Carbon dioxide emission estimation in different zones of the south of Western Siberia

Igor Bobrenko[1], *Irina* Kadermas[1*], *Elena* Bobrenko[1], *Natalia* Goman[1], and *Olga* Drofa[1]

[1]Omsk state agrarian University named After p. A. Stolypin, 644008, 1, Institute sq, Omsk, Russia

Abstract. The research was carried out in key areas of fallow land in three natural agricultural zones of the south of Western Siberia in the Omsk Oblast: steppe (Cherlaksky district, v. Preobrazhenka), forest-steppe (Kormilovsky district, v. Sosnovka), subtaiga (Tarsky district, Tara); in each zone there are three sites with fallow land of different ages: 5-10, 10-20 and 20-30 years. When comparing the intensity of carbon dioxide emission from fallow lands depending on the conditions of natural and climatic zones, it can be noted that its highest value was in the subtaiga zone (average for April-September 39.4 CO_2/m^2 per day), which is higher than the emission in the forest-steppe zone (14.7) and steppe zone (16.6). The maximum intensity of fluxes was observed in the subtaiga zone in August, and in the forest-steppe and steppe zones in July. One of the main reasons for this pattern was the air and soil temperature: the higher it is, the more intensive is the release of carbon dioxide. The influence of the age of fallow land on the level of soil carbon dioxide emission is observed. Younger fallows are characterized by a higher value of CO_2 emission compared to older ones, so in the subtaiga zone the average seasonal emission of fallows of 5-10 years is 1.51 times higher than fallows of 20-30 years, in the forest-steppe zone - 1.46 times, steppe zone - 1.48 times.

1 Introduction

The vast majority of scientists dealing with the problems of global ecology are now inclined to believe that the increase in the concentration of greenhouse gases is the main factor of climate change (warming) today and in the near future. The global balance of CO2 is determined by the volumes of its emission from natural and anthropogenic sources and runoff values. Agroecosystems, as a rule, actively emit carbon, as carbon losses in the form of CO2 exceed its fixation in soils and vegetation. While forest and fallow ecosystems are deponents, this is due to changes in the direction of fluxes of major nutrients in the atmosphere-plant-soil-atmosphere system when former arable soils are converted to fallow land [1-6]. Due to the absence of alienation of plant material in the form of crops and restoration of perennial vegetation on fallow lands, carbon accumulation occurs both in soils and in plants that develop on them [7-11].

At the same time, there is currently insufficient knowledge about the important changes to which carbon fluxes are subjected due to land-use change of arable soils [12-15]. Very

* Corresponding author: ig.kadermas@omgau.org

limited experimental data are available for most regions of the Russian Federation to determine the directionality of carbon fluxes in ecosystems and the rate of change during conversion of former arable soils to fallow land and vice versa [16-17].

In order to develop strategies and select tactics aimed at mitigating climate change, it is necessary to inventory sources, identify runoffs, and quantify carbon pools and fluxes, including in agroecosystems.

2 Research Methods

Monitoring of greenhouse gas emission on plots of different-aged fallow lands in three soil-climatic zones (April-November). For CO_2 monitoring at key plots of fallow lands, field trips to three soil-climatic zones were conducted. Research was conducted at key fallow land sites in three natural-agricultural zones of the south of Western Siberia in Omsk Oblast: steppe (Cherlaksky District, v. Preobrazhenka), forest-steppe (Kormilovsky District, v. Sosnovka), subtaiga (Tarsky District, Tara); each zone contains three sites with different-aged fallow lands: 5-10, 10-20 and 20-30 years.

Gas sampling for CO_2 content in the chambers was carried out with an air sampler for the soil chamber in hermetically sealed vacuumized glass vials (volume 30 ml) during the day (24 hours) at intervals of three hours. Gas samples were analyzed using a gas chromatograph Crystal. 5000-2 using PorapackQ-filled columns.

At the sites selected for studying CO_2 emissions, soil temperature, soil moisture (every 10 cm to 50 cm), and air temperature were determined in parallel with gas sampling throughout the measurement period). Soil temperature was determined using soil thermometers, soil moisture was measured by weight method, and macronutrient content was determined using standard methods corresponding to the soil type. Statistical analysis and modeling of carbon dioxide emission for conditions of different natural-climatic zones were carried out.

3 Results

It is established that the soil cover in the subtaiga zone (Tarsky district) is represented by gray forest thick and medium thick soils with Corg content in A1 and A1A2 horizons of 2.1-2.55%. Differences in properties of gray forest soils on fallows of different ages were revealed. On fallows of 20-30 years the soil is light loamy (physical clay 66.1%) with insignificant value of hydrolytic acidity (0.89 mmol/100 g), on fallows of less than 10 and 10-20 years the soil is light loamy (physical clay 21.8-28.1%) with more pronounced acidity (3.4-5.0 mmol/100 g).

Solonetz meadow-chernozem forest-steppe (Kormilovsky district) have light loamy and heavy loamy, meadow-chernozem soil - medium loamy composition. In terms of exchangeable sodium content, solonetz are low-sodium (9-16% of CEC). According to the depth of occurrence of the upper boundary of the salt horizon, shallow solonetz on the fallow less than 10 years is solonchak with weak and strong degree of sodium chloride-sulfate salinization in horizons B_2-B_{5k}. Total porosity and aeration porosity in suprasolonetz horizons are satisfactory, in illuvial part of solonetz profile on the fallow of 20-30 years the porosity is much less than in solonetz on the fallow of less than 10 years.

Solonetz of the steppe zone (Cherlak district) are light-loamy and medium-loamy in granulometric composition, low-sodium in exchangeable sodium content (7-15.5% of CEC). Solonetz on the fallow less than 10 years old are solonchak, with a weak degree of soda-sulfate salinization. The values of total porosity and its distribution over profiles are similar to solonetz of the forest-steppe zone. Aeration porosity in horizons A1 and B1 at their low field humidity is high (24-47%).

4 Monitoring of carbon dioxide fluxes in different natural-climatic zones at different ages of fallow lands

Seasonal dynamics of soil fluxes of carbon dioxide has its own peculiarities depending on the zone and under two technologies of fallow lands introduction into turnover: agrotechnical (Technology 1 with higher intensity of tillage in 2022 and 2023) and combined (Technology 2). Experiments were conducted on plots with fallow age of 5-10 years. Spring wheat was cultivated in all zones.

Subtaiga zone.

Carbon dioxide emissions were monitored during April-October (Figure 1) and showed significant variation of soil fluxes of carbon dioxide under year conditions with distinct peaks in summer months (53.2-68.5 g CO_2/m^2 per day) and minima in spring (April-early May) and fall (late September-October), respectively, 10.9-12.2 g and 12.5-14.9 g CO_2/m^2 per day. The seasonal dynamics of CO_2 fluxes was significantly determined by the variation of soil moisture, air and soil temperature.

Differences in the level of carbon dioxide fluxes between deposits of different ages were observed. The average flux of the May-September period on fallows of 5-10 years of age was 41.7, 10-20 years - 34.6, 20-30 years - 27.6 CO_2/m^2 per day, which is less than the corresponding values of 2022 61.7, 52.9 and 47.6 CO_2/m^2 per day. This was primarily probably determined by higher soil and air temperatures and moisture deficit - more severe meteorological conditions of the year.

Forest-steppe zone.

Carbon dioxide emission measurements were carried out during April-October (Figure 2) and showed significant variation of soil carbon dioxide fluxes during the study period with distinct maximums in July (24.7-36.1 CO_2/m^2 per day) and minimum in September-October - 5.0-8.5 g CO_2/m^2 per day. The seasonal dynamics of CO2 fluxes was significantly determined by the variation of air and soil temperature.

A certain differentiation of carbon dioxide fluxes was observed depending on the age of the fallow: the older it is, the less the emission. The average value of carbon dioxide flux on the fallow with the age of 5-10 years - 14.3, 10-20 years - 12.6, 20-30 years - 9.8 CO_2/m^2 per day, which, as well as in the subtaiga zone, is less than the corresponding indicators of the last year 35.0, 29.9 and 23.2 CO_2/m^2 per day.

Steppe zone.

Measurements of carbon dioxide emission were carried out during April-September (Figure 3) and showed significant variation of its soil fluxes during the study period with distinct maximums in July (21.0-34.3 g CO_2/m^2 per day) and minimums in September - 4.1-5.2 g CO_2/m^2 per day. Seasonal dynamics of carbon dioxide fluxes was significantly determined by variation of soil moisture, air temperature and temperature: in May and June there was a deficit of soil moisture, very hot weather.

There was differentiation of carbon dioxide flux intensity between fallows depending on their age. The average value of soil flux on fallows with the age of 5-10 years was 17.7, 10-20 years - 13.4, 20-30 years - 12.0 CO_2/m^2 per day, which, as well as in the forest-steppe zone, is less than the corresponding indicators of the last year 31.3, 24.5 and 19.2 CO_2/m^2 per day.

The studied key areas of fallow lands featured certain daily dynamics of carbon dioxide emission: it has an increased level in the morning and daytime hours, decreased in the evening and night hours [19-20].

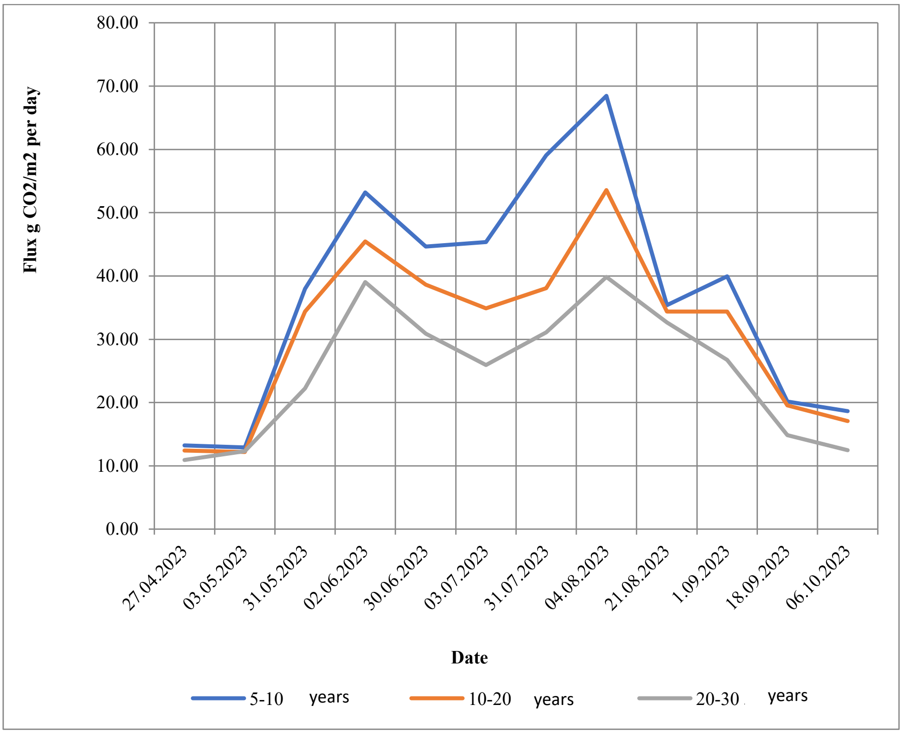

Fig. 1. Seasonal dynamics of soil CO_2 emission in different-aged fallows of the subtaiga zone in the south of Western Siberia (April-October, 2023).

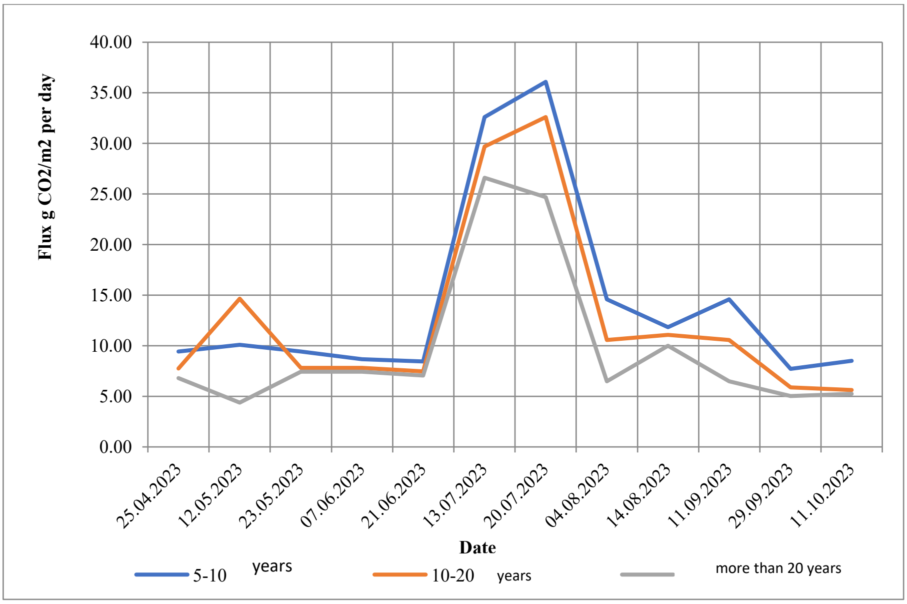

Fig. 2. Seasonal dynamics of soil CO_2 emission on different-aged fallows in the forest-steppe zone of the south of Western Siberia (April-October, 2023).

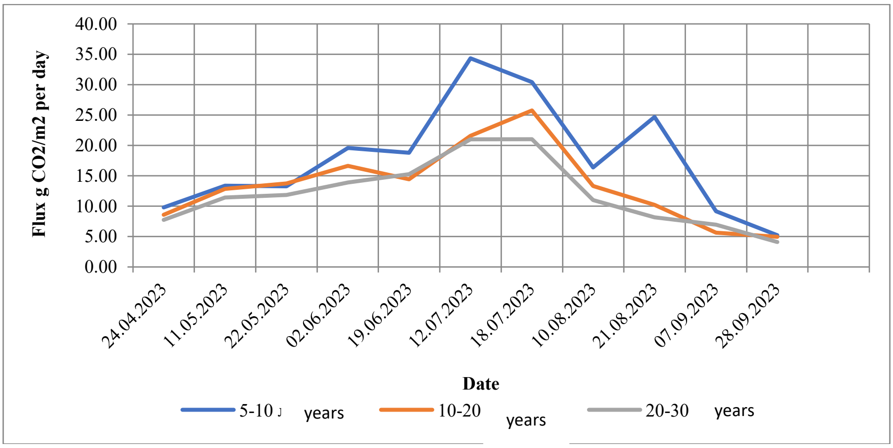

Fig. 3. Seasonal dynamics of soil CO_2 emission on different-aged deposits of the steppe zone in the south of Western Siberia (May-September, 2023).

Modeling of carbon dioxide emission size.

Based on the data obtained for carbon dioxide emission from soil at key sites in subtaiga, forest-steppe and steppe zones, models of soil CO_2 emission as a function of fallow land age were developed. Significant correlations ($r > 0.35$) in year conditions were obtained for the emission (y) of soils of key sites with soil temperature. Soil moisture affected emission to a lesser extent. Therefore, only soil temperature was used as an independent variable in the regression equations for emission estimation (ºC) 10 cm deep (x):

subtaiga zone

1. fallow 5-10 years $y = 2.68x - 1.13$ ($r = 0.59$);
2. fallow 10-20 years $y = 2.26x + 13.73$ ($r = 0,41$);
3. fallow 20-30 years $y = 1.41x + 6.10$ ($r = 0.44$);

forest-steppe zone

1. fallow 5-10 years $y = 1.59x - 8.66$ ($r = 0.53$);
2. fallow 10-20 years $y = 1.58x - 7,62$ ($r = 0,37$);
3. fallow 20-30 years $y = 1.25x - 7.17$ ($r = 0.41$);

steppe zone

1. fallow 5-10 years $y = 0.95x + 0.78$ ($r = 0.63$);
2. fallow 10-20 years $y = 1.08x + 0.13$ ($r = 0.61$);
3. fallow 20-30 years $y = 0.54x + 2.51$ ($r = 0.55$);

The estimation of carbon deposition was carried out by its stocks in layers 0-20 and 0-100 cm of soils. In the subtaiga, the depositing capacity of gray forest soils was estimated by Corg stocks in the 0-20 cm layer of fallow soils less than 10 years old - 77.1; 10-20 years - 54.5 t/ha; 20-30 years - 61.8 t/ha, in the 0-100 cm layer, respectively - 129; 118 and 179 t/ha. In the forest-steppe the value of carbon deposition by solonts and meadow-chernozem soil was the highest: Corg stocks in 0-20 cm of soils of fallows less than 10, 10-20 and 20-30 years old were 85.4; 70.5 and 85.7 t/ha, respectively. In the 0-100 cm layer, Corg reserves were measured as 147 t/ha in fallows less than 10 years old, 187 t/ha in fallows 10-20 years old, and 172 t/ha in fallows 20-30 years old. In the steppe zone, Corg reserves in the 0-20 cm layer of solonets on fallows less than 10, 10-20, and 20-30 years old were close: 66.0; 62.0; and 57.3 t/ha, respectively. In the 0-100 cm layer they were 147; 179; and 125 t/ha.

5 Conclusions

Comparing the intensity of carbon dioxide emission by fallow lands depending on the conditions of the natural-climatic zone, it can be noted that its highest value was in the subtaiga zone (average for April-September 39.4 CO_2/m^2 per day), which is higher than the emission level in the forest-steppe zone (14.7) and steppe zone (16.6). The maximum intensity of fluxes was observed in the subtaiga zone in August, and in the forest-steppe and steppe zones in July. One of the main reasons for this pattern was the air and soil temperature: the higher it is, the more intensive is the release of carbon dioxide.

The influence of the age of fallow land on the level of soil carbon dioxide emission is observed. Younger fallow lands are characterized by a higher value of CO_2 emission compared to older ones, so in the sub-Taiga zone the average seasonal emission of 5–10-year-old fallow lands is 1.51 times higher than that of 20–30-year-old fallow lands, in the forest-steppe zone it is 1.46 and 1.48 times higher, respectively.

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