BGR Bundesanstalt für Geowissenschaften und Rohstoffe

GEOZENTRUM HANNOVER

Leibniz Universität Hannover

Soil protection specific requirements within the framework of carbon dioxide capture and storage (CCS) activities

C.F. Stange[1], W.H.M. Duijnisveld[1] and J. Böttcher[2]

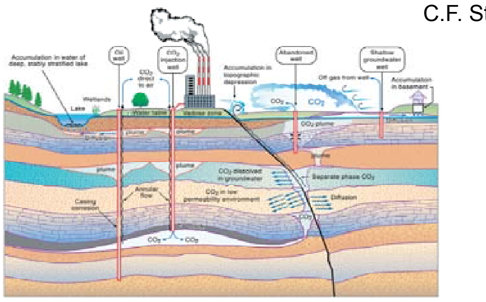

Fig. 1: Potential pathways of CO_2 to the biosphere from CO_2 capture and storage (CCS) projects (Zhang et al. 2004).

1 PATHWAYS INTO THE SOIL

Mitigation of Climate Change is a challenge which requires efforts in different fields. Carbon capture and storage (CCS) in geological formations is discussed as a possible contribution to reduction of CO_2-emission. Risk analyses taking into account also possible risks for the soil compartment are necessary for a well-founded decision. The German Federal Soil Protection Act (BBodSchG) requires, that harmful changes to the soil must be prevented. The main risk for soil is due to CO_2-leakage from transport or from the geological storage formation. There are however up to date no reliable assumptions about the possible amount of leakage, flux densities and the extent of the affected areas. The definition of Critical Loads for CO_2 from CCS might be a way to protect the soil ecosystem. Thus the influence of additional CO_2 fluxes from the bottom should be investigated and thresholds for CO_2 concentration in soils must be defined .

2 CONCEPTUAL SOIL IMPACT ASSESSMENT

Figure 2 illustrates the possible impact of an additional CO2 flux on soil processes and conditions as the basis for an environmental impact assessment. If CO_2 from leakage gets into the soil, different processes and soil conditions might be influenced, like microbial activity, O_2-content, soil pH and sorption characteristics. Due to these changes it can be expected, that important soil functions will also be influenced, for example the natural functions as a basis for life and as a habitat for animals, plants and soil organisms..

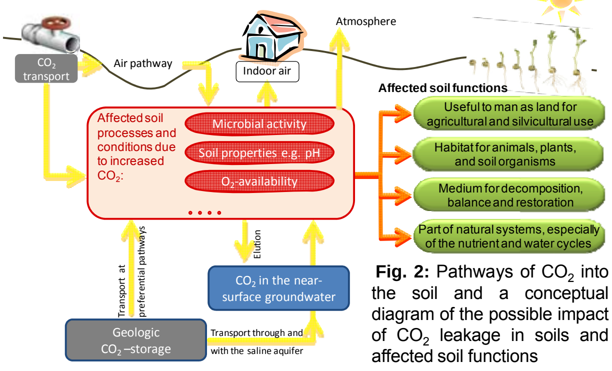

Fig. 2: Pathways of CO_2 into the soil and a conceptual diagram of the possible impact of CO_2 leakage in soils and affected soil functions

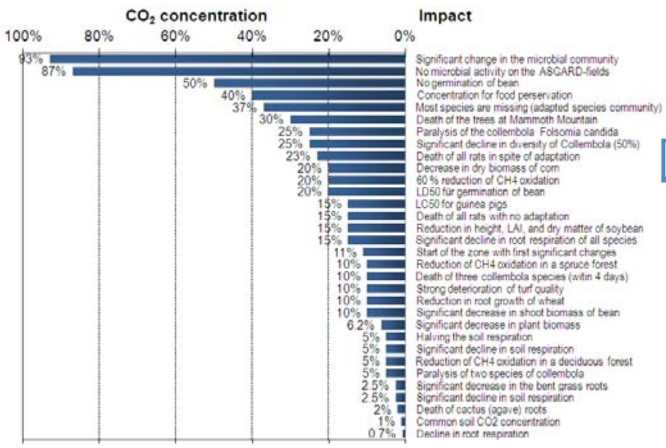

Fig 3: Impact of elevated CO_2 concentrations on soil processes and soil organisms (after Stange et al. 2011, adapted)

3 IMPACT OF CO2 ON SOIL ECOSYSTEM

Natural CO_2 concentrations in soils are highly variable in space and time and depend on processes like mineralisation of soil organic matter, root respiration and gas transport in soils. The high variability in the field complicate the derivation of general thresholds. Also a "no effect" concentration of CO_2 does not exist, for example Qi et al. (1994) show already at 0.7% CO_2 (typical soil concentration) significantly less root respiration in comparison with atmospheric concentrations. The analysis of natural analogues show, that soil functions and soil ecology near to geological CO_2-sources are strongly influenced. Information about the reaction of possible indicators on higher CO_2 soil concentration was compiled from the literature (Fig. 3).The discussion about the values of thresholds is very difficult, because many different aspects have to be considered. First of all soil functions (within the meaning of the BBodSchG) are very broadly defined and therefore indicator processes or indicator organism must be identified to derive the thresholds. In addition also the soil depths for the thresholds must be defined, because an additional flux from the bottom will cause a strong CO_2 gradient in the soil (s. also Fig 4 and 5).

4 SIMULATION OF CO_2 CONCENTRATIONS

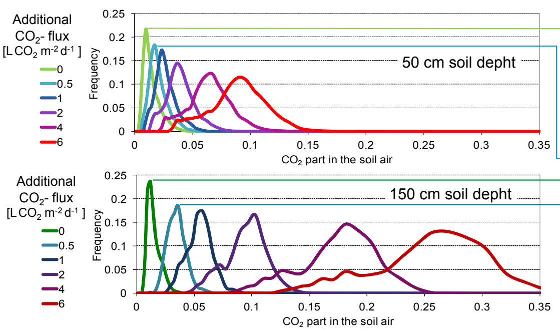

Fig 5: Frequency distribution of the simulated CO_2 concentration at 50 cm (upper Fig.) and 150 cm soil depth (lower Fig.) with varying amounts of additional CO_2 fluxes (in L CO_2 m^{-2} d^{-1}) at the bottom.

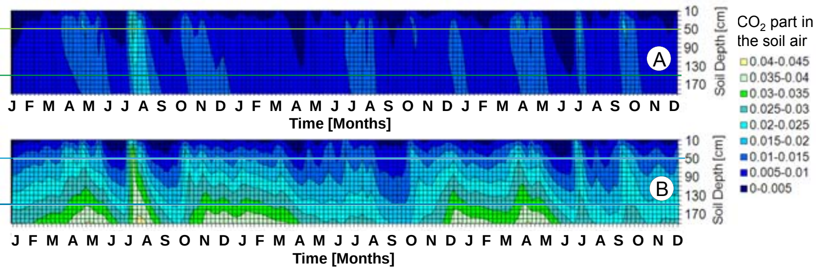

Fig. 4: 3 year simulation of CO_2 concentrations in a sandy loam soil (A) under natural conditions and (B) with an additional flux of 0.5 L g CO_2 m-2 d-1 at the lower boundary

The quantification of additional CO_2 sources on CO_2 concentrations in soils requires the understanding of the natural occurring CO_2 concentrations. Considering the highly dynamic CO_2 concentrations within the soil profile, mechanistic modelling seems the best option to meet this challenge. Simulation of concentration profiles in time in soils with/without additional CO_2-sources using an extended version of HYDRUS-1D will be applied to derive tolerable CO_2-fluxes (Critical Loads) into the soil ecosystem. The presented example (Fig. 4) for a uniform sandy loam soil show, that a time-varying, but significant effect is expected even at a small flux of 0.5 L CO_2 m^{-2} d^{-1}. Figure 5 shows that the average concentration, as well as the variance increases with increasing flux. There are time periods with lower concentrations even at high additional fluxes. This is important because some soil organisms have developed strategies that also allows them to survive extremely unfavorable conditions for a time.

5 CONCLUSIONS

- The available data on impact of CO_2 concentrations on soil functions are sparse, in particular systematic studies with stepwise increased levels of CO_2 concentrations in soils are rare. This hampers the derivation of thresholds.
- The high temporal and spatial variability of CO_2 concentrations in field soils complicate the definition of general thresholds.
- Scenario analysis by mechanistic models offer the possibility to estimate the influence of additional CO_2 fluxes on concentration under realistic boundary conditions.

Funded by the German Federal Environment Agency (UBA)
(funding numbers *370972204 and 371172226)*

[1] Federal Institute for Geosciences and Natural Resources, Stilleweg 2, D-30655 Hannover,
[2] Leibniz University Hannover, Herrenhäuserstraße 2, 30419 Hannover

REFERENCES

Qi, J., J.D. Marshall, K.G. Mattson (1994): High soil carbon dioxide concentrations inhibit root respiration of Douglas fir. New Phytologist *128*, 435-442.

Stange, C.F., W.H.M. Duijnisveld, J. Böttcher (2011): Einfluss CCS-bedingter Zuflüsse auf die CO_2-Konzentrationen in Böden - Anforderungen aus Sicht des Bodenschutzes. Berichte der DBG.

Zhang, Y., C. M. Oldenburg, S.M. Benson (2004): Vadose Zone Remediation of Carbon Dioxide Leakage from Geologic Carbon Dioxide Sequestration Sites. Vadose Zone J 3(3): 858-866.