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MAPPING OF ECOLOGIC-ECONOMIC RISK ON EROSION-HAZARDOUS TERRITORIES

E.A. Talanov

Al-Farabi's Kazakh National University, Almaty
E-mail: polse@kazsu.kz

The erosive processes and the mudflow phenomena can cause severe social and ecological damage, therefore division into districts by the degree of risk serves as an information basis for nature management.

The success of the optimization strategy of the environment and the rational nature management in many respects is defined by necessity of the duly account of the probable ecological risk of geosystem degradation connected with planning and realization of specific nature protection actions. For this purpose it is important to define the criteria of ecologic-economic risk, to develop methods of acquisition and territorial interpretation of the data about the interaction of human and the environment. Criteria of ecological destabilization of the environment differ in a great variety. Integrated specifications of quality estimation of the environment are not yet developed [1]. Ecological risk – probability of the environment degradation or its transition to the unstable condition as a result of the current or planned economic activities; possibility of control loss over the occurring ecological events [2]. Within the limits of the anthropocentric approach the subject of probable estimation is the risk of loss occurrence (disease, death) depending on a condition of the environment and its components.

Any subject can collide with the economic risk – single person (group), industrial-economic unit, the state on behalf of the government agencies. Economic risk – an opportunity of casual occurrence of the undesirable losses measured in money terms. The concept of economic risks does not cover only those risks which occurrence leads to monetary damage. They also include the risks leading to damage of the non-economic nature which would be possible (directly or indirectly) to estimate in the monetary form.

The aim of the research is: to develop methods of calculation allowing to define potential losses depending on the social-demographic condition of the region, existential scale and destructive force of natural phenomena, quality of the environment and the importance of ecological objects; to reveal laws of territorial distribution of ecologic-economic risk for geosystems that are subject to the influence of erosion and mudflows.

The lithogenic basis of the landscape (geological condition and relief) substantially predetermines the spatial distribution of soil differences and biotopes, their external borders. Contours of the territories with various ecological situations in many cases are expedient for coordinating with geomorphological borders. The relief directly influences the processes of geodynamics, including being the factors of ecological risk (collapses, landslips, mudflow, flood). The estimation of risk assumes allocation of potentially unstable conditions of geosystems on the basis of the analysis of topographical, engineering-geological or geomorphological maps and taking into account the information about previous events on the given and similar territories. It means the development of the lists of extreme situations, possible within the limits of the considered territorial units, with an estimation of probability of their occurrence and a degree of danger of natural systems infringement.

The evaluation of occurrence of the situations provoked by economic activities, technogenic failures and accidents with human casualties or infringements in functioning of geotechnical systems prevails among the

applied works. Thus, geologic-geomorphological conditions usually act as the factor defining the probability of extreme situations. At presence of multiple observations or the historical data the probability of emergencies of this or that degree is estimated quantitatively, as a number of possible situations in a year or as an inverse value – possibility of an extreme situation occurring once in a certain number of years. The combination of natural and technogenic components of possible catastrophies allows estimating the ecologic-geographical position of specific objects and the ecological risk for the corresponding territories.

As a result of the water erosion influence in the given area the size of ecologic-economic risk is defined under the expression

$$R = \sum_{i=1}^{n} (P\ P_0\ P(q/\gamma)\ P(IS))_i Y_i,$$

where P is the probability of a fall-out of the atmospheric precipitation forming a superficial water flow (the discharge of water with probability of excess is less than 10 %) and erosion; P_0 is the probability of unfavorable meteorological conditions (rains few days straight) promoting the occurrence of dangerous natural phenomenon; $P(q/\gamma)$ is the conditional probability of the developed situation for ecological objects (q) in view of quality of the environment (γ); $P(IS)$ is the probability of potential losses depending on social conditions, scale of influence and destructive force of erosive processes in the area; Y_i are losses (damage) in the cost expression depending on a degree of erosion influence on ecological objects.

Quantitative characteristics of rain are: the layer, duration and intensity of precipitations which are random variables in time and space. The factor of the eroding ability of rains assumes revealing of the correlation connection with quantity of the eroded soil or plotting of the probability distribution curves for volume of soil washout (discharge of mudflows) [3]. Unfavorable meteorological conditions (UMC), when precipitations fall out during a long interval of time (two days straight), is a very rare event (P_0) but such cases is possible to attribute to the erosion-hazardous. For plain territory the value is P_0=0,3, for intermountain valleys and foothills P_0=0,35, and for mountains P_0=0,5. The probability that two independent events can happen simultaneously (by the quantity of the fallen-out precipitations of today and tomorrow) is the product of probabilities of each of these events, i. e. $P_1=P\cdot P_0$. Thus, characteristics of a storm rain with probability 0,0693 at UMC in the foothill territory (P_0=0,35) can be expected at their joint realization with probability 0,0243, and in mountains at (P_0=0,5) – 0,0346.

For cartography of ecologic-economic risk in territory of economic development of Almaty area are used:

1) The soil-erosive map of Kazakhstan (scale 1:2500000), made in the Institute of Soil Science NAN RAC(1994, author A.K. Alimbaev et al.).
2) The map of land utilization (scale 1:1000000), made by the Kazakh branch of VISHAGI (1991, author M.I. Voynova, V.G. Polyakov).
3) The map of the mudflow danger of the territory of Republic of Kazakhstan (scale 1:1000000), made by Kazakh Scientific Research Institute of Environment and Climate Monitoring (1996, author E.A. Talanov et al.).

On the soil-erosive map of Republic of Kazakhstan the non-eroded and non-deflated territories are allocated, as well as: water erosion, deflation, joint display of water erosion and deflation [4].

On the map of land utilization the natural zones (subzones) and agricultural lands on the plain (А), in mountains (Б) and in intermountain valleys (Б^a) are allocated. In our case, the arable land sites, irrigated arable lands, pastures upland and flooded, hayfields upland and flooded, forests and other угодья which are widely used in economic activities, are of special interest.

The methodical basis of a small-scale map of division into districts of mudflow pools is the analysis of available data on quantitative characteristics of mudflows [5]. The basic elements of a special loading of the map of division into districts of mudflow pools (scale 1:1000000) are a degree of the mudflow danger, genesis of the water component, type of mudflows. The mudflow danger is the threat of deaths and material asset losses owing to recession of the mudflow [6]. In territory of Almaty area (224 thousand km^2) the areas with a various degree of erodibility (fig. 1) are defined. Non-eroded zones are attributed to the zero category (1,3 % from the total area of Almaty), the first and the second categories characterize joint display of water erosion (В) and deflation (Д) which are 6,5 % (ДВ) and 5,2 % (ВД) of the area. Meadow ground of flood plains of the rivers are attributed to the category 2 based on degree of erosion.

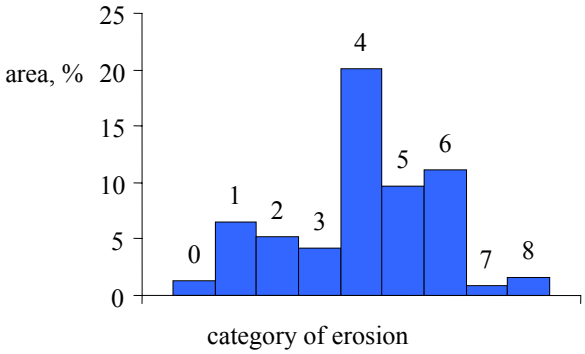

Fig. 1. *Distribution of the area by the degree of erosive danger in Almaty area*

Boharic arable lands of foothills are subject to the channel washout. The intensity of a washout of arable lands varies within the limits of 2...7 sm per rain, the greatest value is concentrated in the average part of the slope. In the upper part of the slope the quantity of subtracted soils from the arable land is equal to 400 m^3/ha, and in the average and the bottom parts of the slope to 700 and 200 m^3/ha accordingly [7, 8]. Rates of a washout are few times higher than the speed of soil formation. The process of annual restoration of soils is much slower. Weak-, moderately- and highly-eroded territories have made 4, 20 and 10 % according to the categories 3–5 (Fig. 1).

Light-chestnut irrigated soils are eroded in an average degree. Theses soils in Almaty area take up 925,7 km^2 whereas highly-washed-out soils take up 29,4 km^2 [7]. The erosive processes (the average degree) in mountains in the wood belt are at a level of the fourth category. The linearly-strip (trodden paths, descent-elevating, channel watering), short-term cattle-campcon centric-focal forms of pasturable erosion are characteristic for mid-mountains. Herb-cereal pastures with bushes on mountainous chernozems (covering 85...95 %, productivity 10...12 centner/he) are attributed to the erosion-steady [7]. Strengthening of erosion sometimes causes growth of bushes. The fifth category is the strongly eroded surfaces, infringement of which makes more than 25 % from the area of the agricultural grounds.

The sixth category characterizes the erosive processes at the plane washout of soils from slopes by means of thawed and rain waters, and also at formation alluvial-water mudflows of a small destructive force. Favorable conditions for such erosion are available on 11 % of the territory (low-mountains and mountains). The low-mountain area, located at absolute heights 600...1200 m and taking up in the Kazakhstan Tyan-Shang 42150 km^2 (28 % of the total area), is a transitive boundary from winter to summer pastures. Cattle grazes here during the most erosion-hazardous periods (late-spring and autumn), there are all forms of pasturable erosion, up to the erosive bedland. In mountainous chestnut unwashed soils the capacity of the horizon A is 17 cm, and weakly washed-out is 13, in moderately and highly washed-out the top horizon is completely washed off and more than half of the B horizon is covered by the washout. The content of humus in the mountainous chestnut soils in the top horizons is the following, %: not washed-out – 2,4; weakly washed-out – 1,9; moderately washed-out – 1,2 and highly washed-out – 1,0 [7]. Long-term subtraction of mountainous chestnut soils at trodden pasture from the bottom and middle parts of northern slopes makes 50 m^3/he, from the top part it is 80 m^3/he.

Foothills of the North Tyan-Shang with gray-brown soils are used as pastures where the unsystematic intensive pasturing of cattle promotes the progressing development of erosion and deflation of soils. Due to washout from foothill pastures 120 m^3/he of soil mass are annually being simply lost. Unlimited pasturing of cattle unites the species structure of plants, reduces biological efficiency of phytocoenosis, and causes the hard-to-restore deformation of superficial horizon of brown soils. Potentially erosion-hazardous territories and the alluvial cones of mudflows (category 7), as well as the area of mudflow (category 8) take up 0,88 and 1,65 % accordingly of the total area.

Powerful mudflows (category 7–10), as a rule, are formed in mountains and render an essential destructive influence in the mudflow channel and at the alluvial cone. Curves of volume distributions of soil subtraction due to the erosive processes at various by the intensity rain flood are presented on Fig. 2. The average volume of the moved soil at falling out of storm rains (curve 1) makes 16100 m^3 (99,7 % of them the mudflows with capacity on a scale of 6–10 points), at the situation ДС (curve 3) – 3670 m^3, and at continuous precipitation (curve 2) only 46 m^3.

At heavy showers of rare repeatability (p=0,00001) the deformation of geological environment due to erosion can make 525000 m^3 in the certain territory, their consequences are attributed to the category of ecological disaster (9 points). Deformation of soil 1000 times smaller than for the category of ecological disaster has the gradation of 6 points.

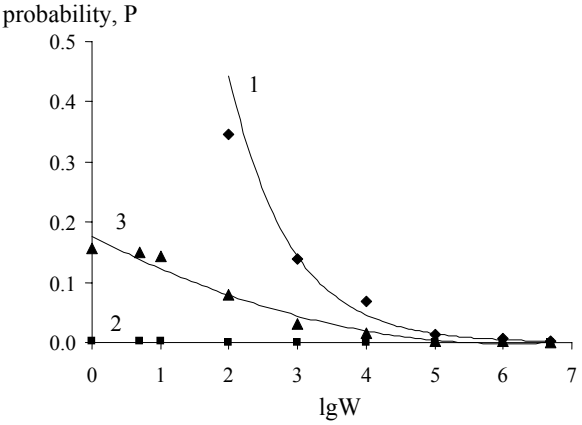

Fig. 2. *Curves of conditional distribution of volume of soil subtraction (lgW) by the erosive process at rain flood*

Existence of the possibility of losses is connected with presence of material assets and vulnerable population which define potential danger of natural catastrophes accidents in the given area. For definition of the index of potential losses the following expression is used [9]

$$IS=IS_g+IS_c. \qquad (2)$$

The first summand of the expression (2) is the function characterizing economic and demographic features of the area (country). The second summand characterizes the scale and the intensity of dangerous natural phenomenon.

In the work [9] on the basis of statistical data the values of geographical component (IS_g) and the index of potential losses (IS) were defined, based on the results of their analyses the ranging of administrative areas of Almaty area by the degree of the mudflow risk were made. We have established the characteristic existential scales of mudflow formation S_0=50 km^2, τ_0=6 h=6,849·10^{-4} a year). The importance of the population density distribution (correlation coefficient 0,81) and the noticeable role of the economic factor (0,44) at definition of potential losses is established. The parity of probability of formation of large earth flows and ecologic-economic harm in view of people deaths is shown at various density of population. The coefficient of affection (E), which depends on character and force of influence of a dangerous natural phenomenon (erosion and mudflows) on objects [10], is possible to present in the form of lg$E$=8J_c at definition of the index of resulted losses IS. It is possible to consider the value of the index of potential losses as casual and submitting to the normal law of distribution.

The set of combinations of ecological objects with various quality of inhabitancy $P(q\gamma)$ which has casual character in time and in space is presented in the work [3]. This parameter represents the characteristic of the situation fraught with occurrence of damage or another form of risk realization (exposure to risk) and is considered in the formula (1).

The interrelation of parameters $\lg Y$ (Y is the sum of direct and indirect expenses providing safe operation of the object under safe conditions) and r (geosyatem safety) isdefined. For Almaty area the actual economic value of objects at influence of erosion is considerably lower than the similar one in view of the ecological factor under normal conditions and in extremely anthropogenous environment [3]. The zone of ecological risk neglect corresponds to the probability of less than $5\cdot10^{-6}$ (at natural favorable condition) and at a level $2\cdot10^{-6}$ (at extremely anthropogenous condition). For these cases of geosystems reliability the real average damage makes \$410 and \$165 accordingly (at the exchange rate as of 2005) at characteristic scales of dangerous natural phenomena.

The territorial distribution of ecologic-economic risk under the influence of erosive processes is presented on fig. 3.

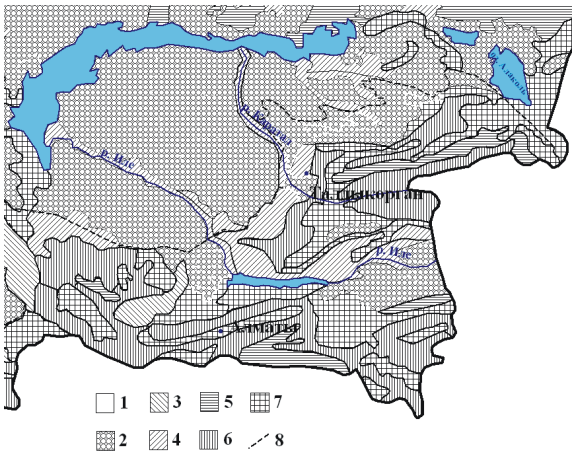

Fig. 3. *Ecologic-economic risk under the influence of erosive processes (mudflow) in territory of Almaty area: 1) glaciers; 2) territories subject to deflation; 3) zone of scornful risk (less than $5\cdot10^{-6}$); 4) ecological norm of risk (from $5\cdot10^{-6}$ up to $5{,}6\cdot10^{-5}$); 5) risk (from $5{,}6\cdot10^{-5}$ up to $1\cdot10^{-3}$); 6) risk of crisis (from $1\cdot10^{-3}$ up to $3\cdot10^{-3}$); 7) risk of disaster (from $3\cdot10^{-3}$ up to $1\cdot10^{-2}$); 8) border of natural zones*

(40 %) Deflationary processes are observed almost on half of the territory of Almaty area (on the map these sites are marked by number 2), but they were not evaluated by us for risk factors. Besides, the belt of glaciers (1 – white background) with the total area of more than 570 km^2 [11] is allocated in the mountains. Mountain areas and intermountain valleys, foothills with intensive economic activities are characterized by high ecologic-economic risk (7 – square shading). On these erosion-hazardous territories, including the sites on the plain with a strong degree of plane erosion, the value of risk is inadmissibly high, as within the limits of the area 50 km^2 (in a short interval of time, 6 hours on the average) the economic damage from \$25000 up to \$1125 thousand can be caused by the erosive processes. In the zone of ecological crisis (6 – vertical lines) average losses reach up to \$2500, whereas in the zone of risk (5 – horizontal lines) the losses are amounted to \$10...40. In Almaty area the potential average damage from water erosion (mudflows) amounts to \$270 thousand a year (as of 2005). Based on our estimations 73,5 thousands of tons of biogenic substances have been washed out in the basin of the river Malaya Almatinka by the erosive processes (annually on the average 75...80 t/ha) and due to decrease in fertility of soils the damage has been done for the sum \$1000 thousand (about \$680/ha).

Thus, the map of ecologic-economic risk for the territory of Almaty area (scale 1:2500000) can serve as the basis for planning and management of nature with introduction of the system of insurance in order to compensate the damage caused by the natural spontaneous phenomena, ecological and social factors of risk.

Conclusion

1. Characteristics of variability of fields of the natural factors defining formation of erosion and their danger in the region are established: erosive processes are observed annually, but the probability of a fallout of mudflow-hazardous showers repeats on the average 1 time in 15 years; the average area of scope and time of process have the following values S_0=50 km^2, τ_0=6 h=6,849·10^{-4} a year; the average erosive ability of soil washout is estimated as 16000 m^3. The situation when the rain is imposed on the snow can be observed in the region (1 time in 6 years). At the same time, the destructive erosive ability is insignificant (washes away and moves no more than 4000 м^3). Continuous precipitation deposits, capable to cause erosion, is an extremely rare phenomenon especially in the deserted zone.
2. The degree of geosystem degradation is defined by the following characteristics: non-eroded territories take up 1,3 % (from the total area), areas subject to water and wind erosion 11,7 %, weakly-, moderately- and highly-eroded territories have made 4, 20 and 10 %, the zone of formation of water-alluvial mudflows of a small destructive force is located in the low-hill terrain (11 %), and in mountains the potential erosion-hazardous territories and the cones of the mudflow washout take up approximately 2 % of the territory.
3. The risk which can have the economic, social and ecological aspects serves as a quantitative measure of danger of geosystems infringement. The threshold of stability (reliability) of geosystems is established: under normal conditions it is possible to neglect the risk of less than $5\cdot10^{-6}$, and at extremely anthropogenous influence the non-risk level is less than $2\cdot10^{-6}$.

The value of density of the population distribution (coefficient of correlation 0,81) and the condition of economic development of the region (coefficient of cor-

relation 0,44) essentially influence the potential losses from the destructive force of erosion (mudflows). In region the erosive processes can cause the potential economic damage on the average $1125 thousand or $22500 on each hectare.

4. The map of ecologic-economic risk in the erosion-gazardous territory of Almaty area (scale 1:2500000) is the first attempt of generalization of the multifactorial processes influencing stability of geosystems of the regional level.

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