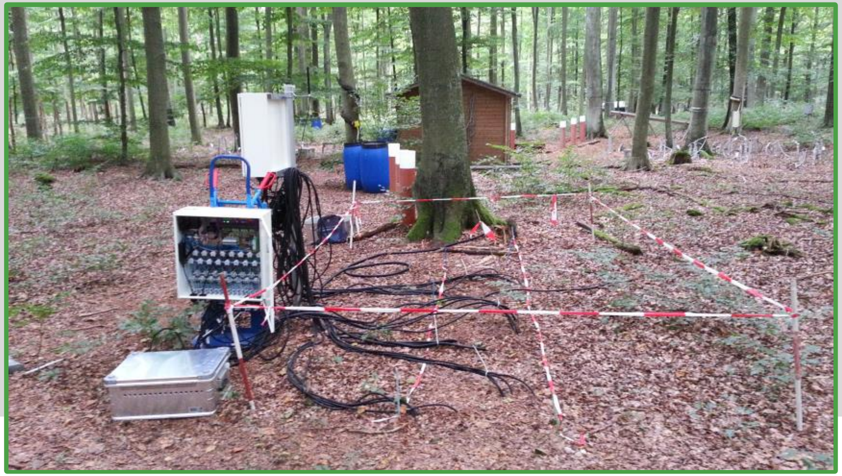
Leibniz Centre for Agricultural Landscape Research (ZALF)

The effect of vertical distribution functions on CO_2 efflux and production calculated with the flux gradient approach



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date: 8 May 2020

Motivation and Objectives

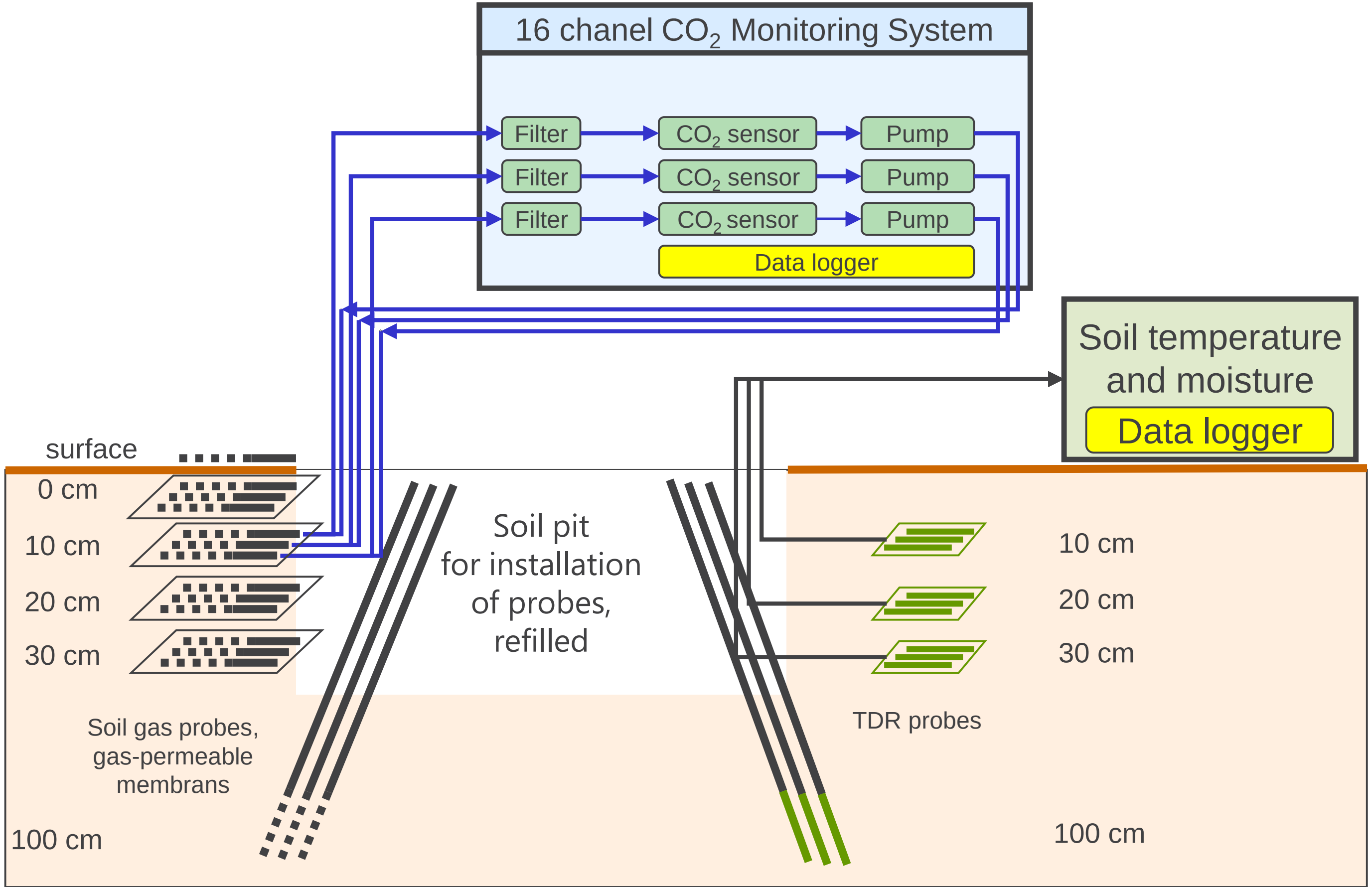
- The analyses and quantification of soil CO_2 production and its influencing factors play a crucial role in the understanding of the global carbon budget.
- The **flux-gradient approach (FGA)** is an alternative method to the chamber method to calculate the efflux of CO_2 from soil and applies **Fick's law to vertical profiles of soil CO_2**.
- The FGA uses the **soil gas diffusivity** to calculate vertical fluxes of soil CO_2 and the CO_2 efflux from soil. The **vertical partitioning of CO_2 production** in different soil layers can be regarded as an option and an **advantage of FGA** as compared to chamber methods.
- This investigation aims at clarifying whether fitting to an **exponential or a cubic spline function** is more suitable for **discretize the vertical distribution** of measured CO_2 concentrations into 5cm steps

Method

- **CO_2, moisture and temperature** was measured at **soil surface and at 0, 10, 20, 30 and 100 cm mineral soil depth** of a **European beech** forest on **sandy soil**
- **Discretization** of **CO_2** between measured soil depths into 5 cm steps over the soil profile by
  - **Exponential** function
  - **Cubic Spline** function
- Discretization of soil moisture and temperature between measured soil depths into 5 cm steps by cubic spline (10 -30 cm) and linear (30-100cm)
- **Simulation of soil moisture** in **organic layer and 5 cm** using Hydrus-1D
- Measurement of **CO_2 efflux** using **chamber method**

Measurement of CO_2, temperature and moisture in soil

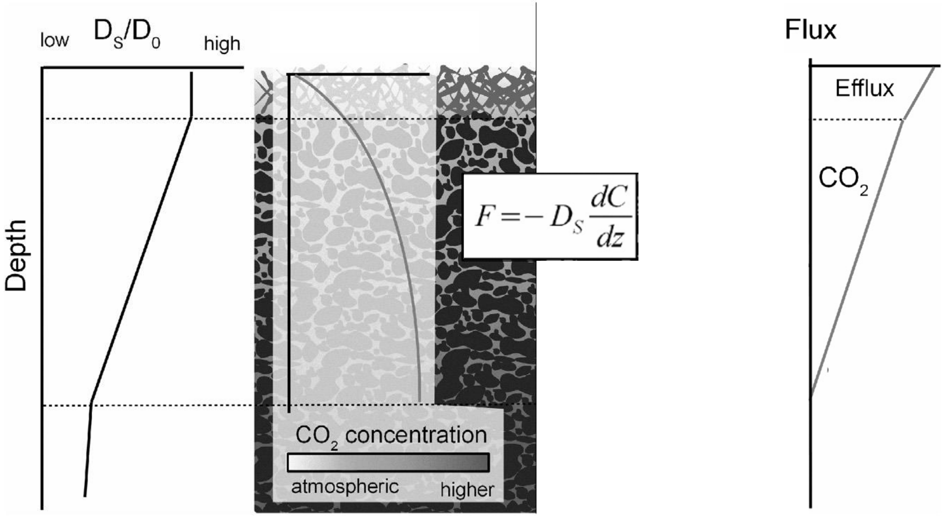
- Gas flux in closed loops
- Measurement every 30 min



After Jochheim et al. 2018, *J. Plant Nutr. Soil Sci.* 181, 61-66

Flux-gradient approach for calculating CO_2 fluxes and production

assumption:
diffusion predominates over advection



F:	CO_2 flux (mol $m^{-2}s^{-1}$)
D_S:	effektive gas diffusion coefficient ($m^2\ s^{-1}$)
D_0:	diffusivity in air ($m^2\ s^{-1}$)
D_S/D_0:	relative diffusivity (-)
C:	CO_2 concentration (mol m^{-3})
z:	soil depth (m)
t:	time (s)
α:	CO_2 production rate (mol $m^{-3}\ s^{-1}$)

Mass conservation equation

$$\frac{\partial C_{total}}{\partial t} = -\frac{\partial F}{\partial z} + \alpha$$

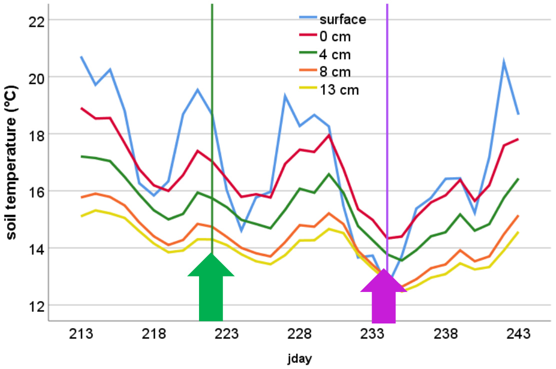
Vertical distribution of CO_2 production

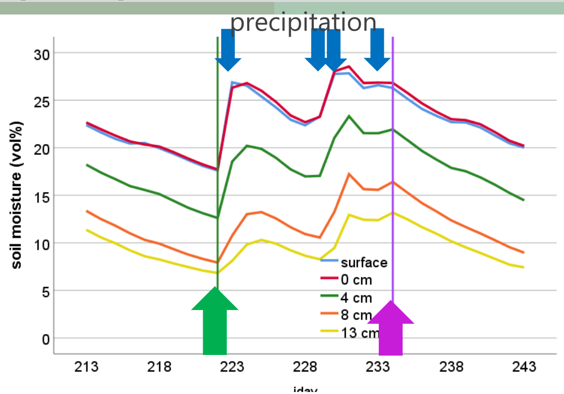
$$\alpha = \frac{d}{dz}\left(-D_s \frac{dC}{dz}\right) = -\frac{dD_s}{dz}\frac{dC}{dz} - D_s \frac{d^2C}{dz^2}$$

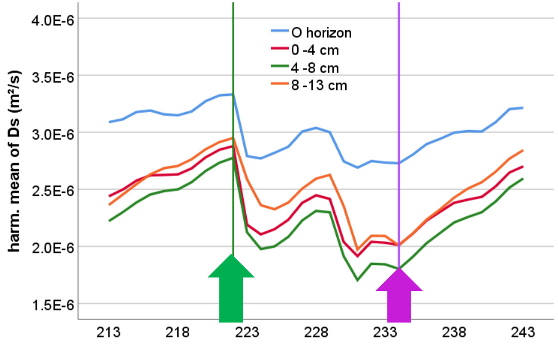
From Maier & Schack-Kirchner 2014. *Agricultural and Forest Meteorology* 192-193: 78-95

Comparing **dry** and **wet** conditions - **10**.+**22**.08.2017

Soil properties



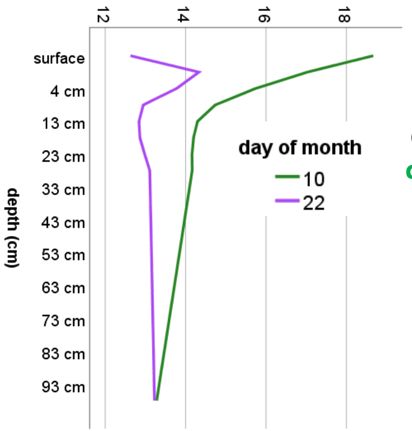




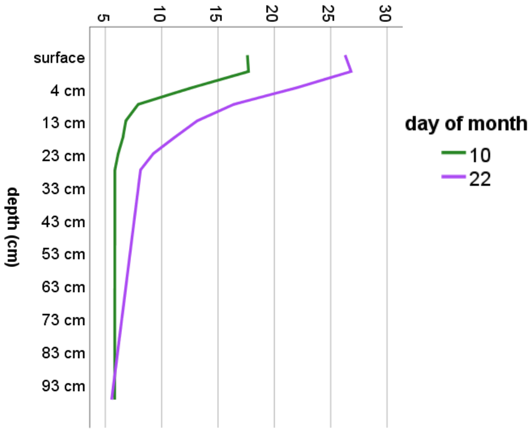
Soil temperature (°)

Soil moisture (vol%)

Soil gas diffusion coeff. (m^2/s)

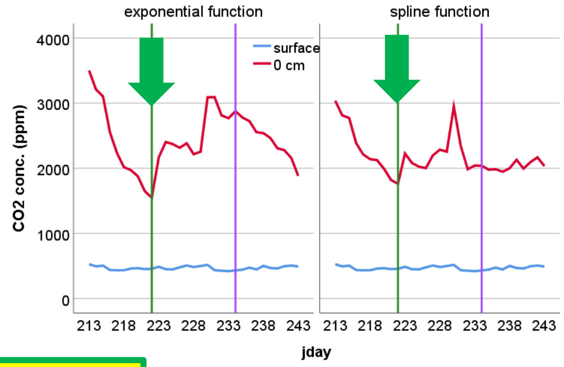


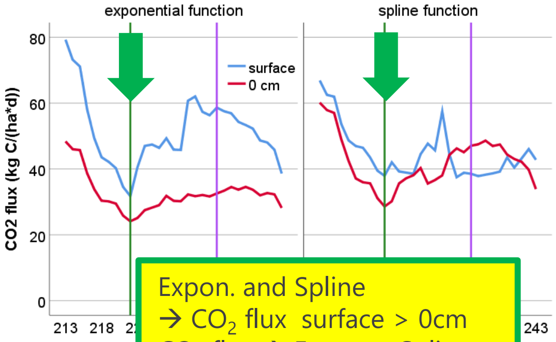
Comparing dry and wet conditions



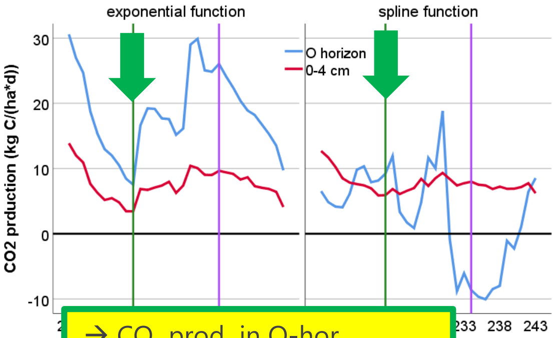
CO_2 conc., flux, production under **dry** conditions

10.08.2017



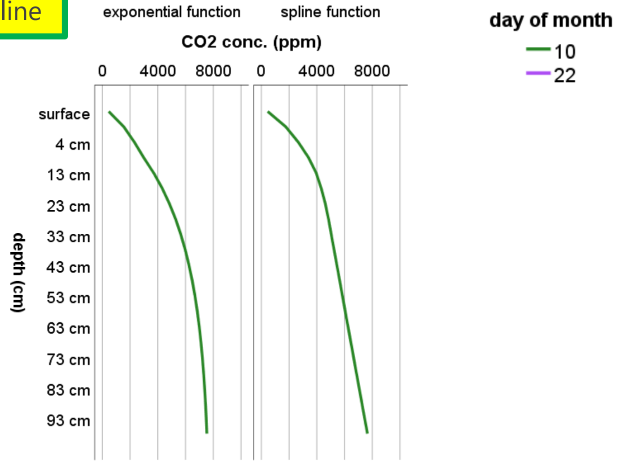


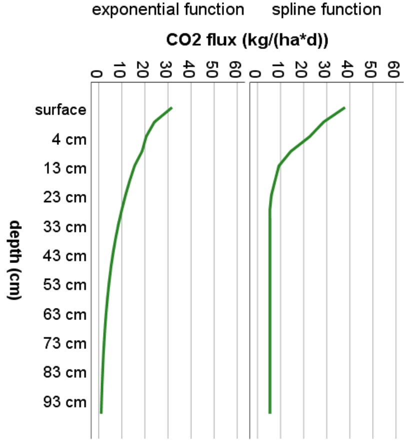
Expon. and Spline
→ CO_2 flux surface > 0cm
CO_2 flux → Expon < Spline

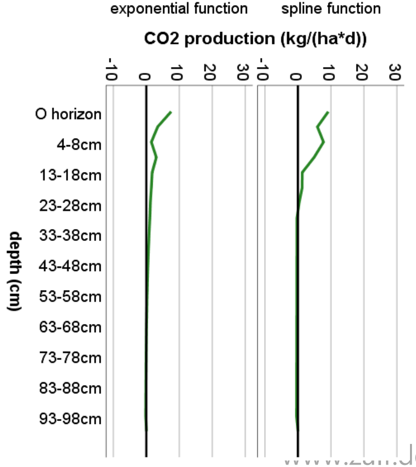


→ CO_2 prod in O-hor.
→ Expon. < Spline

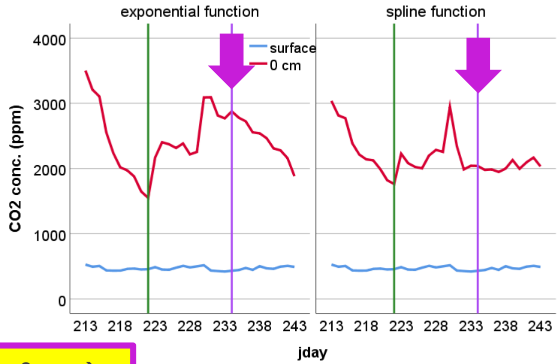
CO_2 in 0cm →
Expon.<Spline



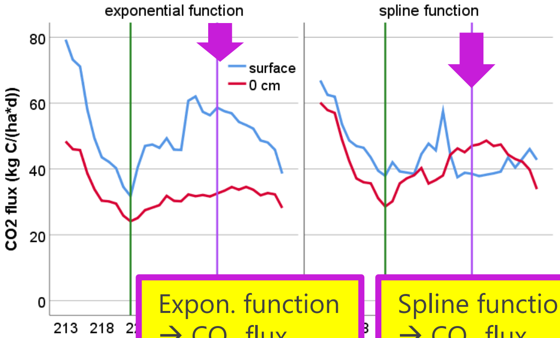




CO_2 conc., flux, production under **wet** conditions 22.08.2017

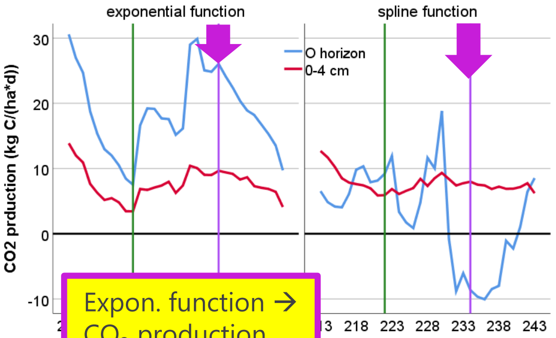


CO_2 in 0cm → Expon. >Spline

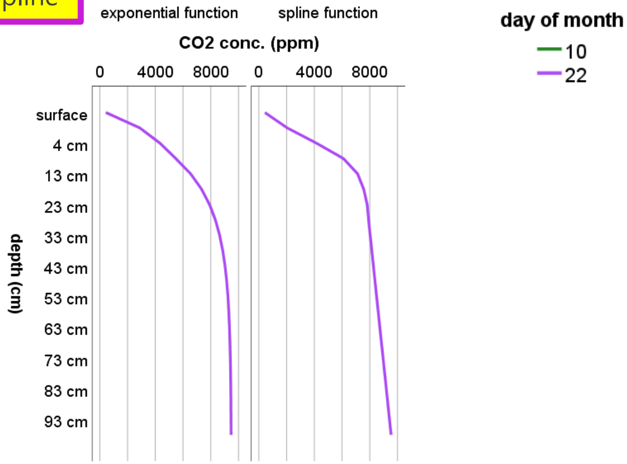


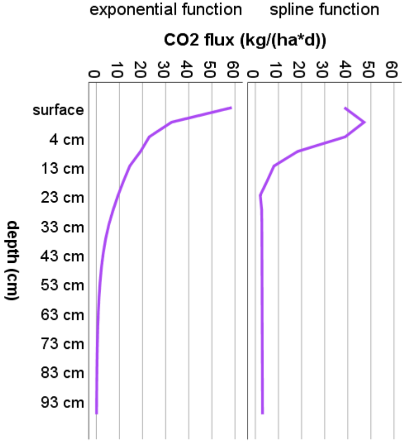
Expon. function → CO_2 flux surface > 0cm

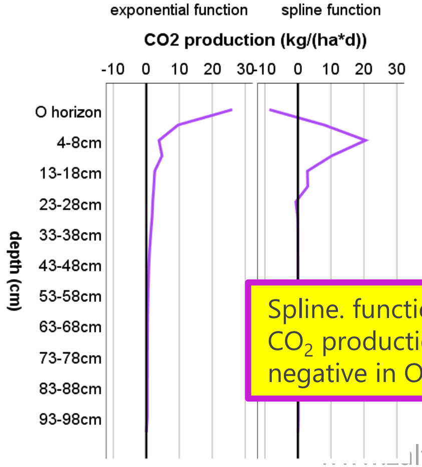
Spline function → CO_2 flux surface < 0cm



Expon. function → CO_2 production O-hor.< 0-4cm

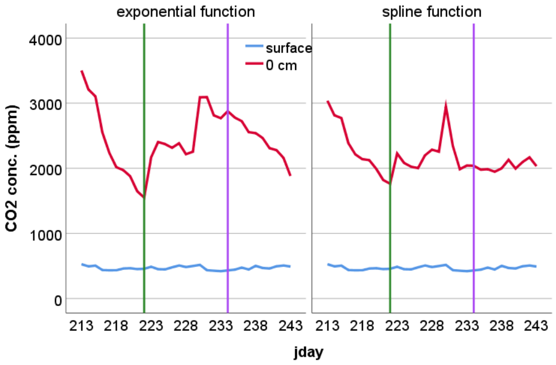


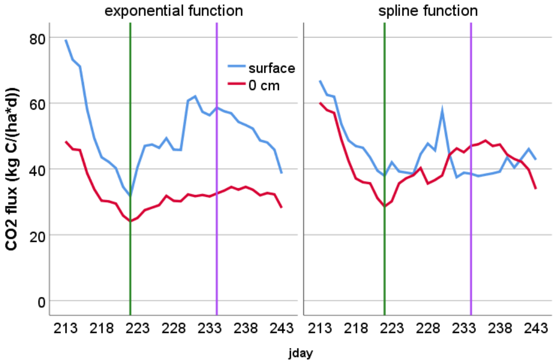


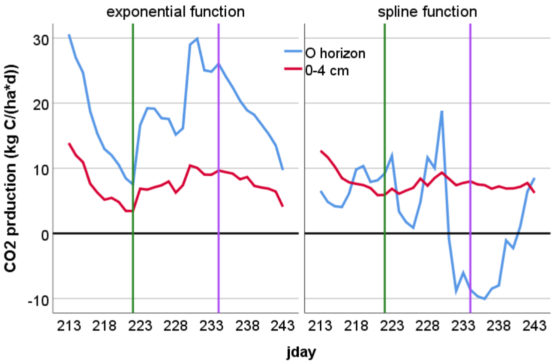


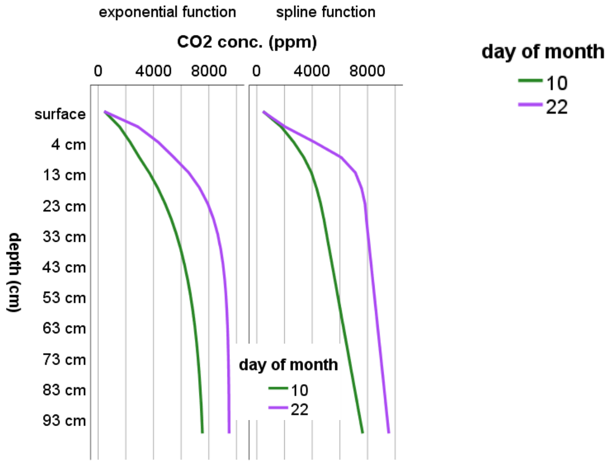
Spline. function → CO_2 production negative in O-hor.

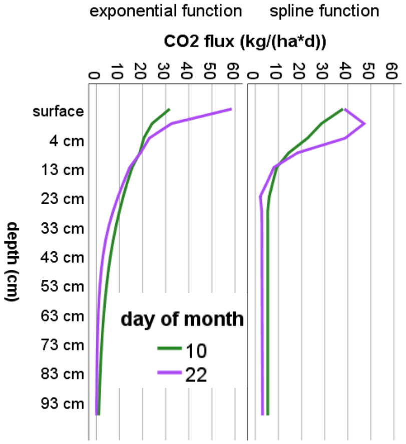
Comparing **dry** and **wet** conditions - **10**.+**22**.08.2017

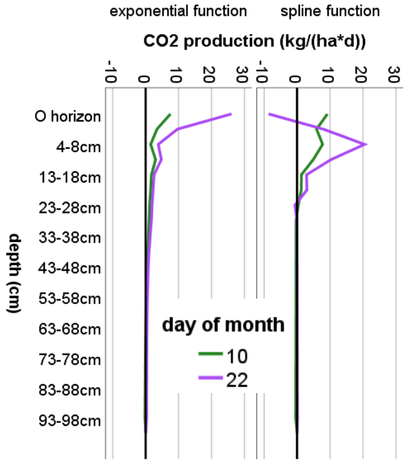












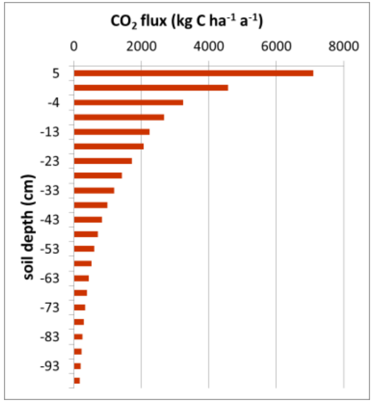
Vertical distribution of CO_2 conc., flux, and production
Comparison of functions – 5 years average

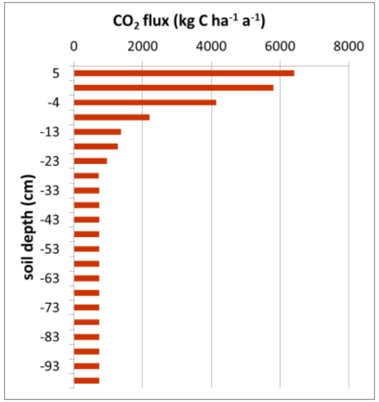
Exponential function

Cubic spline function

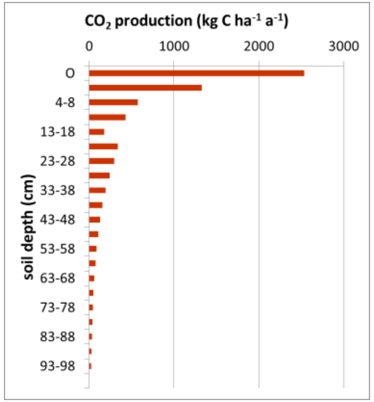
CO_2 concentration

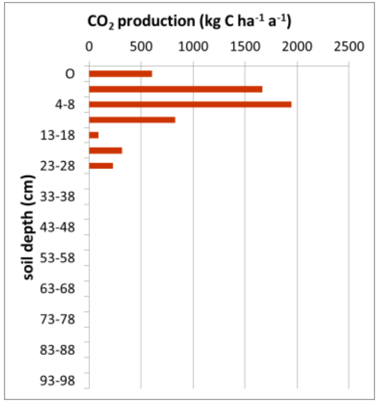
CO_2 flux

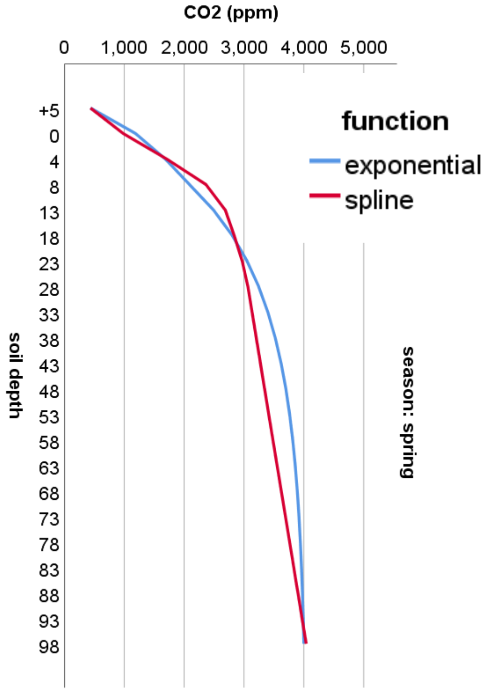




CO_2 production



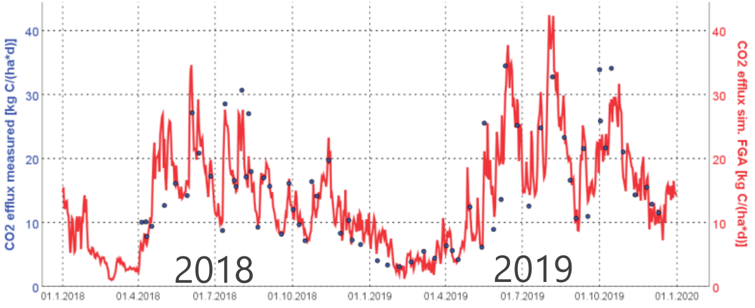


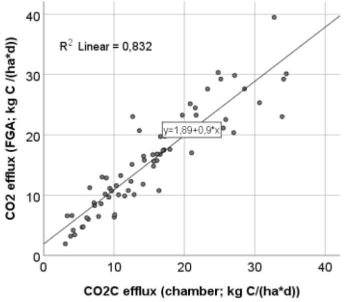


beech

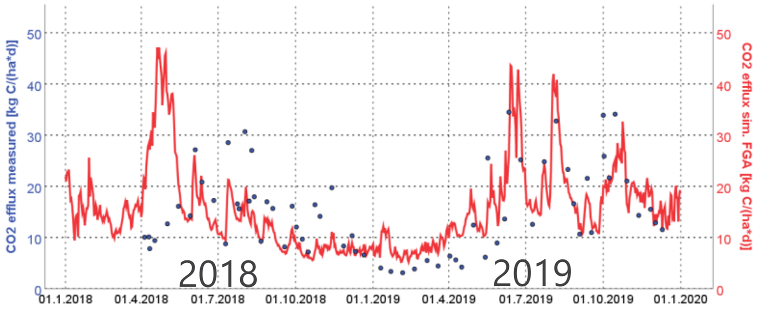
Comparison of CO_2 efflux from the chamber method with flux-gradient approach

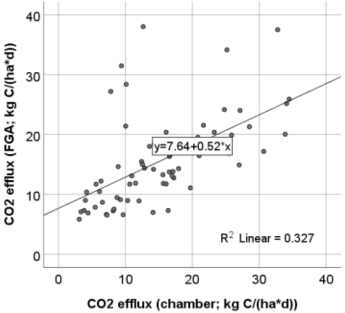
Spline function





Exponential function





Chamber measurement (blue dots)
Flux-gradient approach (red lines)

beech

Conclusion

- **Functions** for discretization of measured soil CO_2 into 5cm-steps over the soil profile **affects** both the calculated **CO_2 efflux** and the **vertical distribution of soil CO_2 production**.
- CO_2 efflux from the **cubic spline** function **fits best** with chamber measurements
- CO_2 efflux from the **exponential** function shows **high temporal variation** of CO_2 efflux with **over and underestimations**
- **Cubic spline** function produces sometimes **negative CO_2 production** within the soil profile, often **following soil wetting**
- Are those observations **artefacts** of soil CO_2, moisture or temperature **measurements** or by **calculating soil gas diffusion coefficients** (Ds)?
- Are negative CO_2 production rates **limitations of the flux-gradient approach**? How to deal with it?


Thank you
for your attention