ISSN 1064-2293, Eurasian Soil Science, 2011, Vol. 44, No. 7, pp. 794–801. © Pleiades Publishing, Ltd., 2011.
Original Russian Text © V.N. Golosov, A.N. Gennadiev, K.R. Olson, M.V. Markelov, A.P. Zhidkin, Yu.G. Chendev, R.G. Kovach, 2011, published in Pochvovedenie, 2011, No. 7, pp. 861–869.

Spatial and Temporal Features of Soil Erosion in the Forest-Steppe Zone of the East-European Plain

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Received January 11, 2011

Abstract—Data on the rate of the erosion–accumulation processes within the sloped junctions of soils studied on key plots in Tula, Kursk, and Belgorod oblasts were analyzed. Using the method of different-age tracers characterizing the erosion–aggradation of the soils during the last 140–150 years (the magnetic tracer) and during the last 20–25 years (the radiocesium tracer), the spatial and temporal features of the redistribution of the drifts on typical slopes in different parts of the forest-steppe zone of the East-European Plain were established. A clear trend of an increase in the soil erosion rate in this zone during the last 20–25 years was revealed compared to the average rate for the last 140- to 150-year-long plowing period, which was related to the climate warming, an abrupt reduction of the surface runoff during the spring snowmelt period, and the increasing soil-protecting role of the agricultural plants in the crop rotations because of the decrease in the proportion of row crops. The obtained results confirmed the continuous nature of the soil erosion and accumulation during the transport of the sediments, which was manifested in the alternation of the erosion zones and deposition zones on the slopes.

DOI: 10.1134/S1064229311070064

INTRODUCTION

A significant advance has been made in the quantitative estimation of the arable soil erosion in the last decades, which is related to the improvement of the estimation methods. In the countries of Central and Western Europe, the rate of the soil erosion under different landscape conditions [38] was estimated on the basis of monitoring the sediment runoff on sloped plots [36] and sloped catchments [39], from the volume of the accumulated sediments in retaining ponds [40], and by the calculations using erosion models [26]. However, the most significant progress was made using different soil microcomponents as erosion tracers (markers), especially radioisotopes [7, 21–25, 33, 34] and spherical magnetic particles (SMPs) [3–6, 27, 29–32]. An advantage of the radioactive and magnetic tracer methods is the possibility of reliably estimating the mean rate of the erosion–accumulation processes during a known time period: the last 25–50 years for the radiocesium method and about 100–150 years for the magnetic tracer method. This is of special importance for studying the trends in the erosion and accumulation of soil material in relation to the fluctuations of the climatic parameters and the changes in the conditions of the land use. Data on soil erosion rate during different time periods allows for the more adequate prediction of the loss of the soil mass, the humus, and the nutrients depending on the variation of the climatic parameters, the crop rotations, and the tillage practices and the development of more efficient systems of soil-protecting measures. Such estimations are also important for revealing the negative impacts of soil material removal and the presents of pesticides, fertilizers, and other pollutants on the quality of the surface waters, which is an ecological problem of priority in Russia, as well as in the European Community, Canada, the United States, and some other developed countries [19].

In the forest-steppe zone of the East-European Plain, surface runoff is almost not formed under natural plants, especially on grassed plots. This is related to the good water permeability of the soils and their high projective cover of herbaceous plants [8]. Under these conditions, the rate of the soil loss on the slopes does not exceed several kilograms of soil per hectare annually [11]. Only rainstorms after long periods of drought can cause a local increase in the soil loss under thin ground cover in forests [10].

Until the middle 17th century, the large-scale plowing of lands in the forest-steppe zone was restricted by the threat of a Tatar invasion. Then, the area of arable lands abruptly increased to reach the maximum in the late 19th century [16]. It should be noted that the relatively gentle slopes most suitable for agriculture were first tilled; only after were the most

Table 1. Physicogeographical conditions of the plots studied

No.	Plot (region)	Relative height, m	Annual precipitation, mm	Soil-forming rocks	Soils
1	Diktatura (Tula oblast)	40–50	500–550	Calcareous loess-like loams	Medium-thick and shallow loamy leached chernozems
2	Gracheva Loshchina (Kursk oblast)	30–35	570–620	″	Medium-thick and thick loamy leached and typical chernozems
3	Gostishchevo (Belgorod oblast)	20–25	470–520	″	Medium-thick loamy podzolized chernozems

erodible surfaces with gradients higher than 3–4 degrees tilled [14]. Later on, the plow land area was slightly reduced because of the increase in urban territories and the removal of marginal and ravine lands from the crop rotations. The soil's plowing favored an abrupt increase in the soil loss rate both during the spring snowmelt period and under rainstorms. The field observations in the forest-steppe zone were mainly performed during the snowmelt period in the spring. They showed that the mean rate of the soil erosion by the thaw water in the forest-steppe of the Central Russian Upland increases from the north to south with the increasing frequency of the surface runoff formation during the spring snowmelt period and the increasing topographic contrast in the same direction. According to the observations of the water-balance and soil-erosion stations performed during the period from the early 1960s to the middle 1980s, the rate of the soil loss from the arable lands during the snowmelt period decreased from 1.5 t/ha per year in Tula oblast to 0.4 t/ha per year in Belgorod oblast [17]. The loss of soil from the slopes of the southern exposures significantly exceeded the loss from the slopes of the northern exposures; it varied from 3–5 t/ha in the northern part of the Central Russian Plain [1] to 1.5–2 t/ha in its central part [15]. In the last decades, an abrupt decrease in the slope runoff occurred in the Central Russian Upland during the snowmelt period because of the climatic changes. This was confirmed by the data of the monitoring observations of the surface runoff on the plots of the Novosil Zonal Agroforestry Experiment Station. The ratio of the water runoff from the slopes during the period of the observations decreased from 0.5 in 1959–1990 to below 0.1 in 1991–2008 [13].

No monitoring investigations of the soil loss from arable slopes in the forest-steppe zone were performed during the period of the storm runoff formation. Fragmentary information acquired from isolated observations indicates the most significant soil loss from the slopes occupied by row crops and from the fallow fields. Its value reached 30–60 t/ha per runoff event [11, 20]. It was noted that the rainstorm erosion was also extremely nonuniform because of the spatial heterogeneity of the rainstorms.

Thus, the determination of the trends of the soil erosion rate in the forest-steppe zone of the East-European Plain, where a complex combination of factors affects the development of the soil erosion in time, is a problem of current interest and practical importance [12]. The combined use of methods for assessing the soil erosion based on the use of different-age markers of the soil loss can be promising for the solution of this problem.

In this paper, new data are discussed on the rates of the erosion–accumulation processes in different parts of the forest-steppe zone on the southern megaslope of the East-European Plain obtained by studying typical soil junctions on arable slopes with the use of the radiocesium method and the magnetic tracer method.

OBJECTS AND METHODS

The objects of the study were the arable slopes located in different parts of the forest-steppe zone of the Central Russian Upland (Table 1) on the key plots Diktatura in Tula oblast, Gracheva Loshchina in Kursk oblast, and Gostishchevo in Belgorod oblast.

The most contrasting topography is typical for the Diktatura key plot in the central part of the Plava River basin in the most dissected northern part of the Central Russian Plain. The soil cover consists of medium-thick leached chernozems and shallow loamy chernozems. The catena under study is located on a convex slope of southern exposure; its length is about 700 m.

The second catena was studied on the Gracheva Loshchina key plot located in the Vorobzha River basin (a left tributary of the Seim River) 20 km to the south of the city of Kursk. The soil cover consists of medium-thick leached and typical chernozems and thick loamy chernozems. The catena is located on a convex slope of southwestern exposure; its length is 470 m.

The Gostishchevo key plot is located in the Severskii Donets and Lipovyi Donets interfluve within the Kamennyi Log Hollow catchment area. The soil cover on the studied slope consists of medium-thick loamy podzolized chernozems. The slope is convex in shape and has a southern exposure; its length is 450 m.

Table 2. Morphological parameters of the studied slopes with concave profiles

No.	Plot	Exposure	Total length	Average/maximum inclination, degrees
1	Diktatura	southern	700	2/5
2	Gracheva Loshchina	southeastern	470	3.3/5
3	Gostishchevo	southern	450	1.4/2.4

All the studied soil junctions are located on the slopes of warm (southern and southwestern) exposures; the slopes are predominantly convex in shape and similar in length, which allows them to be correctly compared. As was noted above, the rate of the soil loss from the slopes of the warm exposures in the steppe and forest-steppe zones significantly exceeded that from the slopes of the cold exposures during the spring snowmelt period [1]. This difference was most significant for the slopes of the different exposures in the highly dissected areas.

The main features of the arable slopes where the soil samples were taken for the analysis are given in Table 2. It should be noted that the slightly longer slope on the Diktatura plot is due to the extended and relatively flat near-watershed part of the slope. On the Gracheva Loshchina plot, the studied slope is convex in shape along its entire length, except for a small segment (no more than 10 m in length) in its lower part, where the slope profile is concave in shape because of the sediment tails deposited before the bend. The buried gullies on both sides of the Gracheva Loshchina ravine indicate that the runoff intensity and soil loss rate were relatively high at the early stage of plowing the catchment slopes, which resulted in the formation of side gullies, along which almost all the sediments were removed from the slopes to the ravine's bottom.

A railroad constructed in 1869 passes in the close vicinity of the plots (Table 1). All of the studied objects were subjected to radioactive contamination in the spring of 1986 after the Chernobyl accident. The concentrations of the ^{137}Cs isotope of Chernobyl origin significantly exceed its residual concentrations of global origin related to the atmospheric nuclear tests in the 1950s.

From the analysis of the ordnance survey maps, the conclusion was drawn that all the studied slopes near the key plots were plowed at the beginning of the railroad's exploitation, and the plowland areas within the territories under study have not significantly changed up to the time of the study. Each plot had some peculiar features, which should be taken into consideration during the interpretation of the results. The Gostishchevo plot in Belgorod oblast had World War II trenches in the forest adjacent to the plowland, which suggested possible mechanical disturbances in the plowland caused by shell bursts or the passage of military and support equipment. It was known from the history of the land use in Plavsk district of Tula oblast where the Diktatura plot was located that horseradish was planted there as a monoculture for several decades from the late 19th century to the 1917 revolution. This is a row crop that could have contributed to an increase in the soil loss during this period compared to the mean level. After the end of World War II, the proportion of row crops in the crop rotations of most economies in the chernozemic zone abruptly increased (to 25–30%) due to the increase in the area of sugar beet and corn plantations. In the last two decades, the proportion of row crops appreciably decreased (to 10%), but the fallow area slightly increased in the recent years. The changes in the land use structure, including the proportions of row crops and fallow in the crop rotations, should always be taken into consideration in the determination of the soil erosion rate.

To assess the rate of the erosion–accumulation processes during different time intervals, the method of different-age tracers was used; i.e., SMPs and ^{137}Cs were simultaneously used as tracers of the soil erosion. The analysis of the radioactive isotope distribution in the sloped soils allows characterizing the rates of the soil loss and accumulation during the last 25-year-long period from the Chernobyl fallout in 1986 to the moment of the soil sampling. The method is based on the ability of ^{137}Cs to be rapidly and strongly sorbed by soil particles and transferred with them [28]. The assessment of the erosion processes is based on studying the transformation of the initial field of radioactive contamination due to the soil erosion–accumulation. The degree of the field's change was estimated against the background (reference) value of the radionuclide reserve corresponding to the total density of the ^{137}Cs fallout from the atmosphere with correction for the radioactive decay. To determine the reference value, the isotope pool in the soils developed on geomorphologically stable plots, where there is almost no removal of soil material or input of sediments from the adjacent areas, was used. To acquire quantitative information on the rates of the soil erosion–accumulation, calibration relationships relating the changes in the ^{137}Cs reserve and the rate of the erosion–accumulation are used [41]. A proportional calibration model based on the direct relationship between the changes in the isotope reserve against the reference value and the rate of the soil erosion or accumulation was used in this work. The procedure of the samples' preparation for the gamma-spectroscopic analysis included drying and grinding of the sample to the fraction <2 mm. The gamma-spectroscopic analysis of the soil samples was performed in the Laboratory of Soil Erosion and Fluvial Processes of the Faculty of Geography of Moscow State University using gamma spectroscopy systems with high-resolution and high-purity germanium semiconductor detectors (1.9 keV energy resolution for the 1332 keV energy line). The time of the exposure was determined by the statistically reliable identification of the ^{137}Cs peak at 661.66 keV and varied from 3 to 12 h. The accuracy of measuring the ^{137}Cs activity was usually 5%.

The magnetic tracer method can provide data on the mean rates of the soil erosion and accumulation during the period since the beginning of the exploitation of steam locomotives on the nearest railroads (the last 130–150 years). The magnetic tracer method was tested for studying the soil erosion in the United States about 20 years ago [27] and in Russia 10 years ago [4]. The intensive input of technogenic SMPs onto the soil's surface in industrial countries began with the appearance of the first railroads and steam locomotives, i.e., about 150 years ago. The studies showed that this source of SMPs prevails over the other possible sources of these substances near railroads: natural (volcanic emissions, space fallouts) and technogenic (different pyrolytic industrial processes related to coal burning) ones. It was unambiguously shown that the content of SMPs in the soils regularly decreases with the distance from the railroads [3].

Magnetic spherules are stable and relatively inert substances in soil material. In the soils with predominant oxidative conditions, they acquire no visible signs of degradation during a long time period (no less than some hundreds of years). SMPs mainly consist of magnetite, hematite, and other iron minerals. The sizes of these particles vary from fractions of a micrometer to hundreds of micrometers. Some features of magnetic spherules such as their shell structure, hollowness, and metallic luster distinguish them from a wide range of other strongly magnetic minerals [5].

Within local areas, SMPs relatively uniformly arrive from the atmosphere into the soil; therefore, the changes in their concentrations in the soil cover result from their redistribution due to the erosion–accumulation of soil material. It is supposed that the mass of the magnetic tracer redistributed due to the erosion is directly proportional to the mass of the redistributed soil material. The determination of the SMPs in the soil involves the separation of the magnetic fraction from the soil and the microscopic calculation of the content of SMPs in this fraction using the corresponding software. The quantification of the soil loss rate is based on the comparison of the concentrations and reserves of SMPs on different sloped plots with those in the reference watershed positions with consideration for the segment lengths and the time of occurrence of the SMPs in the soils (since the beginning of the active use of steam locomotives on railroads).

The procedure for the separation and quantification of the SMPs in the soil is based on the quantitative wet magnetic separation of the soil material and its microscopic analysis with 600- to 1200-fold magnification. The volume fraction of the spherules 1–53 μm in size in the magnetic fraction was estimated using a MiniVid digital camera and the corresponding software.

The principles of the calculation of the erosion–accumulation rates by these methods were described earlier [3, 5, 6].

Each of the catenas studied was tested in three duplicate transects spread along the slope 3 m from each other between the flat near-watershed plot and the foot of the slope. The soil was sampled using a soil sampler from depths of 0–7, 7–15, 15–30, and 30–50 cm.

RESULTS AND DISCUSSION

The summary data on the reserves of SMPs and ^{137}Cs in the soils of the three plots studied (Diktatura, Gracheva Loshchina, and Gostishchevo) and the calculated mean rates of the erosion–accumulation processes on the slopes during the century-long (the last 130–150 years) and recent (the last 25 years) periods are given in Table 3. The numbers of the soil sampling points from the watershed and near-watershed areas to the lower part of the slope are given (from the top to bottom) in column 1. The reserves of SMPs in the specified soil layers at all the sampling points are given in column 2. On all the slopes, the maximum reserves of SMPs are found in the watershed and near-watershed parts, and their minimum reserves occur on the lower parts of the slopes. The widest range of the reserves of SMPs at the different sites of the slope is typical for the Diktatura plot (from 5.5 to 12.8 g/m^2 in the 0- to 50-cm layer); the narrowest range is observed for the Gostishchevo plot (from 4.8 to 7.4 g/m^2 in the 0- to 30-cm layer). The secular soil erosion rate in each sampling point calculated by the magnetic tracer method with consideration for the construction time of the nearest railroad, i.e., the beginning of the SMP input into the soils, is given in column 3. The negative values characterize the rate of the soil loss. The positive values indicate the rate of the soil accumulation. It can be seen that the maximum erosion rate is typical for the middle slope on the Diktatura plot (23–25 t/ha per year); on the Gracheva Loshchina plot, the maximum erosion rate is 13–16 t/ha per year; and, on the Gostishchevo plot, the corresponding value is 13–15 t/ha per year, which largely correlates with the steepness of the slopes and the regional climatic parameters. The wavy distribution of the maximum and minimum values of the SMP reserves in the soils and the soil erosion rates is typical for all the slopes. The reserves of ^{137}Cs in the soils on the slopes of the different plots are given in column 4 of Table 3. On the Diktatura and Gracheva Loshchina plots, the maximum reserves of the radioactive tracers are clearly confined to the watershed and near-watershed areas; on the Gostishchevo plot, this tendency is less evident. The soil erosion rates aver-

Table 3. Reserves of SMPs and ^{137}Cs and the calculated rates of the erosion-accumulation processes in the soils of the studied catena

Profile	Reserve of SMPs, g/m^2	Secular erosion rate, t/ha per year	^{137}Cs reserve, kBq/m^2	Recent erosion rate, t/ha per year
Diktatura key plot, Tula oblast				
TDC 1	12.8	0	82.2	0
TDC 2	13.0	1	45.7	–20
TDC 3	5.5	–25	78.4	0
TDC 4	6.6	–23	51.3	–4
TDC 5	10.3	–9	44.5	–23
TDC 6	9.5	–11	63.5	30
Gracheva Loshchina key plot, Kursk oblast				
TGC 24	2.2	0	9.0	0
TGC 25	2.7	5	10.8	31
TGC 26	0.8	–13	8.6	–6
TGC 27	1.1	–9	7.6	–22
TGC 28	0.6	–16	9.9	15
TGC 29	2.0	–2	6.9	–34
TGC 35	1.3	–8	5.9	–51
Gostishchevo key plot, Belgorod oblast				
BGC 1	6.7	0	19.3	0
BGC 2	7.4	4	18.8	–4
BGC 3	4.8	–13	19.3	0
BGC 4	5.7	–6	20.9	12
BGC 5	4.9	–11	16.7	–20
BGC 6	4.4	–15	19.0	–2

Note: the reserves of SMPs are given for the 0- to 50-cm (Diktatura plot), 0- to 25-cm (Gracheva Loshchina plot), and 0- to 30-cm soil layers (Gostishchevo plot); the reserves of ^{137}Cs are given for the 0- to 100-, 0- to 30-, and 0- to 30-cm soil layers, respectively.

aged for the last 25-year-long period calculated for all the points on the slopes from the lateral distribution of the ^{137}Cs are given in column 5. The maximum rates (34–51 t/ha per year) are observed for the separate segments of the slope on the Gracheva Loshchina plot, as well as increased rates of local soil accumulation (up to 31 t/ha per year). A less contrasting combination of erosion and accumulation zones is typical for the Gostishchevo plot: soil loss of up to 20 t/ha and soil accumulation of up to 12 t/ha per year. In general, the lateral distribution of the radioactive tracer along the slope is also wavy in nature.

The integral rates of the erosion–accumulation processes averaged for each slope of the plots studied are given in Table 4. The average rates are calculated with consideration for the lengths of the slope segments characterized by the sampling points given in Table 3. In other words, the relative contributions of the rates within the separate slope segments to the average rate for the slope were estimated proportionally to the segment lengths. The average rates of the soil accumulation on the entire slope and the average rates of the sediment removal beyond the slope calculated by the same method are also given in Table 4.

The calculations showed that the recent soil loss rate (without consideration for the soil accumulation within the slopes), which was calculated by the magnetic tracer method, decreased compared to the secular period (calculated by the magnetic tracer method) by 2–2.5 times on the average on the Diktatura (from 14.6 to 7.7 t/ha per year) and Gostishchevo plots (from 8.1 to 3.4 t/ha per year); on the Gracheva Loshchina plot, it slightly increased (from 7.6 to 11.2 t/ha per year) (Table 4). However, the average rate of plots sediment removal beyond the arable slope during the last 25 years decreased compared to the last secular period on all of the plots studied. The differences were from 1.8 to 6 times: from 14.5 to 4.9 t/ha per year for the Diktatura plot, from 6.4 to 3.6 t/ha per year for the Gracheva Loshchina plot, and from 7.2 to 1.2 t/ha per year for the Gostishchevo plot. The magnetic tracer method showed that only 17% of the previously removed sediments were deposited on the slope of the Gracheva Loshchina plot, only 12% on the Gostish-

Table 4. The rates of the erosion and accumulation on the arable slopes and of the sediment removal beyond the slopes (t/ha per year)

Parameter	Plot					
	Diktatura		Gracheva Loshchina		Gostishchevo	
	^{137}Cs	SMPs	^{137}Cs	SMPs	^{37}Cs	SMPs
Average soil loss for the entire slope	7.7	14.6	11.2	7.6	3.4	8.1
Average accumulation for the entire slope	2.8	0.1	7.5	1.3	2.2	1.0
Average sediment removal from the slope	4.9	14.5	3.6	6.4	1.2	7.2

chevo plot, and no accumulation during the secular period was revealed on the Diktatura plot. At the same time, the sediments deposited within the arable slope made up 35–65% according to the radiocesium method data.

The calculated rates of the sediment removal beyond the plow land are comparable to the data on the soil erosion rates in different parts of the forest-steppe zone obtained by different methods. From the erodible land map of European Russia, the mean soil loss rate is 10–15 t/ha per year in southern Tula oblast, 5–10 t/ha per year in the Kursk region, and 3–5 t/ha per year to the south of Belgorod [11]. This map was drawn on the basis of the modified model of soil erosion containing blocks of rainstorm and snowmelt runoffs [10]. Data on the climatic conditions and crop rotations in the 1960s–1980s were used as the input parameters. The calculated data were compared to the actual rates of the sediment removal from the slopes found from the volume of the soil deposits in the pools of earth dams (with known construction dates) collecting the water and sediment runoffs directly from the overlying arable slopes. This comparison showed that the calculated soil loss rates are slightly higher than the actual results. However, the error is low: 2.8–58% on the average for the different plots [18]. Thus, the results obtained by the magnetic tracer method fall within the range of soil loss values obtained by other methods. It should be noted again that the average removal of soil material from the slopes determined by the radioisotope method is lower than its value obtained by the magnetic tracer method by 1.8–6 times for all of the soil catenas studied. This difference is not accidental and can be explained by a number of substantive and methodological reasons. First, when ^{137}Cs is used as a tracer, the soil loss rate is estimated for the period of 1986 to 2009 (2007), while the magnetic tracer method gives the values averaged for the period from the middle of the 19th century to the sampling moment. In the last decades, the soil loss during the spring snowmelt period decreased significantly. This was due to the increase in the air temperature in the winter. This resulted in a decrease in the soil freezing depth and, hence, the surface runoff coefficient [9, 13]. According to the observations of the water and sediment runoffs during the spring snowmelt period on the sloped catchment areas, the mean soil loss rate was from 4.5 t/ha per year in the northern region of the Central Russian Plain [2] to 2–2.5 t/ha in its central part near the city of Kursk [9]. Second, the composition of the crops in the rotations changed after 1991 because of the reduced proportion of raw crops, which significantly decreased the soil loss rate during the warm season under runoff-forming rains. Third, it is known that the coefficient of the water runoff from the slopes abruptly increases during the first decades after the plowing of virgin lands [8]. This increases the soil erosion and soil loss. The maximum plowing of the forest-steppe zone on the East-European Plain occurred in the second half of the 19th century, i.e., the period covered by the magnetic tracer method.

With consideration for the above discussion, it can be stated with confidence that the soil loss rate decreased during the last 21–23 years by at least 2–3 times and that this tendency was traced for different parts of the forest-steppe zone of the East-European Plain. A more significant decrease in the soil loss is observed on the Gostishchevo plot. This can be related to the greater differences in the soil-protective role of the crops included in the rotations after 1991 and those used during the functioning of the collective farms (kolkhozes). For example, during the harvesting of sugar beets, whose proportion in the Central Chernozemic Zone of Russia was very high until 1991, a significant part of the soil mass was removed beyond the slopes with the crop. The soil loss could reach 5 to 14 t/ha per harvest season [35, 57].

Thus, the simultaneous use of different-age tracers allowed us to reveal the changes in the ratio between the consequences of the soil erosion and the soil accumulation on the slopes studied during different time periods.

CONCLUSIONS

The combined use of the radiocesium method and the magnetic tracer method allowed assessing the spatial–temporal pattern of the sediment redistribution on typical slopes in different parts of the forest-steppe zone of the East-European Plain. A clear trend of the decreasing of soil loss rate in this zone during the last 20–25 years was revealed compared to the average rate for the last 140- to 150-year-long period of plowing. The absolute values of the soil loss well agree with the data for the soil erosion rate in the forest-steppe zone obtained using the conventional methods and approaches for assessing the intensity of the soil erosion. The main reasons for the decrease in the loss of the soil and nutrients from the arable lands is the climate warming, the abrupt reduction of the soil loss rate during the spring snowmelt period, and the changes in the soil-protecting role of the agricultural plants in the crop rotations because of the decrease in the proportion of row crops. The obtained results confirmed the continuous nature of the soil erosion and accumulation during the transport of the sediments along the slope, which results in the alternation of the erosion zones and redeposition zones on the slopes.

ACKNOWLEDGMENTS

This work was supported in part by the Russian Foundation for Basic Research and the Civilian Research and Development Foundation, project nos. RFBR 10-05-00532-a, RFBR–CRDF 09-05-92513-IK-a, and RUG1-2948-MO-09.

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