AGROECOLOGICAL EFFECTIVENESS OF SOIL EROSION CONTROL METHODS UNDER GLOBAL WARMING CLIMATE CONDITIONS

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Ecological variation resulted from global warming damages stability of erosion harmful agrolandscapes and their balance. The choice of either a cultural practice or the way of tillage in the system of anti-erosion farming should be strictly differentiated taking into account concrete natural climatic conditions of the area.

Key words: global warming, soil erosion, agrolandscapes, run off, antierosion effectiveness, ecological stability, minimalization, slitting, soil degradation.

Experience and modem practice, the world as well, prove it impossible to control water and soil losses on the slopes intensively tilled. However reducing losses and environment pollution can be a real task provided antierosion practices based on landscape peculiarities taken into consideration are introduced.

In the past years climate instability and global warming changes have deformed the main ecology characteristics and landscape conditions that resulted in harmful consequences for farming reflected by the state of slope cultivated soils and processes in them. Cultural practices and soil tillage methods are of special importance in preventing and minimizing negative tendencies in slope arrear ruining.

Methods and conditions

The researches were conducted in 1981-2005 in the permanent field experimental plot M-01-18-OP exposed in autumn 1980 by prof. I.S. Kochetov in Moscow region.

This experiment had two periods. The first (1980-1989) comprised two adjacent slopes on south exposition, where a three stage experiment started. The second period (1990 up today) is under work. The experiments take into account the further soil cultivation systems improvement and are based on the complex study of different depth principles, minimalization, soil protection, expediency and ecological adaptation of soil cultivation practices used for introducing modem landscape farming systems for erosion inclined areas.

The experimental five-course soil protection (cover) crop and grass rotation is introduced with the following time periods: 1-oats; 2-barley + perennial grasses; 3-perennial grasses for the first year utilization; 4- perennial grasses for the second year utilization; 5-winter wheat.

Two factor experience schemes 6*2

A. Tillage	B. Slope
1. Ploughing 20-22 cm deep (Check)	1. 8°
2. Ploughing + slitting 40-50 cm deep at 7-8 m distance	2. 4°
3. Subsurface tillage 18-20 см + slitting at 1,4 m distance	
4. Subsurface + chiselling at 38-40 cm distance	
5. Surface ploughing 6-8 cm + slitting at 3-4 м distance	
6. Surface ploughing	

Seedbed preparation for crop planting except perennial grasses included disking and tilling up to the seed planting depth. Main cultural practices were differentiated. Plowing slits and surface tilling were conducted in the late fall, permanent freezing depth being 3-5 cm; the same practices were used for perennial grasses cultivation in the fall before soil frost penetration. Surface ploughing in combination with slitting and chiseling was applied at usual time with a combined unit. After the first mowing of second year utilization perennial grasses chiseling with the plow was practiced to increase the soil surface protection effectiveness. Ploughing and sowing were done across the slope.

To obtain the above mentioned results of the studied practices and systems of soil cultivation, its fertility, soil moisture conservation and more effective use of postharvensting residues of winter wheat and barley, additional surface mulching with crushed straw and chaff have been introduced since 1990.

Results under their discussion

To understand better the effectiveness of agronomic practices under certain natural-climatic condition of the area it is necessary to summarize data and consequences for a long period. It is also important to distinguish the chosen ways or their combinations for introduction the most effective ones and eliminating useless or even harmful. Information about the up to date natural potential of the certain area is very urgent in this case.

To evaluate non-chernozem zone natural potential recourses of Central Russia we used 25 years meteo observation data (1981-2005) of the Michaylovsky agro-meteo unit "Golohvastovo" located in the area of the field experiment. For example, within the given time period the analyses of the temperature regime of the air surface layer, as one of the most important natural factors, showed a stable tendency to climate wanning. The annual average temperature in this area was 1.5 C higher than the standard one.

More essential alterations were marked in the dynamic of natural-climatic characteristics and their distribution within a year. Considering peculiarities of a crop production process, we took for analyses meteorologic conditions of the most important periods in the farming year that is a cold season (November-March) and the main vegetation period (May-August). Taking into account rapid climate warming, the 25 years observe period was divided into two subperiods of 10 and 15 years correspondingly, reflecting undergoing climatic changes.

For the last decades the cold season temperature has grown by 2.3 C and now it is -5.4 C (standard -7.7 C). However, temperature raising rate hasn't been high, trend is statistically insignificantly low (R^2=0.12). There exists essential temperature fluctuation. The process of winter warming, that is stable predominance of repeated warm winter seasons over cold ones, gained speed since late 1980s and especially in early 1990s. Most noticeable temperature fluctuations occurred within separate months. Temperature in January, February and March was higher than mean annual one. Total raise was approximately 2.6 C and the temperature regime was 0.7 warmer than that during the first 10 years of the experiment. (Table 1)

Table 1

Average air temperature of the cold period, C

Periods, years	Mohth					Average for the period
	November	December	January	February	March	
Perennial average	-2,8	-8,4	-11	-10,3	-5,8	-7,7
1980-2005	-2,6	-6,6	-7,1	-7,8	-2,7	-5,4
1980-1990	-2,8	-6,4	-8,2	-8,7	-2,7	-5,8
1990-2005	-2,5	-6,7	-6,4	-7,3	-2,7	-5,1

The tendency to constant growth of warm days in cold seasons with a temperature rate O C (R=0,44) is the fact that arises no doubt. Moreover, the distribution of such days within a period tends to be preserved. In the first decade (1980-1990) the amount of warm days corresponded to the standard (34) but in 1990-2005 this number increased by 76 %. The number of intensive thaws with temperatures above 2.5 C grew more than twice and it is very harmful for soil characteristics as it decreases its run off regulation and protection abilities.

The same tendency was stated by the observatory named after V.A. Mihelson at Russian State Agrarian University - Moscow Timiryazev Agrarian Academy. 125 years temperature rate data was analysed. Thus summing up these results we can ascertain visible climate warming in the Central Non-Black Soil Regions by late XX early XXI century period, especially in winter of the last decades.

Sowing crops and grasses in rotation on the southern hills with various slope angles we designed different technology schemes of tillage on the basis of mould board ploughing, subsurface, slitting, chiselling, surface ploughing and their combinations applied in different intensity and depth. Complex evaluation of the agroecology effect was the main task of this experimental project.

Technology modelling proved different ploughing of sodpodzole clay loam soils formed different soil profile structure influencing erosion processes during snow melting. For example fall tillage across the slope in combination with 40-50 cm deep slitting and in accordance with each crop individual sowing period, provided evident reduce of surface runoff. Soil loosening and surface turn over, slitting soil layers with stands and thinning with slitter chisels under plough layers promoted active transaction of thaw waters into soil where moisture level was low and freezing was mild. The area of water and soil contact increased, intensifying absorption and distribution in deep soil layers. The effect of runoff regulation slitting was especially noticeable during the first two rotations when the surface runoff on slopes with 8 and 4 ’ angles reduced in relation to the check variant by 40-50% (Table 2)

Table 2

The effect of anti-erosion soil tillage and landscape on the surface snowmelt runoff formation, mm

Variant	Crop rotation, year				
	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005
Slope 8^0					
ploughing(check)	27,4	28,4	20,7	16,9	14,2
ploughing+slitting	19,2	14,3	17,3	16,3	15,8
subsurface+slitting	-	-	25,7	19,3	16,3
subsurface+ chiselling	-	-	20,6	17,6	19,2
surface+slitting	-	-	18,7	17,2	17,7
surface	34,8	33,7	20,8	17,1	18,5
Slope 4^0					
ploughing(check)	13,8	9,9	7,2	8,5	4,4
ploughing+slitting	7,4	4,6	7,9	9,4	4,4
subsurface+slitting	-	-	10,4	9,5.	4,6
subsurface+chiselling	-	-	8,4	8,9	4,4
surface+slitting	-	-	7,0	9,2	4,4
surface	13,0	12,0	10,3	9,3	4,7
HCP_{05} Factor A	5,8	9,1	1,9	1,7	2,5
B	7,1	11,2	3,3	3,0	4,3

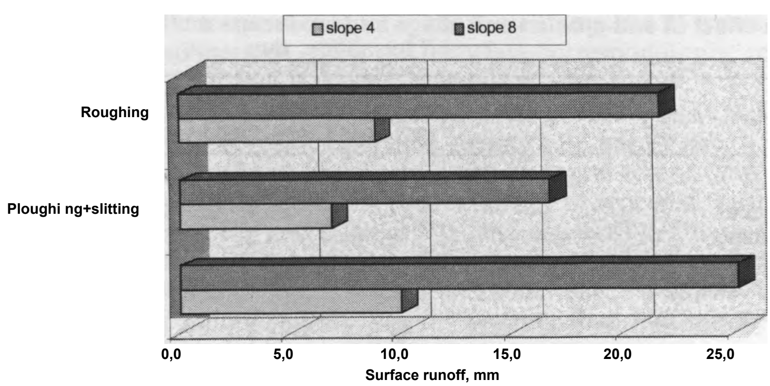
Water regulation slitting and other erosion control practices are affected negatively by wanning in cold periods. Intensive thaws and rainfalls in winter result in overmoistening of cooled soils, ice crust formation and hardening the arable layer. Under these conditions large porous structure of the soil layer does not yield well. And what is more, filling nanows and hollows water reinforces the further freezing processes in the soil, favouring the formation of practically waterproof soil layer. Following thaw releases nanows from ice, water absorption grows but in this case slitting has not any noticeable advantages in relation to mouldboard ploughing or to other examined variants of tillage.

Being conducted yearly ploughing 20-22 cm deep across the slope has made a good showing. Intensive surface layer thinning, vacant pores and large interaggregated hollows, smooth well structured fall-land provide effective water retention, thaw runoff redistribution and moisture penetration into soil. Runoff control effect of ploughing has noticeably increased lately along with the decreasing of frost penetrated soil level, though this relation is not obvious (r=0.28). Nevertheless, underplough bust, poor resistance of the surface layer to erosion and numerous thaw avalanches make application of this agro technique worthless especially on steep slopes.

Water regulating subsurface ploughing together with slitting and chiselling during unstable winters showed very modest affects among all other variants, especially on 8^0 slopes. Plant residues provided more moisture to the soil surface late in the fall and during winter thaws decreasing soil infiltration capability and surface runoff.

All ploughing practices in different landscapes reflect the tendency to surface runoff reduction in relation to crop rotation. Though the volume of winter rainfalls and water stored in snow before spring have increased obviously for the last 15 years, runoff has decreased by 24 %. The most critical cut has been found on slope 8^0. This fact has to be taken into account as it concerns scopes with high erosion risk.

Comparing various agrotechno practices of surface runoff regulation one should note that slittering, being not so effective lately, still has its advantages and remains of cunent importance. It enables to reduce non-productive moisture losses on slopes with 8 and 4 angles to 24-23 % in comparison with surface tillage (Picture 1)



Pict.1. Anti-erosion practices and their effect on the surface snowmelt runoff, 1981-2005

According to the intensity scale the amount of water from melted snow during the experiment varied from very low (up to the 7 mm) to high (41-75 mm) level. Maximum level was fixed in 1986-59,8 mm with the runoff coefficient 0.42. In most cases technoecological schemes were modelled and developed, such as soil erosion protection on slopes with big (4°) and very big (8°) level of potential erosion risk. They were a success in controlling surface runoff with low and moderate intensity.

Soils dispose the weakest water regulation abilities after surface tillage. Minimalization (disking 6-8 cm deep) does not provide efficient thinning of arable layer even if additional chiselling 38-40 deep is practiced once in the rotation period. But some positive changes have been introduced in the infiltration processes caused by soil fertility improvement. The geterogeneous structure of the arable layer (compaction layer deeper than 8 cm) and low water detention accumulating surface capacity lead to additional losses of thaw water on slopes. Together with poor soil erosion resistance of the surface layer it reinforces the general erosion processes.

Table 3

The effect of anti-erosion tillage and relief on the surface washing, t/hec

Variant	Crop rotation, years				
	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005
		Slope 8^0			
ploughing(check)	0,348	0,336	0,696	0,176	0,336
ploughing+slitting	0,146	0,134	0,536	0,092	0,256
subsurface+slitting	-	-	0,668	0,158	0,188
subsurface+ chiselling	-	-	0,694	0,098	0,270
surface+slitting	-	-	0,602	0,096	0,294
surface	0,606	0,470	0,740	0,074	0,390
		Slope 4^0			
ploughing (check)	0,074	0,062	0,402	0,016	0,028
ploughing + slitting	0,028	0,024	0,268	0,020	0,018
Subsurface+ slitting	-	-	0,420	0,018	0,028
Subsurface+ chiselling	-	-	0,328	0,014	0,016
Surface + slitting	-	-	0,300	0,018	0,016
Surface	0,068	0,070	0,392	0,020	0,030
HCP_{05} factor A/B	0,159/0,194	0,131/0,161	0,150/0,259	0,050/0,088	0,073/0,126

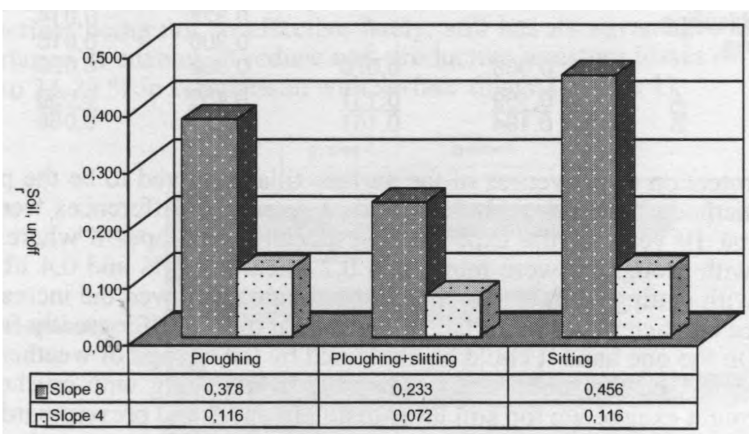
Soil protection effectiveness of the surface tillage proved to be the poorest among the studied methods during the whole period of research. Differences were the greatest during the first 10 years of the experiment, especially on slopes 8 where soil losses in comparison with ploughing were more than 0,2 t/hec or 57 % and 0,4i/hec or 78% in comparison with slitting. But the last three crop rotations showed the increase of soil erosion resistance characteristics of surface tillage and it didn't differ greatly from other agro techniques. On the one hand it could be explained by the change of weather conditions in winter and spring, on the other hand application of mulching with crushed straw since early 1990s might exaggerate top soil layer distinctiveness and prevent hard wash out and runoff.

Additional slitting enlarged noticeably soil resistance effect (Surface + slitting). Slitting with row distance 3-4 mm and thinning with chisels 40-50 cm deep helped to raise absorption intensity of water from melted snow by 10 % and to decrease the runoff erosion consequences by 22% in comparison with the application of disking alone.

The first two rotations with a range of farming practices and their combinations stopped short arable erosion and rotations with surface tillage application decreased it noticeably. But weather and climate changes in the early 1990s made alterations in the positive tendency. There were sudden changes in soil degradation intensity during the third crop rotation period. It rocketed up. But in the forth rotation it slowed down rapidly, and in the fifth one it accelerated again. So that period could be defined as unfavourable for sustainable and ecologically safe management of erosion risky agro landscapes.

To raise moisture storing ability of soil, slits should be done as often as possible. During the field experiment some new tillage combinations were developed and introduced to meet this requirement, for example, subsurface + slitting and chiselling. Since 1990 we have started researching various combinations of different layers mould board ploughing with slitting every other 1,4 m and 0,7 m with chiseling. The experiment was carried out under cold weather unstabile conditions. That's why it was impossible to evaluate fully the effectiveness of the subsurface slitting. Whereas combined non-mould board tillage has potentially high anti-erosion effect due to the stirring up of water absorption processes provided by loosening arable and subarable soil horizons, leaving stubble residues on its surface and lessening technology burden. In spite of complicated circumstances the experiment showed that losses of small particles owing to erosion processes were not big in cases when non mould board agropractices applied.

Analysing the role of the worked out tillage projects and developed technologies for the 25 years period survey within the frames of the permanent multifactor field experiment, it is necessary to stress once more the ecological importance of the method 'ploughing + slitting'. (Picture 2) Productive thinning of arable and subarable horizons provided soil losses decrease in comparison with traditional ploughing and surface tillage by 39% and 44 % consequently. Being an important soil protection method in the system of agrotechno practices aimed to improve ecology and crop growing stability slitting provides real soil fertility conservation on slopes, development of their qualities and regimes, decreasing negative affect of erosion on the environment. But warm winters of the previous years do not let us consider this way rather optimal because of poor runoff regulation effect of slits.



Pic.2. Anti-erosion practices and their effect on soil losses, t/hec 1981-2005

Table 4 exhibits general characteristics of soil erosion processes during snow melting for a long research period including main results of all regulated antropogeneous and unregulated ecological factors determining this process.

Relief being complex and risky for soil degradation processes, slope angle is of great importance. The higher is the slope angle the bigger will be the possibility of soil erosion. It has been proved by depth and level of soil profile frost penetration, time and intensity of snow melting and runoff coefficient. All above mentioned facts together with unfavourable weather conditions heighten ecological soil loading on such slopes, soil degradation processes growing with specific intensive extent dependence. For instance, if surface melted snow water runoff increases 2.5 times soil losses increase 3.5 times correspondingly.

Table 4

The effect of soil protection practices and relief on erosion processes formation and development, 1981-2005

Variant	Soil frozen depth beforerun off, sm	Water amount in snow before run off +rainfall during the flow,mm	Run off period twenty0four hours	Runoff, mm	Runoff coefficient	Soil nash off t/lec
		Slope 8⁰				
ploughing(check)	34	76,4	7,3	21,5	0,30	0,378
ploughing+slitting	32	74,6	6,7	16,6	0,24	0,233
surface+slitting	33	75,8	7,2	25,0	0,33	0,456
		Slope 4⁰				
ploughing(check)	30	79,1	3,8	8,8	0,12	0,116
ploughing+slitting	30	78,4	3,5	6,7	0,10	0,072
surface+slitting	30	80,1	3,9	9,9	0,14	0,116
NSR A/B				2,8/3,4		0,061/0,075

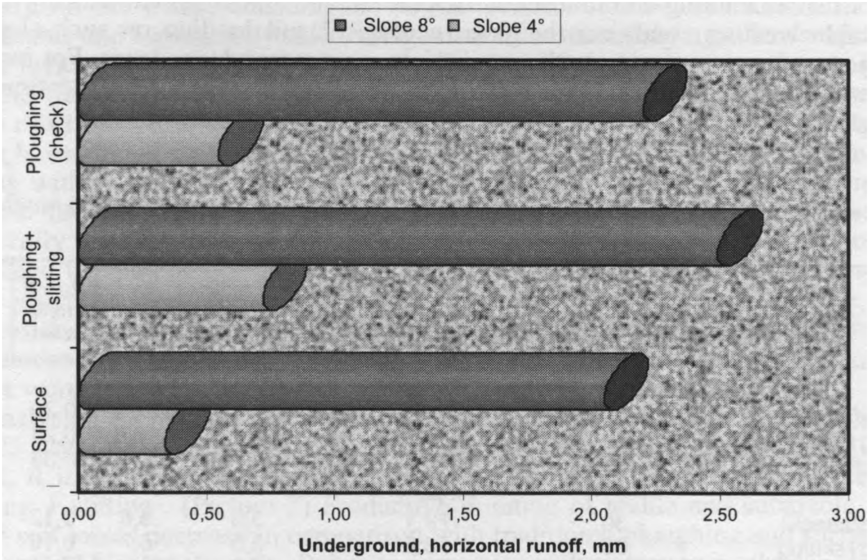
prevented nonproductive moisture losses in comparison with checked method and surface ploughing. Losses of moisture decreased by 23 and 34%, runoff ratio declined to 0,06 and 0,09 and soil wash out dropped by 39 and 46%. The same results were obtained on slopes 4°.

Anti-erosion effect of slitting and other slope tillage methods can be confirmed by the analysis of the surface snowmelt runoff redistribution to the more safe subarable flow horizons. The problem was studied over a long period of time during the experiment with aqua balanced plots of 20 and 50 cm deep. (Table 5)

Nowadays no research of underground horizontal melted snow water runoffs is at work in the Central non-black zone of Russia. The reason might be the lack of proper conditions for observations though this item is of primary importance in the runoff regulation system. Under certain conditions Snowmelt runoff redistribution from the surface to the underground soil levels benefits to detaining wash out processes and soil destruction by running off water. Besides, it is impossible to control soil moisture distribution in the aqua-balance of slope lands without considering horizontal runoff.

Long term experimental research stated the most effective features influencing the underground horizontal runoff flow formation. They are moisture conditions, depth and rate of soil frost penetration, snow melting intensity, arable horizon melting and the degree of soil compression as well.

Slope angle in this connection is of importance too, as it is the slope that makes water move, both on the surface and underground. If slope angle rises twice (from 4° to 8°) the amount of underground water flow increases 4.2 times. The most noticeable differences in the results (more than 5 times) were found in warm winters. The amount of water infiltrated into the soil with the horizontal runoff formation made up 10% to the total amount on slopes 8° and 6% - on slopes 4°, the main horizontal formation being 50 cm deep (96%).



Pic.3. The effect of anti-erosion practices on underground horizontal snowmelt runoff in relation to slope angle, 1981-2005

Underground, horizontal runoff, mm

Table 5

The effect of anti-erosion practices and relief peculiarities on the amount of underground horizontal snowmelt runoff, mn

Variant	Crop rotations, years				
	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005
			Slope 8		
poughing check)	2,76	2,86	0,44	1,60	3,36
ploughing+slitting	3,56	4,10	0,34	0,80	3,64
srface poughing	2,40	1,80	0,52	1,90	3,64
			Slope 4		
poughing check)	1,54	0,02	0,12	0,14	0,92
ploughing+slitting	2,20	0,12	0,20	0,18	0,90
srface poughing	0,90	0,02	0,02	0,08	0,68

The most intensive underground runoff in the sodpodzole zone was provided by slitting appliance. Beneficial soil structure due to mechanical slittering tillage makes available optimal conditions for surplus moisture infiltration into soil. In this case the amount of horizontal runoff on the slope 8° was 13% and 21% higher than in the variants of common ploughing and surface tillage. Provided still more The differences became more obvious on slope 4°, the amount of horizontal runoff being 31 and 111% consequently. Disking appliance has also shown good results lately. Thus redistribution of snowmelt runoff from the soil surface into underground layers due to slitting and mineralization favours soil aqua regime and decreases destruction rates of upper horizon by runoff. Nevertheless positive result doesn't reject any other methods but promotes their differentiated application considering certain local soil and weather conditions.

To sum up, the long term researches on ecological slope farming showed that any cultural practice and tillage method on slopes under consideration has its pro and contra. Sod-podzol soil erosion extent depends on both intensive antropogeneous intervention and changes of soil regimes and their characteristics. Both climate instability due to global warming and dramatic effect of external factors on landscape complex life make the evaluation of soil erosion processes less possible. One should pay particular differentiated attention to cultural practices applied in the system of erosion control farming taking into account peculiarities of the concrete landscape.

Bibliography

1. *Kashtanov A.N.. Yervtushenko V.J.* Slope soil agroecology. M. Kolos, 1997

2. *Kashtanov A.N., Sherhakov A.P., Shvebs G.l. and oth.* Concept of highlyproductive ecologicaly stable agrolandscape formations and farming landscape systems development. Kursk, 1992

3. *Lomakin M.M.* Mulching practices on slopes M., Agropromizdat, 1988

4. *Sennikov V.A., Larin L.G., Belolubzev A.I. and oth.* Petrovsko-Razumovskoye climate fluctuation and changes for 125 year period observation, News, 2005 cd 1. P. 141-146

5. *Bollerweg P.* Modelling the effects of climatic change on runoff and erosion in central southern Norway. Conserving soil resources. European Perspectives, 1994. P 273-285