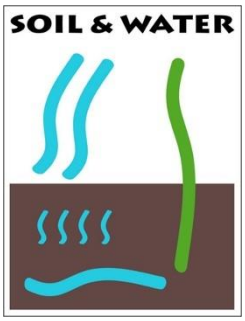

Temperature sensitivity of soil respiration

Supervisor: Petr Čapek

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Group: 3

Students:

Miriam Ahrens, Gabrielle Almecija, Daria Ashmarina,

Petra Polická, David Sednev, Sabrina Tichy

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1. Introduction

Decomposition is an important process involving many factors (Wardle *et al*, 2006) as temperature (Batjes, 1996), microorganisms (Parkinson & Coleman, 1991), substrate availability (Gershenson *et al*, 2009). This process is responsible for carbon recycling. The soil is a global stock of organic matter, twice bigger than is the atmosphere (Shimel, 1995). The carbon arrives from leaves, roots detritus and animal corpse (Davidson & Janssens, 2006). There is also a rate of soil respiration (flux of CO_2). This production of CO_2 in soils comes from root respiration and microbial decomposition of organic matter (Davidson & Janssens, 2006). This soil respiration is essential to understand the potential feedbacks to climate change (Schlesinger & Andrews, 2000).

Figure 1 represents the exponential curve of decomposition dependent on temperature. The temperature sensitivity is explained by the Q_{10}. This Q_{10} is defined as a factor by which the rate of decomposition increases with a 10°C rise in temperature (Davidson & Janssens, 2006).

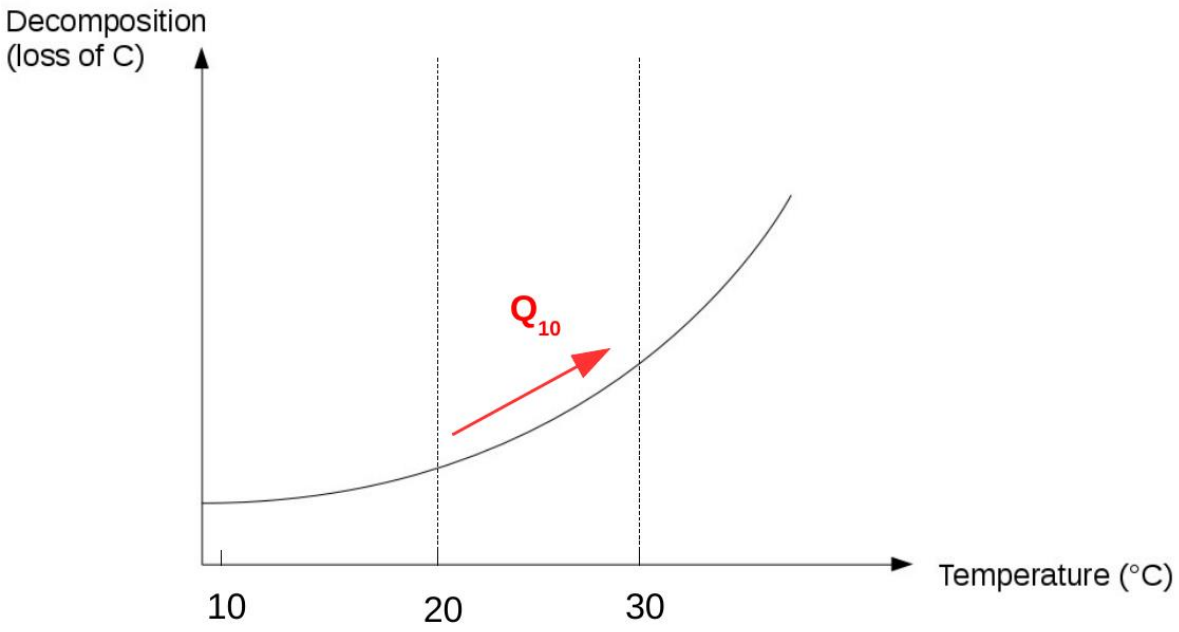

Figure 1: Rate of decomposition dependent on temperature and Q10 value

For now, two theories could explain the relation between the decomposition rate and the temperature – the kinetic theory and the metabolic theory.

The first kinetic theory is mainly focused on activation energy of decomposing material. Basically, the higher is a temperature the higher soil respiration rate occurs. However, this kinetic theory says that the sensitivity of rise with the temperature (represented by Q_{10}) will be higher in the presence of hardly decomposable material in the soil organic matter (Figure 2), as cellulose, than on easily decomposable material, as glucose.

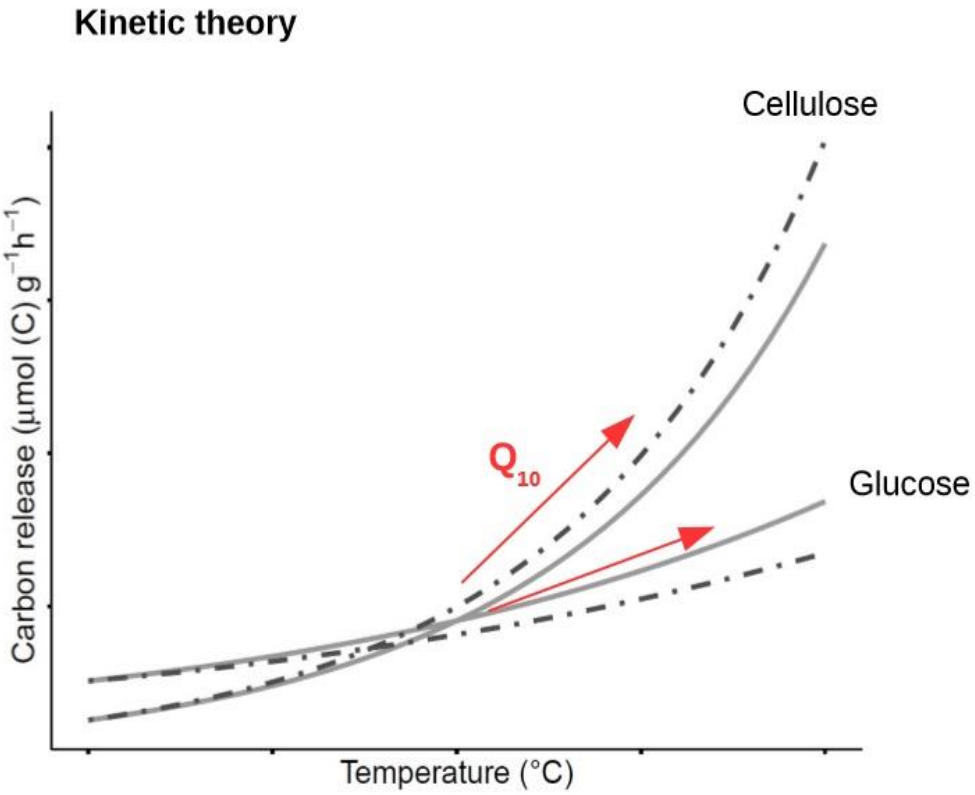

Figure 2 : Decomposition rate of cellulose and glucose

The second theory is the metabolic theory (Gillooly *et al*, 2001). This theory includes microbes as well as all other organisms. Microorganisms decompose the organic matter and their activity depends on the temperature (Gillooly *et al*, 2001). With the temperature increase growths also the activity of microbes and this activity is linked to the respiration rate (figure 3). Gillooly *et al* explained that the Q_{10} is always similar (2.4) for all organisms between 0°C and 40°C. Even if there are more microbes in the soil the shape of the curve is the same which says that the Q_{10} is independent of body mass.

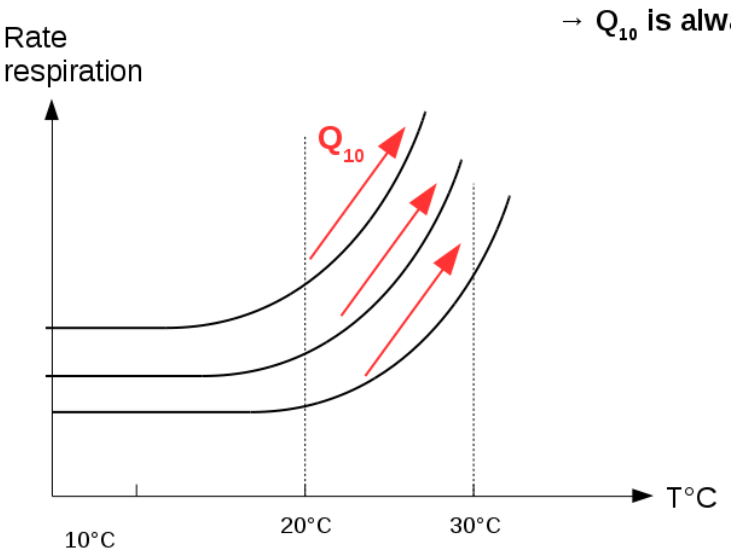

Figure 3: Respiration rate of microbes

Even though both these theories seem to be right, Gershenson et al, 2009 presents some problems. They found that with an increase of substrate availability, the temperature sensitivity increases. These results cannot be explained by both theories therefore in our study we aimed to verify one or both theories by another experiment and find out how Q_{10} varies with the temperature and the availability of substrate. For this experiment, we used one organic soil and one mineral soil to which we added some glucose and cellulose and measured the respiration rate of soil.

2. Material and methods

Soil sampling

Soil sample was collected from randomly chosen location in spruce forest of Sumava mountains. During the sampling soil was divided into organic and mineral part. All soil samples were brought to the laboratory, get off visible roots and homogenized. Each sample of organic and mineral soil was divided into nine 20 g aliquots; each aliquot was placed in a separate flask. The flasks were separated into three groups with three samples – first was treated by glucose (G+), second with cellulose (Ce) and the last was a control (C) sample. Amount of added glucose and cellulose was calculated on the basis of presumed quantity of microorganisms in soil samples. Accordingly, to the flasks with mineral soil was added 3,5 g of glucose and 3,15 g of cellulose and to the flasks with organic soil 8 g of glucose and 7,2 g of cellulose. Then each flask from each group were divided among three temperature treatments (10, 20 and 30 °C) and put into the incubators. The experiment was started two days from the initial collection of samples and passed during 24 hours.

Measuring soil respiration

After keeping samples in incubators via gas chromatograph we measured CO_2 concentrations which detect soil respiration. Briefly, gas chromatograph is a chemical analysis instrument for separating chemicals in a complex sample. A gas chromatograph uses a flow-through narrow tube known as the column, through which different chemical constituents of a sample pass in a gas stream (carrier gas, mobile phase) at different rates depending on their various chemical and physical properties and their interaction with a specific column filling, called the stationary phase. As the chemicals exit the end of the column, they are detected and identified electronically. In our case using gas chromatograph we recorded the concentration of CO_2 in the sample. Respiration measurement for one sample lasted approximately 2 min. The rate of substrate-induced respiration remained constant during the measurement period.

Data processing

After measuring the respiration of soil types at different temperatures, we processed the data using the programs Excel and STATISTIKA, plotted dependence of respiration rate on temperature and calculated Q_{10} for each type of soil sample.

The Q_{10} was calculated for each type of soil from respiration rates for the three different temperatures. For the calculation was used a statistical programme STATISTICA – the nonlinear estimation regression. From this regression we obtained the "a" parameter and the Q_{10} was calculated according to the equation EXP (a*10) and the 95% confidence intervals of Q_{10} estimate were calculated.

3. Results

If the kinetic theory works, Q_{10} should increase with cellulose in comparison to glucose in both soil types because, according to this theory, Q_{10} only depends on the activation energy, which is higher for cellulose than for glucose.

If the metabolic theory works, Q_{10} should be in both soil types and for all substrates the same (around 2.4) as it doesn‘t depend on the biomass.

Of each sample, the respiration rate was measured at the three different temperatures 10, 20 and 30°C. Based on these three measurements of each sample, an exponential graph was approached. For the calculation was used a statistical programme STATISTICA – the nonlinear estimation regression.

As you can see in figure 4 there is a positive relation between respiration rate (µmol C/g*h) and temperature (°C). In each sample a higher respiration rate in the organic soil could be detected than in the mineral soil. The highest respiration rate has the sample with glucose, in organic soil as well as in mineral soil, the lowest have the ones with cellulose in both soil types.

So we can say the higher the temperature the higher the respiration rate in each sample.

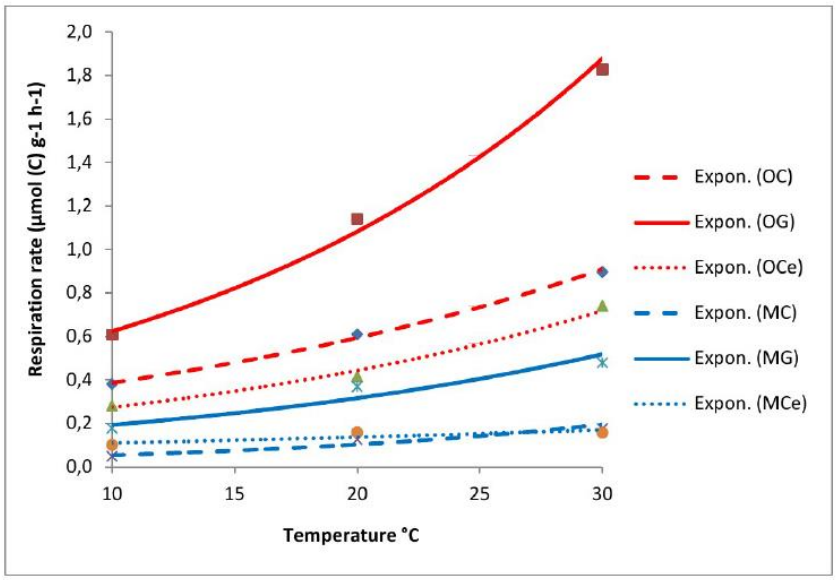

Fig. 4: Respiration rate as a function of the Temperature in °C. OC: Organic Control, OG: Organic soil with Glucose, Oce: Organic Soil with Cellulose. MC: Organic Control, MG: Organic soil with Glucose, MCe: Organic Soil with Cellulose

From the regression we obtained the "a" parameter and the Q_{10} was calculated according to the equation EXP (a*10). The calculation included the pH of the samples and the resultant dissolved parts of CO_2 in the hydrous part of the soil as HCO_3^- and H_2CO_3 to get accurate Q_{10} values. The results are shown in figure 5 and table 1.

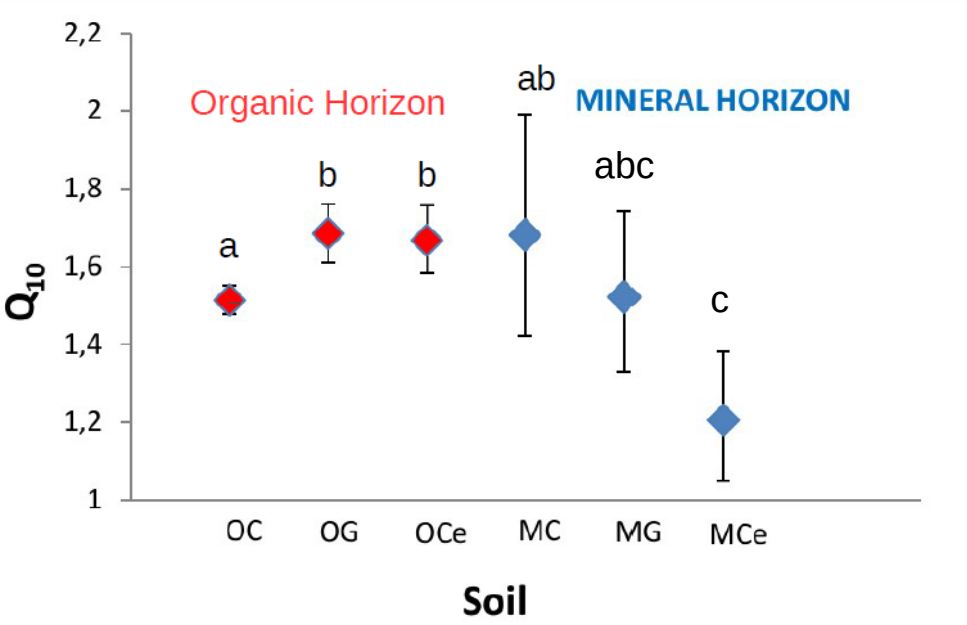

Fig. 5: Q_{10} values and the confidence interval of the different soil types with the different substrates. OC: Organic Control, OG: Organic soil with Glucose, Oce: Organic Soil with Cellulose. MC: Organic Control, MG: Organic soil with Glucose, MCe: Organic Soil with Cellulose.

Tab. 1: Q_{10} values for each sample. OC: Organic Control, OG: Organic soil with Glucose, Oce: Organic Soil with Cellulose. MC: Organic Control, MG: Organic soil with Glucose, MCe: Organic Soil with Cellulose

Soil	**Q_{10}**
OC	1,51
OG	1,69
Oce	1,67
MC	1,68
MG	1,52
Mce	1,21

If the confidence intervals of the samples don't overlap they are statistical different from each other. This means, that the difference in the Q_{10} values are a result of the added substrate and are not coincidental. As you can see, the Q_{10} values of the control of organic soil are significantly different from the organic soil with the added substrates cellulose and glucose, whereas the Q_{10} values of these two samples don't differ. The Q_{10} of the control from the mineral soil and the sample with glucose don't differ from the Q_{10} values of all organic soil types. The Q_{10} value of the mineral soil with cellulose is significantly different from the Q_{10} value of the organic soil with Cellulose and the mineral soil with Cellulose is significantly different from the control of the mineral soil. However the mineral soil with Glucose and with Cellulose are from the same distribution.

These results are in contradiction to the metabolic theory. Furthermore, the Q_{10} values range from 1.21 in the mineral soil with cellulose to 1.69 in the organic soil with glucose added. These values are far below the expected Q_{10} value of 2.4.

To see if the kinetic theory is valid, the Q_{10} values of each soil type have be compared separately. As it is shown in figure 6, the Q_{10} of the organic soil with cellulose and glucose are statistically similar.

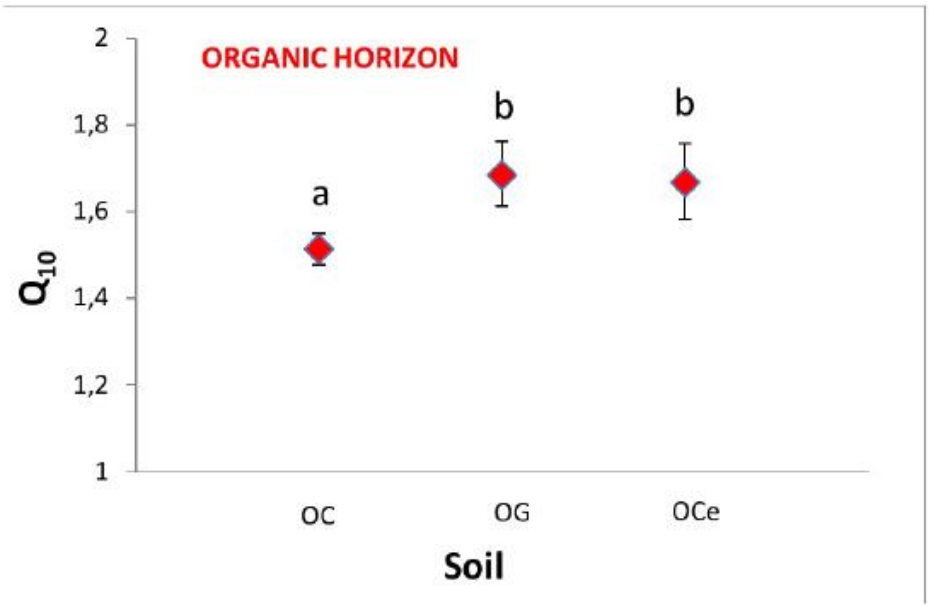

Fig. 6: Q_{10} values of the organic soil. OC: Organic Control, OG: Organic soil with Glucose, Oce: Organic Soil with Cellulose

In the mineral soil, the sample with the cellulose added has a Q_{10} value which lower than the Q_{10} value of the sample with glucose. However, this difference is not significantly (figure 7). These results are in contradiction to the kinetic theory.

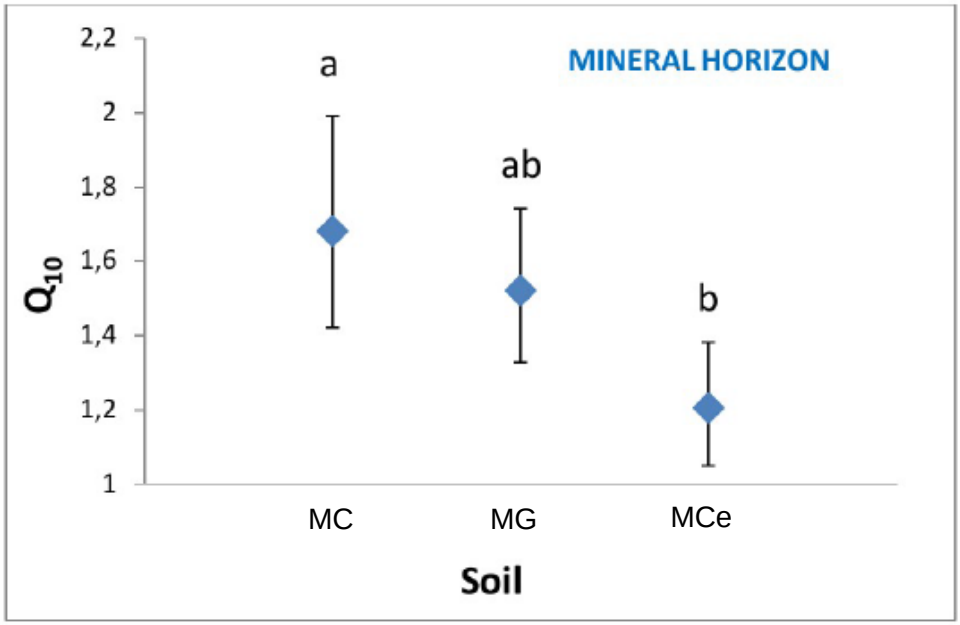

Fig. 7: Q_{10} values of the mineral soil. MC: Organic Control, MG: Organic soil with Glucose, MCe: Organic Soil with Cellulose

4. Discussion

4.1 Comparison with Gershenson et al. (2009)

The results were compared with the conclusions of Gershenson et al. (2009). These results of paper Effect of substrate availability on the temperature sensitivity of soil organic matter decomposition were the main motivation for our experiment.

Gershenson et al. (2009) added a labile carbon to the soil samples (glucose) and as a consequence found a higher temperature sensitivity of the soil respiration rate. The highest temperature sensitivity was induced by the addition of glucose to the mineral horizon in comparison with the organic horizon where the difference of Q_{10} between control and soil with glucose was lower (Fig. 8). These findings are in opposite with the kinetic theory which says more complex the carbon is the higher is temperature sensitivity.

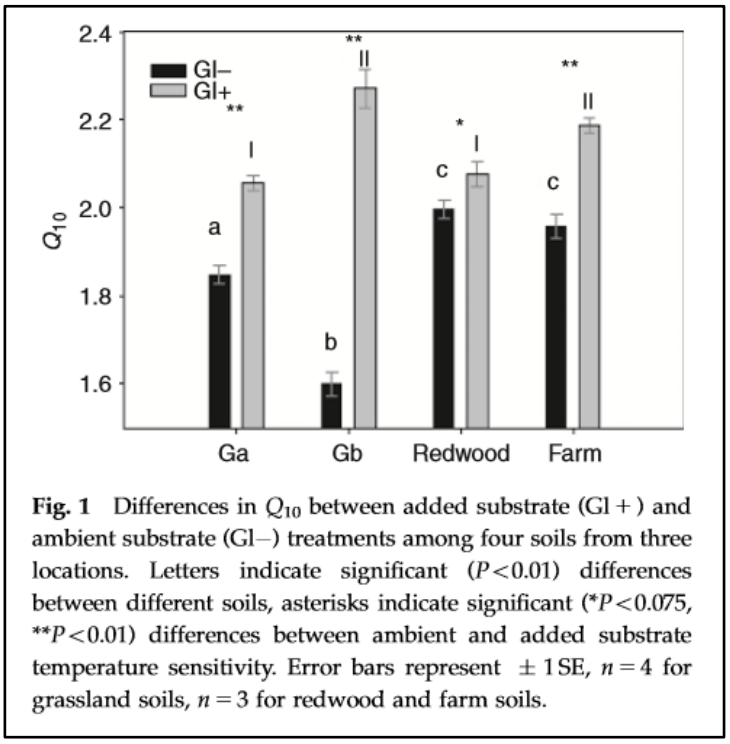

Fig. 1 Differences in Q_{10} between added substrate (Gl +) and ambient substrate (Gl−) treatments among four soils from three locations. Letters indicate significant ($P<0.01$) differences between different soils, asterisks indicate significant (*$P<0.075$, **$P<0.01$) differences between ambient and added substrate temperature sensitivity. Error bars represent ± 1 SE, $n = 4$ for grassland soils, $n = 3$ for redwood and farm soils.

Fig 8: The experiment of Gershenson et al. (2009) - addition of the glucose to the mineral and organic soil horizon.

When we compare our data with these results we can see the same trend in the case of the organic horizon (Fig. 6) but the opposite influence of the glucose for the mineral horizon.

The absolute values of the Q_{10} in Gershenson et al. (2009) vary between 1.6 and 2.3. This is also not consistent with our findings of much lower values (Q_{10} = 1.2 – 1.68). This means that in our case the differences between the respiration rates for the single temperatures were much lower than in the paper from Gershenson et al. (2009).

We can conclude that our experiment does not fit with the kinetic theory and neither with the Gershenson et al. (2009) and therefore we suggest that these experiments are probably much more complicated and require more repetition and measurements to reveal the real factors influencing the temperature sensitivity of the soil respiration rate.

4.2 Potential problems

What could be the reasons for our different results and which factors should be taken into account?
First of all, the soil microorganisms always need some time to adapt for the new conditions which could take even few days. In contrary to that we added the glucose and did not wait to reach some equilibrium and measured the samples after 24 h. This might have caused our indefinite results because the microorganisms did not have enough time to react.
Secondly, we added two substrates with different complexity. Glucose is very easily decomposable and the microbes usually need only hours to use it but in the case of cellulose they need much longer time comprising days, weeks or months. This also does not fit to the measurement after only 24 h.
In the mineral horizon we can see the opposite trend in the Q_{10} values than we were expecting. This means that after addition of a substrate the difference of respiration rate between temperatures was lower than in the control. This could be caused by the reasons mentioned above but we also suggest that the microorganisms did not have enough nutrients to take the available carbon.
Last but not least we should also take into account that we may be made a mistake. Because of the time pressure we had only one replicate for every combination of soil type and temperature therefore we are not able to exclude that.

5. Bibliography

- Batjes, N.H, 1996, Total carbon and nitrogen in the soils of the world. Soil Science, 47, pp151-163

- Davidson E.A, & Janssens I.A, 2006, Temperature sensitivity of soil carbon decomposition and feedbacks to climate change, 440, pp165-173

- Gershenson A., Bader N, Cheng W, 2009, Effects of substrate availability on the temperature sensitivity of soil organic matter decomposition

- Gillooly J.F, Brown J.H, West G.B, Savage V.M, Charnov E.L, 2001, Effects of size and temperature on metabolic rate, Science, 293, pp2248-2251

- Parkinson D, Coleman D.C, 1991, Microbial communities activity and biomass, Agriculture - Ecosystem and Environment, 34, p3-33

- Schlesinger W.H, & Andrews J.A, 2000, Soil respiration and the global carbon cycle, Biochemistry, 48, pp7-20

- Shimel DS, 1995, Terrestrial ecosystems and the carbon cycle, Global change biology, 1, pp77-91

- Wardle D.A, Yeates G.W, Barker G.W & Bonner K.I, 2006, The influence of plant litter diversity on decomposer abundance and diversity, Soil Biology & Biochemistry, 38, p1052-1062