# Carbon Dioxide Emissions from Soil in the Application of Conventional and Soil Protection Technologies for Growing Wheat on Sloping Arable Land

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***Abstract**: Soil tillage has a great impact on soil CO2 emissions and is one of the main agro-technical activities that is thought to reduce organic carbon stocks in the soil. For this reason, much was done to develop agricultural practices combining appropriate tillage with the application of organic soil amendments that will lead to an increase of organic matter in the soil, to improve plant development and to a reduction in greenhouse gas emissions from the agricultural sector. This work examines the results of studies conducted with such conventional and soil conservation practices for minimum and unconventional tillage using manure, as mulching material, in wheat cultivation, on sloping terrain, and determines their impact on soil carbon flows.*

***Keywords**: soil water erosion, loss of soil organic matter, minimum soil tillage, surface mulch, vertical mulch, soil $CO_2$ emissions, labile soil organic carbon.*

## INTRODUCTION

Climate change is mainly caused by the changing concentration of greenhouse gases in the Earth's atmosphere. Concentrations of these gases have increased compared to pre-industrial times, especially in recent decades, mainly due to industrialization, agricultural production and urbanization [2, 4, 5,11].

The agricultural sector is responsible for approximately 10–13% of global anthropogenic greenhouse gas emissions. The net $CO_2$ exchange from agricultural soils is approximately in equilibrium and has significant mitigation potential for the sequestration of atmospheric $CO_2$ [16]. Soil tillage has a major impact on soil $CO_2$ emissions and is one of the main agro-technical activities that is thought to reduce organic carbon stocks in the soil [9, 14, 15].

Another significant source of greenhouse gases in the agricultural sector is related with it productions, and in particular the production of mineral fertilizers. In 2017, 11.6 million tons of nitrogen fertilizers were used in EU agriculture [6]. The production of these fertilizers is associated with significant greenhouse gas emissions. Therefore, reducing their use by substitution with organic residues can contribute to environmental protection.

Organic fertilizers in the form of composts, manure and cover crops are a source of nutrients for the plants, and they also improve soil quality, improve volume and density, moisture retention capacity, electrical conductivity, increase soil organic matter, soil biological activity [8, 1, 15].

Exploring the potential of organic residues and their application to different crop technologies can improve soil quality and lead to economic benefits. Although increasing the amount of organic amendments leads to higher $CO_2$ emissions, but linear increases in total organic carbon are observed ($P < 0.05$). The $CO_2$ flux expresses the amount of carbon lost and depends on the applied amounts of organic soil amendments [16].

Therefore, the application of organic materials should be made according to the available nutrients in the soil and the needs of the plants in order to prevent the application of excessive amounts of nutrients leading to unnecessary increases in $CO_2$ emissions. Reduced $CO_2$ emissions from soil obtained from low nitrogen organic fertilizers such as organic compost indicate that there is less aerobic microbial activity in soil than in cultivated soils with high nitrogen content [1].

All these studies indicate that it is necessary to develop such agricultural practices that combine the appropriate cultivation and application of organic soil amendments, to increase of soil organic matter, to improve plant development and to reduction of greenhouse gas emissions from the crop production.

For the last ten years, the Institute of Soil Science, Agrotechnology and Plant Protection "Nikola Pushkarov" - Sofia together with the University of Rousse "Angel Kanchev" have been working on this problems and have been developed advanced soil protection technologies for minimum and unconventional soil tillage, which have been tested in our country and show good results when applied for growing wheat on sloping arable land. They were created in relation with the reduction of the impact of water erosion, which is the most significant soil degradation process in the Republic of Bulgaria. It affects to about 80% of our agricultural land. Another important degradation process that is closely related to water erosion and depends on its impact is the loss of soil organic matter. These two processes of soil degradation cause considerable damage to our native agriculture [3, 14].

The protection of agricultural land from water erosion and the loss of soil organic matter can be accomplished with so-called erosion control agro-technology, including various soil-protection agro-technical methods and technologies. Such are minimum tillage and unconventional tillage such as surface and vertical (intra soil) mulching, using manure as mulching material, which can be co-applied, as is the case with advanced soil protection technologies.

The purpose of the present study is to determine influence of applied advanced soil protection technology for minimum and unconventional soil tillage with manure application as mulching material for growing wheat on sloping terrain, on soil carbon dioxide fluxes.

## MATERIAL AND METHODS

The study was carried out in the period 2018-2019 yr., in the experimental field of the Institute of Soil Science, Agrotechnology and Plant Protection "Nikola Pushkarov" - Sofia, in the territory of the village of Trustenik, Ruse region, under non irrigation conditions, on middle eroded calcium chernozem on slope with inclination $5^o$ (8.7%). The field of the village of Trustenik, Rousse district is located in the northern climatic region of the Danube hilly plain and is characterized by a temperate continental climate, with a sharper continence than the rest of the country. Autumn and spring are short. Winter is cold, with a minimum amount of rainfall and hot summers with a high maximum of rainfall.

The field experiment with wheat was performed using the block method, in four variants, in four replicates. The variants of the experiments are:

$b_0$ variant - wheat plots, grown by conventional technology, applied along the slope - control;

$b_1$ variant - wheat plots, grown by conventional technology, applied across the slope;

$b_2$ variant - wheat plots, grown by soil protection technology including the erosion control measure - surface mulching with manure, applied across the slope.

$b_3$ variant - wheat plots, grown under advanced soil protection technology including erosion control measures vertically mulching with manure and direct sowing, as well as some plant protection operations for weed control, pests and plant diseases, all applied across the slope.

During the study period, annually, all technological operations performed in variants $b_0$ and $b_1$ are conventional and identical, with the difference between them being only in the direction of their implementation. In the control they are made along the slope, and in variant $b_1$ in the transverse direction. In the same direction, the operations of variant $b_2$ were carried out pre-sowing anti-erosion method surface mulching with manure (4500-5000 kg / ha) was carried out, using the fertilizer trailer 1PTU-6 for this purpose.

In the last $b_3$ variant, pre-sowing, transversely on the slope, was carried out vertical (internal soil) mulching with manure, as mulching material, according to a tape scheme (distance between slots 1.4 m and interval between the strips in the field 3 m) at a depth of 0, 40 m with the help of the reconstructed pruner SHN - 2 - 140 with a mulch.

During the experiment, erosion studies of the applied technologies were carried out, as well as carbon emissions were measured every month during the growing season, as well as the content of labile carbon (oxidisable by potassium permanganate) [18], soil moisture content was determined in the 0-10 cm layer and soil electrical conductivity.

## RESULTS AND DISCUSSION

Climate observations, soil moisture, and carbon dioxide emissions over the study period are shown in Fig. 1, Fig. 2 and Fig. 3.

Fig. 1 shows the average day-and-night temperatures as well as the sum of the precipitation for ten days periods. They show that March 2018 is very cold, with average temperatures in the first and third ten days of the month between 2$^o$ and 4$^o$ C, while April in the same year has average daily temperatures between 15$^o$ and 20$^o$ C. Unlike in 2018, in March and March 2019 average daily temperatures are 10 degrees Celsius, rising to 15$^o$, only in the third ten days of April.

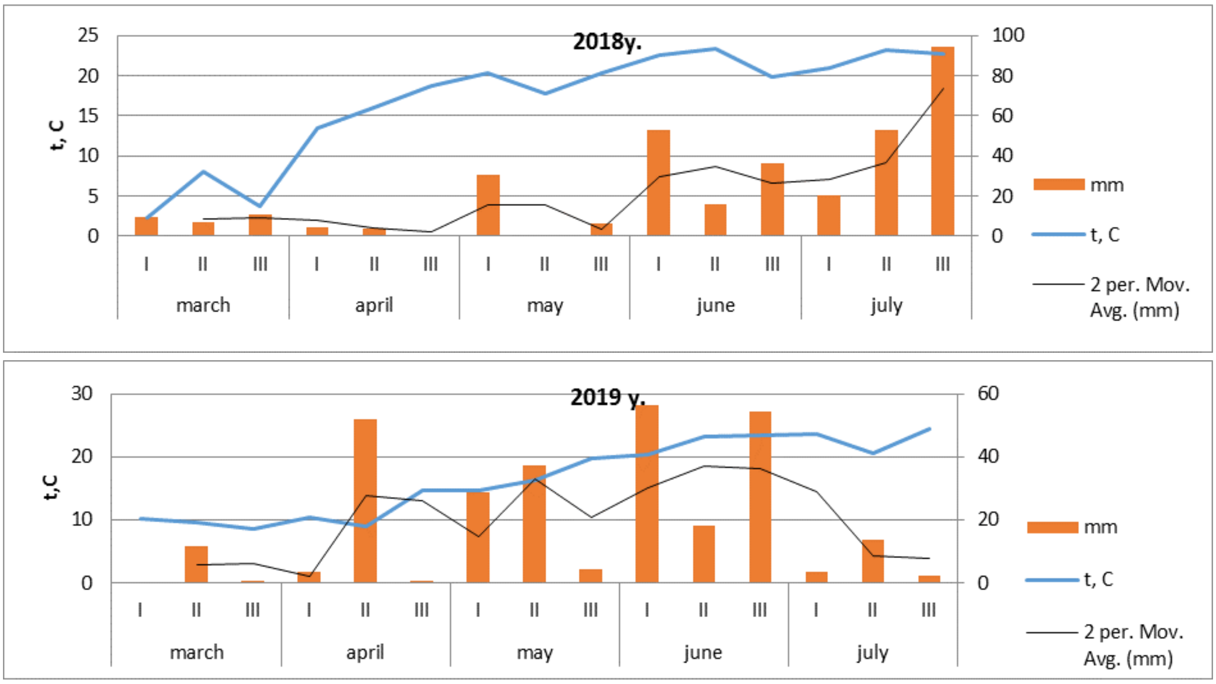
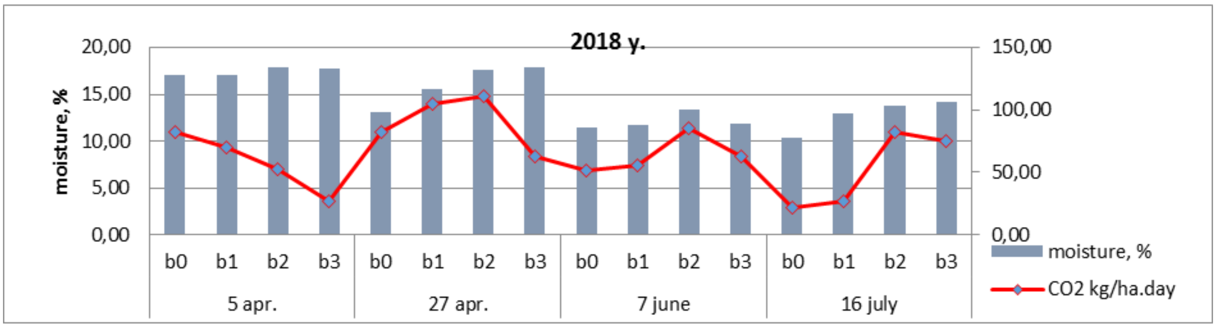



**Fig. 1** Climatic characteristics of the biennium (2018 - 2019)

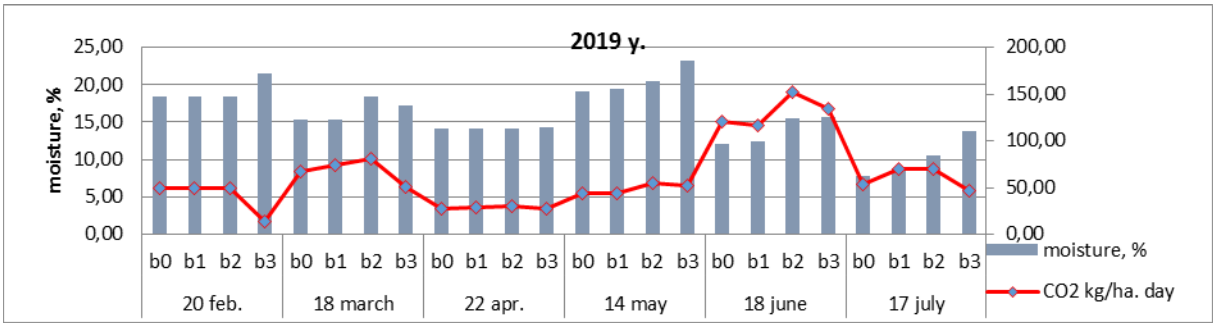
Accordingly, this has resulted in significant $CO_2$ emissions in April 2018y. due to the sharp warming and high humidity, while in April 2019y. there were more moderate carbon dioxide emissions. There were higher $CO_2$ emissions in June for both years, dropping in late July of 2019y, because of low humidity. There was slow rise in temperatures in May, 2019y. The temperatures settled at about 15 degrees by the third ten days of May, reflecting a lower intensity of soil respiration.

Soil moisture and soil temperature do not affect carbon emissions as separate factors. They have an impact on $CO_2$ emissions jointly in our experiments.

$CO_2$ emissions depend most on applied technologies for cultivation. Generally, during the growing season, variant with manure surface application have the highest carbon dioxide emissions. In contrast to these variants, the organic carbon incorporated by vertical mulching, combined with minimum tillage, results in lower carbon emissions.

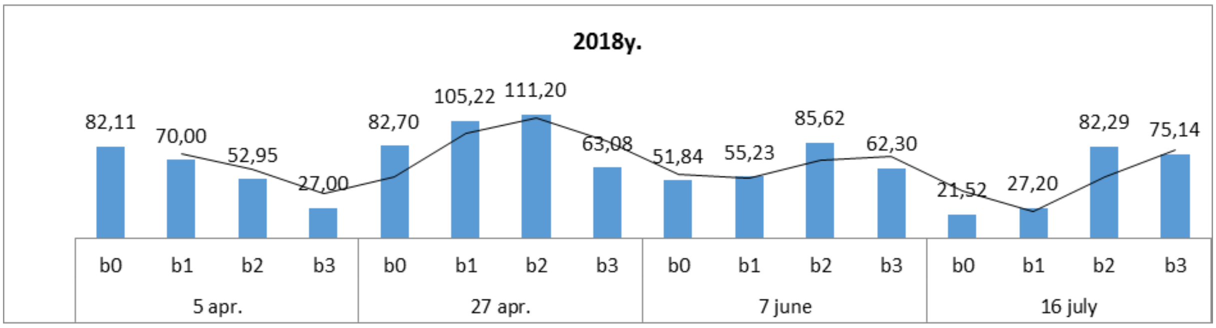



*ANOVA NS ($CO_2$); moisture NS*




*ANOVA NS ($CO_2$); moisture NS*

**Fig. 2** Soil moisture content (0-10 cm),% and $CO_2$ emissions, kg / ha day



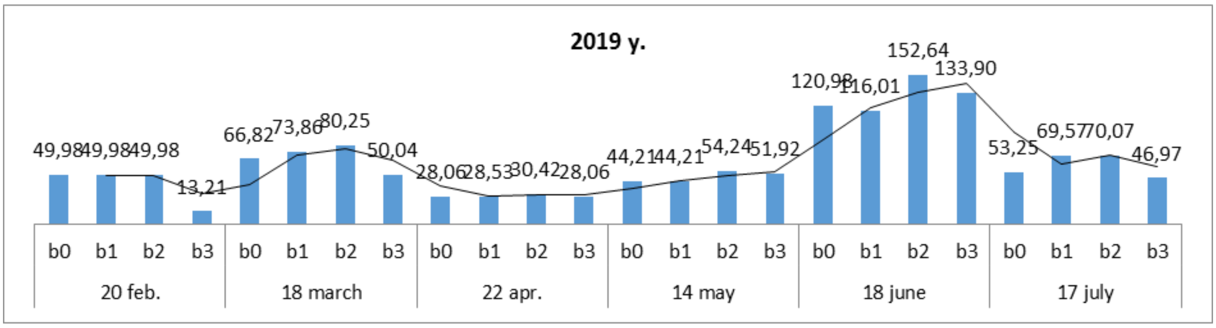
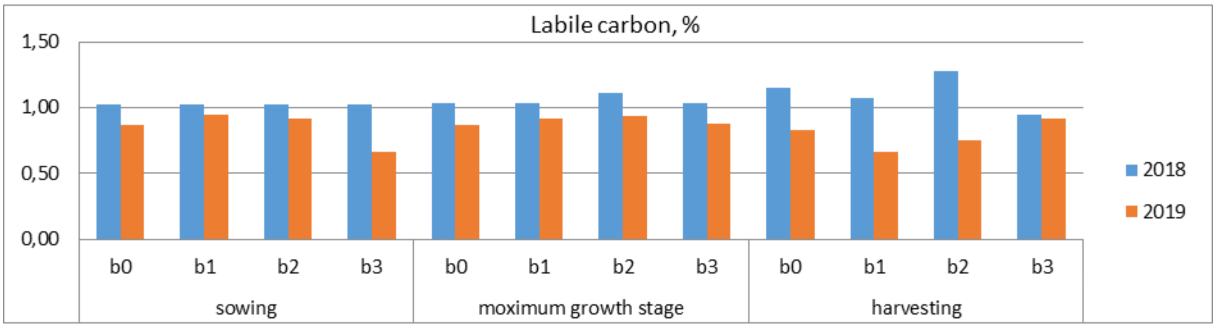



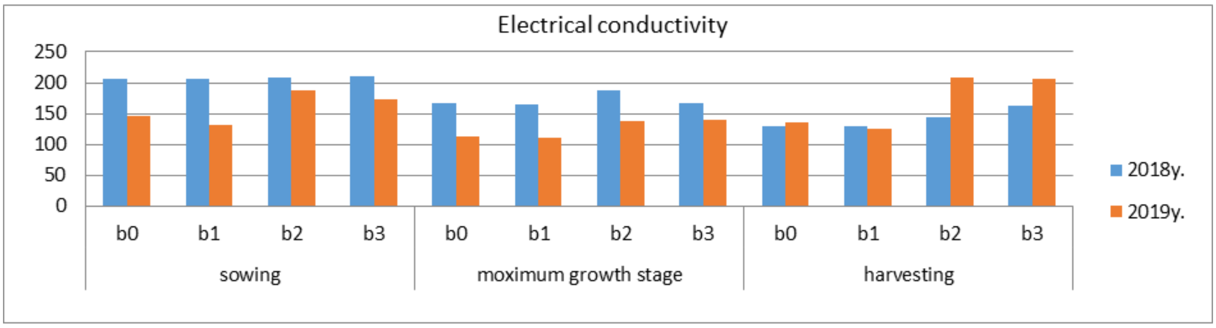

**Fig. 3** $CO_2$ emissions, kg / ha day

In relation with the fluxes of $CO_2$ from the soil, the quantities of labile carbon (Fig. 4) and electrical conductivity (Fig. 5) were measured. The results show higher quantities of labile carbon, total carbon, and electrical conductivity for surface and vertical manure applications. Higher amounts of nutrients are present in the presence of high values of electrical conductivity. All this leads to a more intensive separation of $CO_2$ from the soil in the variant with manure surface application and conventional treatments, while the minimal disturbance of the soil surface and the introduction of organic matter into the slits leads to lower emission values than traditional the variants processed.




*ANOVA: 2018- p= 0.0982; 2019 – NS*

**Fig. 4** Labile carbon content, mg/g




*ANOVA: 2018- NS; 2019 – p= 0.0795*

**Fig. 5** Electrical conductivity, µS / cm

The $CO_2$ emissions of b2 variants with conventional tillage and surface mulching are highest. Accordingly, in this variants the highest levels of labile organic carbon are also observed. In variant with surface mulching in 2018y., $CO_2$ emissions are 83.01 kg/ha day in 2019y. - 72,93 kg/ha day Emissions of the last variant $b_3$, applying minimum tillage and vertical mulching, are significantly lower, with an average of 56,88 kg/ha day and 54 in 2018y and 2019y respectively, 02 kg/ha day, while in the case of conventional treatments applied to the slope of the slope, they are 64,41kg/ha day and 63,69 kg/ha day, which shows the effect of minimum treatments on soil emissions, and is an organic substance imported. The effect is stronger at the beginning of the growing season and the differences in emissions there are much larger. The carbon emissions of the conventional control variant applied along the slope are 59.54 kg / ha day and 60.55 kg / ha day.

## CONCLUSION

From the results obtained in the studies conducted, the following conclusions can be made:

− Carbon dioxide emissions from soil in the present experiments show a dependence on climate factors and their combined action, but are most strongly influenced by the applied technologies for wheat cultivation on sloping arable land.

− The highest $CO_2$ emission values as well as the highest quantities of labile carbon are observed in the variant grown with surface application of manure. The application of organic soil amendments leads to an increase in labile organic matter as well as carbon dioxide emissions.

− Soil $CO_2$ emissions are lower for the minimum tillage with vertical mulching variant, and they are 28.88% lower than the surface mulching variant, which means that it is much higher of the incorporated organic matter remains in the soil. The carbon emissions in this variant are 13.40% on average lower than the variant by applying conventional (traditional) tillage across the slope. Due to compaction and lower humidity, the emissions of the variant using conventional technologies along the slope are lower than those using the same technology transverse to the slope.

− Advanced soil protection technology for minimum and unconventional tillage for growing wheat on sloping terrains has not only high erosion efficiency but is also a way of incorporating organic matter into the soil without observing significant carbon emissions from the soil. Minimum operations also contributes to reducing emissions from both the processing itself and the use of fossil fuels.

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