TP B5 Struktureinflüsse auf C-Transformationen, C-Akkumulation und Mikroorganismen während der initialen Fließgewässergenese

- **Struktureinflüsse auf C-Transformation**
- **Alter org. Kohlenstoff**

L. Gerull, A. Frossard, U. Risse-Buhl, C. Mendoza-Lera, M.O. Gessner, F. Hagedorn, A. Dümig, W. Schaaf, S. Nii-Annang, M. Mutz

SFB/TRR 38 Strukturen und Prozesse der initialen Ökosystemgenese

b-tu Brandenburgische Technische Universität Cottbus

IGB

WSL

Technische Universität München

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

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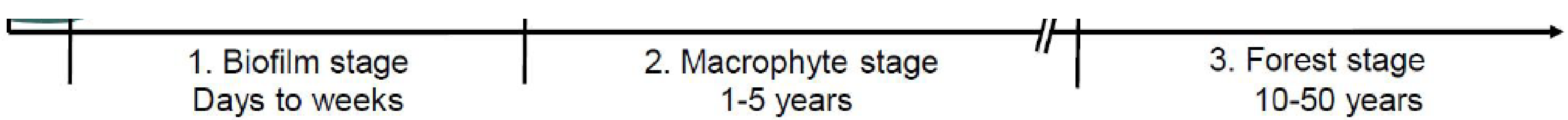
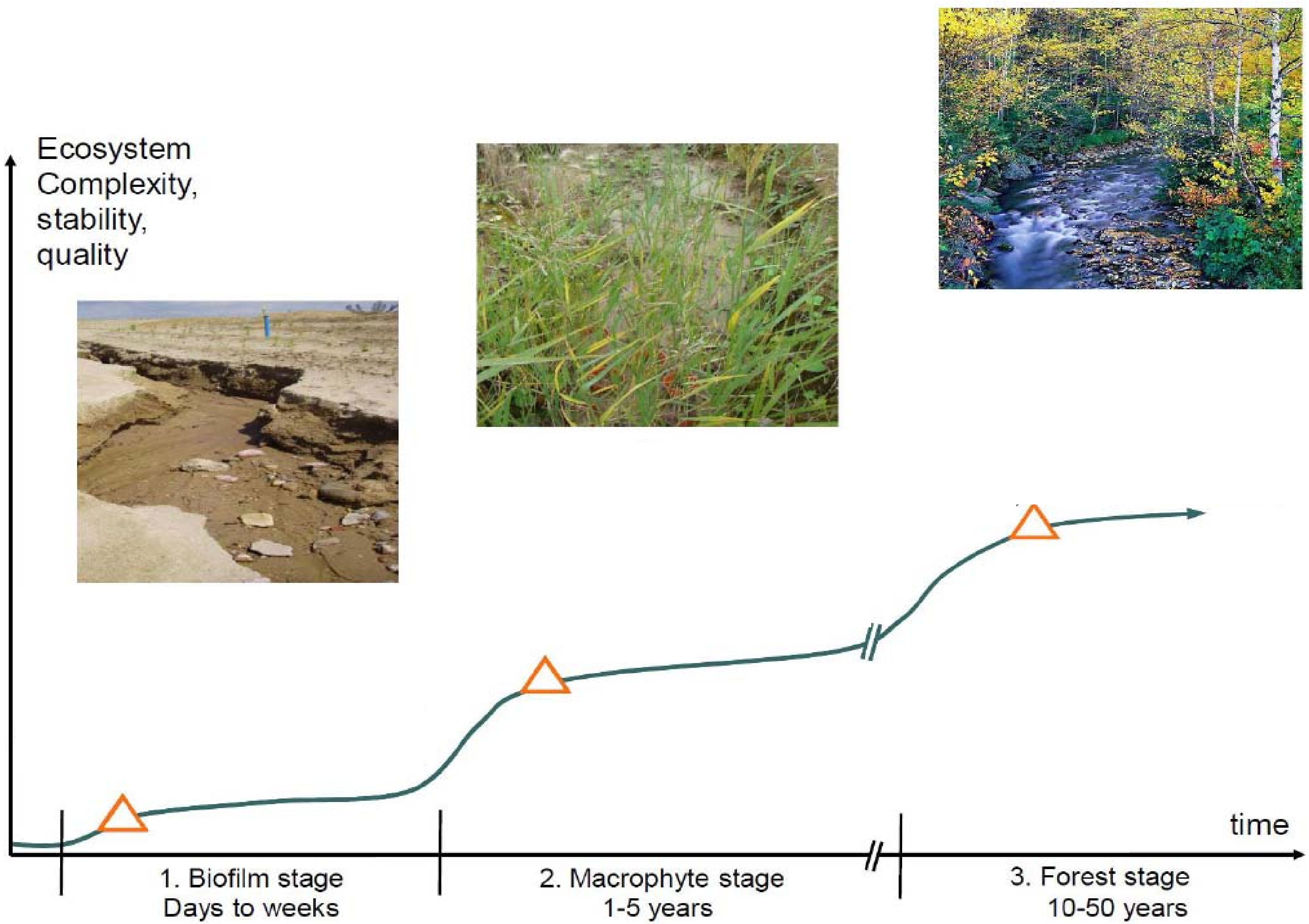


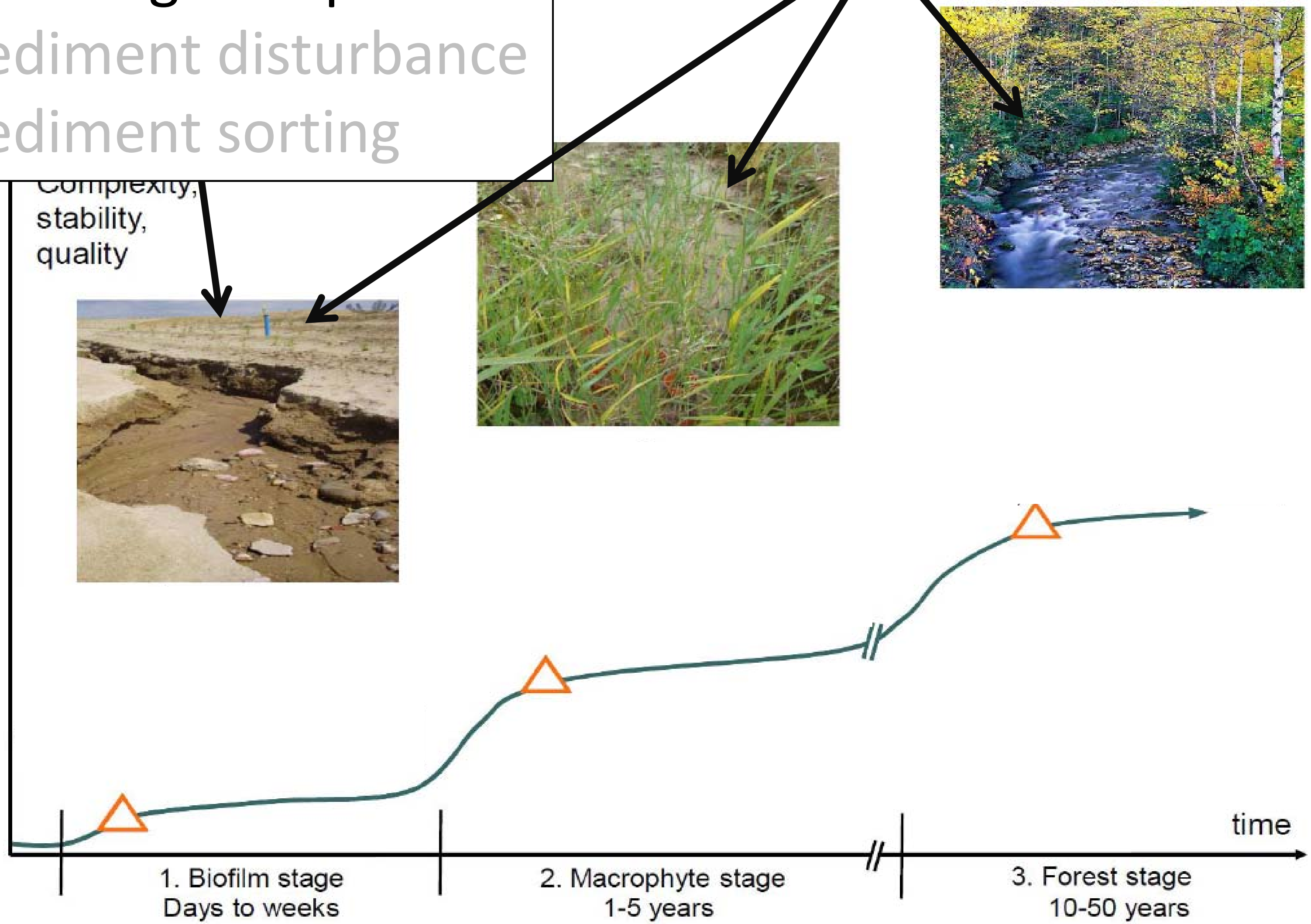
Fisher et al., 1982; Grimm 1994; Mutz et al., 2002; Milner & Gloyne-Phillips, 2005; Benlap et al., 2005; Langhans & Tockner, 2006; Langenheder et al., 2006.



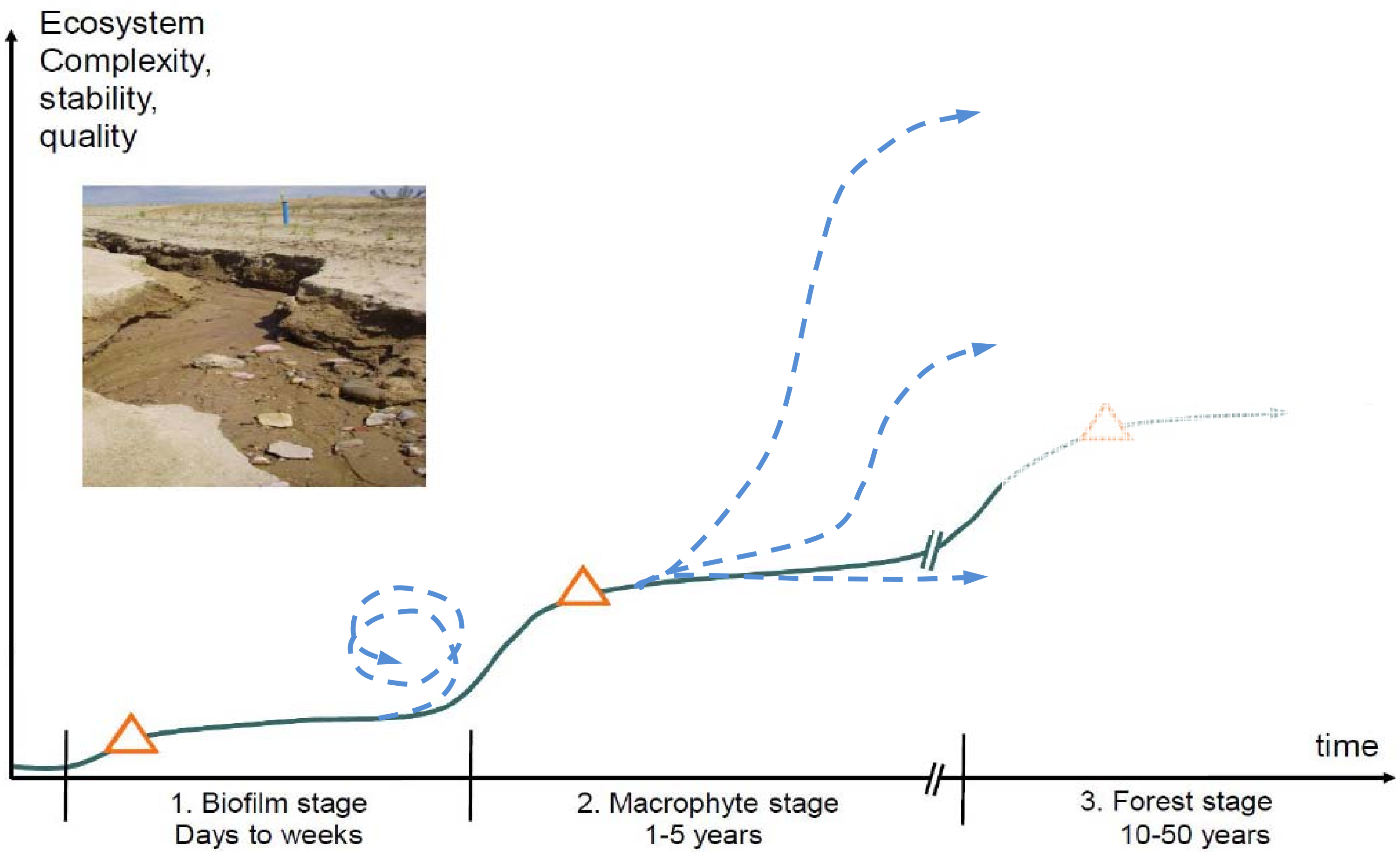
Fisher et al., 1982; Grimm 1994; Mutz et al., 2002; Milner & Gloyne-Phillips, 2005; Benlap et al., 2005; Langhans & Tockner, 2006; Langenheder et al., 2006.

- Water availability along flow path
- Sediment disturbance
- Sediment sorting

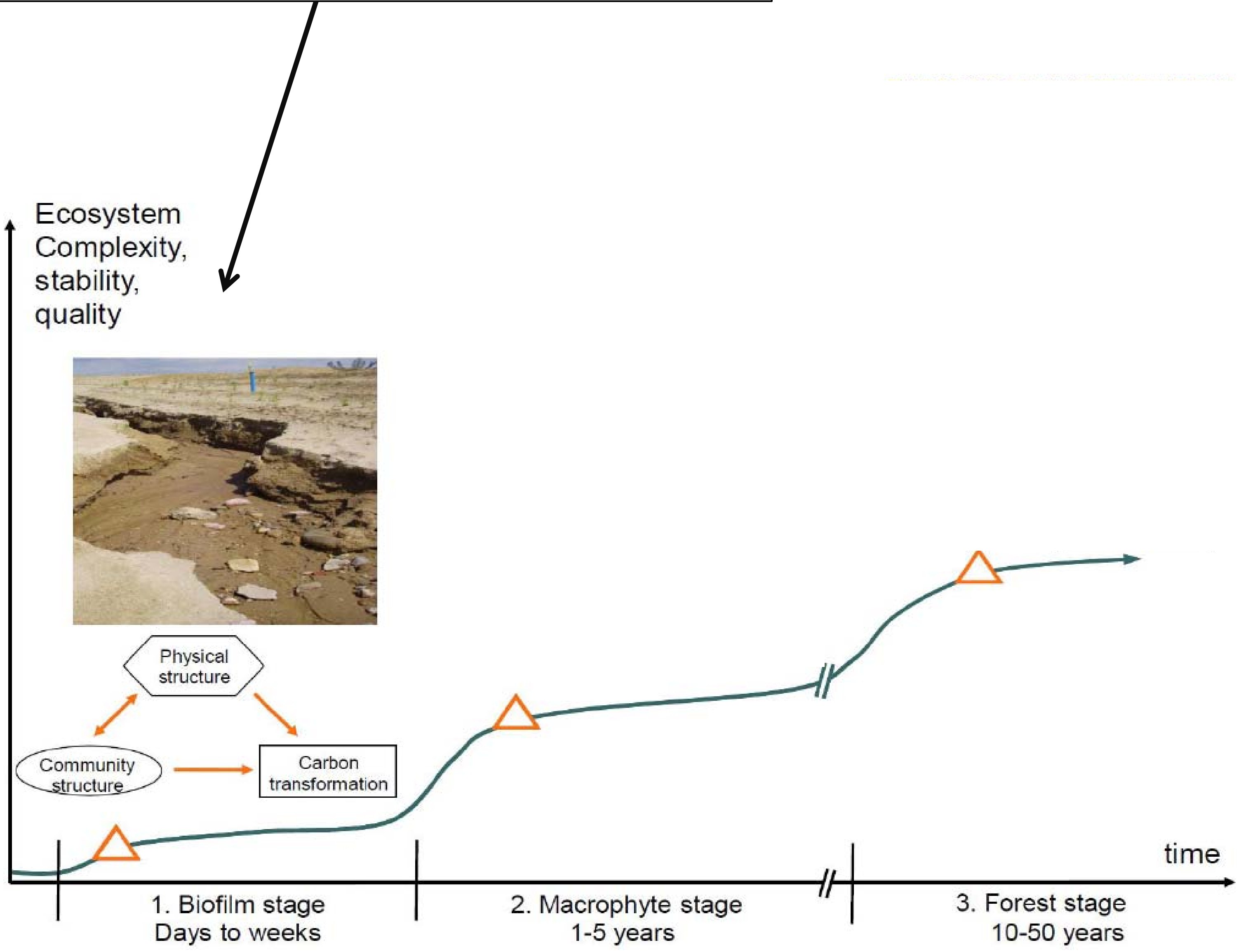
- Quality & quantity org. C



2012

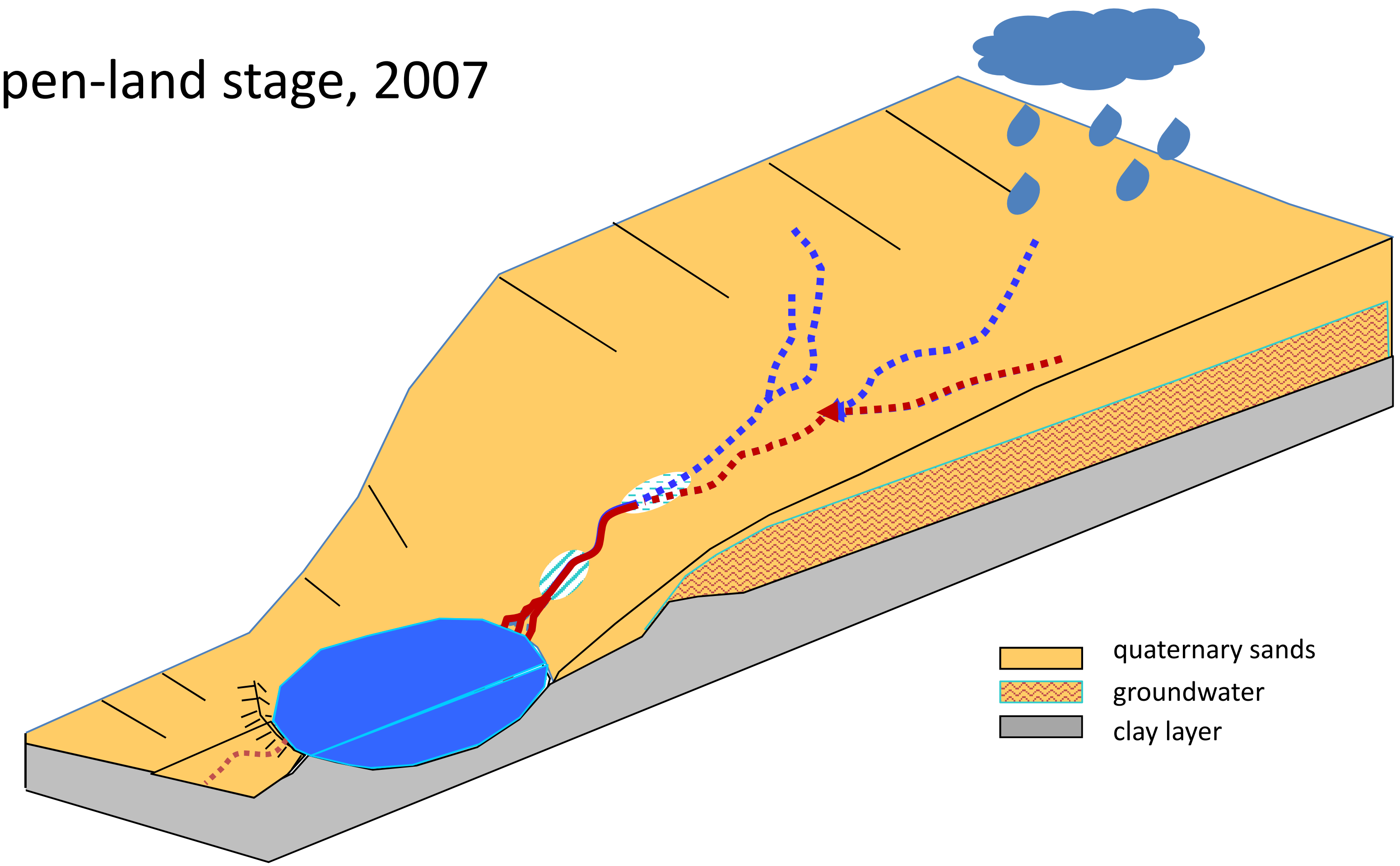

Ecosystem
Complexity,
stability,
quality
time
1. Biofilm stage
Days to weeks
2. Macrophyte stage
1-5 years
3. Forest stage
10-50 years

Water availability along flow path

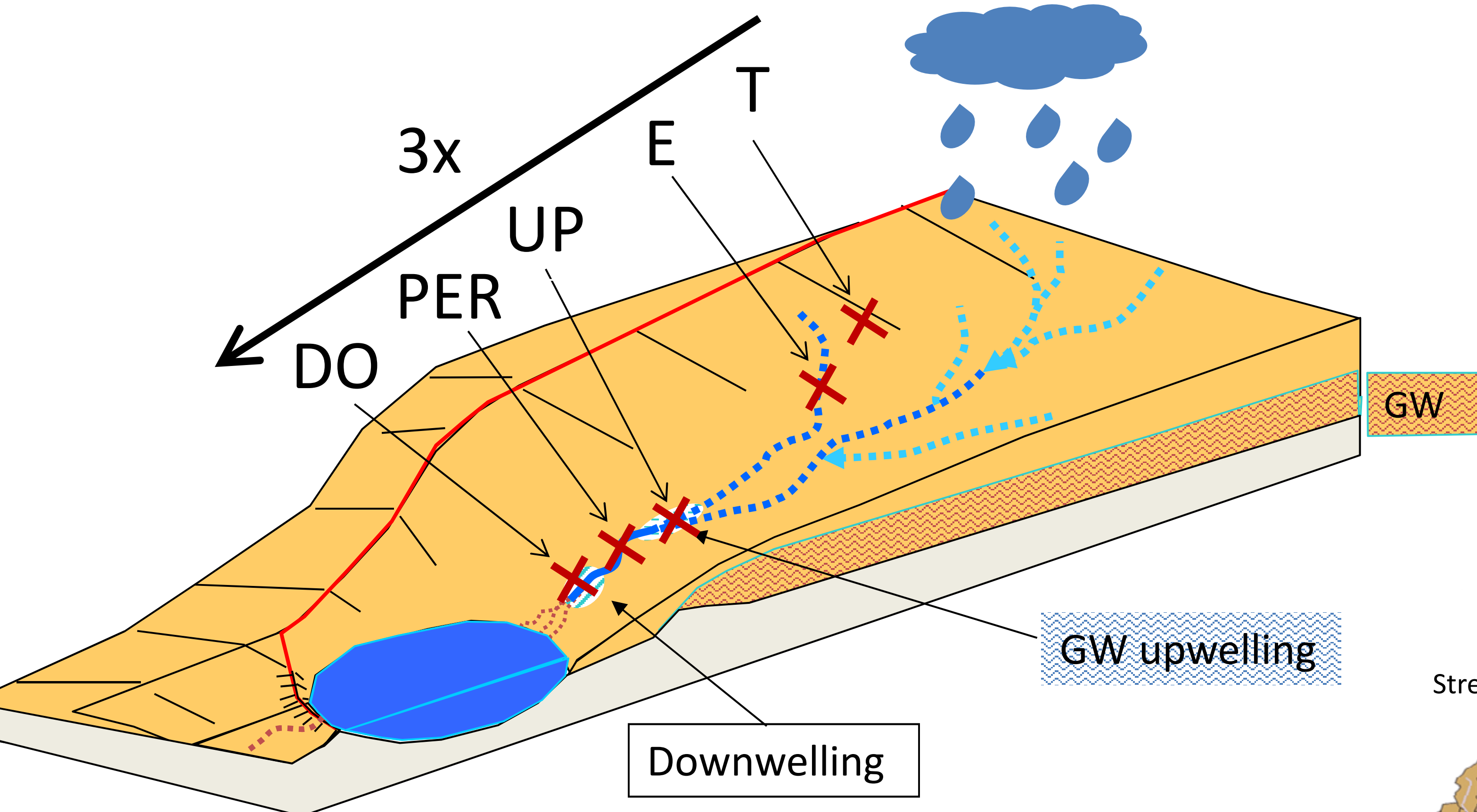


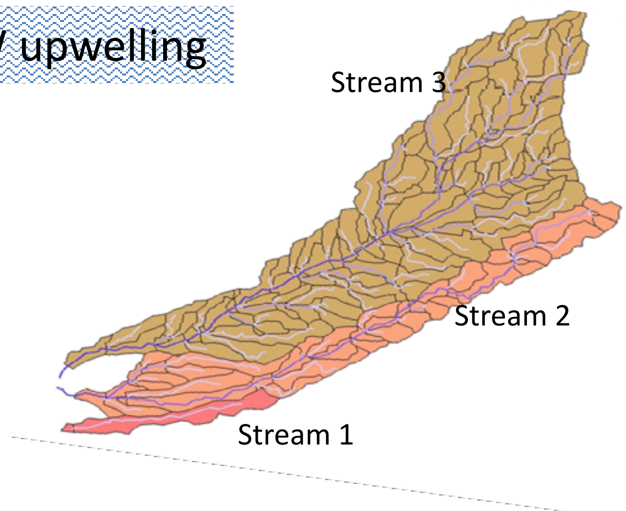
Significance of water avialability along flow path linking terrestrial and aquatic habitats

Open-land stage, 2007

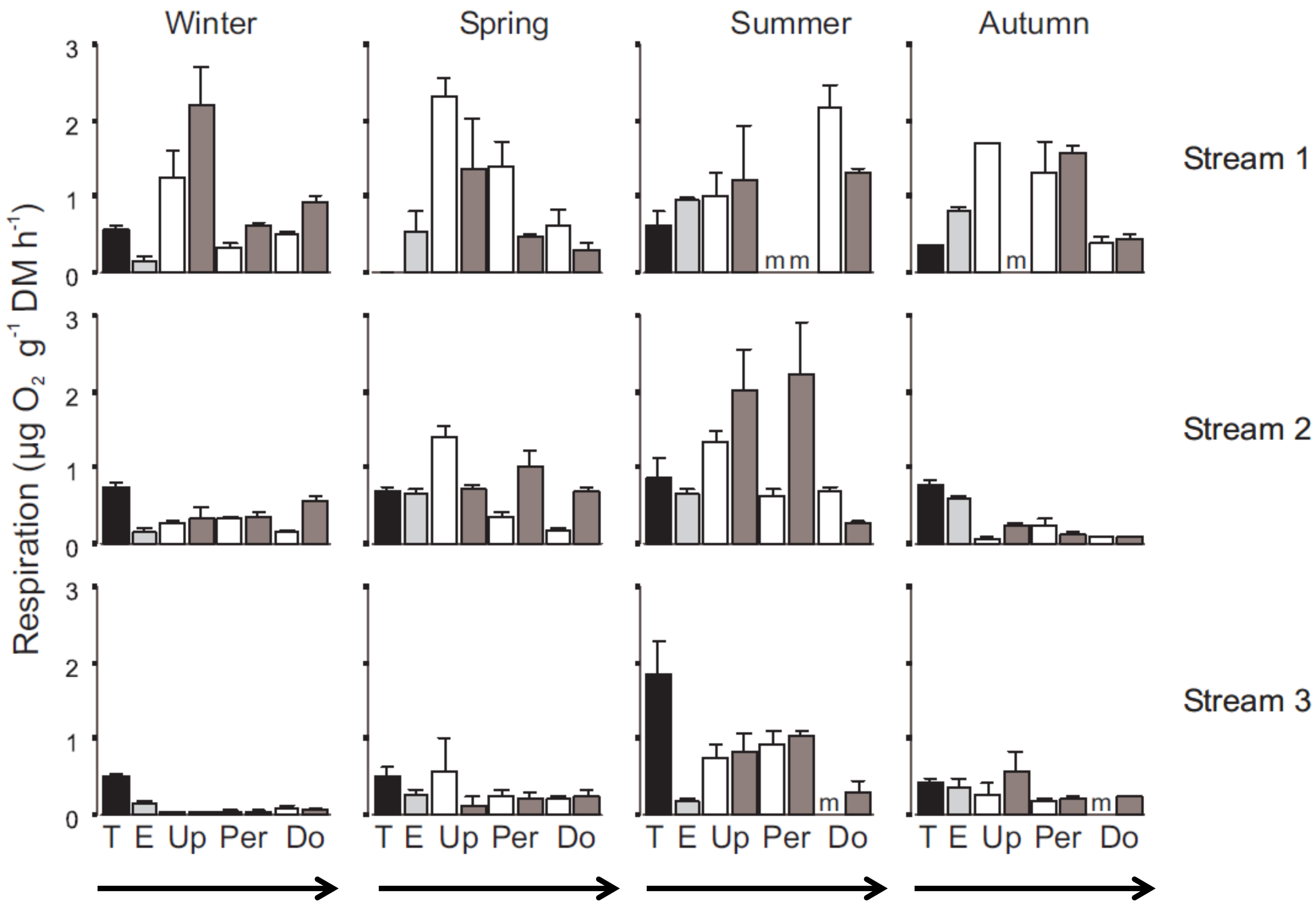


Significance of water avialability along flow path





No significance of water avialability along flow path



Sites along flowpath

Gerull, L., A. Frossard, M.O. Gessner & M. Mutz (2011). Variability of heterotrophic metabolism in small stream corridors of an early successional watershed, Journal of Geophysical Research, 116: G02012. DOI:10.1029/2010JG001516.

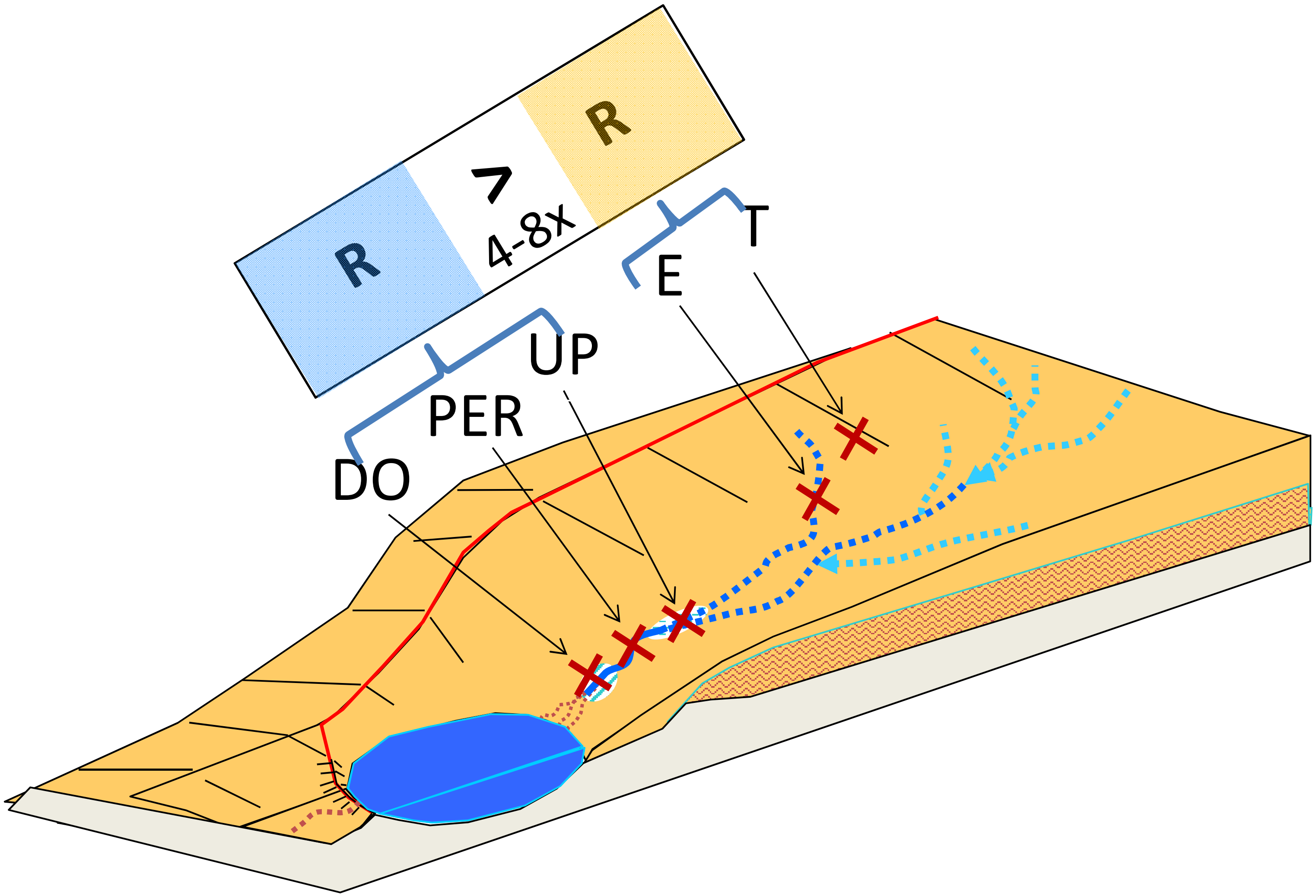
Low level of overal activity

Stream name	Stream characteristics and location	Respiration rate ($g\ O_2\ m^{-2}\ d^{-1}$)	Reference
Chicken Creek	Sand bed, early successional	0.56 (0.0–3.2)	This study
Fort River	Sand bed, temperate	4.08[a]	*Fisher* [1977]
Sycamore Creek	Sand bed, Sonoran desert	4.1	*Grimm and Fisher* [1984]
Hassayampa Creek	Sand bed, Sonoran desert	(1.33–1.5)	*Uehlinger et al.* [2002]
Rattlesnake Springs	Sand bed, cold desert	7.8[a]	*Cushing and Wolf* [1984]
Creightons Creek	Sand bed, warm temperate, south–east Australia	(0.6–3.7)	*Atkinson et al.* [2008]
Various ($n = 64$)		16 (2.44–68.1)[a]	*Battin et al.* [2008]

Gerull, L., A. Frossard, M.O. Gessner & M. Mutz (2011). Variability of heterotrophic metabolism in small stream corridors of an early successional watershed, Journal of Geophysical Research, 116: G02012. DOI:10.1029/2010JG001516.

Catchment level, comparing terrestrial and aquatic habitats

Stream corridors are **metabolic hot spots**



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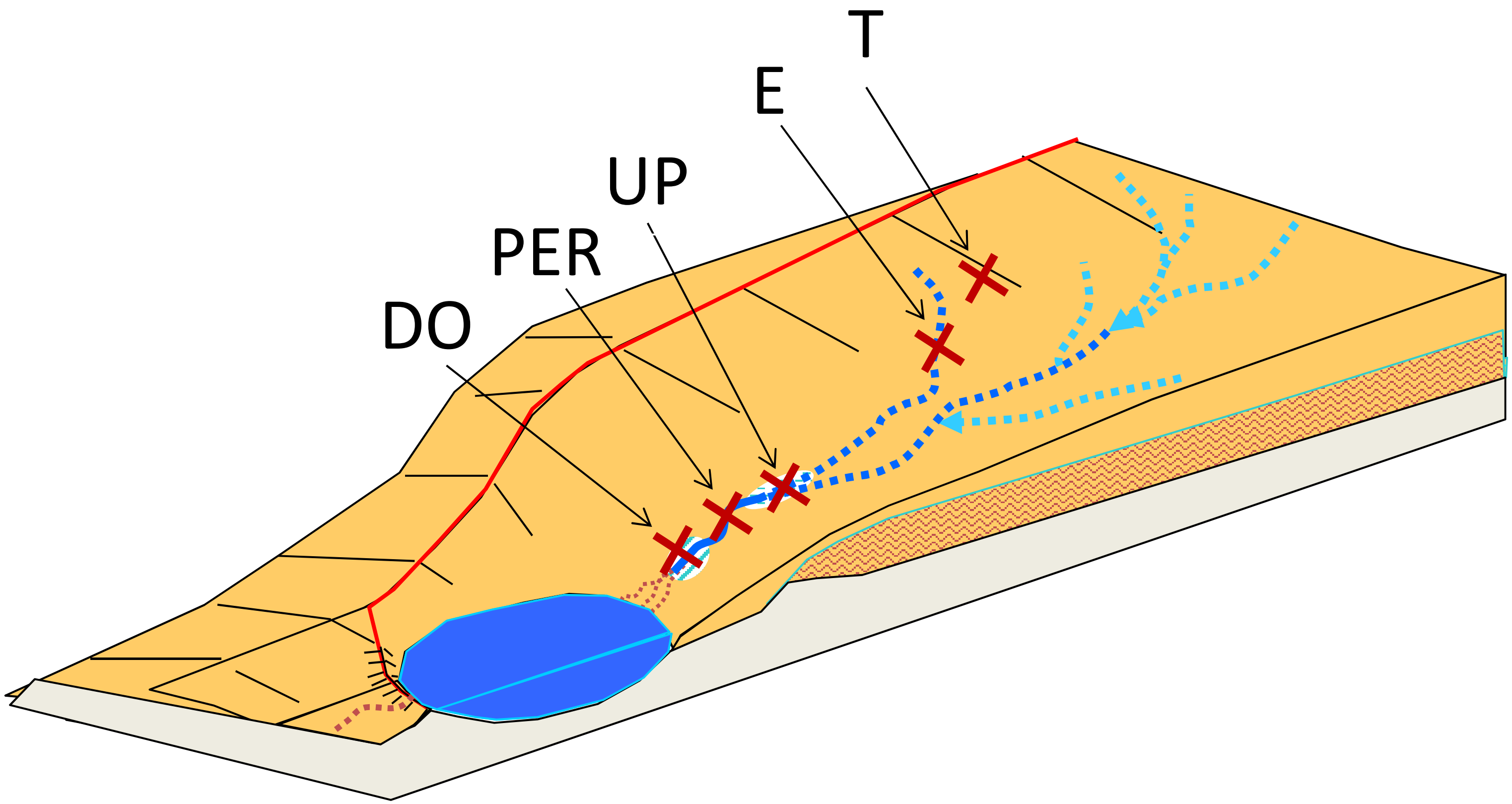
Catchment level, comparing terrestrial and aquatic habitats

Perennial streams ~ 5 % of respiration in catchment

→ **Hot moments in terrestrial soil !!!**

(~ 100 days of wet conditions)



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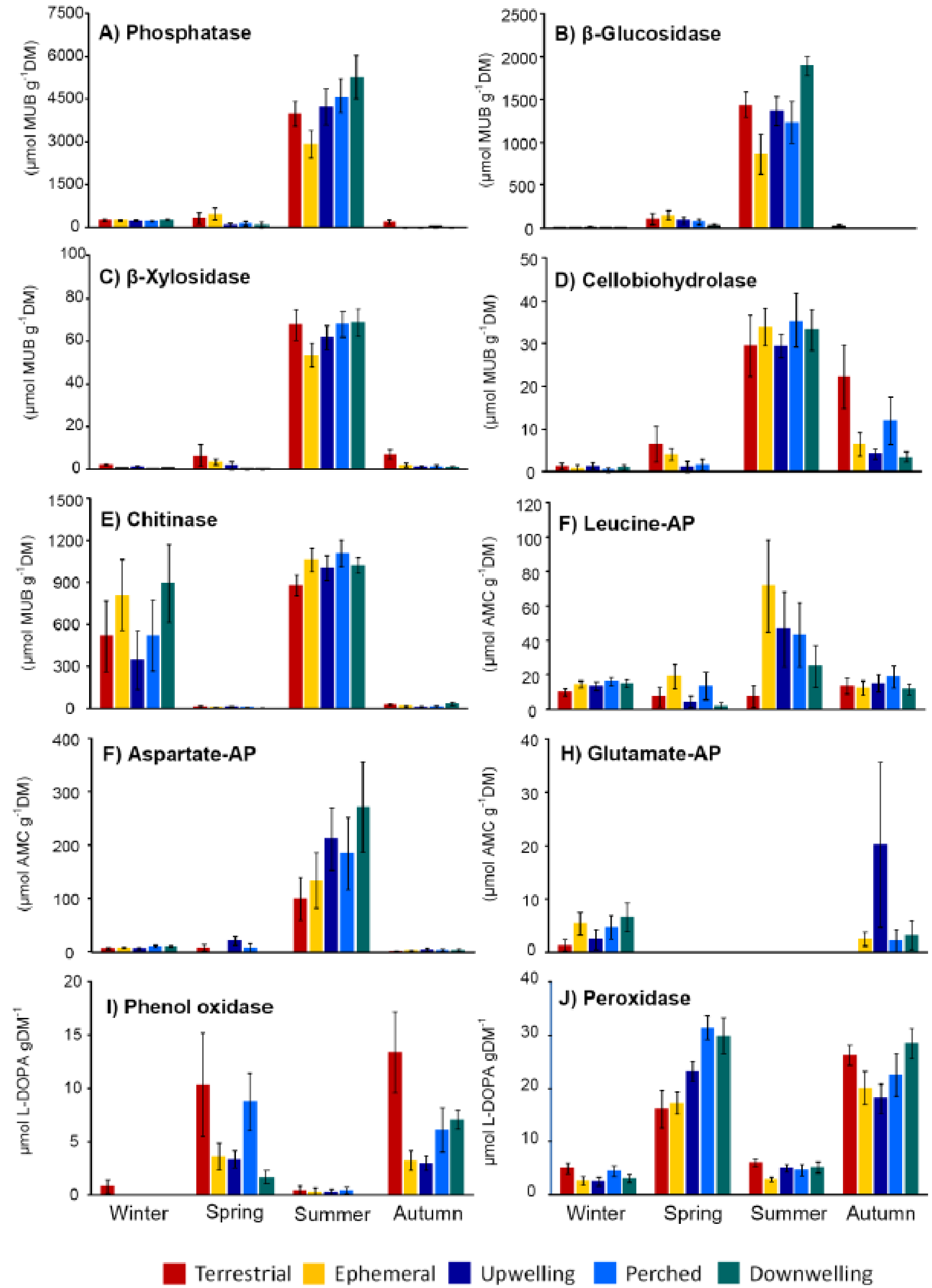
Significance of water avialability along flow path
<u>Enzyme potentials</u>

Carbon-acquiring

Nitrogen-acquiring

Lignin-degrading



Frossard, A., Gerull, L., Mutz, M. & Gessner, M.O. (2012): Disconnect of microbial structure and function: enzyme activities and bacterial communities in nascent stream corridors. The ISME Journal, 6, 680-691.

Significance of season

Enzyme potential

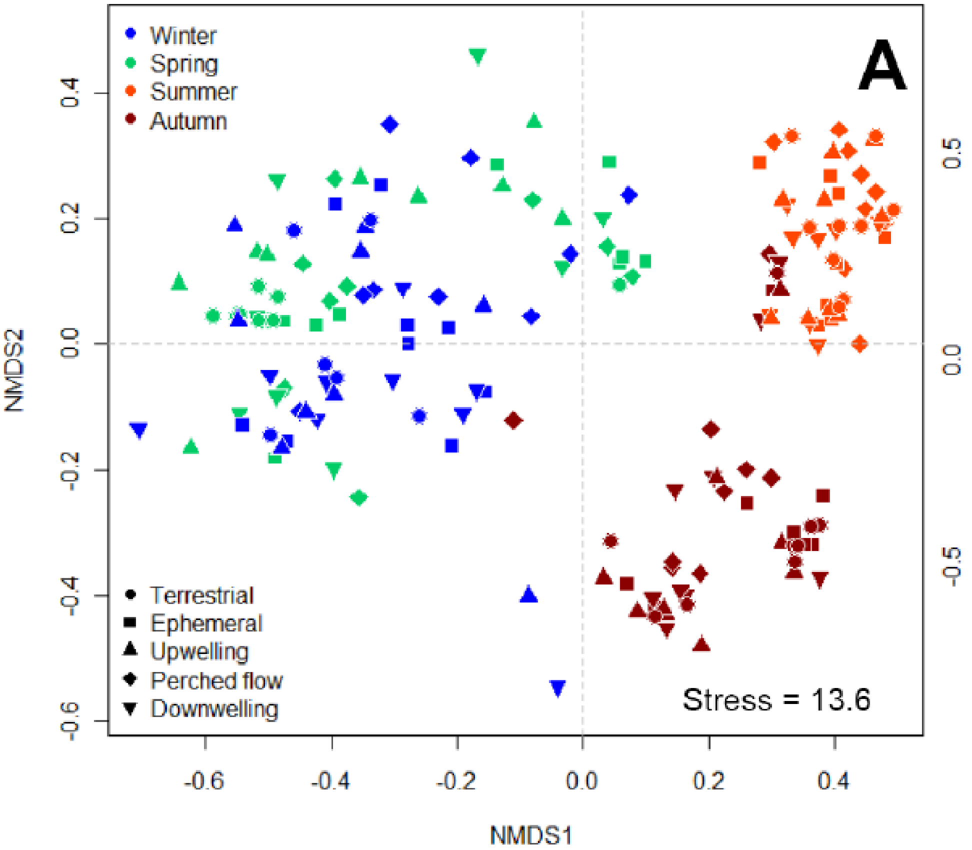


Figure 4. NMDS ordination of A) potential activities of 10 different enzymes, and B) bacterial community structure inferred from DGGE bands.

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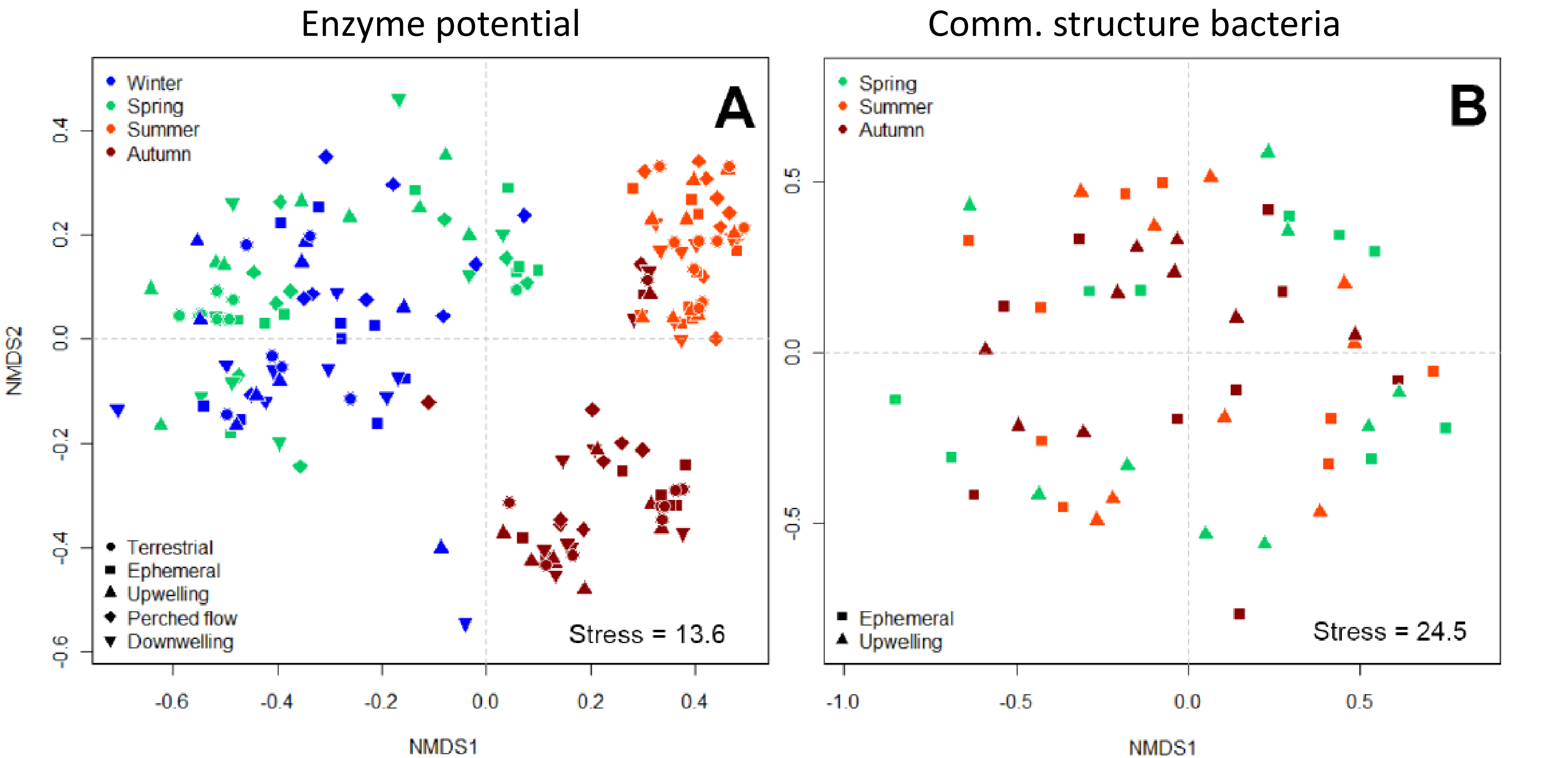
Significance of season



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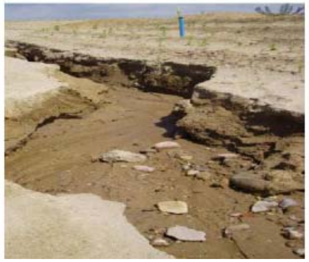
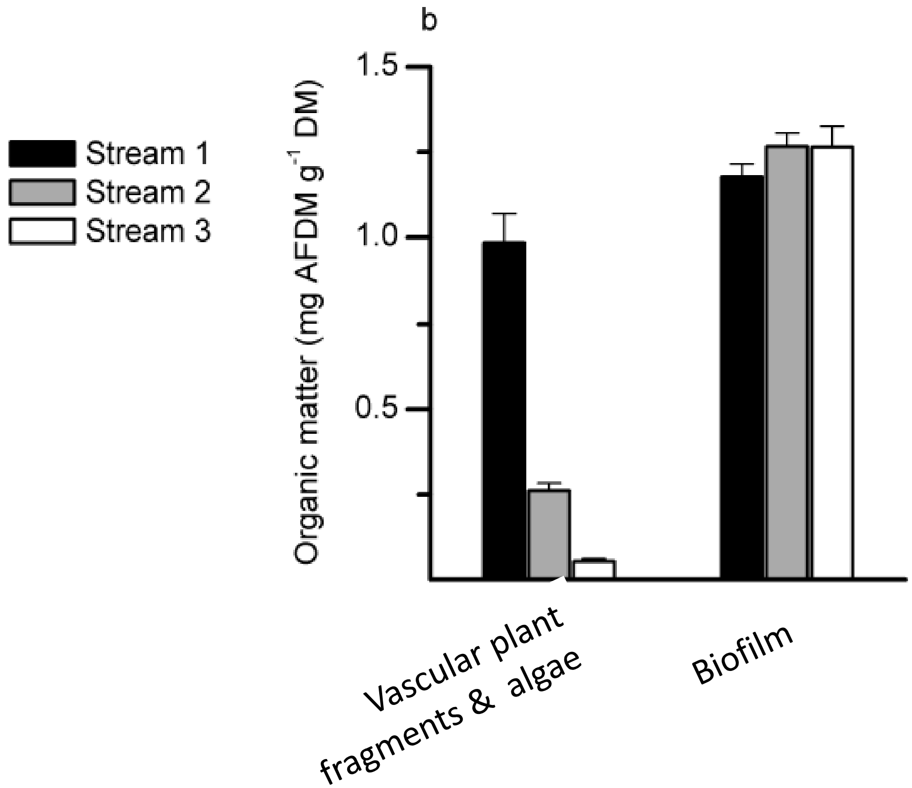


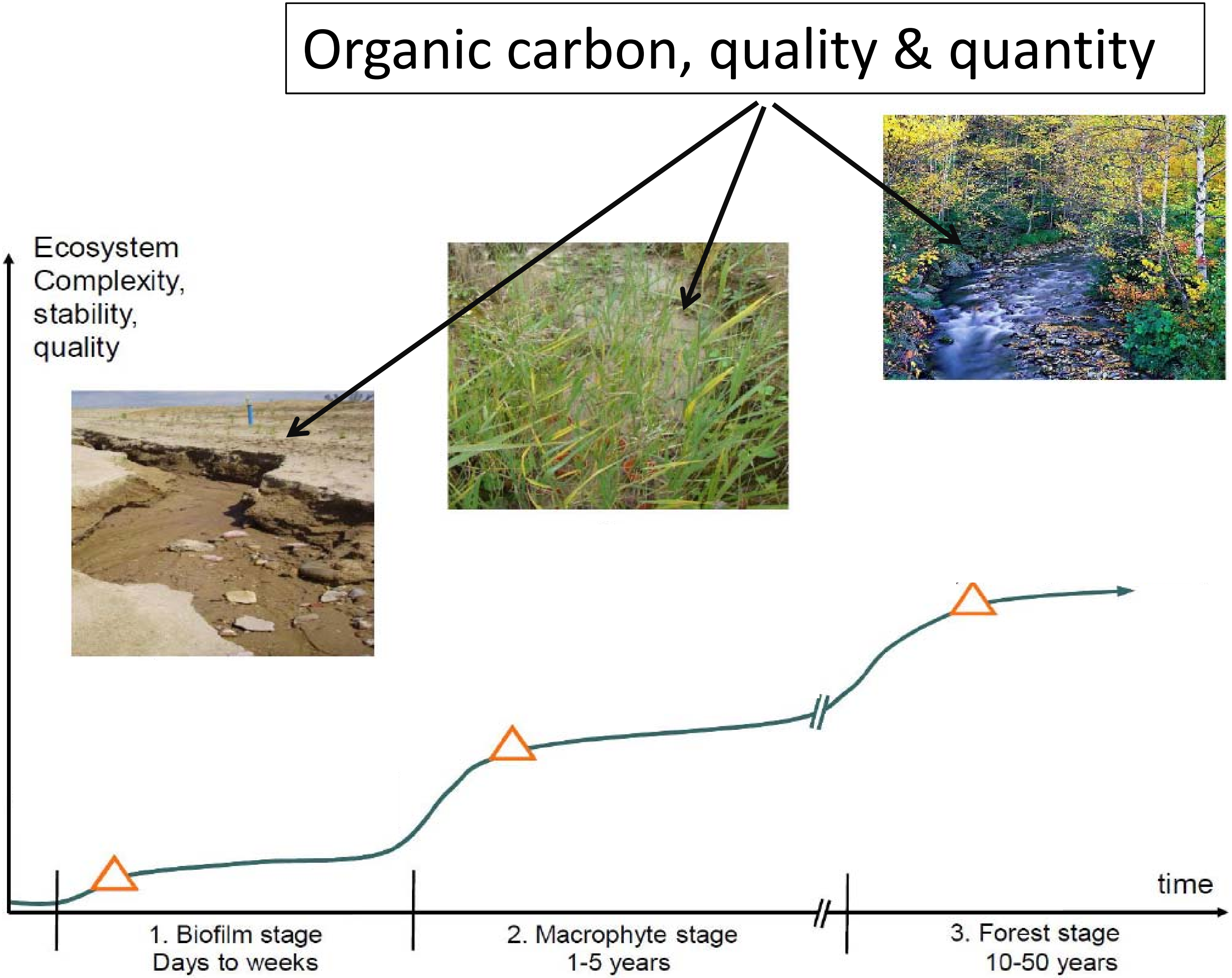
Offenland Stadium

- Keinen Effekt der Wasserverfügbarkeit auf Aktivität , Bakteriengemeinschaft und Enzyme
- Saisonales Muster der Enzymaktivitäten, nicht der mikrobiellen Gemeinschaft
  → Entkopplung von biologischer Struktur und Funktion
- Große räumliche Heterogenität (Teileinzugsgebiete)

- Große räumliche Heterogenität (Teileinzugsgebiete)

Hinweis auf Bedeutung Qualität des OM




Organic carbon, quality & quantity
Ecosystem Complexity, stability, quality
time
1. Biofilm stage
Days to weeks
2. Macrophyte stage
1-5 years
3. Forest stage
10-50 years

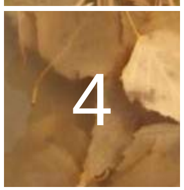
Experimental set-up

Fall 2009, 3 replicates
Sampling after 4, 6, 8 and 10 weeks

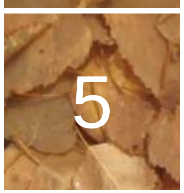
No litter

Calamagrostis 100 g/m^2

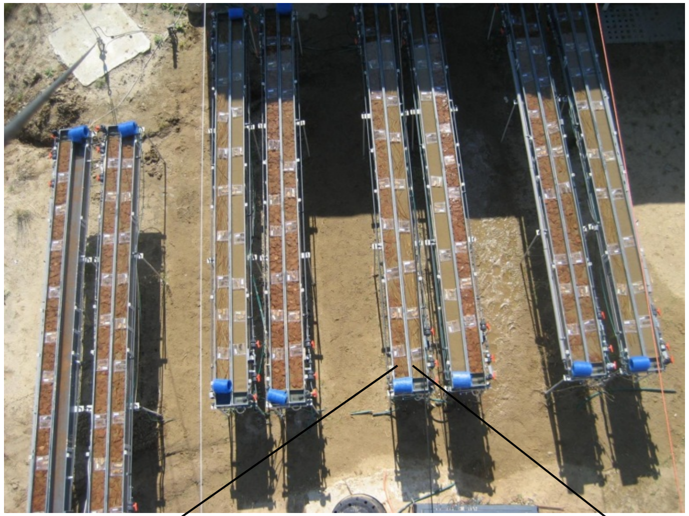
Calamagrostis + *Betula* 2 x 50 g/m^2

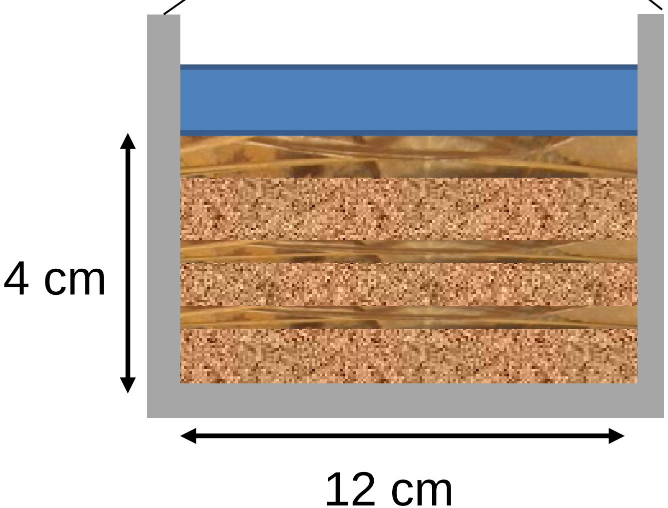


Betula 100 g/m^2



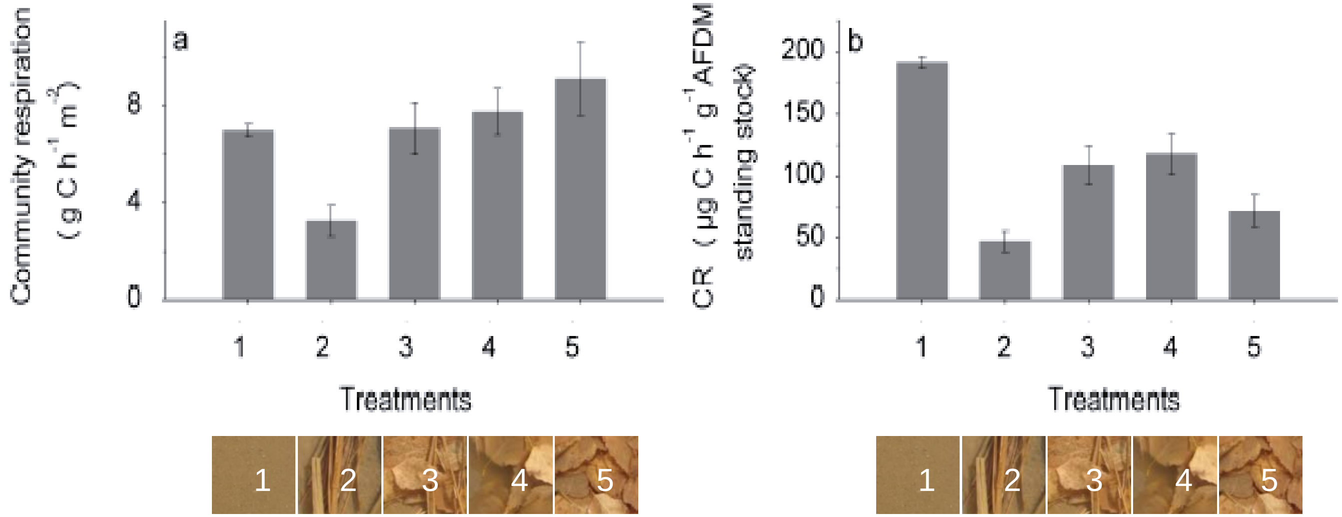
Betula 250 g/m^2





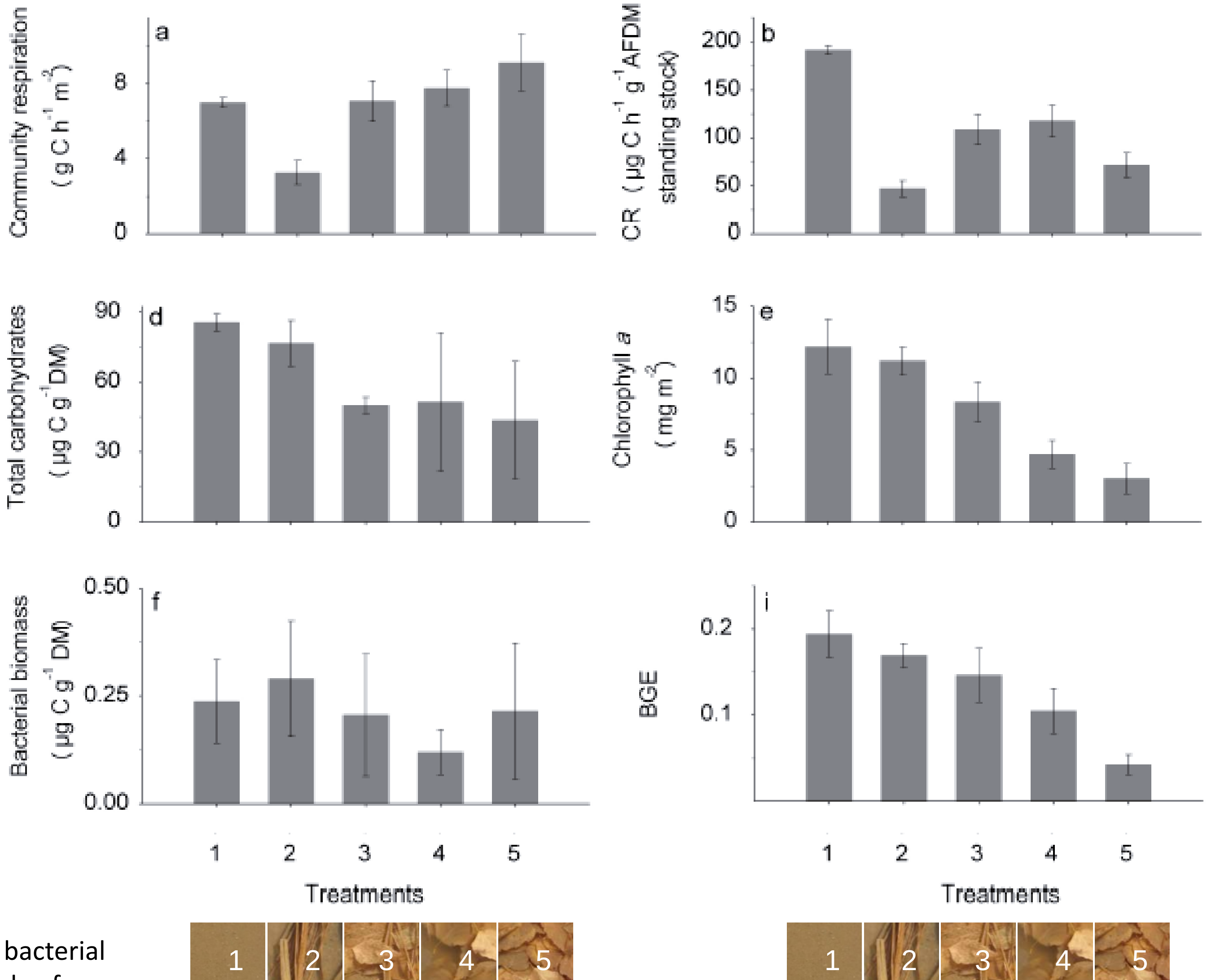
1/5 of the leaves were buried

P/R < 1



Means + 1SE of
3 sampling dates (n = 12).
Sediment associated respiration and bacterial growth efficiency (BGE) show data only of sampling date 3, (means ± 1SE, n = 4) after 10 weeks of the experiment.

P/R < 1



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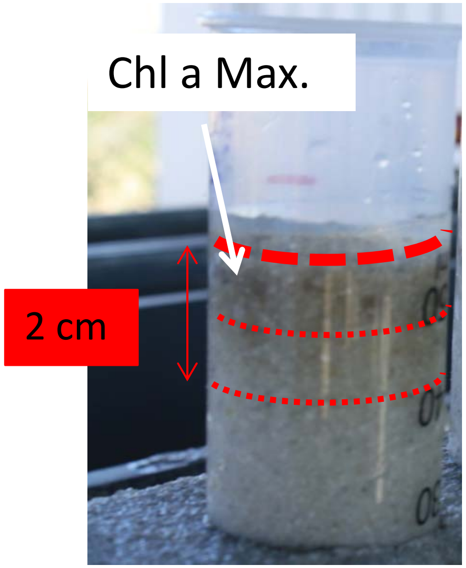
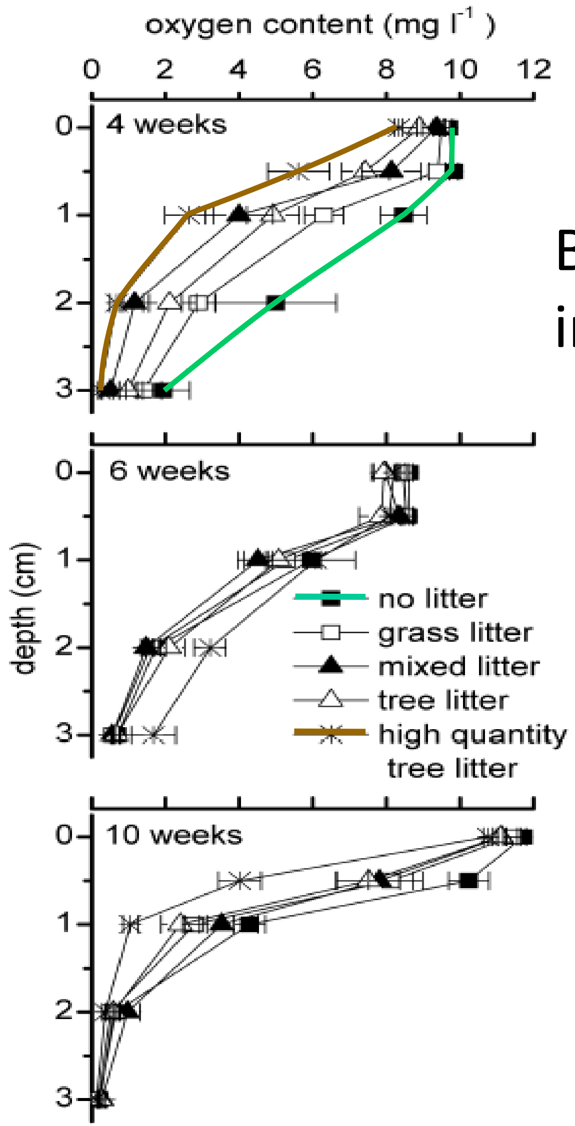


Sediment core
openland treatment



Better oxygen availability in sediments of open land

Comparison of the oxygen profiles in the sediment of the five treatments after 4 ($n = 6$), 6 ($n = 3$) and 10 ($n = 9$) weeks of the experiment.

Keine Zunahme des Gesamtmetabolismus

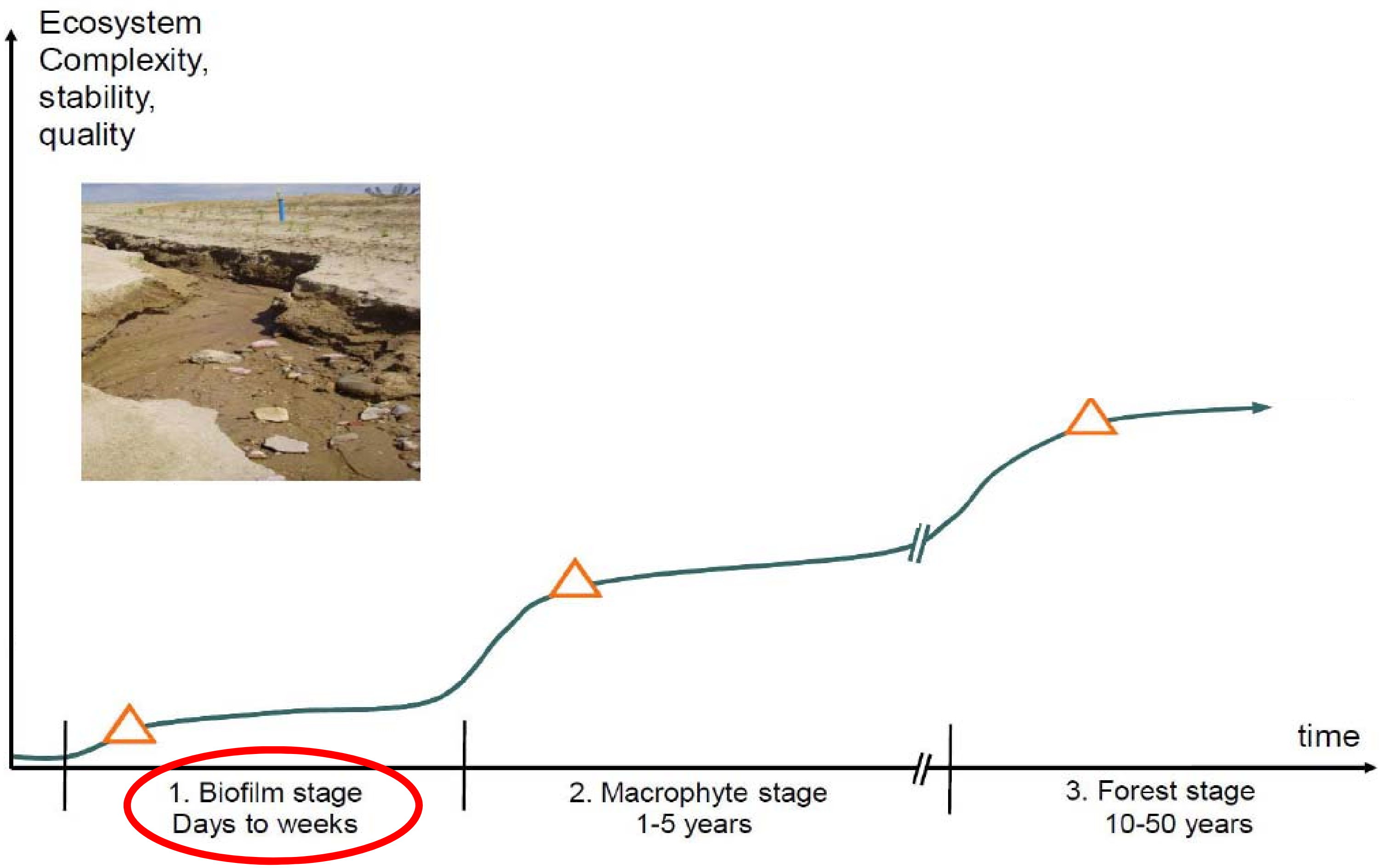
Im Offenland

- höhere Aktivität in den Sedimenten kompensiert Aktivität am Laub

  - Höhere Wachstumseffizienz der Bakterien
    Algen & Exsudate

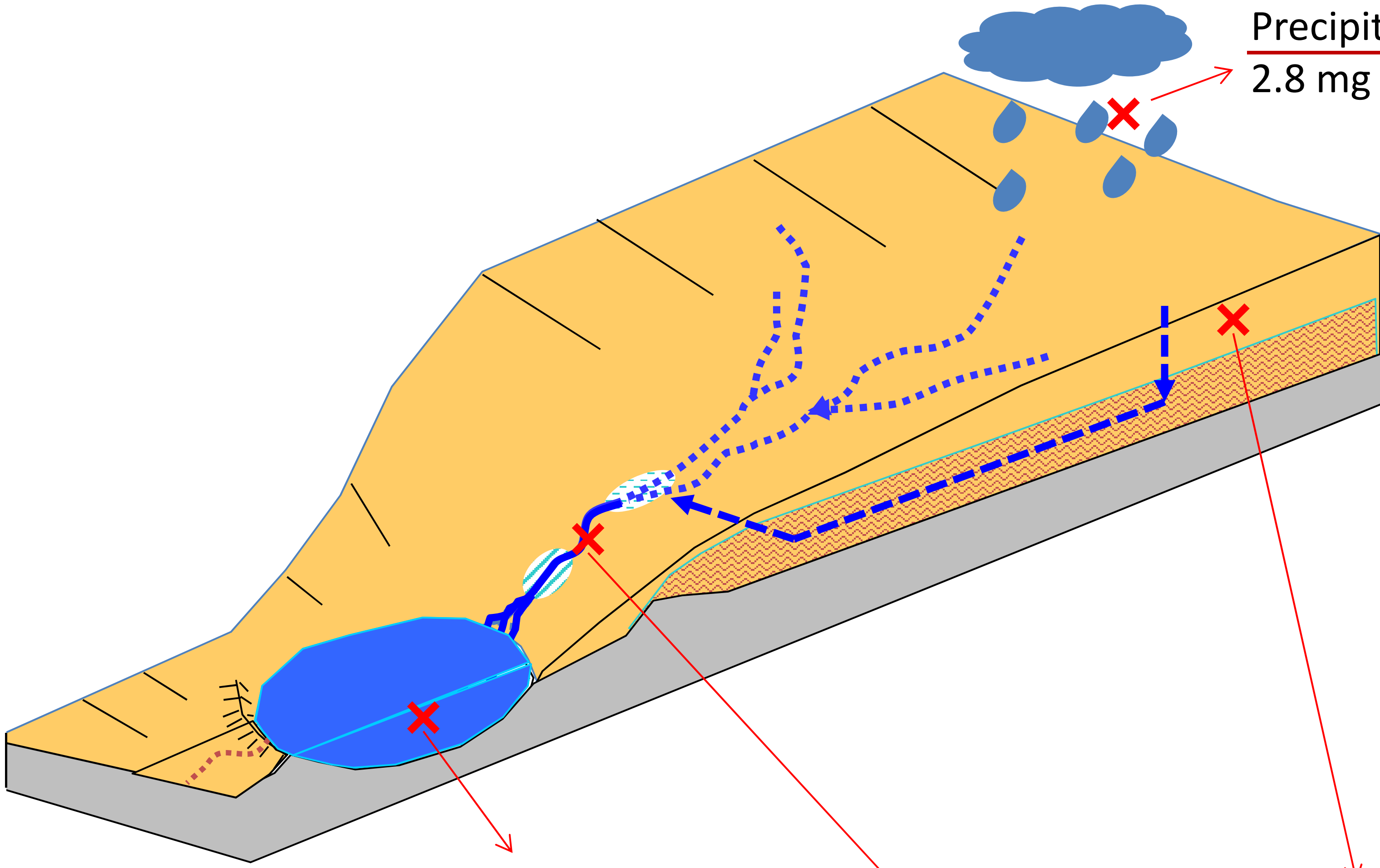
  - Größeren „Sedimentreaktor“
    OC, O_2 Produktion durch Algen

Significance of **old organic carbon** along hydrological flow path



Fisher et al., 1982; Grimm 1994; Mutz et al., 2002; Milner & Gloyne-Phillips, 2005; Benlap et al., 2005; Langhans & Tockner, 2006; Langenheder et al., 2006.

Can old organic carbon drive microbial activity in surface waters of a newly created landscape?



Precipitation

2.8 mg l^{-1}

(Veste et al., 2010)

DOC concentrations

pond water

$5.1 – 14.6$ mg l^{-1}

(Leßmann et al. 2010)

hyporheic + stream water

$10.8 – 18.3$ mg l^{-1}

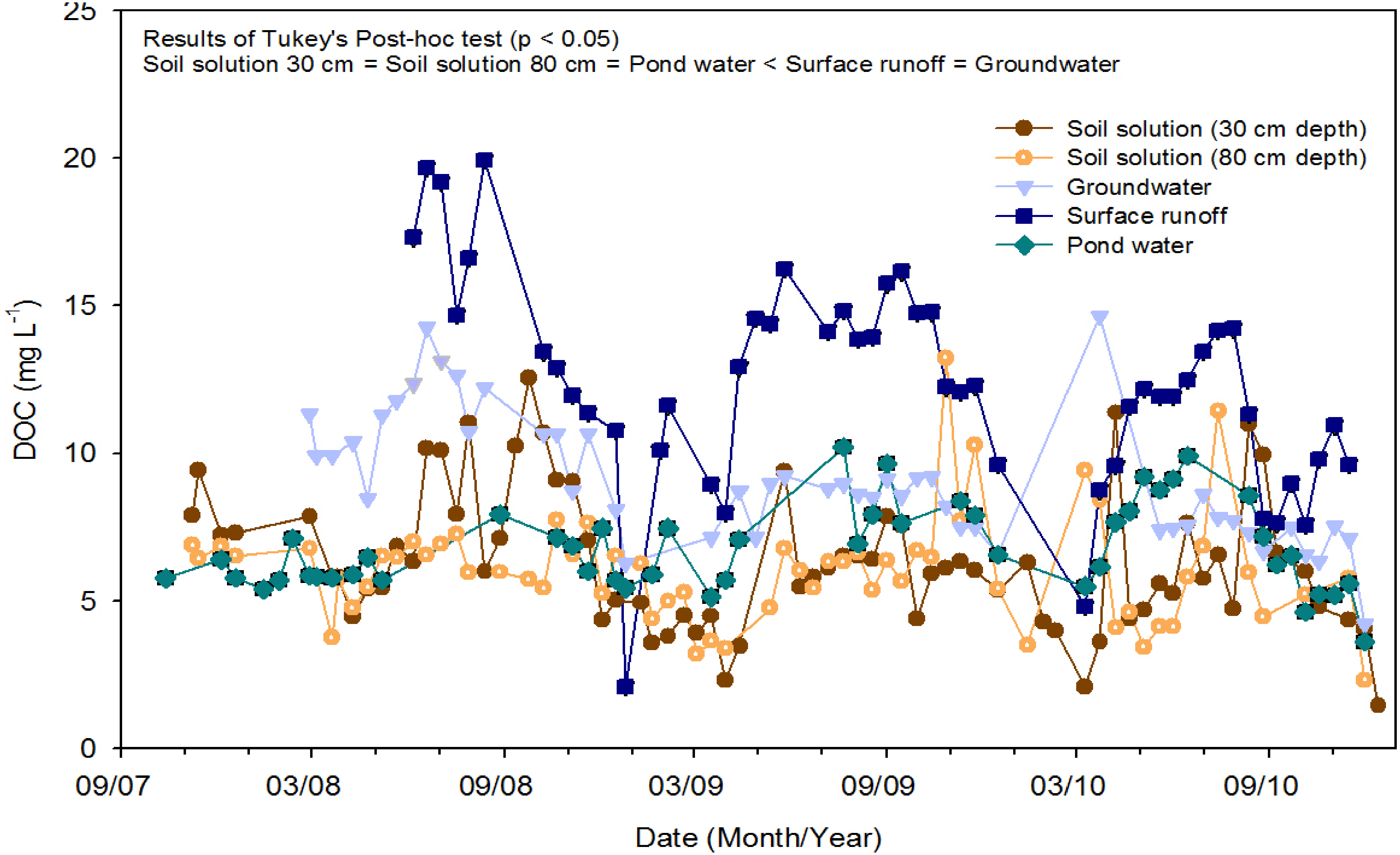
(Gerull et al.2012)

soil solution

$1.6 – 2.2$ mg g^{-1}

(Gerwin et al. 2009)

Dynamics of DOC concentrations along the hydrological flow path



- Seasonality
- DOC increase 2008 - 2010 in pond

(period Feb.-May, permANOVA MS = 6.37, df = 1, $p = 0.03$)

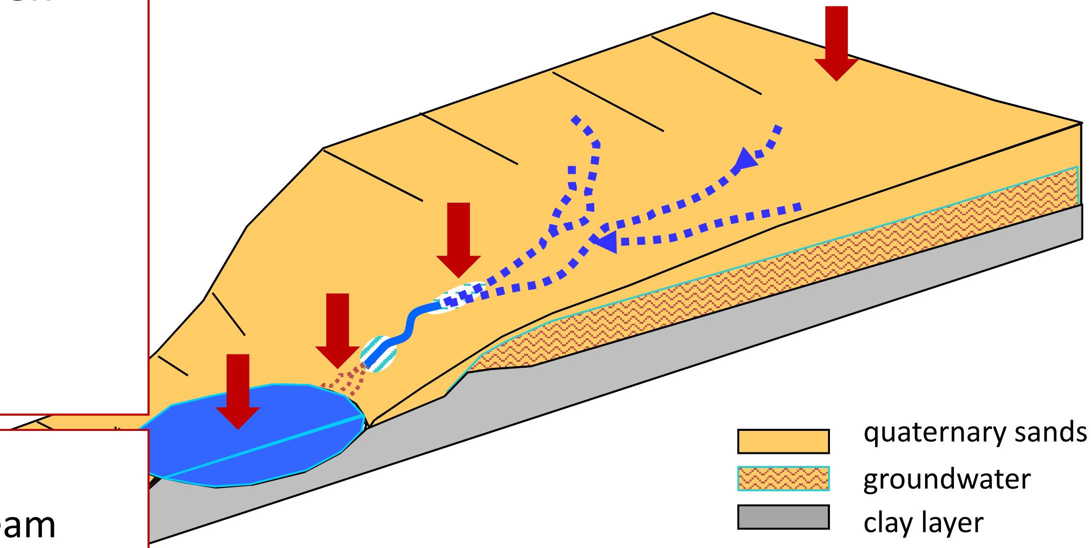
Sampling sites in the experimental catchment Chicken Creek

upwelling groundwater in streams
water passed quaternary sand material

soil solution
trickled rain water, 30-80 cm depth

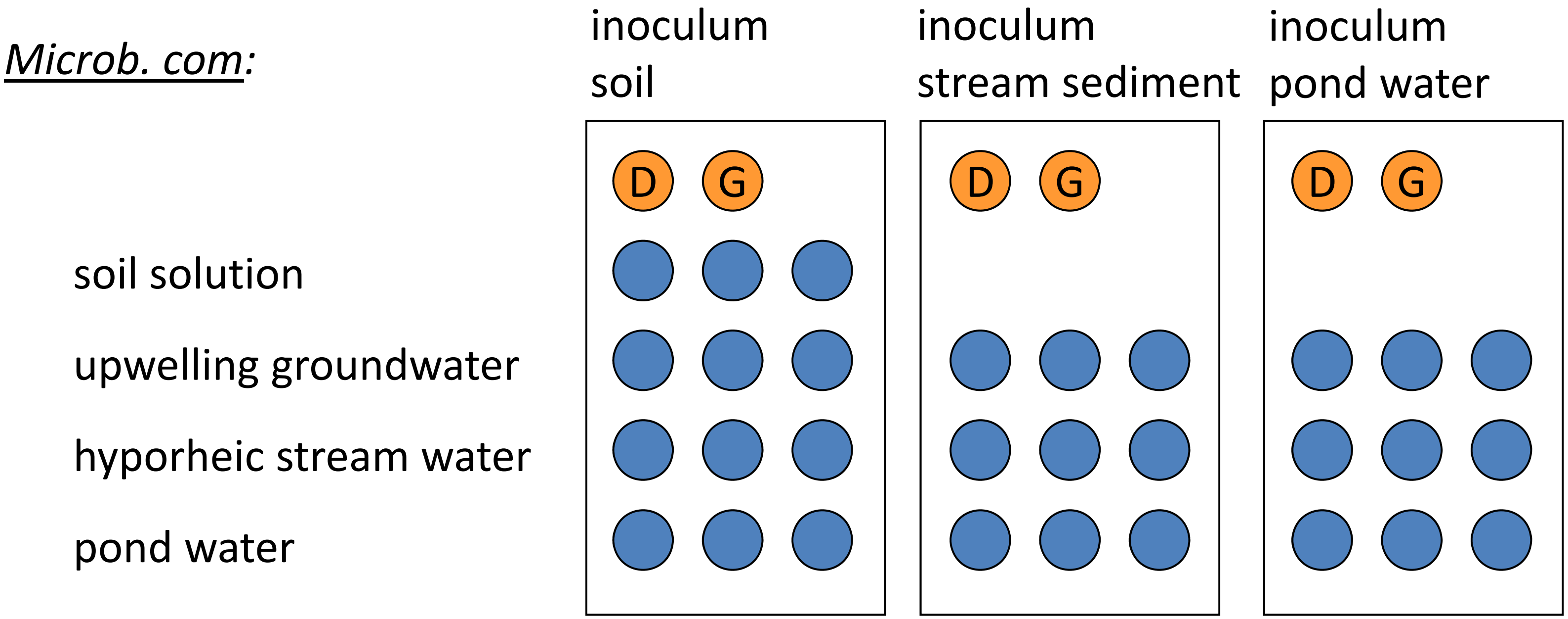
hyporheic stream water from alluvial fen
water passed streams and hyporheic zones
retention time in streams = ~ 0.01 d

pond water
mixture of rain, stream and hyporheic water
retention time in pond = ~300 d (Kleeberg et al. 2009)

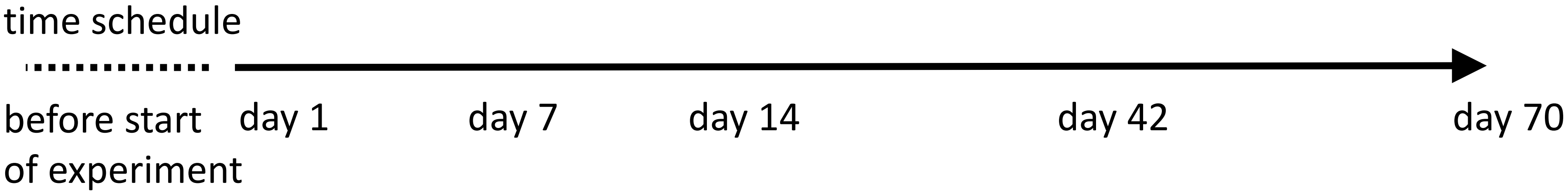


Late winter / early spring 2010
3.5 weeks for soils solution

Experimental design



- water filtered through 0.2 µm and
- inoculated with 1 ml of the corresponding inocula leading to final 2×10^3 bacterial cells ml^{-1}



Mesocosm setup and measured parameters

700 ml water and 5 glass slides (A = 59.9 cm^2)

- **DOC bioavailability**
  - DOC
  - Respiration

time schedule

before inoculation | day 1 | day 7 | day 14 | day 42 | day 70

Mesocosm setup and measured parameters

700 ml water and 5 glass slides (A = 59.9 cm^2)

- **DOC bioavailability**
  - *DOC*
  - *Respiration*
- **Organisms**
  - *bacterial abundance*

time schedule

before inoculation | day 1 | day 7 | day 14 | day 42 | day 70

Mesocosm setup and measured parameters

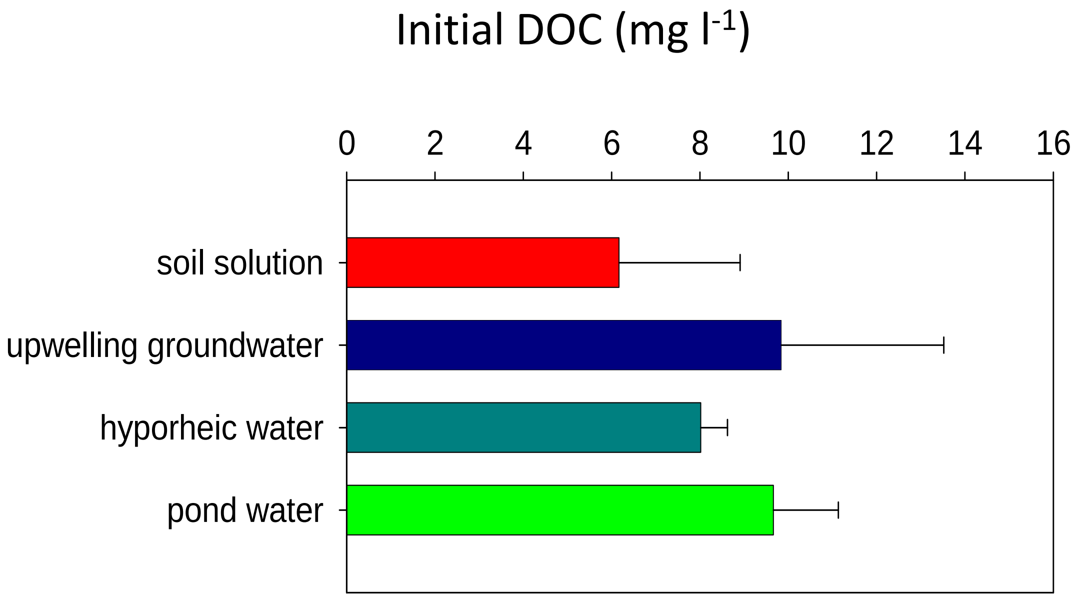
700 ml water and 5 glass slides (A = 59.9 cm^2)

- **DOC bioavailability**
  - *DOC*
  - *Respiration*
- **Organisms**
  - *bacterial abundance*
- **DOC-Quality**
  - *specific UV absorption* at 285 nm
  - *total carbohydrates*
  - *low molecular acids*
  - *^{13}C NMR of initial water*

time schedule

before inoculation | day 1 | day 7 | day 14 | day 42 | day 70

April 2010



mean ± SD, n = 3
(MS = 8.46, df = 3, p = 0.21)

DOC mean ^{14}C age

Quaterny substr.
3 000 – 16 000 years

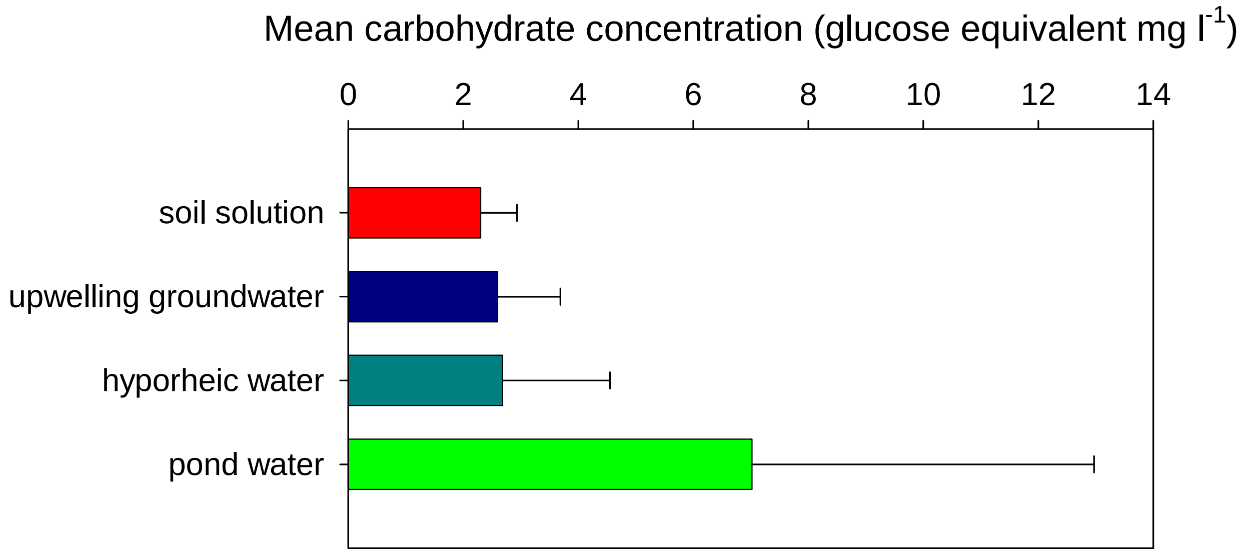
Ground water
2 600 – 2 800 years

^{13}C signature of -25 to -30 ‰

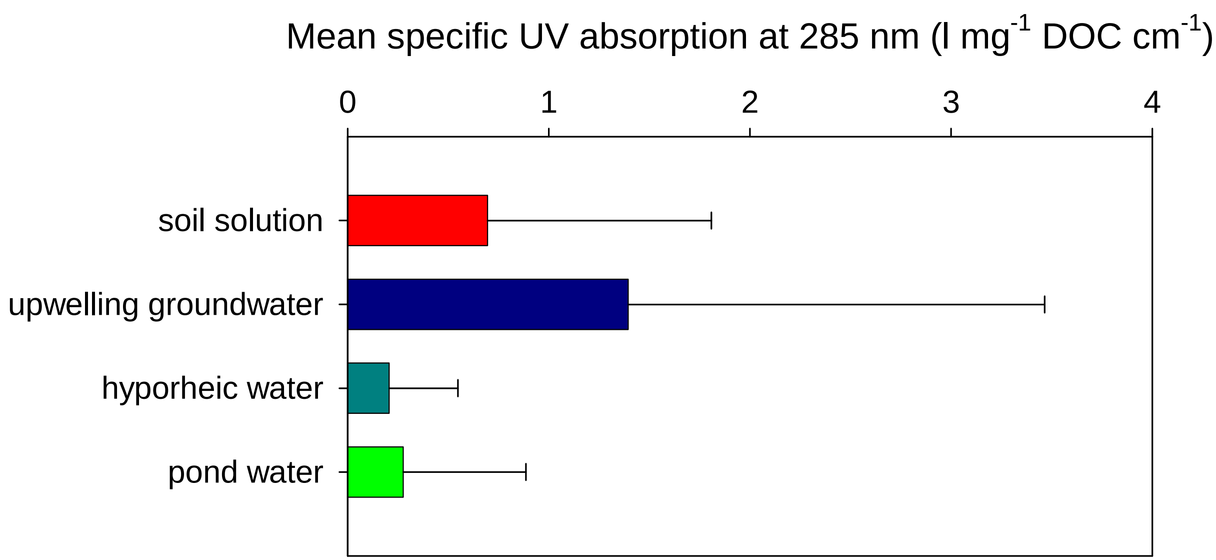
* ∼1,800–4,100 years

* Trumbore S (2009) Radiocarbon and soil carbon dynamics. Annu Rev Earth Planet Sci. 37:47–66.Heimann M, Reichstein M (2008) Terrestrial ecosystem carbon dynamics and climate feedbacks. Nature 451:289–292.17. Rumpel C, Kogel-Knabner I, Bruhn F (2002) Vertical distribution, age, and chemical composition of organic carbon in town forest soils of different pedogenesis. Org. Geochem 33:1131–1142. Fontaine S, et al. (2007) Stability of organic carbon in deep soil layers controlled by fresh carbon supply. Nature 450:277–280.

DOC quality

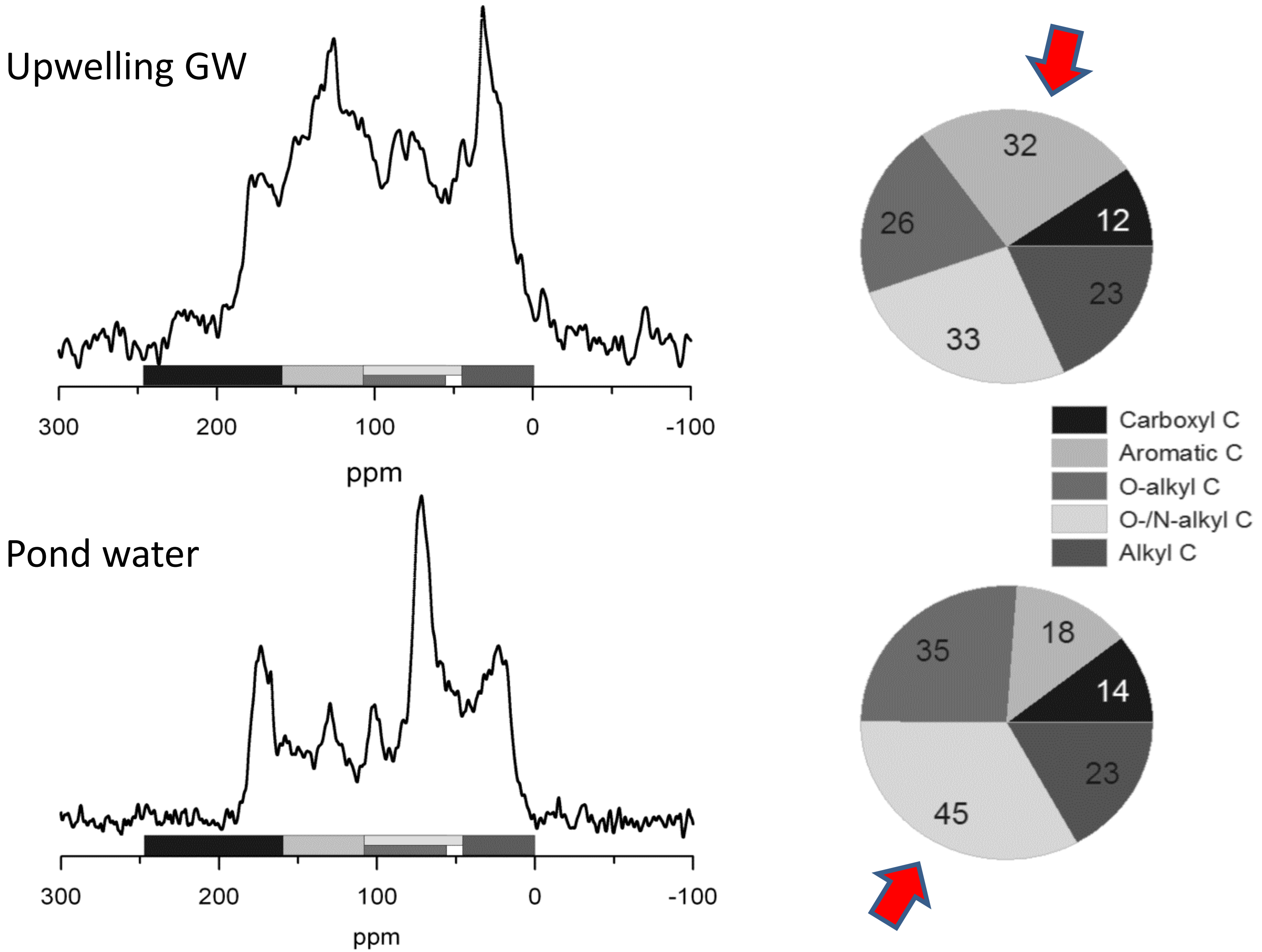


(MS = 5.19, df = 3, p = 0.03)



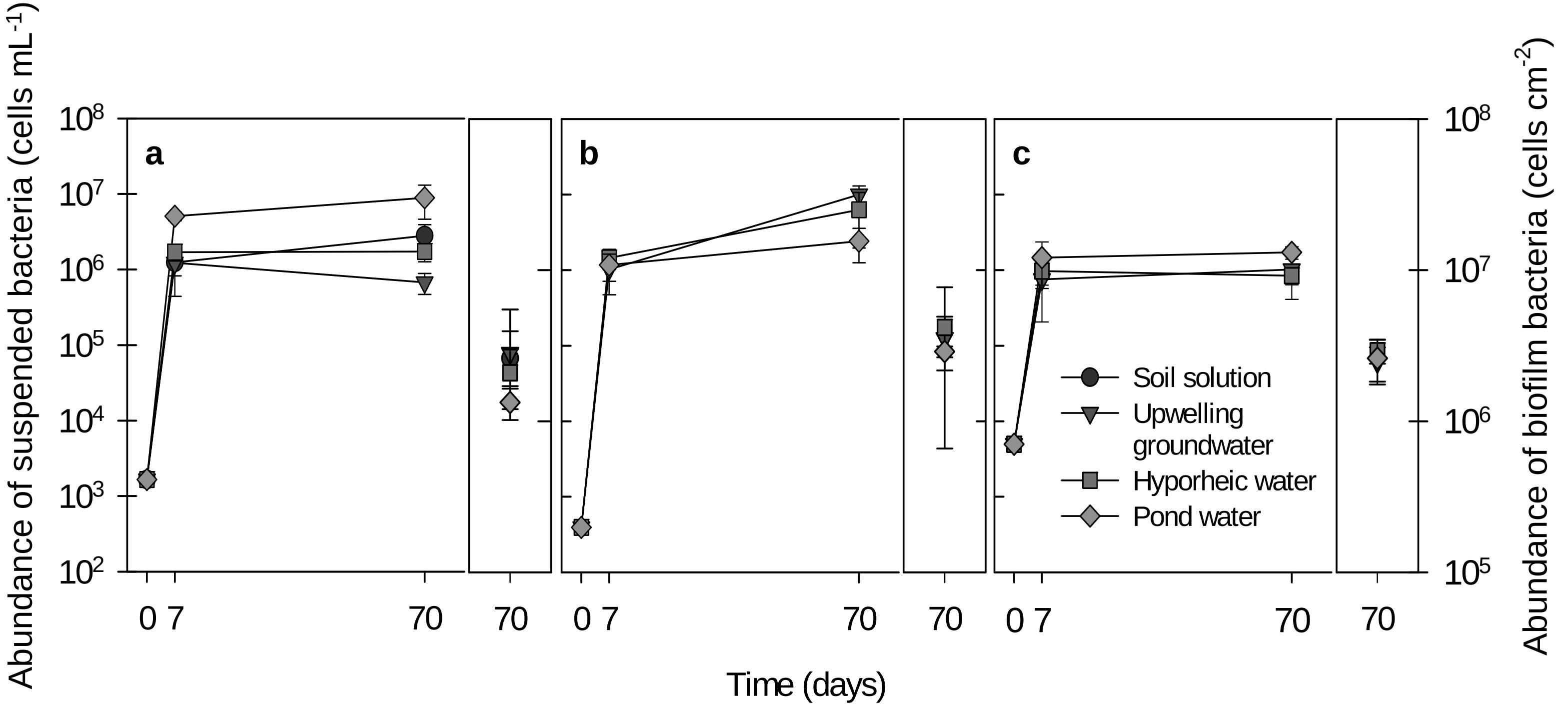
mean of three inocula and time points ± SD, n (soil solution) = 6, n (all other waters) = 18

April DOC composition ^{13}C NMR



Bacterial abundance in mesocosms

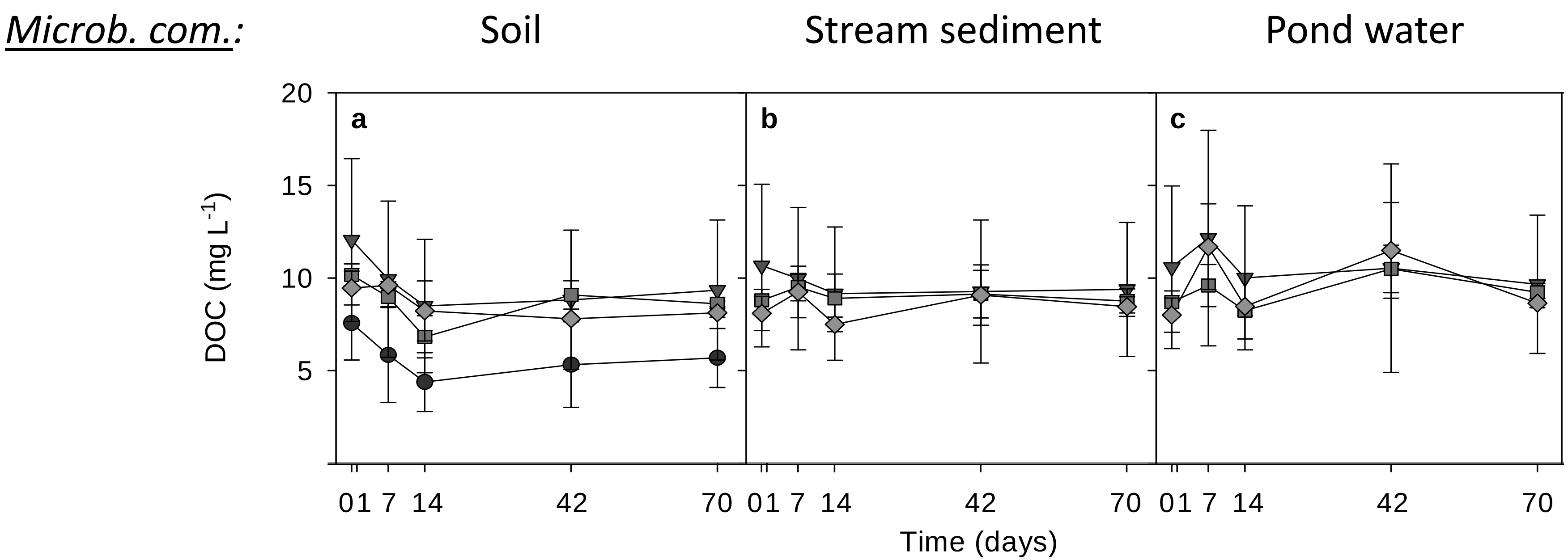
<u>*Microb. com*</u>*:* Soil Stream sediment Pond water



Mean growth rate day 0 to 7 2.3×10^5 cells ml^{-1} d^{-1}

No effect of water type

DOC availability



- No effect of water type, microb. com. (3 factorial permAnova)

$$\mathrm{DOC}(t) = \mathrm{DOC}recalc + (1 - \mathrm{DOC}recalc) \cdot e^{(-k_L \times t)}$$

- 20 % DOC*labile* and 80 % DOC*recalc* (SE 0.02).
- k_L = 0.19 day^{-1} (SE 0.09)
- No decomposition of DOC*recalc* during 70 days

Offenland Stadium
Makrophyten Stadium

Im jungen Gebiet wird alter DOC freigesetzt

DOC-Qualität variiert im Gebiet

Ca. 20 % des DOC sind (schnell) bioverfügbar

Initiale Gebiete exportieren alten DOC

Fazit

Schnelle Differenzierung des anfänglich homogenen HW-Gebietes

C-Transformation für Initialgebiet beachtlich

Alter DOC wird mobilisiert

Struktur-Prozessinteraktionen sind komplex

→ Homogenisierung im Zuge der weiteren Entwicklung?

→ Priming?

SFB/TRR 38
Strukturen und Prozesse der initialen Ökosystemgenese

Danke an

R. Ender

Th. Wolburg

M. Knie

J. Amonat

B. Räpple

L. Federlein

….

German Science Foundation

Collaborative research center TRR38

Vattenfall Europe Mining

b-tu
Brandenburgische Technische Universität Cottbus

IGB

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TECHNISCHE UNIVERSITÄT MÜNCHEN TUM

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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Herzlichen Dank für die Aufmerksamkeit