Dynamics and effects of soil CO_2 on carbonate dissolution and transport in response to precipitation events

Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg

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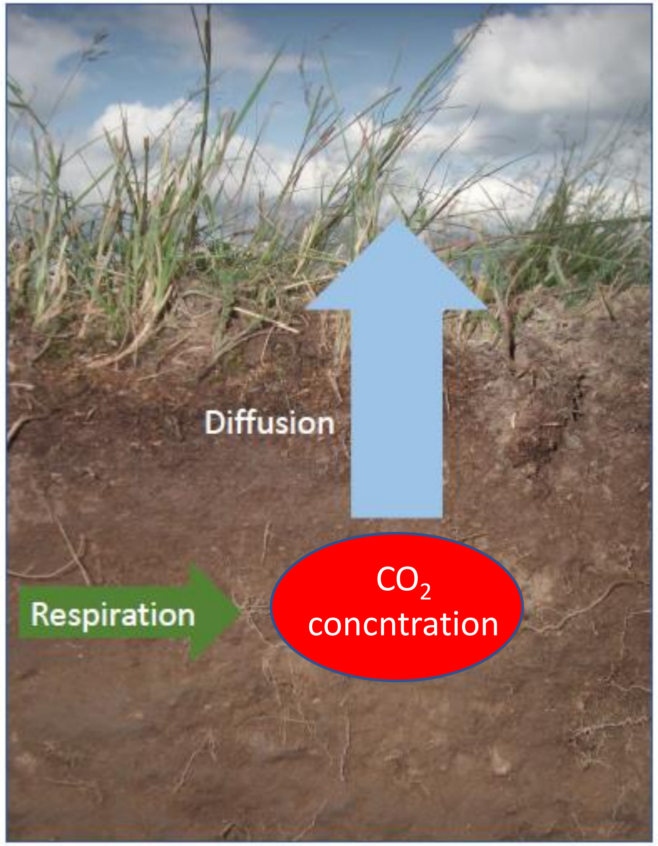

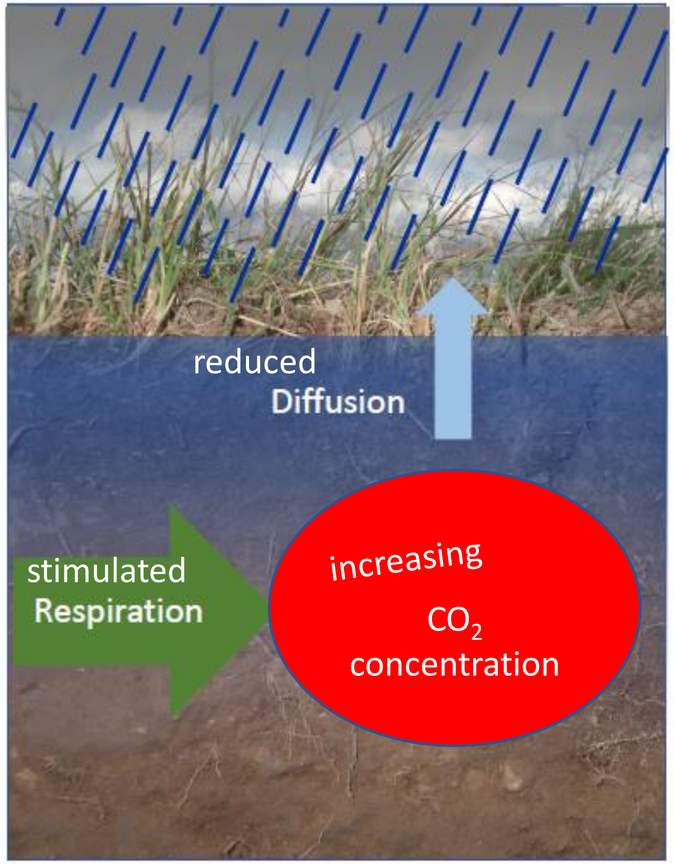

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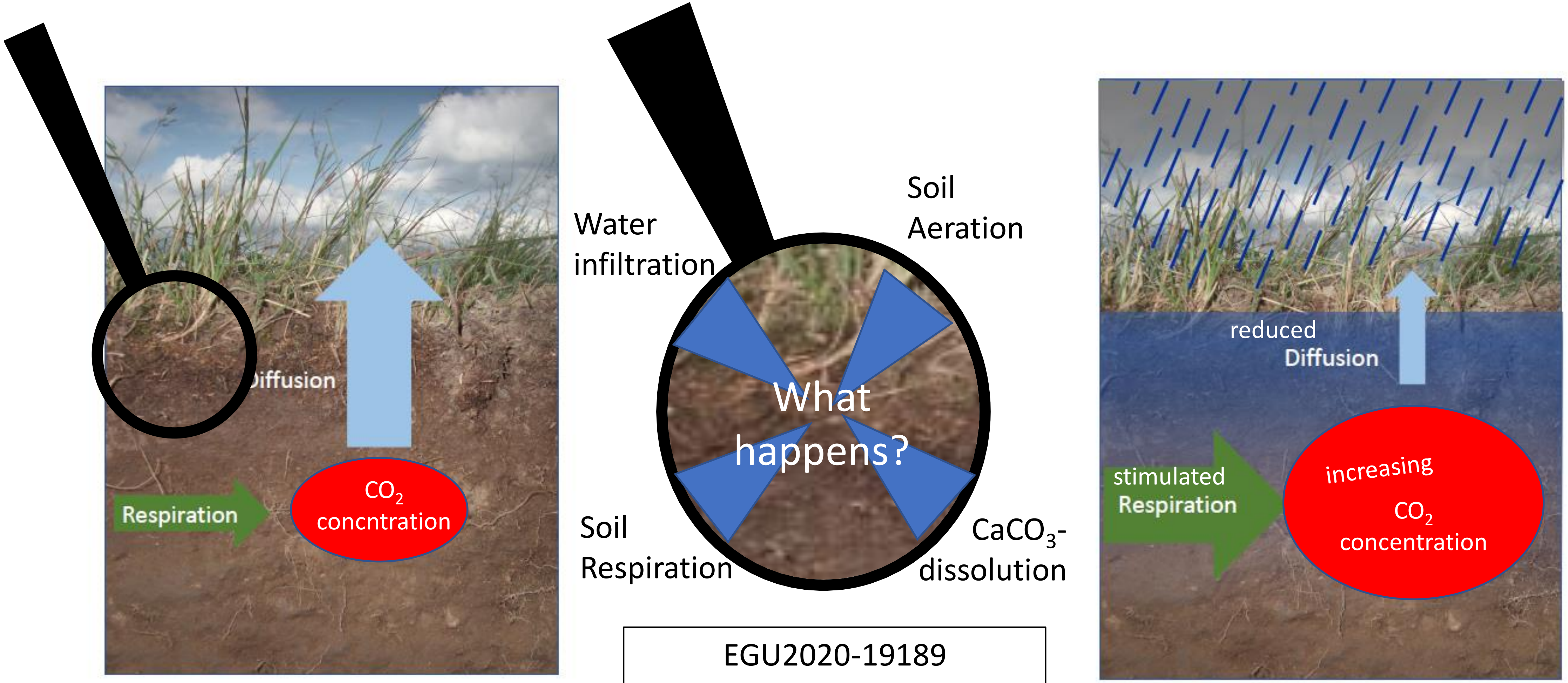

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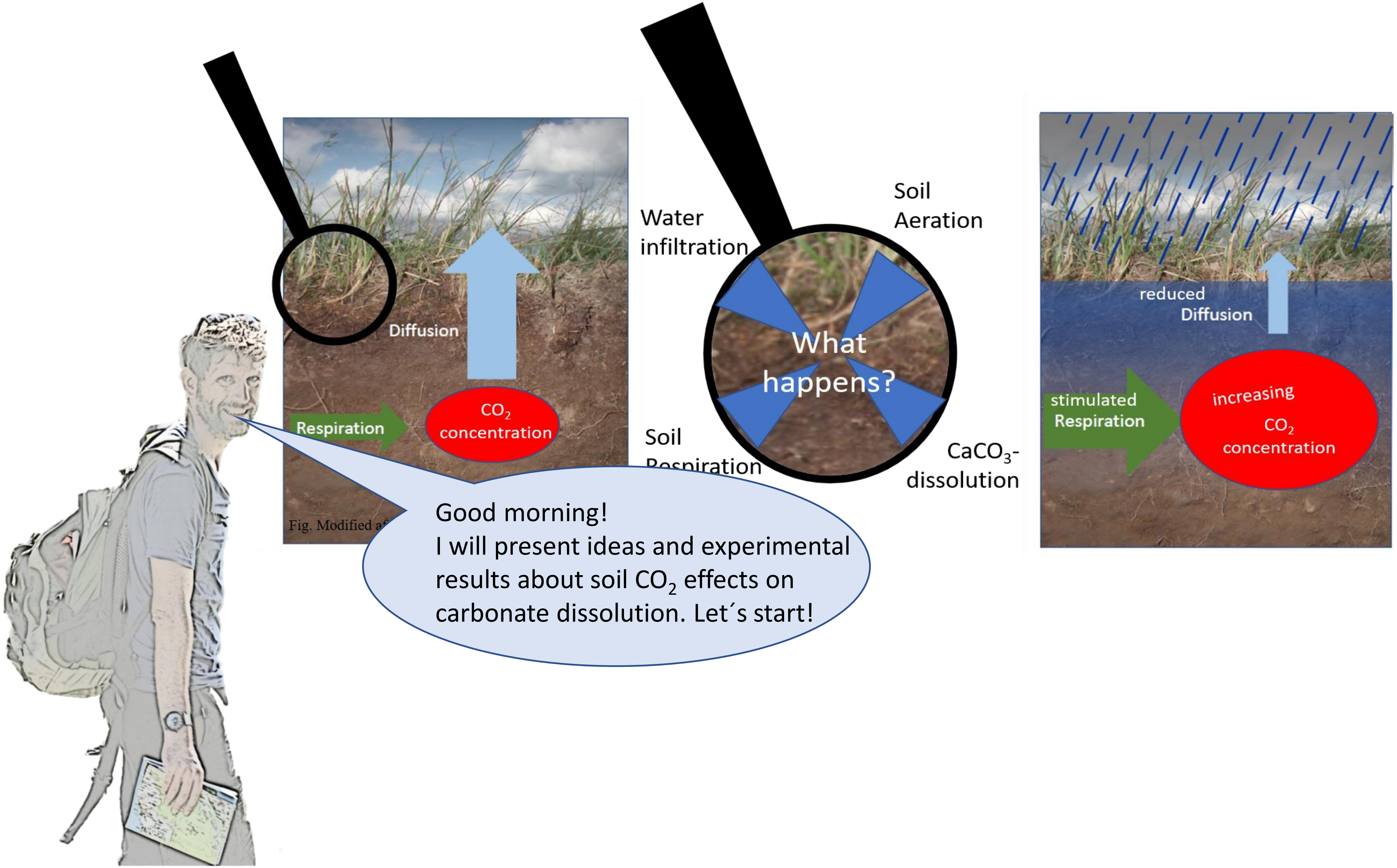
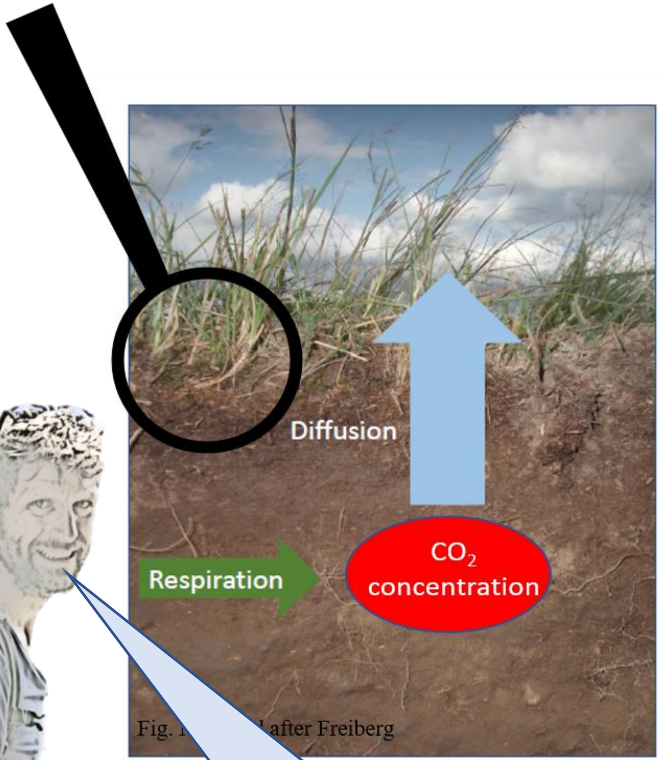
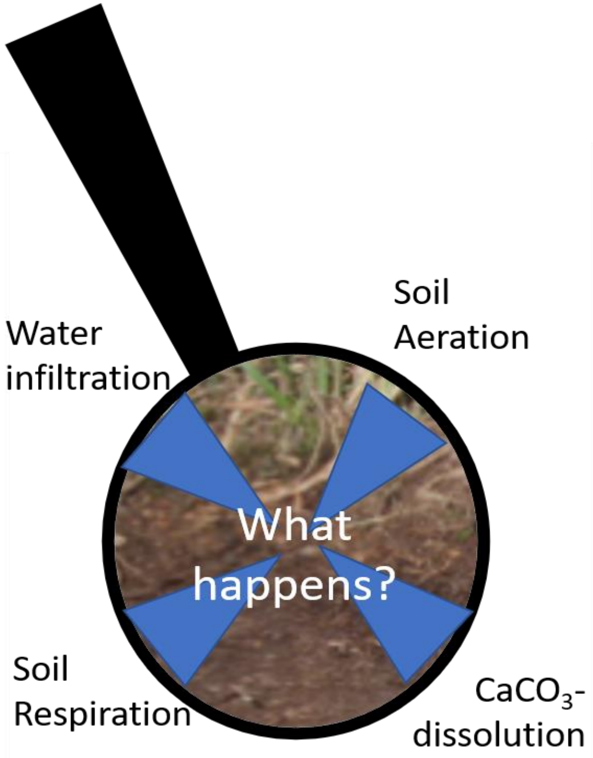
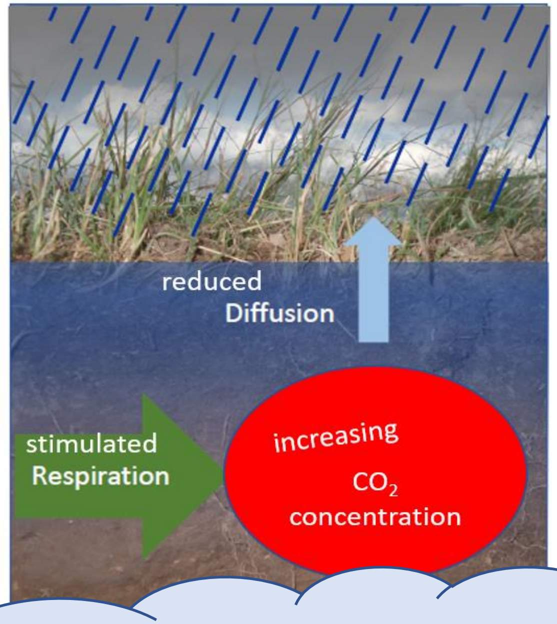
M.Maier: Soil CO_2 effects on carbonate dissolution



M.Maier: Soil CO_2 effects on carbonate dissolution







Carbonate dissolution depends on soil pH which depends on soil CO_2. Soil air CO_2 can easily dissolve in water at pH>7 as described by Henry´s law.

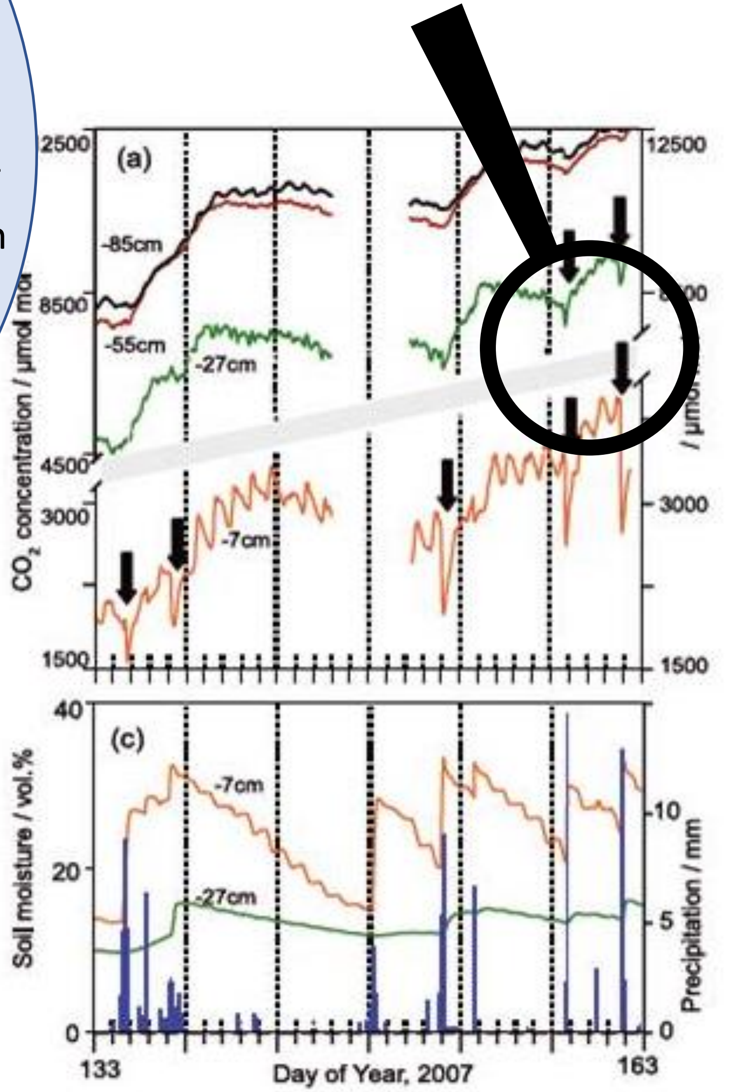
Part	Reaction equations
Dissolution/precipitation of $CaCO_3$	$CaCO_3\ (s) \leftrightarrow Ca^{2+} + CO_3^{2-}$
Dissociation of carbon dioxide $CO_2 + H_2O = H_2CO_3$	$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ $HCO_3^- \leftrightarrow CO_3^{2-} + H^+$

$$H_2O + CO_2 \longleftrightarrow H_2CO_3$$

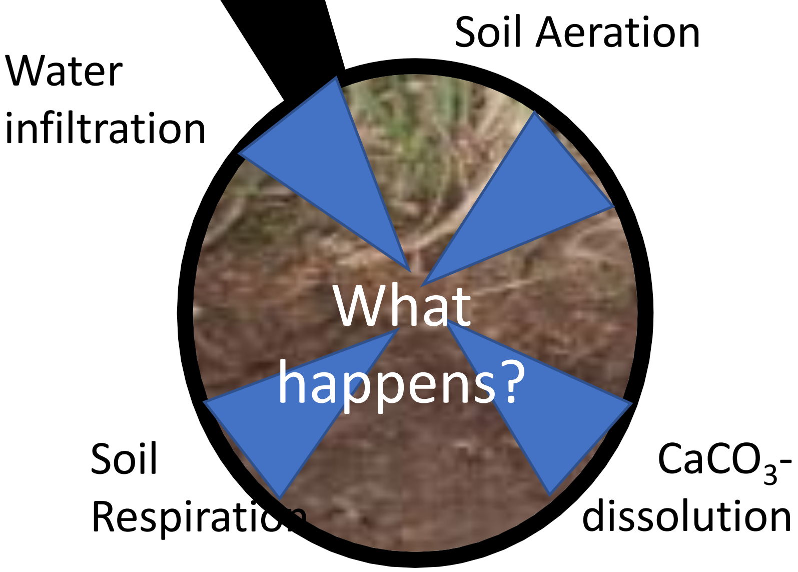
Dissolution of gaseous CO_2 according to Henry-Dalton law

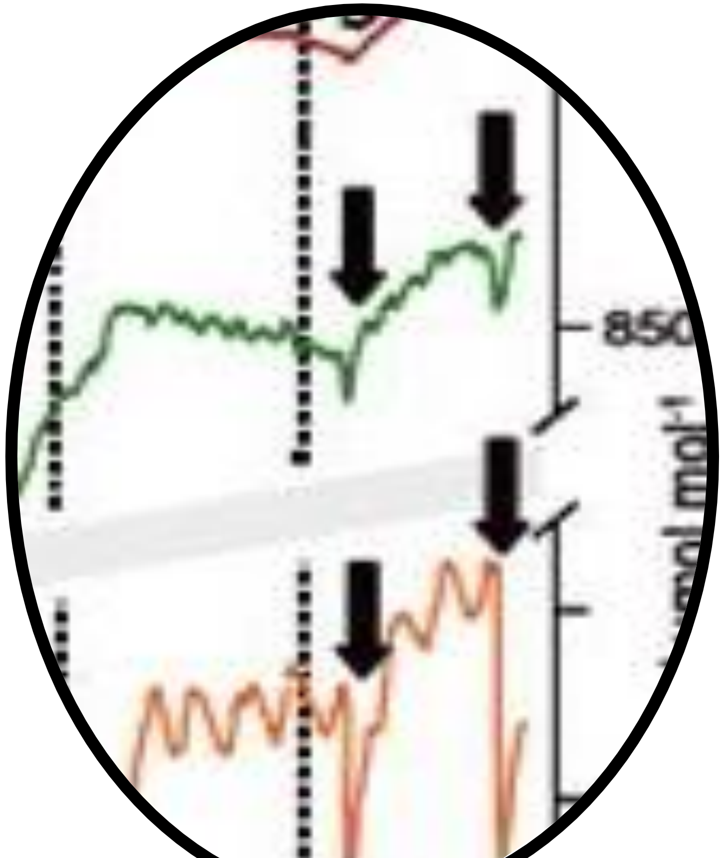
Some time ago we had a field experiment about soil gas fluxes where we installed CO_2 probes in the soil. We measured soil CO_2 concentration at every minute and observed two different types of reaction to rain in the soil air. An immediate effect after intense rain, and a slower reaction after every rain

Field observation:
behavior of soil CO_2 after rain

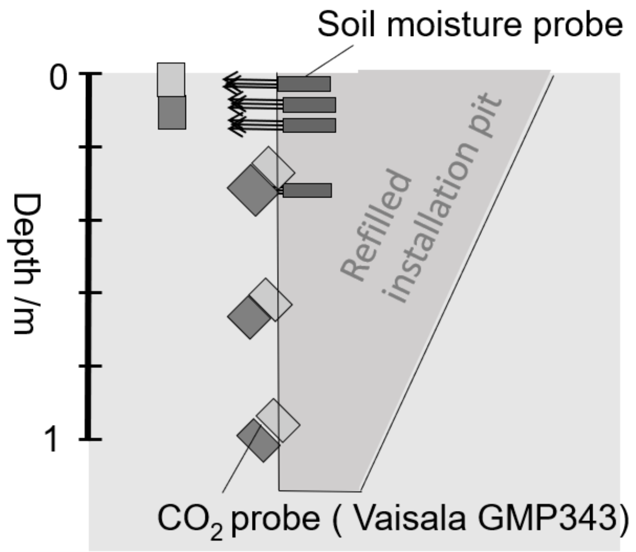


(shown examples from Maier et al. 2010, Eur. J. Soil Science 61; more data available)





Soil profile measurements

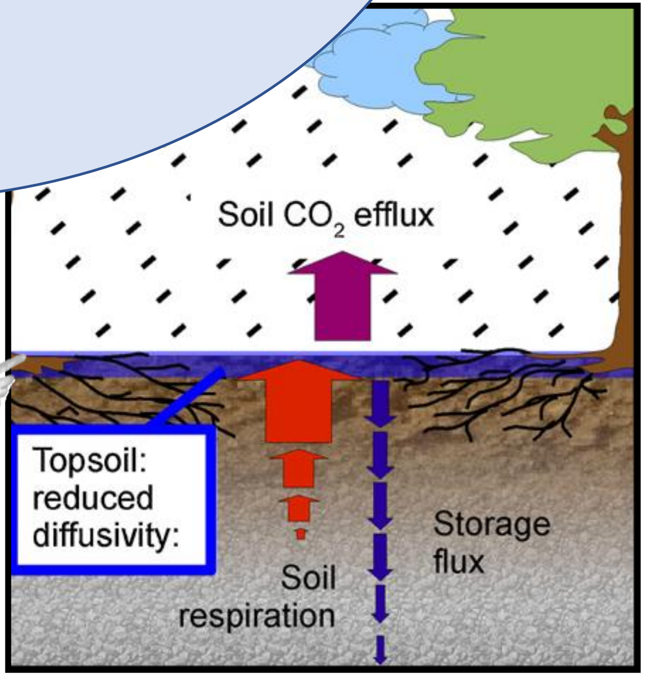


So, what happens after a „normal“ „slow rain event in a calcarous soil?

1. The top soil gets wet, formerly areated soil pores get blocked.

„Slow“ rain event

1. Slow infiltration= reduced aeration
2. Increase in soil CO_2
3. Increase in soil respiration & increase in $CaCO_3$-dissolution



(Maier et al. 2011, Agric. For. Met 151)

Water infiltration

$CaCO_3$-dissolution

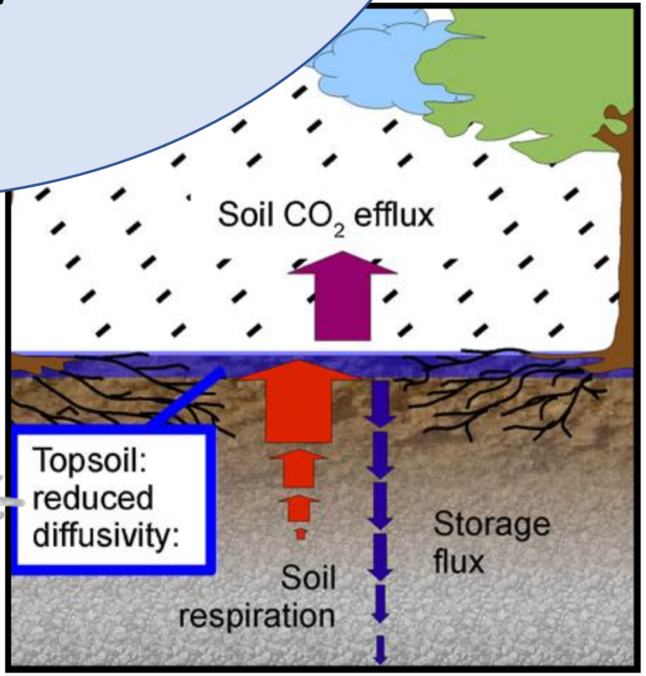
Soil Aeration

Soil Respiration

„Slow“ rain event

So, what happens after a „normal“ „slow“ rain event in a calcarous soil?

1. The top soil gets wet, formerly areated soil pores get blocked.
2. Soil CO_2 accumulates until the reduced diffusivity and increased soil CO_2 concentration reach a new steady state.
3. Soil air CO_2 equilibrates with CO_2 dissolved in soil water, and this means the pH decreases, yet only slightly since it is buffered by the dissolution of $CaCO_3$, which increases



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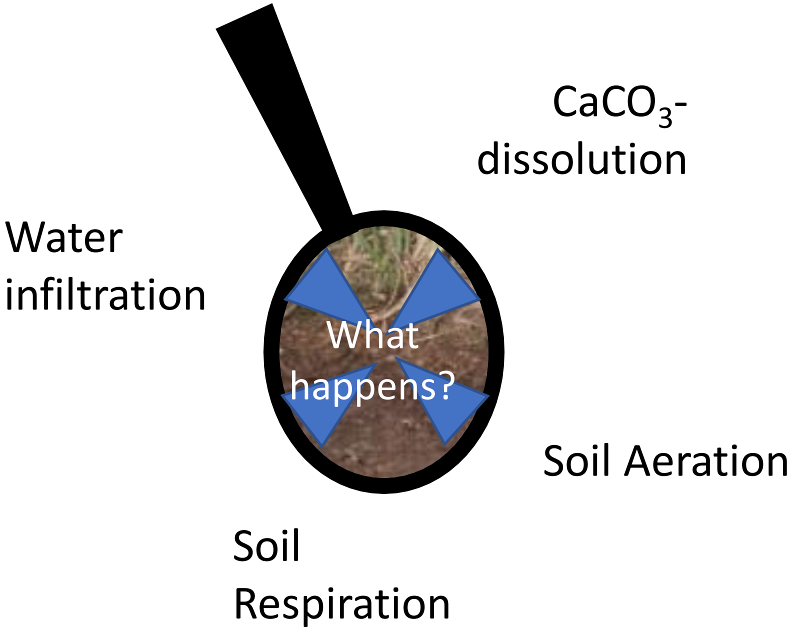


And after a „fast“ rain event?

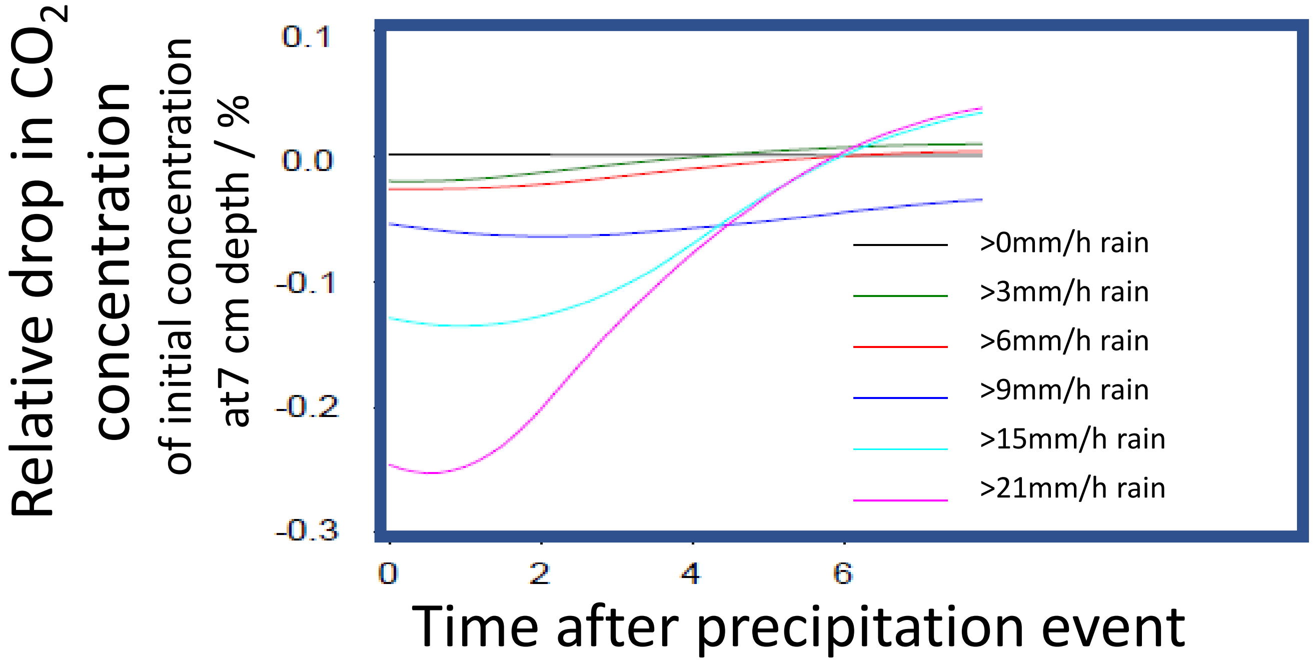
1. The Top soil gets wet quickly, but there is also preferential flow, so that rain water infiltrates quickly into deeper layers.

„Fast“ rain events

First few hours:

1. Fast infiltration & preferential flow= less effect on aeration
2. Mixing of rainwater low in CO_2 with soil water enriched in CO_2

   -> relative undersaturation of new soil water
3. Dips in soil CO_2
4. Increasing $CaCO_3$-dissolution



And after a „fast“ rain event?

1. The Top soil gets wet quickly, but there is also preferential flow, so that rain water infiltrates quickly into deeper layers.
2. The percolating rainwater is CO_2 depleted relatively to the soil water and will thus „draw“ CO2 molecules from the surrounding soil air.
3. Dips in soil CO_2 concentration can be observed due to this effect. The stronger the rain, the more preferentially percolating water, the stronger dips in CO_2
4. And this means that more $CaCO_3$ is dissolved.

„Fast“ rain events

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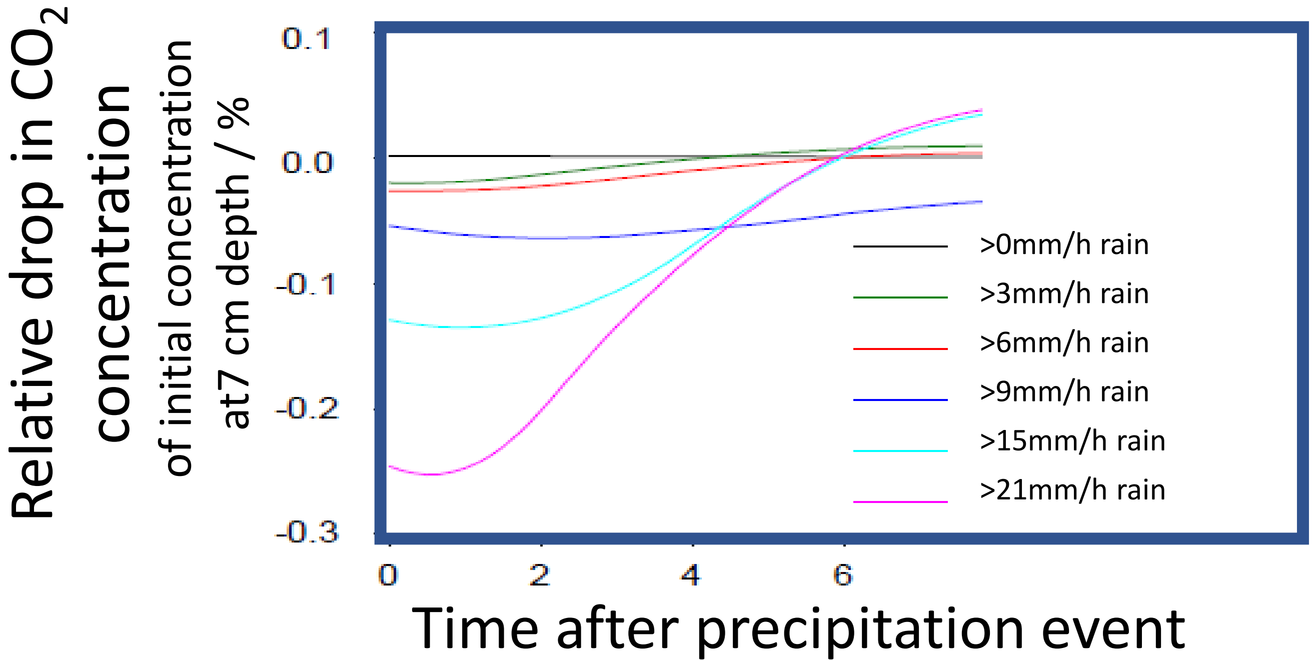

The total amount of Ca^{2+} mobilized due to $CaCO_3$ dissolution is not affected by slow or fast rain event, but the localization where exactly the Carbonate is dissolved is affected.

„Fast" rain events

First few hours:

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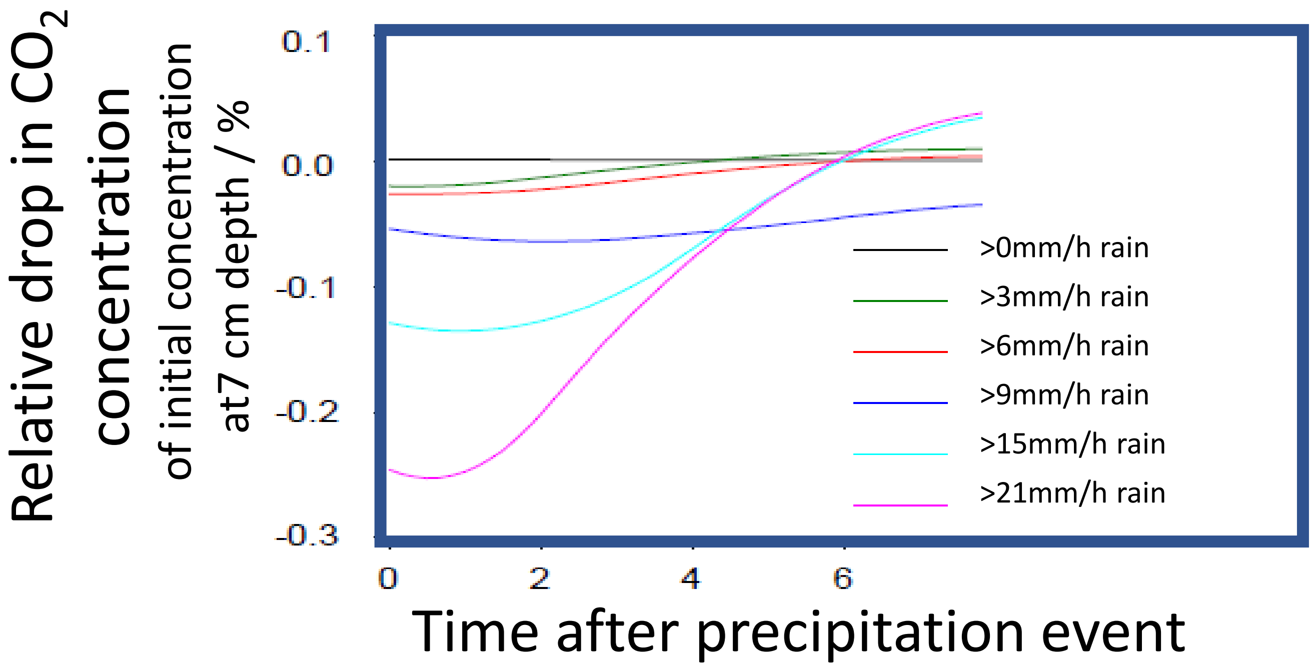


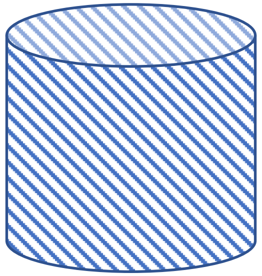
If this interpretation was true,
we should be able to reproduce this effect als in the lab. So we set up an experiment with soil mesocosms. One with intact soil structure, and one repacked mesocosm.

Intact Mescosm

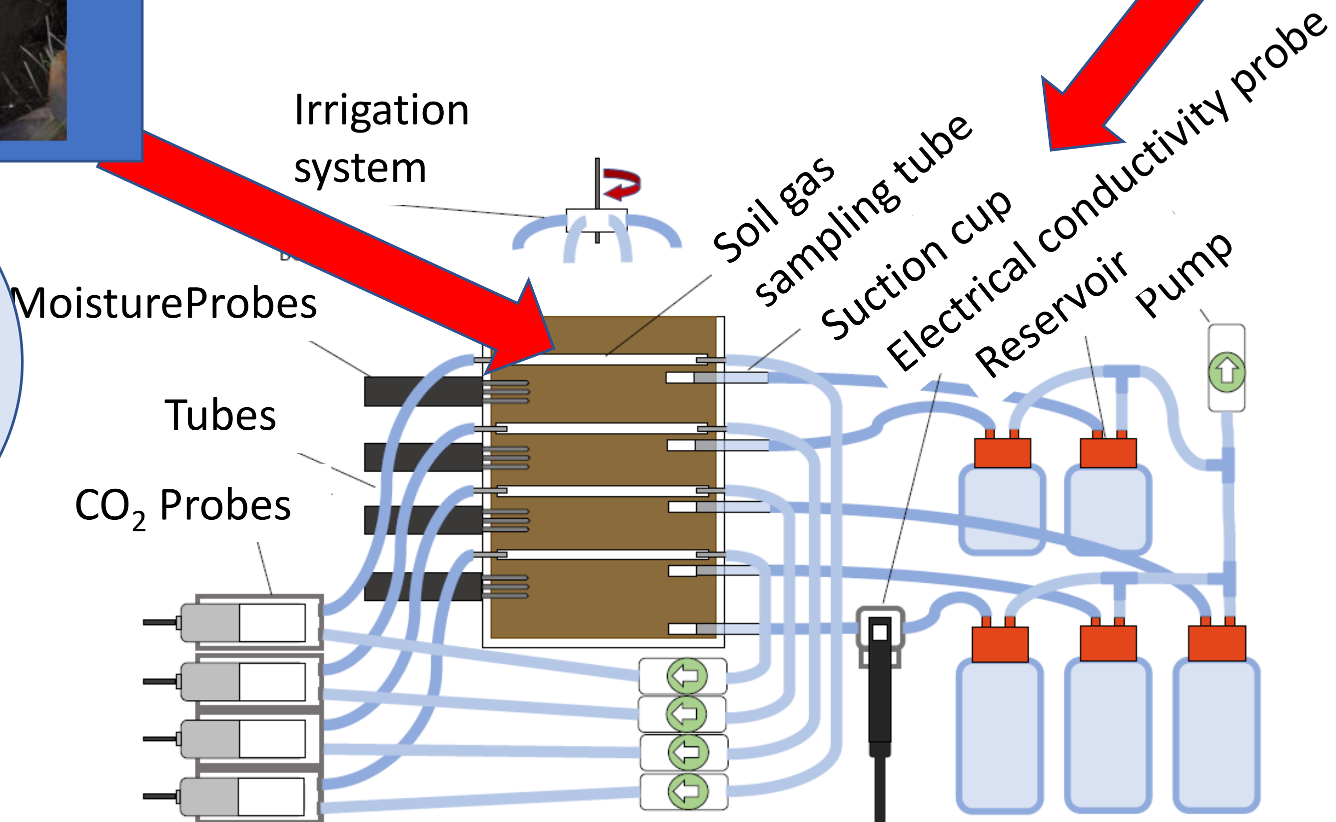
Re-Packed Mescosm

Intact Mescosm

Re-Packed Mescosm



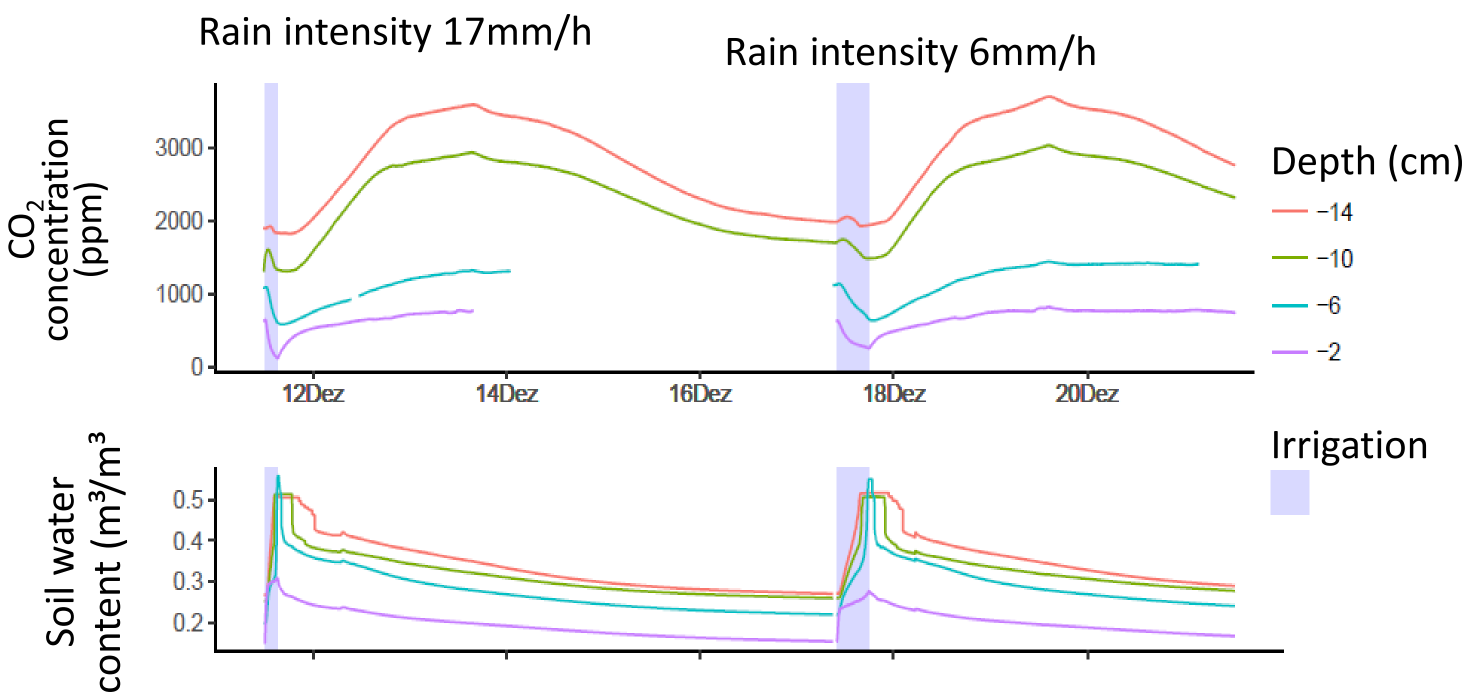
And we ran experiments similar to those in the field, measuring soil CO_2 concentrations, soil moisture, water from suction cups a, an electrical conductivity of the draining water.

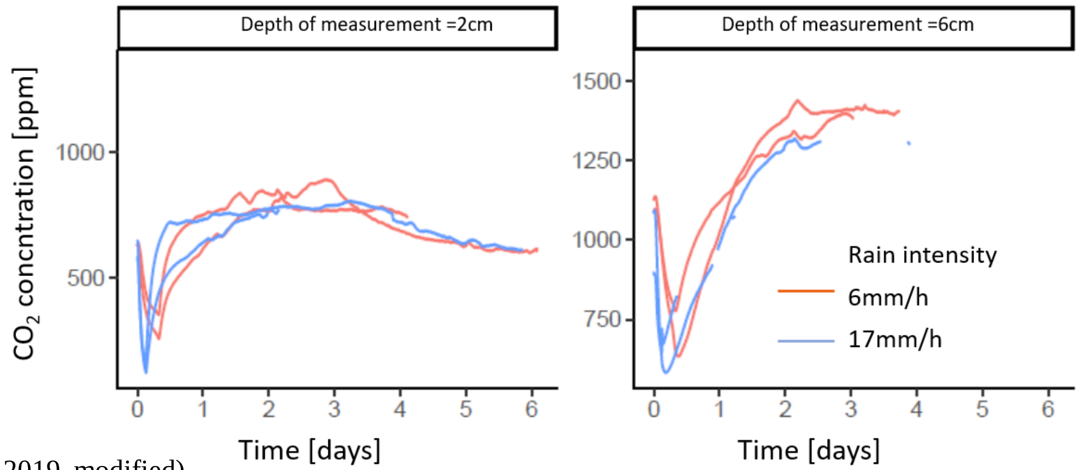


(after Freiberg, 2019, M.Sc. Thesis , University of Freiburg, modified)

And we observed the same dips in soil CO_2 concentrations as in the field, with stronger dips during intense rainfall events.

Examples from the re-packed mesocosm

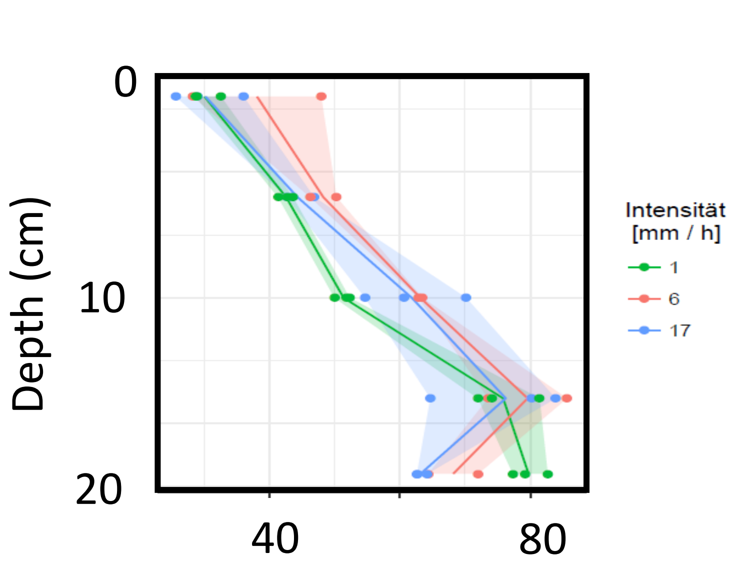


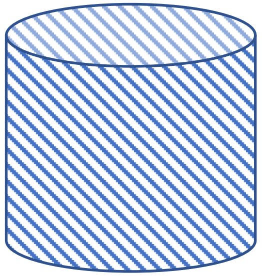


(Freiberg, 2019, modified)

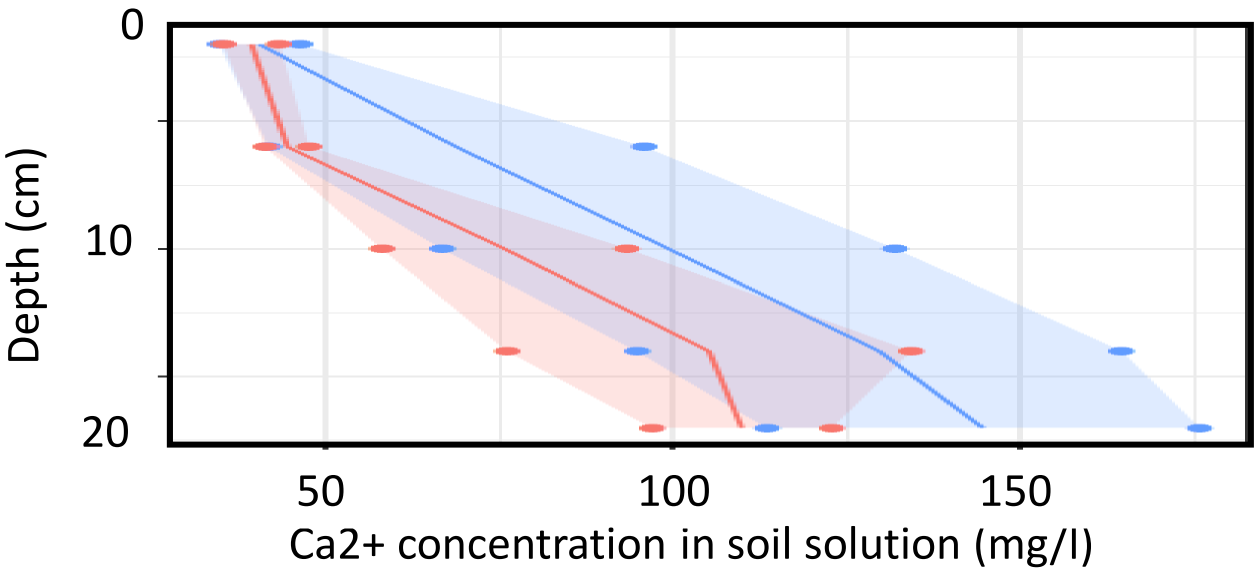
And we also saw that much more Ca^{2+} was washed from the re-packed soil column, especially during the first experiments. The surfaces of the preferential flow paths seem thus less susceptible to mobilize Ca^{2+}, maybe, because most Ca^{2+} has been washed from this pore surfaces already.

Intact Mescosm





Re-Packed Mescosm



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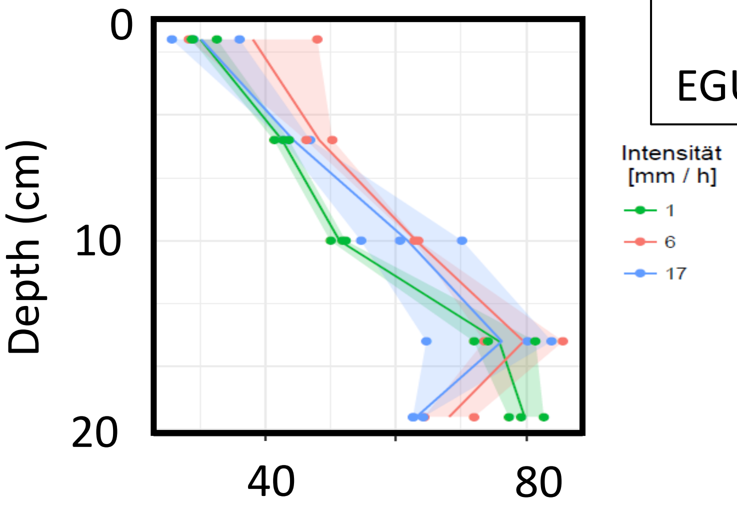

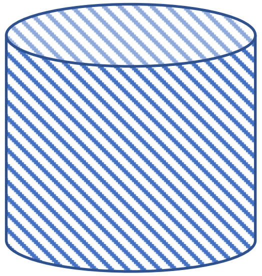

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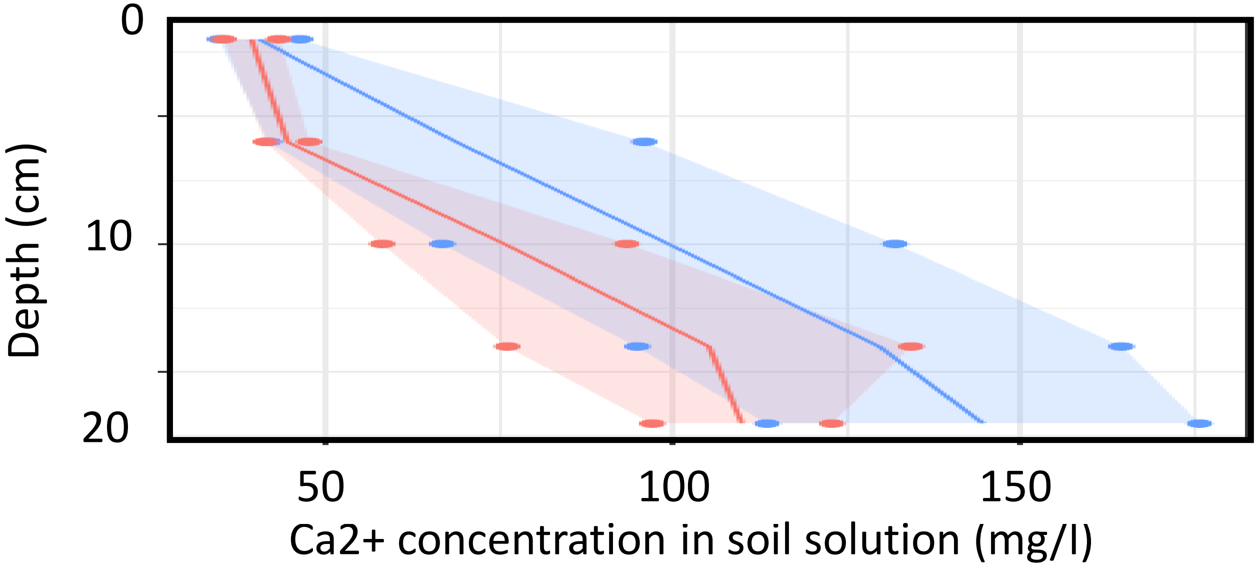

(Freiberg, 2019, modified)

Thank you for watching!
If you have questions or comments you ll find me in the chat on Friday, 8 May 2020, 10:45-12:00, or please find my e-mail via the EGU!