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ECOLOGICAL ADAPTATION OF EROSIVE-HAZARDOUS AGROLANDSCAPES, BOTH CURRENT AND EXPECTED CLIMATIC RISKS TAKEN INTO ACCOUNT

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Abstract. Results of long-term research into soil erosion processes on slope lands of southern exposition in central non-black soil area are provided in the article. It has been established that mulching soil with plant residues, against the background of minimization, in particular, is very important both cultural and biological practice, a powerful means of complex influence upon both soil processes and the functioning of erosive-hazardous agro-landscapes. Mulching under present unfavourable soil-climatic and weather conditions favours both preservation and reclamation of eroded soils, thus, ensuring reliable protection against erosion. In full it shows itself on a slope of four-degree steepness, where the quantity of melt water runoff is only 1.5 mm, in the absence of considerable loss of eroded, washed away soil. It is of great agro-ecological importance in adaptation of erosive-hazardous agricultural lands to both current and expected climatic changes.

Key words: climatic changes, slopes of southern exposition, erosion of soils, mulching, minimization.

Introduction

Increasing ecological unbalance of both environment and climate has become the most important problem for modern society, requiring cardinal change in philosophy of our attitude to environment. Conflict with nature, accompanied by an increase in the number of ecological disasters and their globalization, sharply puts a question of biosphere stability maintenance. Therefore, the head of the government signed a climatic doctrine of Russia at the end of 2009 that predicts possible consequences of global warming for the country. Forecast climatic changes in 10-20 years, by leading scientists and specialists, on the whole, will carry on the tendencies, observed over the last decades, and surpass expectations, in all probability. In this connection, ways to increase effectiveness of economy, without detriment to ecology, are offered in the doctrine. One of the chief tasks of the government in this direction is to work out methods of main branches of economy adaptation to both current and expected climatic changes.

Farming is one of the most climatic dependant spheres of production activities of man. Both condition and productivity of agro-landscapes, their functioning, lots of technological processes in agro-sphere directly depend on both progress and combination of weather conditions. So, global warming of climate and accompanying decrease in farm production stability [3, 8, 9], cause exigency of both search of and working out, applying of various practices in landscape-ecological adaptation of arable lands use systems. The most vulnerable, in this respect, are slope areas, especially of southern expositions, having low natural fertility but with high natural and anthropogenic stress.

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Methods

Research was done in 1981-2005, during long-term, multiple-factor field experiment M-01-18-OP that was started in autumn 1980, in Podolsk region, Moscow area.

History of conducting the experiment includes two periods. During the first period (1980-1989), on two adjacent slopes of southern exposition three-factor experiment was carried out, whereas, in the second experiment, started in 1990 and continuing up till now, taking into account further development of cropping systems, complex study of allopelagic principles, soil-protecting suitability and ecological adaptability of cultural practices, creating, on this base, principal new landscape cropping systems for erosive-hazardous areas, field experiment was modernized:

Scheme of two — factor experiment 6x2

A. Tillage — B.Slope

1. Ploughing to a depth of 20-22 cm, across the slope — 1.8°
2. Ploughing + Paraploughing — 40-50 cm and cutting slots in 7-8 metres — 2. 4°
3. Beardless plowing to 18-20 cm + Paraploughing in 1.4 m
4. Beardless plowing + subsoil plowing to 38-40 cm
5. Disking to 6-8 cm + Paraploughing in 3-4 metres
6. Surface tillage

Five-field soil-protecting cereal grass crop rotation was used: 1 — oats; 2 — barley with perennial grasses; 3 — perennial grasses of the first year; 4 — perennial grasses of the second year; 5 — winter wheat.

Presowing tillage, with the exception of perennial grasses, includes disking and tillage to a depth of covering the seeds. Main tillage practices were applied differentially. Cutting slots and surface tillage (fall-plowed land) were done in late autumn, when steady freezing of soil to a depth of 3-5 cm was observed; cultivating winter wheat — before sowing; perennial grasses — in autumnal period before freezing of soil. In variants including beardless plowing in combination with paraploughing and chiseling, main tillage was done at the usual time with a combined aggregate PTSH-2.5. In order to increase soil-protecting efficiency of surface tillage after the first cutting of perennial grasses in their second growing season (once a crop rotation) chiseling to the depth of 38-40 cm with the plough PCH-4.5M was applied.

To increase soil — protecting effectiveness of both practices studied and tillage systems, soil fertility, water-holding capacity and more rational use of stubble residues during winter wheat and oats harvesting, since 1990, additional mulching with both ground straw and chaff has been used.

Soil cover of the area is a combination of sod and middle-podzol soils, from light loam to heavy loam, light and middle loam predominating. According to a washing away rate-from cumulic soils to considerably washed away soils, slightly and middle washed away soils predominating. Soil-forming rock is limon.

Results and their discussion

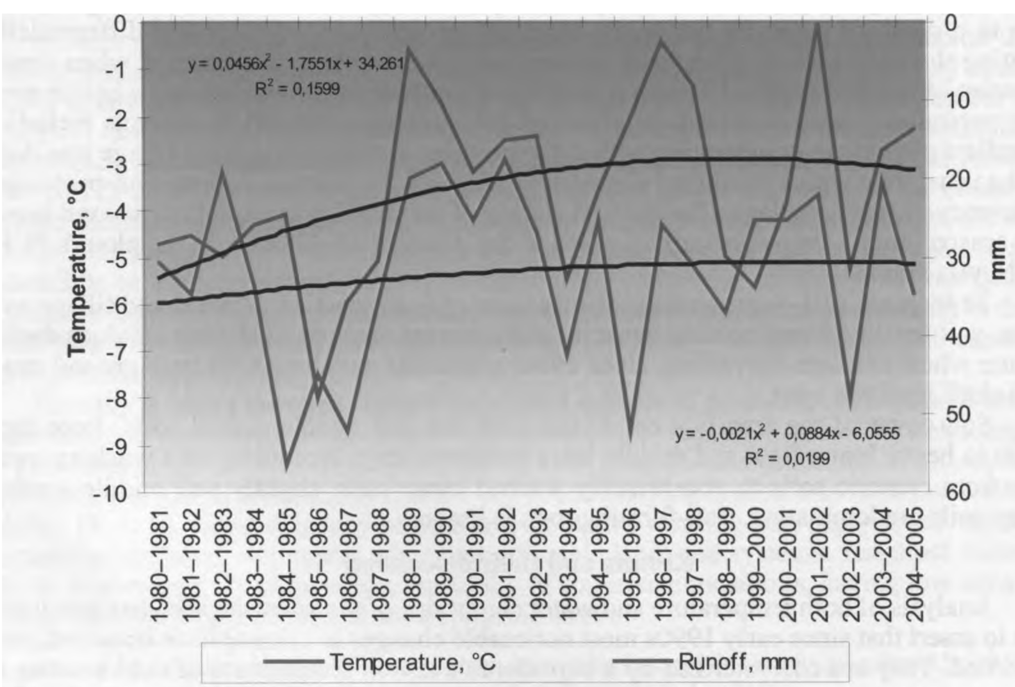
Analysis of both temperature and water conditions of the latest decades has every reason to assert that since early 1990s most noticeable changes in climate have occurred, ever recorded. They are characterized by a considerable rise in temperature of cold seasons of the year, more vaporability, rainfall remains the same or even lowers during warm period, increase in drought recurrence accompanied by simultaneous increase in extreme intensity of both precipitations and temperatures. The latest first decade of the new century, 2010, will go into history as the most dramatic, judging by its social, ecological and economic consequences for modem society and economy of the country.

An important evidence of a global environmental changes and strengthening of their role nowadays in farming is both character and dynamics of soil erosion on slopes of southern exposition. Accumulation and distribution of winter precipitations, water-supply in snow, time and peculiarities of snow melting, soil state and physical processes in it, to a large extent, cause both intensity and direction of ecological changes in such areas.

The process of spring snow melting and destruction of stable snow cover in central non-black soil area, as a rule, begins either late in March or early in April. Depending on global circulating processes development, the date of snow melting beginning and its duration may vary considerably.

The earliest snow cover destruction on slopes occurred in 1990s. Henceforth, in 1990 processes of active snow melting took place on February 23, in 1991 — on February 26, in 1995 and in 2008 — on February 27, in 1998 — On February 28, which is earlier than usual time by longer than a month. And with it, transition periods fuzziness between cold and warm seasons rises considerably

Water inflow in the catchment area, quantitative and qualitative characteristics of runoff, are determined by both melting intensity and water supply in snow. They are due to a temperature condition, both in the period of snow melting in spring and during cold season, on the whole. Steady enough feedback is observed (r = -0.61) between air temperature during cold period and quantitative characteristic of water erosion process (runoff layer) during the first decade of observation, and their noticeable unbalance (r = -0.33) over the last decade (figure).



Trend of air temperature during cold period and surface snow water runoff. Slope of 8°

In connection with sharp, direct influence of external factors on both erosion processes and general functioning of agro-landscapes, especially of southern exposition, and also extreme danger of rapid eroded sols degradation, there is a necessity of additional cultural practices to achieve environmental stability. An important step in this direction is mulching soil surface with ground straw during harvesting of both winter wheat and oats. Mulching is not a principal, new cultural practice. Over a period of its history, which throws back into 1920s-1930s, it aroused various opinions: from positive predominating [4, 6, 7], to rather reserved [5], or even negative [1]. The inconsistency of mulching assessments in agro-landscapes functioning is due to a great variety, complexity and variability of processes both in soil and on its surface. There have never been any studies of the role of mulching, under conditions of steady climatic warming, in eroded sod-podzol soils area.

Mulching soil with plant residues, during the experiment, was used as an additional cultural practice. The comparative analysis of long-term research into various use of straw shows diverse agro-ecological effectiveness of mulching and its effect on eroded soil condition.

Soil-protecting efficiency of mulching, as well as its influence on soil processes, depends, in the main, upon ways of plant residues distribution in topsoil. Mixing of ground straw with soil (vertical mulching) when paraploughing and just plowing in the layer of 0-20 cm, surface tillage and paraploughing in the layer of 0-10 cm (vertical-horizontal mulching) favours, first of all, additional, and often excess, water saturation in upper horizons. Straw makes soil structure mellow and finely porous with a great number of small cavities having very high water-holding capacity over a long period of time. High water-content of the upper layer is also observed when beardless plowing, paraploughing and chiseling (horizontal mulching) are done. In spite of other way of straw distribution, the character and dynamics of water-holding processes in these variants are almost the same when vertical mulching is used. It shows itself very clearly especially in late autumn, after main cultural practices are applied and after heavy rainfall, also during intensive thaws in winter.

Mulching has great, many-sided influence on development conditions, intensity and character of erosion processes when snow melts. Plant residues, distributed not too deeply, either horizontally or vertically, in the layer of 0-10 cm, favour additional accumulation of snow, water supply in the snow, changes in its properties and lowering of soil frost penetration depth. At the same time, excess moistening of the upper horizon, when mulching, increases the level of soil frost penetration, favours ice crust emergence which may lead to reduction in runoff-regulating efficiency of anti-erosion methods and cultural practices in early spring

Snow melting on slopes, mulched with straw, at the first stage of runoff forming, runs uniformly, at the second stage-some differences in variants are observed. Under active, radiative conditions both stubble and straw favours better concentration of sun heat, which increases snow and ice melting rate, ensuring considerable thaw water runoff on frozen soil. Considerable loss of spring moisture on slope soils of southern exposition, resulted from mulching is, undoubtedly, a negative phenomenon, as it causes both negative productive and ecological stress in agro-landscapes. Though, under conditions of warm unstable winters, it is extremely difficult to hold thaw water in a field, and, very often, it's practically hardly possible, one should take measures in order to ensure safe water escape. Allocation of plant residues in sufficient quantities on soil surface completely meets the requirements of agronomists. Moreover, water content stored in soil under mulch, during autumn-winter-spring season often smoothes over these water losses.

Table 1

Soil-protecting methods influence on soil erosion process progress in the years when mulching is used

Variant	Depth of frost penetration before runoff, cm	Water supply in snow before runoff + rainfall, mm	Run-off, mm	Washing away t/h	
				mul-ching	on average (1991–2005)
Slope of 8°					
Plowing (control)	27	75,8	9,3	0,24	0,40
Plowing+Paraploughing	24	71,2	9,7	0,17	0,29
Beardless plowing + paraploughing	23	76,4	10,9	0,15	0,34
Beardless plowing + chiseling	22	72,9	12,3	0,18	0,35
Surface tillage + paraploughing	23	73,7	11,6	0,15	0,33
Surface tillage	21	72,6	13,4	0,26	0,40
Slope of 4°					
Plowing (control)	22	73,2	1,3	0,01	0,15
Plowing+Paraploughing	22	71,7	1,2	0,01	0,10
Beardless plowing + paraploughing	20	76,4	1,6	0,01	0,15
Beardless plowing + chiseling	18	75,1	1,6	0,01	0,14
Surface tillage + paraploughing	19	71,2	1,5	0,01	0,11
Surface tillage	18	74,4	1,7	0,01	0,15
HCP_{05} factor A			0,52	0,09	0,12
B			2,22	0,13	0,21

To make an objective evaluation of soil-protecting mulching effectiveness, under present natural conditions, especially against the background of warm winter periods is rather difficult task. When they use beardless plowing, the effect of this cultural practice on fine earth is ambiguous and depends on various factors. In case of both uneven and insufficient allocation of plant residues on the surface, stubble induces washout, favouring quick melting of both snow and ice crust, thus, causing defrosting of the soil. It thins and becomes liquid and greater kinetic energy of flowing, concentrated melt water flush easily washes it away, increasing its turbidity and general losses of fine earth.

In case of optimal mulch allocation thaw water runoff on a frozen base goes with relatively low detriment to soil fertility. Straw performs a protective function, preventing rapid thawing, but favouring addional cementing soil surface with ice. This is of great importance when soil structure is absolutely destroyed as a result of a cold period unfavourable conditions. Besides that, both stubble and straw disperse the flow without letting it concentrate. This considerably reduces snow water aggressiveness even it flows on a defrosted surface. Time and area of a contact between thaw water and soil can be rather long. Therefore, the less ground straw mixes with soil and the more its surface covered, the more resistant the soil is to washout by thaw water. At the same time, even complete ploughing under the straw (tillage, tillage + paraploughing) ensures reliable enough ecological protection from erosion.

Analysis of anti-erosion resistance of soil to erosive effect of a runoff allows to make an evaluation of mulching stabilizing role, expressed by turbidity indices of snow water per unit of its volume. From anti-erosion variants under study on a eight-degree slope, the minimum fine earth content is 0.013-0.015 g/1 in flowing water, its volume being 10.9-12.9 mm when beardless plowing, paraploughing, chiseling and also surface tillage and paraploughing are applied, which is, on average, 45% lower than in test variant. It is an evidence of more soil surface resistance to both washout processes and destruction by snow water flow.

Further growth of erosion processes on an eight-degree slope is characterized by relatively low indices of detriment to soil fertility, system of cultural practices used. Both soil-protecting and runoff-regulating effectiveness of mulching shows itself in full on a slope of 4 degrees, where the size of a surface runoff, on average, in the variants, is only 1.5 mm, practically, no washout is observed.

According to our results, soil, in which straw is ploughed under vertically in the layer of 0-10 cm, in minimum tillage variant, has poor anti-erosion resistance.

Absolute loss of fine earth on a slope of 8 degrees is 0.26 tones per hectare, when the runoff is 13.4 mm, that is much worse than the test variant analogous indices. Nevertheless, physical resistance of soil to erosive thaw water influence, evaluated by runoff turbidity per unit of its volume is by 25% higher than analogous indices of tillage variant. Surface tillage amplification, by means of paraploughing, favours additional improvement of ecological situation on slopes, where turbidity of snow water decreases by 50% per unit of volume, whereas, real losses of washed away fine earth decrease by 38%.

Runoff turbidity indices are of important, practical significance, one must take them into account when planning and evaluating soil-protecting measures on slope lands. These indices characterize potential resistance of soil to destructive influence of surface runoff. It is very important, besides, when working out ecologically safe methods of soil erosion processes management under present unfavourable soil-climatic and weather conditions in recent years, when runoff-regulating efficiency of cultural practices used considerably fell.

One more way of environmental processes management on slopes through plant residues, in our view, deserves consideration. Harvesting barley with perennial grasses as an intercrop, it was resolved to leave stubble not less than 25-35 cm in height, and at the bottom of the slopes — up to 40 cm (instead of standard 15-20 cm). Strip, natural Assuring and rolling after harvesting machines ensure various height of stubble in the field. It has a certain influence on both accumulation and distribution of snow mass, its structure on a slope, and also on soil frost penetration processes, especially at the beginning of winter. The height of snow in areas with vertical stubble was 5-8 cm higher, and density — 0.03-0.08 g/cm^2 less than in areas with rolled stubble. Snow, due to its rapid accumulation

Table 2

The amount of thaw water runoff and soil washout (t/h) against stubble background

Variant	Frost penetration of soil before runoff, cm	Water supply in snow before runoff + rainfall During it, mm	Duration, days	Runoff, mm	Coefficient of runoff, K	Washout, t/h
Slope of 8°						
Plowing (control)	20	58	5	9,6	0,17	0,01
Plowing + Paraplowing	21	57	5	8,2	0,14	0,01
Surface tillage	16	56	3	6	0,11	0,01
Slope of 4°						
Plowing (control)	15	57	0	0	0	0
Plowing + Paraplowing	15	58	0	0	0	0
Surface tillage	13	59	0	0	0	0

and mellow structure, interferes with intensive chilling of the soil, thus, reducing frost penetration rate of an arable horizon. This index, as you know, is a snow water runoff determinant.

Both in late winter and in early spring insolation energy, accumulated by tall vertical stubble of grain crops, favours considerable acceleration in snow melting processes. Both melting and disposal of snow, against the steepness of a slope, occur 7-13 days earlier than in areas with rolled stubble. Melting away, taking place at different times, and defrosting of soil reduce the danger of unproductive losses of moisture and erosion processes (table 2).

Conclusion

Summing it all up, one can say for sure that mulching soil, especially against minimum tillage, is an important cultural and biological practice, a powerful tool of a complex impact on both soil processes and functioning of erosive-hazardous agro-landscapes. Under present unfavourable soil-climatic and weather conditions, use of both straw and stubble residues ensures reliable enough protection of slope lands from erosion. This is of great agro-ecological significance in order to increase resistance of crops to both present-day and expected climatic changes.

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Аннотация. Представлены результаты длительных исследований процессов эрозии почв на склоновых землях южной экспозиции Центрального Нечерноземья. Установлено, что мульчирование почвы растительными остатками, особенно на фоне минимализации, является важным агротехническим и биологическим приемом, мощным средством комплексного воздействия на почвенные процессы и функционирование эрозионно опасных агроландшафтов. Мульчирующая обработка в современных неблагоприятных почвенно-климатических и погодных условиях способствует сохранению и восстановлению плодородия эродированных почв, обеспечивая надежный режим защиты от эрозии. В полной мере она проявляется на склоне крутизной 4°, где величина поверхностного стока талых вод составляет лишь 1,5 мм, при отсутствии существенных потерь смытой почвы. Это имеет важное агроэкологическое значение в адаптации эрозионно-опасных сельскохозяйственных территорий к текущим и ожидаемым изменениям климата.