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Original Article

# Effect of Tillage Practices on the Moisture, Temperature and Soil Carbon Dioxide Flux

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**Abstract**

The emissions of $CO_2$ gas at the surface of soil is known to be called soil breathing process. Once with the fast developement of industry, agriculture, forestry and other fields, the issue of climate change started to gain weight. The increasing level of $CO_2$ greenhouse gas emissions becomes the main concern. The purpose of this research is to observe the impact of tillage machinery system on gas emissions and also to study the dynamics of moisture and temperature in soil's upper layer. Similar studies revealed that the $CO_2$ flux is lower in soils with no-tillage system compared to soils that have faced minimum tillage. The experimental studies of argic-stagnic faeoziom were carried out at the Experimental Station Jucu of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. In our case the emissions of $CO_2$ in minimum tillage soils was almost 2 times higher than the emissions from direct drilling soils. These emissions are closely related to temperature, increasing and decreasing one linked to the other. $CO_2$ flux is also closely related to humidity. It is easily to observe that the greenhouse emission lowers when soil humidity exceedes normal values and encreases when soil humidity stabilizes.

***Keywords:*** soil tillage systems, $CO_2$ flux, soil temperature, soil moisture.

## 1.Introduction

Once with the fast development of industry, agriculture, forestry and other fields the issue of climate change starts to be more and more discussed. One of the most important factors that affect climate change is $CO_2$ greenhouse gas emission. In agriculture, soil and biological processes related to humification – mineralization is an important source of $CO_2$ emissions into the environment.

The main objective of this research is to determine the impact of different tillage machinery systems on $CO_2$ emissions from soil related to the dynamics of temperature and humidity in the upper layer of the soil during the growing season of plants.

The release of carbon dioxide at the surface of soil is known as soil breathing process. Carbon dioxide comes from multiple sources such as: soil aerobic microbial decomposition of organic matter, the breathing of fauna and plant roots, and dissolution of carbonates in soil's solution. Plant roots absorb oxygen and release carbon dioxide, a fact that (in a closed system) would lead to a dramatic increase of carbon dioxide and lack of oxygen. Gas exchange between soil and atmosphere is provided by the aeration process and this process is possible due to the soil's porous background. Atmospheric oxygen permeates the soil and soil carbon dioxide is emitted into the atmosphere and the oxygen flux magnitude is dependent on soil texture and structure and degree of pore filling with water [13].

Temperature influences almost every aspect of respiratory processes, therefore it is crucial that we

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take it into consideration. It is well known that a large number of enzymes are involved in these processes, and their biological activity is influenced by temperature. It is generally accepted that respiration increases with temperature, reaching its upper values at 45 - 50°C. Low soil-surface temperatures due to accumulation of crop residues [3, 4, 5] can adversely affect emergence and seedling growth under no-tillage in mid-latitudes [9].

Humidity is another crucial factor that influences soil breathing process. Studies in this area have shown that $CO_2$ flow is reduced during drought conditions, (because in extreme drought conditions soil microorganisms enter the state of latency, fact that lowers metabolic activity and soil breathing), reaches its maximum at average values of moisture and lowers at high values of moisture, when anaerobic conditions occur [5].

Soil water content is affected by tillage because of changes produced in infiltration, surface runoff, and evaporation [14, 17]. The increase in soil water storage under conservation tillage can be attributed to reduced evaporation, greater infiltration, and soil protection from rainfall impact [15].

Reicosky and Lindstrom, 1993 [11], Prior, 2000 [10] have shown that plowing causes a high flow, short-term carbon dioxide from soil due to the rapid physical release of this gas. In 1998, Dao [3] compared moldboard plowing to no-tillage system for $CO_2$ flux over a period of two months in a wheat crop and discovered that this flux is way much higher in moldboard plowing soil than it is in no tilled soil.

Soil respiration leads to $CO_2$ emissions from soil to the atmosphere, in significant amounts for the global carbon cycle [8]. Soil respiration is one measure of biological activity and decomposition [6]. Soil capacity to produce $CO_2$ varies depending on soil, season, intensity and quality of agrotechnical tillage, soil water, cultivated plant, fertilizer, etc. Buragiene et al., 2011 [2] found that after the autumn tillage the highest (551 ppm) average $CO_2$ gas emission was in deeply ploughed fields, and the lowest (330 ppm) one was in no-tilled plots.

Before the spring tillage studies showed that the highest (1055 ppm) average $CO_2$ gas emission was in plots subjected to shallow ploughing, while the lowest one (854 ppm) was observed in no-tilled plots.

## 2. Material and Method

The data presented in this paper were obtained on Argic-Stagnic Faeoziom [16], at University of Agricultural Sciences and Veterinary Medicine in Cluj-Napoca, within the Research Center for Minimal Systems and Sustainable Agricultural Technologies.

The field is a class II quality type, having 78 points for arable use. The soil profile is of type: Amp – Am – A/Btw – Btw – B/C – Cca. The clay content on 0-40 cm depth varies between 42.1 and 45.7%. On 0-20 cm depth, soil has a reaction at the limit neutral - weak acid, with a value of 6.02. The presence of carbonates in the next horizon, the 120-210 cm depth determines an increase of pH value to 7.88.

The base saturation degree of 75% frames this soil type in the eumezobasic soils. As for the humus content, the soil is appreciated as good, namely 4.33% in the first 20 cm and 3.27% in the 20-40 cm depth. The field is with 8% slope, with the ground water level at 10 m depth.

These areas were was our research presents a medium multi annual temperature of $8.2^0$C medium of multi annual rain drowns: 613 mm. The experimental variants chosen were: A. Conventional system (CS): $V_1$ – reversible plough (22-25 cm) + rotary grape (8-10 cm); B. Minimum tillage system (MT): $V_2$ – paraplow (18-22 cm) + rotary grape (8-10 cm); $V_3$ – no-tillage (NT).

The experimental design was a split-plot design with three replications. In one variant the area of a plot was 300 $m^2$. The experimental variants were studied in the 3 years crop rotation: maize - soybean – autumn wheat. The analysis and determinations were done according to acting methodology and standards [7, 16]. Determinations were performed in maize crop. The biological material was represented by the LG32 – hybrid maize. In order to obtain data, in each variant was placed a continuous monitoring of soil respiration dynamics system, which recorded data at the depths of 7 cm and 22 cm.

Each depts were provided with four sensors that gathered data concerning $CO_2$ flux, temperature and humidity. The continuous monitoring system is the one described by Turcu in 2007 [12].

This is possibile by using a new generation of $CO_2$ sensors that are capable of measuring in-situ and quasi-instantaneous the concentration of carbon dioxide. Vaisala GMD20 sensors (fig. 1) produced by Finnish company Vaisala were used.

Humidity was determined by measuring the dielectric characteristics of soil.

Strongly influenced by water content, they generate an electrical signal proportional to this water content. EC-5 sensors (fig. 2) produced by the American company Decagon were used. Soil temperature measurement was done by installing temperature sensors, based on the junction of two metals with different properties (nickel-constantan termocouple). ECT sensor was used (fig. 3).




**Figure 1.** Vaisala GMD20 sensor (www.vaisala.com)




**Figure 2**. EC-5 sensor (www.decagon.com)



**Figure 3**. ECT sensor (www.decagon.com)

The sensors are connected to Data Loggers and using specific software program installed on a computer, it is possible to choose various settings such as the number of readings per day.

For $CO_2$ we used Hobo Data Loggers (fig.4) and for temperature and humidity we used Decagon Data Loggers (fig. 5).

Data recording in this period were then stored on a computer and processed with specific programs.

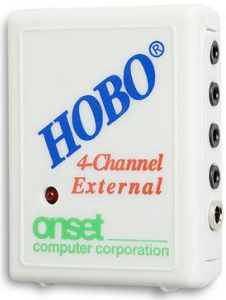



**Figure 4**. Hobo D.L. (www.onsetcomp.com)




**Figure 5**. Decagon D.L. (www.decagon.com)

## 3. Results and Discussions

$CO_2$ greenhouse gas emissions in May 2011 (fig. 6) from minimum tillage (MT) variants were higher then $CO_2$ greenhouse gas emission from no-tilled (NT) variants. The lowest daily average in MT was 1929 ppm and the highest was 8901 ppm. In NT variant the lowest daily average was 1443 ppm and the highest was 4880 ppm.

Fig. 7 shows the evolution of temperature in May 2011. Comparing the evolution of $CO_2$ flux with

the temperature rates it can easily be said that the carbon dioxide emission encreases with temperature, mentioning that in NT this encrease in not so strong as it is in MT.

In the end of the mounth, in MT the flux of $CO_2$ is almost 4 times higher then it is at the begining of the mounth, while in NT the flux of $CO_2$ is only 2 times higher at the end of the mounth then it is at the begining of the mounth. Also, with increasing daily temperature, $CO_2$ flux at the end of the mount gets to be 2 times higher in MT than NT.

Fig. 8 shows the dinamics of soil moisture in May 2011 in MT and NT. Mentioning that in this case the Argic-Stagnic Faeoziom has a 23.91% field capacity it can be seen that at the begining of the mounth when moisture in MT and NT exceeds the optimum, $CO_2$ emission remain at a lower level and when moisture is at field capacity, the carbon dioxide emission encreases. Fig. 9 shows the dinamics of moisture at the depth of 7 cm in CS, MT and NT. The highest moisture volume was in NT and the lowest in CS.

Average temperature was the highest in MT and the lowest in CS (fig. 10).

## 4. Conclusions

In minimum tilled variant the $CO_2$ emission is almost 2 times higher than in no-tilled variant. The greenhouse gas emission encreses with temperature, mantioning that in NT variant this encrease is not so strong that it is in MT variant.

Moisture affects soil breathing process so that $CO_2$ emission encreases at optimal moisture conditions and lowers when moisture exceeds optimal conditions.

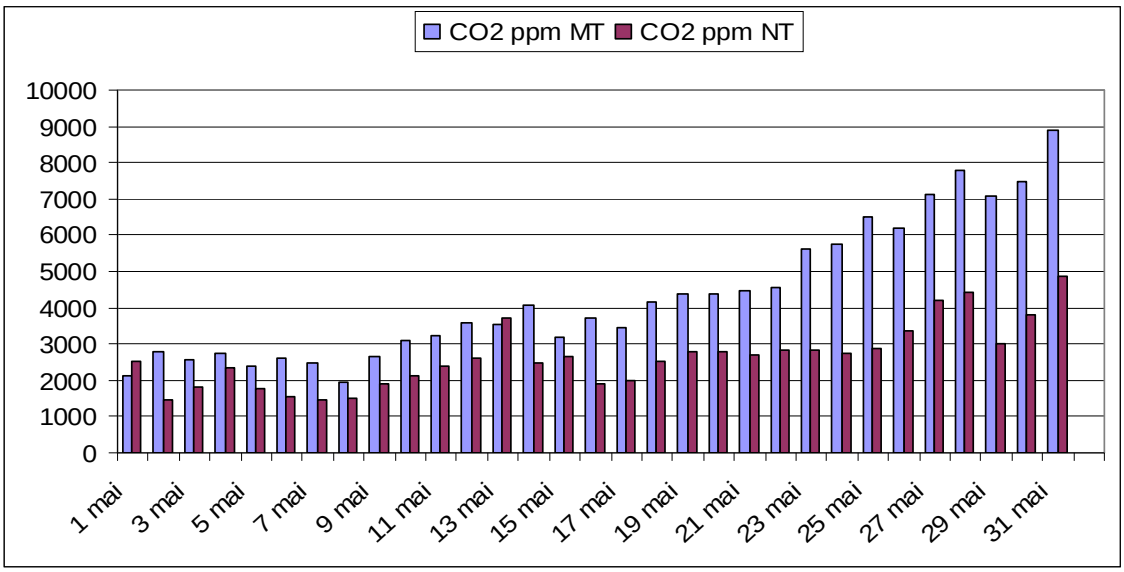



**Figure 6.** $CO_2$ emission in May 2011 (depth - 7cm)

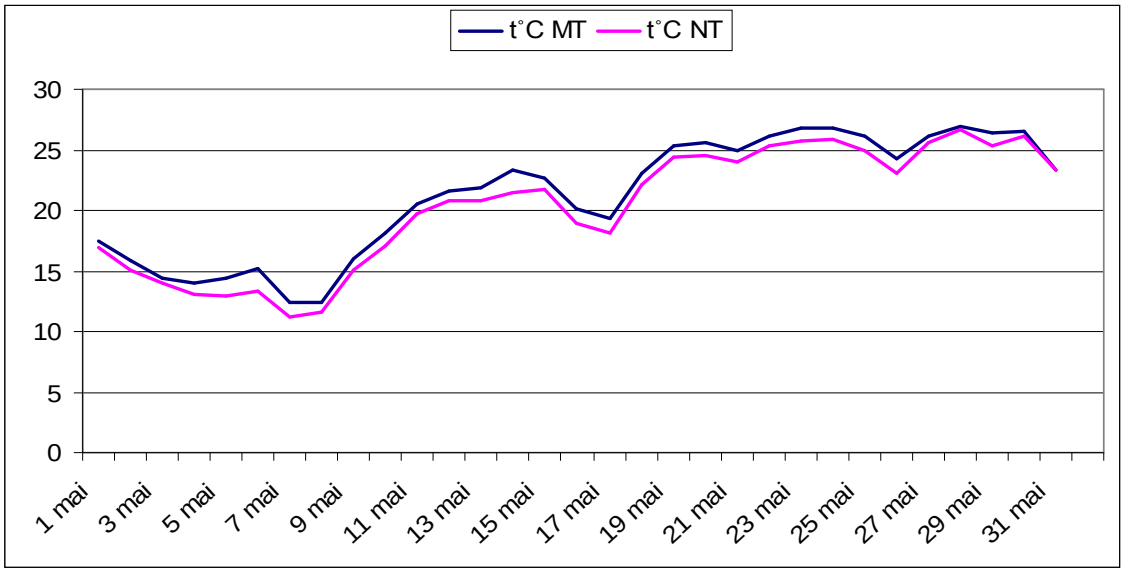



**Figure 7.** Dinamics of temperature ($t^0C$) in May 2011 (depth - 7cm)

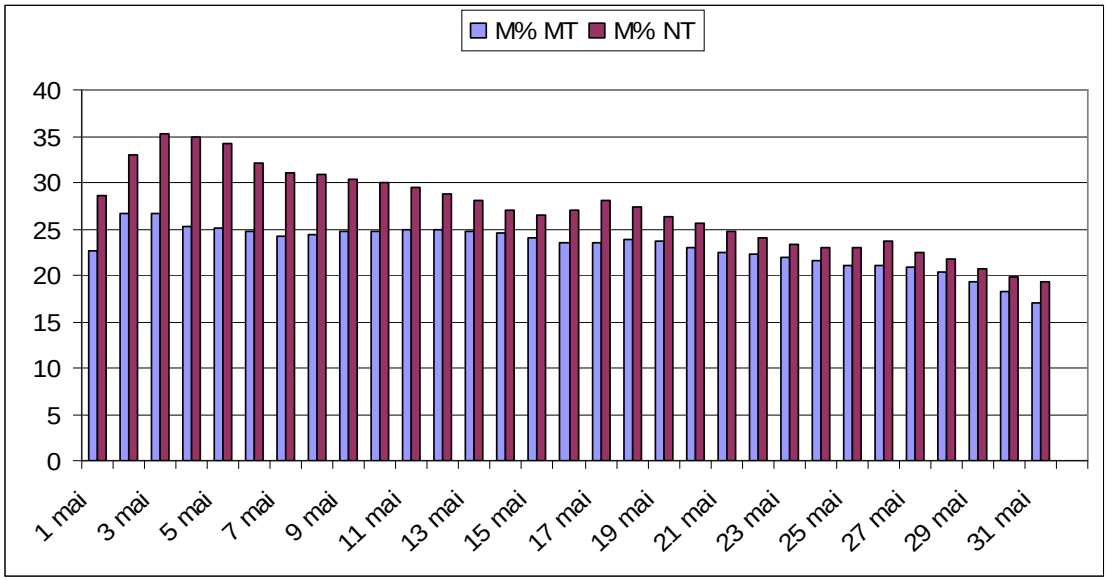



**Figure 8.** Dinamics of moisture (M%) in May 2011 (depth - 7cm)

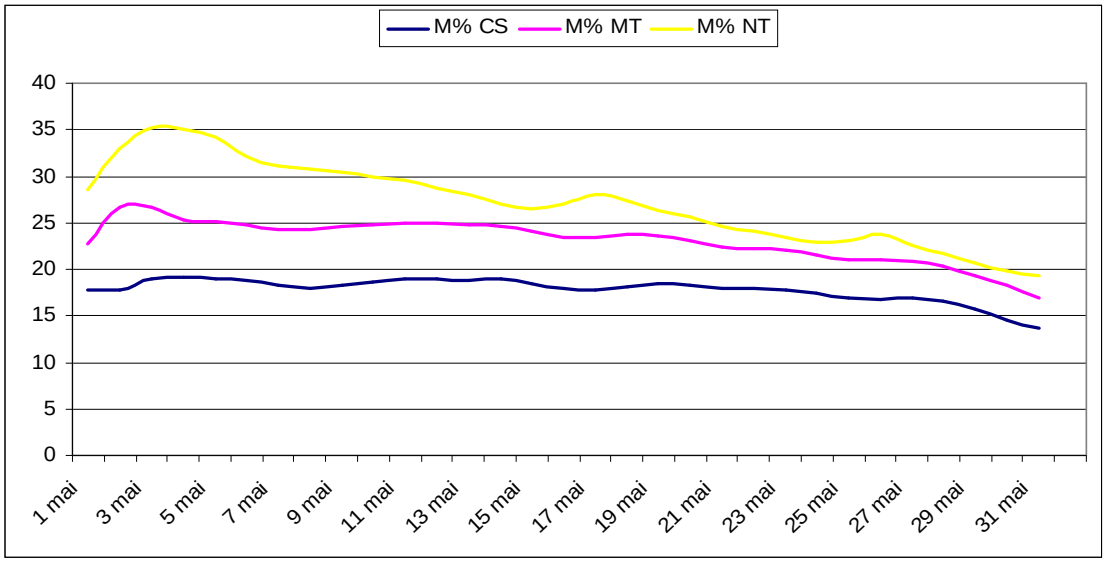



**Figure 9**. Dinamics of moisture (M%) in CS, MT and NT

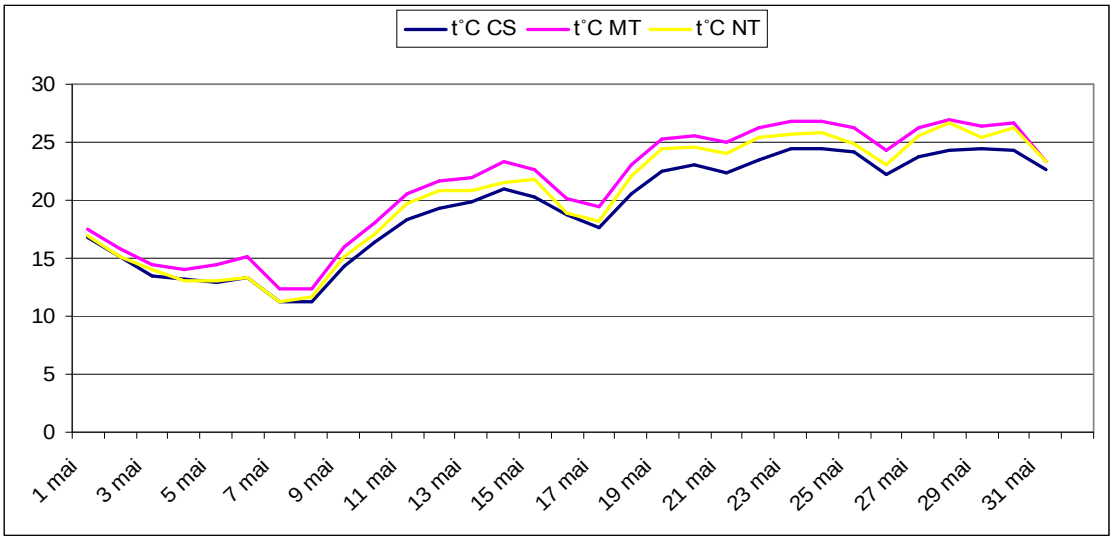



**Figure 10.** Dinamics of temperature ($t^0C$) in CS, MT and NT

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