Coupling reactive transport processes with root system architecture and functions: principles and application examples

Frédéric Gérard
Hannah Gatz-Miller
Renato K. Braghiere
Sergio Bea
Philippe Hinsinger
Loïc Pagès
Uli Mayer

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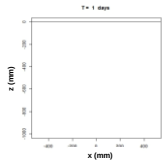
Principles

➡ *A new soil-plant model: **Min3P-ArchiSimple***

Gérard F., Blitz-Frayret C., Hinsinger P., Pagès L. (2017) - *Plant & Soil*, 413, 161-180.

Root system model ArchiSimple
(Pagès et al., 2014 - *Ecol. Model.*)



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(Mayer et al., 2002 - *WRR*;
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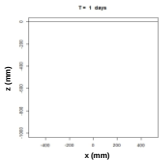

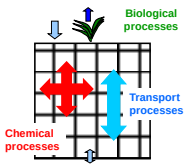

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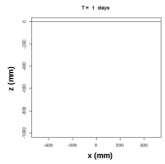
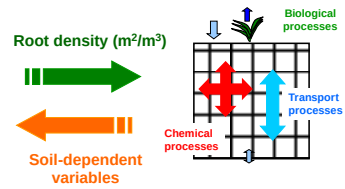




Principles

54 publications showing Min3P capabilities (source WOS using Min3P as topic)

Loomer et al. (2013) – *Applied Geoch.*
Cesium diffusion in a core

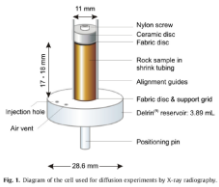
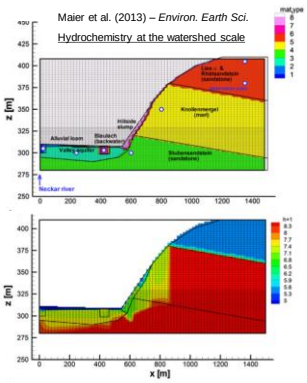
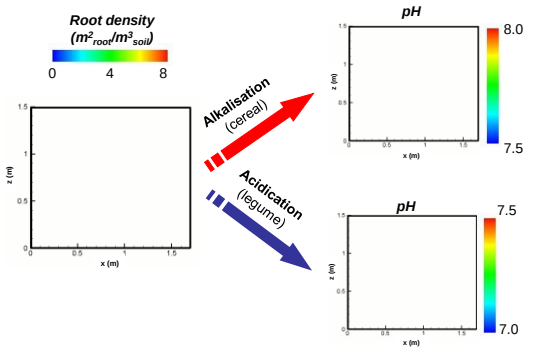


Fig. 1. Diagram of the cell used for diffusion experiments by X-ray radiography.

Maier et al. (2013) – *Environ. Earth Sci.*
Hydrochemistry at the watershed scale



Facilitation of P uptake for cereals



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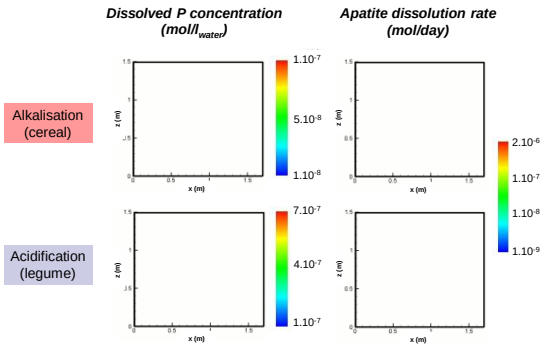

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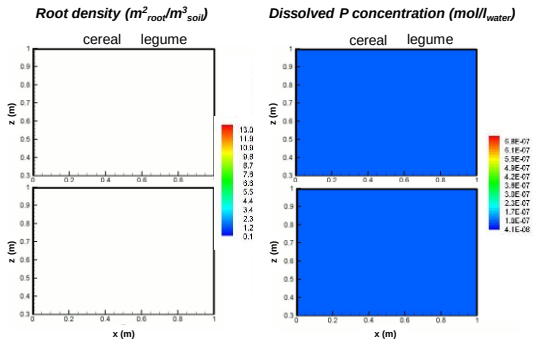

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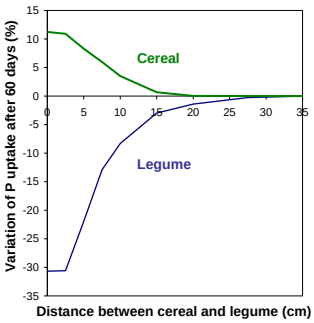


Increase of P uptake for cereal

e.g. 11% (15 to 6% using random RSA)

→ Consistent with literature

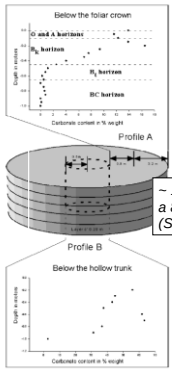
Decrease of P uptake for legume

e.g. 31% (40 to 20% using random RSA)

→ Inconsistent with literature

→ Missing process(es)

Carbonate formation in acidic soil



Field works Prof. E. Verrechia group of the Lausanne University

~ 1 Ton of $CaCO_3$ for a 80 years-old Iroko (Senegal)

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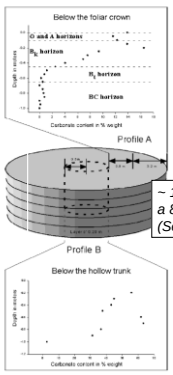

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$Ca\text{-oxalate} + O_{2(aq)} \Rightarrow Ca^{2+} + 2CO_{2(g)} + 2OH^-$

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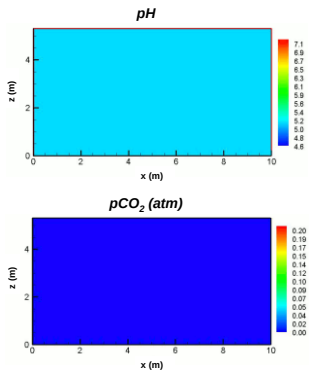
Proportion of C lost as $CO_{2(g)}$?

→ 90 %-70 % for fresh organic matter

Carbonate formation in acidic soil



pH rises to near neutral values at elevated pCO_2

→ Alkaline pH under atmospheric pCO_2

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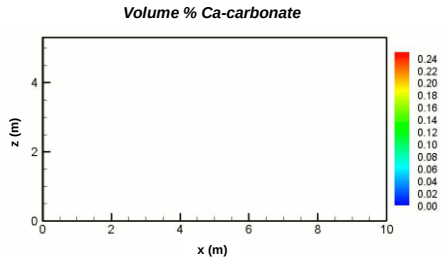
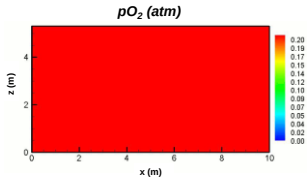
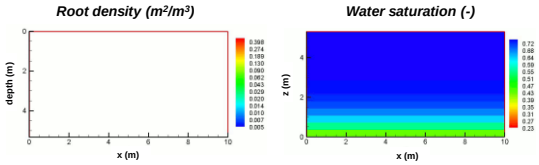


Correct concentrations of $CaCO_3$ → Yield of 50%

Carbonate formation in acidic soil



Overall reaction limited by soil aeration and thus tree transpiration, root system growth, etc.



Conclusions

The coupling of reactive-transport processes with root functions and architecture gives new modelling opportunities

- Mechanistic understanding of the facilitation of P acquisition by cereals in intercropping systems
- Missing process for legumes

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- Costly in CPU-time (new Min3P version allowing // computing: Danyang et al., 2017 – *Environm. Model. Soft.*)

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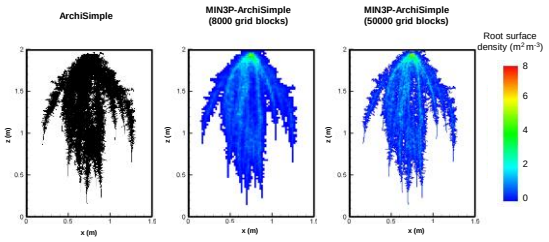
Other applications ongoing: since 1 month, on P acquisition from apatite in rhizotrons (FZ Julich, IBG-3; A. Schnepf et al.)

Thank you

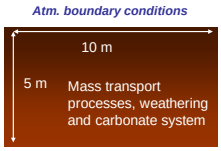
Principles

Numerical verification



Carbonate formation in acidic soil

- Ca weathering set according to literature (mean value of 0.75 kg_{Ca}/ha/yr - initial steady state)
- Litter fall dynamics and biodegradation kinetic parameters optimiazed:
  - ⇒ to get no Ca-oxalate left at t = 80 yrs
  - ⇒ to get the same extension of the $CaCO_3$ zone
- Ca-oxalate input within the first 50 cm of soil
- Water uptake
- Passive uptake of Ca



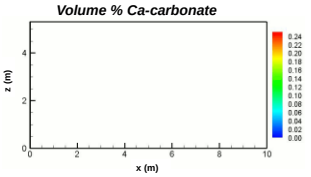
Alkaline pH values (~ 8.5)

Same $CaCO_3$ concentrations

Same formation time (80 yrs)

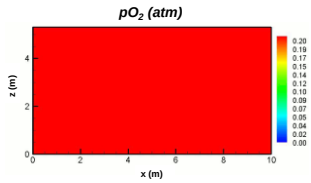
Proportion of C lost as $CO_{2(g)}$

Carbonate formation in acidic soil



Correct concentrations of $CaCO_3$

➡ Yield of 50%



O_2 consumption correlated with CO_2 production

Outline

- Material and method
- Example applications

➡ Improvement of phosphorus uptake by cereals due to intercropping with grain legumes

➡ C-storage in acidic soil through carbonate formation induced by Ca-oxalate biodegradation (Iroko trees)

Thesis H. Gatz-Miller

- Conclusions