Conference Paper

Ways to Reduce Water Erosion on Mountainous Slope Lands

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Abstract

The most important problem in the highland area is development of technologies to reduce water erosion and improve soil fertility preservation. In order to restore degraded soils of slope lands, a number of measure is undertaken, among them planting crops across the slope and rational fertilizer treatment. To reduce erosion processes, mineral fertilizers were applied depending on the steepness of slope. High sections with the steepness of 9--10° received ammonium sulphate in a quantity of 60 kg/ha. Lower part of the slope with the steepness of 5--7° received ammonia nitrate as a nitrogen fertilizer in a quantity of 80 kg/ha, while the gentle sloping part with 2--5° had urea-formaldehyde fertilizer incorporated under winter tillage in a quantity of 50 kg/ha. At that, stripes were formed across the slope where tall-growing perennial herbs were planted: hill mustard (*Bunias orentalis L.*), silphium (*Silphium perfaliatum*), Eastern galega (*Galeqa orientalis L.*), cock's foot grass (*Dakfilis qlamerata L.*). The research results have shown that thanks to fertilizers, yield of crops increases by a factor of 1.5--2, while soil losses reduced from 0.042 to 0.018 t/ha.

Keywords: erosion, perennial herbs, nitrogen fertilizer, grass stripes.

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1. Introduction

During the long history of humankind, impact that human society had onto soils have been constantly increasing. In a distant past, innumerable herds reduced to nothing plants and trampled down the organic mat on the vast territory of arid landscapes.

Our natural environment is characterized with an intimate connection between all its components that is sustained by cyclic processes of metabolism and exchange of energy. These processes inextricably intertwine the soil cover of the Earth (pedosphere) with other biospheric components.

Ill-judged anthropogenic impact to individual natural components has unavoidable effect onto the state of the soil cover. Well-known examples of unforeseen consequences of human activities are soil degradation due to change of water regime as a result of forest devastation, water logging of fertile flood beds resulting from water table rise after construction of large hydroelectric plants and others. Anthropogenic pollution of soils creates a serious problem. Uncontrollable growth in release of industrial and household wastes into the environments reached a hazardous level in the second half of the 20th century.

The Republic of North Ossetia-Alania takes a key location among republics and krais of the Northern Caucasus. Its area is about 8,000 sq.km, out of which 5,200 sq.km pertains to the mountainous part. The republic is characterized with specific and unique natural diversity.

Currently, a number of projects are being implemented in the mountains of North Ossetia-Alania due to construction of federal level facilities, such as a gas pipeline, Zaramag hydroelectric power chain, laying of fiber optic cable.

Nowadays, throughout the route of the gas pipeline there are vigorous activities in the territory of Ossetia. There are blasting operations, striping, tunneling, building of cable-stayed structures, bridges, some of them have already been put into operation. A special base in Alagir received 45 km of pipes, a third of them has been already welded or prepared for welding. New large-scale deliveries are expected soon. Laying of double-purpose fiber optic communication cable is proceeding in parallel. Just as in the case of the gas pipeline, the demands of the Republic of South Ossetia will be covered in this case as well.

Necessity of these projects is indisputable, however, works on such a large scale are accompanied with irreversible processes in the environment caused by destruction of soil cover that had been formed through the previous centuries. A foundational component of the biosphere is being destroyed.

For example, the length of the gas pipeline is over 150 km, at that, majority of its route passes through mountains. There are service roads being constructed for pipeline access.

Destruction of vegetation cover leads to soil erosion, reduced productivity of neighboring soils, increased degression of mountain pastures, deterioration of hay quality, reduction in forested area and depletion of biodiversity; the structure of special protected natural territories is being deformed, etc.

The damage to the environment is not being compensated, thus aggravating the issue.

Erosion control is a nationwide task. In European countries, significant financial resources are put into preservation of mountainous pedosphere.

There are many remedies against the soil erosion. Some of them were applied previously but were unable to stop the erosion, as they did not consider the multifaceted nature of its manifestations and tried to solve only some particular problems.

Monitoring of mountainous territory of Alagir district, North Ossetia, where the above-mentioned works were been proceeding during the period of 2010--2018, has shown that some plants, e.g., juniper, are stable against the erosion processes.

In some areas the authors made soil sections with the aim of studying resistance of the species.

Juniper is an epibiotic medical plant, known to humans from biblical times. Botanically, juniper (*Juniperus*) is a genus of coniferous evergreen aromatic plant in the cypress family (*Cupressaceae*). Its lifespan is from 600 to 3000 year.

This plant has been in use in many countries from time immemorial. It is absolutely forgiving, grows quite fast, generates many off-shoots and is practically immune to pests.

Juniper grows in the forest zone on various types of soil, on mountain slopes, in groups, clumps or individually. It forms undergrowth. Juniper may be seen on pastures. Monoclinous, or, more often, diclinous trees with a height of up to 18 m, or a large shrub with thorny needles, whorls contain 3 needles each. Blooms in April -- May. By the autumn of the first year after blooming, its gallberries stay green and hard, they maturate by the autumn of the nest year and become soft, black-blue with a glaucous bloom, spherical, sized 5-9mm. The seeds are elongated, brown, three-edged, with hard aril.

Juniper is an evergreen plant that has adapted to existence in harsh conditions of both highlands and hot arid regions of the country. The needles are covered with a thick protective layer of scarfskin and vegetable wax, stomatos are deepened to limit water transpiration. Some junipers have regular needles during in the youth of the plant, gradually being replaced with scale-like needles as the plant ages. Some species keep needles in the lower part of crown of mature plants, witnessing to their genesis from needled junipers. The needles are preserved on the shoots for 4--7 years. Juniper buds are bare, without protective scales and are surrounded with just shortened clamping leaves.

Root system is lateral, grows wide and revets the soil; it allows using juniper for slope stabilization. Juniper is poor-soil demanding, may grow on fragmental and sandy poor soils. Bark is thin, gray-brown, laminating in small plates. Junipers grow slowly and are very long-living.

Consequently, biological resources may be used to reduce erosion processes on slope lands of mountainous territories of North Ossetia, preserving its natural richness and integrity of landscapes

Our experiments aimed at a long-term solution of the soil erosion problem, which is one of the greatest problems of today. Annual loss of soil fertility due to erosion is about 500 million tons in the mountainous regions, at that, together with the erosion products about 24 million tons of humus are removed, including 0.96 million tons of nitrogen, 0.68 million tons of phosphorus, 0.94 tons of potassium (according to expert estimates) [1, 2].

Ill-judged anthropogenic impact on individual natural components has unavoidable effect onto the state of soil cover. Well-known examples of unforeseen consequences of human activities are soil degradation due to change of water regime as a result of forest devastation, water logging of fertile flood beds resulting from water table rise after construction of large hydroelectric plants and others. [3, 4]

Anthropogenic pollution of soils creates a serious problem. Uncontrollable growth in release of industrial and household wastes into the environments reached a hazardous level in the second half of the 20th century [5--8].

Currently, a number of projects are being implemented in the mountains of North Caucasus due to construction of federal level facilities, such as a gas pipeline, Zaramag hydroelectric power chain, laying of fiber optic cable.

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In the Northern Caucasus, detritus landslides, soil slips and erosion processes are common, some of them are studied during the monitoring [9].

Among the causes of high erosion in the territory are: Complex rugged topography, features of geological structure, frequent anomalies of hydrometeorological factors and strong technogenic load [10].

Characterizing the prevalence of exogenic geological processes in the territory and analysis of their activity use a diagram of engineering and geological zoning that takes into account geomorphological and geological structure and altitudinal climatic zonation [11].

As a result of erosion processes, the most biologically active soil horizons are being destroyed (A and B), leading to failure of historically developed functions [12, 13]. As a result of erosion processes, development of beneficial soil microorganisms is impeded, much nutrients are lost, and absorption capabilities of soil are reduced. At that, mobility of heavy metals increases: mercury, lead, cadmium and others, agricultural produce gets more radionuclides. [14]

In recent years, (2005--2018), in order to reduce the erosion processes, a number of experiments were conducted aimed at preservation of nutrients and productivity of crops.

2. Methods and Materials

Experiments were conducted on slope lands with a steepness of 9--10° in the mountainous zone (village of Dargavs, 1560 m a.s.l.) on mountain meadow soils. After harvesting winter wheat, ammonium sulfate was applied in a dose of 60 kg/ha. The fertilizer was scattered through the field with an MVU-0,5A machine, then crop residues were plowed into soil, the soil underwent pre-sowing treatment, cultivation, harrowing and sowing of buckwheat by a solid planting method with an interrow spacing of 15смм. Down the slope, where the sloping angle was 5--7°, the soil was ridged across the slope with an interrow spacing of 70 cm in the autumn. Depth of furrows was 25--30 cm. In spring, ammonium nitrate was introduced locally into the furrows in the amount of 80 kg of active ingredient per hectare. The gentle sloping part with 2--5° sloping angle had low-solubility urea-formaldehyde fertilizer incorporated under winter tillage in a dose of 50 kg/ha [11].

In another experiment, stripes of 25 m in width were formed on slope lands with the slope angle of 5--7°. In autumn, a mixture of tall-growing perennial herbs was sowed: hill mustard (*Bunias orentalis L.*), silphium (*Silphium perfaliatum*), Eastern galega (*Galeqa orientalis L.*), cock's foot grass (*Dakfilis qlamerata L.*) in the amount of 35 kg/ha. The width of stripes of the perennial herbs was 4 m, with solid planting. The herbs were left unmowed for the winter to facilitate growth and self-restoration [12].

3. Results

The fertilizers introduced on the slope lands provide preservation of soil water capacity and uniform distribution of crop residues, thus promoting weakening of the erosion processes. In the presence of nitrogen fertilizers, cellulose-fermenting microorganisms uptake nitrogen, thus preventing its wash-out by both surface and underground flows. Simultaneously, decay of crop residues accelerates.

To prevent wash-out, after soil treatment and incorporation of fertilizers, a post-harvest crop with short vegetation period is sowed with narrow interrow spacing. The post-harvest buckwheat plants took root fast and contained the surface flow of water. After harvesting the buckwheat, the optimal variant was to sow winter crops, in particular winter rape or false flax that hold the water erosion flows and allowing reducing soil fertility losses due to their well-developed root systems.

Tall-growing plants with rather well-developed root system sowed across the slope have been growing in the protective stripes for more than 10 years. The root system of these plants is extensive, consisting of a thickened main root and multiple side shoots. Plant height reach 3--4 meters. This plant of family Asteraceae -- perfoliate rosin weed (Silphium perfaliatum) has high winter hardness and can grow on different soils.

Other plants of interest for sowing on slope lands are such perennial herbs as hill mustard (Bunias orentalis L.), Eastern galega (Galeqa orintalis L.), and cock's foot grass (Dakfilis qlamerata L.).

Root system of these plants extends for more than 1 m. They are very much winter-hardy. In particular, cock's foot grass is resistant to unfavorable soil conditions and temperature fluctuations typical of mountainous zone, reaches 1.5 m during its blooming phase, has many root shoots and forms hillocks, thus promoting containment of surface water flows.

Being sowed in autumn, by spring this fodder plant forms a well-developed root system thanks to nitrogen fertilizers introduced and is capable of significantly reducing soil wash-out.

Between the stripes of the above mentioned plants, there are perennial legumes (clover, alfalfa, cock's head, etc.), whose height reaches maximum 60--70 cm during their blooming phase.

Tall grasses create protective stripes around the plots were crops are grown.

Thanks to application of nitrogen fertilizers and formation of protective stripes, it has been determined that the yield in the slope lands increases (Table 1).

TABLE 1: Crop yield as a function of fertilizer amount on the slope land.

Variant	Yield, t/ha		
	buckwheat	corn	potato
Planting winter crops on the slope 7--9° + post-harvest crops (control)	0.6	5.0	18.0
Application of $(NH_4)_2SO_4$ throughout the slope after grain harvest	0.8	6.2	21.5
Forming furrows + application of NH_4NO_3 throughout the slope	0.7	5.6	20.2
Urea-formaldehyde fertilizer + $(NH_4)_2SO_4$	0.9	6.7	20.2
Spring application of ammonium sulfate after harvesting winter crops + aftercrop sowing	--	--	--
Ammonium nitrate in the low part of the slope + slow-acting UFF under winter tillage.	1.2	7.5	24.5

Taking into account the surface slope, nitrogen fertilizers are applied onto the upper part: Ammonium sulfate after harvesting the winter crops, with subsequent sowing of aftercrops and further application of nitrogen fertilizers along the slope provides increase in yields of buckwheat by a factor of 2, corn -- by a factor of 1.5 and potato by a factor of 1.36.

The protective stripes of perennial herbs with well-developed root system are resistant to stress factors of the mountainous zone and create conditions for reduction of soil wash-out.

The data in Table 2 witness to a two-fold reduction of soil washout by means of protective stripes consisting of tall-growing perennial herbs.

The data in Table 2 show that establishing protective stripes with a width of 4--6 m provides reduction in soil loss by 42.8 %, which is quite significant.

Consequently, by planting crops across the slope with protective stripes between them being made of winter-hardy tall-growing perennial herbs with expansive root system that developed for 8--10 years, it is possible to significantly reduce harm from water erosion common in mountainous areas.

TABLE 2: Reduction in soil loss depending on location of protective stripes on slope lands.

Variant	Slope steepness (degrees)	Soil wash-out, t/ha	Percentage of Control
Striped planting (control)	8--10	0.042	--
Striped planting (no protective stripes)	5--8	0.038	90.5
Crops with protective stripes of 2--3 m	8--0	0.024	52.1
Protective stripes of 4--6 m	8--10	0.018	42.8

4. Conclusion

1. Different nitrogen fertilizers shall be applied with accounts for slope steepness. In the upper part of the slope ammonium sulfate shall be used; in the midrange ammonium nitrate shall be applied; at gentle slopes (2--5°) it is better to use poorly soluble urea-formaldehyde fertilizer in a dosage of 50 kg/ha

2. To reduce water erosion, protective stripes are formed across the slope and sowed with perennial herbs with extensive root system.

3. Crops are planted in stripes between the protective stripes, while in the stripes perfoliate rosin weed (Silphium perfaliatum), hill mustard (Bunias orentalis L.), Eastern galega (Galeqa orintalis L.), cock's foot grass (Dakfilis qlamerata L.) are sowed.

4. Winter wheat is sowed as a main crop, after its harvest buckwheat is sowed as an aftercrop, with subsequent sowing of winter rape or false flax.

5. Reduction of soil erosion by a factor of 1.5--2 significantly increases yield of cultivated intertilled crops -- corn and potato. Buckwheat sowed as the aftercrop of winter wheat allowed increasing yield on the slope lands from 0.6 to 1.2 t/ha.

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