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Evaluation of annual carbon losses due to "soil respiration"

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Abstract

Currently, the annual increase of CO_2 in the atmosphere is 1,5 ppmv. Carbon emission in the atmosphere is 50% of the greenhouse effect compared to other gases. The additional inflow of carbon dioxide in the atmosphere greatly depends on the intensity of agricultural land use. Quantitative estimation of the impact of these factors makes it possible to anticipate and adjust the intensity of CO_2 emissions from the soil. Therefore, research in this area acquire a special significance due to global climate change. Minor changes in soil carbon content can have a huge impact on the concentration of CO_2 in the atmosphere. For reduction of greenhouse gas emissions and climate change mitigation the carbon sequestration in soil is one of the best options. By the sustainable use the soils have potential for significant sequestration of carbon. The paper presents the modern methods of monitoring the emission fluxes of carbon from the soil using a portable gas analyzer and calculation of the direct loss of carbon from the soil through soil respiration.

Scientific novelty is in the fact that it is expanded the scientific knowledge on the laws of the dynamics of CO_2 emission flow from chernozems under the influence of agricultural use with the background of seasonal fluctuations of hydrothermal conditions; it is defined emission volume of carbon by chernozems typical and podzolic of Left-bank Forest-Steppe of Ukraine during the growing season and developed predictive models of carbon losses at the expense respiration under different weather and climatic scenarios. The results can be used to improve methods of monitoring emissions of CO_2 from soils on agricultural lands, gradual transition of cadastral evaluation of greenhouse gas emissions on the quantitative and monitoring basis, for constructing mathematical models of forecasting changes in the production of carbon dioxide from the soil under different weather and climatic scenarios and for predicting the impact of new agricultural technologies in carbon balance in the context of sustainable use of soil.

Keywords: soil respiration, loss of soil carbon, method of cultivation, mathematical model

Introduction, scope and main objectives

Soil organic matter is the repository of the largest inventories (1,395.3 Gt) of carbon in terrestrial ecosystems. Thus, the soil cover with its gas function (relative to carbon) performs a critical role in the biosphere support for modern optimal climate. According to various scholars the total annual CO_2 flux from soil surface ecosystems of our planet is estimated at 50 - 77 Gt per year. By increasing soil organic matter in the soil, you can get a higher level of carbon stock (carbon balance). We know that carbon dioxide of atmosphere for about 90% of a soil origin. Since the flow of CO_2 arriving the atmosphere, its emission from the surface of the soil is one of the largest sources of carbon dioxide, minor violations soil respiration on a global scale could lead to serious changes in the concentration of CO_2 in the atmosphere.

According to long-term estimations, the amount of soil carbon that is released around the world in the last century due to adopted agricultural technologies is (136 ± 55) pg (billion tonnes) of carbon. That's about half of all emissions from fossil fuels - (270 ± 30) pg, and cultivation gives carbon emissions at a rate of (78 ± 12) pg and soil erosion - (26 ± 9) pg also it is estimated that in the soil at the expense flora, fauna and terrestrial ecosystems can keep 3 GHG emissions per year (1.41 parts per million of atmospheric carbon dioxide) [Information of Research Institute of Organic Agriculture (FiBL).].

The key factors that determine the level of content of organic carbon in the soil, is the amount of organic residues after harvesting, soil type and its moisture content and methods of cultivation. Optimal conditions for the accumulation of carbon in the soil are a high amount of biomass both ground parts and roots laid in moist soil, where aeration is not limited [Malhanova E.V., 2007]. Thus, the calculation of loss of soil carbon - is a common question that still does not have a single solution.

The objective of our work was to calculate the total emission volume of carbon losses from soil during the growing season in options of different cultivation ways based on observations of the dynamics of soil respiration intensity during the growing season and to build a mathematical model depending CO_2 emissions from hydrothermal conditions of the year.

Methodology

Research was carried out during 2011-2015 on the chernozems of Left-bank Forest-Steppe of Ukraine. To address the problems in the work there were used methods of instrumental monitoring and statistical and mathematical research. Monitoring the CO_2 emissions from soil was carried out in the field (once a month during the growing season) with simultaneous control of moisture and temperature of the soil.
Instrumental control of carbon dioxide intensity from the soil surface was carried out using a portable gas analyzer «testo 535» from the isolation of the air. The measurements were performed 3-5 times a day with subsequent statistical processing and averaging the results.
The results were proceeded by methods of mathematical statistics using the program Statistica.

Results

Conducted observations show a significant difference between the intensity of soil respiration by systematic plowing and other cultivation methods. In our opinion, this is due to the differences in compaction of the soil, and also indicators of temperature and humidity. This is confirmed by the fact that CO_2 emissions from the soil surface has quite clear daily and seasonal dynamics. According to the results, in the summer can be abrupt (4-5 times) increase in carbon dioxide emissions after rainy periods due to high soil moisture and temperature.
Research by Hu Lifeng has shown even greater difference between different types of soil tillage can be expected in the first 5 days after the conducting, especially on surfaces covered with plant remains [Hu Lifeng et al, 2008]. Concomitant monitoring moisture and soil temperature changes also give an explanation of the difference between the respiration, because in November by direct sowing temperature and soil moisture is higher, which has a positive impact on microbial activity.
Obtained during the vegetation period 2011-2015 data show a significant difference between the intensity of soil respiration in different periods of the year. Adjacent monitoring the temperature and humidity of the soil showed that the latast one is the determining factor an abrupt increased respiration of the soil after heavy rains. After that soil moisture reduced, and by the greatest extent - by plowing and surface tillage and by zero tillage was at the highest.
With the help of the data of intensity of respiration we can calculate the value of the loss of soil carbon. We used the method of mathematical calculations, based on the difference between the average height indicator intensity of soil respiration.
Вирахувавши середню висоту показника дихання між місяцями дослідження (травень-вересень) отримали кількість діоксиду вуглецю, що викидається ґрунтом у атмосферу за вегетаційний період року. Потім, обрахувавши пропорційну частину вуглецю у газі, отримали приблизні втрати вуглецю з ґрунту за рахунок дихання за різних способів обробітку (табл. 1).
We calculated the average height of respiration indicator among monthes of the research (May-September), received the amount of carbon dioxide, emitted into the atmosphere by the soil during the growing season. Then, we calculated proportionate part of carbon in gas , we obtained soil carbon loss from soil due to respiration at different ways of tillage (Table. 1).

Options of experiment	Average loss of carbon from soil during the growing season 2011-2015, kg / ha
Plowing	577
Disk plowing	560
Cultivation	578
Direct seeding	613

Table 1: [Loss of carbon from chernozem typical by different ways of tillage during the growing season]

Observations and calculations show that the most significant is the loss of carbon by using direct seeding, ie without basic tillage. Since the experiment studied only direct seeding as a separate component of technology no-till, because of a lack of mulch on the surface layer the moisture and temperature of soil was different from versions of plowing and cultivation surface. At the same time, by the direct seeding all plant residues remain on the surface, their humification is minimal, which causes greater losses of carbon [Siabruk O.P., 2013].

Among general recommendations to eliminate a possible threat of extreme climate change there are indicated preventive measures of scientific nature: to improve models of predictions of climate, assemble into a comprehensive system the models of predictions of environmental, economic, social and political consequences of climate change, to develop methodology for assessing the vulnerability of the country related to possible climatic changes, and so on. In order to predict climate changes, scientists rely on very complex mathematical models. Models are built on the basis of what has been observed in previous years, and the understanding of the relationship of natural processes occurring on the surface of our planet.

Given that the most relationships in the soil as inert system have nonlinear character, for mathematical modeling in the first approximation quadratic model was used.

Summary of research 2011-2015 as a graphical model is shown in Fig. 1. According to a graph, the sampling of experimental values characterized by a gradual increase of carbon dioxide with increasing temperature at low humidity and significant strengthening of the process in moist soil.

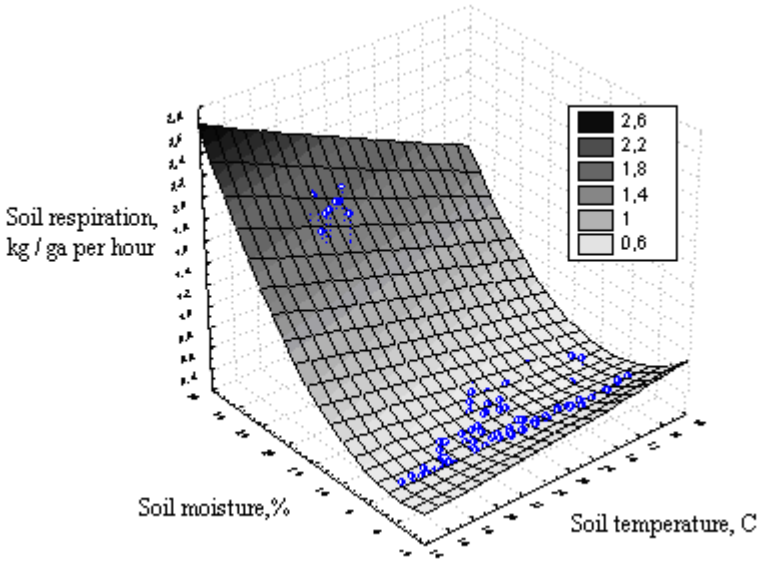

Fig. 1: [Dependence of intensity of CO_2 allocation from the soil on hydrothermal conditions on stationary experiment with soil cultivation]

The equation of this dependence has the form:

$$z = 0,47-0,0048x+0,023y+0,0002x^2-0,0016xy+0,0018y^{2,}$$

where z – intensity of CO_2 emissions from the soil surface, kg / ha per hour;
x – soil temperature, ^oC;
y – soil moisture, %.

Discussion

The foregoing interpretation coincides with the observations of many scientists for changes of humus soil state in the early stages of implementation of no- till technology. In particular, A.D. Balayev with colleagues [Balayev A.D. 2004], believes that systematic use of no- till with the addition of fresh organic matter on the soil surface will not promote its humification and therefore not form enough humic substances. There were no positive changes of humus state under the influence of no- till on chernozem ordinary of Askaniya Research Station of the Institute of irrigated agriculture [Voloshenyuk A.V., Chorniy S.G., 2014], although the intensity of the allocation of CO_2 was higher than traditional cultivation.

It was developed a mathematical model can still be improved and supplemented with new data, but in general can be used to predict the volume of CO_2 emissions from automorphic chernozem under different scenarios of weather and climate warm period. Additionally, it is advisable to introduce an amendment to influence methods of management.

Conclusions

1. It is proved that by the total amount of CO_2 emissions from chernozem typical direct seeding technology prevails over methods studied basic soil processing (loss of carbon from 525 to 701 kg / ha per year), it is due to higher weediness of crops, better water regime and a total mineralization of plant residues on the soil surface. By disking soil in 10-12 cm annual losses of carbon smallest (497-622 kg / ha). At the same time, systematic plowing over 6 years has led to a reduction of labile organic matter and fulvic acid and reduce potential production capacity for CO_2 in the upper soil surface compared with cultivation and direct seeding technology.
2. Since the method of calculating the balance of carbon in crop rotations does not take into account such factors as the peculiarities of water and temperature conditions of the soil, which significantly affect the processes of mineralization and humification of organic matter, it is proposed to estimation of carbon losses from the soil through periodic observations of the release of CO_2 from the soil and generalization of the results in the annual cycle.
3. There are developed mathematical models of depending on the intensity of emissions from hydrothermal conditions. This allows predicting the volume of CO_2 emissions from automorphic chernozem under different scenarios of weather and climate warm period from generalizing models with the introduction of amendments to the method of soil cultivation, fertilization system and culture, etc.