The Dimensions of the Phosphorus Status of European Beech Forest Ecosystems

Friederike Lang, Jaane Krüger, Jürgen Bauhus, Hans-Peter Dietrich, Frank Hagedorn, Cornelia Herschbach, Klaus Kaiser, Jörg Niederberger, Jörg Prietzel, Heike Puhlmann, Ulrike Talkner

Uni Freiburg, LWF Freising, WSL Birmensdorf, Uni Halle, TU München, FVA Freiburg, NW-FVA Göttingen

The motivation for the joint research project:

Global Change Biology

Global Change Biology (2015) 21, 418–430, doi: 10.1111/gcb.12657

Tree mineral nutrition is deteriorating in Europe

MATHIEU JONARD[1], ALFRED FÜRST[2], ARNE VERSTRAETEN[3], ANNE THIMONIER[1], VOLKMAR TIMMERMANN[5], NENAD POTOČIĆ[6], PETER WALDNER[4], SUE BENHAM[7], KARIN HANSEN[8], PÄIVI MERILÄ[9], QUENTIN PONETTE[1], ANA C DE LA CRUZ[10], PI ROSKAMS[3], MANUEL NICOLAS[11], LUC CROISÉ[11], MORTEN INGERSLEV[12], GIORGI MATTEUCCI[13], BRUNO DECINTI[14], MARCO BASCIETTO[14] and PASI RAUTIO[9]

Annals of Forest Science (2015) 72:919–928
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ORIGINAL PAPER

Phosphorus nutrition of beech (*Fagus sylvatica* L.) is decreasing in Europe

Ulrike Talkner · Karl Josef Meiwes · Nenad Potočić · Ivan Seletković · Nathalie Cools · Bruno De Vos · Pasi Rautio

DFG FNSNF Swiss National Science Foundation

ECOSYSTEM NUTRITION: Forest Strategies for limited Phosphorus Resources

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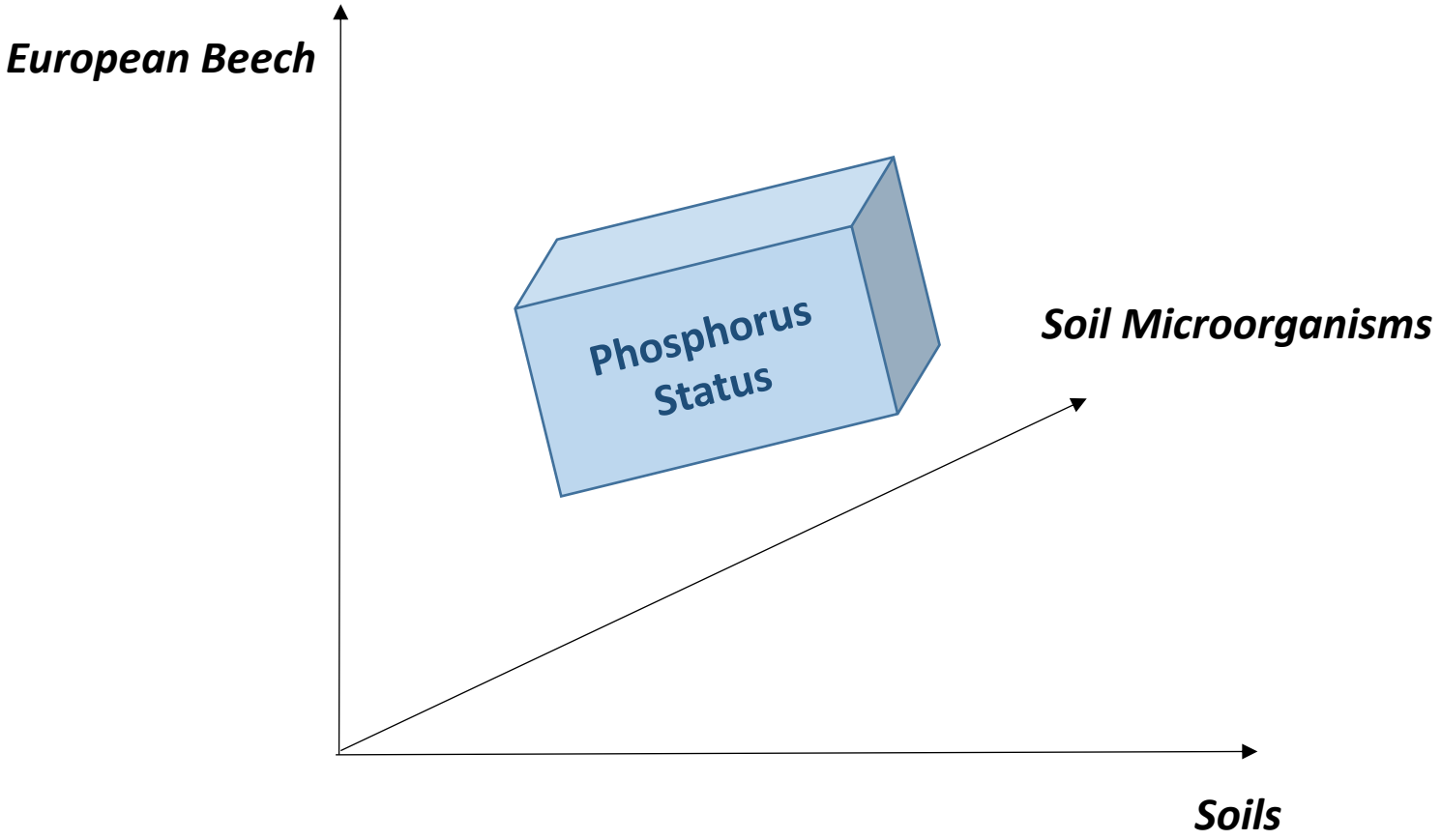
Contact: Fritzi.lang@soil.uni-freiburg.de

How to describe the P status of ecosystems?



central questions:

- Properties?
- Processes?
- Indicators?
- Interactions?

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Study sites of the joint project

The study sites present beech forest ecosystems with different parent materials and thus different total P stocks

Site	Bad Brückenau BBR *	Mitterfels MIT *	Vessertal VES	Conventwald CON	Lüss LUE *
total P stock (1m) [t ha^{-1}]	9.0	6.3	4.6	2.4	1.6

SILICATE

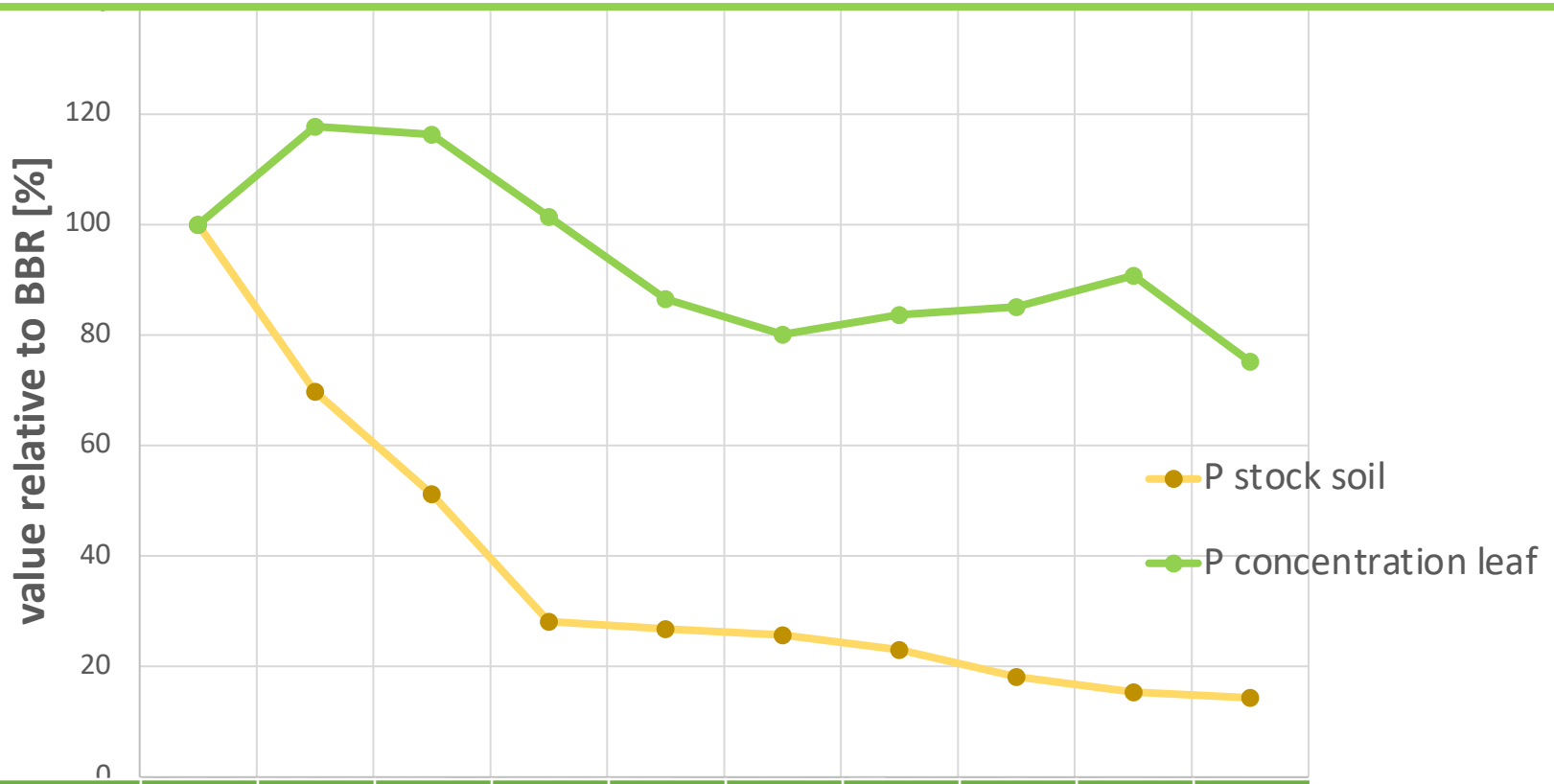
- European beech-dominated stands (100 – 140 years)
- ICP-Forests, Level II monitoring sites *(exception: MAN)*
- Operated by state forest institutions

* NxP fertilization experiment
- P-fertilization: 09/2016 50 kg P ha^{-1}
- Final sampling: 09/2018

	Mangfall MAN S	Schänis SCH	Tuttlingen TUT NE	Mangfall MAN N	Tuttlingen TUT SW
Total P Stock (1m) [t ha^{-1}]	2.6	2.4	2.1	1.4	1.3

CARBONATE

European Beech – P leaf concentrations and stoichiometry



	BBR	MIT	VES	MANS	CON	SCH	TUTNE	LUE	MANN	TUTSW
Leaf [mg P g^{-1}]	1.5	1.7	1.6	1.4	1.2	1.1	1.2	1.2	1.3	1.1
Leaf SD	*0.21*	*0.16*	*0.14*		*0.14*	*0.18*		*0.09*		
Leaf N:P	16.2	16.0	14.6		20.6	21.6	18.9	18.9		22.4

lower limit leaf P conc.
1.2 mg g^{-1} (Göttlein, 2015)

Upper N:P limit:
18.9 (Mellert & Göttlein, 2012)

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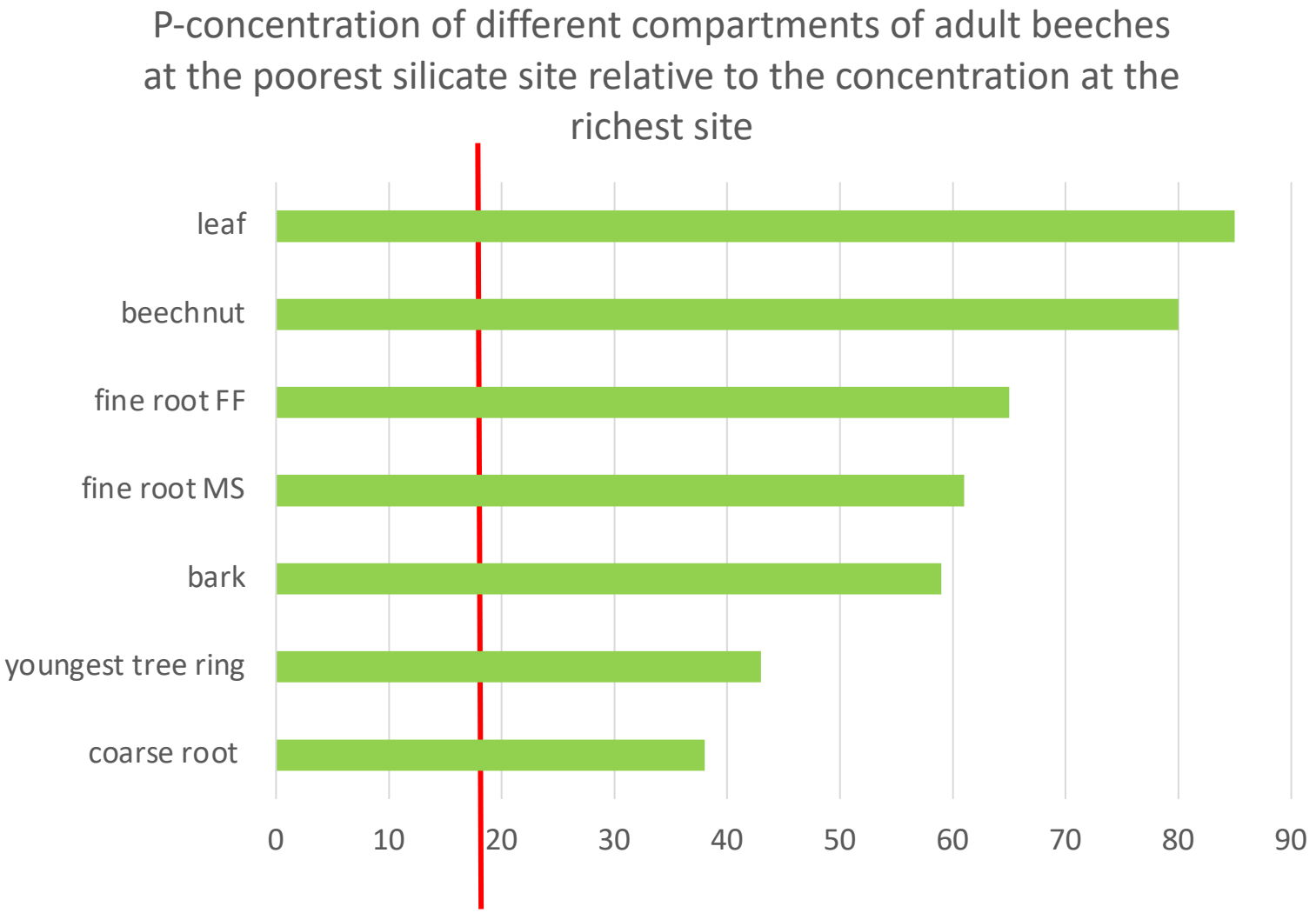
Sensitivity of beech compartments to decreasing soil P supply



Soil P stock: 18% of the P-richest site

Strongest decrease of P concentration in sapwood and coarse roots
identified as **storage pools** of beech (Yang et al. 2016; Netzer et al. 2017; Zavisic and Polle, 2018)

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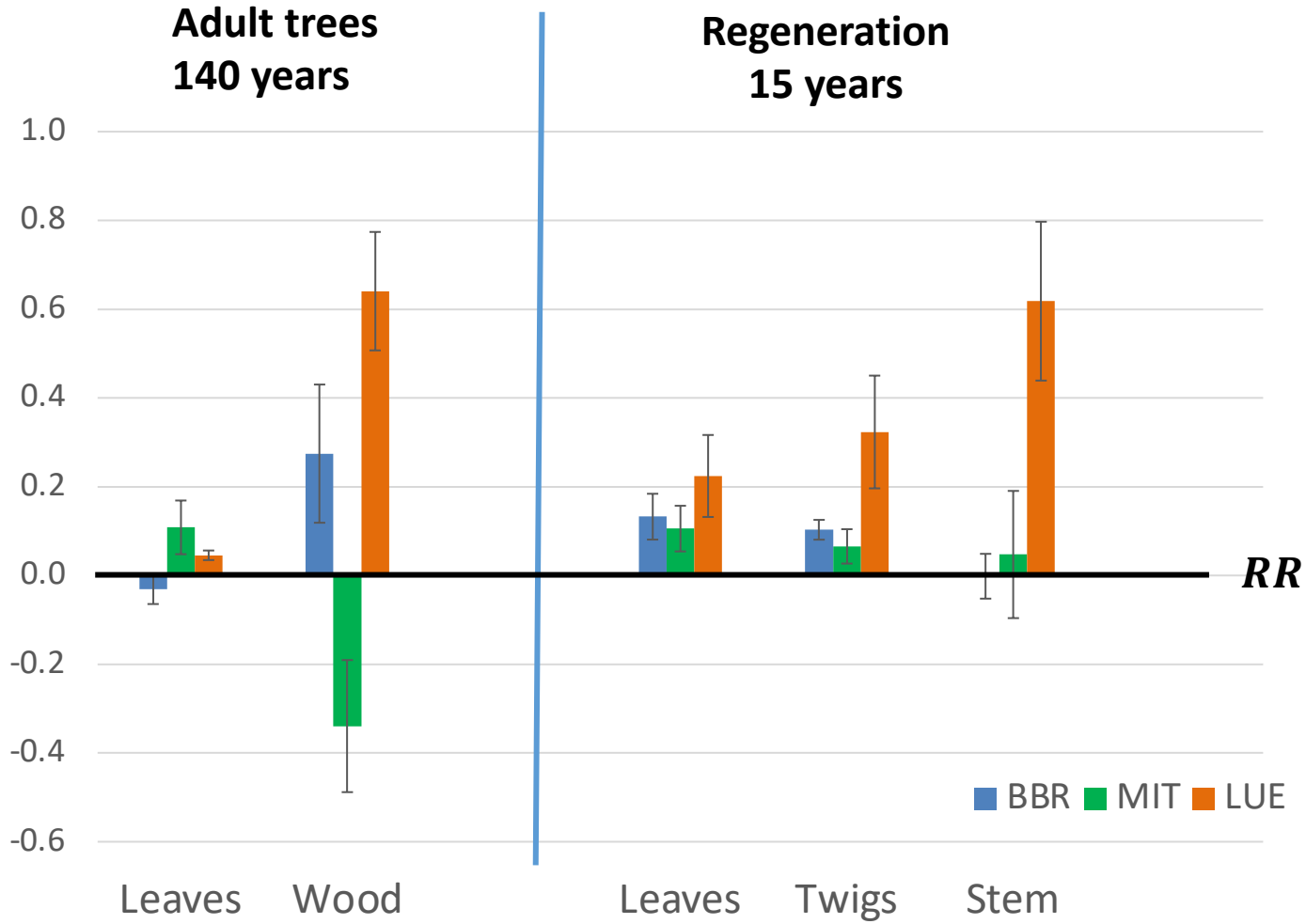
European Beech – response to P fertilization

Concentration higher than control

Concentration lower than control



Response ratio:

$$\boldsymbol{RR} = \ln \frac{concentration\_fertilized}{concentration\_control}$$

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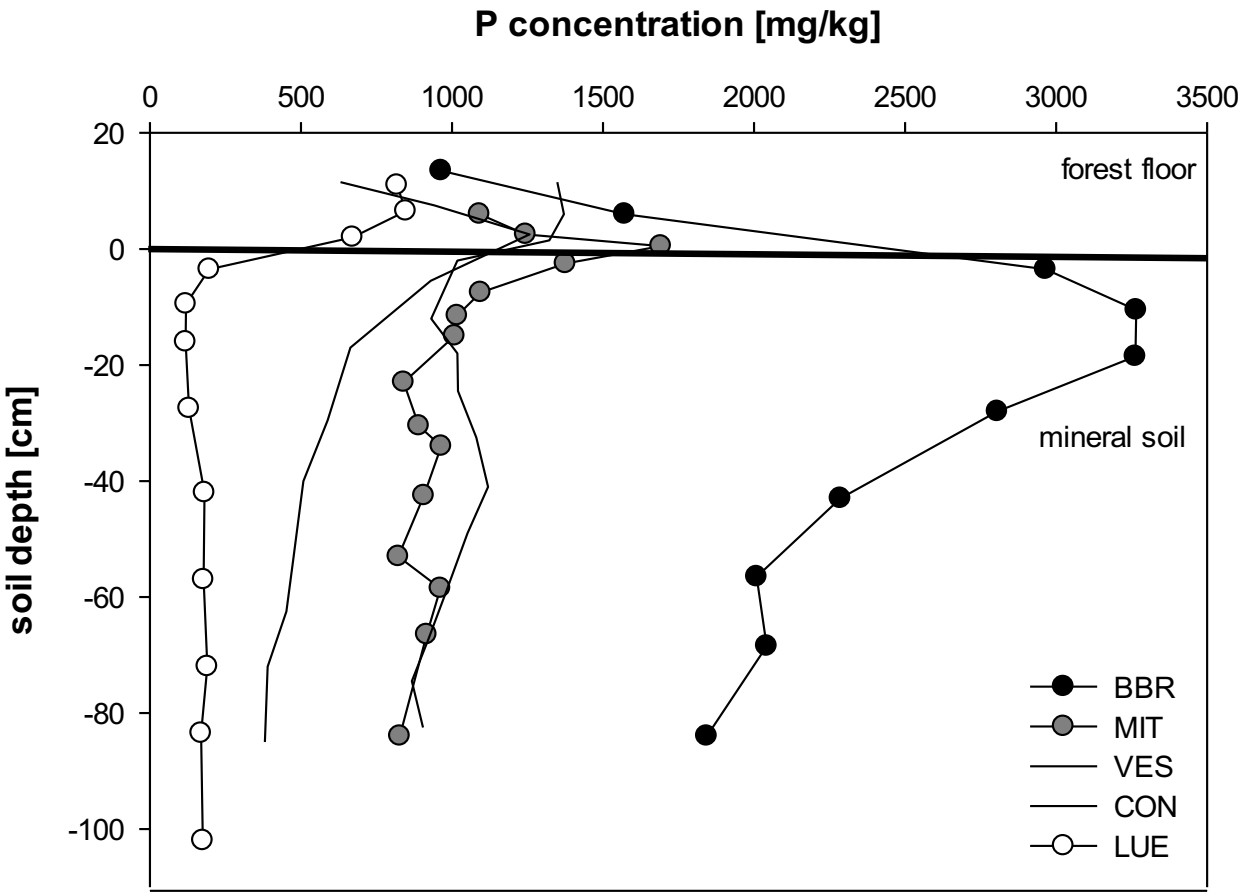
Soils – P depth distribution at silicate sites

LUE:
Hyperdystric folic cambisol (Arenic. Loamic. Nechic. Protospodic)



BBR:
Dystric skeletic cambisol (Hyperhumic, Loamic)

Lang et al. 2017

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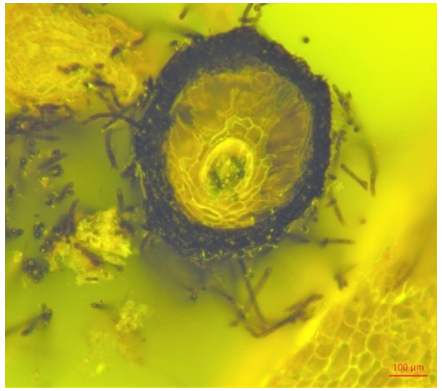
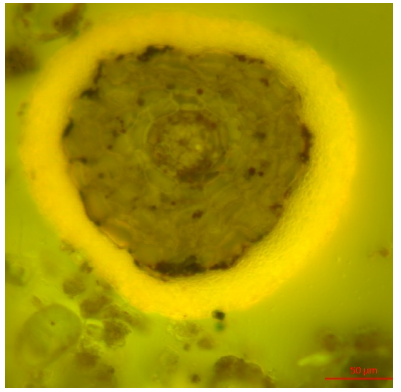
Depth distribution of P-uptake by European beech roots

Contribution of different soil horizons for P uptake by European beech [%]

Horizon	P-poor LUE	P-rich BBR
Forest Floor	42	19
A	54	19
B	4	25
C	0,1	39





*Calculated based on **P mobilisation from the soil phase** (DGT approach, unpublished) and distribution of **fine root surface area** (Löw et al. 2020)*

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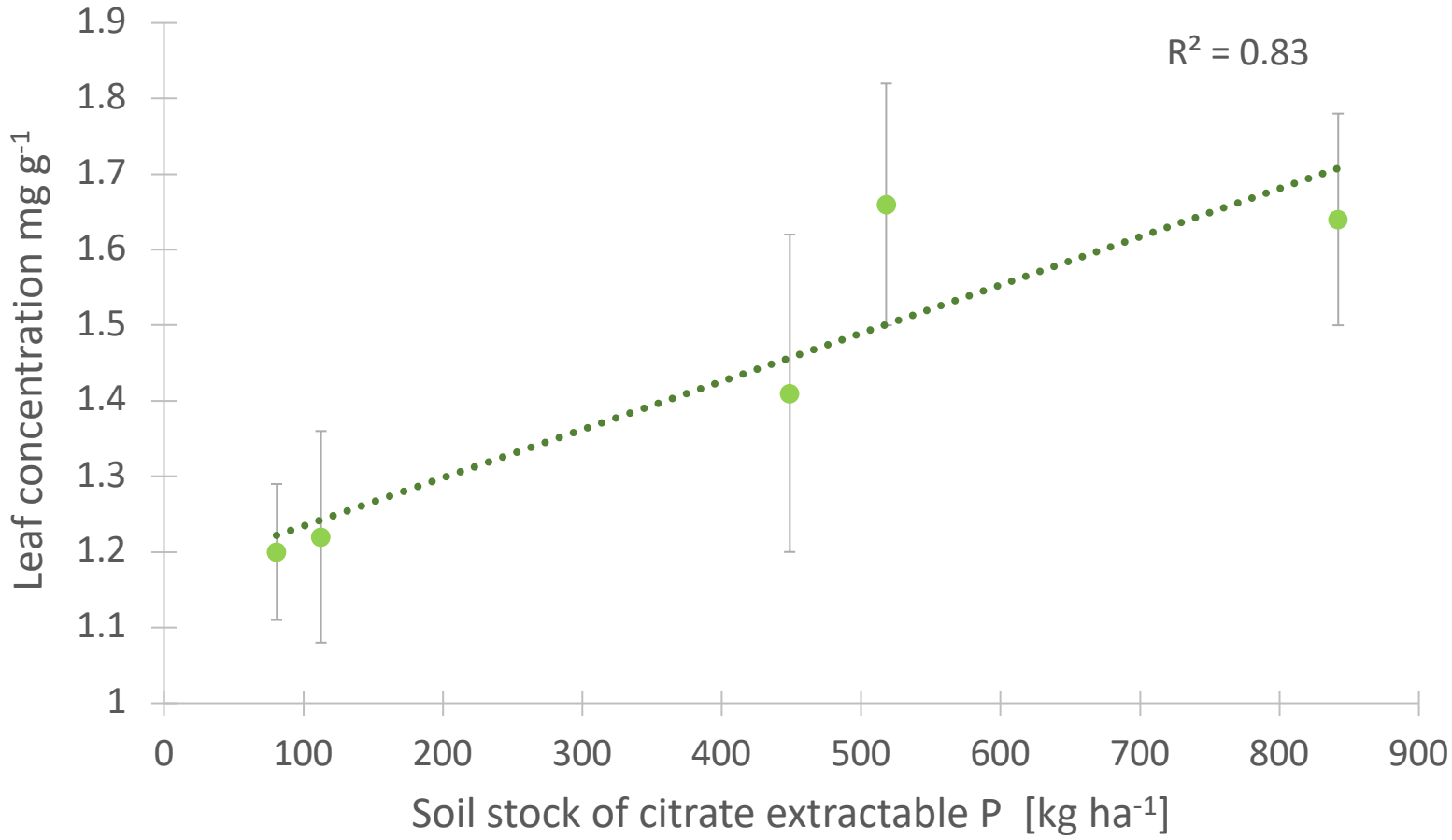
Conclusions for soil P availability indicators



Soil P-stocks (FF down to 1m) provided close correlation with longterm mean leaf concentration;

Soil P-stock 0-10 cm showed no correlations

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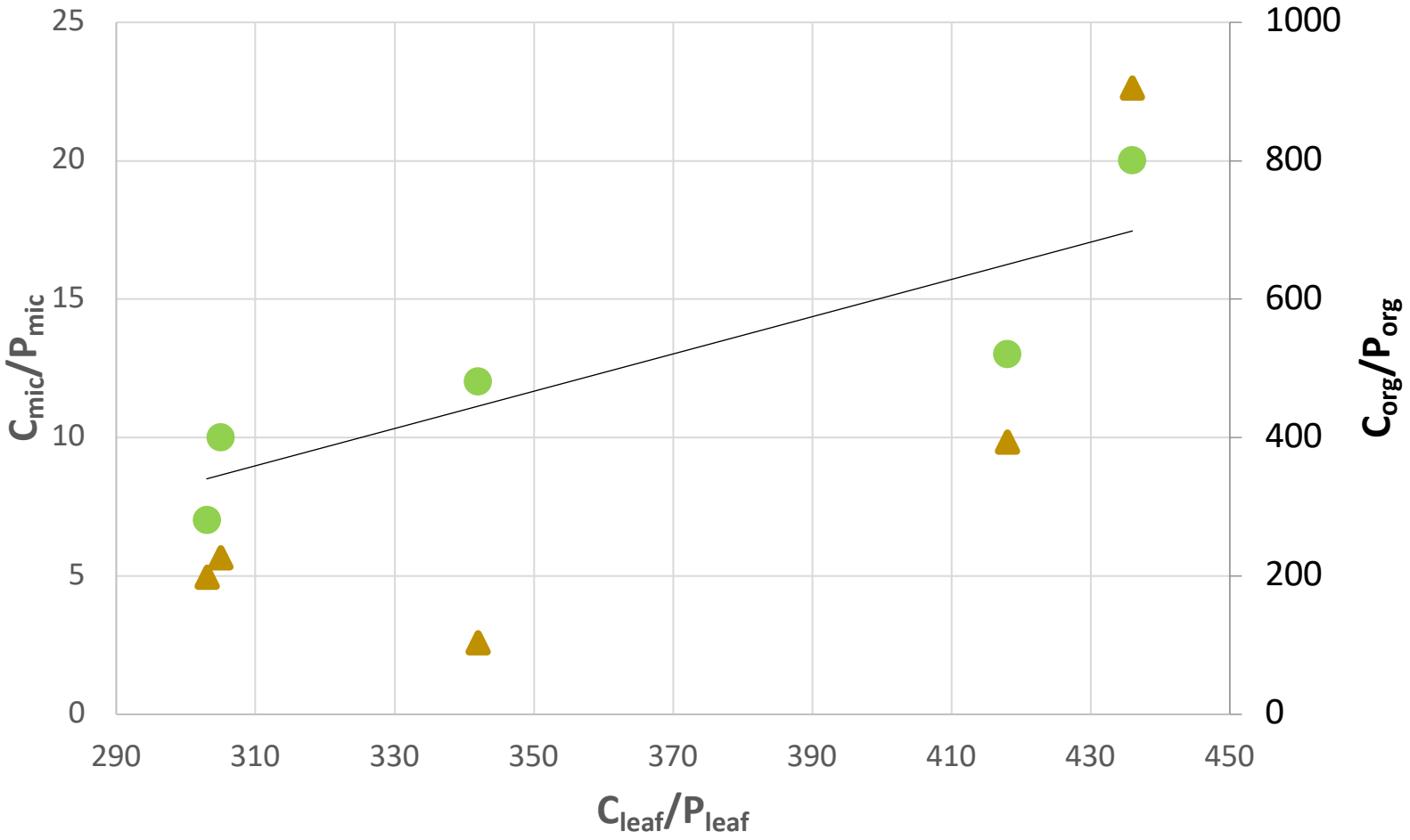
Microorganisms – P stoichiometry

Intense P
mobilisation from soil minerals

…by microorganisms
Pistocchi et al. 2020,
Rodionov et al. 2020

...by beech
Meller et al. 2019



BBR
Microbial P storage

LUE
Microbial P exchange

Intense P
mobilisation from SOM

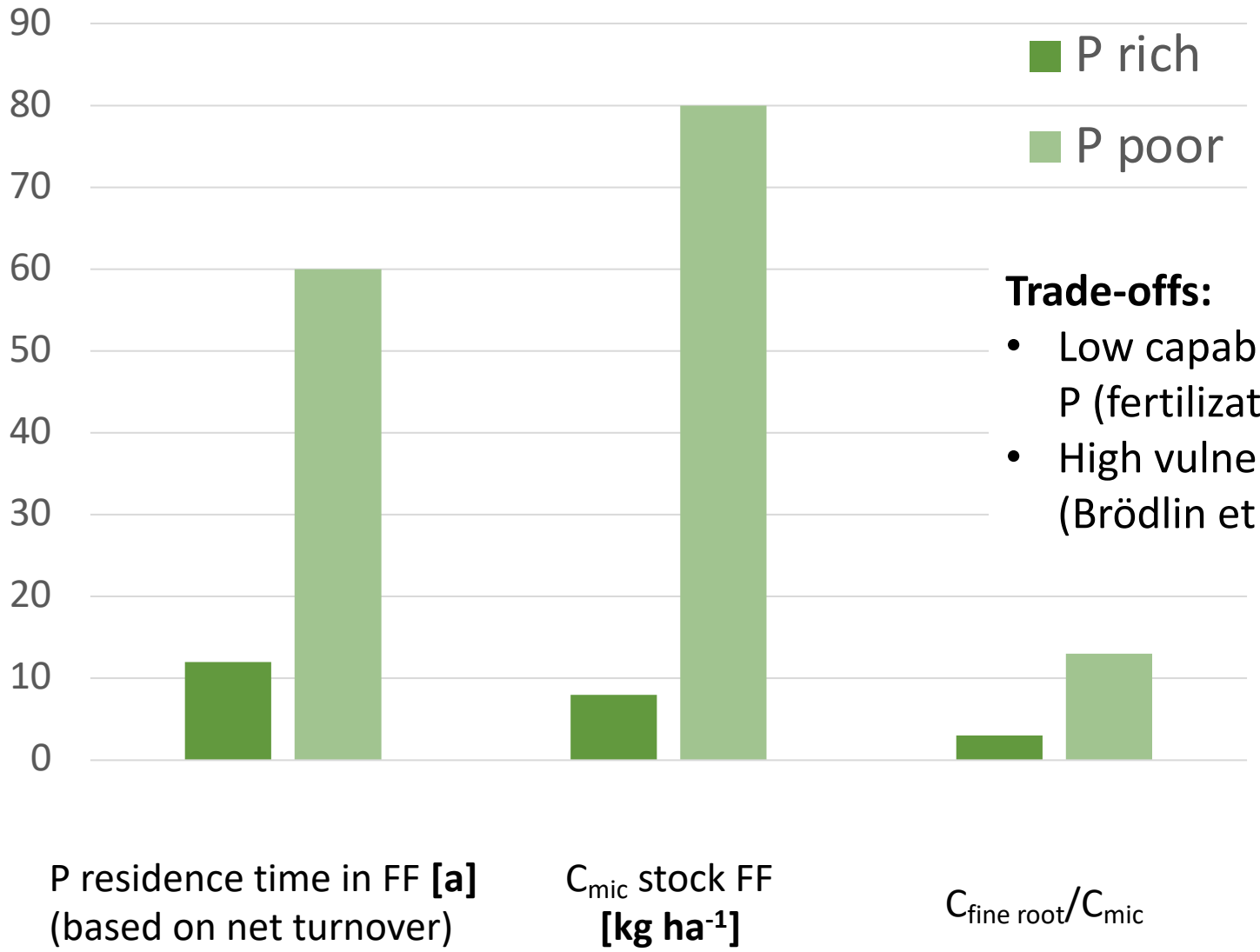
…by microorganisms
Bergkemper et al. 2016
Pistocchi et al. 2018

...by beech + EMF
Hauenstein et al. 2018
Spohn et al. 2018

Chen et al. 2019: $^{33}P/^{14}C/^{15}N$ incubation experiment

Data of Carbonate sites from Prietzel et al, in prep.

P-poor beech forests rely on tight re-cycling of P within the forest floor



Trade-offs:

- Low capability to retain inorganic P (fertilization experiment)
- High vulnerability to drought (Brödlin et al. 2019)

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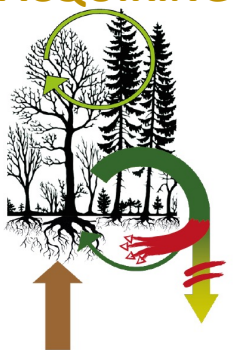
P-storage by
European Beech

ACQUIRING



P storage by
soil Microorganisms

Share of „flowing“ P

P storage by ***mineral soils***

RECYCLING

P interchange by soil microorganisms

Internal P-recycling by
European Beech

Contact: Fritzi.lang@soil.uni-freiburg.de

Thank you!

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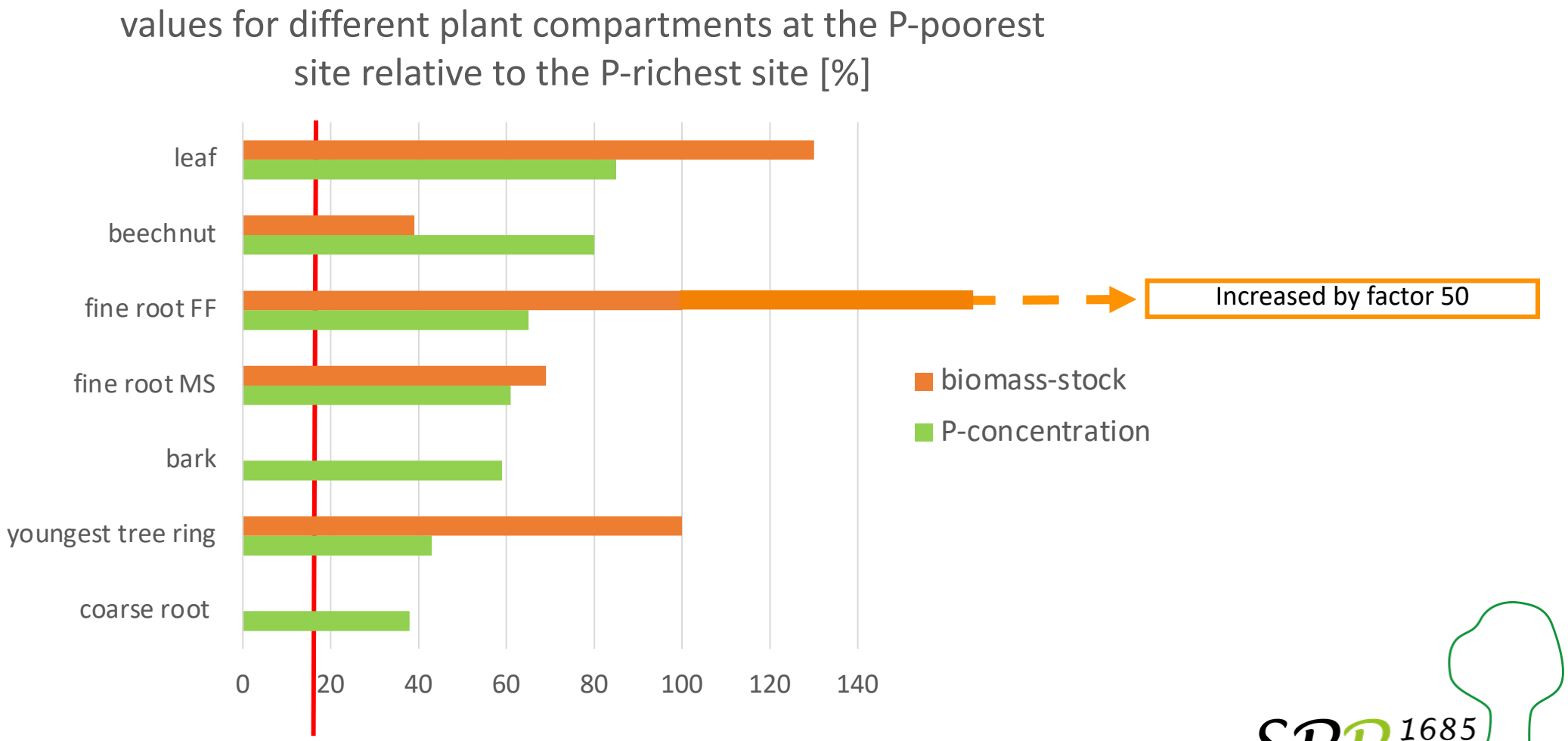
- Members of SPP 1685
- ICP Forests community
- State Forest Institutions: Baden-Württemberg, Bayern, Niedersachsen, Thüringen
- WSL
- Thünen-Institute, Braunschweig
- Special thanks to: Andrea Hölscher, Henning Meesenburg, Stefan Raspe
- DFG, SNF

Sensitivity of beech compartments to decreasing soil P supply



Soil P stock: 18% of the P-richest site

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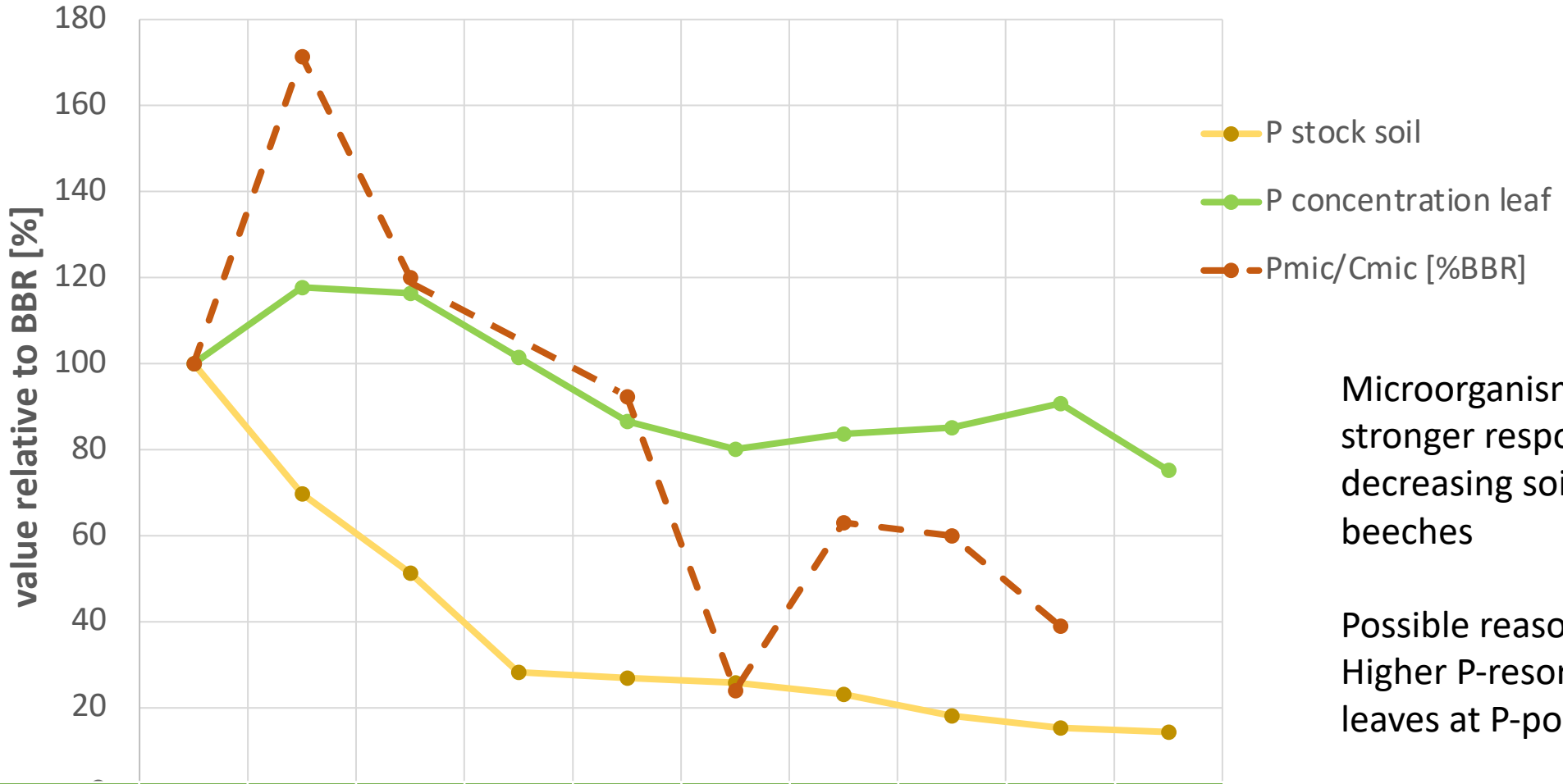


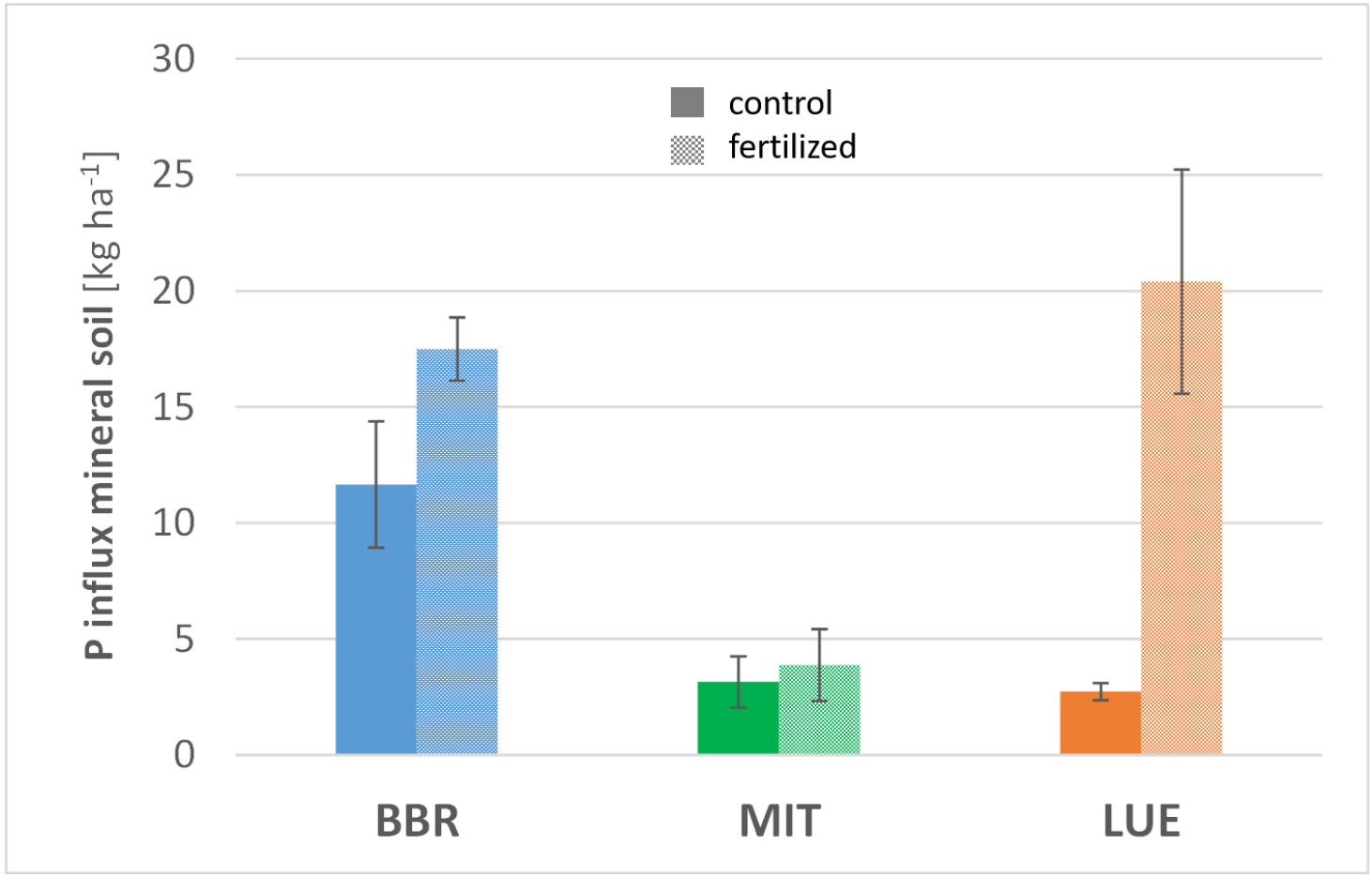
	BBR	MIT	VES	MANS	CON	SCH	TUTNE	LUE	MANN	TUTSW
Microbial C:P	12	7	10		13	50	19	20	31	
Leaf C:P	342	303	305	357	418	425	409	436	391	485
Microbial C:N	14	10	13		11	5	7	16	6	

Microorganisms show stronger response to decreasing soil P than beeches

Possible reason:
Higher P-resorption from leaves at P-poor sites

Resorption efficiency
LUE: 60%
BBR: 10%
Meller et al. 2019

Dissolved P fluxes from the forest floor into the mineral soil of the P-fertilization experiment (over 26 months)

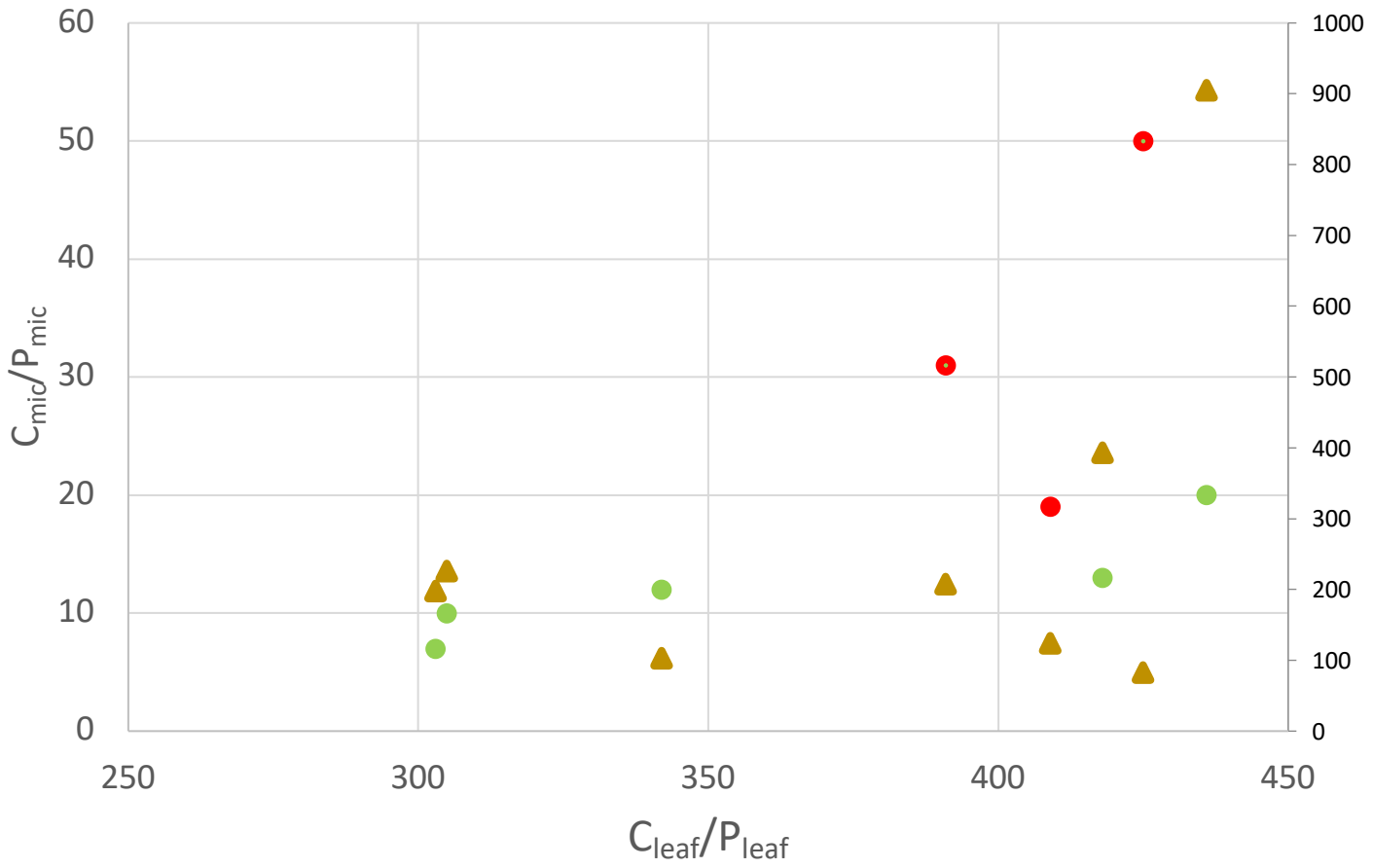


Low capability of the FF at the P-poor site to retain high amounts of inorganic P

P-rich site: Efficient mobilisation and uptake from **inorganic sources**	**P-poor site**: Efficient mobilisation from **organic sources**
…by microorganisms *Bergkemper et al. 2016, Pistocchi et al. 2020, Rodionov et al. 2020 Siegenthaler, sub.*	***…by microorganisms*** *Bergkemper et al. 2016 Pistocchi et al. 2018 Spohn et al. 2018 Siegenthaler, sub.*
…by beech *Meller et al. 2019*	***…by beech + EMF*** *Hauenstein et al. 2018 Spohn et al. 2018*

* *Values for BBR roughly estimated based on Fetzer et al. 2021; values for MIT and LUE measured by resin accumulators*

Stoichiometry carbonate sites



Microorganisms – P stoichiometry

Decreasing soil P stock

	BBR	MIT	VES	MAN S	CON	SCH	TUT NE	LUE	MAN N	TUT SW
Microbial C:P A horizons	12	7	10		13	50	19	20	31	
Leaf C:P	342	303	305	357	418	425	409	436	391	485
Microbial C:N A horizons	14	10	13		11	**5**	**7**	16	**6**	

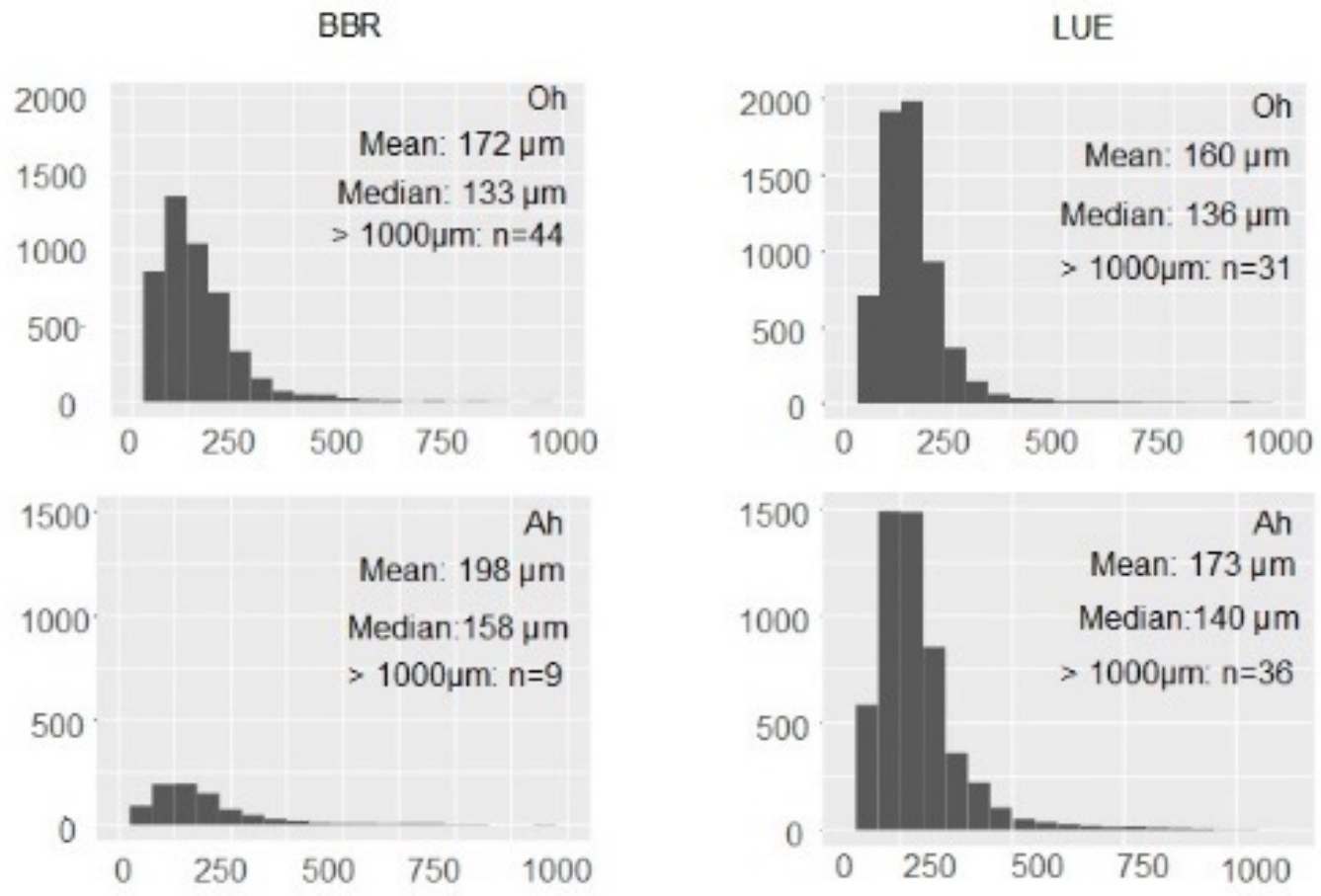
BBR
Microbial P storage

LUE
Microbial P exchange

Chen et al. 2019: $^{33}P/^{14}C/^{15}N$ incubation experiment

Data of Carbonate sites from Prietzel et al, in prep.

Feinwurzelgrößenverteilung Auflage/A-Horizont



Feinwurzelgrößenverteilung Unterboden