Ecosystems in transition

Wechselwirkungen und Feedbacks in der initialen Ökosystementwicklung

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mit Beiträgen von

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Questions

- What abiotic feedbacks exist consistently across different materials and climates?
- How do abiotic feedback relate to biotic-abiotic interactions and feedbacks?
- How can we link interacting feedback processes to landscape self-organisation?
- Is there a unifying framework for capturing the vastly diverse processes during early ecosystems development?

Processes leading to abiotic feedbacks

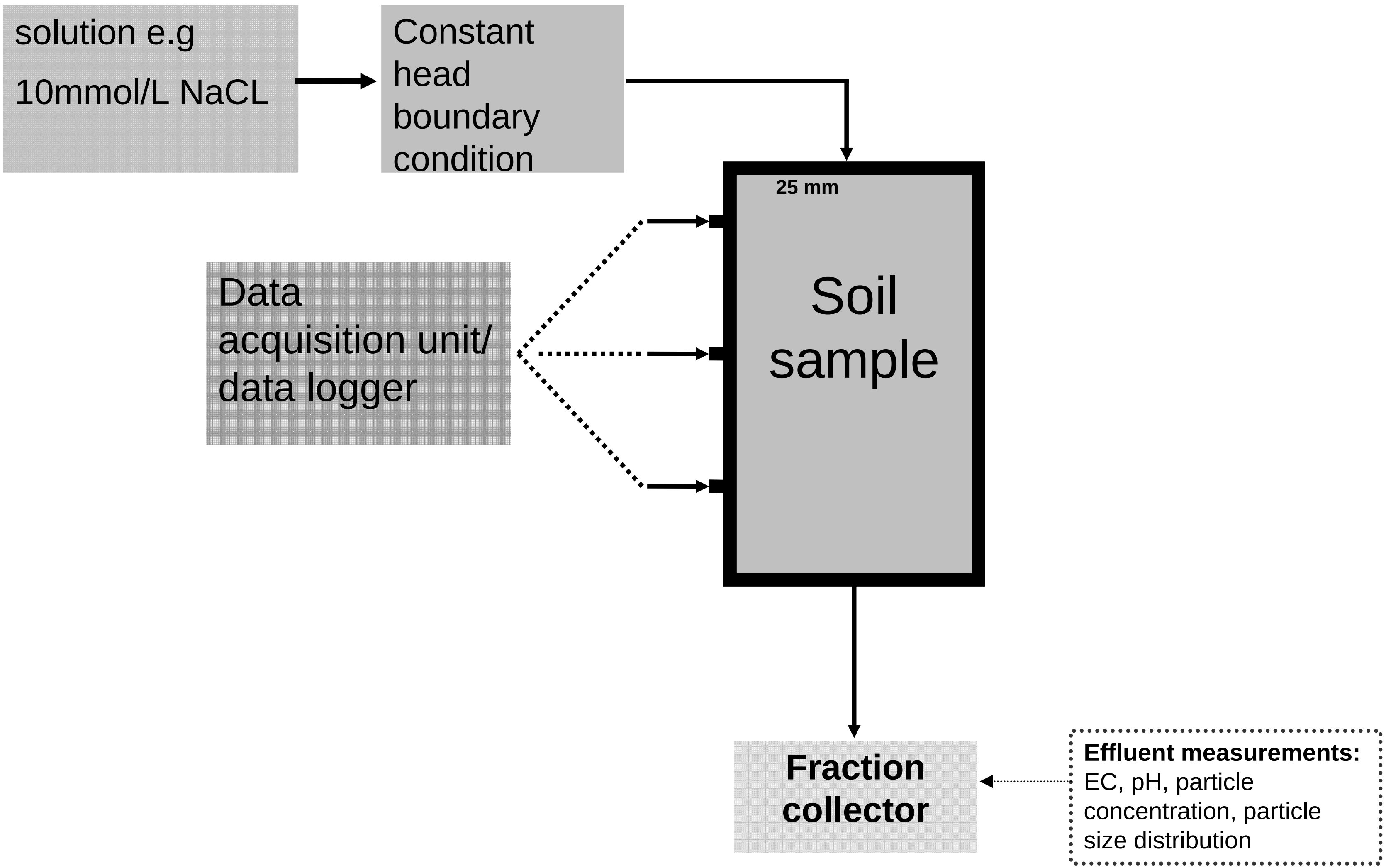
- Substrate as a result of a (deposition process) that either eliminates or simply does not have „biological and ecological memory“ (a gemorphic discontinuity)
- Water as the first agent to affect substrate
- Multiple processes leading to particle mobilisation – for terrestrial and aquatic surface and subsurface environments

Processes leading feedbacks

- Examples:
  - Hydraulic conductivity of repacked substrates
  - *In situ* water retention properties
  - Rock armouring of surface soils

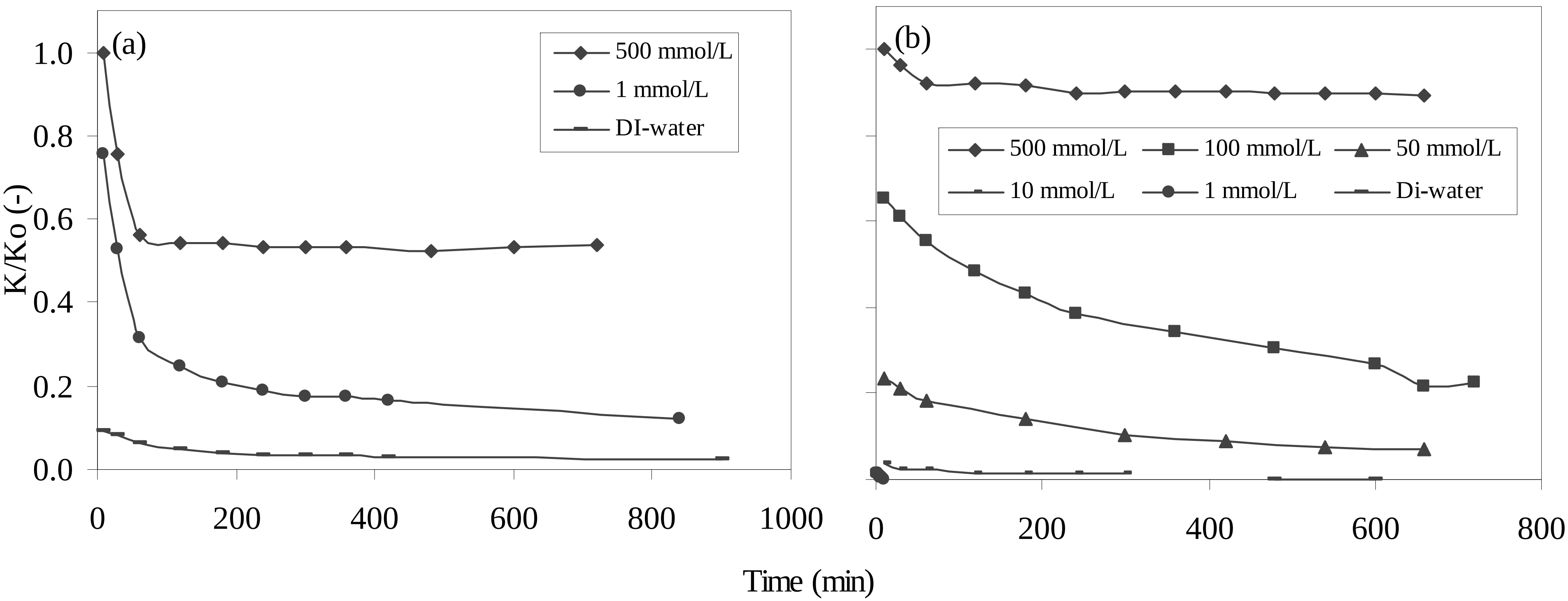
- How fast is the initial organisation of the soil – both subsurface and surface?

Example: Saturated hydraulic conductivity



Dikiniya, Hinz, Aylmore AJSR, 2006 and Geoderma 2008

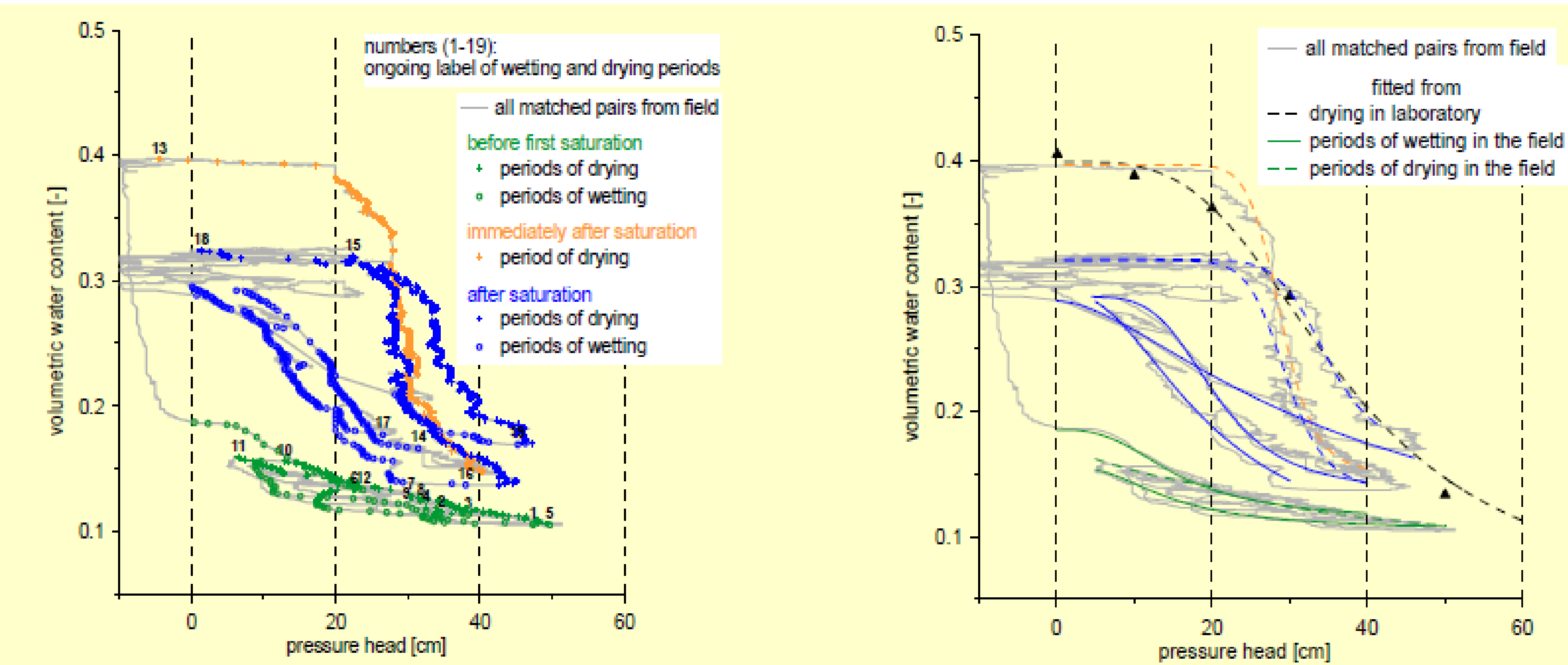
Example: Saturated hydraulic conductivity



Very rapid decrease due mobilisation and deposition of particles even with stablising solution composition

Dikiniya, Hinz, Aylmore, AJSR, 2006

Example: Water retention



Biemelt & Gerke, Geophys. Res. Abstract, 2011

Example: Surface armouring

- Surface erosion and stability
  - Rock fragment accumulation due to selective transport

Mesa Trial Slope

Rainfall Simulations

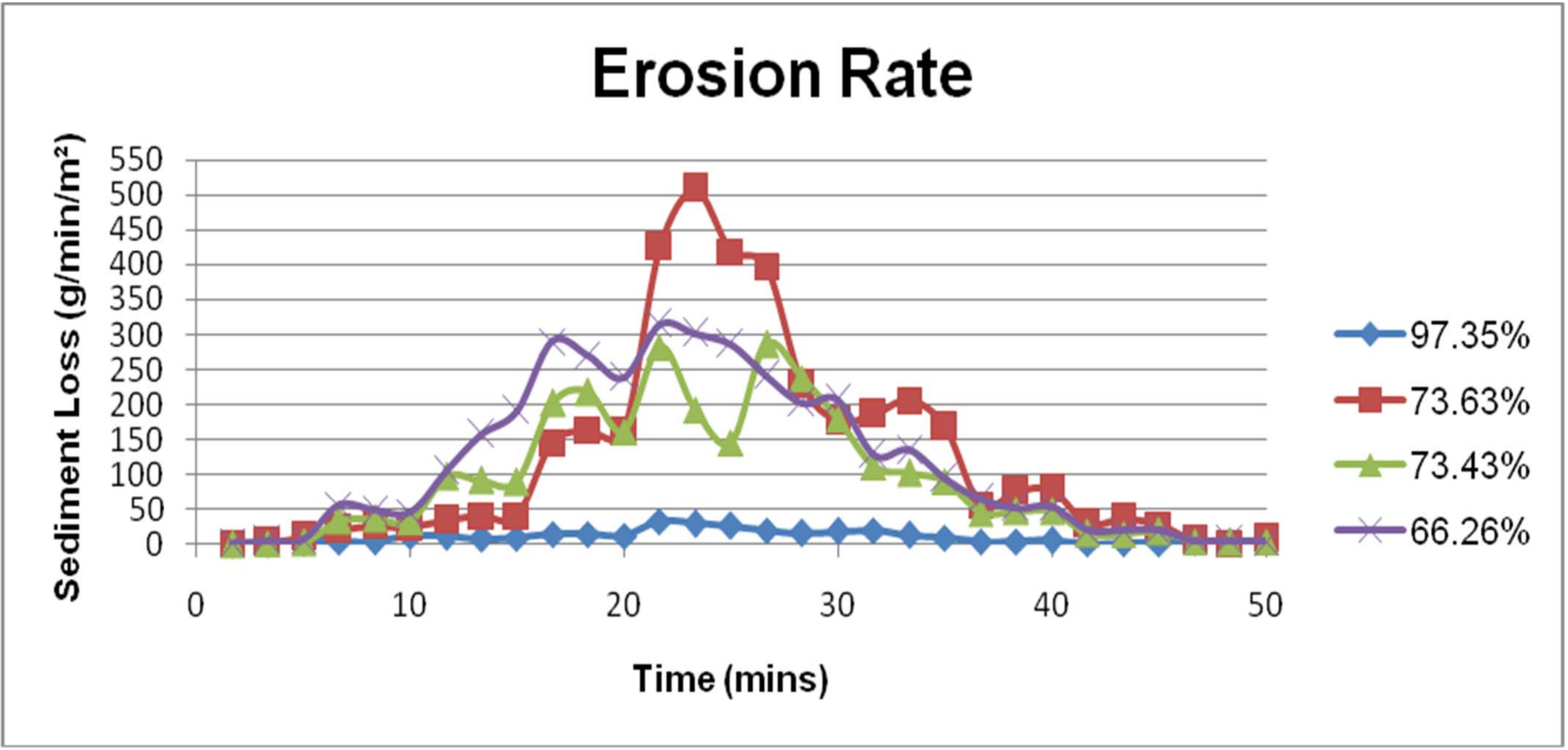
Simulations

- 4 different ratios of top soil to rock fragment
- There were 3 replicates of each ratio
- Water was applied prior to simulation at 100 mm/hr until homogeneously wetted
- Each simulation consisted of 2 runs
  - 20, 40, 60, 80, and 100 mm/hr
  - 100, 80, 60, 40 and 20 mm/hr
- Each intensity ran for 5 mins

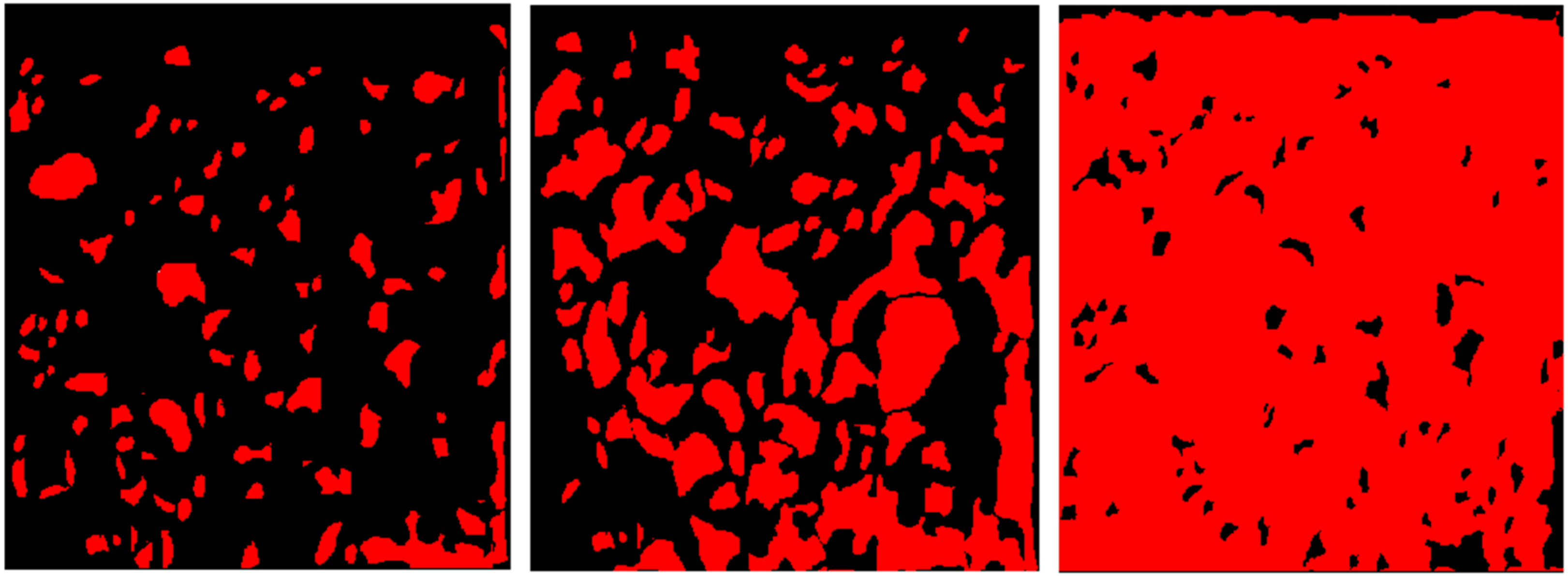
Rainfall Simulations

Simulation	Tray	% (volume) Rock Fragments	% (volume) Top Soil	Slope (°)
1	1	50	50	15
2	4	60	40	15
3	7	70	30	15
4	10	80	20	15

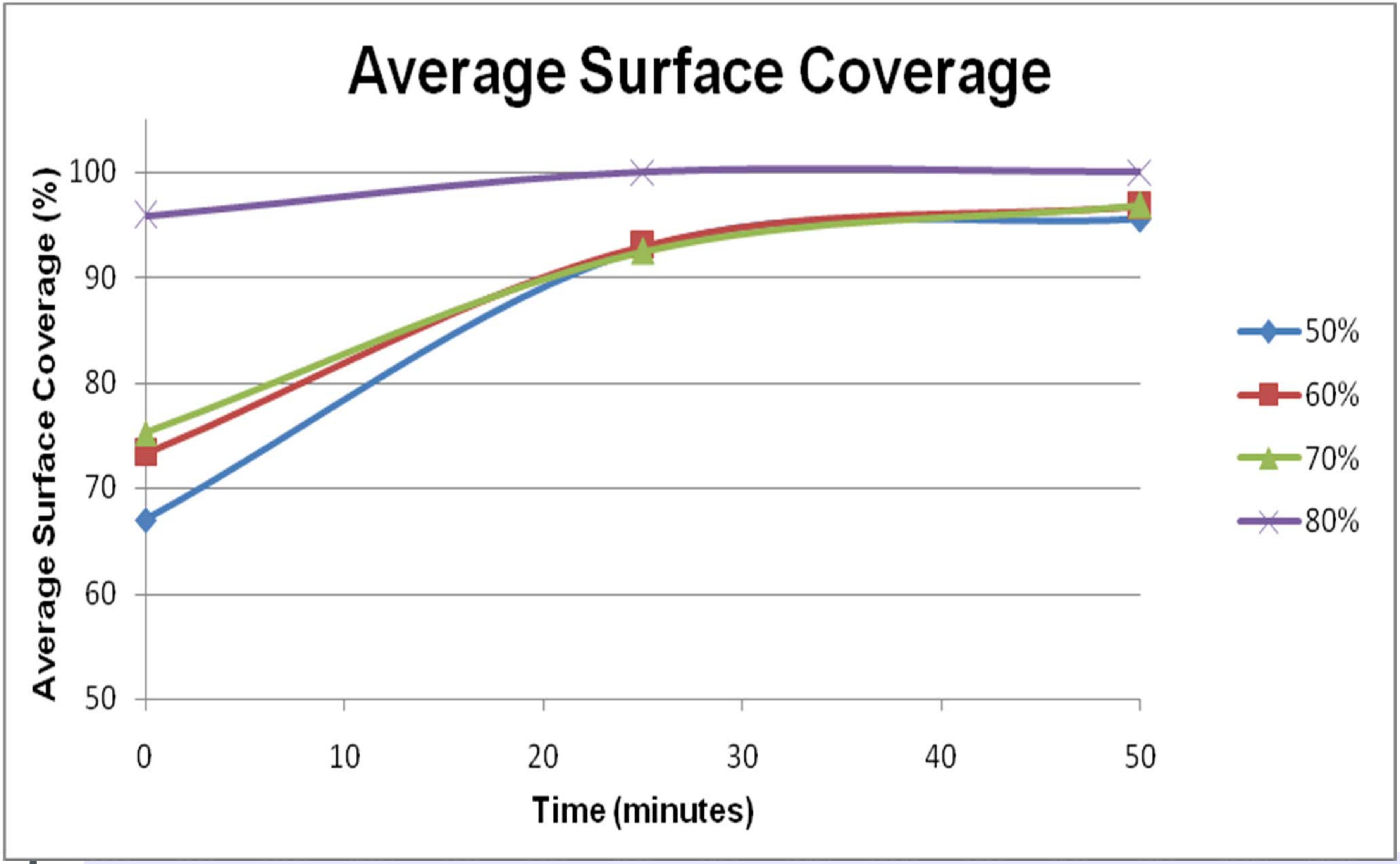
Simulation results



Rock fragment coverage during rainfall simulation



Red represents rock fragment coverage


Average Surface Coverage
Average Surface Coverage (%)
100
90
80
70
60
50
0
10
20
30
40
50
Time (minutes)
50%
60%
70%
80%

Abiotic feedback mechanisms (erosion - soffusion – colmation)

- Particle mobilisation and deposition depends on (pore) water velocity with two limiting cases:

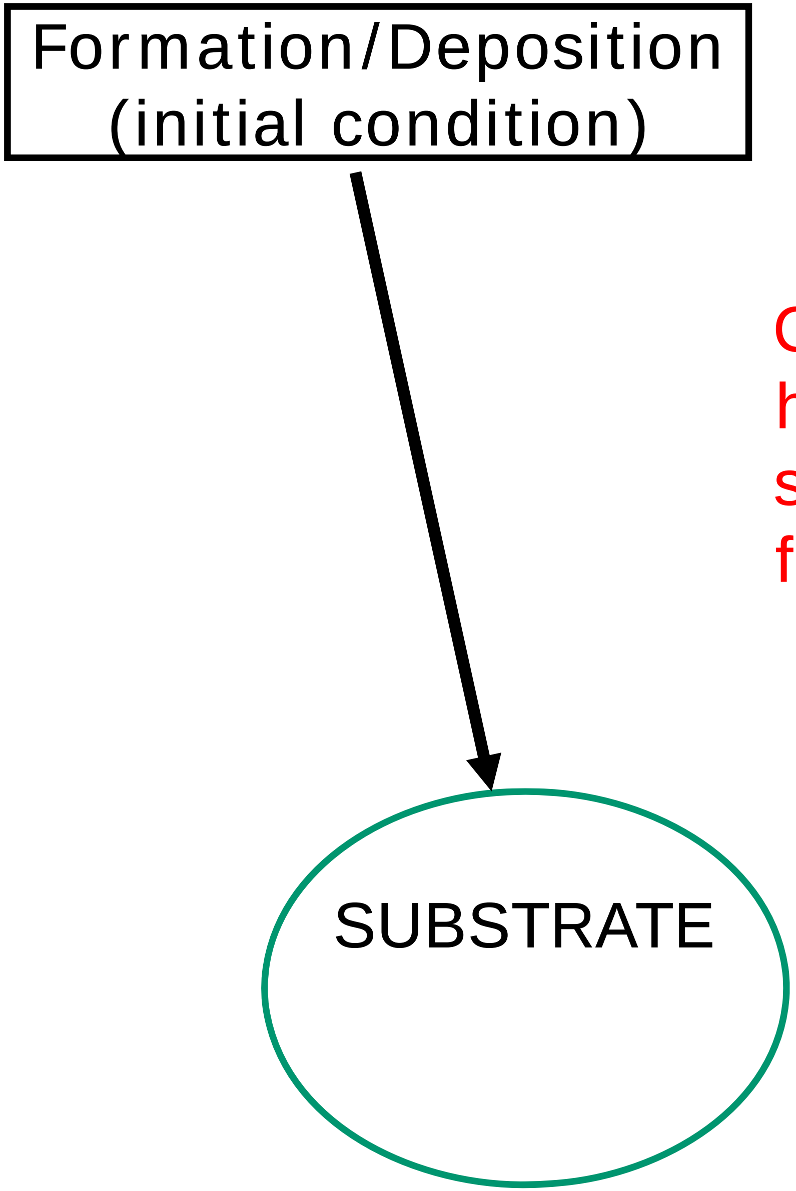
  1. Deposition of particles resulting reduce velocity that itself perpetuates deposition

  2. Mobilisation in large flow pathways increases velocity by enlarging pathways and perpetuate mobilisation

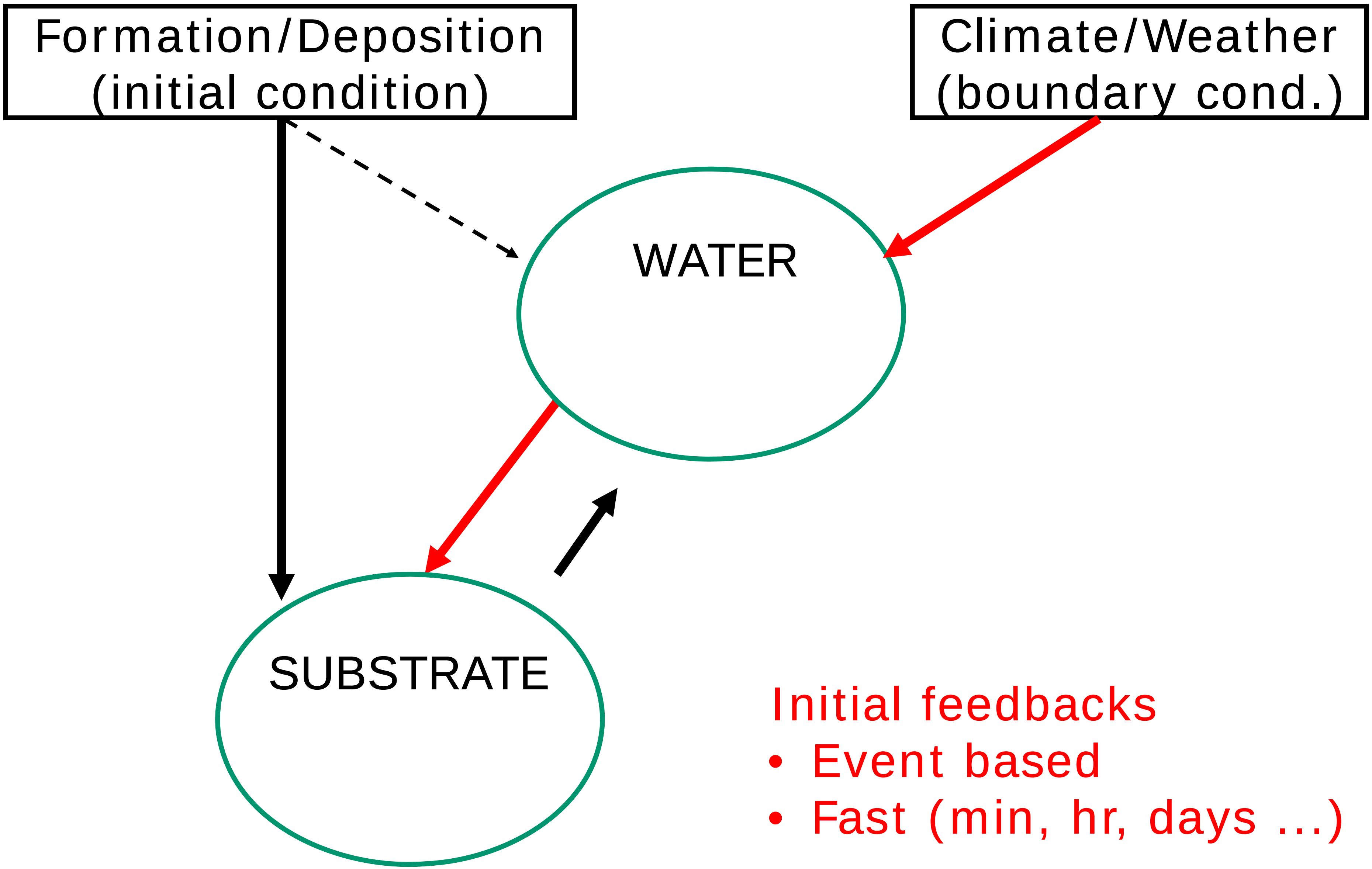
Example: Postmining landscapes

- Subsurface:
  1. Hardsetting soils at depth of 10 to 30 cm after reconstruction with bulk densities above 1.8 g cm^{-1}
  2. Tunnelerosion leading to sinkholes in mine taililngs

- Surface:
  1. Gully erosion



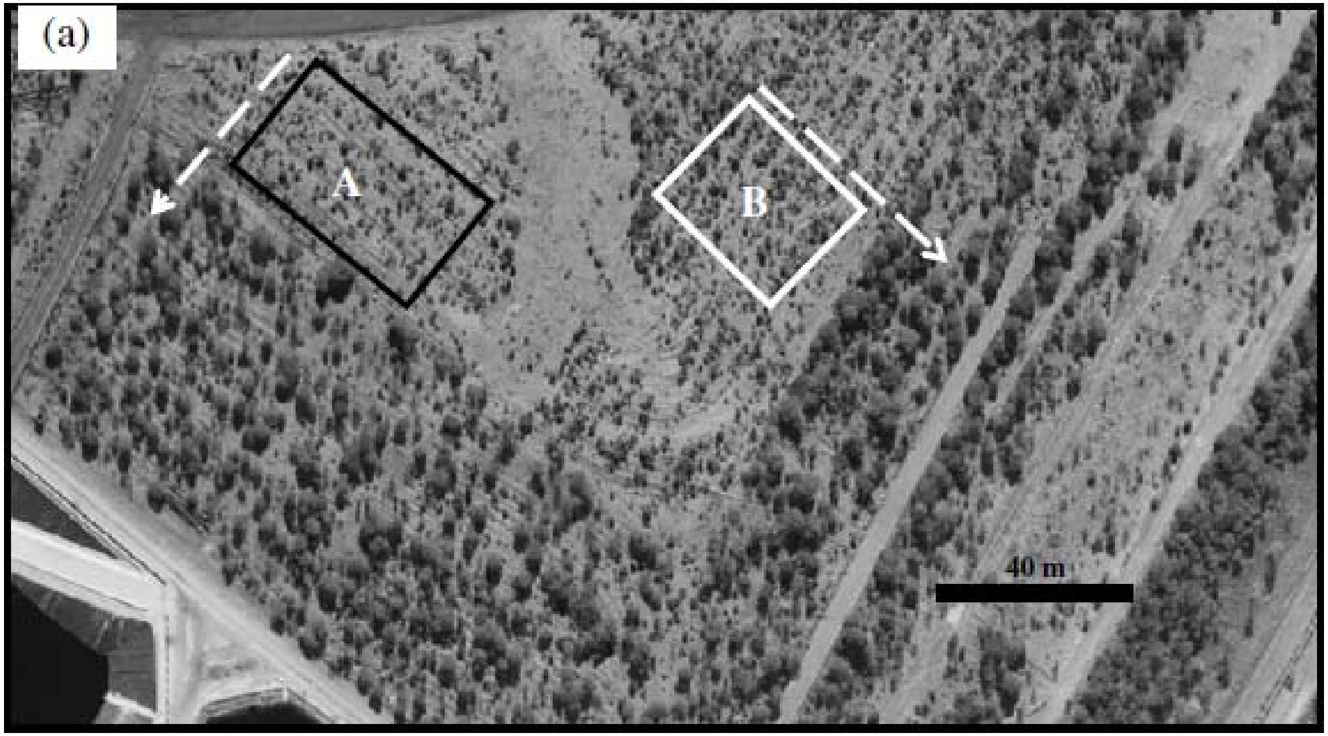
Composition and spatial heterogeneity of substrate depending on formation process

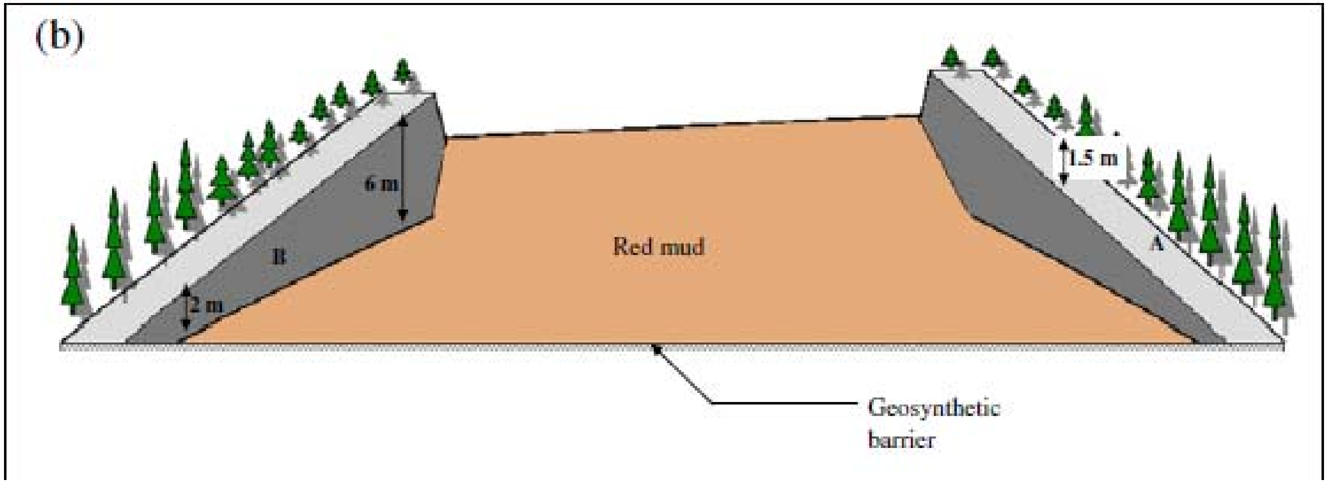


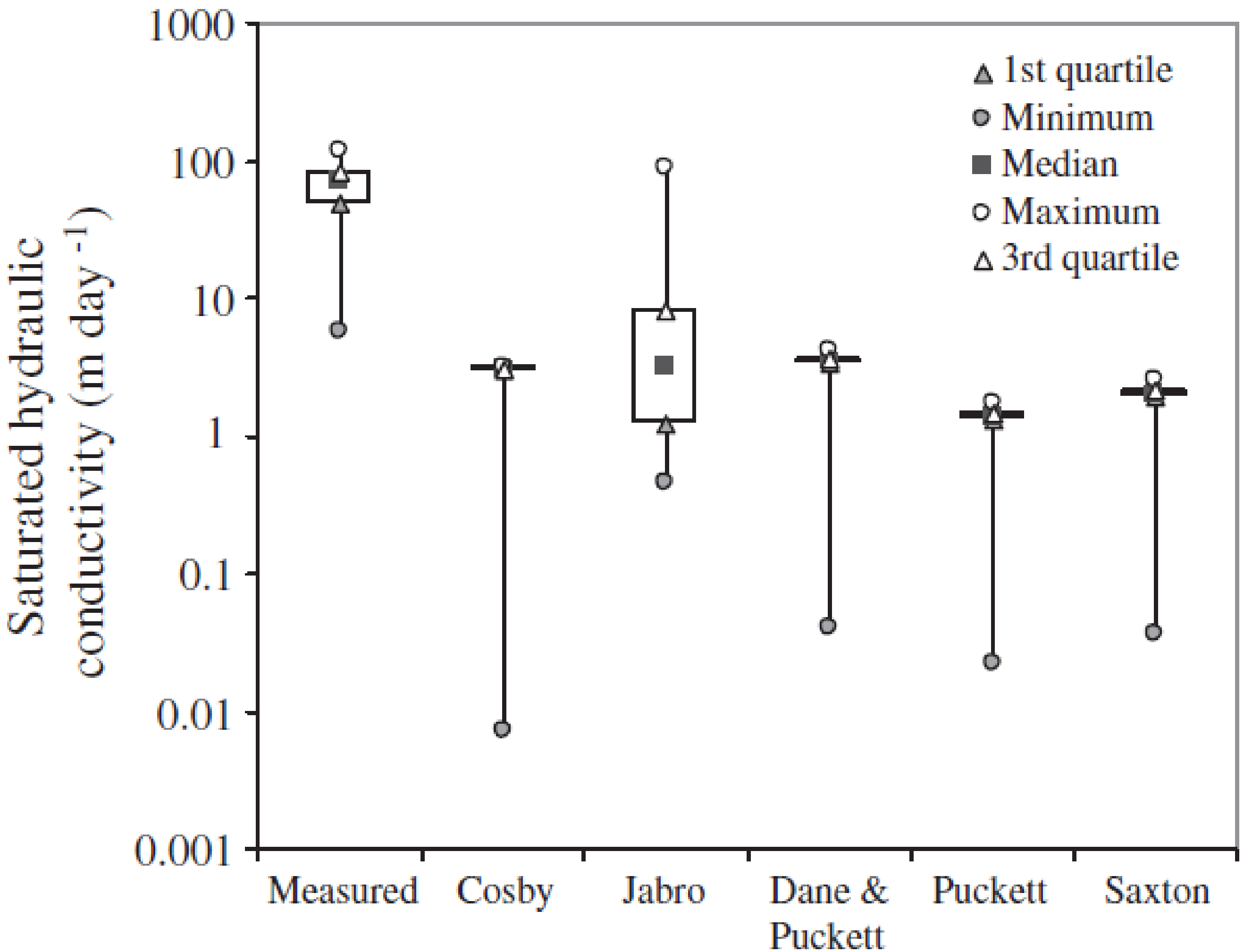
Initial feedbacks

- Event based
- Fast (min, hr, days ...)

How do abiotic feedback relate to biotic-abiotic interactions and feedbacks?


(a)
A
B
40 m

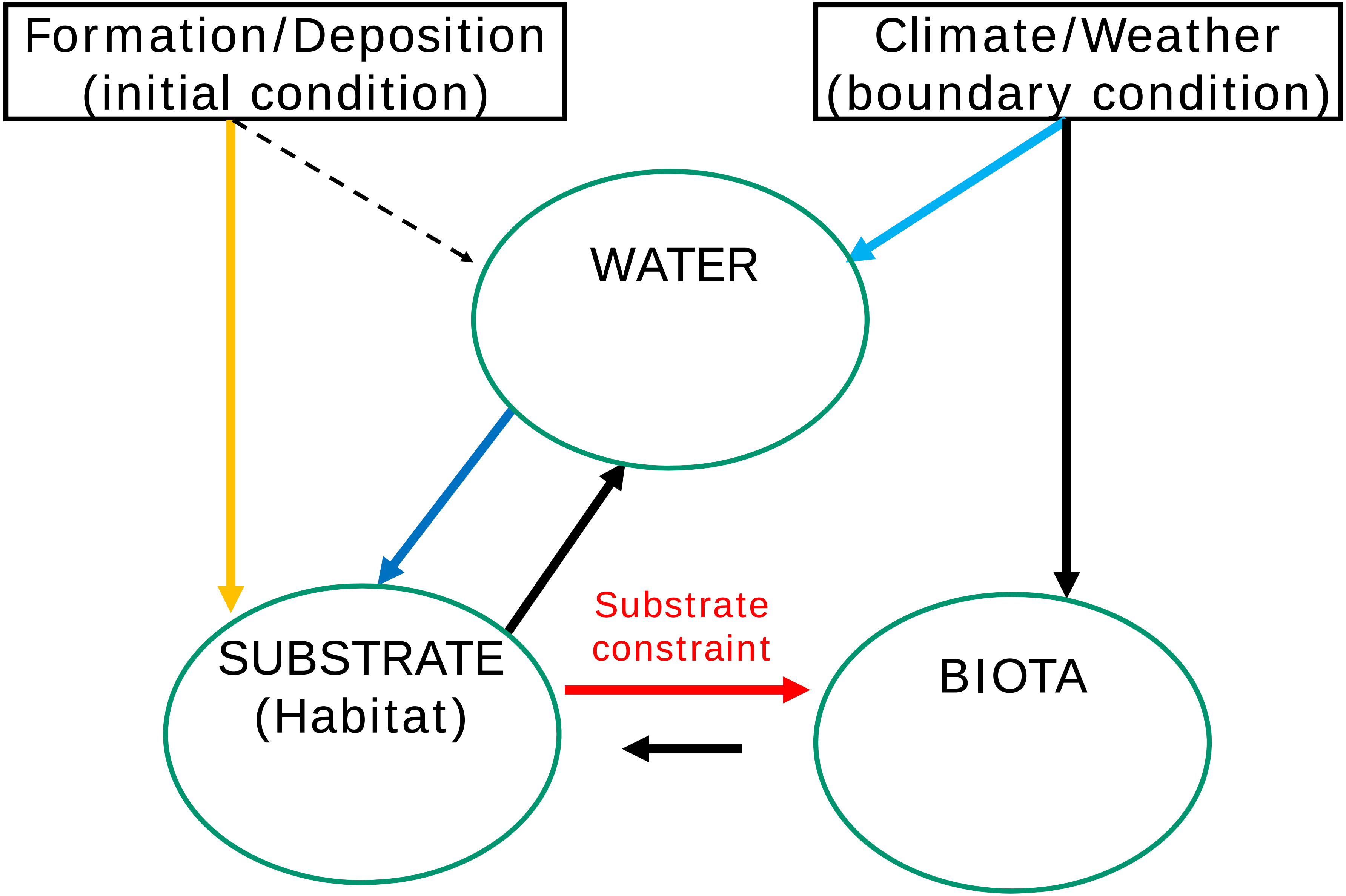

(b)
6 m
B
2 m
Red mud
1.5 m
A
Geosynthetic barrier



1000
100
10
1
0.1
0.01
0.001
Saturated hydraulic conductivity (m day -1)
1st quartile
Minimum
Median
Maximum
3rd quartile
Measured
Cosby
Jabro
Dane & Puckett
Puckett
Saxton

Plant water use - transpiration

- moisture deficit was dominant factor (75%)
- vapour pressure deficit explained 25% of transpiration
- shallow root system and low moisture retention soil factor influencing transpiration patterns
- Storage limitation of development due to initial condition



storage vs transport limited

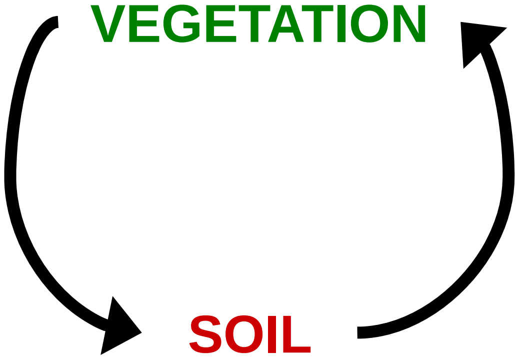
How can we link interacting feedback processes to landscape self-organisation?

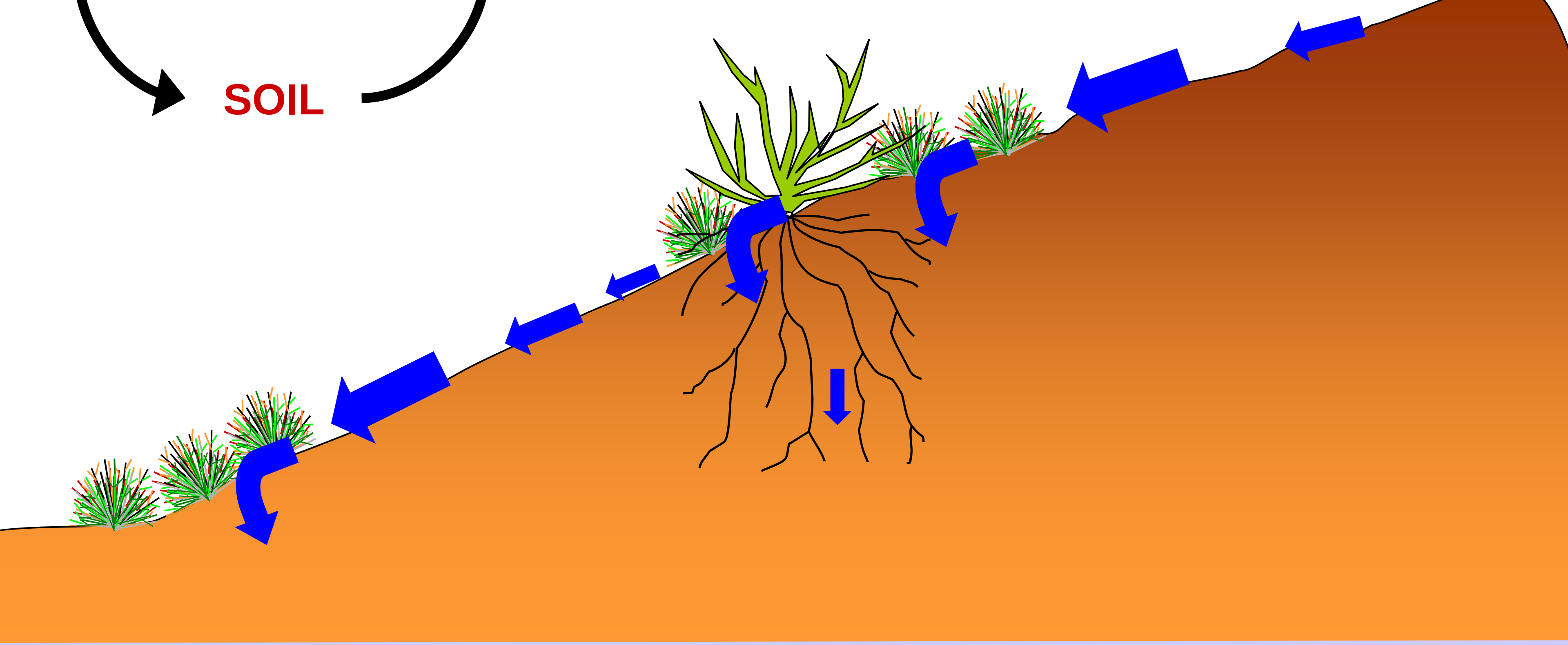
Example: Evolution of vegetation pattern

Vegetation pattern

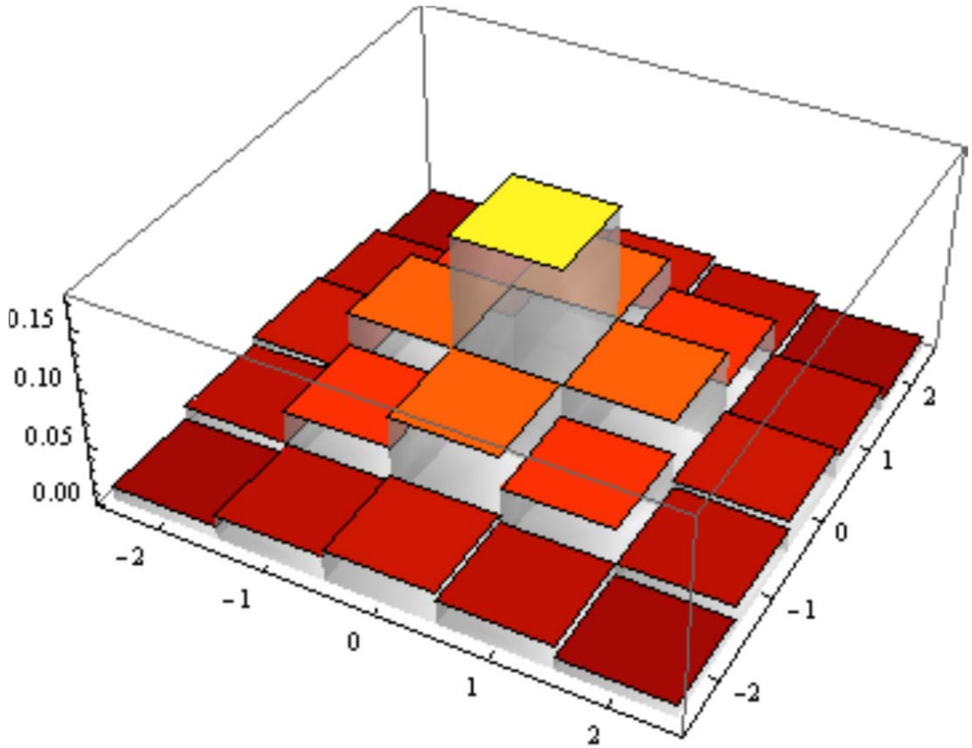
McGrath, Paik, Hinz, JGR, 2012

Soil – vegetation feedbacks



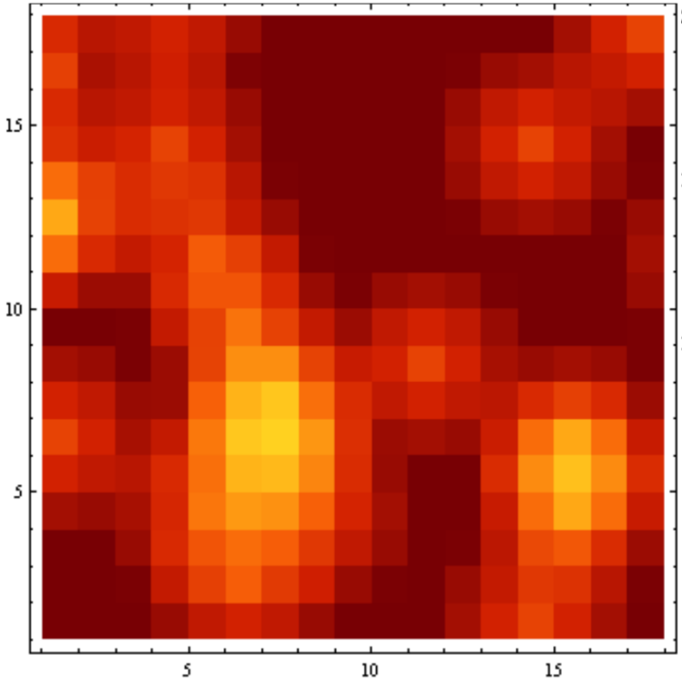


Spatial interactions

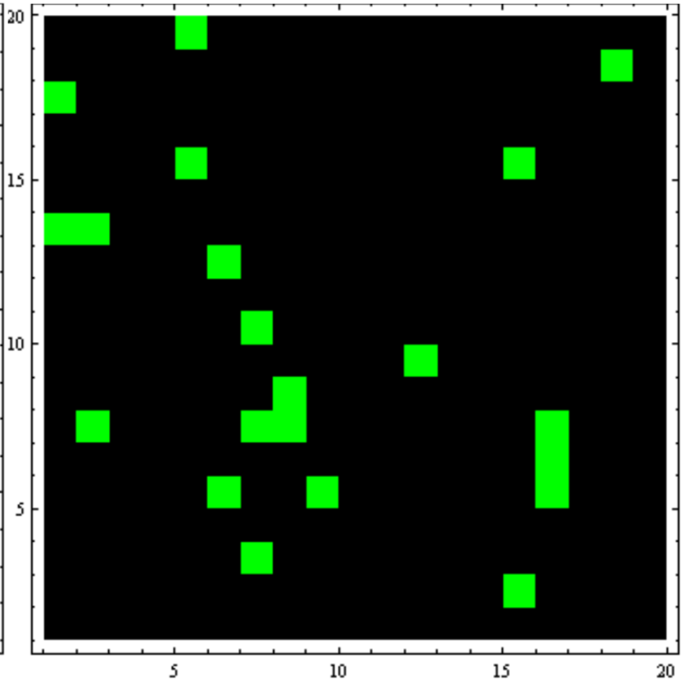


McGrath, Paik, Hinz, JGR, 2012

Facilitation

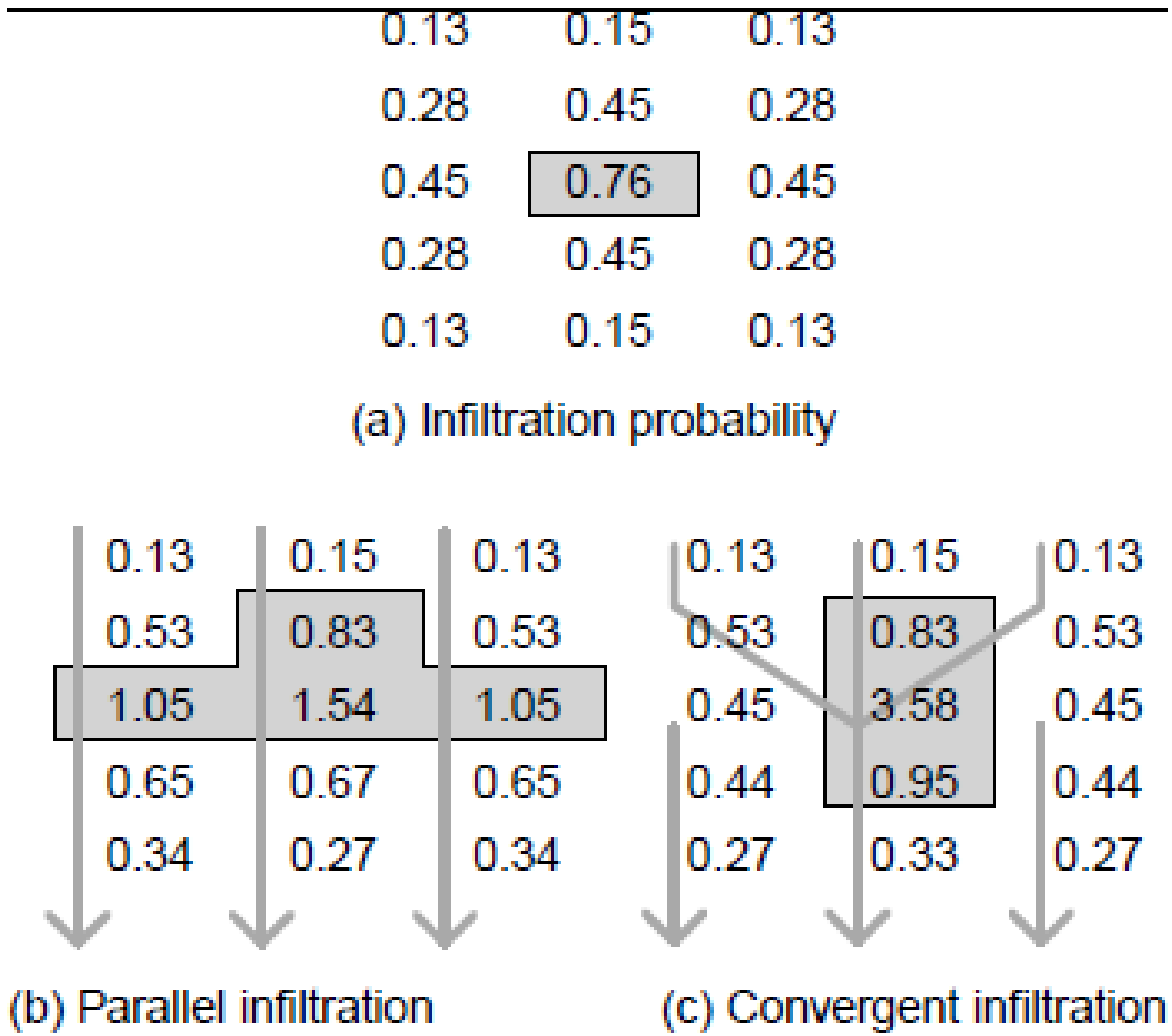


Soil hydraulic property

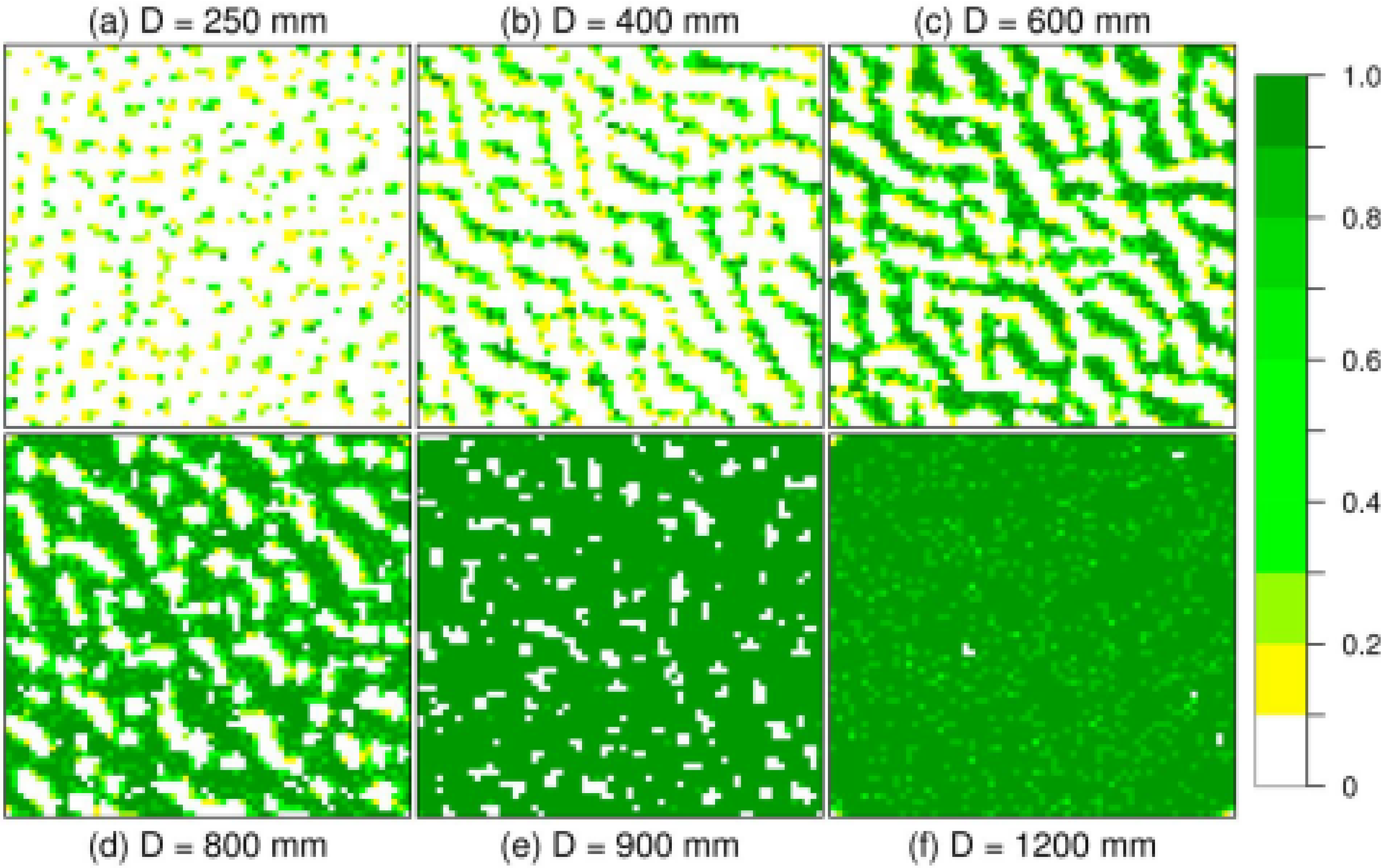


Plants

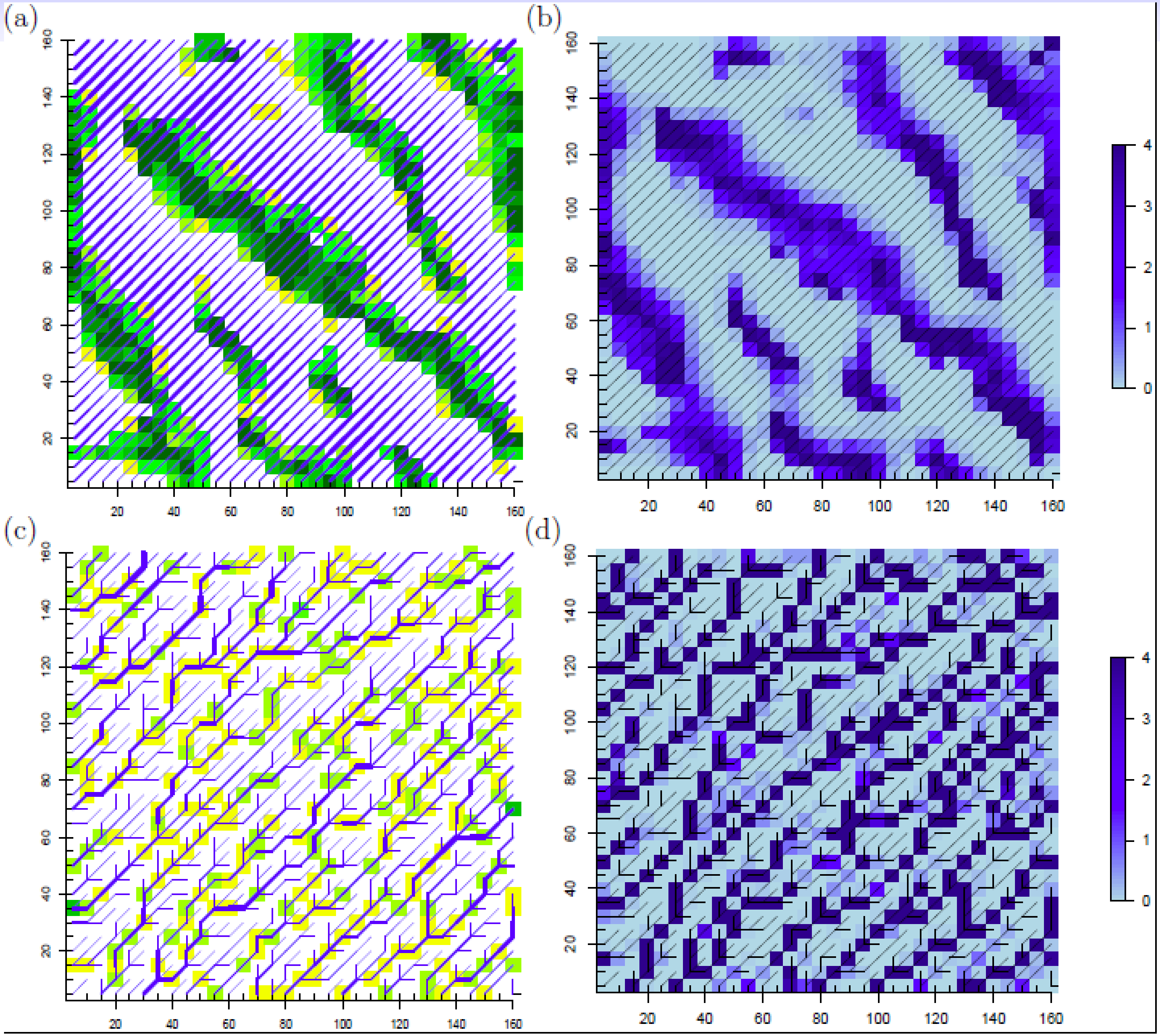
McGrath, Paik, Hinz, JGR, 2012



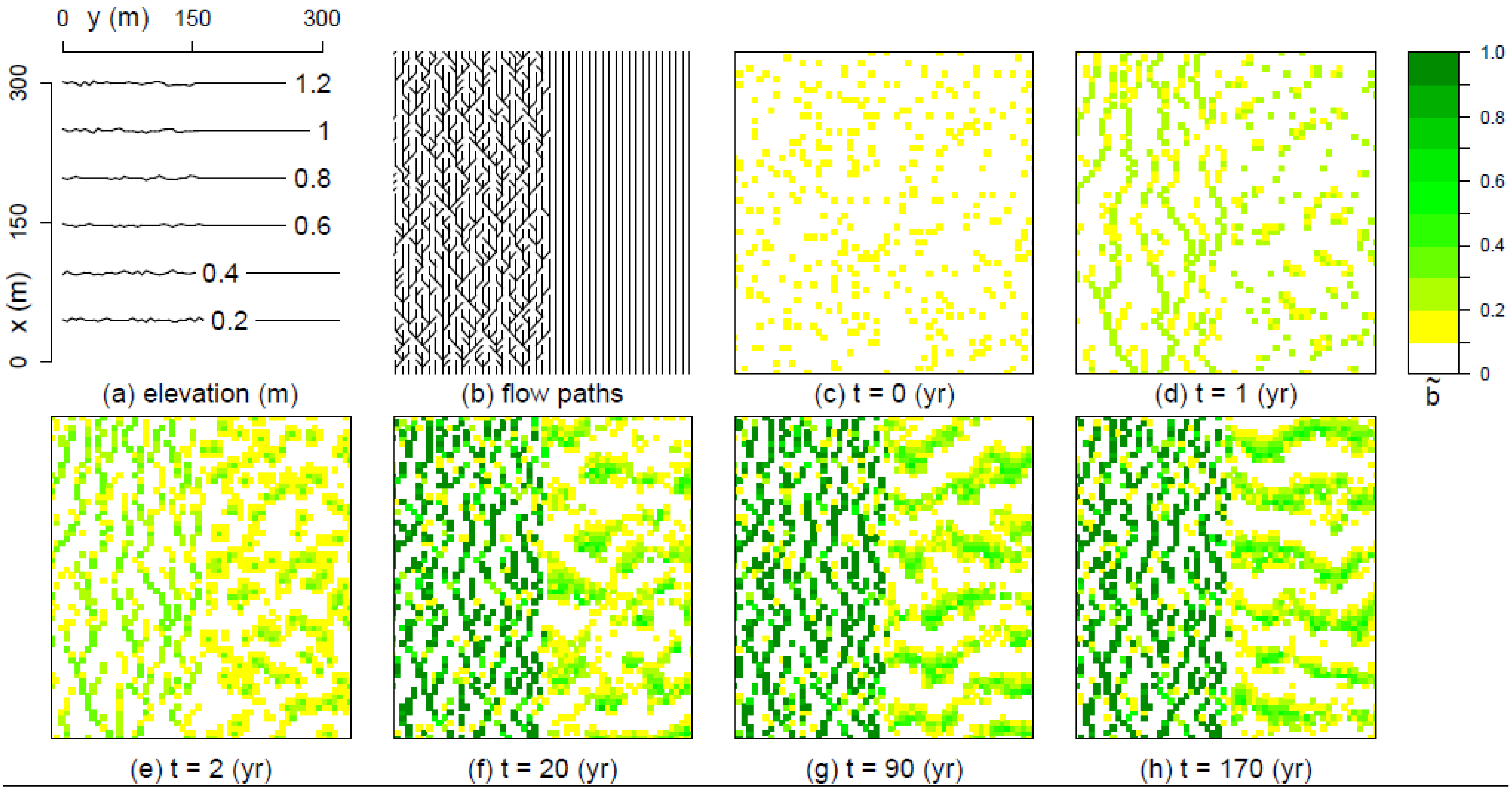
McGrath, Paik, Hinz, JGR, 2012



McGrath, Paik, Hinz, JGR, 2012

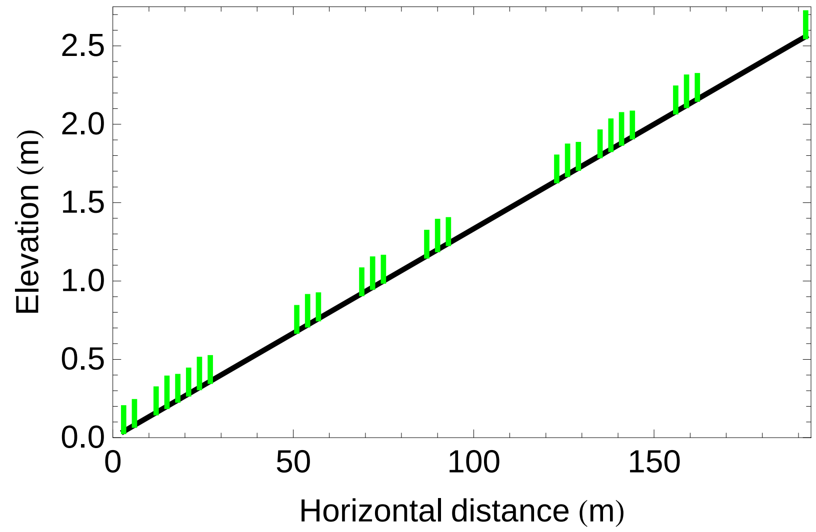


McGrath, Paik, Hinz, JGR, 2012

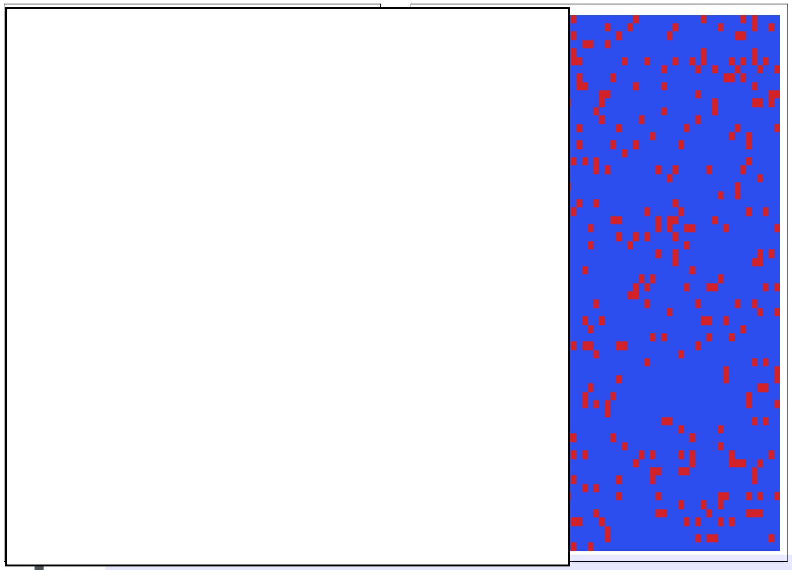


McGrath, Paik, Hinz, JGR, 2012

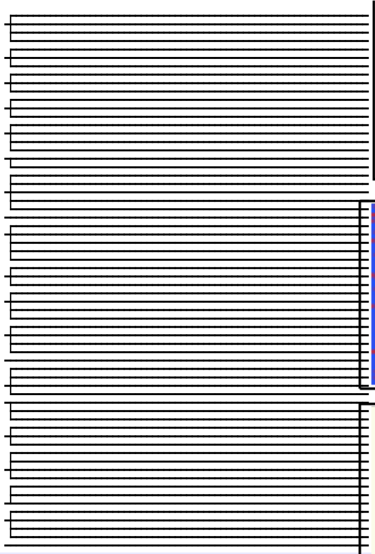
Co-evolution



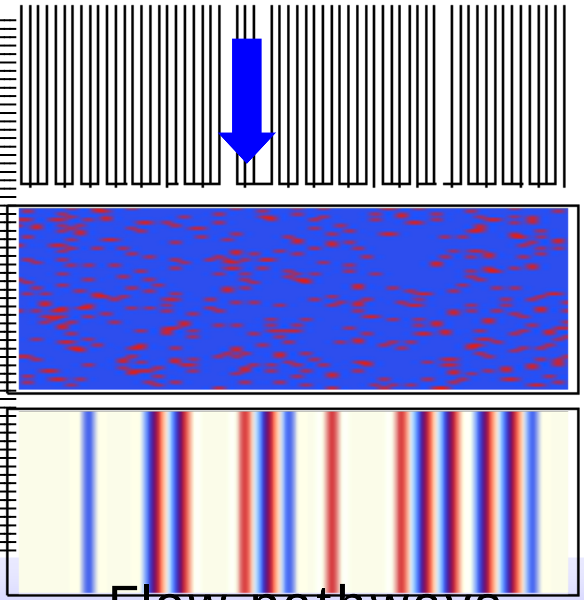
No diffusion



Micro-topography

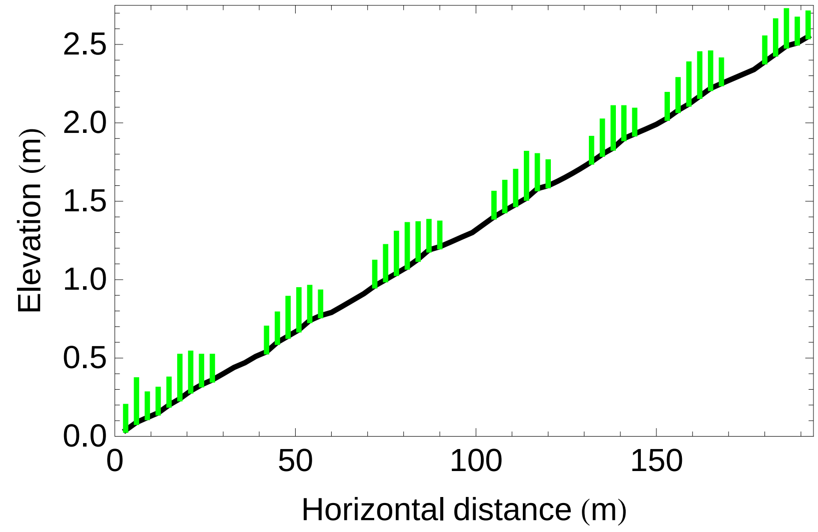


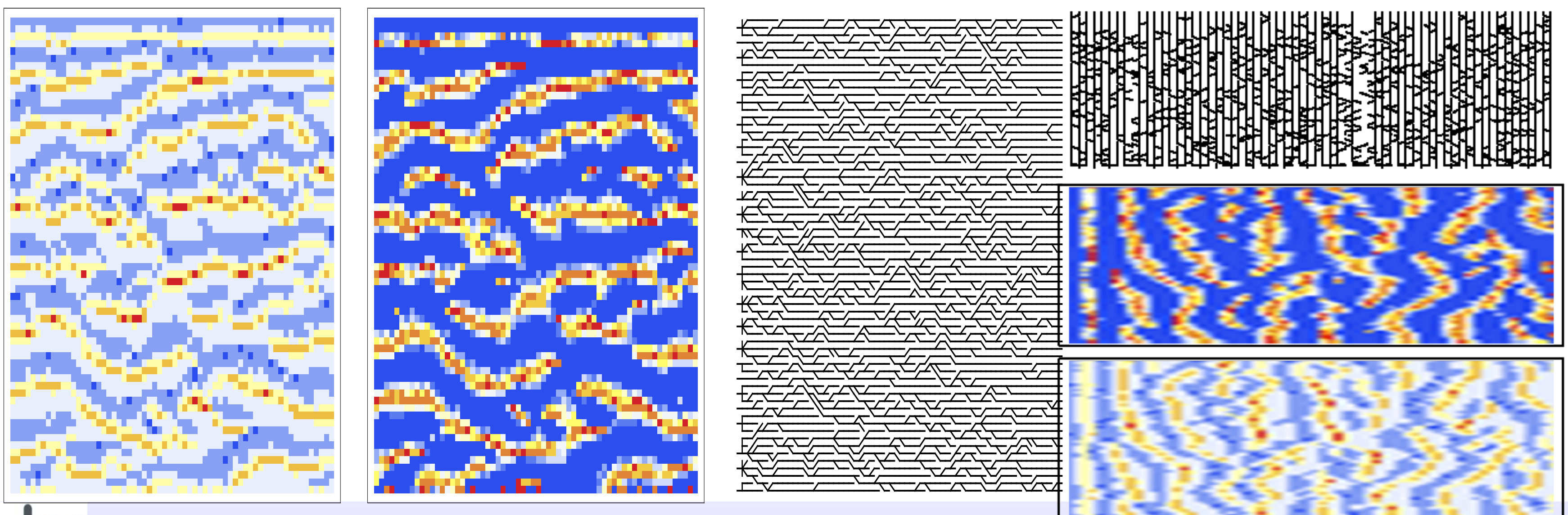
Vegetation



Flow pathways

Co-evolution



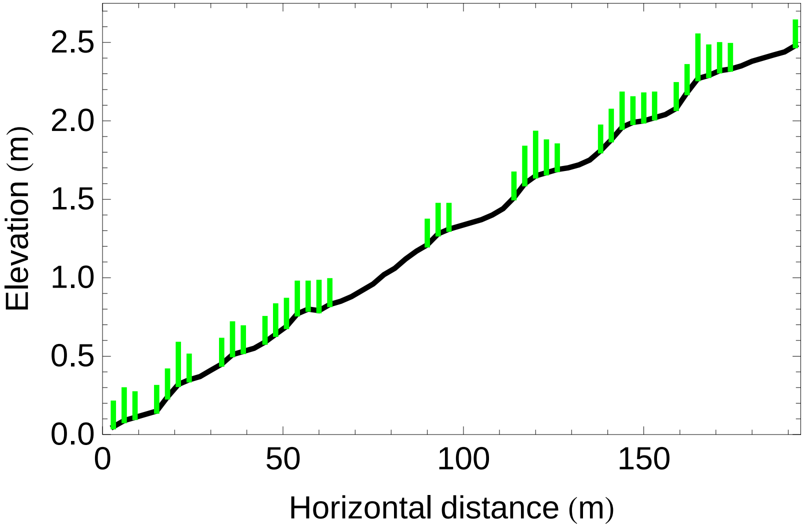


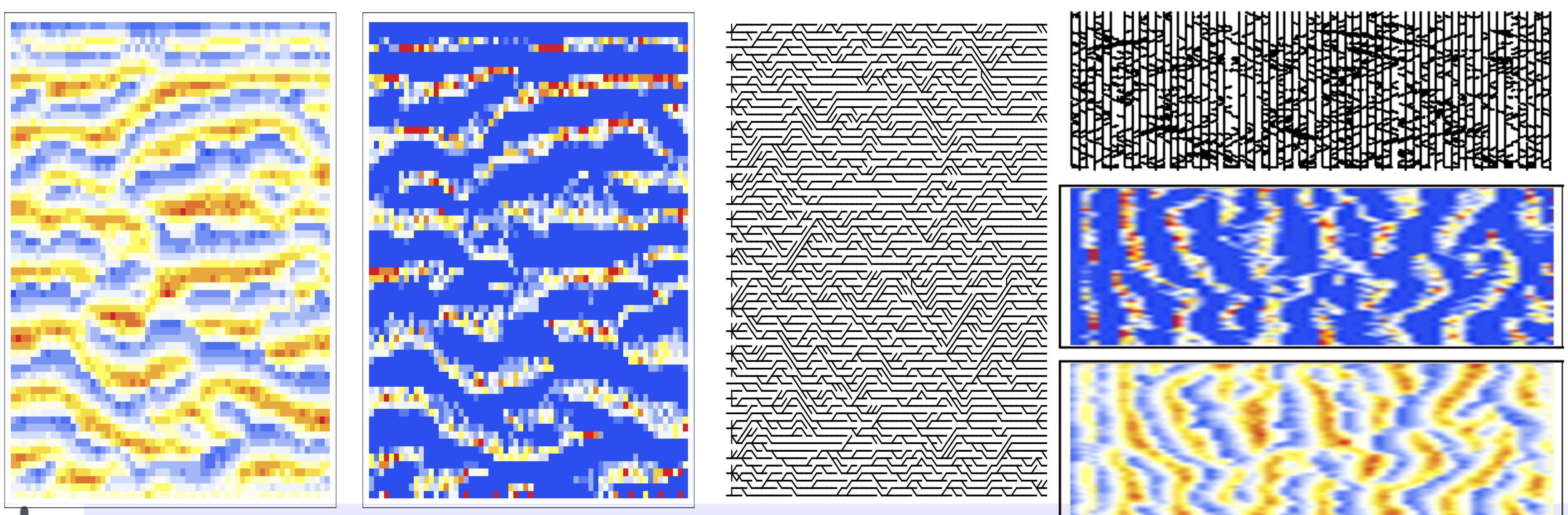
Micro-topography

Vegetation

Flow pathways

Co-evolution





Micro-topography

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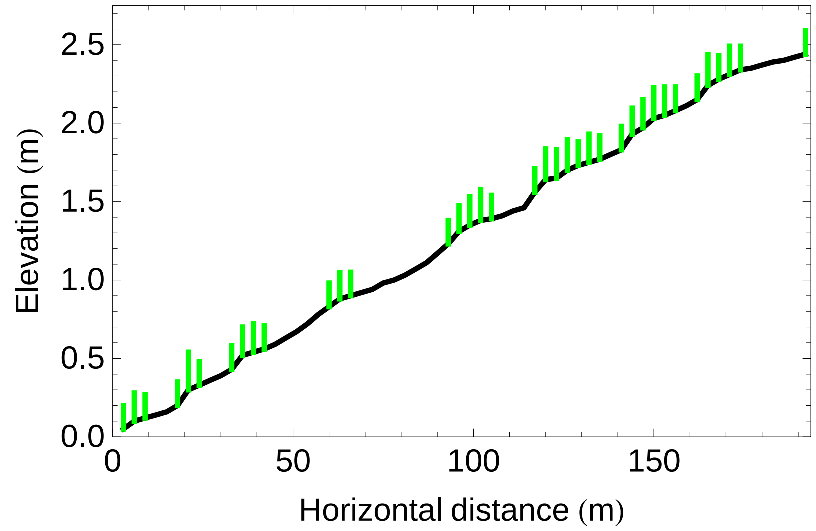
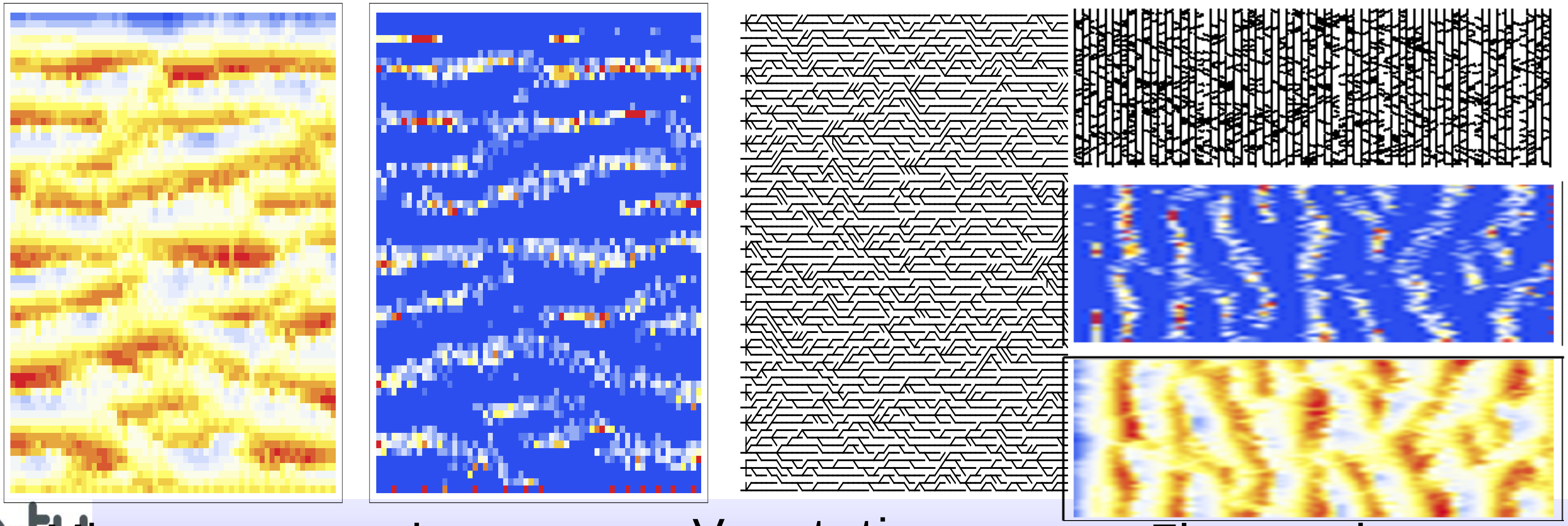
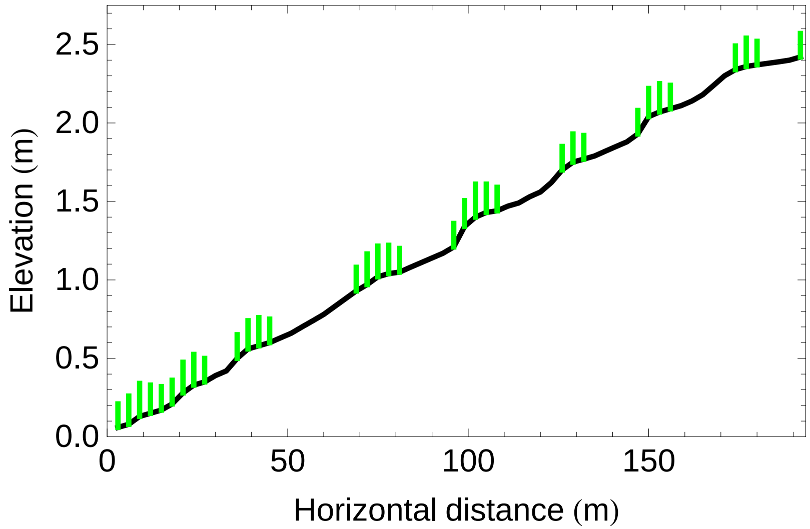
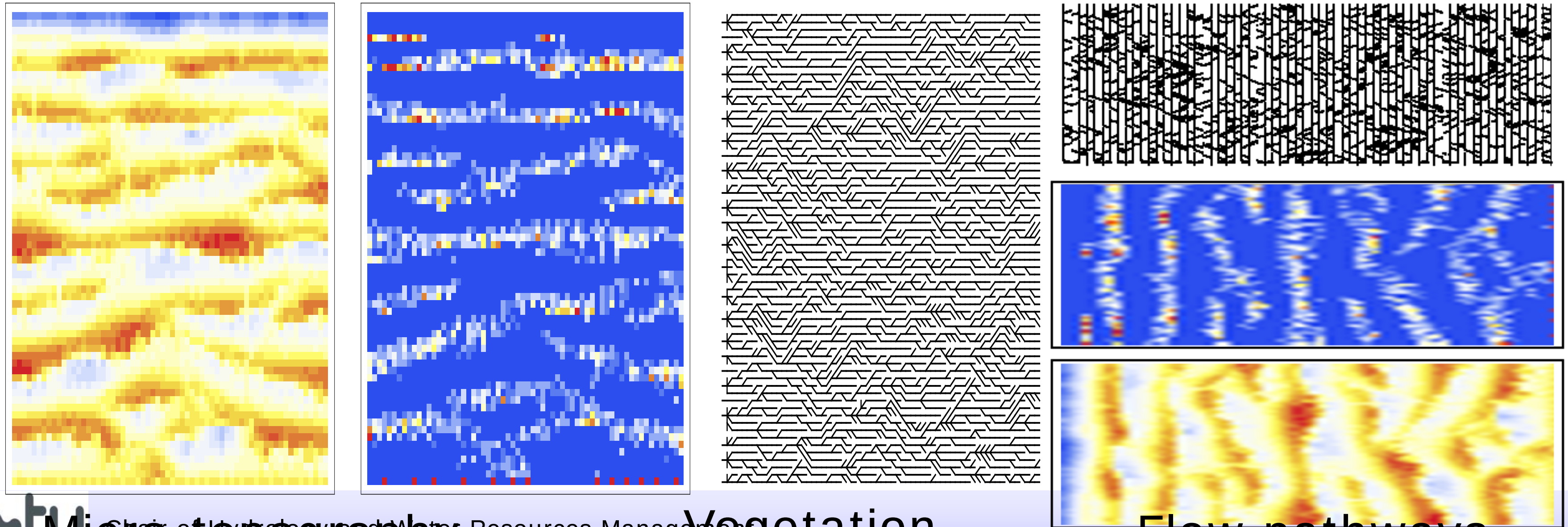




Micro-topography Vegetation Flow pathways

Co-evolution





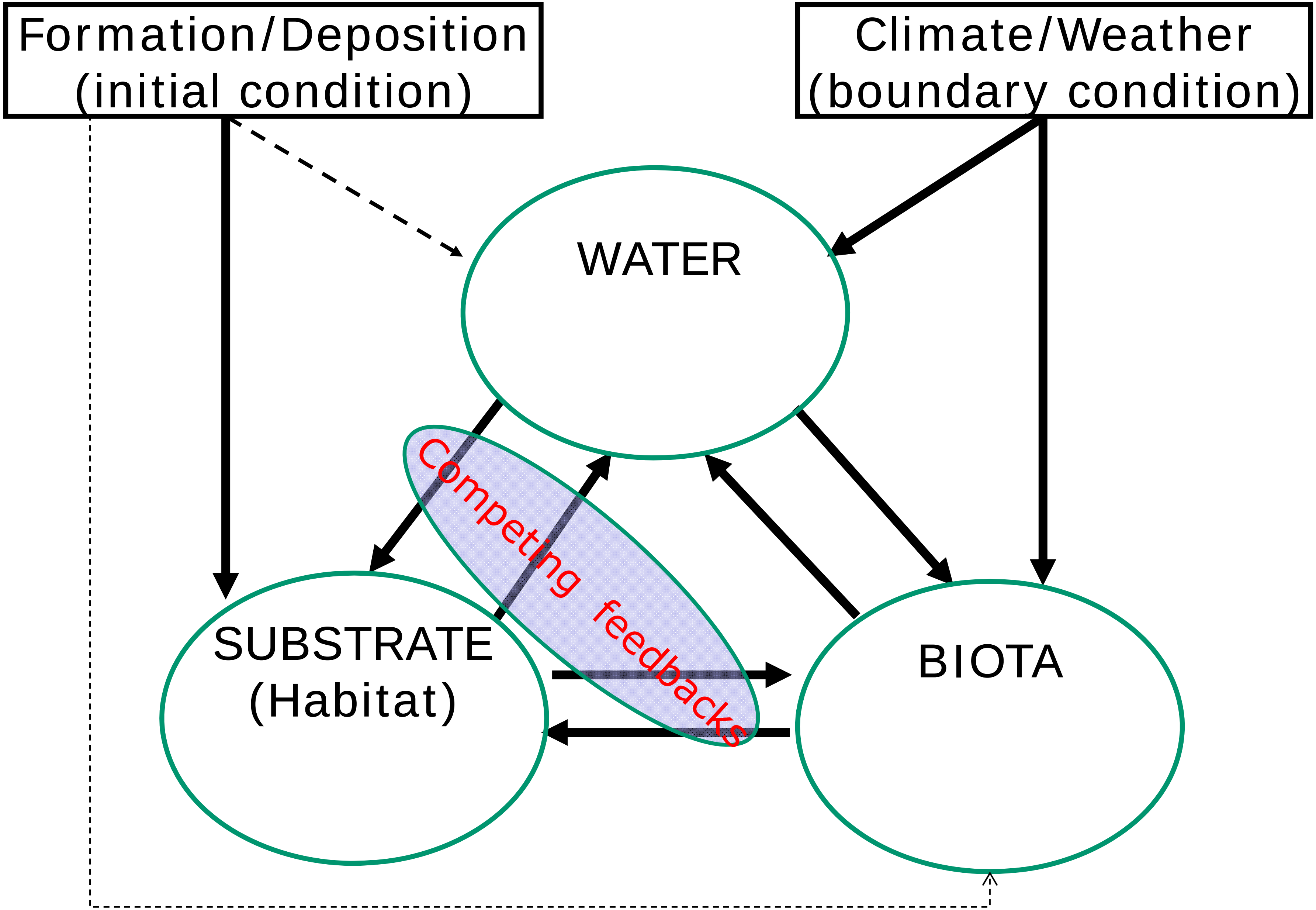
Micro-topography

Vegetation

Flow pathways

Is there a unifying framework for capturing the vastly diverse processes during early ecosystems development?

space Stochastic signals time



- Stochastic drivers for:
  - in space – initial condition
  - in time – atmospheric drivers (precipitation and evaporative demand)
  - Feedbacks may be controlled by both initial conditions and atmospheric drivers
  - Feedbacks may „compete“

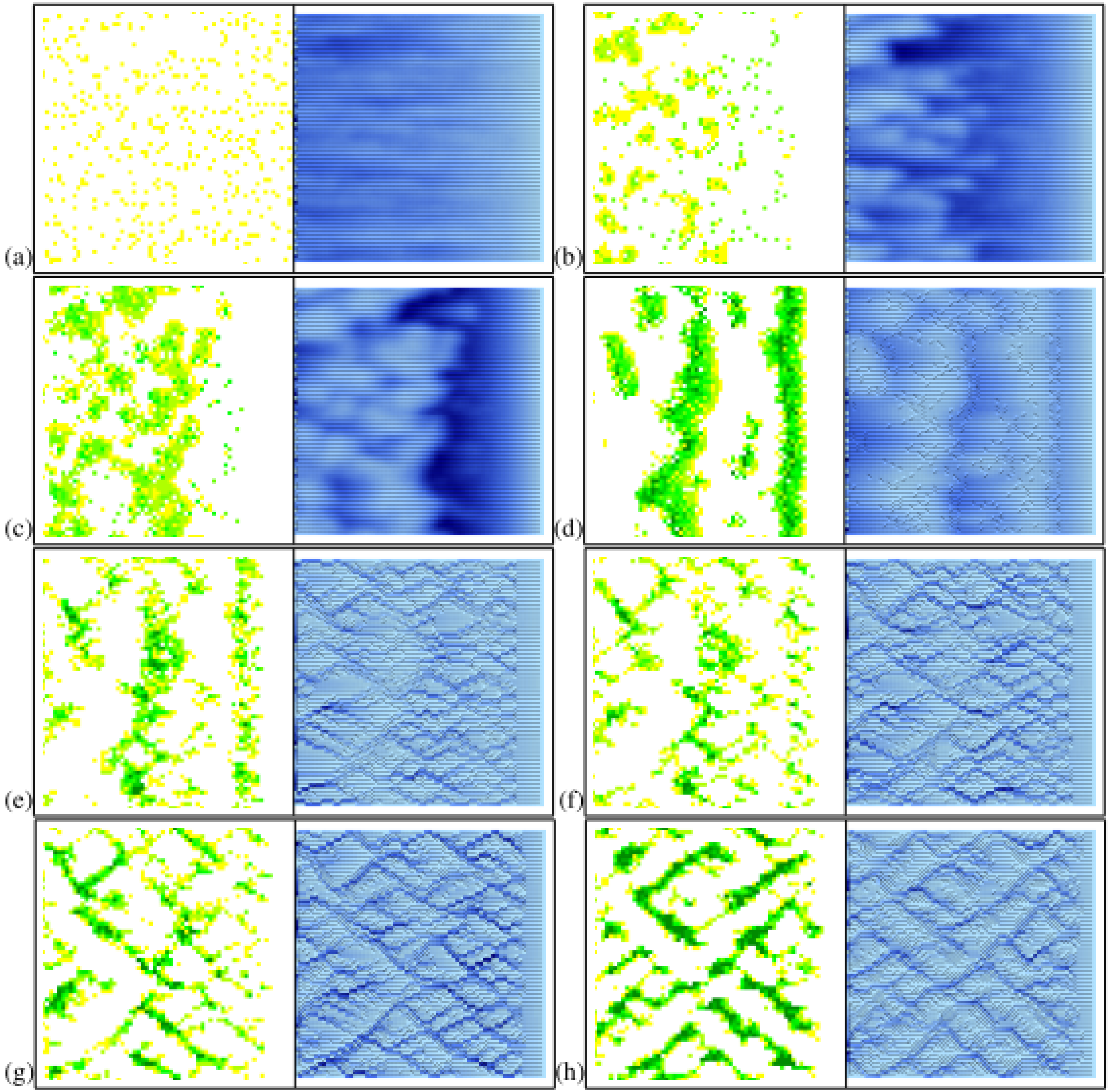
Common aspects

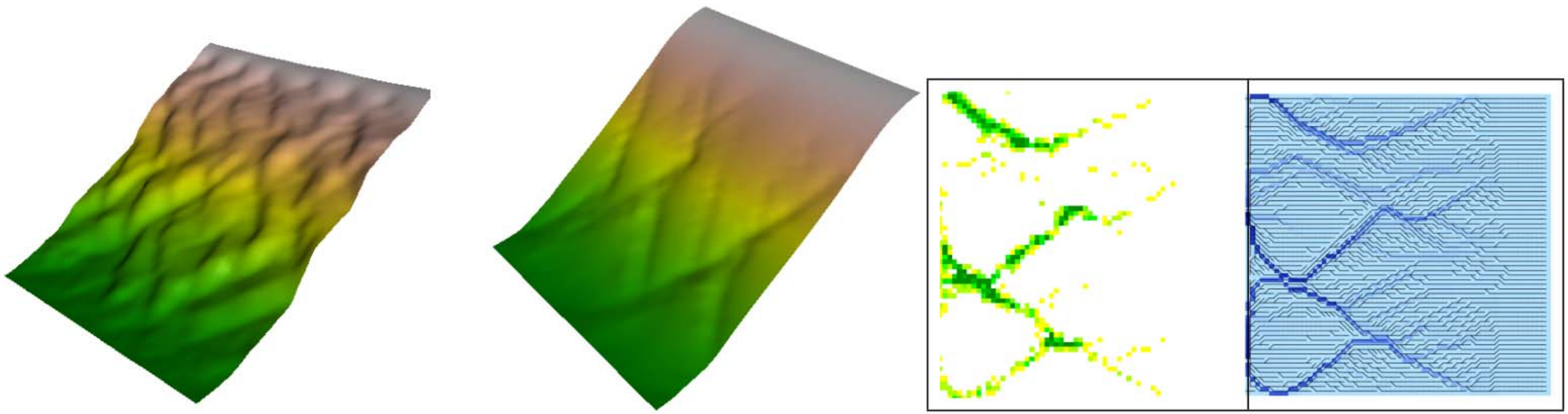
- The initial phase of ecosystems development is characterised:
  1. Evolution of self-organized (adaptive) mass and energy transfer networks
     - Drainage networks
     - Pore networks
     - Root networks
     - Food webs
     - Nutrient cycling

Common aspects

- The initial phase of ecosystems development is characterised by:
  2. Initial condition and atmospheric drivers (events) affecting trajectory and rate of development
     - Question: Under what circumstances will the initial conditions determine the stable state?

  3. Hybrid dynamics – a combination of discrete events (processes) and continuous processes (key word hot spots and hot moments)





(a) Case 1: topography (b) Case 2: topography (c) Case 2: Vegetation and drainage