Spatially-temporal distribution of moisture content and dynamics of greenhouse gas emissions from upper soil horizons in floodplain fallow lands of Bashmakovsky district of Penza oblast

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Abstract. There are more than 1'300 thousand hectares of fallow lands potentially suitable for agricultural producers in the Penza region of Russia, which is 31% of the region total area. More than 300000 hectares of land have been abandoned for more than 20 years, and territory already became forest. Additionally soils under young forests – actively sequester carbon dioxide in soil. How much it makes sense to raise fallow land in terms of climate change and which areas produce the most carbon dioxide from the soil is a research question of great interest. In addition to vegetation, factors such as soil moisture and temperature influence the carbon dioxide emission from soil. As a result, the greenhouse gas fluxes monitoring, we can conclude that forest areas and natural ecosystems mostly deposit carbon dioxide, as the amount of available carbon increases due to a greater increase in biomass. Areas that are used in agriculture produce more nitrous oxide and methane, but less carbon dioxide, which is associated with the specifics of fertilization.

1 Introduction

In order to ensure the food security of our country, after more than 60 years of experience in plowing virgin lands, the state has decided to put back into circulation the lands that for whatever reason have been abandoned and not used in agriculture in recent years. Raising of fallow lands will contribute to the overall increase of areas and partial removal of "fatigue" of actively exploited arable lands through the introduction of innovative farming systems.

Today, 5.1% of the total area of agricultural land in the country is fallow and subject to natural degradation processes, gradually losing its value for agriculture. In the next 10 years, it is planned to put about 12 million hectares of land into agricultural turnover, which will increase crop production for the population of the country and increase exports.

This year, according to Rosreestr data, there are more than 380 million hectares of agricultural land in the Russian Federation, of which almost 5 million hectares are considered fallow lands suitable for agricultural use [1]. In Penza region there are more than 1300 thousand hectares of fallow lands potentially suitable for agricultural producers, which is 31% of the total area of the region. More than 300 thousand hectares of land have not been used for more than 20 years and their territory is covered with forest. The Penza Region is at the top of the rating among the RF subjects of the Volga Federal District in terms of introducing fallow lands into agricultural turnover. For the most part, these areas are young deciduous forests.

Soils on which young forests, in contrast with old ones [2] are established sequester carbon dioxide in the soil and thereby reduce emissions [3]. The feasibility of farming fallow land in terms of climate change and which areas release the most carbon dioxide from the soil is a question that has been under investigation for many years. Besides vegetation, factors such as soil moisture and soil temperature influence the flow of gases from the soil. Soil moisture is one of the main factors affecting soil quality and land productivity, which leads to increased economic benefits, as well as one of the main factors in the growth of greenhouse gas fluxes from soil to the atmosphere.

2 Material and method

The study involved determination of soil temperature and moisture using soil thermometer and volumetric soil water content detector (ML3 ThetaProbe Soil Moisture Sensor). Emission of greenhouse gas fluxes was determined using soil chamber method with concequent gas chromatography.

The research was conducted in Bashmakovsky District of Penza region on fallow plots representative for the territory of the Volga Federal District. At each site, key control points were established on the autochthonous territory, arable fields, on the territory with raised fallow and on the fallow itself, which is only planned to be put into agricultural turnover [4].

The first plot (v. Podgornoye, field SHP-19) with four points is located on the territory of floodplain 25-year-old fallow lands, with the area of 20 ha (Fig. 1) with meadow herbaceous vegetation characteristic for the region (Lactuca tatarica, Epilobium hirsutum, etc.) with rare inclusions of shrubs of Lomkoy willow (Salix fragilis L.)

on meadow-chernozem humus humus heavy loamy soils with increased hydro morphism [5]. The site is located at the mouth of the two rivers Oryev and Pizyaevka, which is the main factor in the formation of the relief.

Fig. 1. Location of key points in the study area (SHP-19).

A total of 4 key control points (1-4) were established at the first site, the first one is located in a meadow ecosystem on the bank of the Orjev River with typical meadow vegetation for the region.

The second point was laid on plowed meadow soils. The third point is located on hydromorphic partially waterlogged periodically waterlogged soils with high requirements for water reclamation works. The fourth point is located on a highly cultivated old arable field, which has been cultivated for more than 30 years.

The second typical fallow plot (v. Belozirka, field ShB-3) with the area of 69 ha (Fig. 2) is located in the zone of 30-year old fallow, overgrown with 25-year old birch forest, on leached medium humus heavy loamy chernozems. On this plot, as well as on the first one, 4 key control points (5-8) of monitoring studies were established.

Fig. 2. Location of key points in the study area (SHB-3).

The fifth point was laid on a fallow land raised in the previous year. The territory at the time of laying the monitoring studies was subjected to a set of agro-technological operations on soil cultivation.

The sixth point is in a 25-year-old birch forest, with very dense projective stand cover, with no ground vegetation in our opinion due to the density of fall.

The seventh point is located in an old forest belt, which borders a 25-year old birch forest, within a forest belt of 50-year old birch (*Betula verrucosa*).

The eighth point is located in the area of cultivated arable land.

3 Results and discussion

The conducted studies from May to September 2022 demonstrated spatial and temporal distribution of soil moisture depending on the relief of the territory, weather conditions and on the "abandonment" of lands (Fig.3). The maximum soil moisture (61.1%) was observed at the site of SHP -19, at point №3 in May, where it is necessary to carry out reclamation measures in order to reanimate a part of the field and bring it into agricultural turnover. The lands on this territory belong to floodplains and during periods of high precipitation, snowmelt process the territory where the key plot is located is flooded and the soil is silted up. This leads to impossibility to use this piece of field without reclamation measures for arable land [6, 7].

The lowest soil moisture (12%) was observed at the site SHP-19 №1 - meadow, which is located at the top of the watershed, has 100% projective ground cover with meadow grasses, which forms a thick turf, which does not contribute to moisture retention in the upper soil horizons and moisture redistribution to the lower horizons and its absorption by plants occurs (Fig. 3). Soil moisture dynamics in the key plots is uniform, except for the periods of increased precipitation and moisture stagnation at the point with hydromorphism manifestation.

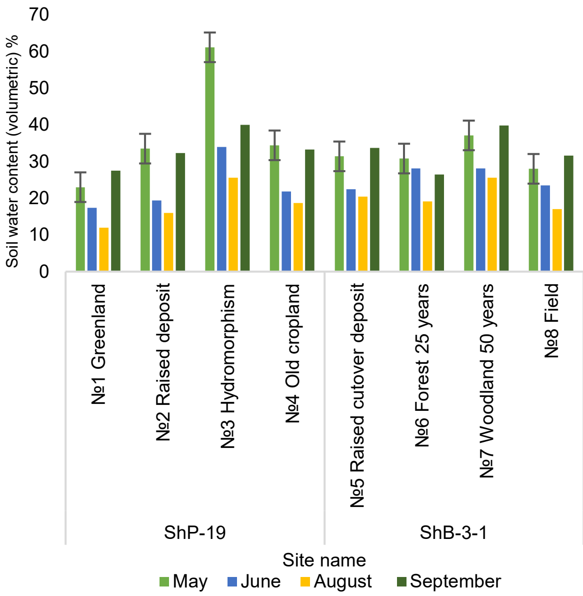

Fig. 3. Soil moisture (%) in the study plots.

Analysis of the dynamics of greenhouse gas fluxes (CO_2, CH_4, N_2O) for the period from May to September demonstrated dependence on the location of points in space, on indicators of soil moisture and temperature, on characteristic vegetation for representative ecosystems.

The maximum values of carbon dioxide emission were observed in August 2022, at site 1 (SHP-19) at key point №1, which is located in the meadow ecosystem - 8.51 gCO_2/m^2 per day. The minimum carbon dioxide emission rates for August were 1.20 gCO_2/m^2 per day at Site 2 (SHB-3) at the key site, which is located in an old-growth forest belt with a stand of 50+ trees (Fig. 4). According to the previously conducted studies, the dependence of carbon dioxide flux on soil temperature was determined,

 https://doi.org/10.1051/bioconf/20248501058

which is confirmed by these studies, as the maximum values of soil temperature occurred in August and amounted to: maximum values - 29.2 at the raised bed (point №2) where the maximum soil warming due to the location and lack of shading. The minimum values of soil temperature were observed in the 25-year-old forest (point №6) for the whole period of measurements, because the shading by the stand crowns is maximum and sun rays do not penetrate the soil surface (Fig. 5). At strong soil warming the activity of carbon dioxide emission decreases.

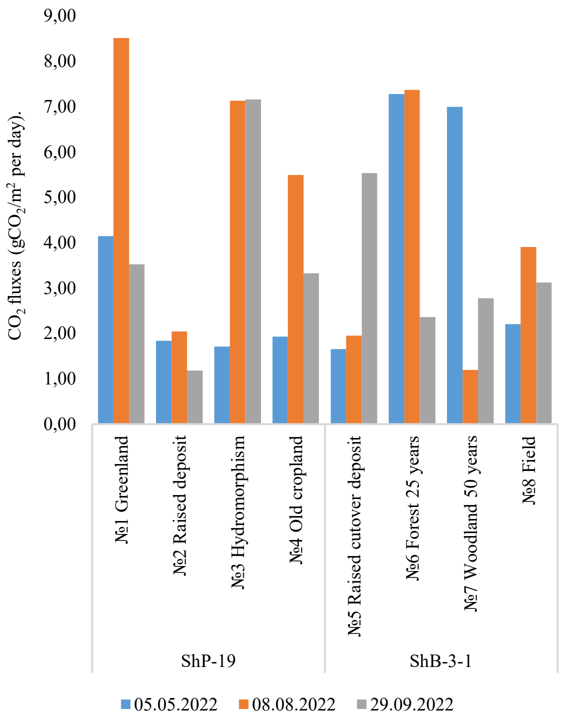

Fig. 4. Emission of carbon dioxide fluxes (gCO_2/m^2 per day).

In May, the maximum values of carbon dioxide emission were observed at site 2 - ShB-3, in forest ecosystems, at point №5 and №6, which are located in the forest part of the 25-year-old birch forest and in the old forest belt. This may be due to the large amount of fall and the presence of organic residues from the stand, which also produces CO_2. In September, the maximum emission values were observed at point №3, which is located in conditions of high humidity and a large amount of organic residues of vegetation.

The maximum values of methane emission from soils were observed in September at the points located on the raised bed (point №2 -0.98 $mgCN_4$/ per m^2 per day and point №5 - 0.91 $mgCH_4$/ per m^2 per day) (Fig. 6). The minimum fluxes occurred in May 0.11 $mgCN_4$/ per m^2 per day at the point located in the meadow area (№1).

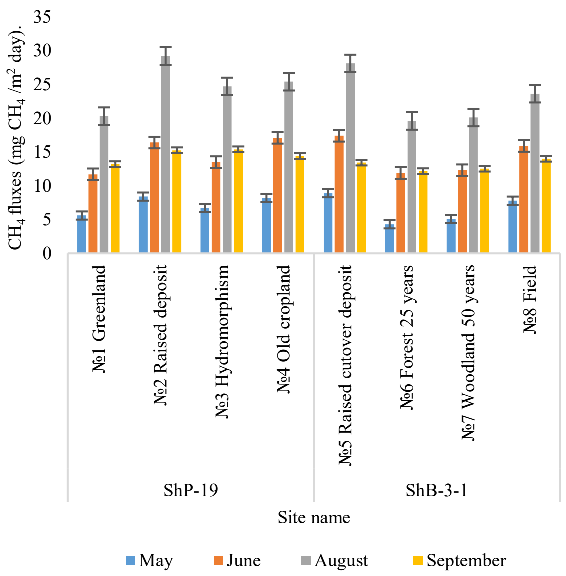

Fig. 5. Methane flux emissions (mg CH_4 /m^2 day).

Greenhouse gas fluxes monitoring showed that forest areas and natural ecosystems mostly deposit carbon dioxide, as the amount of available carbon increases due to a greater increase in vegetation biomass. Areas that are used in agriculture produce more nitrous oxide and methane, but less carbon dioxide, which is associated with the specifics of fertilizer use on active fields.

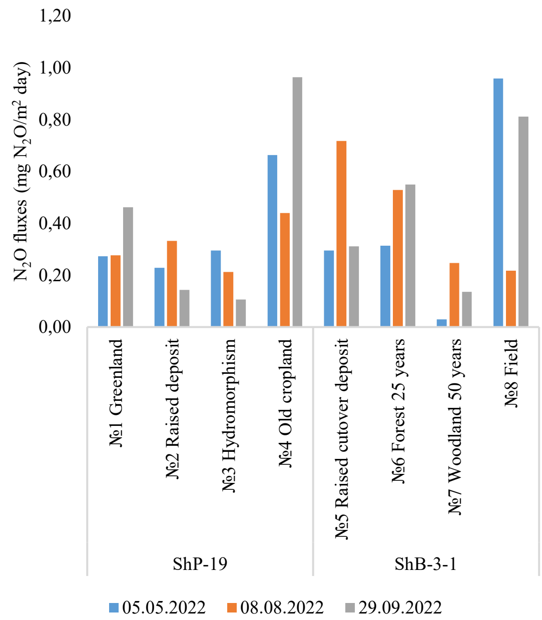

Fig. 6. Emission of N_2O fluxes (mg N_2O/m^2 day).

4 Conclusion

It is necessary to carry out further functional-ecological monitoring of agroecological condition of soils, emission of greenhouse gas fluxes and peculiarities of zoning of the territory of Bashmakovsky district of Penza region to assess ecosystem functions of lands when raising fallow land and introducing them into agricultural turnover to minimize environmental and economic problems.

Funding

The research was financed by the Ministry of Science and Higher Education of Russian Federation, Agreement No. 075-15-2021-1030

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