

SOIL RESPIRATION IN NATURAL CENOSES

Soil Respiration in Agricultural and Natural Ecosystems of European Russia

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Abstract—The results of the assessment of soil respiration in three regions—the Chuvash Republic and Ryazan and Kursk oblasts—are presented. Agricultural and natural ecosystems are divided into seven groups: croplands, pastures, hayfields, fallows, forests, stockyards, and open compost storages. CO₂ emissions were measured in 2020–2022 using the chamber method. The rate of CO₂ emission increased in the following order: croplands (0.03–0.24 g C–CO₂/(m² h)) < pastures (0.07–0.33 g C–CO₂/(m² h)) ≤ hayfields (0.06–0.35 g C–CO₂/(m² h)) ≤ forests (0.07–0.28 g C–CO₂/(m² h)) ≤ fallows (0.08–0.37 g C–CO₂/(m² h)) ≪ stockyards (0.21–8.61 g C–CO₂/(m² h)) ≪ compost storages (1.15–13.85 g C–CO₂/(m² h)). Estimates of CO₂ emission from soils of pastures, hayfields, forests, and fallows did not differ statistically in most cases. The dependence of the soil respiration rate on hydrothermal (temperature and moisture content of the upper soil layer, air temperature) and agrochemical (contents of total carbon and total nitrogen and soil pH in the upper layer) indicators was analyzed for geographic regions and types of ecosystems. The most important factor both at the regional and ecosystem levels proved to be the soil temperature at a depth of 10 cm ($r_p = 0.41–0.88$, $p < 0.05$). Moisture conditions did not play a significant role in the formation of the CO₂ flux. On a regional scale, the content of carbon and nitrogen was important ($r_p = 0.33–0.92$, $p < 0.05$). This indicator depended more on the geographical location of objects than on the character of land use. The considered parameters contribute to 17–78% of the total variance of CO₂ emission from the soils of the studied ecosystems.

Keywords: soil emission of CO₂, arable lands, pastures, hayfields, fallows, forests, Luvic Phaeozems, Luvic Chernozems, Haplic Chernozems

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INTRODUCTION

Soil respiration is the most significant component of the total CO₂ flux from terrestrial ecosystems to the atmosphere [42, 44], the global intensity of which is now estimated from 73 [20] to 91 [31] Gt C/yr and continues to increase during modern climate warming with an average at a rate of 0.1 Gt C/yr [10].

Land use for agriculture and forestry is one of the most significant sources of the anthropogenic emission of greenhouse gases (GHGs): 13 Gt CO₂-equiv./yr (or 22% of the total anthropogenic emission) [21] and 0.9 ± 0.7 Gt C/yr of the CO₂ emission (10% of the total anthropogenic CO₂ emission) [16]. At the same time, agriculture is an economic sector that has the high potential to mitigate climate change by sequestering carbon in the soil [46] and absorbing it in growing crop phytomass [23].

In Russia, agricultural lands occupy about 13% of the territory of the country, including 116.2 M ha of arable lands, 57.3 M ha of pastures, and 18.7 M ha of hayfields [1]. The total CO₂ emission from arable soils in recent years has been 50 million tons of CO₂/yr; the

total emission from hayfields and pastures in 2010–2020 varied within 37–38 million tons of CO₂/yr [3]. Numerous studies of soil respiration are carried out in Russia [2, 4], but, unfortunately, their results are still insufficiently presented in the world databases [11, 33].

Despite the fact that the CO₂ emission from soils has long been widely studied throughout the world, there are still many unresolved problems in this area. In particular, there is no consensus and no final quantitative assessment of the rate of decomposition of organic matter and the influx of carbon into the soil [26]; there are also no unified standards for measuring GHGs emissions from soil and assessing carbon and nitrogen stocks in it [9]. Widely used chamber and micrometeorological methods provide accurate data on soil respiration, but they are reliable only within local ecosystems, while their extrapolation to the regional level is difficult and often leads to erroneous results [39].

By analogy with other GHGs, factors affecting the assessment of CO₂ emissions can be divided into three groups: environmental (microbial biomass, carbon and nitrogen stocks in the soil, temperature, moisture,

pH, texture), management (fertilization, tillage practices, crop residue management, irrigation), and measurement (type of instruments, duration of measurements) [47]. Environmental factors directly affect gas exchange, whereas management factors modify the impact of natural factors. Measurement factors do not directly affect soil respiration, but determine the accuracy and uncertainty of the data obtained.

Soil respiration can be considered an indicator of ecosystem metabolism and carbon stocks in an ecosystem. The intensity of soil respiration, like any chemical reaction, depends on the availability of the substrate. It is closely related to plant metabolism, photosynthesis, and the presence of plant litter [44]. Photosynthesis as the source of carbon and carbon translocation to the roots are more important for root respiration, whereas microbial respiration depends on the stock and features of plant litter, the rate of death of the roots, as well as on the application of fertilizers and the presence of post-harvest residues (if we deal with agroecosystems). Also important are the reaction conditions, i.e., soil temperature and soil moisture content, soil pH, and soil particle size distribution [42].

The purpose of this study was to quantify the CO₂ emission from the soils of various ecosystems and analyze its dependence on the environmental factors taking into account their geographic variability. The objectives of the study included measuring soil respiration in crops and livestock sectors, and natural ecosystems and comparing them with one another. A correlation-regression analysis of the dependence of soil respiration on the hydrothermal and agrochemical factors was also performed.

OBJECTS AND METHODS

Field studies were carried out in three regions lying in the cold humid continental climate (Dfb according to the Köppen classification [40]) in the European part of Russia: the Chuvash Republic, Ryazan oblast, and Kursk oblast. In these regions, operating large farms specialized both in crop production and animal husbandry were selected. Brief information about the studied objects is presented in Table 1. Selected farms are located along an almost 1000-km-long linear transect passing from the southwest to the northeast in accordance with the direction of movement of air masses [40] and the change in soil cover patterns. In each of the three farms or in their immediate vicinity, seven groups of agricultural and natural ecosystems (objects of the study) were identified:

- arable lands (croplands) on which the main crops are cultivated (winter and spring wheat, barley, oats, soybeans, corn, sunflower);
- pastures of cows and horses of varying degree of degradation;
- hayfields with different mowing modes;
- unmanaged fallow lands of different ages;

- forests of different species composition located in the immediate vicinity of the farms,

- stockyards, places of permanent or temporary keeping of cows and horses in the open air;

- open compost storages—heaps or pits of various ages and varying composition formed from a mixture of decomposing manure with sawdust or straw bedding used in livestock facilities, as well as rotted hay.

The CO₂ emission from the soil surface was measured by the static closed chamber method using portable infrared CO₂ gas analyzers based on the AZ 77535 sensor (AZ Instruments, Taiwan) modified for field work (patent RU 174321 U1). The exposure for single measurements was 3 min. Polyvinylchloride cylinders of 20 cm in height and 90 cm² in area, opaque to photosynthetically active radiation, were used as measuring chambers. In each ecosystem, 10 such chambers were installed in advance in a line every 10 m on the soil surface (ground vegetation was removed). Simultaneously with measuring the CO₂ concentration, the air temperature and the soil temperature at a depth of 5 and 10 cm were estimated using the HI 98509 digital thermometers (Hanna Instruments, USA); the volumetric content of soil moisture in the layer of 0–7 cm was measured using the SM150 soil moisture kit (Delta-T Devices, UK).

The measurements were carried out during the growing seasons of 2020–2022. Depending on the natural features and land management in the studied regions, from 11 to 16 local ecosystems belonging to seven compared groups were identified in them. The total data set consisting of emission values averaged for each year for individual ecosystems comprised 41 values for arable lands, 25 for hayfields, 23 for forests, 21 for pastures, 17 for fallows, 11 for stockyards, and 8 for compost storages.

In addition, in each ecosystem, mixed soil samples were taken annually from the layer of 0–20 cm using the envelope sampling pattern. After appropriate sample pretreatment, the contents of total carbon (C_{tot}) and total nitrogen (N_{tot}) were determined in the soil samples using a CHNS analyzer Vario Isotop Select (Elementar, Germany). The pH of soil water suspension (pH_{water}) was measured in the samples using an HI 98121 pH-meter (Hanna Instruments, USA).

For statistical processing of the obtained results, the SPSS Statistics 26.0 (IBM SPSS Inc., USA) software was used. The following approaches and types of analysis were applied:

- Calculation of the mean values of CO₂ emission from the soil and their standard deviations for each ecosystem and their groups;

- Nonparametric Mann–Whitney test (significance level $p = 0.05$) for comparing the mean values of soil respiration in different groups of ecosystems (this criterion was chosen because of the relatively small samples with different group variances);

Table 1. Description of research objects

Region	Zone/ subzone	Mean annual air temperature, °C	Mean annual precipitation, mm	Soil type/texture	Plot coordinates	Name of organization	Represented ecosystem groups
Chuvash Republic (Yadrinsky district)	Mixed forests	4.7 ± 0.8	666 ± 28	Luvic Phaeozems (Siltic)/loamy sand	56.039°–56.047° N, 46.204°–46.269° E	V.I. Chapaev horse breeding farm	All
Ryazan oblast (Sapozhkovsky district)	Broadleaved forests	5.6 ± 0.9	543 ± 130	Luvic Phaeozems and Luvic Chernozems (Loamic)/ heavy loam	53.831°–53.881° N, 40.715°–40.849° E	E.A. Gusev's farm	All
Kursk oblast (Medvensky district)	Forest-steppe	7.2 ± 0.9	631 ± 103	Haplic Chernozems (Loamic)/ heavy loam	51.533°–51.576° N, 36.064°–36.122° E	Kursk Biosphere Station	Croplands, fallow, forests
						JSC Amosovskoe	Croplands, stockyards, compost storages
						V.V. Alekhin Central Chernozem Reserve	Hayfields, pastures, forests

— Correlation (significance level $p = 0.05$) and regression analyses to assess the dependence of the soil respiration rate on hydrothermal (air and soil temperature, volumetric soil moisture) and agrochemical (contents of C_{tot} and N_{tot} , pH) parameters of the environment.

RESULTS AND DISCUSSION

Comparison of soil respiration rates in different groups of ecosystems. The field values of soil respiration in different groups of ecosystems were compared with one another taking into account the C_{tot} and N_{tot} contents as potential factors of the CO_2 emission. The pairwise comparison made it possible to construct the following inequality, which reflects soil respiration rates in agricultural and natural ecosystems ranked according to increasing mean values of the CO_2 emission:

croplands < pastures ≤ hayfields ≤ forests ≤ fallows ≪ stockyards ≪ compost storages,

where sign < denotes a strict inequality of respiration rates between groups of ecosystems; ≤ sign means that the emission levels are often equal; and sign ≪ indicates a significant excess of soil respiration in the given group of compared ecosystems.

Thus, among the considered set of ecosystems, soil respiration turned out to be minimal on arable lands

(Fig. 1). On pastures, hayfields, forests, and fallow lands, in most cases of pairwise comparison, emission rates do not differ significantly. Emissions from livestock facilities (compost storages and stockyards) significantly exceed emissions in other ecosystems.

The resulting relationship between soil respiration levels in different groups of ecosystems generally corresponds to the regularities obtained on the basis of a large statistical sample: arable lands < pastures/hayfields ≤ meadows < forests [38]. However, in our study, soil respiration in meadow fallows turned out to be higher than that in nearby forests, which is associated with the ongoing self-recovery of fallow lands with active annual growth of herbaceous vegetation not only in the aboveground but also in the actively respiring root layer, which also contributes to the entry of a large amount of organic matter of dying phytomass into the soil. In addition, in such comparative analyzes, hayfields and pastures are often considered together, while in our study they are presented separately, which is undoubtedly its advantage.

The respiration of arable soils (0.035–0.244 g C– CO_2 /(m² h)) is much less intense compared to other groups of ecosystems (Fig. 2a), which is consistent with the low contents of carbon (1.34–3.70%) and nitrogen (0.12–0.29%) in the upper soil layer (Fig. 3). The main reason for the loss of biogenic elements is

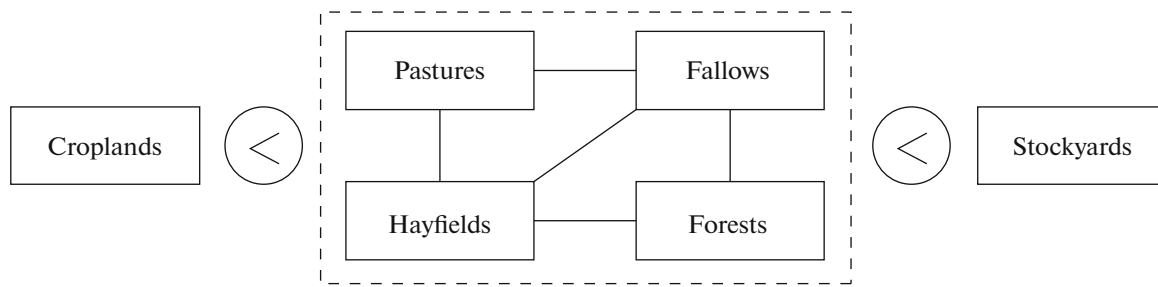


Fig. 1. Scheme of soil respiration ranking in different groups of ecosystems. Dotted block shows similar levels of soil respiration, and the lines inside it indicate approximate equality of respiration between ecosystem groups. Sign < is the inequality sign.

the annual removal of phytomass with the main product and with by-products and only partial return of produced phytomass with plant residues against the background of the absence of sufficient amounts of organic and mineral fertilizers to compensate for the deficiency of macronutrients. Indeed, as a result of the involvement of soils in agricultural use, they can lose 1/2–2/3 of the initial carbon stock at a rate of 30–40 t C/ha per year [27] and contain 1.9–3.9 times less potentially mineralizable carbon than soils in the nearby natural ecosystems [45].

In addition, there is no litter on arable lands and, compared to natural ecosystems, they contain significantly less root biomass, which also contributes to an overall reduction in emissions. Thus, in agroecosystems, the share of root respiration is estimated at an average of only 33% [29] compared with 35–57% in meadow ecosystems [49] and 59% in forest ecosystems [5].

The results of our study indicate that the emission from soils subjected to moldboards plowing is much higher than that from soils of no-till systems [35], and that deep plowing enhances soil respiration by 22–32% compared to the traditional plowing depth [51]. At the same time, the absence of plowing leads to a much higher CO₂ emission in the post-harvest period than in the case of traditional tillage, which is probably due to the decomposition of plant residues remaining on the soil surface and increased respiration of microorganisms and invertebrates [18]. Therefore, many researchers propose to reduce carbon emissions by replacing traditional farming with organic [19] and precision farming [8] systems.

Pastures (0.071–0.326 g C–CO₂/(m² h)) and *hayfields* (0.056–0.346 g C–CO₂/(m² h)) are perennial herbaceous phytocenoses, part of the biomass of which is annually alienated, as well as on croplands. There can be either natural or seeded phytocenoses. For these types of land use, it is objectively more difficult to identify patterns of the dependence of CO₂ emission on external and internal factors, since, in addition to soil and climatic conditions, different mowing regimes, grazing intensity, types of grazing animals, and different species composition of herbs have their influence. Nevertheless, the distribution of

carbon and nitrogen content in this group of ecosystems, despite differences in economic use, displays definite geographical patterns and increases from north to south in the studied regions (Fig. 3). A specific feature of pasture soils is a relatively high nitrogen content (C_{tot} 2.07–6.86%, N_{tot} 0.19–0.66% in pastures compared to C_{tot} 2.62–5.99%, N_{tot} 0.23–0.50% in hayfields), which is probably associated with nitrogen return with animal waste.

The CO₂ emission on pastures depends on the intensity of their use: for example, in semiarid regions, moderate grazing reduces emission increasing the sequestration potential, while intensive grazing releases CO₂ [25]. Another way to reduce soil respiration on pastures by almost 1/5 is the alternation of grazing areas [24]. At the same time, some researchers argue that grazing intensity and plant biomass do not affect the emission [7]. Our data confirm the first point of view and show that soil respiration in pastures is comparable to soil respiration in hayfields and fallow lands, i.e., in ecosystems with significantly higher phytomass values. As the amount of phytomass in pastures is much lower, the high emission indicates a significant contribution of grazing to the formation of carbon flux from the soil to the atmosphere.

The conversion of croplands into hayfields and pastures is a widely discussed way of carbon sequestration in the soil and its removal from the atmosphere, which will obviously help to mitigate climate change [13, 30]. Conversion of croplands into hayfields, or grassing, is certainly the most efficient way to restore the content of soil carbon allowing to increase its stock by 1.6–1.7 times over 25 years [28]. On the other hand, the conversion of croplands to pastures remains largely debatable, since grazing animals produce additional GHGs, which can completely neutralize the benefits obtained or even surpass them in terms of their impact on the climate system [34].

The CO₂ emission on *fallow lands* (0.084–0.369 g C–CO₂/(m² h)) and in *forests* (0.070–0.285 g C–CO₂/(m² h)), where the phytomass is not alienated, the carbon cycle is more closed and is closer to the equilibrium state. As already noted, soil respiration on

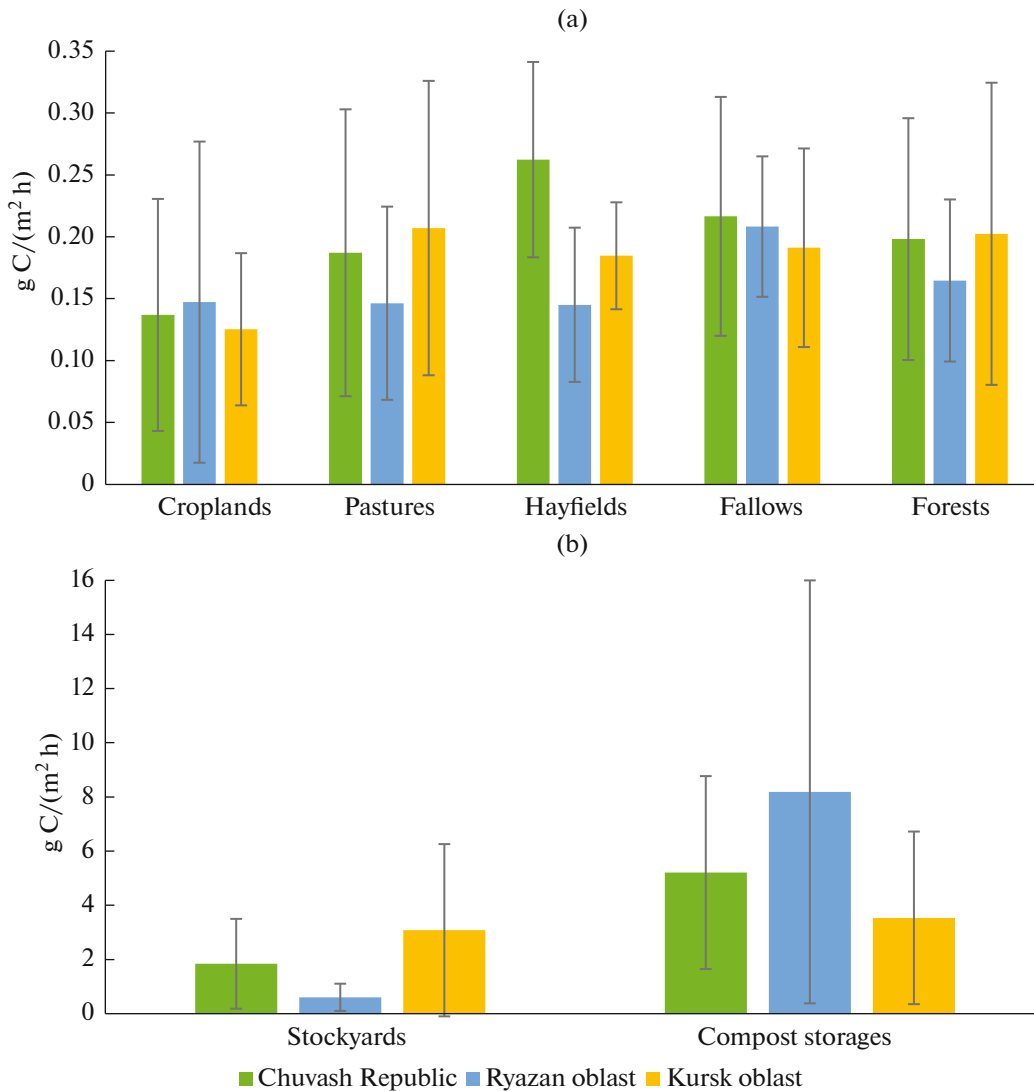


Fig. 2. Soil respiration in (a) plant communities and (b) livestock facilities.

fallow lands overgrown with meadow vegetation often exceeds the level of soil respiration in adjacent forest ecosystems. This is inconsistent with the fact that the stocks of carbon (1.99–4.91%) and nitrogen (0.19–0.42%) on fallow lands are most often small, because, as a rule, the least fertile plots are withdrawn from land use in the agriculturally developed areas. However, this contradiction can be easily explained by the significantly greater respiration activity of fine roots (mainly, herb roots) in the upper soil layers of fallows at the early stages of the restorative succession. In the studied forest soils, the carbon content (2.50–5.63%) is indeed higher, although these soils are poor in nitrogen (0.20–0.47%); the content of both elements naturally increases from north to south.

The CO_2 emission from soils of *stockyards and compost storages* (Fig. 2b) turned out to be an order of magnitude higher than that from soils under plant communities; the content of biogenic elements in the

soils of stockyards is also the highest (C_{tot} 4.60–13.96%, N_{tot} 0.45–1.30%) (Fig. 3). According to the results obtained, the emission from stockyards (0.207–8.611 $\text{g C-CO}_2/(\text{m}^2 \text{ h})$) and compost storages (1.145–13.851 $\text{g C-CO}_2/(\text{m}^2 \text{ h})$), despite their small area, is the most significant source of CO_2 in the considered farms. As manure and compost are the main types of organic fertilizers, the data obtained indirectly confirm the general opinion that the application of fertilizers significantly increases the emission from agricultural soils [7, 36]. Moreover, the impact of organic fertilizers and their doses on the CO_2 flux from the soil significantly exceeds the impact of air temperature, soil temperature, and precipitation [43]. It should be noted that emissions from stockyards and compost storages can be reduced by quite available methods, e.g., by composting under anaerobic conditions [41]. Among the most radical measures to com-

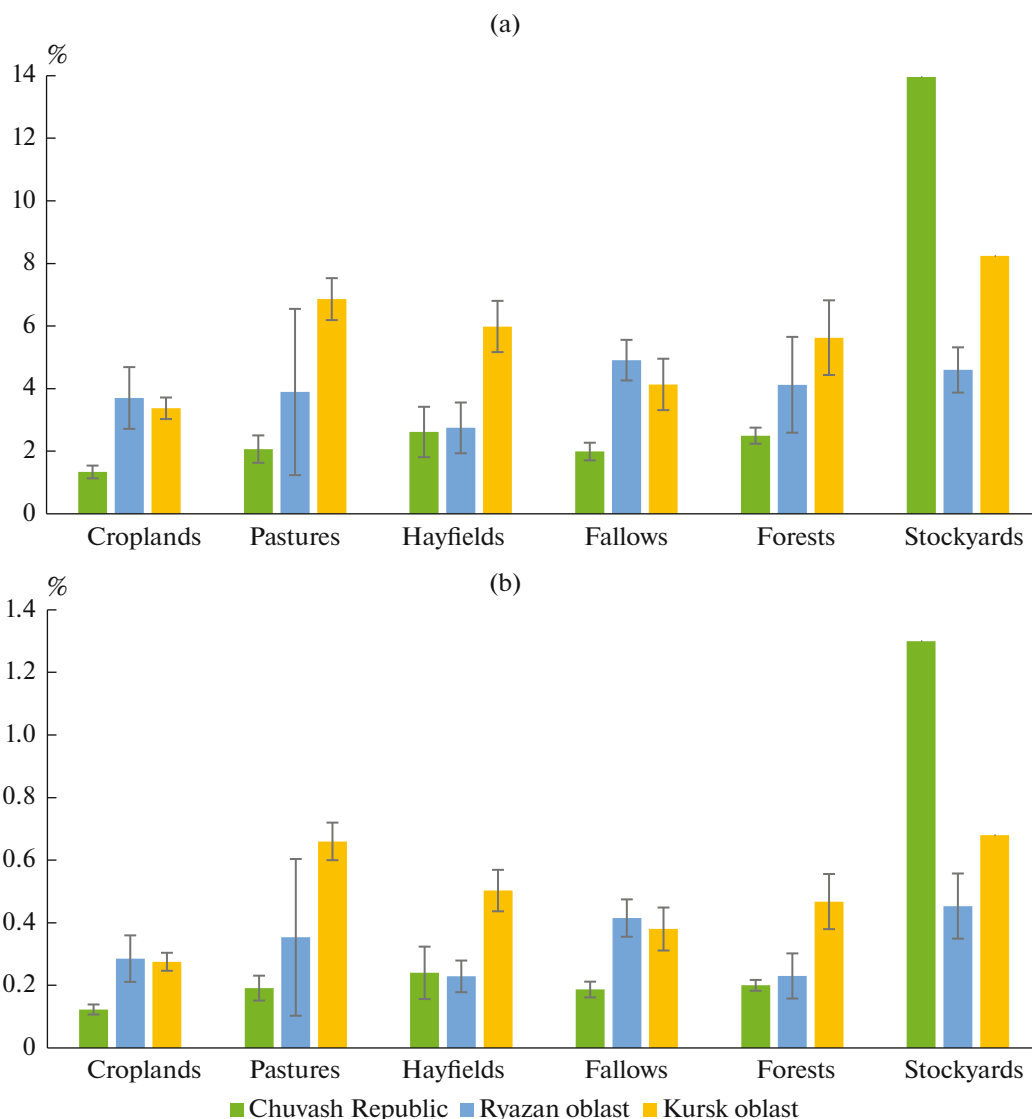


Fig. 3. Contents of (a) carbon and (b) nitrogen in soils of different groups of ecosystems.

bat emissions from the livestock sector is the gradual abandonment of livestock breeding [14].

Dependence of soil respiration on the environmental factors. The dependence of soil respiration in the studied ecosystems on the agrochemical and hydrothermal factors was assessed in two ways: by averaging over regions and over groups of ecosystems.

When averaged over regions, positive dependences of CO_2 emission on soil temperature at different depths and on the contents of carbon and nitrogen in the topsoil were obtained (Fig. 4a). Relationships of emissions with air temperature, soil moisture, and soil pH were not found. Strong correlations with external conditions were obtained for the Chuvash Republic; moderate correlations, for Ryazan oblast; and weak correlation, for Kursk oblast. Thus, the influence of external conditions on the emission decreases from north to south. In all regions, the most important indi-

cator of the formation of CO_2 flux from the soil is the soil temperature at a depth of 10 cm. In general, the identified significant factors explain 51–74% of the total variance of soil respiration.

The dependences of soil respiration on the studied factors in different regions have the following form:

Chuvash Republic:

$$SR = -4.094 + 0.274T_{10} + 0.843C - 8.134N$$

($R^2 = 0.691$; $RMSE = 0.099$, $n = 36$),

Ryazan oblast:

$$SR = -3.852 - 0.043T_5 + 0.269T_{10} + 1.616N$$

($R^2 = 0.509$; $RMSE = 0.103$, $n = 43$),

Kursk oblast:

$$SR = -0.054 - 0.492T_5 + 0.536T_{10}$$

($R^2 = 0.736$; $RMSE = 0.412$, $n = 67$),

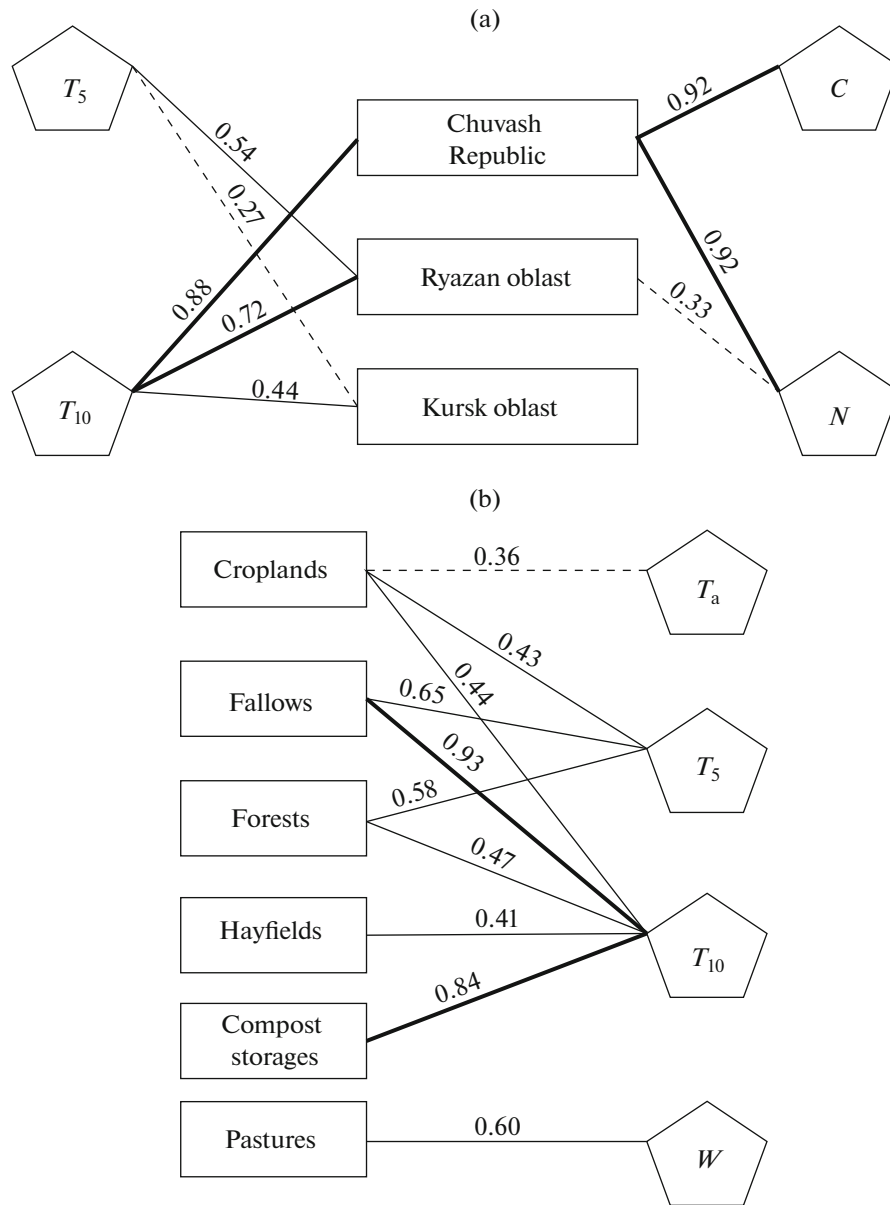


Fig. 4. Schematic representation of the correlative relationships between soil respiration and hydrothermal and agrochemical parameters of the environment when averaged over (a) geographic regions and (b) ecosystem groups. Strong correlation ($r_p > 0.70$) is indicated by thick lines; moderate correlation, by thin lines; and weak correlation ($r_p < 0.40$), by dotted lines. The values of the correlation coefficients are indicated above the lines; in all cases, the significance level $p < 0.05$. T_5 is soil temperature at a depth of 5 cm, °C; T_{10} is soil temperature at a depth of 10 cm, °C; T_a is air temperature, °C; W is the volumetric soil moisture content, %; C is the total carbon content, %; and N is the total nitrogen content, %.

where SR is soil respiration, $g\ C-CO_2/(m^2\ h)$; T_5 is soil temperature at a depth of 5 cm, °C; T_{10} is soil temperature at a depth of 10 cm, °C; C is the content of total carbon, %; and N is the content of total nitrogen, %.

The obtained dependence of soil respiration on the agrochemical factors is interesting. For relatively poor gray soils of Chuvashia, the contents of both C_{tot} and N_{tot} in the soil are significant, while only the second of these elements is important for CO_2 emission from soils in Ryazan oblast, and neither of them limit emis-

sion in typical chernozems of Kursk oblast. According to other researchers, if the correlations between CO_2 emission and soil carbon content are usually positive [6], then the correlations with nitrogen content are more complicated. An increase in the soil nitrogen content enhances autotrophic respiration on arable and fallow lands, but reduces it on soils under meadow and forest cenoses. On the contrary, the heterotrophic respiration of soils increases with an increase in the nitrogen concentration in meadows, swamps, and deserts. In general, an increase in the nitrogen

content reduces soil respiration and its temperature sensitivity by 19.5 and 32.1%, respectively [48].

The noted geographic distribution of carbon content in the studied soils displays a general trend towards its increase from north to south. Indeed, the upper layer of gray soils (Phaeozems) contains 1.2–2.0% of organic carbon [22], while to the south, in Chernozems, it reaches 3.5–4.3% [17].

When averaged over ecosystem groups (Fig. 4b), the leading influence of the temperature factor (soil temperature at depths of 5 and 10 cm) is confirmed, while no dependence of the CO₂ emission on the content of carbon and nitrogen in the soil and its pH was revealed. Unlike other ecosystems, pastures show a positive relationship between soil respiration and soil moisture. There is no single explanation here. Probably, the formation of such a relationship is facilitated by the fact that pasture soils are overcompacted as a result of trampling by livestock, due to which their density increases, porosity decreases, and high volumetric moisture is maintained. On croplands, temperature conditions determine only 17–18% of the variance of soil respiration, while on fallows and compost storages, this factor is responsible for 69–78% of the variance. No significant regression equations were obtained for hayfields and stockyards.

The following dependences of soil respiration on the considered factors have been obtained for different types of ecosystems:

Croplands: $SR = 0.024 + 0.006T_5$
 $(R^2 = 0.172; RMSE = 0.084, n = 41),$
 $SR = 0.020 + 0.007T_{10}$
 $(R^2 = 0.179; RMSE = 0.092, n = 41),$

Pastures: $SR = 0.040 + 0.006W$
 $(R^2 = 0.238; RMSE = 0.097, n = 21),$

Fallows: $SR = -0.175 + 0.029T_{10}$
 $(R^2 = 0.780; RMSE = 0.070, n = 17),$

Forests: $SR = 0.078 + 0.024T_5 - 0.019T_{10}$
 $(R^2 = 0.355; RMSE = 0.053, n = 23),$

Compost storages: $SR = -3.787 + 0.296T_{10}$
 $(R^2 = 0.693; RMSE = 2.902, n = 8),$

where SR is soil respiration, g C–CO₂/(m² h); T_5 is soil temperature at a depth of 5 cm, °C; T_{10} is soil temperature at a depth of 10 cm, °C; and W is the volumetric moisture content of the soil, %.

As follows from the obtained regression equations, in all groups of ecosystems, soil respiration demonstrates a relationship with hydrothermal factors. Similar conclusions are confirmed in many works. However, if the intensity of respiration, as a rule, increases with an increase in temperature [6, 12, 32], then the relationship with the soil moisture in the same tem-

perature range is nonlinear. Usually, with a decrease in precipitation, soil respiration also decreases [7], while an increase in the soil moisture affects soil respiration in dependence of the particular range of soil moisture values: soil respiration decreases with excessive moisture [50] or significantly increases in ecosystems of arid regions [37]. The influences of temperature and soil moisture are closely interrelated, and moisture is usually the determining factor. If it is higher than the minimum value necessary for the vital activity (respiration) of soil biota, then temperature becomes the limiting factor; if it is lower, then moisture itself becomes the limiting factor [15]. Moreover, the alternation of moistening and drying cycles contributes to a much greater release of CO₂ than stable moisture conditions [41]. As a result, CO₂ emission from soils of semiarid regions can be even higher than that from humid boreal regions [35].

CONCLUSIONS

Among the considered agricultural and natural ecosystems, the most significant sources of CO₂ for the atmosphere are livestock facilities—stockyards and compost storages. The levels of soil respiration in pastures, hayfields, fallows, and forests are comparable; respiration of arable soils is the lowest. From north to south within the studied regions, the contents of carbon and nitrogen in soils increase regardless of the type of ecosystem under consideration, and the relationship between soil respiration and these parameters weakens. The most significant factor in the formation of the CO₂ flux from the soil into the atmosphere is the soil temperature at a depth of 10 cm. In general, hydrothermal and agrochemical parameters determine 17–78% of the total variance in CO₂ emission from the studied soils. The obtained knowledge of the specific values of soil CO₂ emission and its main factors, as well as the regression equations calculated on their basis, make it possible to regulate and predict the emission in agricultural ecosystems in dependence of the actual contribution of different land uses to the greenhouse effect and climate change and to reduce emissions at the level of a given farm.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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