Dynamics of CO2 emission when introducing fallow lands into circulation

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Abstract. The results of CO2 flows variability from fallow land soils, when they are introduced into circulation in the Western Siberia steppe are described in the present paper. The purpose of the research consists in studying the dynamics of CO2 emission by meadow-chernozem solodized fallow solonetzes when they are introduced into circulation with the use of various technologies. The research was carried out in Tarsky district of the Omsk region in 2023. The soil type: meadow-chernozem solodized solonetz (medium, low-sodium, columnar); slightly loamy and medium-degree loamy in terms of granulometric composition; and low-sodium content in terms of exchangeable-sodium content (7-15.5% of cation-exchange capacity (CEC)). Solonetz is an alkali soil characterized by low degree of soda-sulfate salini-zation. Based on obtained data for carbon dioxide emission from the soil of key land plots, the authors developed models of CO2 emission from soil depending on a technology used to introduce the fallow land into circulation on the solonetz. Significant correlation ($r > 0.50$) throughout a year were obtained for emission (E) by key land plots with soil temperature. Moisture content of soil exerted lesser-degree influence on emission value. Agrotechnical technology for introducing fallow lands into circulation contributed to higher CO2 emission than the combined one. Compared to the reference land plot, CO2 emission increased by 1.17 times when using agrotechnical technology and by 1.09 times when using combined technology.

1 Introduction

The problem of climate remains the most important one among the issues currently discussed in the field of global ecology. Greenhouse gases represent the primary cause of climate change on the planet. Territories occupied by reclaimed lands as well as non-functioning ones (such as fallow lands) play a prominent role in the structure of greenhouse gas emissions.

A significant portion of fallow lands is represented by solonetz soils in the steppe zone of the Omsk region. Solonetzes are characterized by predominance of sodium and magnesium cations in the composition of the absorbed bases. As a consequence, as well as due to poor physical properties and increased alkalinity, solonetzes are infertile without additional resource investments [1]. In addition, according to a large body of evidence,

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when plowing (i.e., introducing into agricultural circulation) fallow lands, carbon dioxide (CO_2) emission from soil increases [2-4].

In this regard, the issues of land resources management for the purposes of sustainable development of territories, monitoring the ecological state of soil cover and forecasting carbon dioxide emissions in the course of anthropogenic transformation of soils acquire particular importance [5, 6].

The purpose of our research consists in studying the dynamics of CO_2 emission by meadow-chernozem solodized fallow solonetzes when they are introduced into circulation with the use of various technologies.

2 Materials and methods

Research project devoted to studying various agricultural technologies for introducing fallow lands (aging within 5-10 years) into circulation was carried out on steppe soils of Cherlak district of the Omsk region.

Field experiment procedure:

1. Reference land site (fallow land).
2. Agrotechnical technology. Pre-sowing tillage of soil with a 7x2P redesigned disk tiller to a depth of 10-12 cm.
3. Combined technology. Direct sowing without pre-sowing tillage of soil.

The soil type: meadow-chernozem solodized solonetz (medium, low-sodium, columnar); slightly loamy and medium-degree loamy in terms of granulometric composition; and low-sodium content in terms of exchangeable-sodium content (7-15.5% of cation-exchange capacity (CEC)). Solonetz is an alkali soil characterized by low degree of soda-sulfate salinization. Aeration porosity in A_1 and B_1 horizons for the case of low field moisture is high (24-47%).

The amount of C_{org} in the 0-10 cm layer of solonetz lied within 3.8-3.9% (average value - 3.9%) and in the 10-20 cm layer - 2.5-3.3% (average value - 2.8%). The amount of C_{org} in the solonetz plowed according to technologies 1 and 2 was 25% lower as compared to its amount in the 0-10 cm layer of the fallow land. This difference in C_{org} amounts could be explained by mechanical removal of the sod layer – respectively, by a decrease in easily hydrolyzable organic matter, by processes of humus mineralization in the course of treatment and possibly by blowing away of soil.

The content of mineral nitrogen in the 0-20 cm soil layer prior to sowing was very low, while the content of mobile phosphorus was increased and that of mobile potassium was very high.

Spring wheat (first crop of crop rotation) was cultivated on experimental land plots. The first technology involved soil treatment prior to sowing, while the second one – direct sowing of spring wheat (without pre-sowing soil cultivation) using chemical herbicide treatment in the course of vegetation (combined technology).

Sowing was carried out on June 1 (Sanitary Protection Zone (SPZ) – 2.1); seeding rate - 3.5 million/ha, spring wheat variety - Uralsiberskaya. Herbicide treatment was carried out on July 5, and harvesting - on September 20.

Agricultural technology (crop production practice) was adapted to the area of research project implementation. The area of experimental land plots was 200 m^2.

Green weight of plant tops during heading and blooming stages on the fallow land plot was 0.75-2.47 (average value - 1.67 t/ha). The yield of spring wheat was taken into account in field experiments on the introduction of fallow lands into circulation. It was equal to 2.35 t/ha for agrotechnical technology and 2.14 t/ha for combined technology.

Carbon dioxide emission was determined for reference plots of fallow lands (5-10 years of age) and for plots cultivated by various technologies for introducing fallow lands into circulation on a monthly basis with a time interval of 10-15 days. Plastic devices were used as chambers – in particular, portable soil chamber consisting of a base unit (10 cm in height) and cylindrical vessel with an opening intended for soil air intake (20 cm in height and 23.5 cm in diameter) - see Figure 1.

Fig. 1. Portable soil chamber for measuring soil gas exchange.

Each field experiment was repeated three times for each technology under study. The base units of the portable soil chamber (intended for measuring CO_2) were placed into the soil to a depth of up to 3 cm prior to determining the respiration intensity. Gas samples were taken by means of an air sampler into hermetically sealed vacuumed glass vials (30 ml in volume) during 24-hour period at time intervals of 3 hours. Samples were analyzed by means of Crystal 5000.2 gas chromatograph. Soil temperature, moisture content of soil and soil properties were determined by standard methods.

3 Results

Emission of CO_2 by soil is a parameter, the value of which depends largely on soil type, meteorological conditions, seasonal and daily variability and agricultural technology (crop production practice) [5-8].

Monitoring of carbon dioxide emission from soil throughout a year for a fallow land plot when introducing fallow land into circulation using agrotechnical technology showed a significant variation in its value (see Figure 2). The highest values were observed in July (46.6 g of $CO_2/m^2 \cdot$ 24-hour period) and the lowest were observed in September (6.3 g of $CO_2/m^2 \cdot$ 24-hour period), while carbon dioxide emission from soil when introducing fallow land into circulation with the use of combined technology – 43.8 and 5.9 g of CO_2/m^2 per 24-hour period, respectively. Agrotechnical technology of introducing fallow lands into circulation contributed to a higher emission of CO_2 than the combined one. At the same time, the value of flow intensity significantly decreases by September.

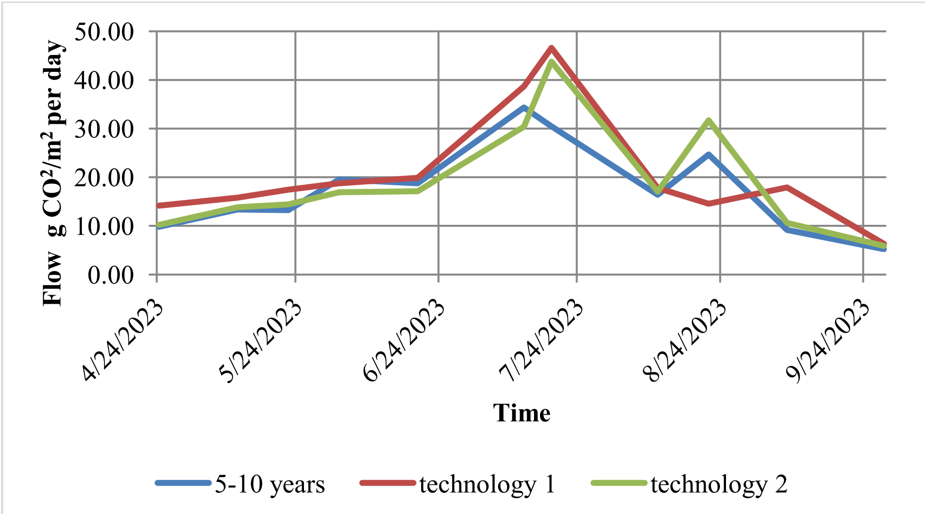

Fig. 2. Seasonal dynamics of CO_2 emission by soil of meadow-chernozem solodized solonetz type when introducing fallow land into circulation on solonetz soil (April-September, 2023).

Technologies for introducing fallow lands into circulation have a significant impact on carbon dioxide emission. Compared to the values obtained for the reference plot, carbon dioxide emission increased when using agrotechnical technology (with pre-sowing treatment) from 17.7 g CO_2/m^2 · 24-hour period for the reference plot to 20.7 g CO_2/m^2 · 24-hour period on average; and when using combined technology (with direct sowing) – to 19.3 g CO_2/m^2 · 24-hour period.

The key areas of fallow lands under study were characterized by a certain daily dynamics of carbon dioxide emission – increased level of carbon dioxide emission was observed in the morning and afternoon, while decreased level was observed in the evening and night (Figure 3).

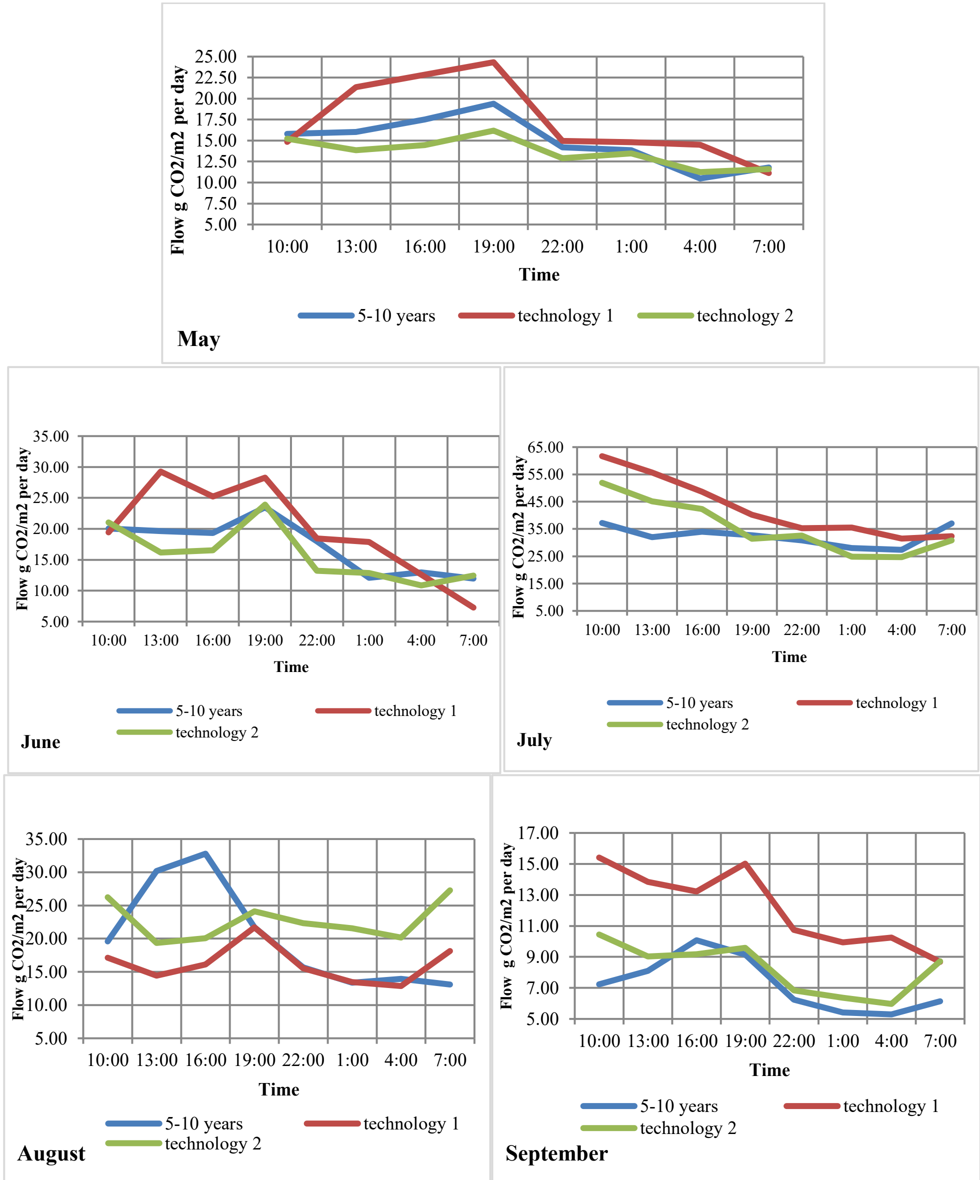

Fig. 3. Daily dynamics of CO_2 emission by soil of meadow-chernozem solodized solonetz type when introducing fallow land into circulation (May-September, 2023).

4 Conclusion

Emission intensity depends on air temperature, soil temperature and moisture content of soil [4, 9-12]. Based on obtained experimental data, the authors developed models of CO_2 emission from soil depending on a technology used to introduce the fallow land into circulation on the solonetz. The highest correlation coefficients ($r > 0.50$) throughout a year were obtained for the emission (E) by solonetzes of meadow-chernozem solodized type with their temperature. Moisture content of soil influenced emission levels to a lesser extent, and only soil temperature (ºC) at a depth of 10 cm (P) was used in regression equations as an independent variable:

1. fallow land plot 5-10 years: $E = 0.95P + 0.78$ ($r = 0.63$);
2. agrotechnical technology: $E = 1.03P + 2.66$ ($r = 0.53$);
3. combined technology: $E = 0.62P + 2.14$ ($r = 0.76$).

The technologies used to develop fallow lands have a significant impact on CO_2 emission. As compared to the reference land plot, its value increased by 1.17 times when using agrotechnical technology and by 1.09 times when using combined technology. The agrotechnical technology for introducing fallow land into circulation contributed to a greater CO_2 emission than the combined one probably due to the higher intensity of soil treatment when introducing the soil into circulation using this technology and enhanced aeration resulting in improved microbiological activity in the plowing layer.

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