ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Basin Approach to the Study of Erosion Processes Occurring in the Territory of the Russian Plain.

Oleg P. Yermolaev*.

Kazan Federal University, Kremlevskaya str. 18, Kazan.

ABSTRACT

This paper deals with main types of operational-territorial units used in the spatial analysis of slope erosion development. The analysis of the entire system of operational-territorial units used in the study of slope erosion processes in the plains of the temperate zone of the Earth, shows that a drainage (river) basin is an operational and territorial unit most suitable for this purpose. This is because of the fact that the basins are a geosystemic formation and reflect the specific nature of surface slope runoff, due to which a range of erosional processes occurs. An important feature of the basin approach is the simplicity in defining these units in the geographical space and the reasonable transition to other scale levels due to hierarchy feature of river basins. Their limited use is associated with the landscape specifics of the terrain: such as ice and arid zones of the Earth. We have electronically mapped the territory of lowland and upland landscapes of the eastern part of the Russian Plain with total area of 150,000 km^2 by defining the boundaries of 3,331 basins used in the analysis of soil and gully natural-artificial erosion. Other types of operational-territorial units such as the regular geometric grids, the political-administrative division, and sample characteristics can be used for collection of data geobank but poorly suited for identification of erosion patterns. Landscape territorial units allow performing a stiffly accurate spatial analysis of erosion and its determining factors. The factor limiting their use is the complexity of landscapes defining, lack of their internationally standardized taxonomy and poor cartographic exploration of the territory at regional and local generalization levels.

Keywords: river basin, landscape, operational-territorial unit, soil and gully erosion

Corresponding author

ISSN: 0975-8585

INTRODUCTION

The choice of the so-called operational-territorial unit (OTU), adequate to a current problem, is of fundamental importance when conducting a spatial analysis of a natural or social process or phenomenon. The choice of OTU type is largely determined by the object of study and the geographical position and specifics of the landscapes of a certain territory. The most common OTU type used in studying the socio-economic phenomena is the administrative boundaries. When studying natural phenomena, OTU may vary depending on the process or phenomenon. It may be either a separate slope or a whole mountain range, or a landscape (or its taxon), or a drainage basin.

TECHNIQUE

When studying the slope erosion processes on the territory of the Russian Plain and choosing the type of OTU, we proceeded from the following conceptual approaches. Firstly, it had be a task of required generalization level. A type must match the regional level or scale of 1:200,000 in order to ensure both the representation of the contours of eroded soil and gully dissection, and a set of diverse thematic information. This information, in turn, should be well spatially distributed to ensure the analysis of basin erosion processes. With a view to the chosen level of generalization, we require such type of OTU, which will ensure a hierarchy, i.e., the transition from one scale to another. Secondly, we had to ensure the principle of continuity. This assumes a lack of "holes" in the territory, which must be covered with a continuous network of OTU. Thirdly, the choice of OTU must take into account the physical laws of the process under study. Fourthly, OTU must easily stand out against the ground and we could use modern information technologies for their demarcation and spatial analysis. All currently existing OTU have found application in the practical studies of erosion processes. We shall consider their features and choose the type of OTU most suitable for use in humid landscapes of the temperate zone of the Earth.

Sample characteristics or use of key sites as the OTU. These sites are usually represented by the individual elements of the river valleys, small drainage basins, and experimental farms. We used the similar type of OTU to solve a number of tasks: working out the decrypting signs upon identifying the structure of the basin erosion; establishing the typical standards of humus horizons of unwashed soil and determining the intensity of soil wash in arable land.

All obvious advantages common to these territorial units have become unsuitable for regional studies of erosion development. It primarily concerns the representativeness of OTU and reliability of using data in geographical extrapolation of observation results.

Geometric regular grids are widely used in quantitative evaluation of the erosion factors such as length, steepness, slope exposure, relief erosion potential, etc. [1-4]. Methodologically, this approach succeeds a method of systematic sampling widely used in geographical research [5]. While these OTUs are rarely used in assessing the propagation of erosion processes. Lack of geometric grids in the study of erosion is obvious and is primarily due to generalized spatial reference. In addition, the grids cannot reflect the conditions of formation of surface runoff. Distinct advantages of such grids lie in the ability to select a grid pitch and quickly obtain large amounts of factual material, and in the convenience of spatial modeling.

We used the regular-shaped grids when needed to enrich the database of erosion factors and its zoning. These OTUs are indispensable in the development of GIS technologies for data collection, storage and processing. They are also the most effective means of creating the map data geobanks [6-8], and convenient for automation of mapping of different content. As a positive example of the use of OTUs we can refer to the experience of drawing up soil-erosion plans for the US County [9] and the works by the author on the assessment of erosion in the eastern part of the Russian Plain.

The political-administrative and economic division is most frequently used when describing the propagation of erosion. Small-scale evaluation of the process involves subjects of Russia as the OTUs, medium-scale involves municipal districts, and large-scale evaluation involves individual farms. At first glance, these OTUs may well be used in the study of erosion. Firstly, it is of their captivating simplicity of demarcation of territorial units. Secondly, the values of washed-off soil areas are calculated with the use of large-scale maps and cannot be generalized upon transition to the regional level. The available information of the inventory plan on areas

under arable land, hayfields, road networks, settlements, hydrographic objects, etc., assumes significant importance. In addition, the farm grid is narrow enough and could be used in a regional assessment of erosion. At the same time, we know well about random nature of the boundaries between farms, which often differ from natural boundaries.

Landscape approach is considered the most reasonable in the analysis of environmentally unfriendly processes. It maximally takes into account the diversity of natural conditions in the typological units of different taxonomy. At the same time, we cannot pass over a range of existing problems. Here are some of them. This is primarily true of the choice of a specific natural boundary, running which is always a willful act and therefore is of subjective nature [10]. There is also a lack of single-valued relations between the units of physiographic and landscape taxonomy [11]. Another problem is a poorly studied landscape. No medium-sized landscape maps are available for the area of research. Speaking about the already published maps, we can mention only the small-scale physiographic schemes of the Middle Volga and a "Landscape Map of the USSR" as an example [12]. These materials can be used in challenging the erosion study only in the first approximation. There is an obvious fact of very limited use of landscapes as the OTUs when studying the erosion processes. As usual, this approach is declared only. This is largely due to high complexity of landscape mapping, lack of the necessary material, and to the requirements for the qualification of a researcher. Both theoretical and methodological support of the landscape approach in the study of erosion processes is given in papers [13, 14], and in other works. Relying upon the landscape basis is the only way to successfully address one of the main problems of the erosion studies, such as identification of types of soils, their systematization and the development of regional erosion models. Foreign studies implement the landscape approach in terms of erosion upon studying the parameters of water balance of basins and regularities of slope runoff formation, considering the diversity of soil sequences and other parameters, which has been defined as a landscape-ecological approach. Such works are usually carried out on small experimental sites [16, 17].

RESULTS

Analysis of different types of OTU used in studying the erosion processes suggests that the basin approach is the best one to be used in the plain landscapes of the temperate zone of the Earth.

The basin approach used in the structural and functional analysis of the environment, including erosion, is considered the most acceptable OTU. The rationale for this approach can be found in numerous publications by both domestic and foreign researchers [18-24]. The basin principle was declared as a fundamental one for the regional studies in the territory of Russia, and 20 basin districts were created as the main administrative units for use and protection of water bodies.

The basin approach is most commonly used in the assessment of solid river runoff, and gully erosion, and lesser in the study of soil erosion. Depending on the scope of works performed, the size of the basins under analysis varies greatly: from tens of thousands of square kilometers [25] to a few hectares upon allocating the so-called morphological units [19]. In the first case, all basin characteristics are very generalized. Using morphological units gives good results in the development of empirical dependences of soil loss in the slopes, and in the study of erosion mechanism by a detailed record of various indicators. During the investigation of erosion processes, the basin size is usually limited in accordance with the scope of work, defining it as elementary. In this case the procedure of defining the basins in order of their hydrographic network is considered reasonable. In our studies of the basin erosion structure we used the tertiary basins. We also chose the secondary and tertiary basins to analyze the process of areal erosion.

The choice of river basins as the basic territorial unit of analysis is determined by a number of advantages over other types of the above OTUs. We shall note the key features:

- A river basin has all features of geosystems such as integrity, uniqueness, hierarchy, stability, and self-regulation.
- A river basin is characterized by a unidirectional flow of substance and energy. It has the so-called systems with horizontal connections formed therein. In this sense, the basins form anisotropic category of structures, which are characterized by unidirectional gradients real-energy fields and the corresponding lateral geoflows [26]. Our studies of the structure of basin erosion firmly confirm these properties of the basin geosystems.

- Objectivity and relative ease of isolating the boundaries. The ability to "design" the OTU upon changing different scales. This allows using the basin as a topological unit upon sequential transition from one scale to another.
- The basins allow simulating can simulate the processes of erosion and runoff, and setting up the balance equations with maximum reliability.
- The first-order basins are characterized by morphological landscape structure similar in both composition and spatial organization.

As a result of using the basin approach, we have defined 3,331 discharge basins in the area of more than 150,000 km^2 in the territory of the eastern part of the Russian Plain. These are the basins of tertiary rivers and their interbasin spaces. Thus, the OTU grid covers the territory under study in planar manner. We have drawn an electronic vector map of the basins (Figure 1) with the use of automated methods of analysis of digital terrain models [21-23]. We have counted both the areas of eroded soils and the density of gully system in each basin. In addition, we have obtained for each basin the subject information on more than 40 parameters, which allows us to make quantitative evaluation of the role of each factor in the development of erosion, to identify its basic laws and define zones of erosion occurring and developing on the slopes of basins in this vast region of the Earth.

Despite all obvious advantages of the river basin approach, it also has several drawbacks and cannot be considered universal. Thus, it is problematically used in the semi-desert and desert landscapes, in a low-level and heavily waterlogged relief, and in the belt of high-mountain glacial landscapes. It also seems difficult to reasonably run boundary lines of the basins in case of very wide discharge basins.

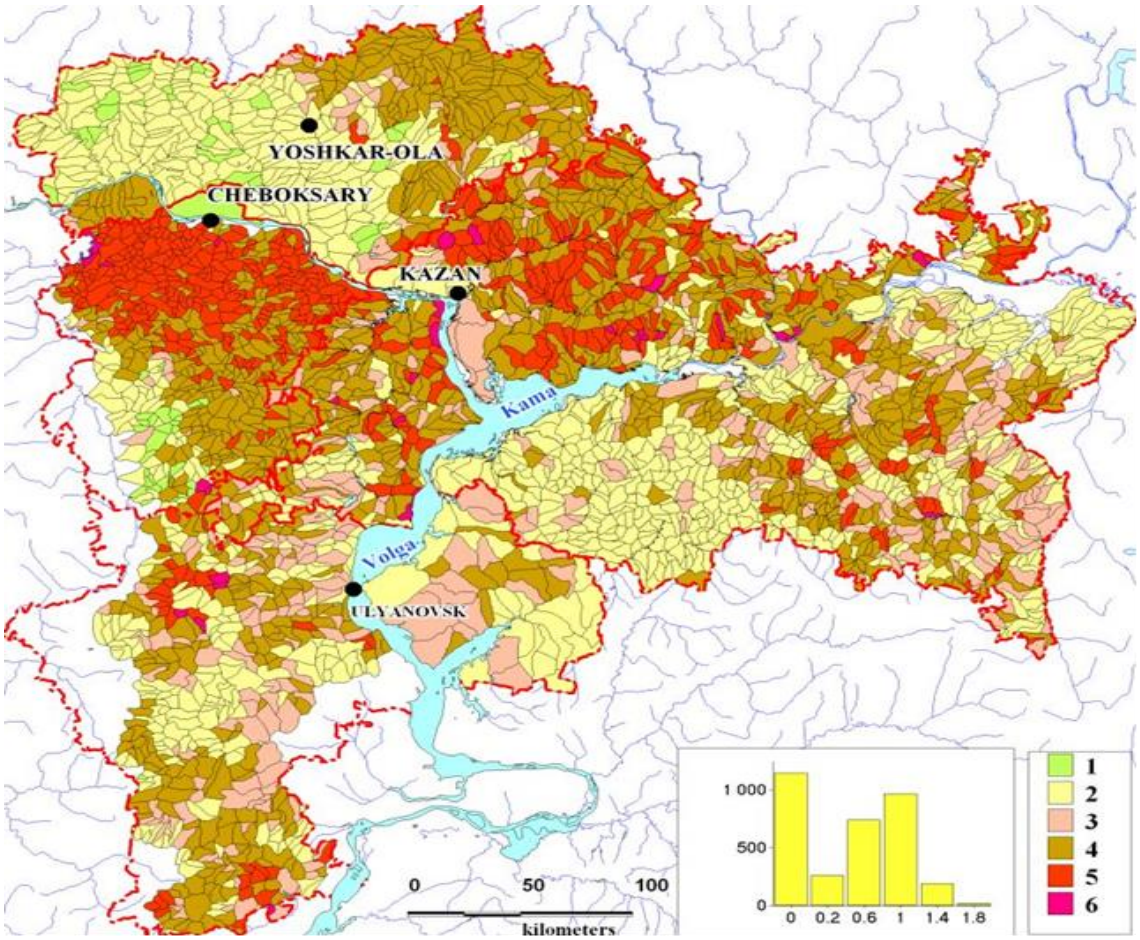

Figure 1: Territorial demarcation in accordance with the soil erosion intensity

Fig. 1. -no arable lands; 2 - very ittle erosion; 3 - slight erosion; 4 - moderate erosion; 5 - severe erosion; 6 - very severe erosion

SUMMARY

In our paper we have analyzed different types of OTU for the purpose of spatial analysis of slope erosion. We have determined that the types of operational-territorial units such as the regular geometric grids, the political-administrative division, and sample characteristics can be used for collecting data geobank of erosion processes but poorly suited for identification of erosion patterns. The best type of OTU for these purposes is a river basin and landscapes represented by terrains and stows.

We have drawn an electronic vector map of the basins of tertiary rivers and their interbasin spaces for the territory of the eastern part of the Russian Plain of more than 150,000 km^2 with the use of automated methods of analysis of digital terrain models. We have drawn a range of subject electronic vector maps of the studied territory, which show the development of soil and gully erosion. The above map of soil erosion based on the basin approach demonstrates good opportunities for the spatial analysis of erosion processes.

CONCLUSION

Thus, the analysis of the entire system of operational-territorial units used in the study of slope erosion processes in the plains of the temperate zone of the Earth, shows that a drainage basin is an operational and territorial unit most suitable for this purpose. This is because of the fact that the basins are a geosystemic formation and reflect the specific nature of surface slope runoff, due to which a range of erosional processes occurs. Another important feature of the basin approach is the simplicity in defining these units in the geographical space and the reasonable transition to other scale levels due to hierarchy feature of river basins. Their limited use is associated with the landscape specifics of the terrain: such as ice and arid zones of the Earth. Landscape territorial units allow performing a stiffly accurate spatial analysis of erosion and its determining factors. However, a significant factor limiting the use of this approach is the complexity of landscapes demarcation, lack of their internationally standardized taxonomy and poor cartographic exploration of the territory at regional and local generalization levels.

ACKNOWLEDGEMENTS

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University. The work is performed according to the Russian Science Foundation (project №15-17-10008).

REFERENCES

[1] Litvin L.F. Relief evaluation at medium- and small-scale mapping of erosion-prone lands // Current problems of erosion study. - M.: Kolos, 1984. - p. 66 - 88.
[2] Kosov B.F., Konstantinova G.S. USSR zoning in density of gullies // Soil erosion and riverbed evolution. - M.: Publishing house of MSU, 1974. - Vol. 4. - p. 6 - 15.
[3] Larionov G.A. Soil erosion and deflation: basic laws, and quantitative assessments. - M.: Publishing house of MSU, 1993. p. 198.
[4] Berliant A.M. Space image: map and information. - M.: “Mysl”, 1986. p. 240.
[5] Arkhipov Iu.R. Blazhko N.I., Grigoriev S.V., Zabotin Ia.I. Trofimov A.M., Khuzeev R.G. Mathematical methods in geography. - Kazan: Publishing House of Kazan University, 1976. p. 352.
[6] Krupochkin E.P. Use of regular spatial grids in geoinformational mapping // collection: GIS for optimization of environmental management for the sustainable development of territories. Mater. Int. Conf. “Intercarto - 4". - Barnaul: Publishing house of Altaisk University, 1998. - p. 203 - 207.
[7] Koshel S.M., Musin O.R., Serbeniuk S.N. Methods of geofield modeling with the use of data in the irregularly located points // Geodesy and Cartography. - M.: Nedra, 1990. - No.11. - p. 31 - 35.
[8] Torbel W. Zi-tan Chen. A guadtree for global Information Storage. – ''Geographical Analysis'', 1986, October, Vol. 18, N4.
[9] Ventura S. Dane County Soil Erosion Control Plan. Dane County, Wisconsin, 1988. 110p.
[10] Armand D.L. The science of landscape. - M.: “Mysl”, 1975. p. 288.
[11] Mikheli S.V. Concept, structure and content of landscape unit of ecological and geographical atlas of Ukraine // Geography and natural resources. - Novosibirsk: USSR Academy of Sciences, the Siberian branch, 1993. - No.2. - p. 19-25.

[12] USSR landscape map (1:4,000,000) / ed. by Isachenko A.G. - M.: State department of geodesy and cartography, 1988.
[13] Shvebs G.I. Theoretical Foundations of erosion study.- Kyiv - Odessa: High School, 1981. p. 224.
[14] Y. Stan Rowe. Land classification and ecosystem classification // Environmental Monitoring and Assessment 39: 11 – 20, 1996.
[15] Gregory K.Y., Walling D.E. Drainage basin form and process: a geomorphological approach. Great Britan. – 1983. 458 p.
[16] Konecny M., Rais K. Geograficke informacni systemy // Folia prirodoved. Fak. UYEP Brno, 1985. – t. 26. – N 13. 196 p.
[17] Y. Stan Rowe. Land classification and ecosystem classification // Environmental Monitoring and Assessment 39: 11 – 20, 1996.
[18] Makkaveev N.I. Riverbed and its basin erosion. M.: Publishing House of the USSR Academy of Sciences, 1955. p. 346.
[19] Timofeev D.A. Elementary morphological units as an object of geomorphological analysis // Geomorphology. - M.: Publishing House of the USSR Academy of Sciences, 1984. - No.1. - p. 19 -29.
[20] Khorton R.E. Erosional development of rivers and discharge basins. - M.: IL. 1948. - p. 156.
[21] Ermolaev, O.P., Semenov, F.V. Use of digital terrain models in morphometric analysis of tectonic structures and prospecting of placers of alluvial genesis(2014) Geography and Natural Resources, 35 (1), pp. 82-87.
[22] K.A. Mal'tsev, O.P. Yermolayev (2014) Using dems for automatic plotting of catchments // Geomorphology 1: pp. 45-53.
[23] O. P. Ermolaev, K. A. Mal'tsev and M.A. Ivanov Automated Construction of the Boundaries of Basin Geosystems for the Volga Federal District // Geography and Natural Resources, 2014, Vol. 35, No. 3, pp. 222-228. DOI: 10.1134/1875372814030044
[24] Walling, D. E., 1988. Measuring sediment yield from river basins. In Lal, R. (ed.), Soil Erosion Research Methods. SoilWat. Conserv.Soc., Ankeny, Iowa: 39–73.
[25] Dedkov, A.P., Mozzherin, V.I. (1984) Erosion and Suspended Sediment on the Earth Kazan: Publishing House KSU. – 264 p.(in Russian)
[26] Kolomyts E.G. Polymorphism of landscape and zonal systems. - Pushchino: Department of Scientific and Technical Information, Pushchino Research Center of Russian Academy of Sciences, 1988. p. 311.