Soil CO_2 Emissions in the Application of Conventional and Erosion Control Technologies for Growing Maize on Sloping Terrains

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Abstract *Soil tillage of agricultural lands is a basic practice in agricultural management. Conventional soil tillage systems include more tillage operations, including plowing with reversing the layer, which results in higher CO_2 emissions and also requires higher amounts of fuels. In contrast, soil protective agricultural practices have great potential for increasing soil organic carbon and reducing carbon dioxide and other greenhouse gas emissions. This work defines the impact of some conventional (traditional) technologies and advanced technology for minimum and unconventional tillage for growing grain maize on soil organic matter and CO_2 emissions.*

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

INTRODUCTION

Soil contains twice as much carbon as the atmosphere and three times more than vegetation [9]. Soil respiration has been found to be 68–80 PgC/yr, which is the world's second largest carbon flux between ecosystems and the atmosphere [16, 18]. This amount is 10 times higher than current carbon emissions from burning fossil fuels.

For this reason, small changes in soil respiration, covering large areas, can have a significant effect on atmospheric CO_2 concentrations [19].

Therefore, information is needed on soil CO_2 emissions and the factors that affect these flows, in order to limit organic matter losses in ecosystems and to determine soil response to changing land use and global climate change.

Crop production is a source of greenhouse gas emissions due to disturbance of the soil during cultivation, improper management of harvest residues, application of fertilizers, but also due to the use of equipment in various technological operations (these are emissions from energy sources necessary for soil cultivation, as in the production of mineral and organic fertilizers, etc.) [8].

CO_2 emissions from fossil fuels used in agricultural machinery operations are estimated at 0.4-0.6 Gt CO_2 eq. annually in 2010 [1]. The production of nitrogen fertilizers contributes to the release of 410 Tg CO_2 eq. per year, equivalent to 0.8% of global greenhouse gas emissions [2]. Other types of fertilizers and pesticides are considered not to have a significant contribution to increasing atmospheric CO_2.

Soil tillage is a basic practice in agricultural management. Conventional soil tillage systems include more and more tillage, including plowing with reversing the layer, which results in higher CO_2 emissions and also requires more fuel to be consumed. In contrast, soil protection technologies are based primarily on reducing impacts on soil by limiting all soil tillage activities, shallower operations, and eliminating soil inversion while maintaining and managing crop debris [6]. Also, reducing the passes of equipment across the field results in lower emissions from the use of fuels.

According to Carmo et al. (2014), the introduction of organic materials into soil increases carbon dioxide emissions, with a strong relationship between soil temperature and CO_2 emissions observed in all treatments. However, the loss of C-CO_2 from the soil amended with sludge and composted sludge, and the amount of carbon contained in these residues, conclude that more organic carbon is left in the soil [5].

Organic farming tend to have higher CO_2 emissions and lower N_2O emissions than conventional systems. Lower N_2O emissions are likely to be related to lower nitrogen inputs, while higher CO_2 emissions could be due to more organic matter applied by organic fertilizers and due to the higher autotrophic respiration of live mulch [4].

Improved agricultural practices have great potential for increasing soil organic carbon and for reducing carbon dioxide and other greenhouse gas emissions. On the other hand, agricultural production systems, which involve intensive cultivation, lead to soil degradation and erosion, which negatively affects soil quality and has a major impact on climate change.

The average altitude of the territory of Bulgaria is 470 m. The erosion assessment of the relief of the country shows that 16% of the total territory is inclined from 0 to 3 °, while more than half (55.3%) are inclined from 3 to 12 °, and 23.9% of the area is inclined from 12 to 18°. According to Ruseva (2010), 60.1% of the soils in our country are of medium, strong or very strong erosion susceptibility (over 0.03 ha h / ha MJ mm) [17]. On sloping terrain, the application of already established traditional (conventional) technologies does not solve the problems of degradation, and even according to Dimitrov (2008), can accelerate its appearance and development, especially if the operations are carried out along the slope [7]. For this reason, it is necessary to use appropriate soil protection technologies on sloping agricultural land sown with maize for the purpose of limiting or completely preventing degradation processes - water erosion of the soil, compaction and loss of soil organic matter. One of them is the advanced soil protection technology for minimum and unconventional tillage for growing maize on inclined terrains. It includes both combined systems for reduced tillage and erosion method of vertical (intra-ground) mulching using manure. This technology was developed and tested by the Institute of Soil Science, Agrotechnology and Plant Protection "Nikola Pushkarov" - Sofia, in cooperation with the University of Rousse "Angel Kanchev".

The purpose of the present study is to determine the impact of conventional and soil protection tillage systems using manure with surface mulching and advanced technology for minimum and unconventional soil tillage for grain maize cultivation on sloping terrain, including vertical mulching on soil CO_2 emissions.

MATERIAL AND METHODS

The experimental field 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 study was conducted 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, of medium eroded calcium chernozem with inclination of the slope of 5^o (8.7%).

A single factor field experiment with grain maize based on the block method, in four variants, in four replicates, was conducted. The variants of the experiment are:

c_0 - maize plots, grown by conventional technology, applied along the slope - control;

c_1- maize plots, grown by using conventional technology applied across the slope;

c_2 - maize plots, grown by erosion control technology, including surface mulching with manure, all operations applied across the slope;

c_3 - maize plots, grown by erosion control technology, including soil tillage without reversing the layer - loosening and soil protection operation vertical mulching with manure, forming slits with ducts, along with sowing and digging and furrowing along the hilling (advanced technology for minimum unconventional soil tillage) applied across the slope.

During the two-year study period, annually, all technological operations performed under variants c_0 and c_1 are traditional (conventional) and identical, the difference between them is only in the direction of their realization. In the control they were applied along the slope, and in variant c_1 in the transverse direction. In the same direction, the operations of variant c_2 were carried out and, prior to the pre sowing tillage, the anti-erosion method of surface mulching with manure (4500-5000 kg / ha) was carried out, using the fertilizer trailer 1PTU-6 for this purpose.

The last c_3 variant includes erosion control methods of loosening, such as basic tillage, vertical mulching with manure, forming slits with ducts, along with sowing and digging, and furrowing along the hilling. Loosening in this case replaces the plowing with the reversal of the soil layer. It is carried out, across the slope, at a depth of 0.40 m, with cultivator CP – 9, aggregated with tractors with a nominal power of 120 to 150 kW. Vertical mulching is also carried out across the slope, before sowing with a specialized device for incorporation of organic matter into the soil, by a band scheme (with interval between the slits of 0.60 m and the interval between bands 3 m in the field), at a depth of 0.40 m. In these operations were used specialized soil machine for incorporating organic materials, combined device mounted on the frame of the SPC-6 pneumatic seed drill and a soil cultivator KRN-4,2 and a combined tillage, for making cuttings with slits and ducts.

During the study period, climatic observations, erosion studies of the applied technologies were carried out, as well as the carbon emissions for each month during the growing season, as well as the content of labile carbon (oxidized by potassium permanganate), was determined, soil moisture of 0-10 cm and soil electrical conductivity.

RESULTS AND DISCUSSION

Data on fig.1 shows the average day-and-night temperatures as well as the sum of the precipitation for ten days periods. Precipitation in the area is unevenly distributed throughout the year. The highest rainfalls in 2018 yr. has fallen in the warm months - June and July, and in 2019 yr. the precipitation peak is in April, May and June. In 2018 yr. there is very low rainfall in April and August, and in 2019 yr. - August and September.

Figure 1 shows the average day-and-night temperatures. There is a slightly cooler April in 2019, associated with more heavy rainfall in the second ten days of the month.

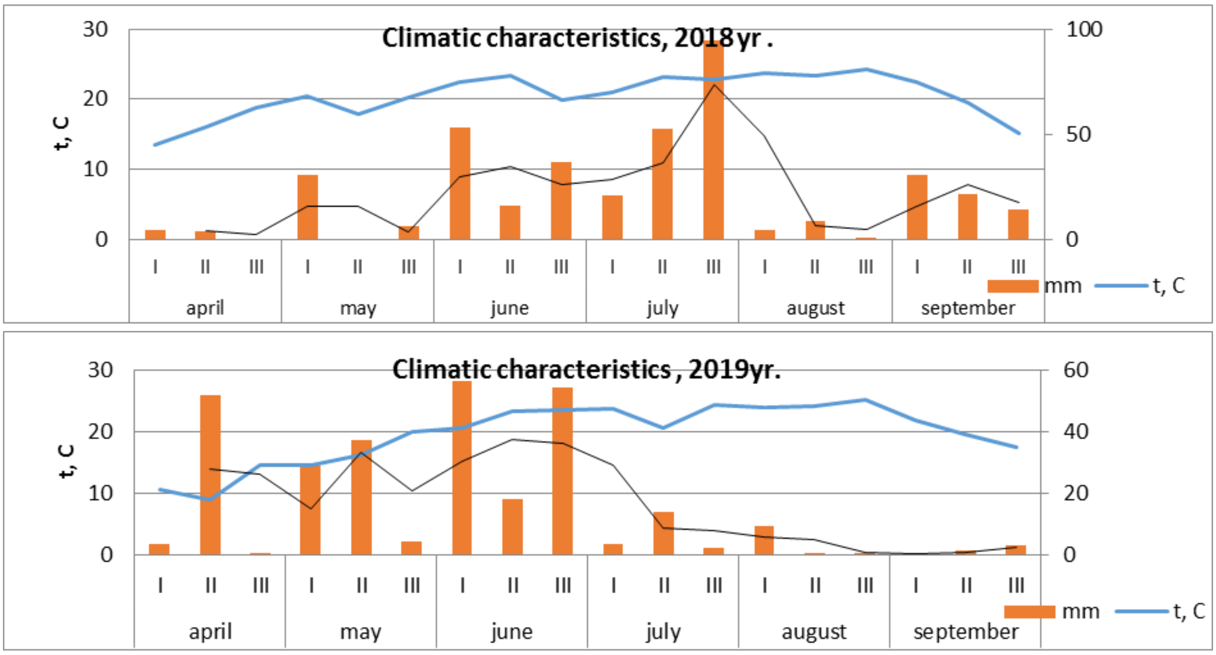
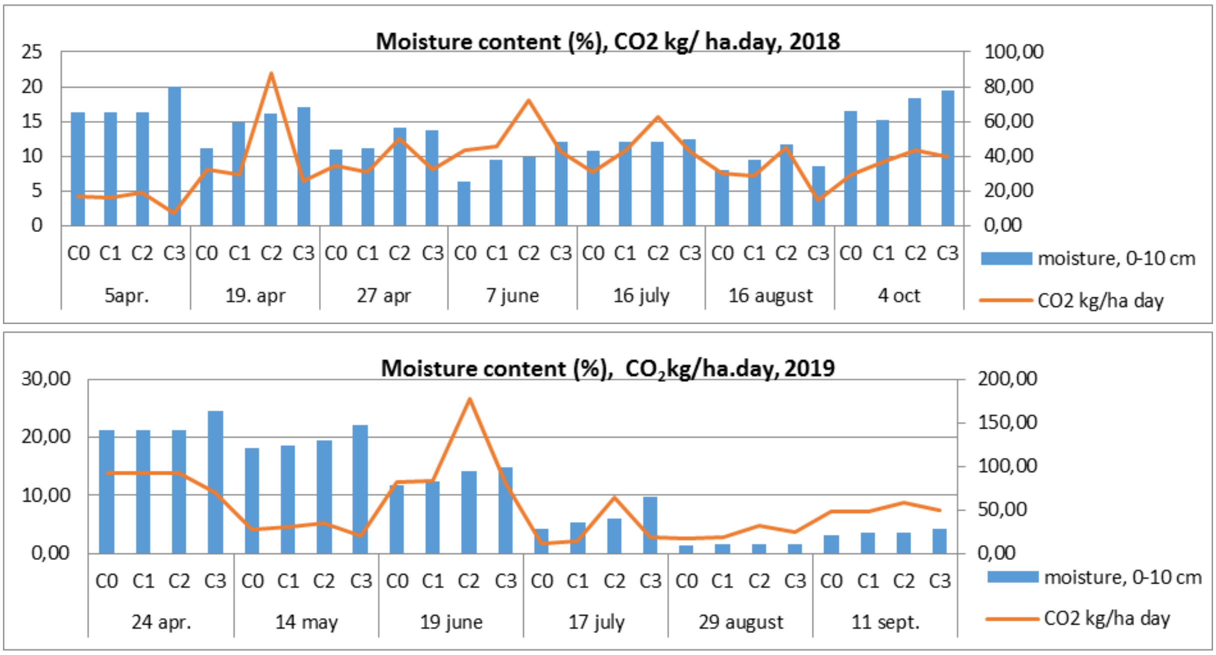


Fig. 1 Climatic characteristics of the two-year study period (2018 - 2019)

Figure 2 shows soil surface moisture and CO_2 emissions (kg/ ha day). Figures 1 and 2 show that temperature and rainfall have a combined effect on carbon emissions. They in April 2018 yr. are lower than those in April 2019 yr. due to lower rainfall and cooler March' 2018. At the end of April and May 2019 yr. it can be seen lower temperatures compared to the same period in 2018 yr., which has led to lower CO_2 emissions. In both years, the drought in August is observed, that in 2019 yr. was particularly severe and combined with high temperatures. In both years, this has led to low CO_2 emissions in August. Low temperatures, high humidity, and high temperatures combined with low humidity suppress soil respiration. Another reason for the different peaks in carbon fluxes is the systems of tillage and the organic substances applied.

In September 2019 yr. after a prolonged period of soil drying, low rainfall in September leads to enhanced mineralization of organic matter with higher CO_2 emissions, known as the Birch effect [3,11]. Precipitation after prolonged dry periods causes the Birch pulsating effect. Emissions increase within minutes or hours after the onset of rainfall and return to background levels within a few days [14].



ANOVA NS (CO_2); moisture p=0,3137
ANOVA NS (CO_2); moisture NS

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

The direct relationship between soil moisture and carbon emissions is not observed, as can be seen from Figure 2. Only the difference in humidity does not cause a change in the intensity of soil respiration. Soil moisture combined with other factors causes such changes.

The intensity of soil respiration depends on applied system for soil tillage. At the beginning of the growing period, before sowing, higher CO_2 emissions were measured in conventionally tilled variants. Total for the season, in variant with surface manure application, emissions are the highest. In contrast, the organic matter incorporated by vertical mulching, combined with minimum tillage, results in lower carbon dioxide emissions.

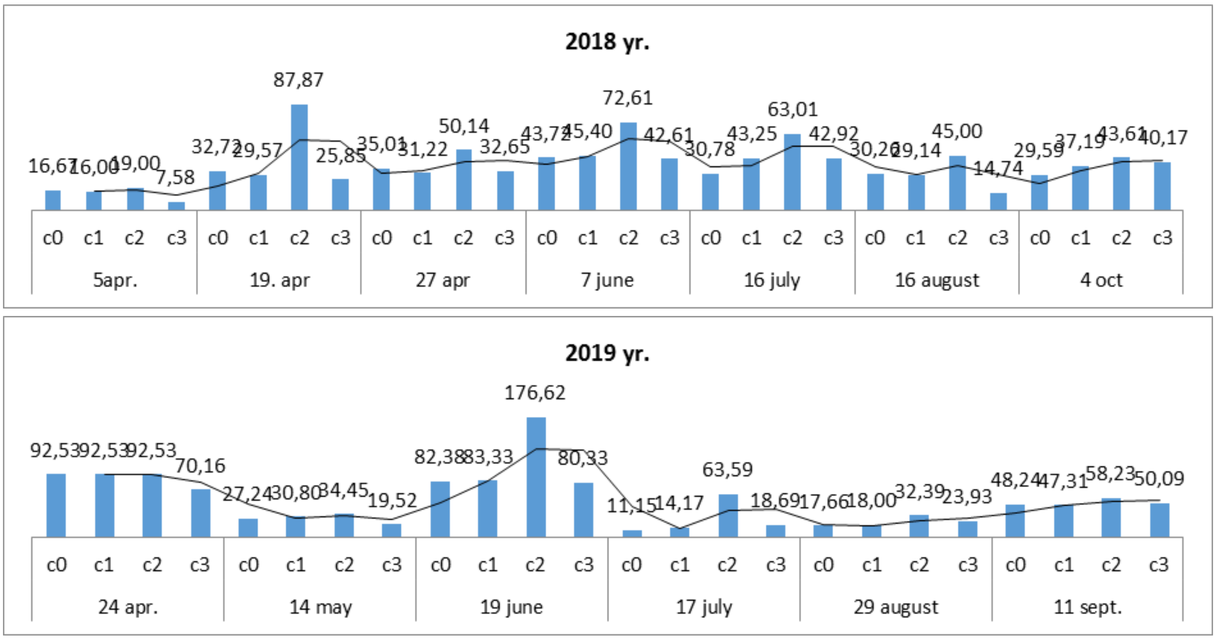
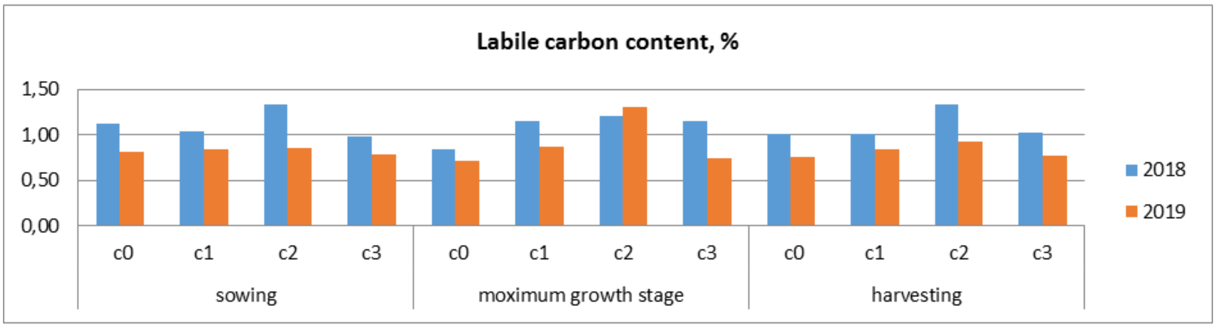


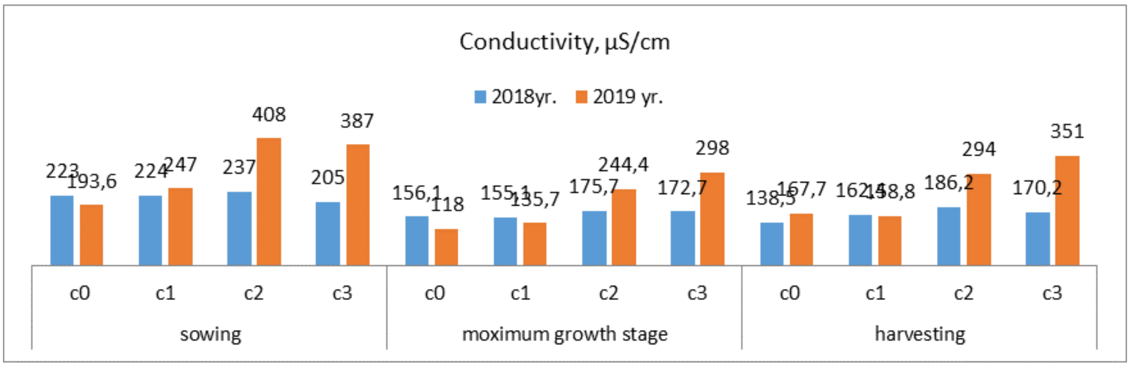
Fig. 3 CO_2 emissions, kg / ha day

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 amounts of labile carbon and electrical conductivity for variants with surface application of the manure and for minimum tillage with vertical mulching. Higher amounts of nutrients are available in the presence of high EC values. Consequently, nutrient content in soil, as with the application of manure or mineral fertilizers, plays an important role in the formation of carbon emissions.



ANOVA; P=0.037793 HSD[.05]=0.27; HSD[.01]=0.35

Fig. 4 Labile carbon content, mg/g



ANOVA; P= 0.046323; HSD[.05]=113.3; HSD[.01]=143.58

Fig. 5 Conductivity, µS / cm ,%

The CO_2 emissions of c_2 variants with application of conventional tillage and surface mulching are the highest. Accordingly, in this variant, the highest levels of labile organic matter are also observed. When applying surface mulching in 2018 yr., CO_2 emissions are 54.46 kg/ha day in 2019 yr. - 76,30 kg/ha day. Emissions of the last variant c_3, with the application of minimum tillage and vertical mulching, are significantly lower, and in 2018 yr. and 2019 yr. respectively the average are 29,50 kg/ha day and 43,79 kg/ha day, whereas in the case of conventional tillage applied along the slope, they are 33.11 kg/ha day and 47.69 kg/ha day, which also shows the impact of minimum tillage on soil emissions, and is an organic substance incorporated. The effect is stronger at the beginning of the growing season and the differences in emissions there are much higher. The carbon dioxide emissions of the control variant conventionally grown along the slope are 31.25 kg/ha day and 46.53 kg/ha day.

CONCLUSION

− Soil CO_2 emissions depend on a number of factors; temperature, humidity, soil cultivation, application of organic amendments, nutrient content.

− The highest CO_2 emission values as well as the highest quantities of labile carbon are observed in the variant grown with soil protection technology with surface application of manure. The application of organic fertilizers inevitably leads to an increase in labile organic carbon as well as higher carbon dioxide emissions.

− Carbon dioxide emissions are lower for the minimum tillage in combination with vertical mulching, and they are 43.95% lower than the surface mulching variant, which means that much more the imported organic material remains in the soil. The carbon emissions of this variant are on average 9.28 % lower than the variant using conventional tillage system applied across the slope.

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

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