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Biotic versus abiotic drivers: Disentangling key factors shaping rhizosphere phosphorus speciation along a climatic gradient

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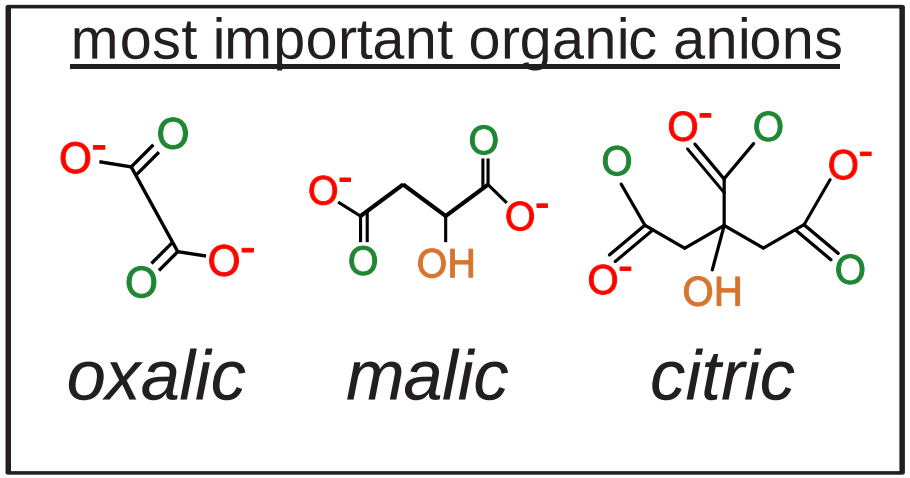
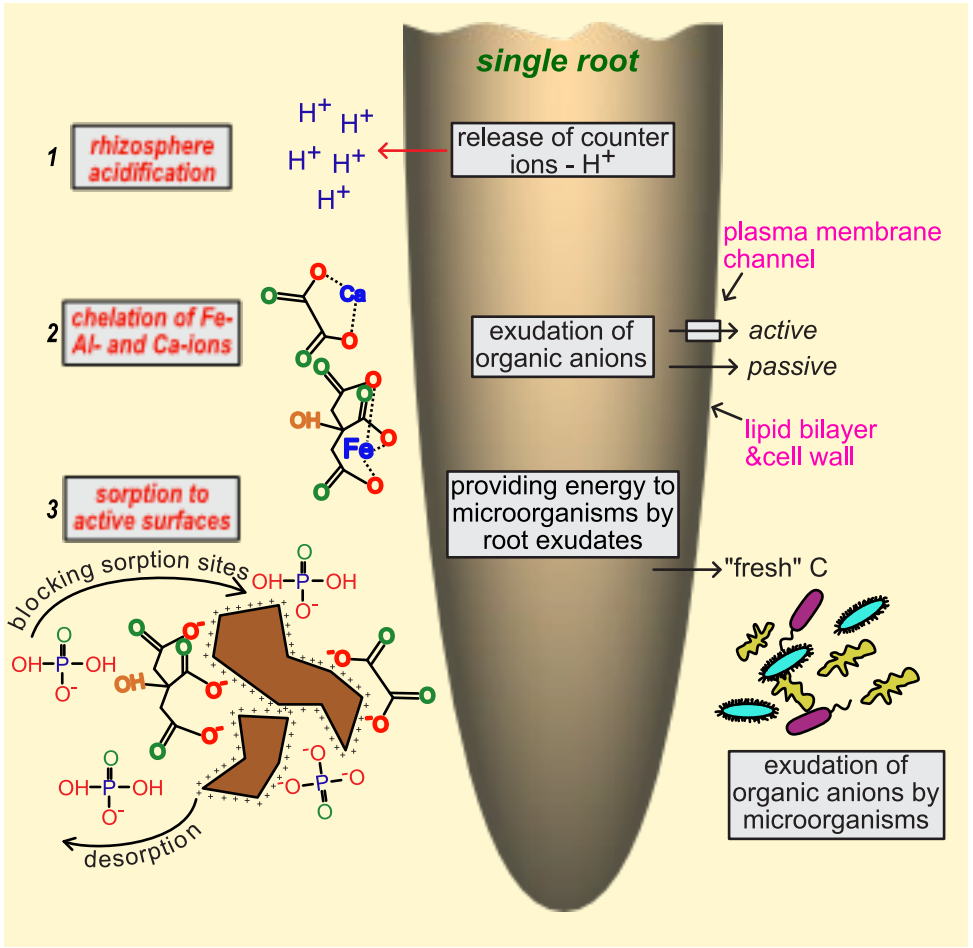
Exudation of organic anions in the rhizosphere and mechanisms of mineral dissolution

1. Rhizosphere acidification
2. Chelation of Fe- and Al-ions
3. Sorption to active surfaces





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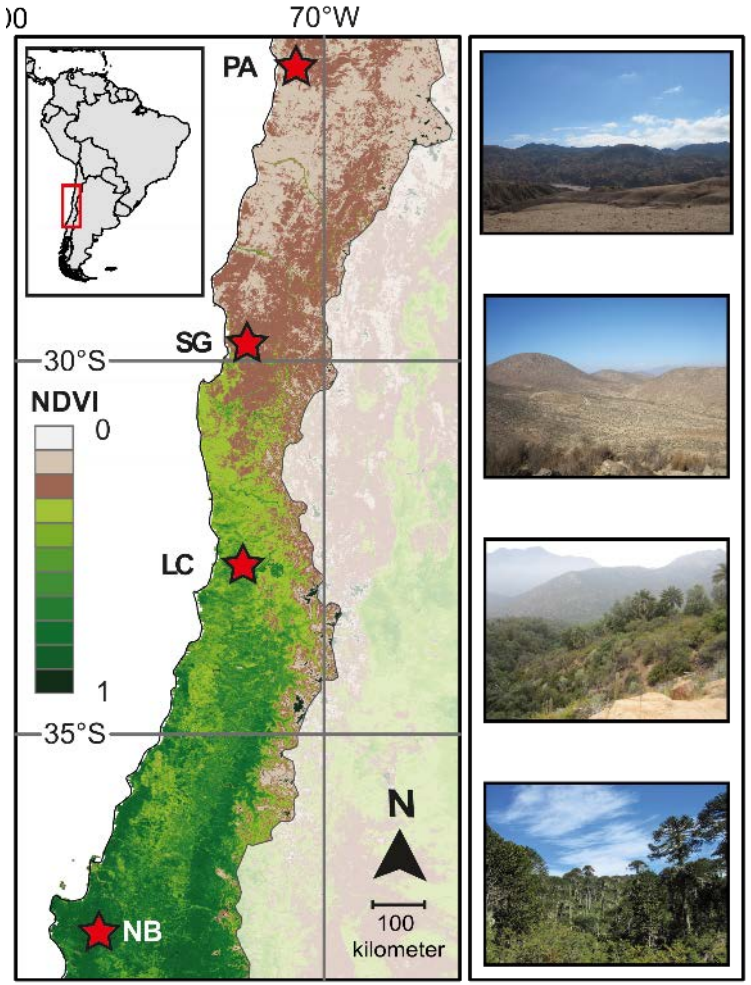
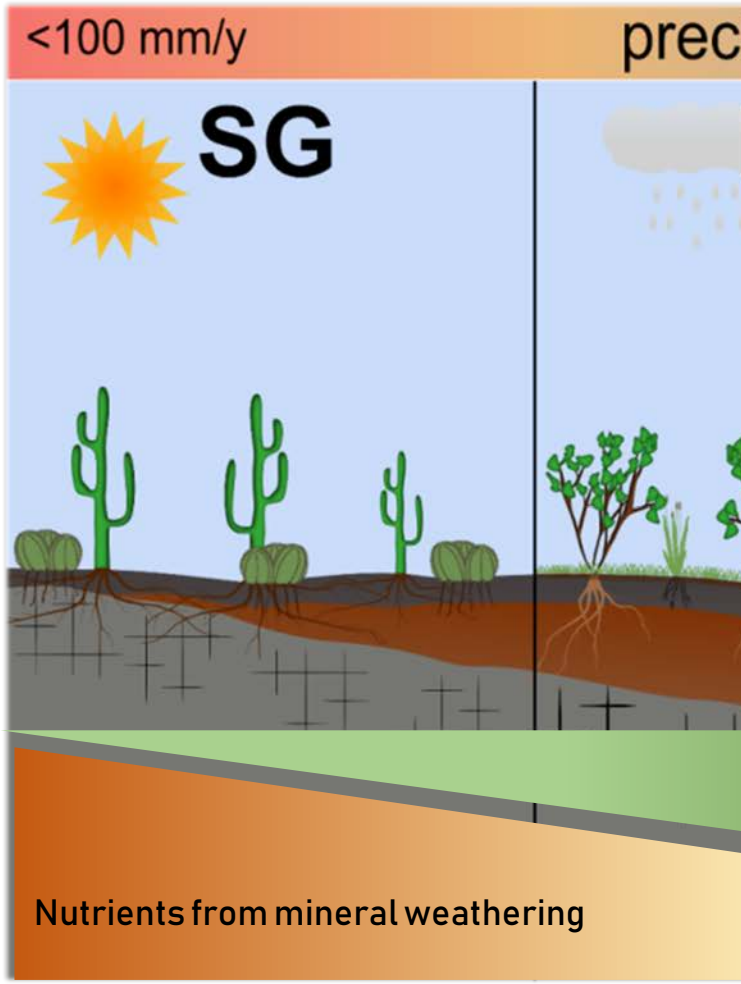
Study sites along the Chilean Coastal Cordillera





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Hypotheses

H1: With increasing precipitation the acquisition strategy for nutrients will change from a system relying on P directly from mineral weathering to a system mainly utilizing organic P.

H2: The content of apatite will be diminished in root proximity.

H3: LMWOA in soil have a positive correlation with apatite content.

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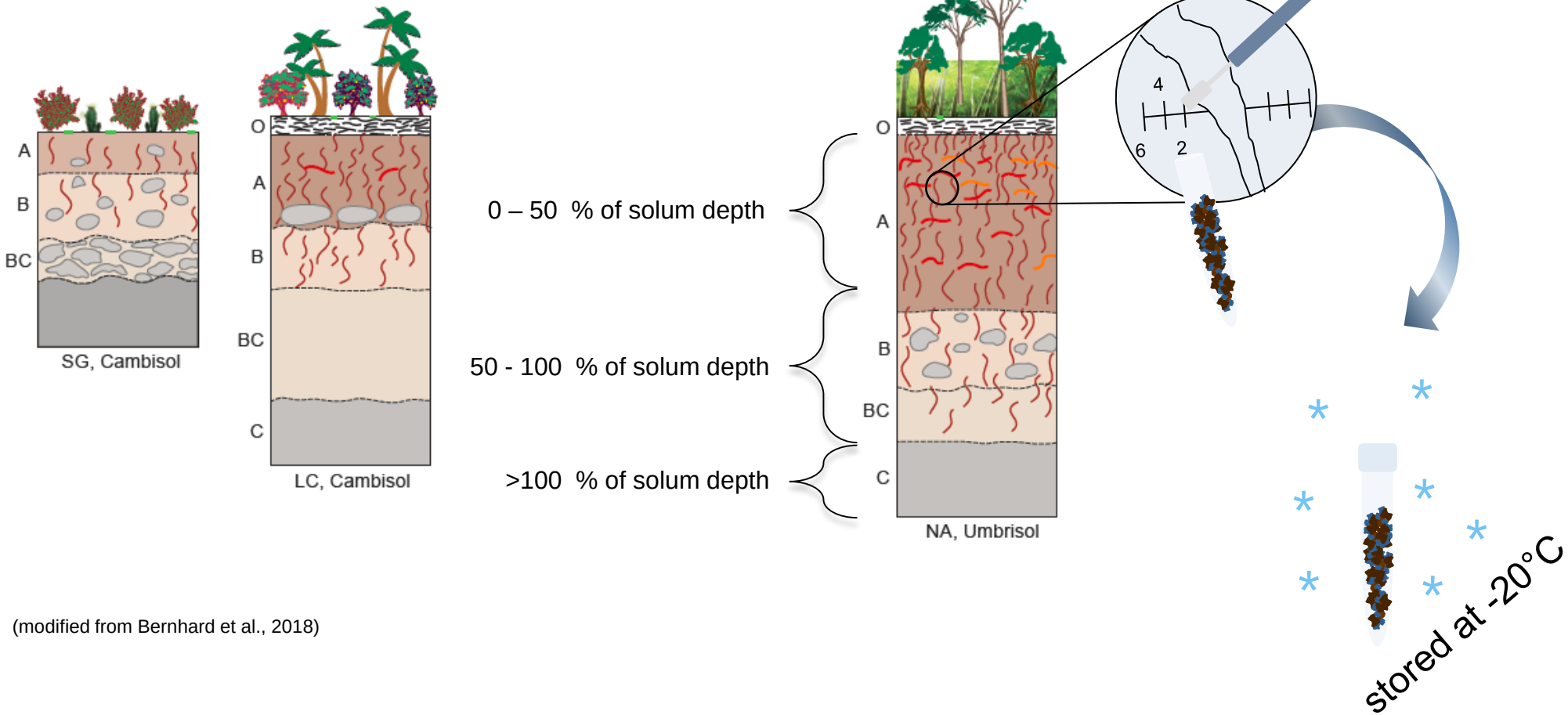

(modified from Bernhard et al., 2018)

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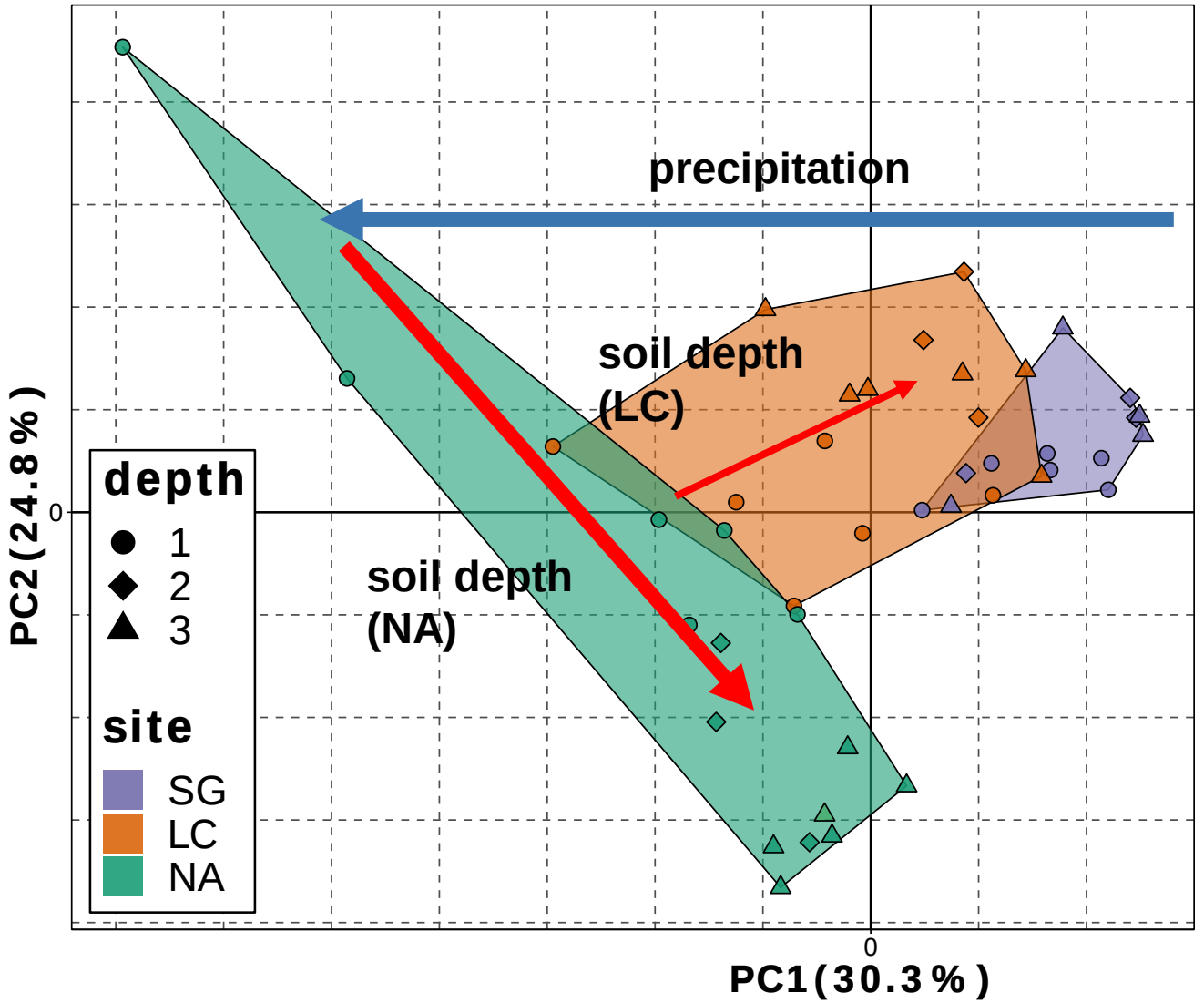
PCA by P species and LMWOA

- Ordination along PC1 with climatic conditions
- Within polygons
  - Separation with soil depth in NA (humid) and LC (Mediterranean)
- No separation with soil depth in SG (semi-arid)



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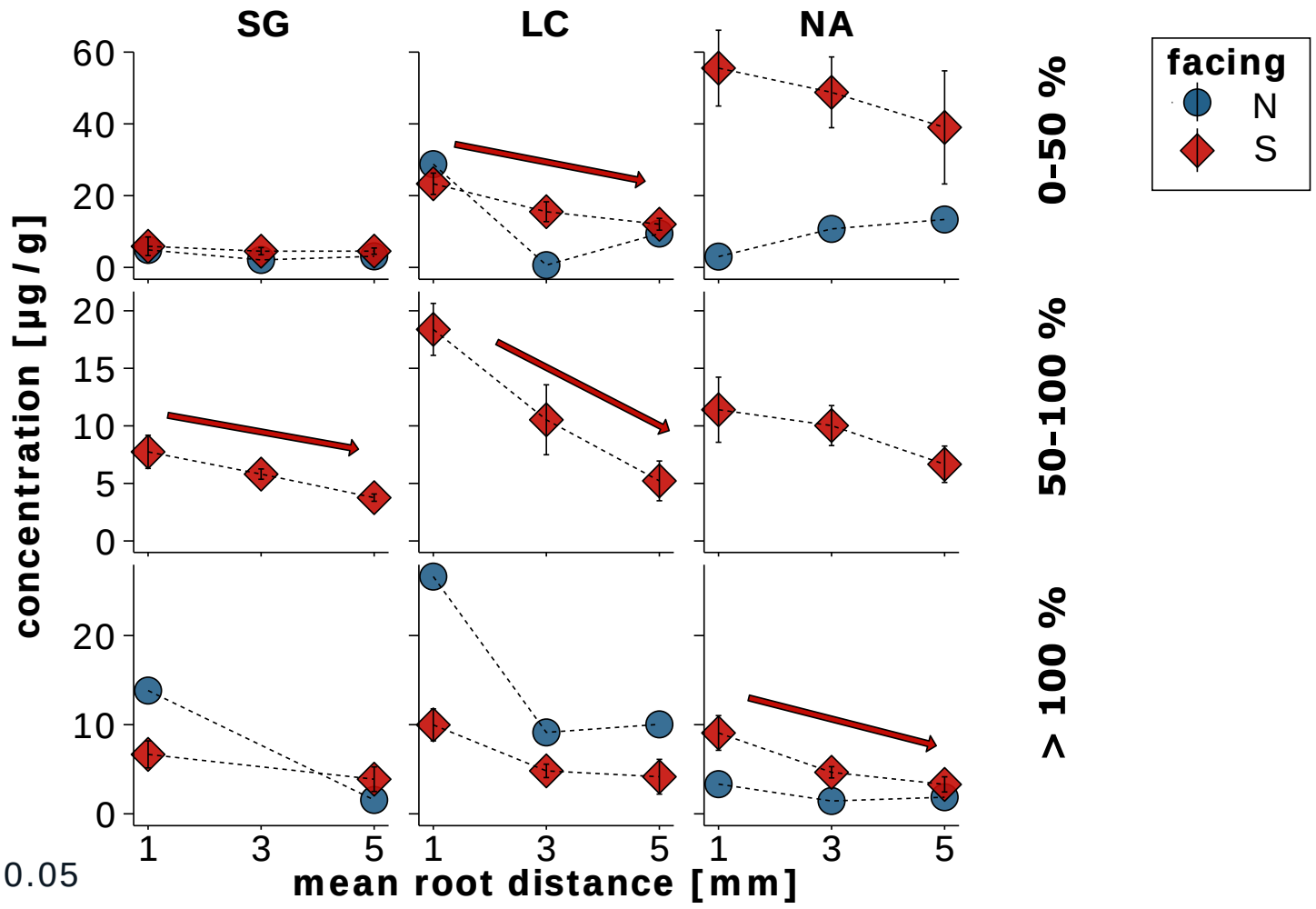
Oxalic acid concentration in the rhizosphere and along the climosequence

- Increasing concentration with increasing precipitation
- Decreasing content with increasing root distance
- Decreasing content with increasing depth



n=1 (N); n=3 (S) ; p<0.05

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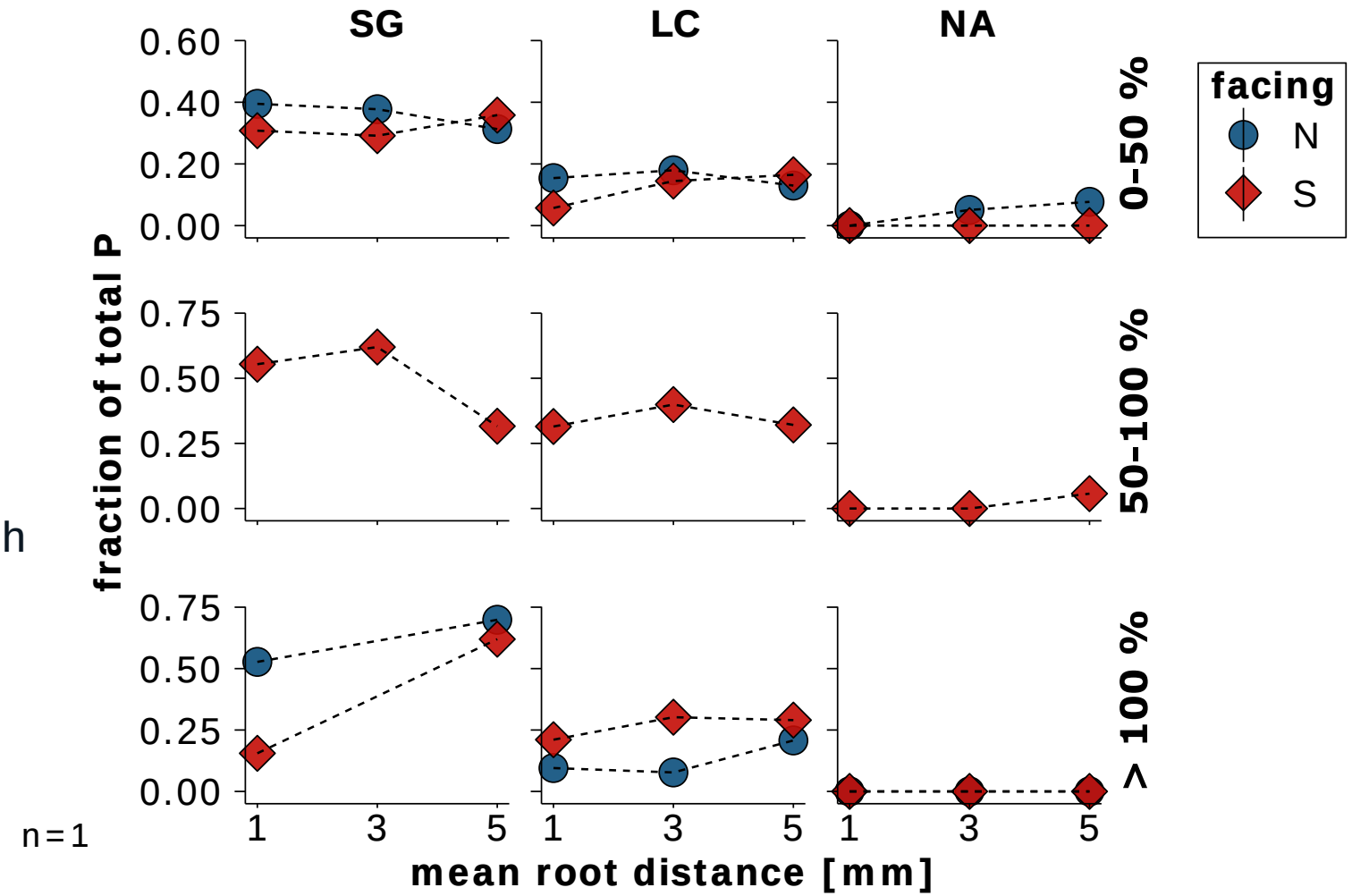
Apatite in the rhizosphere and along the climosequence

- Decreasing apatite concentration with increasing precipitation
- Increasing apatite content with increasing depth
- Constant apatite concentration with increasing distance to roots



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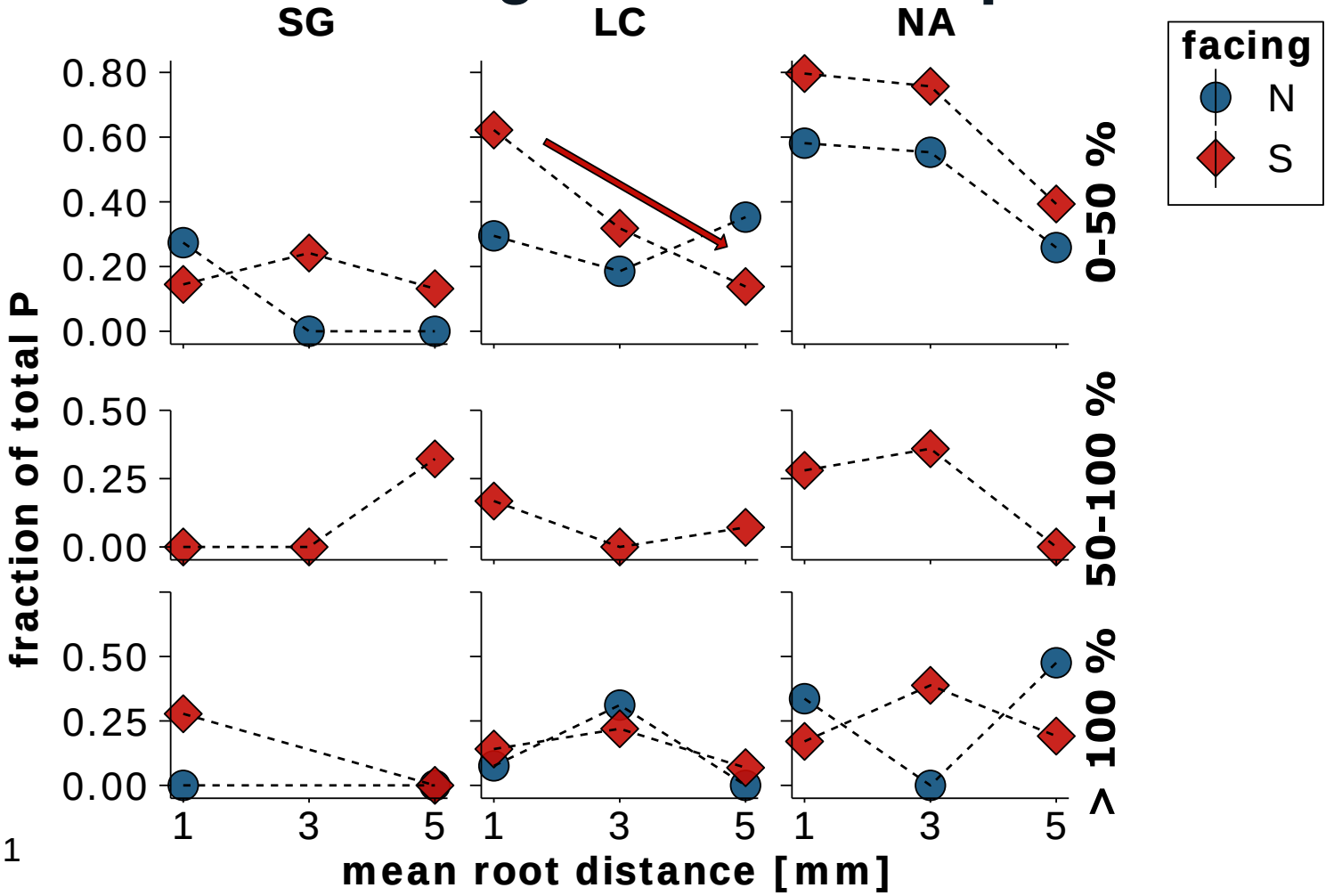
Inorganic P in the rhizosphere and along the climosequence

- Clear rhizogradient
  - Increases with increasing root distance
- +/- stable over the continental and depth gradient



n = 1; p < 0.1

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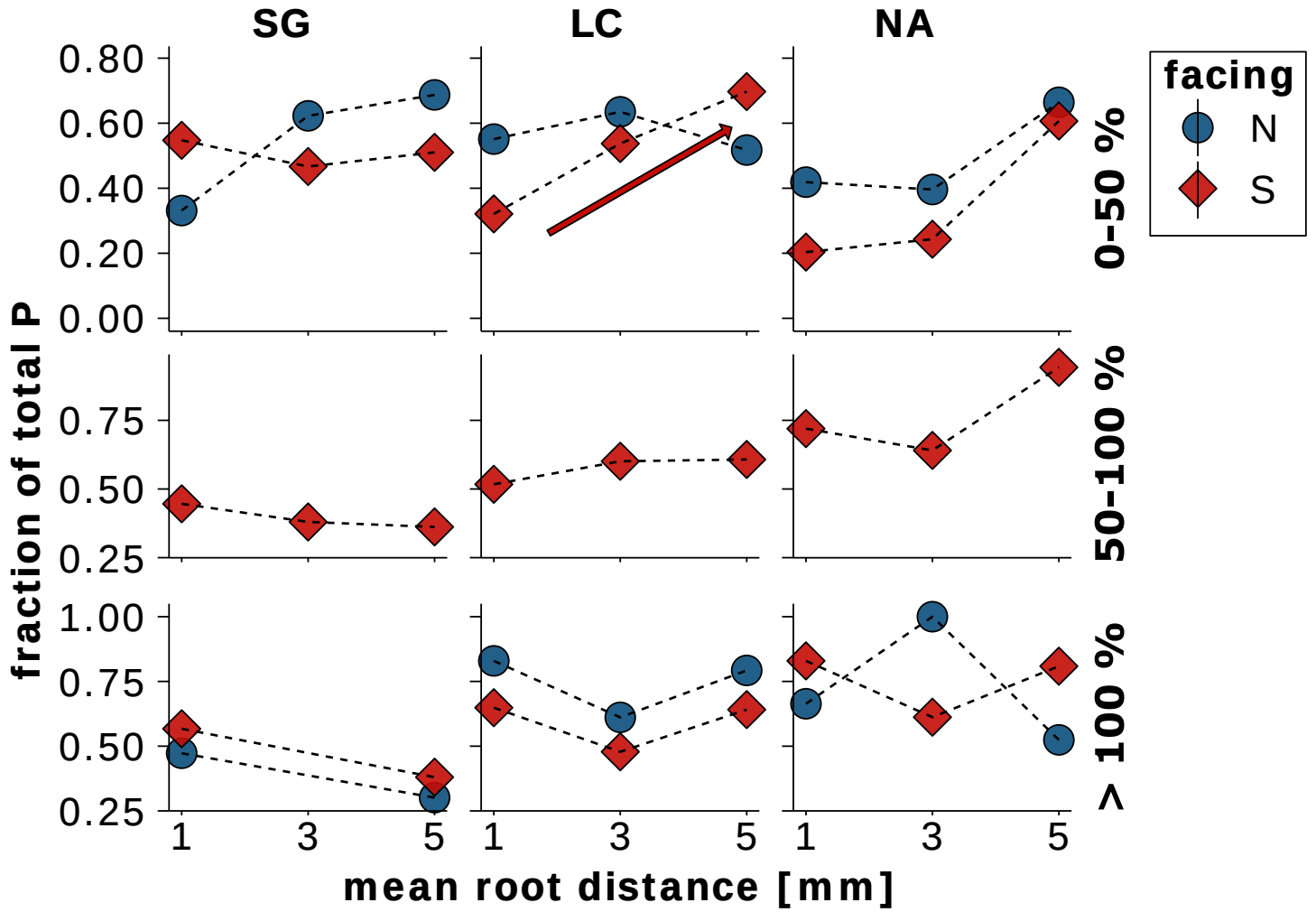
Organic P in the rhizosphere and along the climosequence

- Clear rhizogradients
  - Decrease with increase in root distance
- Decreases with depth
- Increases with increasing precipitation



n=1; p<0.1

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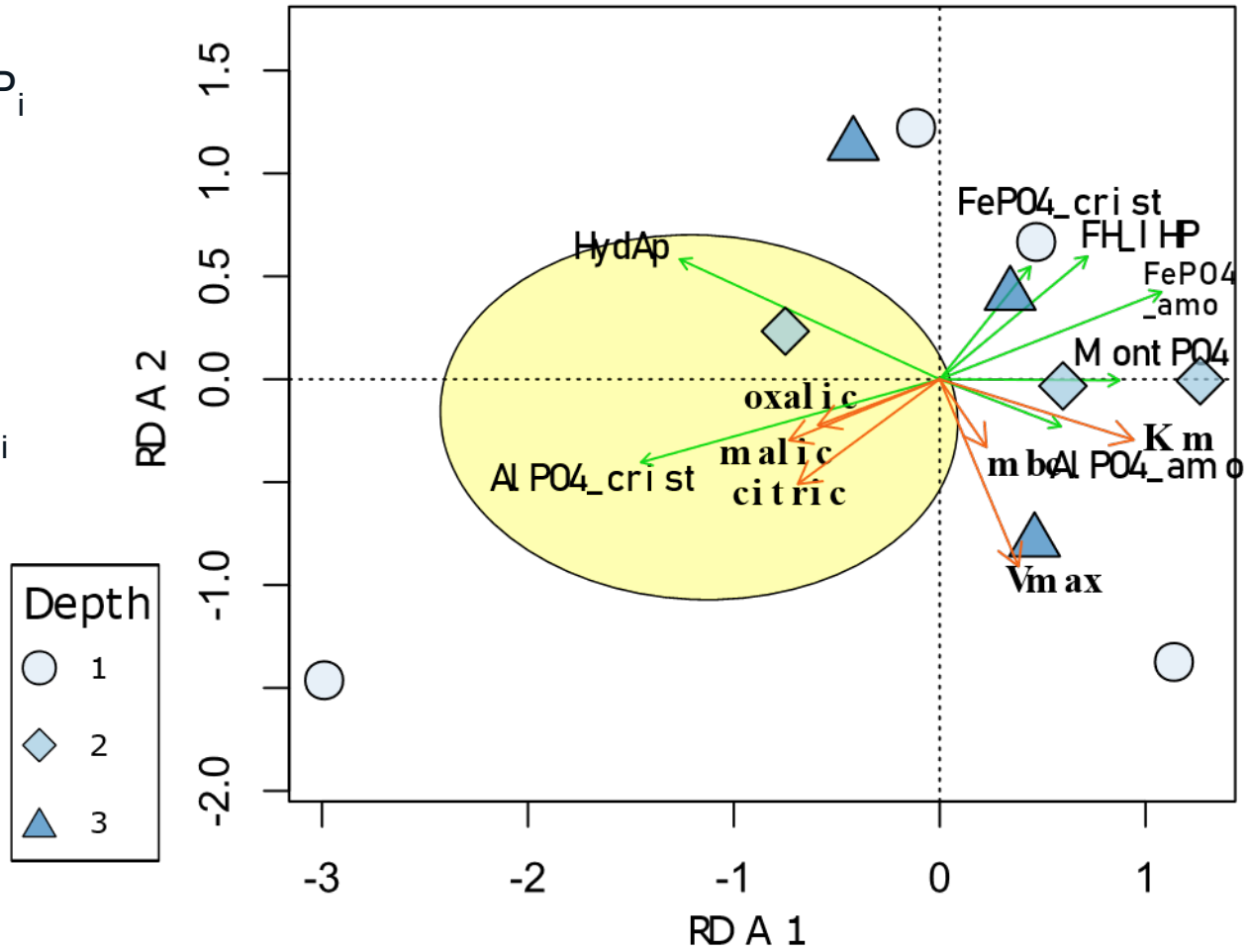
RDA disentangling factors shaping P speciation - SG

- Strong correlation of LMWOA with apatite and P_i adsorbed to crystalline Al-minerals
  - AlPO4_crist + HydAp ~76% of total P
- Phosphatase parameters correlated only with P_i adsorbed to amorphous Al-minerals
  - AlPO4_amo <5% of total P



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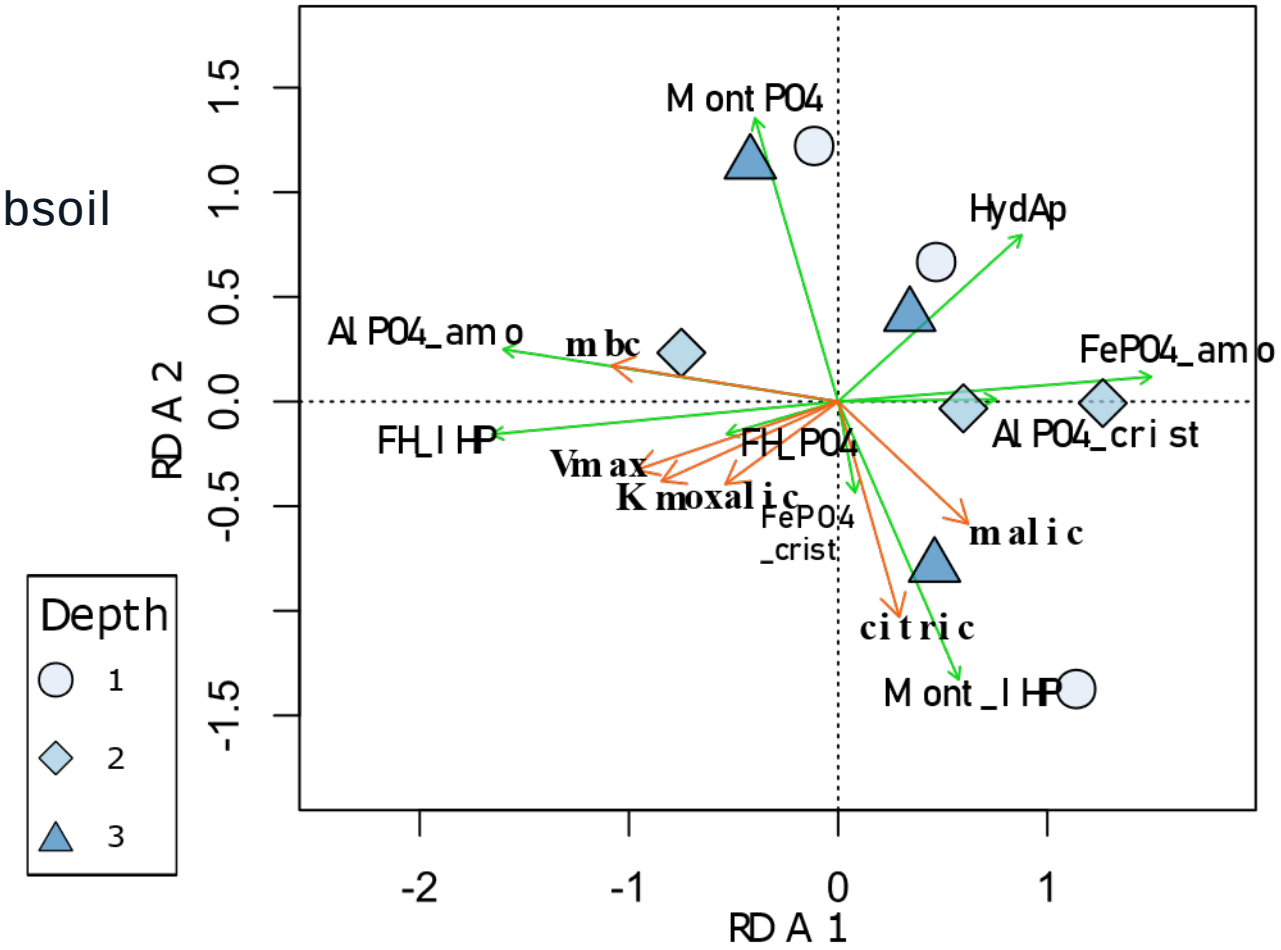
RDA disentangling factors shaping P speciation - LC

- No clear pattern
- Conditions in the topsoil resemble NA while subsoil conditions are more close to SG



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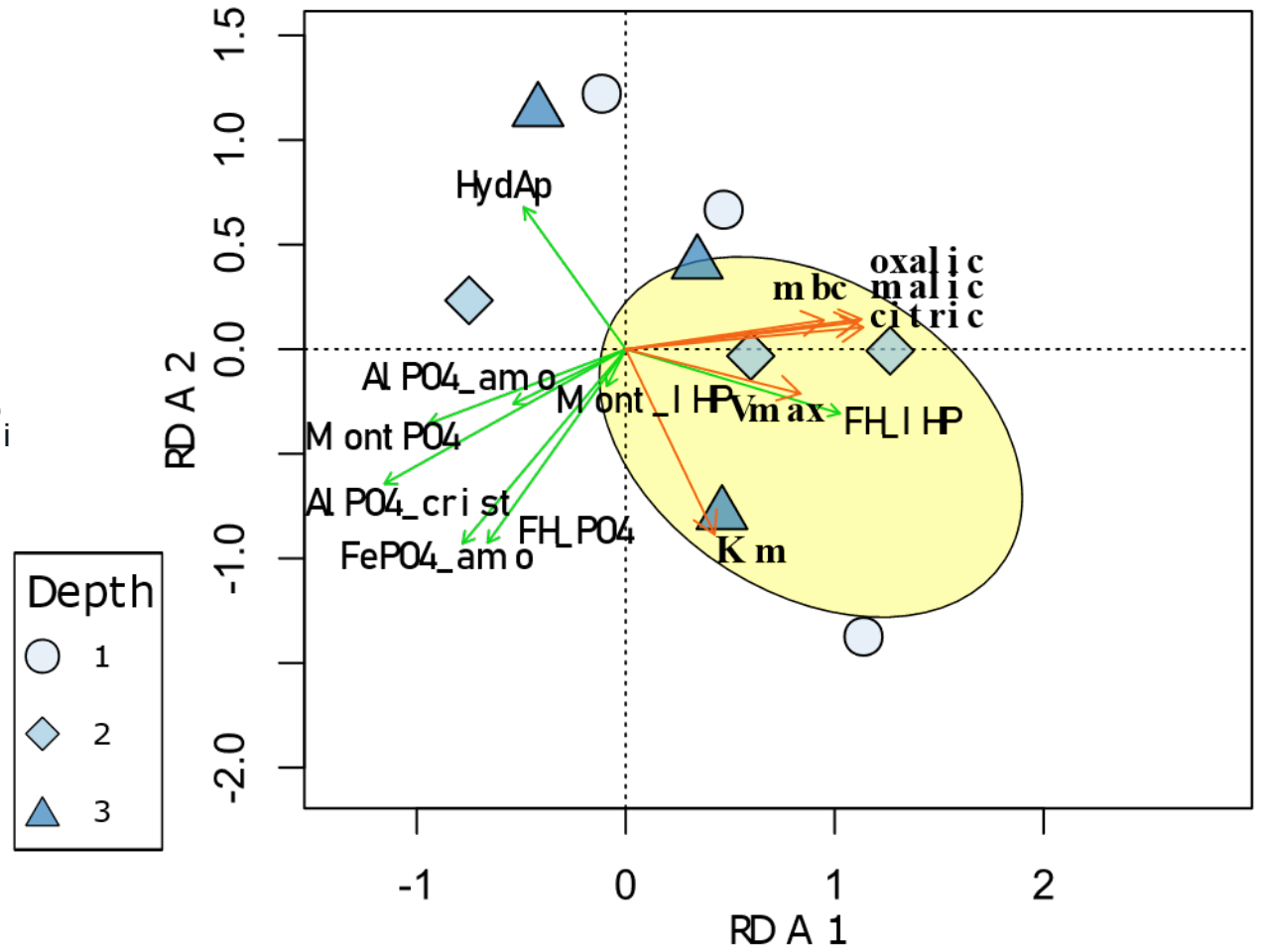
RDA disentangling factors shaping P speciation - NA

- Both, phosphatase parameters, MBC and

  LMWOA show correlation with P_o

  - FH_IHP ~ 20% of total P
- But no correlation or negative with apatite or P_i
  - AlPO4_amo ~ 31% of total P



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Summary

- **Climosequence:**
  - Primary and organic P strongly influenced by precipitation
  - Adsorbed inorganic P not influenced by precipitation
- **Rhizogradients:**
  - Strong impact on inorganic (+) and organic (-) P
  - Strong impact on LMWOA (+)

Conclusion

- **P acquisition strategy**
  - In the semi-arid environment P acquisition is driven by biotic weathering of P minerals
  - Under humid conditions P demand is covered by organic sources
  - Mediterranean site in topsoil as the humid site, subsoil resembles the semi-arid ecosystem

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Thank you for your attention

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References

BERNHARD, N., MOSKWA, L. M., SCHMIDT, K., OESER, R. A., ABURTO, F., BADER, M. Y., … KÜHN, P. (2018). Pedogenic and microbial interrelations to regional climate and local topography: New insights from a climate gradient (arid to humid) along the Coastal Cordillera of Chile. *Catena*, *170*, 335–355. https://doi.org/10.1016/j.catena.2018.06.018

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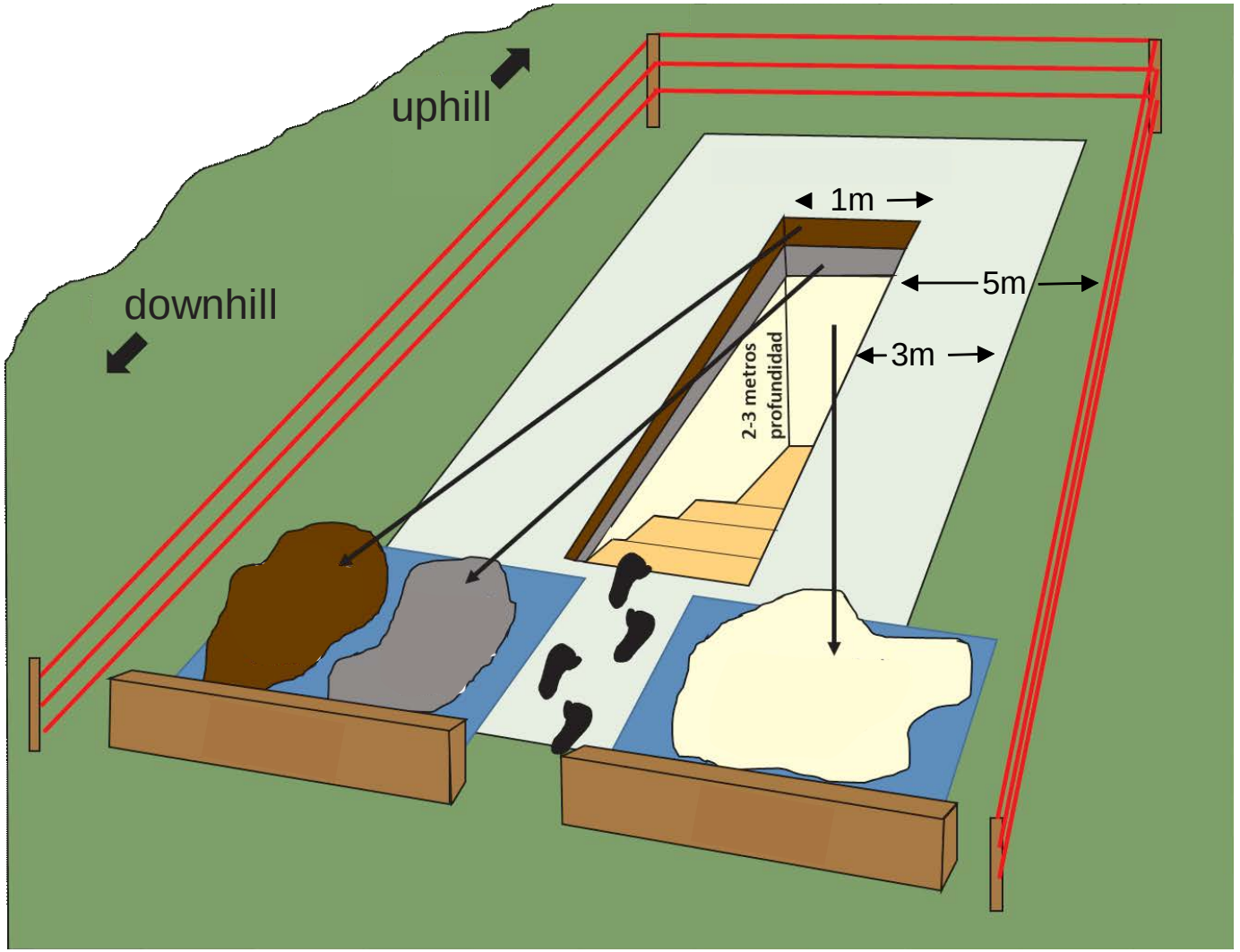
Study design



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Standards for fitting XANES spectra

Standard	Description	Abbreviation
Ca-hydroxy-apatite	Primary P bearing mineral	HydAp
PO_4-Al crystalline	Inorganic P associated with Fe- Al- and clay particles.	$AlPO_4$_crist
PO_4-Al amorphous		$AlPO_4$_amo
PO_4-Fe amorphous		$FePO_4$_amo
PO_4-Fe crystalline		$FePO_4$_crist
PO_4-Ferryhydrite		FH_PO_4
PO_4-Al-Montmorilonite		Mont_Al_PO_4
IHP-Ferrihydrite	Organic P associated with clay particles and Ferrihydrite (inositolhexakisphosphate serves as a proxy for organic P in general).	FH_IHP
IHP-Al-Montmorillonite		Mont_Al_IHP

- **Sample spectra were fitted by linear combinations of standard spectra**

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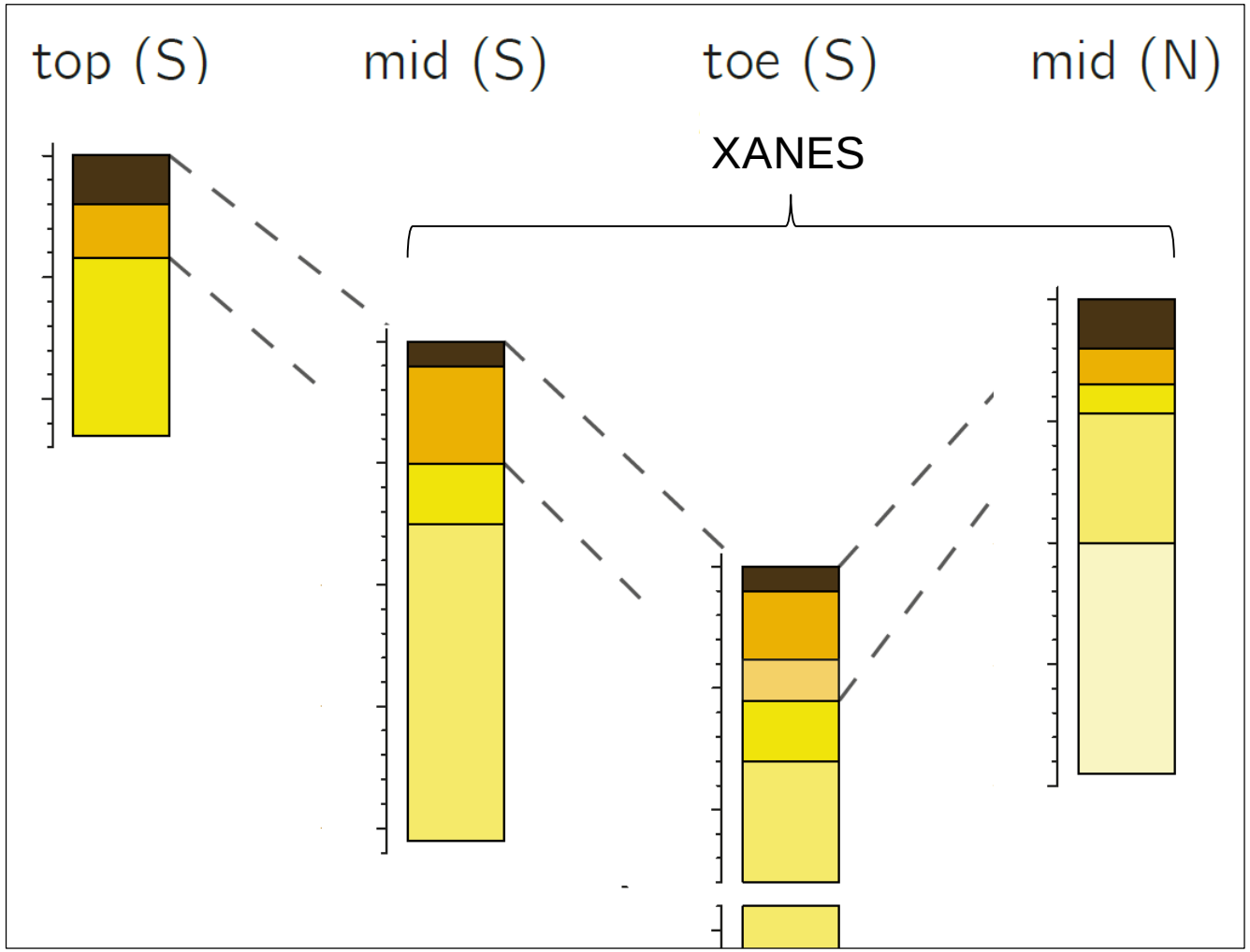
Study design

- X-ray absorption near edge structure (XANES) at the k-edge of P atoms
  - Midslopes north- and south-facing



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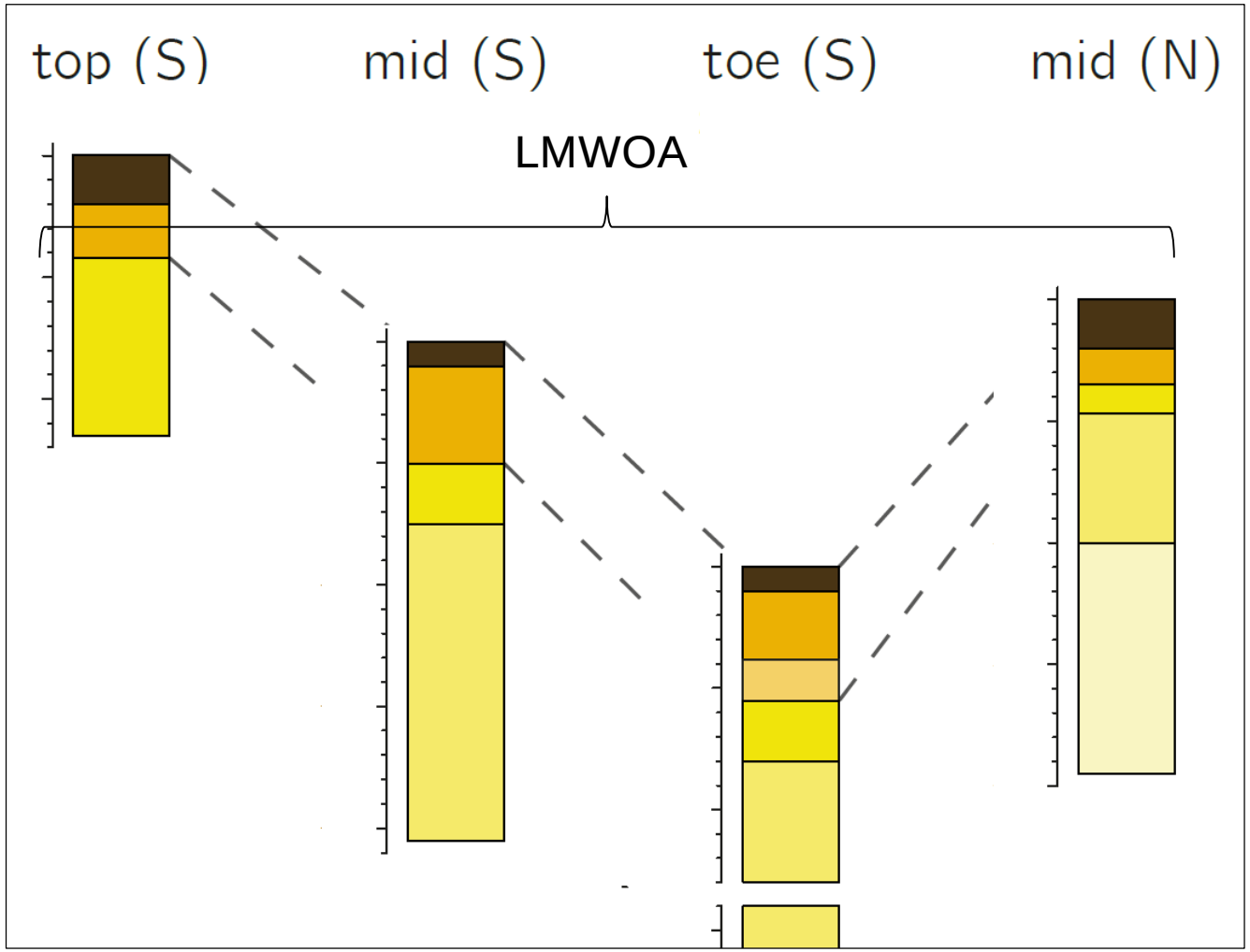
Study design

- Low-molecular weight organic acids (LMWOA)
- Phosphatase activity and substrate affinity (V_{max} and K_m)
- Microbial biomass carbon (MBC)
  - All soil pits



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