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The Impact of Melt- And Rainwater on Soil Erosion by Water in The North-Western Part of Stavropol Upland.

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ABSTRACT

The article describes the data on snowmelt runoff and soil loss depending on the slope exposure on the territory of Stavropol upland and the relationship between the amount of soil loss and runoff rate. It also outlines the impact of the main types of cultivation on the degree of soil erosion by melt-water as well as the influence of the runoff on the amount of eroded soil due to intensive rainfalls over the tilth.
Keywords: erosion by water, soil loss, land runoff, slope, soil cultivation

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INTRODUCTION

Water erosion is the result of the outwashing activity of water on the earth surface. Water erosion depends on the land runoff and the depth of erosion base, inclination, length and shape of slope. On a short slope with low inclination (up to 1^o) there is almost no sign of erosion, while it becomes more noticeable with the higher slope inclination and length [1].

Critical inclination of slope, i.e. the starting point of intensive outwash, depends on regional and local conditions and on land runoff which is influenced by the acreage type (tilled field, layland or forest) [2],[3].

At first, deluvial erosion which is characterized by sheet flood followed by washing-out develops on the slopes. It is the first stage of erosion while the rill erosion is its second stage. Sheet and rill type of erosion occur simultaneously [4].

As a result of sheet erosion and in some areas regardless of it, gullies begin to form according to the following stages: 1) the development of drains and washouts with the slope-contoured bottom; 2) the development of gullies with growing heads; 3) the growth of bottom-contoured gullies; 4) gradual extinction of bottom washout at the base level alongside with the flattening, strengthening and grassing of the slopes and the bottom. At this stage, a gully becomes a cavin with flat grassy slopes and wide bottom, frequently without obvious bed. Sometimes rill erosion continues, which leads to the development of a new bed [5].

Soil erosion by water depends directly on the climate. It becomes more intensive with high and intensive rainfalls in summer and snowmelt in spring. The latter is particularly noticeable on the southern slopes. Deep soil freezing due to the reduced infiltration during snowmelt contributes to faster erosion [6]. Vegetation that increases surface roughness and entraps land runoff affects water erosion largely. Vegetation, meadow grasses in particular, prevents erosion directly and indirectly, blocks runoff, enriches soil with humus and makes it more structured, permeable to air and increases its moisture capacity. To some extent, preventing stubble plays the same role [7]. Every type of soil is subjected to erosion of different kind. Steppe soil is less erosion-resistant while soil in the regions with higher humidity demonstrates the highest resistance to erosive processes. Soils of other areas take the intermediate position. Sheet erosion is characteristic for soil with homogeneous structure while rill erosion is typical for complex-structured soils with the tendency to deep erosion [8], [9].

Soil examination of the north-western part of Stavropol upland including field observation and identification of degraded soils, their type and degree of degradation was conducted. The observation was done on the whole territory [10].

The evaluation of agricultural land is essential to establish its potential productivity and validate the best ways of its use [11]. The methodology of land evaluation that includes continuous observation and was done according to the regulations of intrafarm land evaluation adopted in Russia on the territory under investigation is based on the land evaluation methodology of the Russian Federation. Intrafarm land evaluation includes general assessment of degradation and soil taxation [12].

RESEARCH METHODS

The evaluation of soil and the assessment of land degradation was carried out according to “The guidelines to the identification of degraded soils”. We revealed that two main types of soil and land degradation on the examined territory are water erosion and waterlogging. Water erosion is represented by sheet and rill types in the form of runoff of surface layers and formation of water galls (to a lesser degree). Waterlogging occurs due to the undersurface groundwater (up to 3 metres deep).

Surveying using distance measurement from solid land contours and along the bottoms of cavins and shallows was done to identify the boundaries of eroded and water-logged soils. For this purpose, we used the lay of land on the 1:25000 topographic plan. Plot areas were calculated with a planemeter and a measuring grid as well as applying graphic method. The calculations are attached to field data.

In the course of experiments and land development, machinery and tools currently employed in agriculture were used.

The research was based on the following experiments:

Experiment 1. To study the impact of slope inclination on the snowmelt runoff and water erosion of soil.

Variant 1. Slope with 0.5-2.0^{o} inclination.
Variant 2. Slope with 2.1-5.0^{o} inclination.

The experiments were carried out on the winter tillage of southern and northern exposition tilled to 25-27 cm. The soils were represented by chernozem. The experiments were repeated three times. The plots were sized 100 m X 100 m = 1.0 ha. Snowmelt runoff and soil loss were measured according to the method introduced by Stavropol Research Institute of Hydrotechnical Melioration.

Experiment 2. To study the influence of agricultural methods and slope inclination on water erosion. The experiment included two factors. Factor A was soil cultivation type: variant 1a – tillage with ПЛН-4-35 mounted plough to 25-27 cm (control); variant 2a – subsurface cultivation with АКП-2,5 seedbed combination to 10-12 cm; variant 3a – two-trace disk ploughing with БДТ-3 disk tiller to 6-8 cm. Factor B was slope inclination: Variant 1b – 0.5-2.0^{o} slope inclination; variant 2b - 2-3.5^{o}, variant 3b – 3.5-5^{o}. All types of cultivation were done across the slope. The experiments were repeated three times. The plots were sized 100 m X 100 m = 1.0 ha.

RESULTS AND DISCUSSON

The undertaken research of snowmelt water runoff impact on soil erosion allowed us to conclude that the amount of snowmelt water depends on the depth of snow cover, slope exposition and temperature during snowmelt. We revealed the inverse relation between the depth of snow cover and water reserves in the form of snow and slope inclination, i.e. the thickness of snow cover increases with lesser slope inclination (table 1).

Table 1 – The dependence of snowmelt runoff on slope exposition at tilling to 25-27 cm

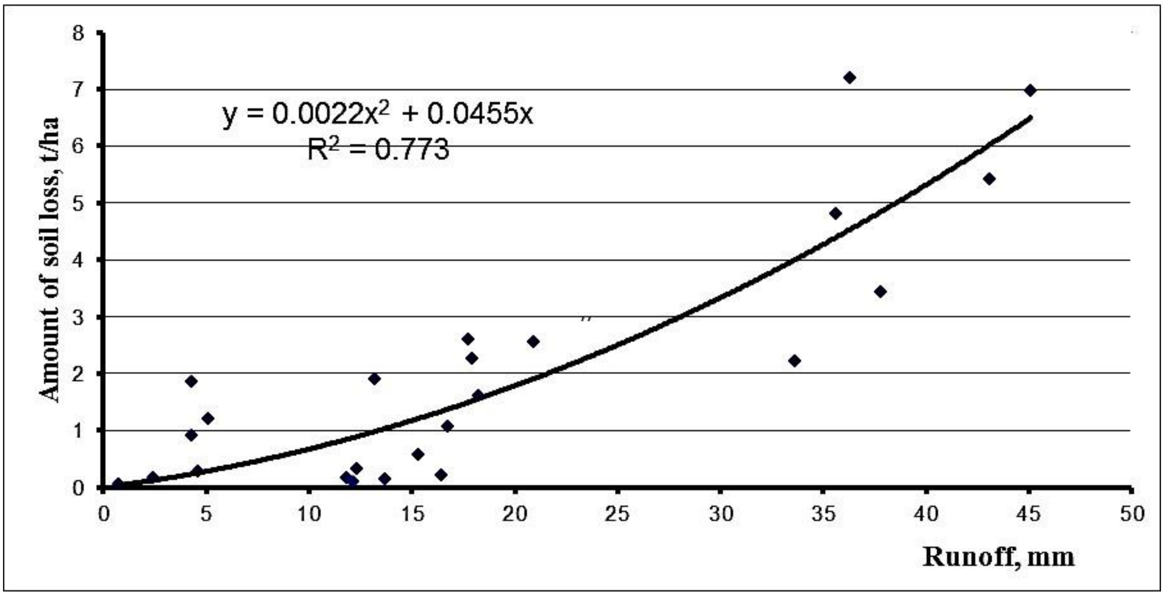
Indicator	Exposition	inclination		
		0.5-2.0^{o}	2.1-3.5^{o}	3.6-5.0^{o}
Water reserve in the form of snow, mm	northern	56.3	44.5	38.9
	southern	47.0	35.8	31.4
Runoff, mm	northern	16.7	17.9	17.7
	southern	18.2	13.2	20.9
Runoff coefficient	northern	0.30	0.4	0.49
	southern	0.39	0.50	0.59
Soil loss, t/ha	northern	1.08	2.27	2.61
	southern	1.61	1.90	2.57

The destructive effect of water increases with slope inclination and length.

Erosion on southern slopes is much greater than on the northern slopes. Convex slopes are more subjected to erosion than concave ones. On convex slopes erosion increases with higher inclination downward the slope while on concave slopes it decreases downward due to lower slope inclination and slower runoff of melt- and rainwater flows.

On slopes with northern exposition and 0.5^{o}-2.0^{o}, 2.1^{o} – 3.5^{o} and 3.6^{o} – 5.0^{o} inclination water reserves in the form of snow were 56.3, 44.5 and 38.9 mm correspondingly. At the same time, under these conditions runoff rate varies directly with inclination from 16.7 to 17.7 mm, while runoff coefficient varies from 0.30 to 0.49. Table 1 shows that the amount of soil loss rises 2.4 times from 1.08 to 2.61 t/ha. These data demonstrate that if other conditions are almost equal, slope inclination and runoff factors produce the most significant impact on erosion by water (pic. 1).

Pic. 1 – The relation between the amount of soil loss and runoff



In addition, table 2 shows significant influence of soil cultivation methods on the degree of erosion by meltwater (table 2).

On milder slopes (with 0.5-2.0° inclination) soil loss on the plots cultivated by surface methods of cultivation (subsurface cultivation and disk ploughing) increases by 14 and 22% correspondingly compared to tillage (control).

The amount of soil loss is higher in all variants, but it reaches the highest value of 1.4. t/ha in variant 3 – disk ploughing at 3.6-5.0° inclination, which is 1.9 times greater than in control (variant 1). There is a great outwash of nitrogen, phosphorus and potassium up to 1kg/ha.

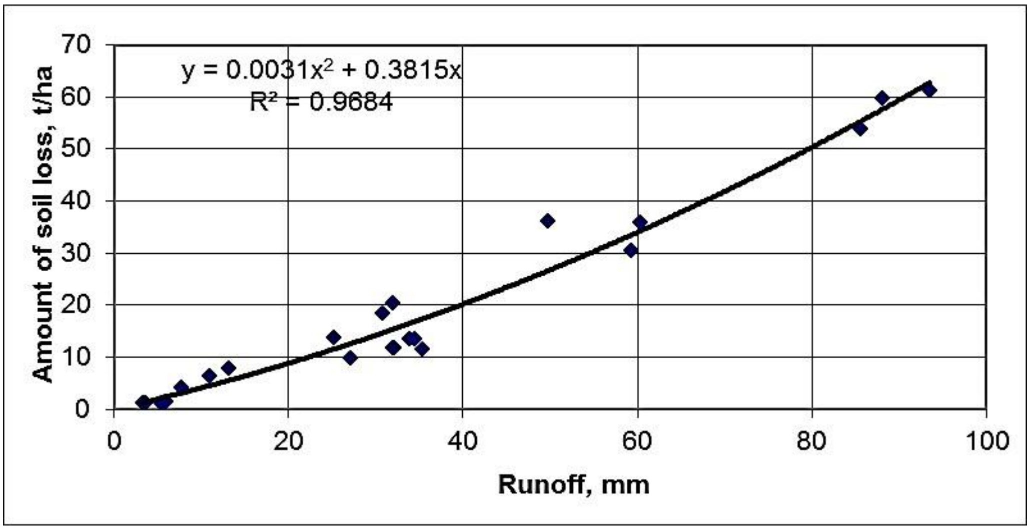
Table 2 – The relation between soil and nutrients loss due to meltwater and cultivation method and degree of inclination, southern exposition.

Variant	Soil loss			NPK soil runoff with soil, g			
	t/ha	±Δ, t/ha	%	N	P	K	total
0.5-2.0° inclination							
1.Tillage	1.61	-		9.7	6.4	488	504.1
2. Surface cultivation	1.83	0.22	14	10.9	7.3	549	567.2
3. Disk ploughing	1.96	0.35	22	11.8	7.8	588	607.6
2.1-3.5° inclination							
1.Tillage	1.90	0.29	18	11.4	7.6	570	589.0
2. Surface cultivation	2.09	0.48	30	12.5	8.4	627	648.9
3. Disk ploughing	2.28	0.67	42	13.7	9.1	684	706.8
3.6-5.0° inclination							
1.Tillage	2.57	0.96	60	15.4	10.3	771	796.7
2. Surface cultivation	2.69	1.08	67	16.1	10.8	807	834
3. Disk ploughing	3.01	1.40	87	18.1	12.0	903	933.1

Our research of runoff due to intensive rainfalls during pre-sowing period revealed similar regularity that was studied on the runoff plots by creating artificial rainfall of certain intensity and exposition).

With higher inclination, longer rainfall or its increased intensity, the amount of soil loss rises dramatically and reaches disastrous values – 102.4 t/ha (pic. 2).

Pic. 2 – Runoff impact on the amount of soil loss during intensive rainfalls over tillage



CONCLUSIONS

The data on the impact of different variants on erosion by water received during the first and second experiments were used to develop technological schemes and conservation activities for erosion-exposed soils on the territory of Stavropol upland.

Research results were applied to prepare a map of soil erosion where soils were grouped into four categories according to their degradation accounting for both their current degree of erodibility and potential development of erosion.

It is recommended to sow perennial plants that should be chosen with regard to soil phase and applying the developed technological schemes of soil grassing.

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