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MEASUREMENT OF SOIL CO_2 RESPIRATION ON ARABLE LAND TREATED BY SEWAGE SLUDGE COMPOST

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1. INTRODUCTION

The key question of the global climate change is the change in the atmospheric concentration of carbon dioxide. It is obvious that the increase in CO_2 concentration in the last 100 years is caused by the accelerated utilization of fossil fuels, but we must not forget the effect of the intensive agriculture, with special attention to crop production on arable lands. This is responsible for the 30% of the global CO_2 emissions along with silviculture [1]. One part of this emitted carbon dioxide is lost forever from the soil; it is derived from the decreasing soil organic matter and unfortunately it can add to the atmospheric CO_2 concentration for a long time. Other part is in dynamic equilibrium with its environment and it has a daily and yearly cycle depending on soil biological activity. Photosynthesis plays the most important role on the input side of this cycle [2].

The problem of decreasing soil organic matter can be met favorably with problems of waste material emplacement derived from several different human activities. Examples are liquid manure from livestock ranches; fermented manure from biogas plants or sewage sludge from municipal wastewater treatment [3], [4]. There are two advantages of the deposition of these waste materials on arable lands: not only we have disposed of them, but they are useful fertilizer for soils and for plants. Their high organic matter content and nitrogen, phosphorus and potassium concentrations can improve soil quality and help increase crop yield. On the other hand, there are several risk factors in applying waste materials to arable lands, such as their high salt and nitrate content or toxic elements contained in them.

While these waste materials have positive effects on crop production and on the soil's biological activity, what is the effect on the global carbon cycle? Can this carbon surplus be built into the soil for long time? How can the intensified biological activity increase the soil respiration? Is it possible to show higher CO_2 emissions on arable lands treated with sewage sludge?

In this study we have investigated the changes in soil CO_2 flux on Chernozems treated with sewage sludge compost in the south-eastern part of Hungary. Besides the above questions we have tried to find answers to others: are there changes in soil CO_2 respiration after treatment; if so, how large are the changes; does what significantly exceed other influencing factors, e.g. effects of soil moisture and temperature?

2. Material and methods

2.1. Study Area

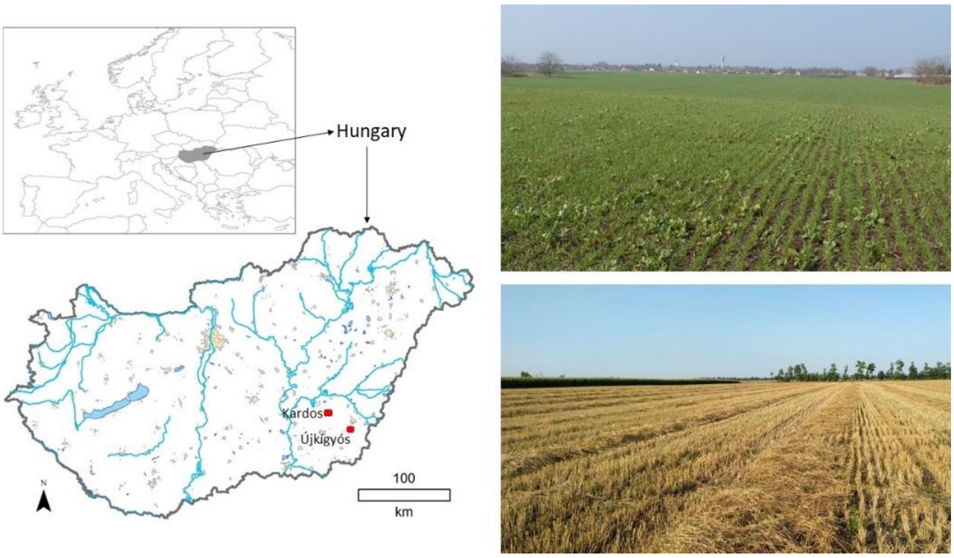

Figure 1
Location of the study areas and the arable lands in springtime and after harvesting

One of the areas with the highest soil quality in Hungary is located in the south-eastern part of the country, in Békés County. Its soils are Chernozems formed on loess with loam and sandy loam texture. Their thickness is 100–120 cm and their humus content is still more than 2% in spite of long-term and very intensive cultivation. Two arable lands with 25.6 and 15.7 ha area were chosen near the settlements of Újkígyós and Kardos *(Figure 1)*. Both of them were covered with winter wheat in 2018 and 2019. Municipal sewage compost has been regularly applied to these fields since 2013 during October and November. The amount of sewage sludge compost was 2.5 m^3/ha/year at Újkígyós and 35 m^3/ha/year at Kardos, in a rotating manner. The compost was placed and plowed into the upper 30 cm of the soil.

2.2. Methods

Three treated study plots at each location (2.5 m^3/ha at Újkígyós in 2017 and 35 m^3/ha at Kardos in 2018) were assigned on both study areas in order to collect soil and plant samples for other parts of this project. The extent of these plots was 50 × 50 m and soil CO_2 flux was measured in the center of the parcels. A further three control plots at each site were chosen near them, which have never been affected by compost applications.

CO_2 respiration measurements were applied 5 times in 2019: twice in springtime (6 March 2019; 28 March 2019), twice in summer (19 June 2019 – before harvest;

16 July 2019 – after harvest) and once at the end of summer (28 August 2019) on both areas. The planned autumn measurements were cancelled due to the extremely low values of soil moisture, biological activity and CO_2 respiration [5].

We measured the CO_2 efflux with an EGM-5 portable gas analyzer. This system contains an SRC-2 closed dynamic chamber for collecting the air which flows from the soil to the atmosphere *(Figure 2)*.

Figure 2
Application of the EGM-5 under winter wheat near the village of Kardos

The system is closed; the air in this chamber is totally isolated from the ambient air. Also the system is dynamic because of the continuous circulating sample gas between the chamber and the infrared gas analyzer (IRGA). The core of the instrument is the IRGA, where measurement actually takes place, and the principle of the method is the infrared absorption of CO_2. As we know, infrared radiation can be absorbed by CO_2 and a nondispersive infrared (NDIR) sensor in EGM-5 can measure the absorbance in the CO_2 molecules' absorption band at 4.26 μm wavelength, where the infrared radiation is completely absorbed by the carbon dioxide. As a result, it is a selective and sensitive method for measuring the concentration of CO_2 because of the minimal overlap with other ambient gas molecules. The built-in infrared source provides light in middle-infrared range and an optical filter corrects the light to the appropriate 4.26 μm wavelength. The absorption of carbon dioxide causes a decrease in the intensity of infrared radiation and the detector can measure the rate of decrease. Thus, the exact concentration of CO_2 is calculable from the ratio of the intensity of incident and transmitted light using the Lambert–Beer law. Furthermore, we can measure the soil moisture and soil temperature in the top 5 cm of soil using a Hydraprobe II sensor. The EGM-5 with this sensor provides data in every second on soil moisture between 0% and 100% and soil temperature between –10 °C and 55 °C. Thus, we can obtain a great deal of information about these two parameters in parallel with CO_2 efflux data [6].

Soil CO_2 respiration were measured each time in 10 repetitions in the middle of each assigned plot. That means that the value belonging to a given plot in a fixed time was created as the average of 10 measured data.

3. Results and discussion

The measured data and their main statistic parameters – after filtering false data – are summarized in *Table 1*.

The high values of standard deviations are caused by various conditions of measurements: soil moisture and soil temperature changed within a wide range and the vegetation was extremely different, from the bare soil surface via mature winter wheat until uncontrolled weeds. Although the measurements were taken on the same day on both treated and control plots, the measured data obviously show the role of the daily period of soil temperature and moisture. There are several scientific publications about the important role of soil moisture and temperature in CO_2 efflux (e.g. [7], [8], [9], [10], [11]) and our own measurements confirm that the daily rhythm of soil moisture and temperature changes have much stronger effects on CO_2 respiration than the treatments. This means that the differences measured inside a day are often caused from the few hours' differences between the measurement times.

Table 1

Averages of measured CO_2 respiration in 2019

Plots	Average CO_2 respiration ($g \cdot m^{-2} \cdot h^{-1}$)	Number of cases	Min/Max	Standard deviation
Újkígyós – treated	0.930	47	0.566/1.586	0.244
Újkígyós – control	0.803	38	0.467/1.489	0.229
Kardos – treated	0.529	59	0.369/0.853	0.095
Kardos – control	0.532	59	0.351/0.808	0.107

Besides the summarized data, the last three measurement campaigns in Kardos can demonstrate the role of the soil temperature in the CO_2 flux very well *(Figure 3)*. The temperature dependent biological activity is the highest at about 30 °C and soil respiration decreases above it.

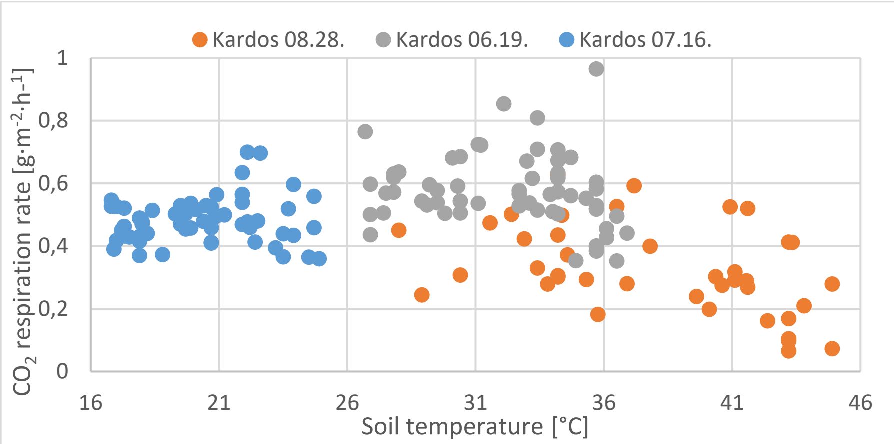

Figure 3

Respiration rates in function of soil temperatures
on three different days, near Kardos

An irrigation experiment provided further information on the role of soil moisture. Two small plots (plot A and B) were irrigated and CO_2 fluxes were measured in parallel on both plots *(Figure 4)*. The increasing soil moisture can cause the growth of respiration as far as field capacity. The main limiting factor for microbiological activity is the low amount of air in the soil pores above field capacity (25–30 v/v%). Results show that this harmful water surplus can obstruct the activity; the CO_2 respiration will decrease after this point [5].

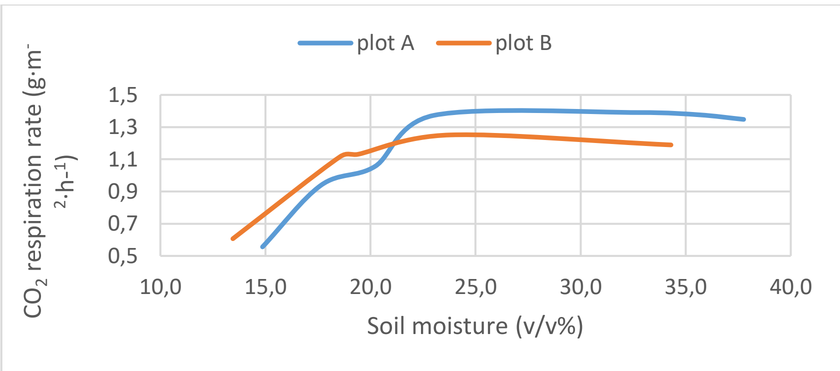

Figure 4

Respiration rates as a function of soil moisture during irrigating experiment

Our conclusion is that there was no obvious evidence to verify increasing CO_2 respiration after sewage sludge treatments on any study plot. The background of the undetectable changes could be the low doses and the fact that the effect of the soil moisture and temperature is higher by at least one order of magnitude than changes caused by the sewage sludge treatment. Measurements give evidence not only of this well-known correlation but they also highlighted the optimal values of soil moisture and temperature for biological activity via CO_2 respiration on the two study areas. The limiting factors of these two parameters are field capacity and a temperature around 30 °C.

The accurate establishment of the effects caused by sewage sludge treatment is possible if not only the measurement method is standardized but the surroundings conditions also, such as soil moisture and temperature. The best way to accomplish this is if the measurements are carried out at the same time of day in parallel on all plots with several sets of instruments.

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