Georgian Technical University

With the right of manuscripts

Vasil Khorava

Prediction of Water Erosion in Natural Open Channels

Doctoral Program: “Water Engineering”

Code: 0732.2.2

Has been nominated for the Doctor’s academic degree

Synopsis of

submitted Thesis

Tbilisi

2019

The work is done at Georgian Technical University

Faculty of Civil Engineering

Department of Water Supply, Wastewater, Thermal Improvements and Engineering Equipments

Supervisor: Professor, Alexander Bagration-Davitashvili

Co-supervisor: Professor Lech Dzienis

Reviewers: ______________________________

____

Presentation of Thesis will take place "____" July, 2019 year at ____ o'clock

In Georgian Technical University ____________________________________

________________________ at the meeting of the Dissertation Colleague

Building ___, in Meeting room ______

Address: 68 M. Kostava St., Tbilisi, 0175

The dissertation may be available in the central library of GTU,
and the Synopsis - in web-site of the Faculty of Civil Engineering

The secretary of the Dissertation Council: Professor, Demur Tabatadze

Introduction

The overall characterization of the work

Actuality

Water erosion is one of the major economic and environmental problems that really define the national security of countries.

According to the Global Assessment of Human-induced Soil Degradation (GLASOD), conducted in 1988–2015 under the protection of the United Nations Environment Program (UNEP), there were 1,093.7 million hectares world soils are eroded, that by a large margin brought water erosion to the first place among other sources of soil degradation (deflation, repackaging, salinisation, etc.).

Georgia belongs to countries where the erosive processes are widespread and dangerous. In mountainous regions of Georgia rarely find a slope that is not eroded and scarified with ravines. Intensive landslides and mudflows are observed.

One of the reasons for the increasing of erosion processes is the intensive agricultural usage steep slopes of mountainous areas. Usage for this purpose inappropriate agricultural techniques, instead of using these slopes as cultural pastures which would be much less dangerous for the development of erosion processes, started to grow corn, tobacco and other more profitable vegetable crops. Such an approach has caused great and irreparable damage to the land. Where these events took place developed erosion processes, desertification, salinisation, withers, soil structural changes, reduction of humus content in the soil and accompanying processes.

Thus, in maintaining the ecological stability of a number of regions of Georgia, as well as ensuring the level of agricultural effectiveness of the country and the solution to the economic and social problems associated with it requires the elaboration of a wide range of anti-erosion measures and practical implementation. Without this, the ecological and economic and related social stability of the country is in serious danger.

Based on this prediction of water erosion in open channels is very important for such countries as Georgia.

Scientific innovation

The main objectives are obtained:

1. It was studied the mechanism of moving of particles on the slope of the channel;
2. It was established non-blurring rates for uniformly sized cohesive soils in order to determine empirical coefficients for the obtained theoretical dependencies;
3. It was established the value of non-blurring rates for cohesive soils;
4. It was established the limiting value of the cohesive force of a cohesive soil, above which the laying of a slope does not affect the stability of its aggregates;
5. It was studied the formation of the kinematic structure of the stream in the trapezoidal bed, depending on the adopted form of the section. At the same time, the study of empirical regularities of the distribution of detuned bottom and average vertical velocities across the width of the trapezoidal bed;
6. It was studied the patterns of change in the pulsating components of the velocities at the height of the roughness protrusions from the axial part of the channel to the coastal part.
7. As a result of the analysis of the photo material obtained by the spacecraft and their processing in GIS program, it was established risk zones and appropriate preventive measures are proposed.
8. Based on the totality of regional features of the development of linear landforms and erosion of the soil cover, it is possible to perform soil-erosion zoning of the Alazani river territory.

The purpose of the work

The purpose of the work is prediction of water erosion in natural open channels, investigation and quantitative description of the influence of individual factors on the intensity of soil erosion and the development of equations for calculating or forecasting water erosion. Also define and specify their calculation characteristics.

Despite the obvious successes in the field of mathematical modeling and the development of methods for calculating water erosion, such a large and constantly increasing number of models and the absence of a generally accepted regulatory framework for calculating the characteristics of water erosion indicate the insufficient adequacy of existing models.

Assessing this group of water erosion models as a whole, we note that formal-statistical models, of course, have a right to exist. However, the scope of their application to the greatest degree in comparison with other empirical models is limited to those natural-economic conditions for which the model was developed.

Attention is also drawn to the fact that the model does not take into account the effect on the intensity of soil washout of the length of the slope, which significantly limits the possibility of using the model for anti-erosion design.

Practical meaning

Esteblished methodology may practicaly implement for prediction of water erosion in a Georgian rivers.

The analysis of the photo material of rivers obtained by the spacecraft and their processing in GIS program, it it will be used for determination of risk zones and providing appropriate preventive actions.

Research object and methods

The research object was most eroded regions of Georgia, in particular banks of Alazani river, where passes a large part the border between Georgia and Azerbaijan.

During mathematical, theoretical and numerical experiments carried out during the research, technologies used in engineering hydrology, hydraulics and soil mechanics universally recognized methods of modelling erosion processes.

The main results of the work and scientific innovations

- It was established non-blurring rates for uniformly sized cohesive soils in order to determine empirical coefficients for the obtained theoretical dependencies;
- It was established the value of non-blurring rates for cohesive soils;
  It was established the limiting value of the cohesive force of a cohesive soil, above which the laying of a slope does not affect the stability of its aggregates;
- As a result of the analysis of the photo material obtained by the spacecraft and their processing in GIS program, it was established risk zones and appropriate preventive measures are proposed.

- Based on the totality of regional features of the development of linear landforms and erosion of the soil cover, it is possible to perform soil-erosion zoning of the Alazani or other river territory.

Scope of the results.

The results of specific tasks developed in the work will greatly assist the scientists working in environmental protection, engineering ecology, hydraulics, hydrogeology, hydro technological melioration, and other neighboring fields in the area of future research and instructing the engineers to prevent water erosion processes. The research results can be used to prevent erosion processes and determine design standards штsolving engineering problems.

The volume and structure of the Thesis

The Thesis consists of the introduction, 2 chapters and key conclusions. It includes 117 printed pages, including 9 tables and 10 drawings; 67 literary sources were used.

The main results of the thesis according to chapters

In the first chapter of the Thesis are considered the modern approaches to the study of open channel processes and the analysis of literary sources.

It has been studied classification of open channel flow: Steady Flow, Unsteady flow, Uniform flow, Non-Uniform flow, Gradually Varied flow and Rapidly Varied flow. Open Chanel flow is that type of flow which is neither completely enclosed by the boundaries nor is under any external pressure but gravity. It is subjected to atmospheric pressure, e.g. rivers, natural and artificial canals, streams, channels etc. Partially filled pipes flow is also an example of open channel flow.

It has been also studied sediment transport in open channels sediment transport mechanisms. The bed of channel form results from the drag force exerted by the bed on the fluid flow as well as the sediment motion induced by the flow onto the sediment grains. This interactive process is complex.

In a simple approach, the predominant parameters which affect the bed form are the bed slope, the flow depth and velocity, the sediment size and particle fall velocity. The basic bed forms which may be encountered are the ripples (usually of heights less than 0.1 m), dunes, flat bed, standing waves and antidunes. At high flow velocities (e.g. mountain streams and torrents), chutes and step-pools may form.

Here also considered erosion and transport processes in open channels. The process of erosion can be described in three stages: detachment, transport and deposition. Detachment of sediment from the soil surface was originally considered to be exclusively the result of raindrop impact, although the importance of overland flow as an erosive agent has now been recognised. Rainfall detachment is caused by the locally intense shear stresses generated at the soil surface by raindrop impact. Likewise, overland flow causes a shear stress to the soil surface which, if it exceeds the cohesive strength of the soil, termed the critical shear stress, results in sediment detachment. In different situations, the major processes leading to sediment detachment will differ.

In general, models fall into three main categories, depending on the physical processes simulated by the model, the model algorithms describing these processes and the data dependence of the model:

- Empirical or statistical/metric;
- Conceptual;
- Physics based.

The distinction between models is not sharp and therefore can be somewhat subjective. They are likely to contain a mix of modules from each of these categories.

In the second chapter of the Thesis are considered mathematical modeling of water erosion.

A systematic study of water erosion in the world began in the second half of the nineteenth century. The first descriptions of erosion processes and attempts the development of soil protection measures against water erosion dates back to the 18th century.

The most detailed classification of erosion models was proposed, apparently, by M. S. Kuznetsov and G. P. Glazyrin, who divide all water erosion models into statistical, which do not reveal the physical meaning of erosion processes, and logical-mathematical, based on equations, with varying degrees of completeness describing the influence of erosion factors on the runoff and soil washout.

Logic-mathematical models are divided into three classes by authors:

- models with lumped parameters, i.e. not taking into account the spatial heterogeneity of the catchment, erosion area or a separate field of crop rotation;
- models with concentrated parameters, i.e. transient;

- models with distributed parameters based on partial differential equations.

The existence of various approaches to the classification of mathematical models of such a complex process as water erosion, in principle, is not something unusual, since any complex phenomenon can be classified on various features.

Empirical models of water erosion by their **intellectual index** are definitely divided into two levels.

Empirical models of the first level, taking into account the experience of classification of erosion models, as well as existing approaches to the classification of mathematical models in related scientific disciplines, are formally named statistical. These models are derived from the processing of empirical data based on a formal statistical approach. Empirical models of the second level are called physico-statistical. Physico-statistical empirical models differ from first-level models in their desire to take into account as much as possible a priori (theoretical) knowledge of the process being modeled, therefore, they are more detailed and have great potential for solving erosion-proof design problems.

From the developed mathematical models of water erosion to conceptual should be attributed the formula for calculating the average long-term soil erosion proposed by IK Sribny, as well as the soil erosion models developed at the All-Russian Research Institute of Agriculture and Protection soil. These models include a number of water erosion models developed in the 1980s – 1990s in Western Europe, North America and Australia: MMF, LASCAM, MMMF, SWAT2000 and some others. Within the allocated classes and subclasses of models, further classification detailing of models on other bases possible with their assignment to a) deterministic or stochastic, b) 0-dimensional (lumped), 1-dimensional (1D) or two-dimensional (2D), c) realized for sites (plot scale), slope scale, catchment scale or a large area (regional scale).

It can be added that all models are ***logical-mathematical*** because, by definition: **Mathematical modeling is modeling conducted by expressive and deductive means of mathematics and logic**.

$$A_R = 10^{3} X_E^{2,7} (5,0 - 0,04 X_c - 0,1 X_h + 0,1 X_{cc}) X_\alpha X_n X_\varphi X_p,$$

where A_R is the amount of soil loss, t/ha, on average for the slope; X_E is the weighted average total kinetic energy of the erosive part of the heavy rainfall, kJ/m^2; X_c - the content of physical clay (the sum of particles is less than 0.01 mm),%; X_h - humus content,%; X_{cc} - carbonate content ($CaCO_3$),%; X_α - bias, degrees; X_{ri} - relief factor, taking into account the influence of the shape of the slope (straight, convex and concave), exposure (by four points) and the ratio of the length of the slope (L) to its width (B); X_{of} –open background,%; X_p - a factor in the effectiveness of anti-erosion measures, dimensionless. It is recommended to determine the magnitude of the kinetic energy of rainfall for the territory under consideration for the settlement period (decade, month, warm period, rotation of crop rotation) by summing the ***probability-weighted*** values of the energy of daily precipitation maxima:

$$X_E = \frac{E_1 F_1 + E_2 F_2 + \ldots + E_n F_n}{F_1 + F_2 + \ldots + F_n},$$

The energy of the erosive part of heavy rainfall is determined by the equation:

$$E = 23{,}1\ r^{0{,}21},$$

where r is the average intensity of the erosional part of the rainfall, mm / min.

Physical-statistical models of soil washout

The group of physico-statistical empirical mathematical models of washout should be attributed to a large number of models of soil washout, varying in their degree of validity and information support, from models of soil washout developed in different countries of the world.

This is exactly what gives grounds to assign RUSLE in the classification of empirical mathematical models of water erosion to the second level of hierarchy.

The universal equation of soil loss is:

$$W = (0{,}224)\ R\ K\ LS\ C\ P,$$

where *W* is the average annual loss of soil module (kg / m^2); *R* is the factor of eroding ability of rain; *K* - soil erodibility factor; *LS* is a relief factor, and *L* is a slope length factor, *S* is a slope factor; *C* - factor of crop rotation (agrotechnology); *P* - factor of conservation measures.

The factor of eroding ability *R* (erosion index of precipitation) for an individual rain is defined as the product of the total energy of rain and its maximum 30-minute intensity according to the formula:

$$R = 0{,}00576\left[\sum_{j-1}^{n}(1{,}213 + 0{,}8901\,lg\,r_j)(r_j\Delta t_j)\right] r_{30}\ ,$$

where r is the rain intensity for the j-th time interval, mm/hour; Δt_j is the length of the calculated interval, hours; r_{30} - maximum intensity of rain in 30 minutes, mm/h; n is the number of calculated intervals with a constant intensity within the rain. In order to obtain the annual value of the factor R, the pluviograms of all the drain-forming rains that fell during the year must be processed. Statistical processing of the annual values of the factor R, calculated over a sufficiently long period, makes it possible to obtain the mean average multiyear value of the factor of the eroding ability of rain or its value of the calculated provision.

Soil erodibility factor K is the ratio of the average annual soil run-off from a square meter of standard drainage area to value R. The surface of the site is processed along the slope and is contained by the type of black steam. Direct measurements of factor K were carried out for 23 main US soil types, on the basis of which a nomogram was constructed to determine the erodibility factor depending on soil characteristics: the percentage of dust (fraction 0.002-0.05 mm) plus very fine sand (0.05 -0.10 mm), sand, organic matter, structure and water permeability. It was proposed to take into account the influence of the rubble of the surface and the cation composition of the soil exchange complex (Na and K):

$$K = \left[6\cdot 10^{-4} S\left(1 + 0{,}0015AC\right)\left(12 - OM\right) + 0{,}021\left(Ka + Na\right)\right]\cdot e^{-0{,}05ST},$$

where S is the dust content,%; C - clay content,%; A - sand content,%; OM is the content of organic matter,%; Ka and Na - the percentage of potassium and sodium in the soil absorbing complex, respectively; ST is the percentage of surface covered by the stone debris. For soils with an extremely high content of sand or clay, as well as a high content of potassium and sodium in the exchange complex, the original K – factor value is 75% of the K – factor value of U.

The slope factor S (in RUSLE) for slopes longer than 4 m is determined by the expression:

$$S = \begin{cases} 10{,}8\,sin\theta + 0{,}03 \ \ npu\ \ I < 9\% \\ 16{,}8\,sin\theta - 0{,}50 \ \ npu\ \ I \geq 9\%, \end{cases}$$

where θ is the slope angle, degrees, I is the slope slope,%.

For slopes less than 4 m long:

$$S = 3{,}0\,(sin\,\theta)^{0,8} + 0{,}56.$$

The slope length factor is:

$$L = \left(\frac{x}{22{,}13}\right)^{p},$$

where *x* is the length of the slope, m; *p* is an exponent.

In the first edition of the Universal equation (Wischmeier et al., 1958) the magnitude of the exponent at the slope length *p* was assumed to be constant and equal to 0.5. In the second version of the equation, it was recommended to assign *p* depending on the slope: if the slope is less than 1%, *p*=0.2; if the slope is more than 1% but less than 3 %, *p*=0.3; if the slope is more than 3% but less than 5%, *p*=0.4, and finally for slopes with a slope of more than 5%, *p*=0.5. In the third edition of the Universal equation (RUSLE), based on the concept of rill sources of sediment a wider range of *p* – values is justified, theoretically from 0 to 1. In practice, it is recommended to use the following expression to determine p:

$$p = \frac{sin\theta}{sin\theta + 0{,}269(sin\theta)^{0,8} + 0{,}05}.$$

Factors C and P are the ratio of soil loss from a site occupied by a crop with certain anti-erosion measures to soil loss from a control site without anti-erosion measures. The values of factors C and P are given in the form of tables of dimensionless coefficients obtained on the basis of statistical processing of data of stationary studies.

Present the values and dynamics of factors C and P for the main crops (winter, spring, corn and sunflower, beets and potatoes, perennial grasses) for the physical and geographical provinces of the forest zone.

Attempt to consider the peculiarities of soil loss on the slopes of the complex shape is suggested by G. R. foster and W. H. Umaira variant of the universal equation, which takes into account the changes in the factors of relief conditions S and L along the calculated profile of the slope along intervals of arbitrary length:

$$W = (0{,}224)RKCP\left[\frac{\sum_{j-1}^{N}\left(S_j x_j^{p+1} - S_j x_{j-1}^{p+1}\right)}{x_c\,(22{,}13)^m}\right],$$

where x_j is the distance from the watershed to the bottom of the segment j, m; x_j-1 is the distance from the watershed to the top of the segment j,

m; x_c-the total length of the slope, m; S_j - the value of the slope factor for the segment j;

N – the number of segments into which the calculated profile is divided.

Equation is obtained on the basis of solving the problem of determining the average loss of soil on a certain j-th segment of the slope, the lower limit of which is at a distance x_j from the watershed, using the formula of the average weighted soil washout module for two parts of the slope profile: the calculated - Δx_j and the overlying - x_j-1. In this case, the average module of soil loss for the slope length of xj is equal to:

$$W_j = \frac{W_{j-1}x_{j-1} + \Delta W_j \Delta x_j}{x_{j-1} + \Delta x_j} ,$$

where, remember that x_j-1 + Δx_j = x_j the desired average of the module is flush on the lower part of the slope:

$$\Delta W_j = W_j x_j - W_{j-1} x_{j-1} .$$

Substituting in the expression instead of W its value in which the length factor L is replaced by its value by another, we obtain the desired formula of the average on the slope segment of the soil washout module. The summation defined in a similar way the values of the middle module flush into N segments leads to the expression in the case that the factors R, K, C and P are assumed constant along the length of the slope. In that case, if they are variable, then they can be entered into the expression of the average on the slope segment of the soil washout module. The most relevant is, first of all, for the soil conditions of the erosion process, presented in the Universal K-factor equation.

Interesting and promising is the spatial implementation of the Universal equation using the capabilities of geoinformation technologies, known as RUSLE-3D. With the aim of accounting for cross-concentrations in surface runoff into a factor of the length of the slope in RUSLE was introduced catchment area. The modified equation for calculating the factor LS at the slope point r with coordinates (x, y) in accordance with has the form:

$$LS(r) = (p+1)\left[A(r)/a_0\right]^p \times \left[\sin b(r)/b_0\right]^m ,$$

where A is the catchment area for a given cell (for raster representation of spatial data), m; b is the slope, deg.; a_0 is the length of the standard USLE runoff site equal to 22.1 m; b_0 is the slope of the standard runoff site equal to 0.09; p, m are the exponents of the length and slope factors, respectively.

The basis for the conclusion of the logical and mathematical model of stormwater runoff based on numerous experiments on artificial sprinkling slope sites assumption that the number of slope sediments in any alignment is determined by a combination of conditions of water loss, sedimentation and transport capacity of the flow throughout the overlying part of the slope. At the same time, the role of different areas is less, the farther they are from the design target. This feature is most fully expressed by the genetic formula of water flow. Simplified by analogy with the genetic formula of liquid runoff for the total flow of sediment from the slope during the rain (W_H) is written:

$$W_н = k_p^{'} \gamma_н \int_0^T \varepsilon_{t-\tau} dt ,$$

where $\varepsilon_{t-\tau}$ is the average for the intensity of the formation of sediment during the time of running water on the slope; cr ′ - coefficient of dimension.

In this dependence, with insignificant changes along the length of the slope of the conditions of sediment formation, it is assumed that $\gamma_H \varepsilon$ can be replaced by h_ρ where h is the water yield intensity ρ is the turbidity of the flow, taking into account the influence function of the relief Φ (L, I). Based on observations from stationary runoff sites and experiments on artificial sprinkling, a relationship was obtained between the turbidity of the stream ρ in g / l, the intensity of water loss h in mm / min, and the specific power of precipitation M_i in g cm / s per 1 m^2:

$$\rho = (b_\rho + \delta A M_i) h^{1,7} ,$$

where b_ρ, δ, A are parameters.

Experimental study of the natural precipitation spectrum and generalization of existing studies allowed the author of the model to obtain a simplified expression for the precipitation power M_i (g cm /s/m^2):

$$M_i = 5880 \, i ,$$

where i is the intensity of precipitation, mm / min.

It was also found that the value of water yield h is more appropriate.

Express as indicators of precipitation, the main characteristic of which is –washout their intensity of fuel :

$$r_{см} = r_0 + \Delta r' e^{-b_i(I_x + x_t)},$$

where r0 is the minimum intensity of precipitation at which there is no soil washout; Δr'=GPR'r0, where GPR' is the intensity of precipitation at which washout occurs at any minimum soil moisture conditions; Ix is the moisture index at the beginning of the washout rain; XT is the layer of precipitation at the time t, counting from the beginning of the rain; bi is the parameter that determines the soil and plant conditions.
Annual rainfall runoff module (Wл) taking into account equations and f(L,I)=1 after the transformation is obtained in the form:

$$W_л = \delta_л \sum_{i-1}^{N} \left[\frac{X_{см}^{2.7}}{\Delta t_{cm}^{1.7}} (1 + 17{,}5A \frac{X_{cm}}{\Delta t_{cm}}) \right] = \delta_л \sum_{i-1}^{N} K_{ГМ},$$

δл where – coefficient of proportionality; Khsm – savoureuse the amount of precipitation; Khst – the amount of precipitation during the time when the rainfall intensity exceeds the intensity savoureuse rj > GSM plus 15 minutes, i.e. Δtcт; A – coefficient characterizing the influence of soil and vegetation; N – number of savoureuse showers for the year; - the total annual value of the hydrometeorological factor of stormwater runoff.
Washout amount of precipitation is calculated by the formula:

$$\sum_{i-1}^{N} K_{ГМ}$$

where rj is the intensity of precipitation; JCM is the washout intensity of precipitation; Δtj is the estimated time interval.
The expression for the washout intensity of precipitation for the soil, adopted in the framework of the model for the standard (ordinary heavy-loamy not washed), is obtained in the form of:

$$r_{см} = 0{,}08 + 5{,}92 exp\left[-0{,}151 \left(B_0 + \sum_{j-1}^{N} \Delta X_0 \right) \right],$$

where $\sum_{j=1}^{N} \Delta X_0$ the amount of precipitation from the beginning of the rain to the estimated time j, mm; B_0-index of previous moisture N. at the beginning of the rain, characterizing the moisture content of the top layer of the soil.

Experimental study of the influence of relief on soil washout and generalization of extensive materials of other studies (conducted primarily in the United States) allowed to obtain a General expression for the average washout module on a slope of length L (m) with an average slope I (%o):

$$\overline{W} = aI^m L^{0,5} .$$

Consequently, here the relief factor f(L, I) is represented by ImL0, 5 and the calculated washout module, ceteris paribus, monotonically increases in proportion to the square root of the distance from the watershed

(L) and the mean slope (I) of degree m, averaging 1.2. In this case, m depends on the erosion stability of the surface and varies from 0.7 for forests, meadows and virgin lands to 1.3-1.5 for the treated surface without vegetation.

In the final form, the calculated expression of the average annual module of stormwater runoff (t/ha) is obtained in the form of:

$$W_л = 1,2 \cdot 10^{-4} j_R e^{-\lambda_p (0,85 - 100 m_1)} \Phi(L; I) \sum K_{ГМ} ,$$

where

W_L-average annual value of the average for the slope of the soil washout module for the summer-autumn period, t / ha; j_R^e-indicator of the relative soil washout, which is determined taking into account its erosion;

m1 is the parameter of the speed formula that takes into account the roughness;

λp is the parameter that characterizes the erosion control properties of vegetation varies from 1.0 for bare ground to 5.0 for the virgin lands and forests;

F (L, I) – relief function, determined by the formula ImL0, 5; $-\sum K_{ГМ}$

average annual (normal) hydro-meteorological factor in the shower-

model soil loss.

The main advantages of the logical and mathematical model of storm water washout are the theoretical and experimental validity of the hydrometeorological factor of storm washout and the block of soil conditions, good information security and verification, conducted on the basis of observations of a number of runoff and water balance stations of Ukraine and Moldova. The disadvantages of the model include its zero-dimensional nature (allows you to calculate only the average for the slope average annual soil washout module) and the monotonous nature of the relief function, the development of which is largely based on the results of studies carried out in the United States in the 50s-60s of the last century.

Formula washout

Similar to the Universal equation structure is the formula of soil washout, published in 1979 by P. Surmach, which was the basis of Guidelines for the design of complexes of anti-erosion measures on a calculation basis for a large part of the European territory of the former RSFSR and left-Bank Ukraine and later called ***logical-mathematical model of washout***.

To calculate soil loss caused by snowmelt and stormwater, G. P. Armacham (1992) proposed the formula:

$$W_a^{тал} = \frac{K}{10\sqrt{a}} I_a^m L^p \gamma \; y_{тал}^j u P_m P_{мех} P_{э.см} P_{э.ст} A,$$

$$W_a^{лн} = \frac{K}{10\sqrt{a}} I_a^m L^p \gamma \; y_{лн}^j P_m P_{мех} P_{э.см} P_{э.ст} A,$$

where Wамал Wалн - mean annual soil erosion from snowmelt and stormwater, respectively, on the segment of slope length a (m), a distance L (m) of the watershed, per unit area, t/ha; a - cut horizontal distance of the slope, which is determined by erosion and which shall be equal to 75 m; Ia - slope cut slope a, Ia = tgα, where α is the angle of the surface slope, degrees; L is the distance (horizontal distance) from the watershed to the end point of the segment a, which is determined by the flush, m; m and p - exponents, whose values for different conditions are given in tables (table. 4.8-4.9); γ-parameter characterizing the saturation of the water flow with sediments (turbidity) on the drive-separated segment of slope a at its length of 75 m and slope of 0.004, g / m3, on typical, leached and ordinary Chernozem; K-parameter representing the product of the relations of slopes with $p\left(\frac{I_{пр}}{I_{пр}^m}\frac{L_{пр}^{0,5}}{L_{пр}^p}\right)$

the exponents of 1.0 and m and the length of the slope with the exponent of 0.5 and on the drive-separate segment of the slope, leading to the value of the initial turbidity to its value at the slope of the segment IPR, equal to 0.004 (table. 4.8-4.9); utal – mean annual annual runoff layer of meltwater with a variety of farmland, or annual runoff of the spring flood of a given security, mm; ULN – layer flow of rainwater design of security, mm; i is the exponent for y, for stormwater runoff equal to the average of 1.1, changing depending on the flow intensity in the range of 0.70 to 1.25, increasing with increasing flow intensity; for washout with melt water-varies within 0.95-0.89, decreasing with the growth of the runoff layer; u-coefficient, taking into account the influence of the nature of snow deposition on the slope of the washout intensity, which is determined either by the formula

$$u = \frac{h_0 - h}{2h_0} + 1,$$

where h0 is the average long-term supply of water in snow in the middle and lower part of snow – blown and snow-covered slopes, mm, or, in the absence of observational materials; RM , Rmex.see, p e. St-coefficients characterizing the influence of erosion of its different types and subtypes on the relative flexibility of the soil, mechanical composition, degree of washout, as well as the influence of the degree of washout on the values of runoff of storm and melt waters, respectively; A – coefficient characterizing the influence of agronomic and agroforestry techniques to reduce runoff and erosion.

The considered model is one of the most information-based for the territory of the Russian Federation models of this group. Its undoubted advantage from the point of view of anti-erosion design is the desire to assess the average soil washout module not for the entire slope, but within a given segment. The disadvantages of the model include not taking into account the eroding effects of raindrops – in the model of storm washout is not taken into account the intensity of the rain – appears only the flow, and in the form of a layer (and not the intensity, as would be expected). In addition, the degree of runoff, which determines the nature of the dependence of soil washout on this, in this case, a complex hydrometeorological indicator, appears to be underestimated. In the model, it varies depending on the intensity of flow in the range of 0.8-1.25. A significant drawback of this formula, as well as other models of this group, is the adoption of a monotonic increase in the module of soil washout down the slope in proportion to the distance from the watershed, in this case, to a degree varying from 0.3 to 0.6 with a median value of 0.5. The author of the model States that when constructing calculation equations erosion into account theoretical and experimental studies of domestic and foreign, mostly American, authors, concerning especially the influence of the steepness and length of slope influences the intensity of washout.

Model of the State hydrological Institute

Model of soil washout, developed at the state hydrological Institute and included in the Instructions for determining the design characteristics in the design of anti-erosion measures in the European territory of the USSR. VSN 04-77, can be called hydrological-geomorphological. It allows you to calculate the amount of soil loss estimated availability average slope or catchment, depending on the drain layer of the corresponding security, types of time streaming network on the slope and agricultural use of the slope or catchment in the current and prior years.

In relation to the calculation of storm water washout, the model has the following form:

$$M_{r,p\%} = h_p a_1 b k_1,$$

where Mr,p% – the unit of the sediment load for rainfall flood design of security p %, t/ha, hp – layer storm water the provision of R %, mm; a1 – coefficient characterizing features of washout on different grounds, taking into account the type of stream network; b – the coefficient considering influence of agricultural use of the soil in the previous year (if the field was steamed or was occupied by tilled, b=1,0 if-grain, b=0,9 if perennial grasses-b=0,8); k1 – coefficient characterizing the role of the steepness of the slope: k1=0,01 I, where I<100 %o, k1=1,0 (here I is the average slope of the slope in ppm).

For the spring flood period, the model expression looks like:

$$M_{s,p\%} = h_p^n a b k_1,$$

where Ms, p% is the module of sediment load from slopes (t / ha) for the period of spring flood of the calculated security p %; hp is the layer of runoff for the period of spring flood of the same security, mm; a, n – parameters depending on the type of stream network on the slope, soil and agricultural background; other designations are the same as in the formula.

The average annual value of washout from the slopes for the period of crop rotation in accordance with is calculated by the formula:

$$M_o = \frac{\sum_{i-1}^{N}(M_{si} + M_{ri})}{N},$$

Despite the title of the document in which this model was published, the possibility of its application for the design of anti – erosion measures is very limited, since it does not explicitly include the length of the slope-a very important control parameter in the system of optimization of the agricultural landscape, and at a steepness of less than 10 %, the slope is not taken into account, although in flat conditions, the vast majority of arable land has exactly such slopes. In implicit form, both the length and slope of the slopes are taken into account through the structure of the temporary stream network and the average

for the river basin, the flush values correspond well to the results obtained by other equations. However, for the purposes of designing anti-erosion measures, it is difficult to use a model that does not explicitly take into account the influence of the slope and the length of the slope.

This group of models include a model of the erosion-accumulative process based on geomorphological approach and implemented a model for natural-economic conditions of territory of the Volgograd and Orel regions of the Russian Federation. It also has a multiplicative structure and is close to the model G. P. Surmach – module flush is proportional to the layer flow, slope, length of slope, erosion properties of soils and soil fertility. This group also include some less known models, which due to the limited information support have local significance.

Table 1. Averaging bottom non-washing velocity at the height of roughness projections in the trapezoidal bed, V_Δ, m/s

Particle diameter dmm	At the bottom α=0 $V_{\Delta(H)}$	On the slope $V_{\Delta(H)}$			$\frac{V_\Delta - V'_{\Delta(H)}}{V_{\Delta(H)}} \times 100$, %		
		α =20°	α =30°	α =40°	α =20°	α =30°	α =40°
0,5	0,14	0,11	0,09	0,06	21	36	57
0,75	0,16	0,13	0,11	0,09	19	31	44
1,0	0,18	0,15	0,13	0,10	17	28	44

2,0	0,24	0,22	0,19	0,16	8	21	33
3,0	0,30	0,25	0,22	0,19	17	27	37
5,0	0,38	0,34	0,28	0,25	11	26	34

When α =20°averaging bottom non-washing velocity at the height of roughness projections in the trapezoidal bed is:

$$V_{\Delta(H)} = 0.0975 ln(d) + 0.1607;$$

$$R^2 = 0.966.$$

When α =30°averaging bottom non-washing velocity at the height of roughness projections in the trapezoidal bed is:

$$V_{\Delta(H)} = 0.0824 ln(d) + 0.1367;$$

$$R^2 = 0.9871.$$

When α =40°averaging bottom non-washing velocity at the height of roughness projections in the trapezoidal bed is:

$$V_{\Delta(H)} = 0.0806 ln(d) + 0.1091;$$

$$R^2 = 0.9861.$$

Table 2. Averaging non-blurring flow rates in the trapezoidal bed, $V_{н}$, m/s

Particle diameter d mm	$V_{н}$ taking into account the slope of the channel			$V_{н}$ without taking into account the slope of the channel			Discrepancy $(V_H - V'_H) \cdot 100/ V_H$ %		
	m=2,75 (20°) H=5 м	m=1,73 (30°) H=6 м	m=1,2 (40°) H=7 м	H=5 α=0	H=6 α=0	H=7 α=0	m=2,75 (20°)	m=1,73 (30°)	m=1,2 (40°)
0,5	0,26	0,23	0,19	0,28	0,30	0,32	7	23	41
0,75	0,28	0,26	0,22	0,31	0,33	0,35	10	21	37

1,0	0,33	0,30	0,24	0,35	0,38	0,39	6	21	38
2,0	0,41	0,36	0,30	0,45	0,46	0,48	9	22	38
3,0	0,46	0,40	0,34	0,50	0,53	0,55	8	25	38
5,0	0,54	0,46	0,39	0,58	0,61	0,63	7	25	38

When $m = 2.75\ (20°)$ and $H = 5\ m,$ equation for the calculation of $V_{Н}$, taking into accountthe slope of the channel is:

$$V_{Н} = 0.1237ln(d) + 0.3301;$$

$$R^2 = 0.9893.$$

When $m = 1.73\ (30°)$ and $H = 6\ m,$ equation for the calculation of $V_{Н}$, taking into accountthe slope of the channel is:

$$V_{Н} = 0.1016ln(d) + 0.2927;$$

$$R^2 = 0.9957.$$

When $m = 1.2\ (40°)$ and $H = 7\ m,$ equation for the calculation of $V_{Н}$, taking into accountthe slope of the channel is:

$V_{Н} = 0.0871ln(d) + 0.2449;$

$R^2 = 0.9964.$

Private examples of water erosion prediction

1. Determine the amount of washout soil

Objectives of the task:

It is necessary to define the amount of washout soil from the slope per year: length x = 300m, width b = 100m,slope i = 0.15 countertraction in full tenacity c = 0.02kg/cm^2. The trial area is located in a dry climate zone it rains once, I = 0.06 mm/min. Approximately at this time σ = 0.10.

In the first period the rain comes in 3 times:T_2 = 0,8 hour, I_2 = 0,06 mm/min, T_3 = 0,2 hour, I_2 = 0,60 mm/min and T_4 = 0,5 hour, I_4 = 0,30 mm/min.

In the second period the rain comes in 2 times:T_5 = 0,3 hour, I_5 = 0,6 mm/min, T_6 = 1,25 hour, I_6 = 0,6 mm/min

In the third period there is no rain.

In the fourth period the rain comes in 2 times: T_7 = 0,35 hour, I_7 = 0,30 mm/min, T_8 = 1,2 hour, I_8 = 0,20 mm/min.

The amount of washout soil per year should be determined by summarizing the number of erosive soil during each rain.

Solution:

Previous Period (Vacation Period).

Roughening coefficient during the vacation time n = 0,025, $= 0.025$, plowingcoefficient m_1 = 2, runoff coefficient σ = 0,10.

The flow power coefficient on the slope during the time of the vacation is equal to: σn_0 =0,025 × 0.10 = 0,0025.

Due to the lack of special research results, the erosive equation takes into the average meanings of the input parameters: ω =(1/10 s), d = 0,004 m, γ = 1,3 t/m^3.

According to the data, the precipitation duration will be: T = 1,5 × 3600 = 5400

The values of non-washout speed required for the account are taken out of state standards and norms. During fulltenacity the countertraction C = 0,02 kg/cm^3 .The permissible non-washout bottom speed V_Δ = 0,21 m/s. This value of speed multiplying by the working condition coefficient that provides the initial moisture content. for dry climate region m = 0,5. Then V_Δ = 0,21 × 0,5 =0,1 m/s.

It should be noted that for most soils the non-washout bottom speed had such value.

Rain intensity:

$$I = \frac{0.06 \cdot 0.001}{60} = 0.000001\ m/s$$

Length of the no eroded part of the slope:

$$x_1 = \frac{0.000034 \cdot V_\Delta^{3,32}}{m_1^{2.32} \cdot i^{1.16}\ \sigma n_0\ I} = \frac{0.000034 \cdot 0.1^{3.32}}{2^{2.32} \cdot 0.15^{1.16} \cdot 0.0025 \cdot 0.000001} = 11.77\ m$$

$l_{aqt.} = x - x_1$ It is a positive value, so the erosion equation is right.

Then estimated the distance from the watershed to the end of the erosive part of the slope. The slope erosion process continues, until the flow of flattened flow of flaked particles does not reach the marginal value. This value can be determined by any reliable dependence.

n a practical calculation, the slope of the sloped part of the slope x_2 can be obtained as the length of the slope x.

In Task 2 is calculated amount of washout soil from the slope by the erosion equation which dimensions are: length - x = 300 m, width - b = 1 m:

$$q_{x2T} = 11 \cdot 10^{-3} \cdot 1{,}3 \cdot 10 \cdot 0{,}004 \cdot \left[\frac{308 \cdot 0{,}0025^{0{,}6} \cdot 0{,}15^{0{,}7} \cdot 2^{1{,}4}}{0{,}1^{2}} 0{,}000001^{0{,}6} \cdot\cdot\, 300^{1{,}6} + \frac{13 \cdot 10^{-6} \cdot 0{,}1^{3{,}32}}{0{,}000001 \cdot 0{,}15^{1{,}16} \cdot 2^{2{,}32} \cdot 0{,}0025} - 300 \right] \frac{5400}{300} = 11{,}02 tn/ha$$

From this, the amount of washout soil from 300 m and 100 m wide slope will be:

$$F = 300 \cdot 100 = 30000\ m^2 = 3\ ha;$$

$$q_{x2T} = q_{x2T} \cdot F = 11.02 \cdot 3 = 33.06\ \text{ტ}/ha.$$

The amount of washout soil can be calculated for the rest of the periods and rains with a similar score.

First period, the first rain

The complex indicator of the runoff capacity is determined, for which the runoff capacity coefficient should be multiplied by 0.19.

$$\sigma n_0 = 0.0025 \cdot 0.19 = 0.000475$$

Duration of precipitation:

$$T = 0.8 \cdot 3600 = 2880\ s$$

The size of the non-washout bottom speed is determined by the adjustments

$$V_{\Delta.} = 0{,}10 \cdot 1{,}05 = 0{,}105\ m/s.$$

Rain intensity:

$$I = \frac{0.06 \cdot 0.001}{60} = 0.000001\ m/s.$$

Length of the noneroded part of the slope$x_1 = 72.86m$,$l_{act.} = x - x_1$ represents a positive value. Distance $x_2 \approx x$

During the first rain, the soil amount in 1 m from the area is $q_{x2T} = 1{,}02\frac{tn}{ha}$, while the length of the slope is 300 m and the width is 100 ∂ -$q_{x2T} = 1{,}02 \cdot 3 = 3{,}06\ tn$.

The first period, the second rain

$$\sigma n_0 = 0.0025 \cdot 0.19 = 0.000475$$

$$T = 0.2 \cdot 3600 = 720\ s$$

$$V_{\Delta ini} = 0{,}10 \cdot 1{,}05 = 0{,}105\ m/s$$

$$I = \frac{0.6 \cdot 0.001}{60} 0.00001\ m/s$$

$$x_1 = 7.31m\ , \quad l_{xqt} = x - x_1 > 0$$

$$x_2 \approx x\ , q_{x2T} = 2{,}09\ tn/ha$$

$$q_{x2T} \cdot F = 2.09 \cdot 3 = 6.27\ tn$$

The first period, the third rain

$$\sigma n_0 = 0.0025 \cdot 0.19 = 0.000475$$

$$T = 0.5 \cdot 3600 = 1800\ s$$

$$V_{\Delta ini.} = 0{,}10 \cdot 1{,}05 = 0{,}105\ m/s$$

$$I = \frac{0.30 \cdot 0.001}{60} 0.000005\ m/s$$

$$x_1 = 14{,}75\acute{o}\ , \quad l_{aqt.} = x - x_1 > 0\ , x_2 \approx x$$

$$q_{x2T} = 3{,}11\ tn/ha$$

$$q_{x2T} \cdot F = 3{,}11 \cdot 3 = 9{,}33\ t$$

The second period, the first rain

$$\sigma n_0 = 0.0025 \cdot 0.14 = 0.00035$$

$$T = 0.3 \cdot 3600 = 1080\ \ s$$

$$V_{\Delta ფსნ.} = 0{,}10 \cdot 1{,}1 = 0{,}11\ m/s$$

$$I = \frac{0.6 \cdot 0.001}{60} = 0.00001\ m/s$$

$$x_1 = 11{,}53\acute{o},\ l_{aqt.} = x - x_1 > 0$$

$$x_2 \approx x$$

$$q_{x2T} = 2{,}24\ t/ha$$

$$q_{x2T} \cdot F = 2{,}24 \cdot 3 = 6{,}72\ t$$

Second period, the second rain

$$\sigma n_0 = 0.0025 \cdot 0.14 = 0.00035$$

$$T = 1{,}25 \cdot 3600 = 4500\ s$$

$$V_{\Delta ini} = 0{,}10 \cdot 1{,}1 = 0{,}11 m/s$$

$$I = \frac{0.6 \cdot 0.001}{60} = 0.00001\ m/s$$

$$x_1 = 11{,}53\acute{6}, \quad l_{aqt.} = x - x_1 > 0$$

$$x_2 \approx x$$

$$q_{x2T} = 9{,}32\ tn/ha$$

$$q_{x2T} \cdot F = 9{,}32 \cdot 3 = 27{,}96\ t$$

The fourth period, the first rain

$$\sigma n_0 = 0.0025 \cdot 0.21 = 0.000525$$

$$T = 0{,}35 \cdot 3600 = 1260\ s$$

$$V_{\Delta ini.} = 0{,}10 \cdot 1{,}2 = 0{,}12\ m/s$$

$$I = \frac{0.3 \cdot 0.001}{60} = 0.000005\ m/s$$

$$x_1 = 20{,}73\acute{6}, \quad l_{aqt} = x - x_1 > 0$$

$$x_2 \approx x$$

$$q_{x2T} = 1{,}64\ tn/ha$$

$$q_{x2T} \cdot F = 1{,}64 \cdot 3 = 4{,}92\ t$$

Fourth period, the fourth rain

$$\sigma n_0 = 0.0025 \cdot 0.48 = 0{,}0012$$

$$T = 1{,}2 \cdot 3600 = 4320\ s$$

$$V_{\Delta ini.} = 0{,}10 \cdot 1{,}1 = 0{,}11\ m/s$$

$$I = \frac{0.2 \cdot 0.001}{60} = 0.0000033\ m/s$$

$$x_1 = 10{,}2\acute{o}, \quad l_{aqt.} = x - x_1 > 0$$

$$x_2 \approx x$$

$$q_{x2T} = 9{,}81\ t/ha$$

$$q_{x2T} \cdot F = 9{,}81 \cdot 3 = 29{,}43\ tn$$

All:

$$q_{x2T} = 11{,}02 + 1{,}02 + 2{,}09 + 3{,}11 + 2{,}24 + 9{,}32 +$$

$$+1{,}64 + 9{,}81 = 40{,}25\ tn/ha$$

From the total area, measurements 300 × 100 m will be 40.25 · 3 = 120,75 tn.

The report reveals that the volume of the washout soil is quite large and it is necessary to carry out relevant works of erosion; The slope topography parameters (such as rhinitis, length) also knowledge of rain on the specific area gives us the opportunity to write a spreadsheet, which will determine the expected erosion taking into account providing actions.

2.2. Remote Method in Erosion Research

Remote sensing methods for determining the geography of soil erosion at a regional level can be useful for environmental planning, as well as help in solving problems of reducing land degradation and sediment inflow into rivers and water bodies.

When performing studies on images presented in raster form, the commonly used indicator of the thickness of the dismemberment can be replaced by the relative total area (% of total area) attributable to erosional landforms.

To obtain such quantitative characteristics of the intensity of the ravine network development, use is made: analysis of histograms of brightness distribution for reference areas, quantization of brightness and pixel-by-pixel calculation of the relative share of areas.

The vegetation index, or the index of the normalized difference NDVI (Normalized Difference Vegetation Index), calculated from satellite images, is the most universal indicator that can be used for different tasks and scales of research. Vegetation indices can be used for bioindication in order to assess the heterogeneity of the soil by the state of the vegetation. So, the potential danger of soil deflation caused by the degradation of vegetation as one of the types of desertification is estimated by the seasonal NDVI values in the deflationally dangerous period.

In most common vegetation indices, only the red-to-near-infrared ratio is used, assuming that the so-called open soil line lies in the near-infrared region.

Vegetation indices are less effective in studying vegetation cover, if it is sparse. To study the soil, on the contrary, the absence of vegetation cover or at least its rarefied state is necessary. Soils can vary greatly in reflection, even if very wide spectral ranges are used for analysis.

The use of soil-oriented indices is promising. Thus, the use of normalized difference ratios of the NIR (near IR) and SWIR (middle IR) channels of the Landsat 7 ETM + satellite in research (Nield, 2000) allowed accurate mapping of gypsum and sodium soils in the Colorado Basin (USA). When using the PVI (Perpendicular Vegetation Index), developed for analyzing Landsat MSS data, the position of a point on a straight line of soil can characterize, among other things, soil moisture.

Within the Alazani region, using the results of decoding of aerial photographs of 1: 200 000 scale (of the whole territory) and 1:50 000 (at key sites), 9490 were identified erosion forms from the 1st to the 7th order. Due to the combination of regional features of the development of linear landforms and erosion of the soil cover, it is possible to carry out soil-erosion zoning of the territory.

Widespread use of this method in studying soil erosion is facilitated by recent revolutionary changes associated with the wide availability of remote sensing data from the Earth, including high-resolution data and digital surface models based on stereo pairs of satellite images and radar data from the Earth's surface. In this regard, the integration of the results of Earth remote sensing with GIS technology is of great value. It becomes possible not only to visually interpret the erosion network and the ranges of eroded soils, but also to apply automated procedures for morphometric analysis of digital relief models to increase the reliability of interpretation.

In conclusion, we define the basic functionality of remote sensing when studying erosion processes:

- mapping eroded lands;
- adjustment of soil maps with the display of the current degree of eroded soil cover;

- mapping the distribution of linear forms of erosion.
- assessment of the rate of development of linear forms of erosion.
- 3D modeling of the earth's surface using radar altitude data with the possibility of morphometric relief based on its digital model;
- analysis of the orthotransformed space image, superimposed on a three-dimensional digital elevation model.

Conclusions

- It was established non-blurring rates for uniformly sized cohesive soils in order to determine empirical coefficients for the obtained theoretical dependencies;
- It was established the value of non-blurring rates for cohesive soils;
- It was established the limiting value of the cohesive force of a cohesive soil, above which the laying of a slope does not affect the stability of its aggregates;
- As a result of the analysis of the photo material obtained by the spacecraft and their processing in GIS program, it was established risk zones and appropriate preventive measures are proposed.
- Based on the totality of regional features of the development of linear landforms and erosion of the soil cover, it is possible to perform soil-erosion zoning of the Alazani or other river territory.

Scope of the results.

The results of specific tasks developed in the work will greatly assist the scientists working in environmental protection, engineering ecology, hydraulics, hydrogeology, hydro technological melioration, and other neighboring fields in the area of future research and instructing the engineers to prevent water erosion processes. The research results can be used to prevent erosion processes and determine design standards штsolving engineering problems.

Approbation of work.

The main provisions of the Thesis were presented in 2018 at the 86th International Scientific Conference in Georgian Technical University.

List of published works

1. V. Khorava. Comparison of Water Erosion Prediction Models In Open Cannels. Abstracts of the 86th International Scientific Conference. “Technical University”, 2019. p.37

2. I. Inashvili, A. Bagration-Davitashvili, I. Klimiashvili, V. Khorava. Modeling es a Method for Erosion Studies. Hydroengineering. 2019. № 1–2 (27–28)

3. A. Bagration-Davitashvili, I. Inashvili, I. Klimiashvili, V. Khorava. Water Erosion Processes in Georgia. Hydroengineering. 2019. № 1–2 (27–28)

4. I. Inashvili, A. Bagration-Davitashvili, *L. Dzienis, V. Khorava. Modeling of Washing-Out of Non-Converse Soils. Hydroengineering. 2019. № 1–2 (27–28)

დასკვნები

- დადგენილი იყო ერთგვაროვანი ზომის ბმული ნიადაგების გამორეცხვის სიჩქარე, რომელიც გამოყენებული იყო მიღბული თეორიული დამოკიდებულებების ემპირიული კოეფიციენტების დასადგენად.
- დადგენილი იყო ბმული ნიადაგების გამორეცხვის ზღვრული სიჩქარეების სიდიდე;
- დადგენილი იყო ბმული ნიადაგის შეჭიდულობის ძალის ზღვრული სიდიდე, რომლის შემდეგ ფერდობის წყობა აღარ მოქმედებს მათი აგრეგატების სატბილობაზე;
- თანამგზავრიდან მიღებული ფოტომასალის და მათი დამუშავებით გის-პროგრამით, დადგენილი იყო რისკების ზონები და შემოთავაზებულია მათი პროფილაკტიკის ღონისძიებები;
- ხაზოვანი რელიეფების და საფარის ეროზიული პროცესების რეგიონალური მახასითებლების თავისებურებებისაგან გამომდინარე, შესაძლებელია ალაზნის ან სხვა მდინარის ტერიტორიის ნიადაგოობრივ-ეროზიული რაიონირება.