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Seasonal Dynamic In Co₂ Absorption Capacities Of Natural Grasslands

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Abstract. **A world problem of increasing importance is the continuous increase of greenhouse gases and the accompanying global warming. Growing global industries, excessive use of fossil fuels, along with deforestation and agriculture, which are major greenhouse gas polluters, are cited as the main causes. Of the greenhouse gases with the largest share, but also the possibility of control is CO_2. This gas is vital for the growth and development of plants and, through them, is included in the continuous carbon cycle. On this basis, strategies for sustainable development in agriculture are built since this is one of the main sectors contributing to the increase in carbon emissions. The present study tracked the seasonal dynamic of CO_2 uptake by natural grasslands positioned at two altitudes by measuring photosynthesis and plant and soil respiration. A significant variation in CO_2 uptake capacity was observed depending on the climatic conditions.**

Keywords: Canopy photosynthesis, CO_2, greenhouse gas, pastures, soil respiration

I. Introduction

Greenhouse gases contribute to global warming when present in large quantities in the atmosphere. For the period 1906-2005, an increase in the average global temperature near the earth's surface by an average of 0.74 ± 0.18 °C was found (IPCC, 2007). The main greenhouse gases (GHGs) are water vapor (H_2O), which accounts for 36-70% of the greenhouse effect, carbon dioxide (CO_2) - 9 - 26%, methane (CH4) - 4-9%, and ozone (O_3) - 3 - 7% (Spahni Renato et al. 2005; Siegenthaler, Urs, et al. 2005).

The greenhouse gases whose concentration has increased since the beginning of the Industrial Revolution are carbon dioxide, methane, tropospheric ozone, freon, and nitrous oxide. Since 1750, the concentrations of carbon dioxide and methane have increased by 36% and 148%, respectively (Petit et al. 1999).

According to the World Meteorological Organization, the temperature in 2010 was - (0.53 °C) higher than the annual average, making it the warmest year since the early 19th century. The second warmest year was 2005 - (0.52 °C) and 1998 - (0.51 °C), higher than the average annual temperature, although the differences between them are not significant (Sutton, Rowan, et al. 2007; Ehhalt et al. 2001). Carbon dioxide is released into the atmosphere mainly through the burning of fossil fuels, agriculture, animal husbandry, decomposition of organic matter, volcanic activity, plant, and soil respiration. It is one of the main causes of the greenhouse effect and climate change. Although other gases also cause global warming, CO_2 is responsible for about three-quarters of global warming.

The Intergovernmental Panel on Climate Change has published a special report on global warming of 1.5 °C, which warns that if the current rate of greenhouse gas emissions is not reduced, major changes will occur by 2040, as the planet warms by 1.5 °C (Brigham-Grette et al. 2006).

The effects of global warming on the environment and man are numerous and varied. One hypothesis with a huge impact is that global warming will significantly weaken or even stop the Gulf Stream due to the release of too much freshwater from melting ice in the North Atlantic (Weart, R. Spencer 2008, 2014; IPCC, 2007).

The increased concentration of GHGs in the atmosphere affects plants' growth and physiological activities (Sharma et al., 2014; Domec et al., 2017; Tausz et al., 2017; Gamage et al., 2018). From the plant leaf physiology point of view, the rate of photosynthesis usually

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increases, while stomatal conductivity and transpiration rate decrease with increasing CO_2 concentration (Aspinwall et al., 2018; Paudel et al., 2018; Pastore et al., 2019). In terms of leaf morphology and anatomy, CO_2 increases the thickness, mass, and area of plant leaves (Ainsworth and Long, 2005; Leakey et al., 2009), reduces stomatal density (Woodward and Kelly, 1995), increases mesophilic tissue (Lin et al., 2001; Smith et al., 2012).

Soil respiration (SR) contributes to the most significant release of CO_2 into the atmosphere. It results from the metabolic activity of plant roots, soil microorganisms, and agricultural activity (Högberg & Read 2006). In turn, these events significantly impact SR through changes in the soil environment (e.g. soil water content and temperature) (de Araujo Santos et al., 2019; Huxman et al., 2004; Knapp et al., 2015; Nielsen and Ball, 2015). Therefore, many studies have been conducted to study the reaction of SR at different soil moisture contents. Apart from the different water regimes, other climatic elements (e.g. air temperature and solar radiation, etc.) also change the SR. Monitoring of SR is needed to clarify its impact on the climate and to make prescriptions for crop and tillage systems. The search for innovative and easy-to-implement methods for monitoring greenhouse gas ecosystem processes is crucial for the planet's sustainable development.

The research aims to adapt a methodology for monitoring the dynamics of CO2 fluxes in natural and artificial grasslands. The methodology establishes the influence of climate on the processes of photosynthesis and respiration of plants and soil in grass communities by tracking these processes during the different annual seasons and a certain time range. The results can help to develop and implement sustainable agricultural practices.

II. MATERIALS AND METHODS

Methodology

A camera was constructed to determine the activity of absorption or release of CO_2 from a unit area of the monitored objects for a limited period. The camera has the following dimensions: length - 100 cm, width - 25 cm, height - 25 cm, with internal volume - 0.0625 m^3 and area - 0.25 m^2, made of Plexiglas, is presented in Fig.1. The monitoring analysis for the detection of CO_2 includes a gas analysis system "PTM600" Multifunction Meter for determining the amount of CO_2, which can measure up to 6 types of gases simultaneously. It has a sensor for temperature and humidity. This analysis makes it possible to trace the dynamics of the absorption and release of CO_2.

The model presented here is based on the assumption that all other potential errors in the closed chamber, which are unrelated to the inherent changes in the concentration in the closed chamber space, are insignificant due to the careful planning of the experiment. This means that during the setup of the chamber, the air and soil temperature, the photosynthetically active radiation, and humidity are considered constant and approximately equal to the ambient conditions. When covering a vegetative surface of the soil with a closed chamber, the concentration of CO_2 changes over time in the chamber space, which is the effect of several separate processes with partially opposite directions Fig. 1. The free space is isolated from the surrounding atmosphere from the walls of the chamber. Depending on the time of the analysis - day or night, there is an increase or decrease in the concentration of CO_2. When measuring soil respiration, the soil surface is freshly cleared from the vegetation, and CO_2 is released from the soil (FSr) into the chamber. When measuring soil covered with plants, since they photosynthesize (Fph) during the day but respirate (Fr) during the night, in the chamber, the concentration of CO_2 could decrease or increase, which means that plants absorb or release CO_2.

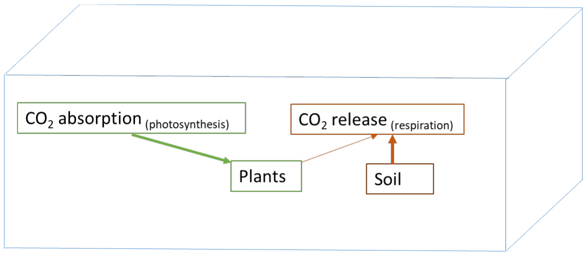


Fig. 1. Schematic description of CO_2 flows in the chamber, representing the net flow of CO_2. The scheme is a modification of one published by Kutzbach et al., 2007.

In the presented experimental setup, the change in the CO_2 content was traced at different times of the day, during different seasons, and on fields with different plant species compositions. To determine soil respiration (CO_2 release), the measurement was performed in field zones with freshly removed vegetation cover. That illustrates the CO_2 release during agricultural soil tilling. The measurement was performed in field zones with a comparable vegetation type to determine plants' photosynthesis or respiration (CO_2 absorption or release). All measurements were done in triplicates. The time range for the measurements was from 9:00 to 10:00 a.m. for photosynthetic or soil respiration and from 23:00 to 00:00 for respiration measurements (of plants and/or soil). Climatic data such as air temperature, humidity, and precipitation were collected for the same time ranges in which the measurements were made as the monthly average value was used for precipitation. Each measurement in the chamber was performed twice, immediately (initial) and 10 minutes after placing the camera. The limitation in the measurement duration is imposed by the fact that with a longer exposure, the humidity in the chamber increases significantly, which can affect the measurement's quality. The change in CO_2 concentration is determined relative to the external concentration, equal to the initial one, according to the formula Fnet = (Fph + Fsr + Fr)t0 - (Fph + Fsr + Fr)t10, where the "Fxs" are the different types CO_2 flows. The results are expressed per area of one square meter in one second CO_2 mg/m^2/s.

Object of investigation

The method was tested in two different areas, differing in altitude, to compare the CO2 absorption capacity of the vegetation in them. The measurements were carried out in May, July and October for three consecutive years. These months were chosen as representative of the different stages of vegetation development, namely active plant growth, summer retention and the onset of autumn changes.

Area 1 - Plovdiv

Location: On the land of Plovdiv, 1000 meters east of Plovdiv with exposure south-southeast and altitude:156 m. GPS: 42008`08``N 24048`28``E. The density of the soil cover is 100% composed of cereals and deciduous grasses.

Description: Artificial pasture from AU-Plovdiv, managed and used for grazing sheep from the Department of Animal Husbandry. Created for educational purposes.

Area 2 - Devin

Location: The plot is located in the western Rhodopes, 5 km northeast of the town of Devin, the boundaries of the municipality of Devin in the Smolyan region with south exposure, the tilt of 10 °, and an altitude: 1145 m. GPS: 42045`10``N 24027`07``E. The density of the soil cover is 85%, composed of cereals, deciduous grasses, legumes, sour grasses, and weeds. Bare soil is 15%. Description: The area is located about 600 m from the Kehayovi eco-farm. The pasture is used for grazing sheep.

Statistical analysis

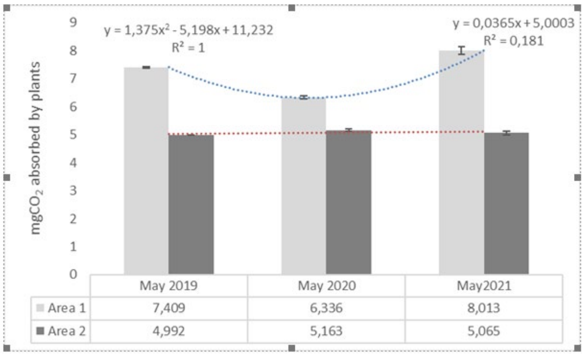
The data from the measurement with the gas analyzer are presented in ppm and then precalculated in mg. The data processing was performed with the statistical program SPSS 26.0. Data reported in the experiment was the mean of 4 replicates. Subsequently, Tukey's test was conducted to determine the significant differences among the values.

III. RESULTS AND DISCUSSION

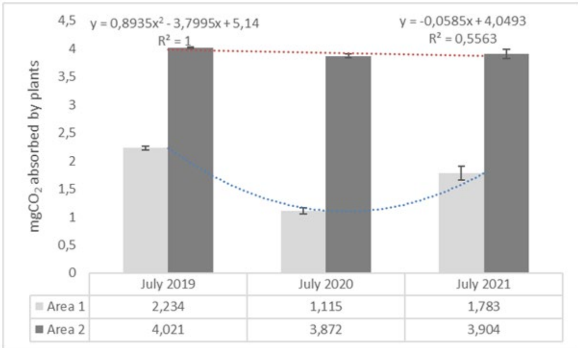
The results presented in Table 1 and Fig. 2 summarize the measurements of CO_2 flows in two pasture areas over three years. The activity of photosynthesis and respiration from the plant surface during the day, as well as respiration at night, were monitored. Similarly, soil respiration without vegetation was recorded during the day and at night, according to the description of the material and methods. As expected, the highest activity of photosynthesis and corresponding absorption of CO_2 was observed in May, when the vegetation cover is in active growth and the soil has sufficient water reserves (Fig. 2A). In the mountainous region (Area 2), CO_2 absorption during May shows a stable linear trend over the three-year period, which corresponds to the relatively stable daily temperatures at the time of measurement (Fig.3), as well as to the more substantial monthly precipitation characteristic of this area (Fig. 4).

In the years' basis comparison, the CO_2 absorption in area 1 shows a clear decline in all three months of measurement for 2020. These results correspond to the monthly precipitation data, which are the lowest for the Plovdiv region in 2020 (Fig. 4).

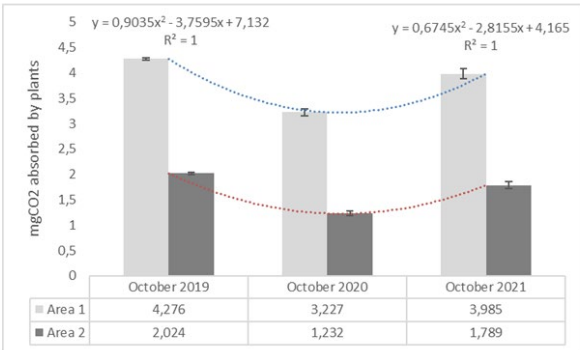
Usually, during the hot months, there is a significant decrease in the photosynthetic activity of vegetation, which is more pronounced in Area 1 (1,115 mgCO2 mg/m2/s) compared to the results obtained in Area 2 (3,872 mgCO2/m2/s). This can be explained by the altitude and the amount of precipitation, which are traditionally lower than in mountainous areas (Fig.3) and typically higher temperatures in Area 1 (Fig.2).



A)



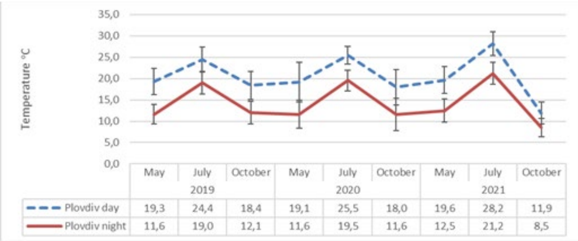
B)



C)

Fig. 2. Comparative analysis of CO2 absorption in two grassland Areas during the growing season. The values represent the amount of CO2 in milligrams absorbed by vegetation through photosynthesis, expressed per area of one square meter in one second (mgCO2/m2/s). A) CO2 absorption in May, B) CO2 absorption in July, and C) CO2 absorption in October.

During the measurements in October, the opposite trend was observed – photosynthesis activity is lower in Area 2 than in Area 1. This may be due to the earlier dormancy of plants in mountainous areas due to adverse weather conditions.



A)

B)

Fig. 3. Temperature values recorded in both areas – A) Area 1 – Plovdiv, B) Area 2 - Devin. The day temperatures were measured at 9:00 a.m., and the night temperatures at 11:00 p.m., i.e. at the time when the gasometric analyzes were conducted.

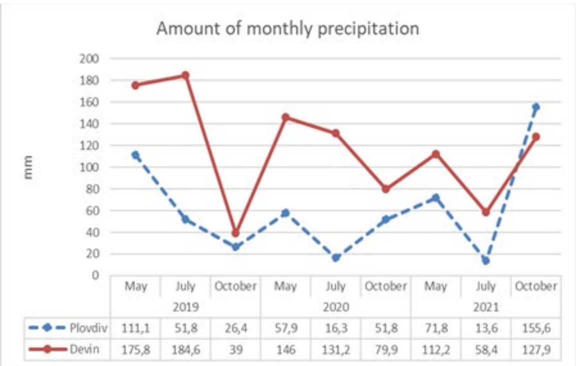


Fig. 4. Average monthly precipitation values in the two measurement areas - Area 1 - Plovdiv and Area 2 – Devin.

Regarding respiration as a process that releases CO_2 into the atmosphere, the results are very indicative (Table 1). Soil without vegetation is a serious factor contributing to increased carbon emissions. For this reason, freshly plowed fields are considered a serious source of CO_2. During the day, soil dwellers had increased respiration, as the strongest CO_2 release was reported in July in Area 1 (12,203 $mgCO_2/m^2/s$) (Table 1). The high temperatures in this month and the sunlight stimulate the activity of soil microorganisms, affecting the values of CO_2 released. The release of CO_2 from the soil at night is also to be considered. Depending on the metabolic activity of the soil microorganism populations and the environmental conditions, the values of released CO_2 vary. They are lowest in Area 2 (Devin) in the month of May (the lowest measured value of 0.185 $mgCO_2$ m^2/s is for the year 2021) because the soil in the mountainous areas is still very cold due to the past winter months, and the metabolic processes are not particularly active. With the increase in temperature in July, higher values of released CO_2 were recorded again in Area 2 (5,357 $mgCO_2/m^2/s$). As metabolic processes are affected by temperature, the observed results for soil respiration are consistent with it.

Table 1. Comparative analysis of CO_2 release flux in two grasslands during the growing season. The values represent the amount of CO_2 in milligrams released into the atmosphere through respiration, expressed per area of one square meter in one second ($mgCO_2/m^2/s$).

	Measurement	Day		Night
Area	Date (month/year)	Released CO_2 by soil respiration (soil without vegetation)	Released CO_2 by plant respiration	Released CO_2 by soil respiration (soil without vegetation)
Area 1 Plovdiv	05/19	3,038b	4,984b	3,986c
	05/20	2,816c	5,867a	4,576ab
	05/21	3,265a	5,923a	4,899a
	07/19	11,086c	1,654a	2,003a
	07/20	12,203a	0,763c	0,939c
	07.21	12,101b	1,035b	1,652b
	10/19	2,145b	2,784b	3,128b
	10/20	2,288a	3,813a	3,461a
	10/21	1,967c	2,939b	2,689c
Area 2 Devin	05/19	4,311b	5,023b	0,513a
	05/20	4,459b	4,869bc	0,235b
	05/21	5,002a	5,921a	0,185c
	07/19	5,782a	6,345c	4,801b
	07/20	5,925a	6,981b	4,576c
	07/21	5,038b	7,012a	5,378a
	10/19	1,022b	0,219b	2,934b
	10/20	0,997b	0,176c	3,285a
	10/21	1,216a	0,323a	2,433c

Normally, plants breathe at night in addition to soil organisms. The intensity of this process depends on many factors - plant age, physiological condition, the presence of stress from injury, low or high temperatures, drought, season, etc. The activity of this process follows the physiological development of plants. In Area 1 in the month of May, the vegetation is growing, and the environmental conditions are favorable - the temperatures are not too high, and there are still water reserves in the soil. This determines the higher values of CO_2 released through respiration (5.923 $mgCO_2/m^2/s$). As the temperatures rose in July, there was a decrease in the respiratory activity of the vegetation in Area 1, as the vegetation died due to the very low rainfall values for this region (Fig.4). At the same time, in Area 2 (Devin) increased values of CO_2 released by plants were recorded for the month of July, in which there is active growth of vegetation supported by a sufficient amount of soil moisture. The lowest values for CO_2 released by plants through respiration were obtained for October in Area 2 (0,176 $mgCO_2/m^2/s$) because at this time of the year, in the mountainous regions the plants are at quiescency, and their metabolic processes are reduced to a minimum.

Pasture grasses assimilate and accumulate carbon in the form of organic matter used to grow aerial parts and the root system during their life cycle. As a result of the seasonal dying of different plant parts (aboveground and roots), organic matter passes into the soil and takes part in the soil carbon cycle. Some of this organic matter is used by soil dwellers as a food source and subsequently released as CO_2, referred to as soil respiration. Another part of the organic matter undergoes mineralization and enriches soil fertility. For this reason, grasslands can play a key role as sinks of CO_2 and the carbon cycle (Silveira et al., 2018). Proper pasture management can also promote carbon storage in the soil. Most techniques used to improve forage production promote carbon inputs to the soil and increase soil carbon sequestration. For instance, fertilization, irrigation, and grazing management can boost plant productivity while promoting soil carbon sequestration (Silveira et al., 2018, Whitehead, 2020).

IV. CONCLUSIONS

The methodology presented here is suitable for measuring pastures in all regions of the country. The obtained data are reliable and can be used for analysis, conclusions, and recommendations. On the other hand, they can be traced to the influence of climate change on photosynthesis and respiration, which are the main biological processes associated with the C cycle. The methodology can be used to build a system of sustainable pasture management, thus affecting the reduction of greenhouse gas emissions.

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