THE WATER FROM NATURE AND THE EROSION PROCESS

G. PANDI[1]

ABSTRACT. – The water from nature and the erosion process. Studying earth's surface erosion process is necessary for practical reasons. The theoretical approach requires knowledge of the alluvial system's structure and operation as the cascade sequence of fluvial system's mass and energy. Geosystem research methodology requires that the water energy and the role of adjacent surface must be expressed. The expression of water power can be grouped according to the shape of movement and action in the basin. A particular, important case is the energy variation in a basin-slope. An important role in energy expressions is considering the existence in nature of biphasic fluid - water as dispersion phase and solid particles as dispersed phase. The role of the adjacent surface is taken into account by using the erosion resistance indicator, which is calculated using the indicator of geological resistance and the indicator of plant protection. The evolution of natural systems, therefore of river basins too, leads to energy diminishing, thus affecting their dynamic balance. This can be expressed using the concept of entropy. Although erosion processes are usual natural phenomena for the evolution of river basins, they induce significant risks in certain circumstances. Depending on the circulated water energies, water basins can be ranked in terms of potential risks.

Key words: alluvial system, water energy, basin – slope, biphasic fluid, active and passive forces, resistance indicator, erosion risk

1. INTRODUCTION

The existence, structure and functioning of natural systems is determined by control factors. The factors, characterized – among other properties – by diversity, interconnectedness and synergy, confer a great complexity to systems. The hierarchical structuring of natural systems is axiomatic, which also means that subordination expresses intrinsic functional connections.

A link in this connection is the river system. The system, determined by watershed, channel, slope and continuous moving water, like functional subsystems, is well spatially and temporally defined. Each subsystem analysis leads to the conclusion of system's great diversity and complexity. In such assessment is necessary to consider that all analyzes should be based on the role of water in the system. Only then can be highlighted the reality of a flowing system's existence. System's "active" component –

[1] Babes-Bolyai University, Faculty of Geography, pandi@geografie.ubbcluj.ro

water – acts over the other subsystems with "passive" role. The determinant process in this action is erosion, which models the adjacent surface. Of course, there are influences in the reverse direction – the feed-back relationships.

In the assessing erosion process operation is necessary to consider that there is no clean water (chemically speaking) in nature. So, the river system water always contains dissolved salts and gases, and also solid material. Thus defined, the water in nature is a multiphase fluid. The dissolved substances and solid particles from water affect its properties, in general, and the mechanical action of moving water, in particular.

In this context, Outhet has outlined the structure of an alluvial system, as an open system, a defining property of any natural system. The inputs are represented by the control factors. Internal processes form a hydro-morpho-dynamic triad "erosion-transport-deposition". The system output is the production of alluvium. Such a structure represents a causal convergent system (Simoi, 1978), where the number of inputs is greater than the number of outputs.

This system's functioning involves the transfer of solid material and formation of storage. The alluvia source is represented by the water basin (slopes and river beds), which suffers because of the influence of natural erosion processes, but also because of anthropic processes resulting from land use. Following the evaluation of these judgments, resulted four levels of alluvial system organization (Outhet, 1984). Based on this idea, Ichim defined alluvial system as a sequence of mass and energy cascade from the flowing sub-system of a river system (Ichim, 1987).

The need to address the erosion process, and, in general, the erosion system operation, comes from the alarming proportions of Earth's adjacent surface degradation. Agricultural and forest lands, mining industry regions, built spaces etc. suffer from erosion processes at an accelerated pace. Local and regional measures are no longer effective for stopping or reducing land degradation. Approaches should include comprehensive global strategies, in which a decisive role is the complex watershed planning. This way may be reduced the risk of major land degradation, which is the inevitable result of the erosion processes. It should be noted that such strategies already exist, but their effective functioning still needs improvement, sometimes substantially.

2. THE WATER FLOWN ENERGIES

Energy approach of erosion process is necessary from several points of view: the knowledge of erosion genesis, correct interpretation, interdisciplinary analysis, the possibility of quantifying and, not lastly, the integration of research methodology geosystems.

In all cases prevails the knowledge of water energy, because it is used to generate forces that act over the water surfaces which it comes into contact.

In this context it should be highlighted that the evaluation of water action over the adjacent surface involves axiomatic three directions:

- water is the most active modeller of Earth's surface because it is an element with a particular mobility, and because – different forms – it can be found in all climatic zones;
- river water acts within the water basin, and so directs both material and the energy and information flows;
- the potential energy of moving water is converted into kinetic energy, acting on the river basin's morpho-dynamic equilibrium.

Water energy acting on the basin's surface is expressed in general form by Bernoulli's equation, which shows that the energy of a water quantity depends on its volume and density, and hydrodynamic load:

$$E = 9{,}81 \cdot \rho \cdot W \cdot \left(\frac{v^2}{2g} + \frac{p}{\rho \cdot g} + z \right) \quad \text{(J)} \qquad (1)$$

where: ρ – water density;
W – volume;
v – average flow speed;
p – atmospheric pressure;
g – acceleration due to gravity;
z – altirude of the point above a reference plane.

The analysis of water's action into the hydrographic basin follows first the ways water move, by which it gets into contact with the adjacent surface. In this sense can be distinguished the following types of movement / action, which are all types of energy (Pandi, 1997): rain drops; areal slope flow; concentrated slope flow; river bed flow.

Without detailing, we will refer to each mechanism briefly.

The impact energy of raindrops causes dislocation and spreading of solid particles, which depends on the mass, size, direction, intensity and speed of the droplet. Areal flow energy is demonstrated by soil erosion after it is oversaturated with water, after slope's micro-depressions are filled and after turbulent flow type, able to dislodge solids, has begun. Displacement occurs under the impulse of static and dynamic pressure exerted by the moving water film.

On the slope, water focuses successively along the lines of maximum slope and minimal resistance. Mass concentration leads to energy concentration and to intensification of displacement action. And so appear ravine forming processes, the most efficient in production of alluvia.

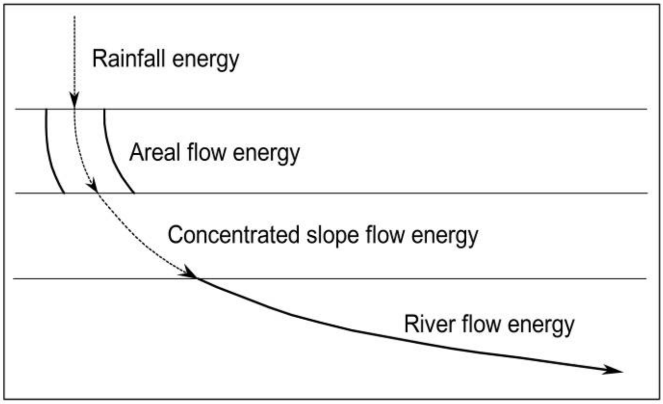

Figure 1. Water flown energy types from a hydrographic basin

River flow energy is an energy type of a higher quality movement. Continuous flow nature of a river bed is a qualitative leap, where energy transformations become continuous. This gives to the hydro-morpho-dynamic triad a continuous nature.

These types of energy can be manifested differently in time and space. The energy of each water movement type can be expressed separately. But basin surface's denudation is the result of their synergistic action within a highly complex mechanism. The power of this action expresses the water volume's erosion power, which is the active, mobilizing forces. The system includes, however, passive forces, expressed by the hydrographic basin surface material susceptibility to erosion. The displacement of solid particles from the adjacent surface – the erosion process – depends on the system of forces.

2.1. Basin – slope energy

Qualitative analysis of adjacent surface often focuses – from practical slope development considerations – on small basins. Basin – slope is relatively small hydrographic unit (undefined exactly as surface), with factors influencing the hydro-morpho-dynamic triad relatively homogeneous. The energy in a basin – slope can be separated in slope areal energy and linear river bed energy.

Slope energy can be calculated for slope's successive horizontal strips using the following formula (Podani, 1987):

$$E_v = K\int_{H\min}^{H\max} q \cdot A \cdot dH \qquad \text{(kWh)} \qquad (2)$$

where: K – a dimensional parameter;

H_{max}, H_{min} – extreme basin elevations;
q – specific discharge;
A – basin surface;
dH – fall of a calculus strip.

When there are calculated the specific values of energy's successive strips, it can be observed that in the middle of the slope they are maximum, expressing a critical energies stripe.

$$e_v = \frac{E_v}{\Delta H} \qquad \text{(kWh/m)} \qquad (3)$$

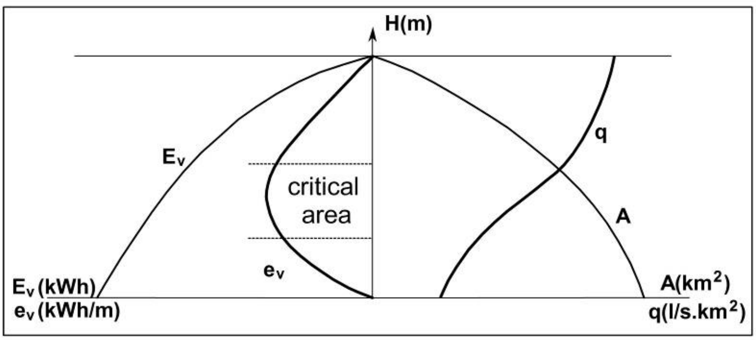

Figure 2. Energy variation in a basin – slope (Podani, 1987)

Here can be most likely triggered high intensity erosion processes. This finding may give new orientation to optimization strategies of slope erosion constructions placement.

The location of a critical strip depends on many factors: specific flow variation with altitude, slope morphometry and morphology, the substratum nature, vegetation cover etc. Computational simulations showed that, together with these factors, the critical strip's location and shape depend also on the shape of basin – slope (Pandi, 1997).

Linear energy of basin – slope is represented by the collector river. It is calculated for successive river sectors to avoid the equivalence of longitudinal profile's parabolic shape with a straight line.

$$E_l = K \cdot Q \cdot \Delta H \qquad \text{(kWh)} \qquad (4)$$

where: K – dimensional parameter;
Q – river sector discharge;
ΔH – profile fall in considered sector.

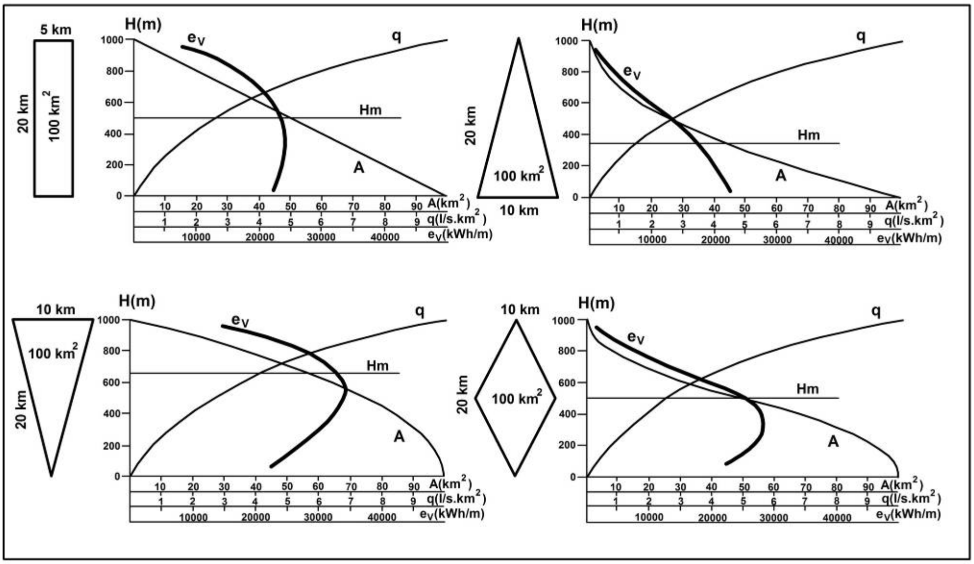

Figure 3. The effects of river basin’s shape on specific energy distribution

Here also can be calculated the specific values of sector’s energy. Regarding the linear energy, some authors consider more accurate the expression of water power in the analysed river sector.

The basin – slope energies that act over the hydrographic basin cause the erosion processes and the amount of eroded material. They can be calculated for multiannual or annual averages, and for only one rain.

3. BIPHASIC FLUID ENERGY

The water and surface of a hydrographic basin exist in a system of forces that influence each other. These forces can be grouped into active forces – that act, and passive forces – who oppose to action. The result of system operation is the hydro-morpho-dynamic triad, in which erosion process plays a decisive role. Because of this process, water is charged with solid particles that form a continuously flowing system, represented by the biphasic fluid. It is composed of the liquid phase – the dispersion (as a continuous medium) and the solid phase – dispersed (representing a discontinuous medium).

The water moving on basin’s surface exerts two pressure types on the substratum, which serve as active forces:

- static pressure, proportional to the thickness of water layer, is the result of pressure difference in vertical direction;

- dynamic pressure, due to water's kinetic energy, is the result of upstream – downstream pressure difference.

The other system component is represented by passive forces (resistance forces), which include to particle weight, friction and cohesion forces.

The space-time ratio between forces system's components determines five states of the solid phase towards the liquid phase of biphasic fluid – water fom nature:

- Repose state: The ration between active and passive forces is subunit (Fa / Fp <1), because water is not able to dislodge solid particles.

- Critical dislodging state: Active forces have approximately the same value as the passive ones (Fa / Fp ≈ 1). It is an unstable equilibrium, when the first phase of the hydro-morpho-dynamic triad is activated – erosion.

- Moving on the river bed bottom: The forces ratio is higher than one (Fa / Fp > 1), as a result of solid particles' move on the contact surface through sliding, crawling, rolling, small jumps.

- Suspension movement state: The active forces value greatly exceeds that of passive forces (Fa / Fp >> 1); some rotational and ascending forces appear, making the alluvia to spread throughout the water volume and to remain afloat for a long time. The two states of motion represent the second phase of the hydro-morpho-dynamic triad - transport.

- Sedimentation state: It comes back to a subunit forces ratio (Fa / Fp <1). Water is no longer able to maintain the suspension and to further transport solid particles; they are deposited, thus activating the third phase of the triad.

It must be emphasized that the solid particles alter the water flow energy. At the beginning of this process, the particles consume a part of water's energy, but once in move, the biphasic fluid receives higher energies, because the solid material has a higher specific weight than water. So, the biphasic fluid exerts higher pressure on adjacent surface and the erosion becomes a more active and efficient process. The veracity of reasoning is confirmed inclusively by physical modelling, where it was shown that the water with no alluvia acts with much less efficiency on the adjacent surface.

From the energetic point of view, river water discharge measurement includes both phases, as they are inseparable. Water's mobilizing energy, which erodes the adjacent surface and provides a certain risk to this process, is combined from the sum of water energy and alluvia energy. The unified equation that expresses this action is:

$$E = 0.086 \cdot \gamma \cdot q \cdot A \cdot \Delta H \qquad \text{(kWh/an)} \qquad (5)$$

where: 0.086 – a constant for the calculus of energy / year;
γ – equivalent specific weight of solid material;

q – annual average specific discharge of biphasic fluid;
A – hydrographic basin's surface;
ΔH – altitude difference.

4. THE ROLE OF ADJACENT SURFACE IN EROSION PROCESS

The surface that comes into contact with the moving water serves as an opposition to the mobilizing forces. The main components of the adjacent area and also the resistance forces' factors are the geological substrate and vegetation cover. Besides these main factors, the erosion process is also influenced by other factors – with a much diminished role, such as slopes and river bed's gradient, slope length and height, slope river bed's longitudinal profiles shape, soil characteristics etc.

In comparison with the active forces, the forces represented by these factors are characterized by a much higher stability. The substrate, the vegetation, the relief's morphology and morphometry, the soil all change under the influence of natural factors only in a long time. Human interventions through actions of land use, improvement, construction etc., can cause major changes in a relatively short period of time.

It can be concluded that due to the remarkable stability of the adjacent surface, its characteristics can be expressed as parameters which remain constant over relatively long periods of time.

It should be noted that the factors of erosion resistance forces influence active forces directly or indirectly. Also, their action may be manifested in the same direction, increasing the reducing role of erosion, or in opposite directions, when attenuates each other and oppose less resistance.

The geological substrate is the main source of sediments. Particles reach the water through their mobilization by the erosion process. There appears a direct source when the bedrock is at the surface and indirect when the surface is covered by the soil. The role of the substrate is manifested primarily through its petrographic nature, which causes resistance against mechanical displacement forces. The classification criteria are based on the rocks' genesis (metamorphic, igneous, and sedimentary) and age. They determine the rock's physical and mechanical properties, according to which the mechanical action of water opposes. By principle, the metamorphic, volcanic and old rocks oppose a greater resistance to erosion processes, and sedimentary and newer rocks are more easily dislodged.

Because of the multitude of rocks, classified by origin and by age, their classification is very laborious and cannot be exhaustive. As with any modelling, simplifications were necessary here, leading to 16 groups of geological resistance. For example we remember that the first group includes sands, gravels and clays from the upper Holocene and the last includes andesites, diorites, dacites, rhyolites, granites, granodiorites, all of volcanic origin. Each group was assigned with a coefficient of resistance (raging from 2.5 to 10).

The vegetal cover serves as protector of the earth's surface, because it intercepts rainfall, diminishes the mechanical action of raindrops, influences the accumulation of water in snow and soil, slows areal flow and ravine forming process, and, through evapotranspiration, alters the characteristics of water resources. The leading role in this phenomenon is casted by the forest, but also by the herbaceous layer, which may delay the activation of erosion processes for a shorter period.

Taking into account the natural vegetation and the crops (which have a very important role in influencing erosion) there were established six groups of resistance. The first group is represented by associations of meadow and farmland, and the last one by deciduous forests. Here, the resistance coefficients have values between 1 and 6. Among other factors stands out – sometimes – the gradient. Its influence is highlighted especially when geological substratum and vegetation cover in the basin are relatively homogeneous.

Sometimes deterministic models take into account dozens of factors for multi-factors analysis. The results are not always on the level of the efforts made to determine the parameters of each factor. And in such cases are required some simplifications for the purposes of assessing the impacts and by grouping factors.

4.1. Expression of erosion resisting forces

Although the factors that oppose to erosion process show a remarkable stability, their quantification is difficult. This is because it is difficult to measure the erosion opposing forces, compared to determining the water quantities, which are the active forces.

Over time, different authors expressed resistance coefficients/indicators or erosion coefficients/indicators. In their determination were taken into consideration various factors: surface flow, liquid and alluvial discharge, eroded layer, land's slope, percentage of slopes with varying degrees of degradation etc.

An attempt of simple and effective expression of the factors role that oppose to erosion is made using the resistance indicator (R_E) (Pandi, 1997).

$$R_E = R_G \cdot P_V^{\,0.5} \tag{6}$$

It takes into account the influence of the 16 geological resistance groups, which is expressed by the geological resistance indicator (R_G), and the 6 groups of vegetation resistance, which is the indicator of plant protection (P_V):

$$R_G = \frac{R_{G1} * f_1 + R_{G2} * f_2 + ... + R_{Gn-1} * f_{n-1} + R_{Gn} * f_n}{A} \quad (7)$$

$$P_V = \frac{P_{V1} * f_1 + P_{V2} * f_2 + ... + P_{Vn-1} * f_{n-1} + P_{Vn} * f_n}{A} \quad (8)$$

where: $R_{G1} \ldots R_{Gn}$ – resistance coefficients of the 16 rock groups;
$P_{V1} \ldots P_{Vn}$ - resistance coefficients of the 6 vegetation groups;
$f_1 \ldots f_n$ – surfaces covered with rock / vegetation from that group
A – total surface of hydrographic basin.

The method can be used by taking into consideration the sub-basins of a hydrographic basin (which however have different surfaces), or in distributed parameters system, where there appears the advantage of equal sized surfaces.

5. RISKS INDUCED BY EROSION PROCESSES

One of the main problems of sustainable development is the erosion of hydrographic basins. Accelerated mechanical processes have major economic and social consequences that would create risks. Such alteration crust removal and deepening of torrential formations in unconsolidated slopes bedrocks produce large amounts of alluvia. These processes lead to soil degradation, reducing riverbeds transit capacity, meadows alluviation, lakes clogging, blocking of water intakes and of bottom discharge etc. In this context of increasing risks due to erosion and alluvial production is necessary an interdisciplinary approach of the alluvial system, as a subsystem of water flow.

Natural factors, plus increasingly anthropogenic factors, generate quasi-continuous erosion processes, which occur in time and space. Their degree of "efficiency" depends on the interaction between the poly-phasic fluid and the adjacent surface. In certain circumstances, these processes pose a risk to the balance and evolution of the hydrographic basin.

If we analyze the hydrographic basin in terms of systemic analysis, it can be observed that it has an evolutionary structure and operation. According to the theory of entropies, geosystem's quality is closely related to system's evolution. A "normal" evolution leads to structural and functional uniformity, which is expressed through developed entropy.

System's stability and resistance to the action of disturbances factors in a hydrographic basin expresses the dynamic equilibrium of the system. This balance and sense of evolution have an energy background. In this context, Simoi (1978) defines the entropic sense of free systems evolution and the concept of energetic entropy.

As a result, even the systems of hydrographic basins evolve towards dynamic balance, minimum energy consumption, which means lower erosion risks. The developed entropy expresses a small amount of energy for erosion processes. It should be noted that the entropy expresses the energy available in the system for process development and not the amount of the system's total energy (Ichim, 1989).

Ujvari (1987) establishes four categories in the evolution of geosystems: elementary, incipient, develop, and with higher evolution, depending on the nature and diversity of components. For each can be defined differential energy consumption, respectively entropy levels, and expressed differentiated degrees of development. Of course, in this hierarchy, erosion processes involve varying degrees of land degradation risks.

Making a similarity and taking into account the sizes of biphasic fluid's calculated energies inside the hydrographic basins, they can be ranked in terms of potential risks: hydrographic basins with elementary risk; hydrographic basins with incipient risk; hydrographic basins with medium risk; hydrographic basins with developed risk.

Because the risk includes, along with the likelihood of the process appearance, also the damages, the ranking is influenced by the value of goods displayed that can be potentially destructed.

6. CONCLUSIONS

The potential risks of erosion process influence more and more the life and work of our society. Therefore it requires a solid theoretical foundation of structural measures which are wanted to diminish the damages.

In analyzing the erosion phenomenon must start from the fact that the alluvial system is structured and functions as an open, flowing and hierarchical system. The existence in nature of biphasic fluid causes erosion processes to be more effective, and the energy approach facilitates a better theoretical knowledge and a better application. Quantification of natural factors that oppose to active forces is more difficult, but their expressing through resistance indicators is a usable solution. Thus there is a good possibility for systemic analysis of interactions and inter-conditioning inside a river basin or even on a slope.

The strategies for minimizing the erosion induced risks must be global, regional and local, but concrete approaches and practical measures must target hydrographic basins as well defined unitary systems in space and time, in which processes converge due to its systemic structure and functioning. In this regard it is useful the hierarchy of hydrographic basins according to the potential risks induced by erosion processes.

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