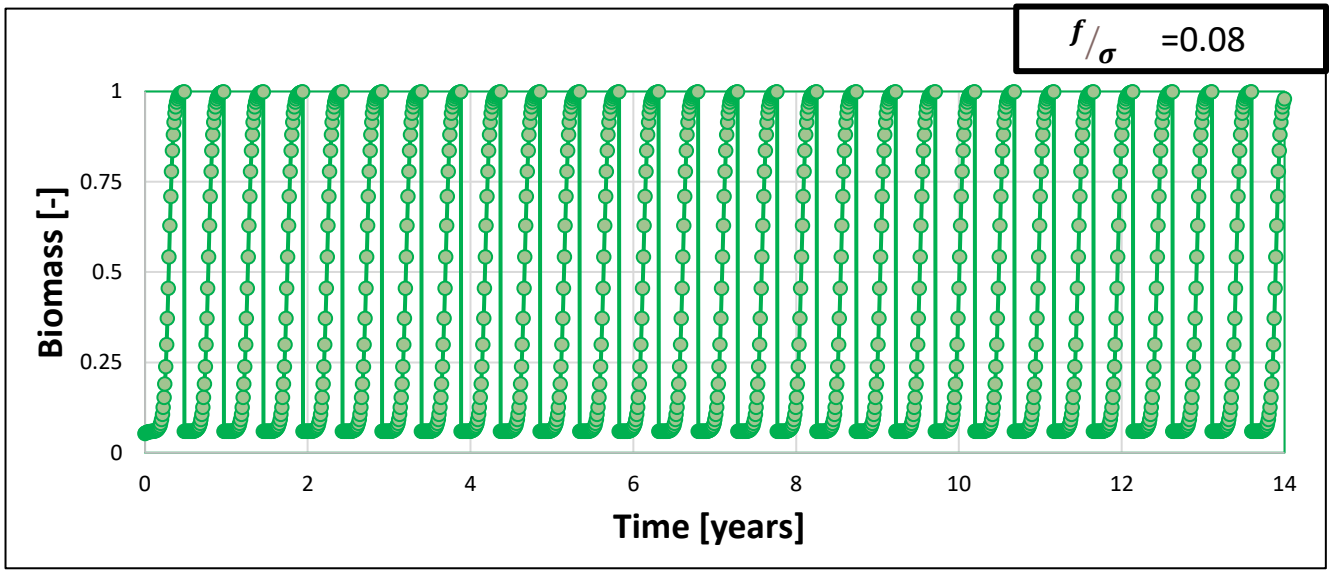
Flood disturbance

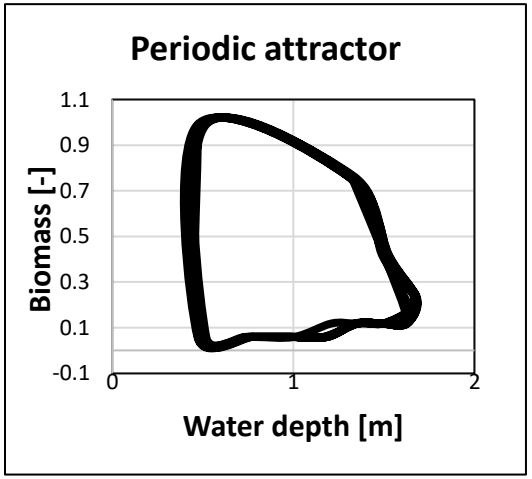




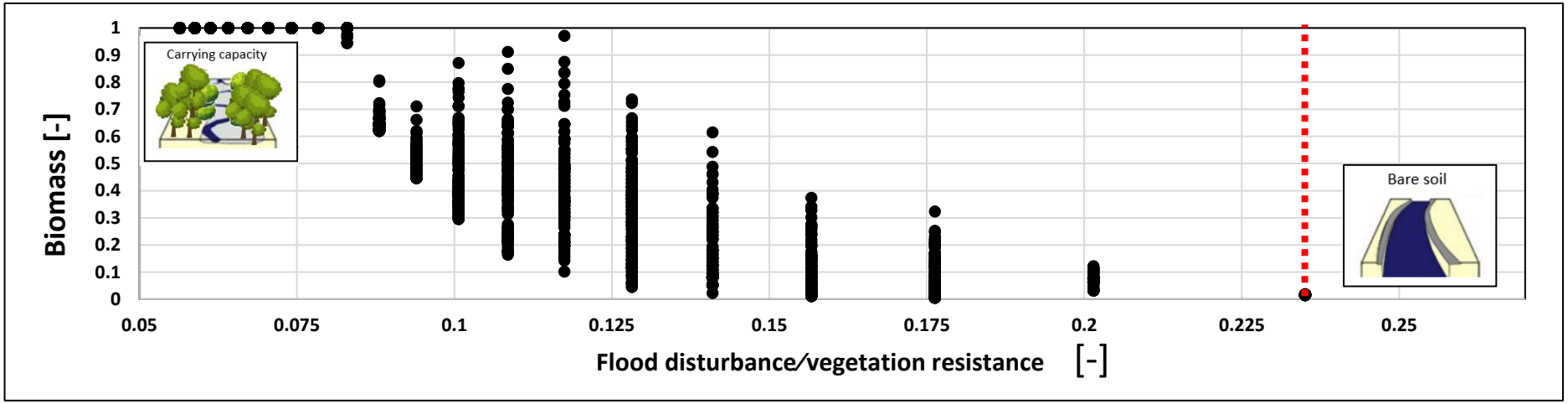
Results


Biomass [-]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Carrying capacity
Bare soil
0.05
0.075
0.1
0.125
0.15
0.175
0.2
0.225
0.25
Flood disturbance/vegetation resistance [-]

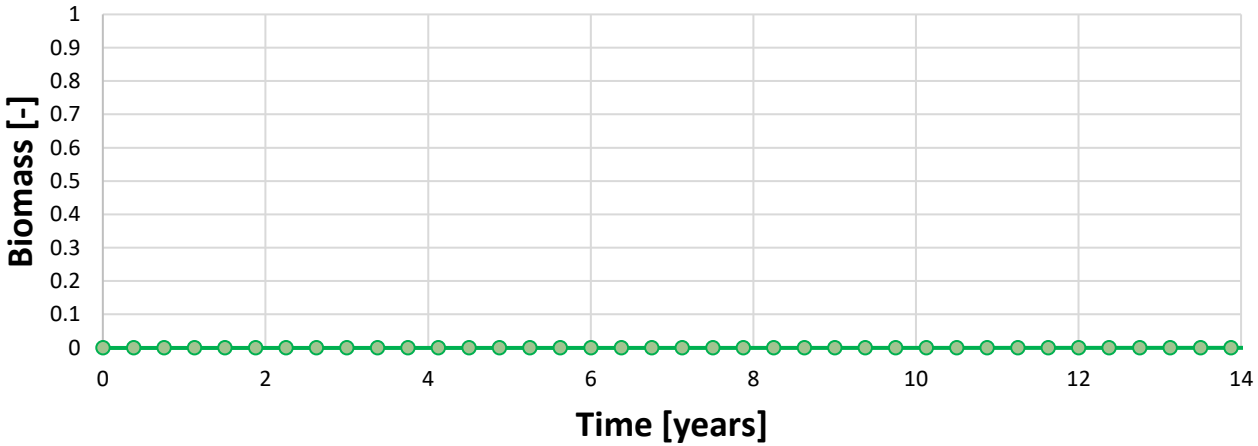

f/σ =0.08
Biomass [-]
1
0.75
0.5
0.25
0
0
2
4
6
8
10
12
14
Time [years]

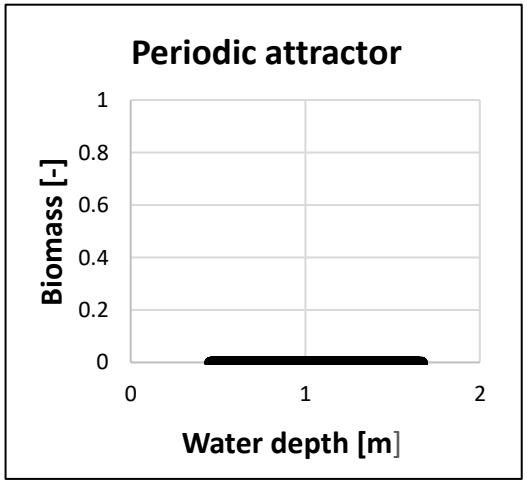

Periodic attractor
Biomass [-]
1.1
0.9
0.7
0.5
0.3
0.1
-0.1
0
1
2
Water depth [m]

Results

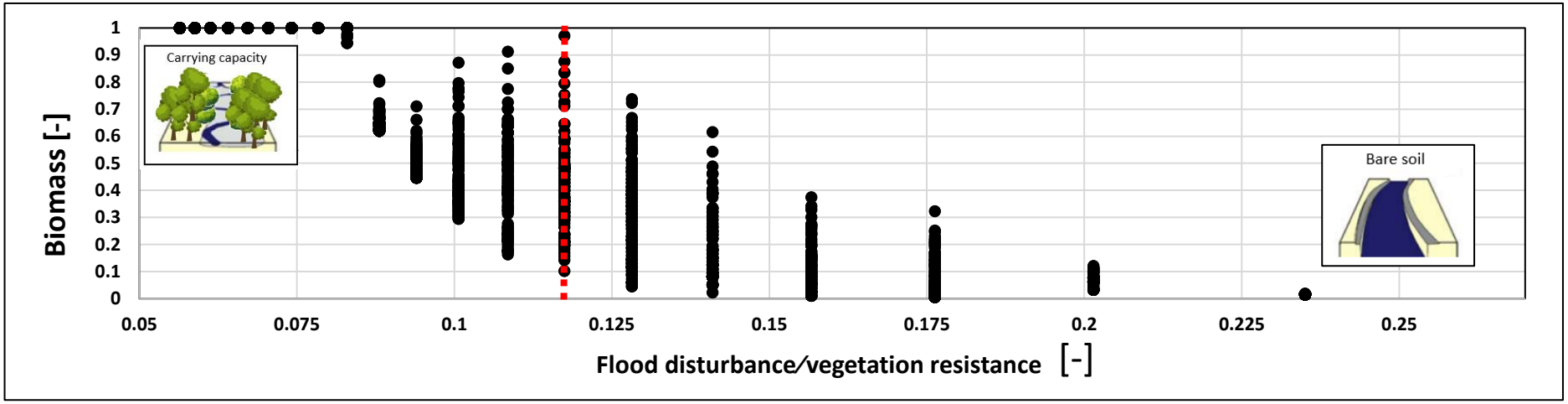


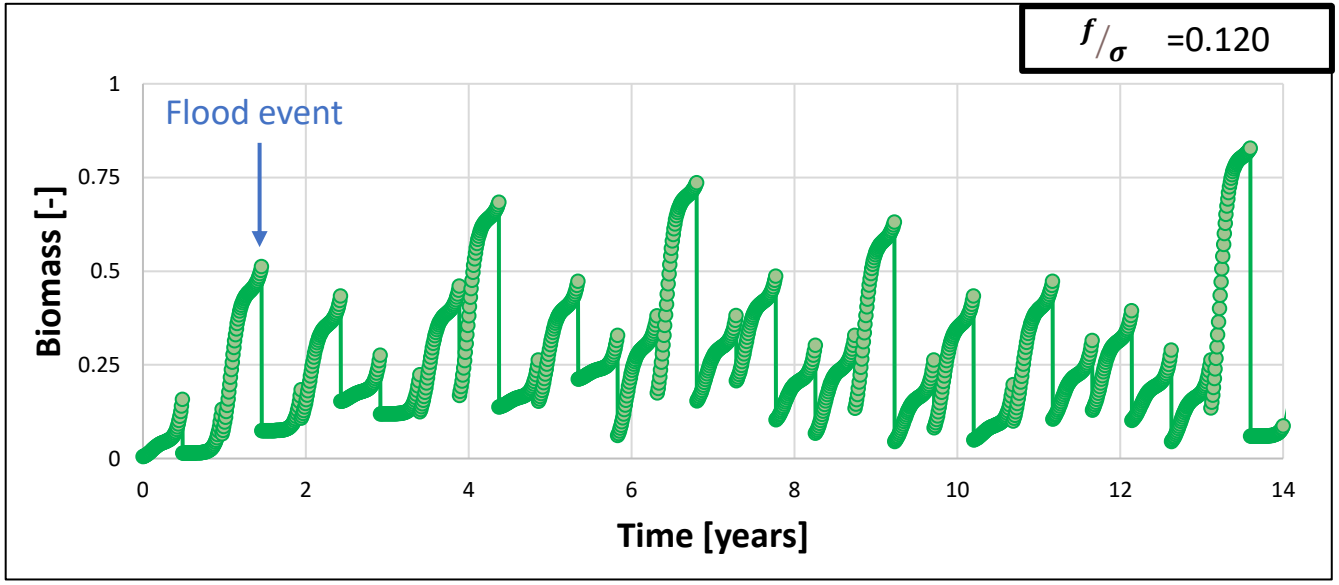
f/σ =0.23

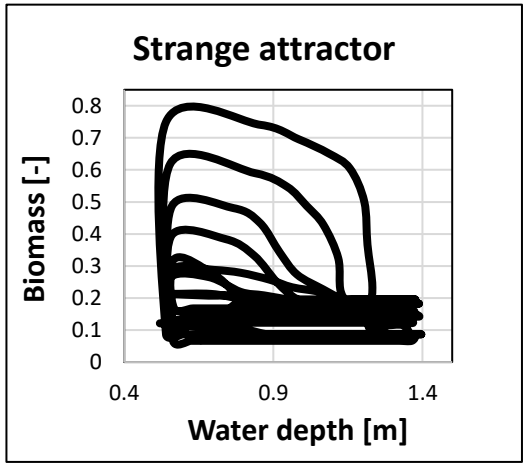




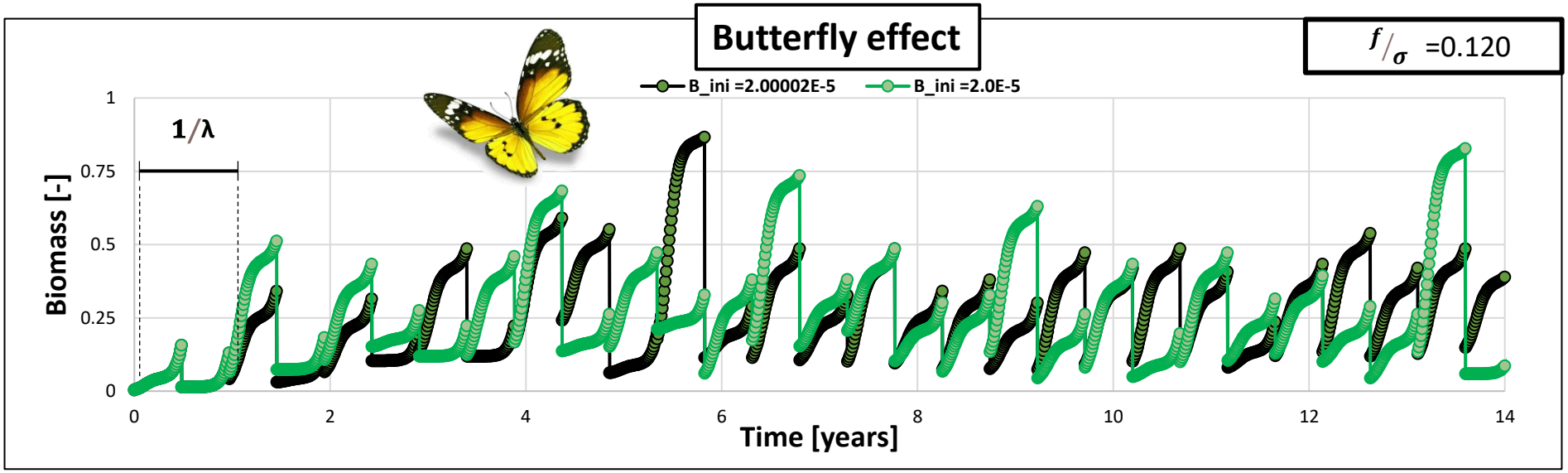
Results

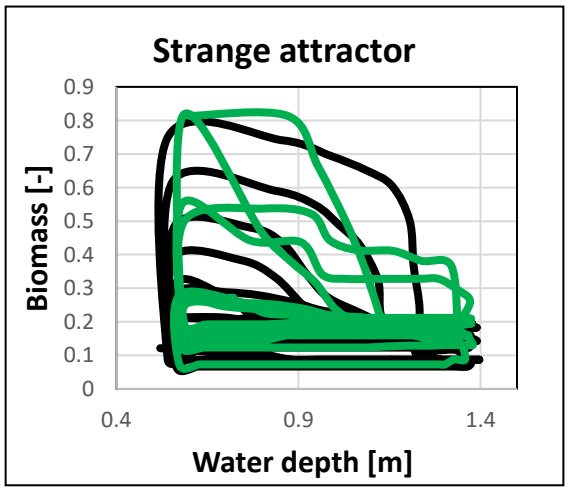

Biomass [-]
Carrying capacity
Bare soil
Flood disturbance/vegetation resistance [-]

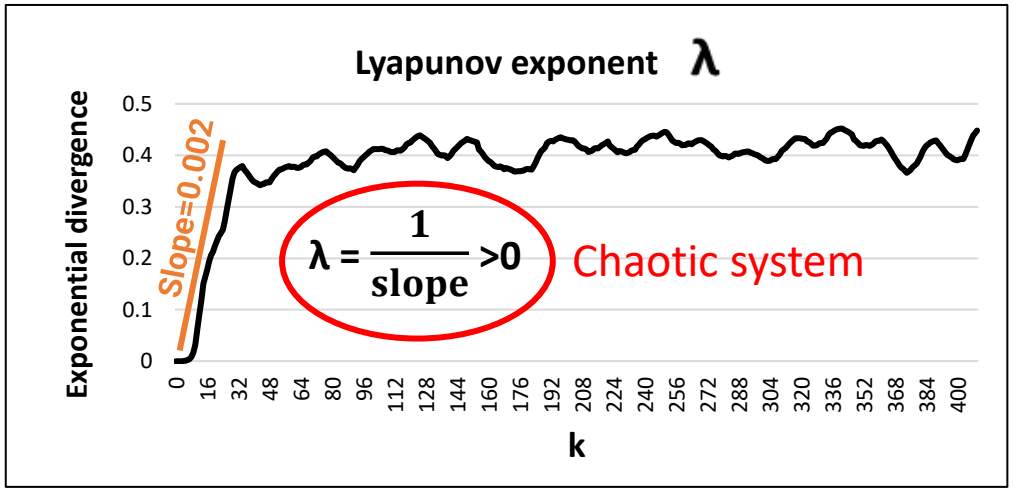

f/σ =0.120
Flood event
Biomass [-]
Time [years]


Strange attractor
Biomass [-]
Water depth [m]

Results & conclusion







Thanks for the attention

"Our eyes once opened, we may pass on to a yet newer outlook of the world, but we can never go back to the old outlook."

–A. Eddington,1927 -

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