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Humus State of Soils in the System of Landscape Agriculture in the Conditions of the Middle-Russian Upland, Russia

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Abstract

Soil erosion is a catastrophic problem for the world's environment, including agro-ecosystems in erosion-dangerous regions of Russia. Studies were performed in the most eroded district (Krasnogvardeiskiy) of the most eroded area (Belgorod) in the Central Chernozem zone of Russia. The aim was to study the effect of soil-protecting technologies on the dynamics of organic matter in soil monitoring survey system in real conditions of agricultural production during 27-29 years. As a result, positive dynamics of organic matter content in soils of two model facilities and the district as a whole was found. During the studied period, the content of organic matter in the soils of the "Repny Log" facility increased by 0.30% in the 0-20 cm layer, and by 0.75% in the 20-40 cm layer, in the soils of the "Krasnogvardeiskiy Range" facility - by 0.79% (20 - 40 cm) and by 0.50% (20-40 cm), in whole for the Krasnogvardeiskiy district - by 0.4%. However, the rate and direction of the soil-forming process in various periods of time have been non-uniform and depended on the degree of landscape agricultural systems development, as well as on the relief conditions and the state of soil cover. While in the 0-20 cm soil layer of the "Repny Log" facility there was first a 10-fold reduction in organic matter loss followed by its accumulation at the rate of 0.05% per year, the 20-40 cm layer is initially characterized by a statistically significant increase in this indicator. Study of humus soil status of the "Krasnogvardeiskiy Range" facility established a statistically significant increase in organic matter content in topsoil and subsoil by 29% and 20%, respectively, for the whole water catchment. Thus, landscape agricultural systems are able not only to reduce the rate of soil erosion, but also to prevent it and to enhance soil fertility. This provides a basis for decision-making about their large-scale development in erosion-dangerous regions with intensive agricultural production.

Keywords: erosion, soil organic matter, conservation techniques, landscape agricultural systems

1. Introduction

1.1 The Problem of Soil Erosion in the World

Despite a long history and a planetary scale, the problem of soil erosion does not cease to be relevant. Like a catastrophic boomerang, erosion returns to the man as a result of his unreasonable activities in the agriculture that results in loss of soil fertility, loss of productivity in natural ecosystems, agro-ecosystems in particular, pollution of air and water sources, and increases frequency and severity of droughts. According to expert estimates (Lal, 1994; Speth, 1994), the majority of agricultural land is exposed to erosion; 80% - to moderate and severe erosion, and 10% - to slight erosion. This resulted in loss of productivity of almost a third of the world's arable land during the last 40 years (Kendall and Pimental, 1994; World Resources...,1994). The average rate of soil loss due to wind and water erosion around the world is about 30 t/ha per year, ranging from 0.5 to 400 t/ha (Pimental et al., 1995). The largest losses are in the agro-ecosystems of Asia, Africa and South America - average of 30-40 t/ha per year (Pimental, 2006). Even in developed countries like the United States, the annual loss is still high - 13 t/ha (USDA/NRCS, 2007). Russia also features high level of soil erosion loss - 15 t/ha per year. The share of the eroded agricultural land in Russia is 30% (Problems of Degradation ..., 2007), and during the last 20 years, the rate of such lands growth is 6-7% every 5 years. Erosion losses growth is noteworthy (Management Models..., 1998; Vasenev, Vaseneva 2003).

Taking into account the growth of the world population, which is currently over 7 billion people, and by 2050 is expected (UN. World Population Prospects, 2011) to reach 9.3 billion, and the existing high rates of land degradation and disposal due to erosion, the problem of providing food for population will aggravate. According to FAO data, within the last 20 years there has been a sharp decline in corn production per capita, level of which has fallen below the level of the 60s of the past century (Sundquist, 2010). And now, according to the WHO (World Health Organization), 66% of people in the world are starving to some extent (WHO, 2000).

Currently, the use of the land-and-resources potential of Russia, especially of arable land, is in crisis. With 10% of productive land of the world, and 55% of the world's black soil reserves, the Russia's share in agricultural production is only about 2%. The prevailing manner of management has led to alarming degradation of the soil cover, which makes it one of the most important socio-economic and environmental problems that threatens the national security of Russia. According to estimates of experts, the total annual shortage of crop production caused by deterioration of land use is minimum 120 million tonnes in grain equivalent, or about 350 billion rubles per annum (Agro-ecological State ..., 2008).

In modern conditions, the assuring of the production sustainability is the key activity of experts and researchers in the field of agriculture. Sustainability of development requires consistent preservation and restoration of the biosphere, and security of economic activities. The need of farming based on the laws of natural ecosystems and landscapes functioning has become well recognized. Starting with the great Russian scientist, V.V. Dokuchaev who at the end of the XIX century defined the problem of erosion and drought as a comprehensive one, and proposed comprehensive actions to solve it, too, many generations of researchers in our country and around the world have been developing his ideas into a coherent system of agriculture that is friendly to the environment (nature). This system includes soil conservation techniques such as biomass mulches, crop rotations, no-till, ridge-till, added grass strips, shelterbelts, contour row-crop planting, and various combinations of these and others. In our country, the soil protection complex was named "Landscape Agricultural Systems" (LASs).

Development of Landscape Agricultural Systems makes it possible to lay the foundation for a mechanism of sustainable agro-ecosystems operation. That being said, the issue of new type agro-ecosystems' ability to provide ecosystem services inherent in natural surroundings, including soil preservation and productive function, becomes very urgent. Analysis of publications on this topic shows that the more there are works in various aspects of studying erosion and its consequences, the less there is information about positive results of fighting erosion. Obviously, this is due to the relatively short period of using soil preservation technologies, as compared to the duration of the period of soil formation process. For example, over the last decades, in the United States, using a number of soil preservation technologies, they were able to reduce the rate of arable land erosion loss by 25% (USDA, 1994, 2000). However, the rate of soil loss still exceeds permissible limits: 10-15 times for arable land and 6 times - for pastures (NAS, 2003).

The purpose of this work is to study the LASs effect on soil fertility and assessing the direction and intensity of soil-forming processes by the dynamics of soil humus status. The results of the study will be of considerable scientific and practical interest for further development of soil preservation technologies in the areas with intensive agricultural development of erosion processes.

2. Experimental Details (Materials and Methods)

2.1 Study Area

The Belgorod region, where the study was performed, is traditionally agricultural, and the success of agricultural production has a direct impact on its economic well-being. Therefore, the task of protecting soil, i.e., the main means of production in agriculture, from erosion is highly relevant, especially since the region is the most eroded in the Central Chernozem zone (CCZ). The share of the eroded land there is 53%, which is almost 2 times higher than the average for the zone. The reason for this is a high share of the ploughed up land - 80%, and high share of the slope land - 72%. In the Belgorod region, the most eroded area is the Krasnogvardeiskiy district, with the share of eroded land being there at 72.7%. The annual soil loss was 1 cm/year there and was assessed as "catastrophic". No accident that this area had been chosen for development of Landscape Agricultural Systems; it was assumed that if in such stringent conditions they are able to prevent erosion, then such a system will be even more effective in more favorable conditions.

Since 1981, under the guidance of the member of the Russian Academy of Agricultural Science, Kotlyarova O.G., in the entire area of the Krasnogvardeiskiy district of over 132 thousand hectares, including 92.5 thousand hectares of arable land, Landscape Agricultural Systems have been assimilated. In whole in the area of 8,700 hectares of forest ranges were planted, including field-protective and water regulation shelterbelts - 1,763 hectares, ravine shelterbelts -5,520 hectares, riverine - 157 hectares, and areas with continuous afforestation - 1,229 hectares. Over the years of system assimilation, ravine tops have been fixed, over 315 earth-dams have been built, 121 anti-erosion ponds created, many ravines has been graded, and perennial grasses have been sown on 50 graded erosion scars and streams. Agricultural crops have been adaptively placed, stipulating sowing arable crops in graded areas and perennial grass - on slopes. By now, an environmentally sustainable highly productive natural-anthropogenic complex has been built there. 2 facilities and reference points have been designated for monitoring the state of soil fertility under the influence of the soil preservation complex in real management conditions.

The study area is located in the southern part of the forest-steppe zone of Russia; it is characterized by a temperate continental climate with average temperature of 6.2°C, the total sum of daily temperatures above 10° of about 2,900°, and the average annual total precipitation 475 mm. Annual hydrothermal coefficient is about 1, which indicates that the area features unstable moistening. The probability of humid years is 25-40%, and that of semi-arid and arid years is 30-50%. Major crops are winter wheat, sugar beet, corn, sunflower, soybean, barley, etc.

The two model facilities with full implementation of all elements of LASs designated in the territory of the Krasnogvardeiskiy district represent the most typical and at the same time contrasting conditions of the regions of the CCZ Middle-Russian Upland. The first facility with the area of 300 ha, "Repny Log", with coordinates 50° 43' N -38° 31' E, was introduced into the monitoring survey system in 1993. It had 11 reference points. Morphological features of 11 full-profile pits have been described. The study focused on typical carbonate black soils and typical black soils with different degree of erodedness of light clay and clay particle composition formed on loess-like loams. Reference points are fixed on the watershed, and on the upper, middle and lower parts of the slope of southern exposure with the steepness of 1-4º.

The second model facility, "The Krasnogvardeiskiy Range" (50° 40' N - 38° 20' E) with the area about 300 hectares was allocated in more complex terrain conditions. It is located between hollows on the scattering catchment, which includes the watershed and the slopes of the southern and northern exposures 1 to 8º steep. It is a compact complex of a system of 7-contour 5-row forest belts and the intra-belt space occupied by crop rotation fields and grassland. The species composition of the studied protective forest plantations includes oak, birch, poplar, acacia, golden currant. Soil is moderately eroded residual carbonate black soil. In 2004, 42 reference points were fixed in the water catchment, 3 in each forest belt (by the wood sides and in the center), and in each inter-belt area (in the center and fifteen meters from the northern and southern boundaries of the fields). Soil samples were taken from various positions of the relief, including the watershed, the top, the middle and the lower parts of the slope. Such points placement made it possible to study the influence of interaction between protective forest plantations and fields, and the relief conditions, on soil fertility.

2.2 Soil Sampling and Analysis

In the system of monitoring survey soil samples were collected from a depth of 0-20 cm and 20-40 cm in each reference point on the "Repny Log" facility in 1993, 2004, 2009 and 2013; on the Krasnogvardeiskiy Range" - in 2004, 2009 and 2014. Data of large-scale soil survey study of the area in 1985-86 were used for reference. (Farming system ..., 1985, 1986). The soil was analyzed for organic matter content and pH_{KCl} in accordance with the recommended methods (State Standards GOST 26213-91 and GOST 26483-85) in the research lab of the Belgorod State Agricultural Academy named after V.Y. Gorin.

Descriptive statistics, method of dispersion and correlation analysis were performed for data analysis using MS-Excel 2003 and Statistica 6.0 besides the calculation of means, standard deviation, variation coefficient and correlation coefficient (Dospekhov, 1979).

3. Results and Discussion

3.1 Changes of OM Content in Soils at Different Period of Lass Development

In this paper, the study of soil fertility under the influence of Landscape Agricultural Systems is assessed by changes in organic matter content in soil. Organic matter in soil is an integral component of soil fertility, since its content influences agro-physical, agro-chemical, physico-chemical and biological properties of the soil. Soil organic matter (SOM) is involved in formation of soil aggregates, improves structure, water permeability and water-holding capacity of soil, increases cation exchange, delivery of nutrients to plants, stimulates development of micro-flora and enhances biological activity of soil, which has positive effect on crops growth and development, and on their productivity.

Since the beginning of LAS implementation, 4 rounds of the Monitoring Survey were performed at the "Repny Log" facility. The baseline characteristic was the content of organic matter in the soils of the facility in 1986, which was 5.2%. Thus, the study of the dynamics of organic matter content in soil of model facility covers 27 years, which makes it possible to estimate the direction and intensity of the processes occurring in the soil.

The pace and direction of the soil-forming process in different time intervals during this period were not uniform.

In the first years after the implementation of Landscape Agricultural Systems, loss of organic matter in the topsoil (0-20 cm) still continued (Table 1). However, its pace eventually dropped significantly. While during the period between 1986 and 1993 they amounted to 0.1% per year, between 1993 and 2004 their value was only 0.01% per year, i.e., ten times less. The next five years are characterized by an increase in organic matter content in soil by more than 0.05% per year.

Table 1. The dynamics of organic matter content (%) in topsoil (0-20 cm) of the Repny Log facility

Reference points	Years			
	1993	2004	2009	2013
1	3.62	3.78	4.73	4.33
2	3.75	3.81	4.95	5.00
3	4.39	4.45	3.93	4.75
4	4.40	4.49	4.35	4.45
5	3.79	4.50	4.53	4.66
6	4.32	4.35	4.38	4.85
7	4.97	4.67	4.45	4.89
8	4.77	4.85	5.56	4.88
9	5.39	5.10	4.73	5.02
10	5.16	4.86	5.03	5.05
11	5.06	3.74	4.93	5.06
X	4.51	4.42	4.69	4.81
Sx	0.61	0.47	0.43	0.24
Cv, %	13.53	10.53	9.23	4.99
LSD_{05}	$F_{act.}<F_{theor.}$			

Note: here and further, X is the arithmetic mean, Sx is the standard deviation, and Cv,% is the coefficient of variation.

In subsurface soil layer (20-40 cm), unlike the plowable, between 1993 and 2004 there was organic substance accumulation at the rate of 0.02 % per year. In the subsequent period till 2009, OM content in the subsurface layer increased at a much more rapid rate - 0.09% per year (Table 2).

Table 2. The dynamics of organic matter content (%) in the subsoil (20-40 cm) of the Repny Log facility

Reference points	Years			
	1993	2004	2009	2013
1	3.04	3.40	3.77	4.23
2	2.31	3.21	4.38	4.84
3	3.33	4.01	3.86	4.24
4	3.69	3.88	4.86	4.31
5	3.74	4.01	4.18	4.46
6	3.93	3.62	4.15	4.64
7	3.89	4.26	4.12	4.55
8	3.25	4.41	5.08	4.60
9	5.25	4.81	3.68	4.29
10	4.57	4.58	4.92	4.22
11	3.88	2.74	4.71	4.77
X	3.72	3.90	4.33	4.47
Sx	0.77	0.62	0.49	0.23
Cv, %	20.82	15.91	11.28	5.15
LSD_{05}	**0,53**			

The results of the studies in 2013 showed that the desired, expected and emerging in previous years trends remain unchanged. On average per facility, OM accumulation in the topsoil was 0.12%, therefore, the annual growth of OM content was 0.03%. In the subsoil, the growth of OM during the entire period was 0.14%.

Reference point No. 9 is located on a plain in initially non-eroded soils in the conditions of more intensive use of crop rotation with arable crops. Within the sixteen years of the preceding stages, the organic matter content both in topsoil and in subsoil layers decreased by 12 and 30%, respectively. The reason is that in previous years, removal of nutrients by crops demanding to soil fertility, which are primarily located in flatlands, was not compensated by introduction of either organic or mineral fertilizers. Harvest creation mainly consumed potential fertility, organic matter mineralization was high, which resulted in a reduction of its content.

The last stage of the survey showed that even in this case, the negative tendency was broken; a very considerable increase in organic matter content is observed, both in topsoil and in the subsoil layers - 0.29% and 0.61%, respectively. The growth rate was 0.07% and 0.15% per year.

As shown in Tables 1 and 2, organic matter content in eroded soils (all other reference points) varied non-uniformly due to various conditions of soil fertility use (crop rotation, fertilizers, tillage, etc.). However, the average organic matter content in various years indicates certain tendencies in its dynamics. Due to less significant harvest than in the plain, nutrients removal by plants decreased. Stabilization of fertility and its subsequent growth was caused by reduction of soil loss due to its removal by melt water and storm water in a system of soil protection measures, mainly water-regulating forest belts, as well as introduction of perennial grasses in crop rotation on slopes.

Observations in 2013 showed that in recent years agricultural producers have allowed themselves to cultivate sunflower on slopes, which is contrary to the principles of adaptive crops placement, however, the dynamics of OM content is positive.

It should be noted that statistical analysis of the results of 4 stages of monitoring revealed no significant difference for the topsoil. This again emphasizes the characteristic sharp contradiction between the rate of erosion loss and the rate of soil formation. However, the variation coefficient that decreases with each stage of survey confirms that the positive processes in the soil are not accidental. In 1993 it was 13.5%, and then decreased sequentially to 10.5% in 2004, to 9.2% in 2009, and finally, in 2013 it is equal to 5%. This points to the fact that soil-forming processes in all reference areas that describe this model facility are unidirectional and serve the same goal. This is supported by a significant increase in organic matter content in the 20-40 cm layer; this value increased by 0.75% (LSD_{05} = 0.53).

3.2 Dynamics of Soil Reaction (pH)

Another argument in support of the non-randomness of positive dynamics of organic matter content in soil of the "Repny Log" facility is a statistically significant change of pH_{KCl}.

The main factors that determine acidity of eroded soils are the nature of parent rock material, natural features of genetic soil horizons that form topsoil, the degree of erosion and soil cultivation (Chestnuts, Yavtushenko, 1997). The south-eastern and eastern districts of the Belgorod region, including Krasnogvardeiskiy district, are characterized by significant development of water erosion. As a result, prevailing ordinary and carbonate black soils formed on cretaceous parent rocks are characterized by high alkalinity (Solovichenko, 2005). Therefore, reduction of pH of the studied soils will indicate their improvement.

Indeed, our results show that there was a significant decrease in the pH_{KCl} value of topsoil from 7.57 in 1993 to 6.82 in 2003, to 6.36 - in 2009 with LSD_{05} = 0.40, and finally in 2013 pH_{KCl} = 6.31, indicating that the stabilization of soil reaction in the area of neutral values of this indicator (Figure 1).

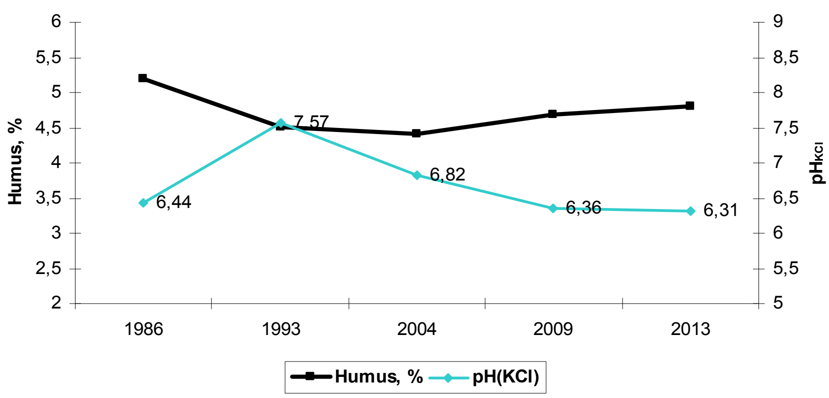

Figure 1. Dynamics of organic matter and pH_{KCl} in topsoil of the Repny Log model facility

For subsoil, the difference between the values of the studied indicator in previous periods was also significant at 5% of the level of significance (LSD_{05}= 0.34). The pH_{KCl} value = 6.35 in 2013 indicates stabilization in the area of neutral reaction (Figure 2).

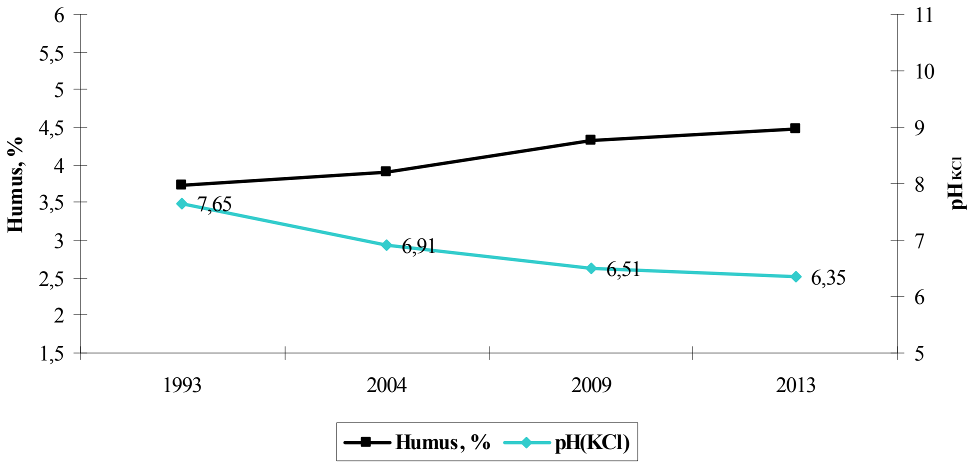

Figure 2. The dynamics of organic matter content and pH_{KCl} in the subsoil of the Repny Log model facility

The observed negative significant correlation (r = -0.57) for topsoil, and very tight correlation (r = -0.94) for subsoil between studied parameters also speak in favor of the predicted dependence of medium reaction on the content of humus. Figures 1 and 2 show typical mirror behavior of the dynamics diagrams for medium reaction and content of organic matter in topsoil and subsoil of the Repny Log model facility.

3.3 Changes of OM Content in Soils of "Krasnogvardeiskiy Range"

Studies of the effect of Landscape Agricultural Systems on soil fertility were also performed in the model agro-ecosystem "Krasnogvardeiskiy Range". "Krasnogvardeiskiy Range" is an interesting facility for studying the relief conditions effect on soil fertility. Relief elevations here are 76 m. Presence of the southern and northern slopes make it possible to estimate the direction of soil processes, depending on slope exposure. As already noted, soil is the moderately eroded residual carbonate humus. Study of calcareous soils (typical carbonate black soil, ordinary and residual-carbonate black soils) is of particular importance for the Belgorod region, since their share in the total area is about 8%, and in the structure of arable soils they occupy 19.4% (Solovichenko et al., 2007). Distribution of calcareous soils and cretaceous denudations is typical not only for the Central Chernozem zone, where, according to the current estimates, their area is over 800 thousand hectares, and is expected to increase in the future up to 3 million hectares or more (Solovichenko, 2005). The area of calcareous soils in the world reaches 800 million hectares (FAO, 2000).

Research shows that over 29 years after the anti-erosion development of the area, there was a statistically significant increase in the content of organic matter in topsoil (0-20 cm). In general for the water catchment, the excess over baseline was 29% (Table 3). OM accumulation is already observed in the first period of the area transformation. Rate of increasing OM content between 1985 and 2004 was 0.03% per year. In the next five years, the rate of growth of the main fertility factor was maintained at the level of 0.02% per year, and between 2009 and 2014 - at 0.03% per year.

Table 3. The dynamics of organic matter content (%) in the topsoil (0-20 cm) of the Krasnogvardeiskiy Range

Element of relief	Field	Years			
		1985	2004	2009	2014
Southern slope	1	2.29	3.85	3.97	3.53
	2	2.31	3.13	3.64	3.23
	3	2.40	2.77	3.19	3.35
	4	2.50	2.95	2.87	3.56
	X	**2.38**	**3.18**	**3.42**	**3.42**
	Sx	0.10	0.47	0.49	0.50

	Cv, %	4.2	14.9	14.2	14.6
	LSD_{05}		**0.36**		
Northern slope	5	3.71	3.54	3.13	3.89
	6	3.69	3.52	3.44	3.53
	X	**3.70**	**3.53**	**3.29**	**3.71**
	Sx	0.01	0.01	0.22	0.27
	Cv, %	0.4	0.4	6.7	7.3
	LSD_{05}		**0.25**		
Water catch	**X**	**2.73**	**3.29**	**3.37**	**3.52**
	Sx	0.66	0.41	0.39	0.45
	Cv, %	24.0	12.4	11.7	12.8
	LSD_{05}		**0.27**		

Slopes of opposite exposures are quite markedly different by combination of micro-climatic conditions, formation of hydrothermal regime (Shabaev, Medvedev, 1997), which defines different direction and intensity of soil-forming process (Environmental factors ..., 2009; Luoetal., 1998). All this leads to the fact that the ongoing processes of soil erosion and organic matter mineralization on the southern slopes are more active than in the other elements of the relief. The authors who conducted their research on black soils in the Midland of Russia found that soil of the northern slopes have higher potential fertility (even virgin land) than that of the southern, and in some cases than that in planes with heavy-cropped soils (Kashtanov, Yavtushenko, 1997, Environmental factors..., 2009).

Indeed, analysis of the 1985 data about the content of organic matter in soils of the Krasnogvardeiskiy Range shows that prior to development of Landscape Agricultural Systems on the slopes of southern exposure, this rate was 35% less than in the northern slope. Obviously, soils of both southern and northern slopes lost a significant amount of OM during their agricultural use. Approximate value of losses can be defined by indicators of undisturbed counterparts.

In our studies, the reference point may be the OM content in topsoil of the two reference points, one of which is fixed in the forest belt located on the watershed, and the other - on the pasture of the northern slope. The first point is characterized by OM content in the topsoil - 5.7%, the second one - 5.4%. This is confirmed by the message (Solovichenko et al., 2007) that residual carbonate black soils in the topsoil contain 5.6% OM. Thus, OM loss in soils of polar slopes of the studied water catch amounted to 34-57%.

However, after LASs implementation, direction of soil processes on the southern slope changed, while northern slopes continued to lose arable soil fertility. The rate of loss between 1985 and 2004 amounted to 0.01% of OM per year. In the next five years, they increased to 0.05% per year. This is largely due to the introduction of row crops and fallow into crop rotation in recent years after changing land owner. Only the last stage of the survey revealed a significant increase in organic matter content to 3.71 %, which made it possible to reach the initial level of 1985.

Previous stages of the study (2004 and 2009) showed that soils of the southern slope are characterized by accumulation of organic matter at quite a significant pace. They amounted to 0.04% of OM per year between 1985 and 2004 and a little more, 0.05% per year, between 2004 and 2009. The last five years have seen stabilization of organic matter content in soils of the slope of southern exposure at the level of 3.42%. Obviously this was due to reduction of soil erosion and preservation of corn-and-grass crop rotation on these lands.

Due to lack of data for 1985 about humus content in the subsoil, we can follow the change of this parameter only during the last ten years (Table 4). Results of the research showed that in all elements of the relief the content of organic matter increased in subsoil, both in the whole for the water catch by 0.5% (LSD_{05} = 0.35), and for the southern and northern slopes - by 0.45 % ($F_{act.}<F_{theor.}$) and by 0.59% (LSD_{05} = 0.35), respectively. The average growth rate was 0.05% per year. Despite the fact that the increase in organic matter content at the southern slope is statistically insignificant, it is backed by a decrease in the coefficient of variation with each stage of the survey from 28.7% in 2004 to 18.5% in 2009, and finally to 11.5% in 2014.

Table 4. Dynamics of humus content (%) in the subsoil (20-40 cm) at the "Krasnogvardeysky Range" facility

Element of relief	Field	Years 2004	2009	2014
Southern slope	1	3,26	2,87	2,69
	2	1,85	2,97	2,78
	3	1,83	1,98	2,90
	4	2,42	2,31	2,79
	X	**2,34**	**2,53**	**2,78**
	Sx	0,67	0,47	0,32
	Cv, %	28,7	18,5	11,5
	LSD_{05}		$F_{act.}<F_{theor.}$	
Northern slope	5	2,52	2,70	3,41
	6	2,93	3,07	3,23
	X	**2,73**	**2,89**	**3,32**
	Sx	0,29	0,26	0,15
	Cv, %	10,6	9,1	4,5
	LSD_{05}		**0,35**	
Water catch	**X**	**2,47**	**2,65**	**2,97**
	Sx	0,57	0,42	0,37
	Cv, %	23,1	16,0	12,5
	LSD_{05}		**0,35**	

In some studies (Wei et al., 2008; Miller et al., 1998), it was shown that organic matter content varies according to the position on the slope. Pierson and Mullah (1990) found that the content of organic carbon is typical of soils located at the foot and the lower part of the slope. According to (Wei et al., 2008; Gregorich, Aderson, 1985), content of organic carbon increases down the slope. The authors associate such a spatial distribution to erosion processes, which resulted in washing topsoil out; it especially affected areas of the top part of the slope, at the same time eroded soil was deposited in relatively low parts of the water catch.

Our research showed that the topsoil in the lower part of the slope contained more organic substances than the top and the middle parts. However, it should be noted that in the last period, when intensive development of erosion processes was stopped, accumulation of organic matter in the middle and top parts of the slope was faster than in the bottom. The results of the last stage of the study (2014) point to normalization of this indicator in various parts of the southern slope, both in topsoil and subsoil.

Thus, preservation and accumulation of organic matter in soil of model facility "Krasnogvardeiskiy Range" indicates high efficiency of Landscape Agricultural Systems. The rate of change of humus content is differentiated depending on the relief conditions and completeness of LASs implementation.

In whole, according to a survey of regional agro-chemical service, contents of organic matter in the soils of the Krasnogvardeiskiy district have increased during last twenty-five years from 4.8% to 5.2% (Kotlyarova et al., 2013). Excess of today's humus state over the original is over 8%. The purpose of Landscape Agricultural Systems has been achieved. We managed to not only prevent intensive erosion losses, but to increase soil fertility on this basis as well.

3. Conclusion

High degree of erosion processes in the Belgorod region as a whole, and in the studied Krasnogvardeiskiy district in particular is mainly due to complex erosion-dangerous terrain and used technologies. The loss due to erosion of soil before the implementation of LASs reached "catastrophic" values of 1 cm per year. After LASs implementation, the monitoring research showed positive dynamics of organic matter content in soils of two model facilities and the Krasnogvardeiskiy district as a whole. During the period of the study, the content of organic matter in soils of the "Repny Log" facility increased by 0.30% in the 0-20 cm layer, and by 0.75% in the 20-40 cm layer, and in soils of the "Krasnogvardeiskiy Range" facility - by 0.79% (0-20 cm) and by 0.50% (20-40 cm), in whole for the Krasnogvardeiskiy district - by 0.4%. However, the rate and direction of the soil-forming process in various periods of time have been non-uniform and depended on the degree of landscape agricultural systems development (including age), as well as relief conditions (steepness, slope exposure, placement on the slope) and the state of soil cover.

During the 27-year period of monitoring soil at the "Repny Log" facility, it has been found that in the first stage of LASs development soil loss in topsoil reduces 10 times from 0.1% to 0.01% per year. In the next period that covers the last 2 stages of the study, a marked accumulation of organic matter is observed at the average rate of 0.05% per year. Despite the fact that these changes in the topsoil were statistically unreliable at 5% of significance level, the non-randomness of positive dynamics of organic matter content is supported by statistically significant change in the pH_{KCl}, since these indicators in this case are closely correlated, by the reduction of the coefficient of variation and, most importantly, by a statistically significant increase in organic matter content in the 20-40 cm layer.

The study of humus soil status of the «Krasnogvardeiskiy Range" facility during 29 years has established a statistically significant increase in organic matter content in topsoil and subsoil by 29% and 20%, respectively, for the whole water catchment.

Thus, landscape agricultural systems are able not only to reduce the rate of soil erosion, but also to prevent it and to enhance soil fertility. This provides a basis for decision-making about their large-scale development in erosion-dangerous regions with intensive agricultural production.

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