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Mirosław Bogacki, Ivan Kovaltchouk, Andrei Mykhnovitch

THE DYNAMICS OF THE RIVER NETWORK STRUCTURE IN THE DNISTER BASIN AS A REACTION TO THE ANTHROPOGENIC CHANGES OF NATURAL CONDITIONS

INTRODUCTION

Ecological problems, wherever they arise, have an origin: human impact on nature. River valleys, floodplains and river beds are most unstable. River valleys are irreparably and detrimentally changed by the long-term action of agriculture, settlements, industrial pollution, transport and mine working (Kovaltchouk, 1997). In order to solve those problems a solid scientific basis, quantitative and qualitative information about the ecological state of rivers and river valleys, and on the tendencies of change of the ecological state of river systems are needed.

Investigations of river systems structure (Strahler, 1952) take one of the central places in the regional ecological-geomorphologic analysis of the fluvial basin scale systems (Kovaltchouk, 1997). These investigations include the assessment of structural transformation by the impact of erosional-accumulation processes and human activity, changes of the state of small rivers and also evaluation of long-term tendencies of these changes. It is expedient to distinguish the natural and the man-made changes of basin scale systems.

For this reason the research of the river systems structure is directed at the evaluation of the role of river systems structure in the functioning and evolution of the drainage basin as the complex geomorphologic systems.

In Western and Central Europe the research of floodplain landscapes and river systems have high priority. In Eastern Europe, in Ukraine, such investigations were started in the years 1982–1987 by the scientists from Lviv. Recently, such investigations were started in Russia (Ivanova, Larionov, 1996).

The results of these studies which provide knowledge about man-made changes of water systems (Vishnievskiy, 1976; Vendrov, 1970; Perekhrest, 1974), permit to determinate the scale of water runoff and river systems structure changes, as well as the reasons of these changes and their impact on the ecological situation in the basin, and to forecast next events.

With respect to the drainage basin of Dnister it is not fully clear until now what has a stronger impact on rivers ecosystems. The impact of the changed climatic conditions is not excluded. It is necessary to carry out studies directed at the evaluation of the level of structure organization of the river systems on the basin scale for the Dnister river in different instances in connection with climatic conditions.

STUDY AREA

The head waters of Dnister includes the north-west of the Ukrainian Carpathians. The most typical litological rocks are sandstones, aleurolites, argillites, conglomerates, sandy-clay flysch. High erosive-denudative potential, differentiative present-day and neotectonical movements, intensive development of erosive-accumulative, gravitation processes and mud flows are typical for the relief of Carpathian mountains within the limits of head waters of Dnister. Here the river valleys have mainly step-like slopes. The number of terraces in the different parts of the study area changes from 2 to 7. Their origins are: erosion (high terraces) and accumulation (1^{st}–2^{nd} terraces).

In the head waters of Dnister the mean temperatures of January fluctuate from –6,0°C to –4,5°C, in July — from +18,0°C to +16,5°C. The mean annual sediments vary within the limits of 800–900 mm/year. The long-term means of discharges range from 5,2 m^3/s (the settlement of Strilky) to 10,7 m^3/s (the town of Sambir), 23,5 m^3/s (the village of Chaikovychi).

METHODS

The process of functioning of the river systems was studied by method of investigating the features of the river system structure in time and space.

This method includes:

1. Selection of the classification scheme for the river systems and the parameters, which characterize the state of river systems in definite time. The structure of the river systems in definite time may be described by a number of parameters. Among them, the series of morphometrical parameters is the most appropriate for the achievement of the main tasks of exploration. For this reason, the orders of the rivers, the total number of rivers in the system, the total length of rivers of every order, the mean lengths of rivers of every order, the share of the number and lengths of rivers of every order, the bifurcation coefficients, the drainage density and the classification scheme of A. Strahler (1952) were chosen. According to this scheme the permanent stream without any tributaries (on the maps of scale 1:100 000) is a simple elementary river.Therefore, complexity of the structure increases in correlation to the order.

2. Finding of the same-scale maps from different periods reflecting the design of river network, forestry tillage of the slopes, density of population areas, and transport network on the territory of the basin studied. The structure of the river systems was analyzed with topographical maps of the scale of 1:100 000 from different time periods.

3. Calculation of the selected parameters of the river systems structure by means of the topographical maps from different time periods. Evaluation of changes of the structure of river systems. Quantitative evaluation of the scales of long-term changes of river systems structure. Calculation of the coefficients of transformation of river systems structure, which characterize the scale of these processes. Parameters of the river systems structure on the basin scale of Upper Dnister in 1855, 1925 and 1975 were compared. From that, the tendencies of changes of transformation processes intensity were determined.

4. Creation of the series of cartograms of the drainage density for definite time points of the scale of 1:100 000, with the windows 2 × 2 cm and the cartograms of total magnitude of changes in the drainage density.

RESULTS

The rivers of the I and II order form accordingly 68–82 and 16–24% of the total number in the river system encompassing IV–V orders. The mean lengths of rivers of I and II order are not bigger than respectively 0.5–1.2 km and 1.2–2.5 km. In the river systems of head waters of Dnister the total number of rivers of the I–III order has considerably decreased from 1885 to 1975 (Table 1).

Table 1.

Transformation of the river system structure in the head waters of Dnister in the 19^{th}–20^{th} centuries

River order	Year	Total number	K_t of number %	Total length km	K_t of length %
I	1855 1975	1351 498	+63.1	576.95 396.40	+31.3
II	1855 1975	372 135	+63.7	300.85 192.30	+36.1
III	1855 1975	88 32	+63.6	141.95 73.40	+48.3
IV	1855 1975	23 9	+60.9	57.50 71.30	-24.0
Total	1855 1975	1840 675	+63.3	1143.90 741.80	+35.2

Five out of eight rivers have dropped from V to IV order. Only three rivers have kept their order: Ripyanka (IV), Lehneva (IV) and Mshanka (V).

The coefficients of transformation of the river systems structure are positive almost everywhere and fluctuate within the limits of 60–64% (transformation of the total number of rivers). The coefficients of transformation of the total length of rivers are equal to 31–48%. In spite of considerable decrease in the length of rivers (especially of I–II orders) there are areas with an increase in the lengths. This process is apparent first of all for the rivers of IV–V orders — –24% (Table 1).

Increase in the length is caused by the transformation of the river systems structure — decrease in the order of a river by one unit and keeping at the same time the length and the role of the chief river in the system.

The bifurcation coefficients $r_b = n_1/n_2$ vary from 2.8 to 5.2 (Table 2).

The drainage density in the head waters of Dnister in 1855 fluctuated from 1.4–2.4 to 1.6–3.5 km/km^2 (Table 2). The areas with the density 1.8–2.7 km/km^2 predominated. In 1925 the drainage density considerably decreased: from 1.7–2.5 to 0.5–1.0 km/km^2. In 1975 the drainage density was not bigger than 2.0 km/km^2. In almost all catchments of head waters of Dnister the density decreased in 0.1–1.5 km/km^2 and only locally (in the catchment of Lehneva, in the valley of Dnister at the border between Carpathian mountains and foothills and also Verkhnyodnistrovska lowland it has increased.

DISCUSSION

Very short lengths of the rivers of I and II order cause their small discharge and high dependence on the slope water flow, first of all on the atmospheric and partly underground alimentation. Such rivers become shallow during low-water or even dry off. Drying off is characteristic for years with total sediments smaller than the long-term norm. The high degree of saturation of the streams by suspended loads, the small discharges and the appreciable annual and long-term variability of the hydrological regime are the signs of the low hydro-geomorphological stability of these rivers. This fact, in the conditions of increasing anthropogenic pressure (felling of forests, tillage of the steep slope lands, grazing) leads to silting of the river beds, worsening of hydro-ecological conditions, transformation of the permanent streams in temporary ones, that is degradation process in the river systems. It is also an indication of the high sensitivity of small and smallest rivers to the human influence, and particularly to the river water, forest and land use. Another indication of the high natural potential of eco-geomorphologic and hydrological instability of these small rivers is the bifurcation coefficient of the low-orders streams in the structure of the river-systems. It points out the high degree of saturation of the river systems of the non order-forming streams.

The analysis of correlation between the number and length of the rivers of different orders in 1855, 1925, 1975 showed that in spite of considerable decrease in the number of length of I, II and III orders the correlation between the rivers of different orders changed only slightly.

Table 2

The mean lengths of the rivers of I, II and III order, the bifurcation coefficients and the mean drainage density in the considered catchments of Upper Dnister

River system	1855						1975					
	L, km I	L, km II	L, km III	$R_b = n_1/n_2$	$R_b = n_2/n_3$	Mean drainage density km/km^2	L, km I	L, km II	L, km III	$R_b = n_1/n_2$	$R_b = n_2/n_3$	Mean drainage density km/km^2
Topilnychanka	0.45	0.65	1.68	4.0	4.3	1.3–3.0	0.84	1.16	3.27	4.1	3.7	1.0–1.6
Yasenychka	0.44	0.72	2.50	3.7	6.5	1.9–2.7	0.47	1.54	3.22	4.1	3.8	1.0–1.6
Ripyanka	0.46	0.77	1.80	3.7	7.5	1.7–2.8	0.45	1.55	1.55	2.8	4.0	1.5–2.6
Dnister (down to Lehneva)	0.38	0.88	1.90	4.0	5.0	1.6–3.5	0.49	0.49	2.40	3.6	4.8	2.3–2.6
Lehneva	0.57	1.22	1.65	3.8	3.3	1.4–2.4	1.19	1.19	1.30	3.4	3.3	1.8–2.6
Mshanka	0.41	0.94	1.31	3.2	3.4	1.7–3.0	0.50	0.50	2.05	2.8	6.0	1.3–2.3
Linynka	0.41	0.78	0.90	3.6	3.2	1.4–2.8	1.05	1.05	1.87	4.1	3.8	0.9–2.0
Yablunka	0.45	0.73	2.22	3.3	4.7	1.4–2.8	0.55	0.55	3.00	5.0	4.5	1.0–1.6

L, km — the mean length of the river of certain order; R_b — bifurcation coefficient; n_1, n_2, n_3 — the total number of the rivers of I, II, III order.

Such relative stability (variation within the limits of 7%) in the correlation between the rivers of different orders testifies about the mechanism of self-regulation in the river systems and the ability to keep the dynamic equilibrium between the subsystems of different ranks. And also about the typical for certain regions correlation between the order-forming and non order-forming streams in the structure of the river systems.

The fast reaction to the human activity in the catchments of the small rivers is reflected first of all in the change of parameters of the river systems structure.

The arguments for the anthropogenic causes of the degradation processes in the head waters of the small rivers of basin scale of Dnister are as follows:

1. the big stratum of alluvium-alluvial fan deposits with humus sediments — the products of erosion of slope soils in the bottoms of balkas and in the river beds and river flood areas of the streams of I–II orders (2–6 m). This fact demonstrates the long-term domination of accumulation in the head waters of the rivers. Erosive-accumulative processes, especially mudflow-like ones caused by felling of forests have important impact on the silting of the river beds and flood plains in the mountain regions;

2. the results of comparisons of information about decrease in the length of the rivers of I–II orders and information about changes of forestry and tillage in the catchments. Thus, over the last 120 years the forest area has decreased by 3–15% and 37% in the local catchments (Kovaltchouk, Mykhnovych, 1997). The tillage of the catchments has increased by 10–31%. This is one of the causes of intensive development of the slope erosion, silting of the balkas and head waters of the small rivers and their degradation;

3. land improvement at the end of 19th and in the three decades of 20th century in 1960–1970 in the river valleys, causing the discharge of the excess water, which had been piled up in the Holocene, a decrease in underground water level, drying off many springs and decrease in the role of underground alimentation in the functioning of the streams, a decrease in the transport ability and an increase in accumulation of the load;

4. changes of water-physical properties of the soils, which has been caused first of all by tillage with the use of heavy machines, and development of erosion. Among these changes we see destruction of the soils by heavy machines, a decrease in anti-erosion stability, deterioration of filtration ability. By these causes he share of underground alimentation decreases the water flow over the years is becoming arhythmical, activity of the slope, and river bed erosive-accumulative process is increasing. These processes cause the silting and drying off of the head waters of the rivers, first of all of the I–II order;

5. in the second half of the 20th century an increase in the degree of influence on the river beds, flood-areas, river valleys exerted by the hydrotechnical structures industry, transport, settlements exploitation of the quarries in the river beds and flood areas, surface and underground mining (potash salts, native sulphur) took place;

6. building in the river valleys and river beds of many water intake buildings, which use surface and underground waters of the rivers for the industrial, municipal, agricultural water supply. For example in 1994 enterprises had taken out 401 million m^3 of fresh water from the natural springs including 337 million m^3 of ground water and 124 million m^3 of surface water (*Ekologiya Lvivshtschiny*, 1994).

The volume of not purified wastes, which are being discharged into Dnister in the Lviv region was bigger than 7.2 million m^3 of insufficiently purified — 16,8 million m^3.

The development of the erosion processes is an important factor of degradation of the small rivers. The stationary and semi-stationary investigations in the Carpathian foothills and in the Podolian upland showed that intensity of washing away of soils from the slopes under different crops is equal to 0.001–3.5 mm/year; intensity of washing away of soils from the agricultural catchments equals 0.06–0.83 mm/year, and from the catchments of the rivers of I order — 0.06–0.23 mm/year. On the slopes and bottoms of the agricultural catchments 40–60% of the products of slope erosion is accumulated. The major part of this load (60–80%) is accumulated in the flood-plains of the rivers of I–II orders, 11–43% get into the river beds. Washing into the river beds of the small rivers of so big load cause their silting. Special investigations of the intensity of accumulation processes in the river beds of the head waters of the small rivers of Podolian showed that this intensity changes within the limits of 0.4–11.7 mm/year.

In certain conditions (for example in the mountains, where upper part of the river systems have a big discharge and inclination of the river beds) the quantity of deposits getting into the rivers is not bigger than their transport ability. Deposits, which get out of the rivers of I–II orders do not cause silting of the head waters. In case when regressive erosion causes cutting of the river beds and drainage of the bigger part of aquifers, an increase in the length and number of small rivers takes place. This phenomenon is characteristic for the local river systems of the head waters of Dnister: Topilnyt-chanka, Yasenychka, Ripyanka, Lehneva, Mshanka, Linynka, Yablunka. An increase of number and length of low order rivers in the catchments of the head waters of Dnister from 1925 to 1975 which has been discovered by the cartometrical method is doubtful. It is necessary to carry out a special field investigation of the small rivers using drilling to determine the thickness of the channel alluvium and its degree of saturation by humus. Such data will permit to clear up the degree of reliability of parameters of cartometrical evaluation of the degradation processes in the river system structure.

CONCLUSIONS

The results obtained permit to evaluate the mechanism of the degradation processes. These processes in the catchments of small rivers may be described by the following cause-and-effect sequence: felling of forests → tillage of the slope lands which were under forests and meadows in the past → intensification of the slope erosion → an increase in deposits getting into the small rivers → land drainage and tillage of the flood–plains → a decrease in underground water level and in their role in the river alimentation, especially during the low water → straightening of river beds → surface and underground water intake for the economy → an increase in variability of water flow during the year → accumulation of the deposits from the slopes on the flood-plains and in the river beds and also of the organic substances, components of mineral fertilisers, pesticides, herbicides → partial overgrowing of the river beds, eutrophication of the streams → decrease in the transport ability of the streams → intensive accumulation of the deposits, especially in the head waters, colmatage in the river beds, decrease of the role of underground alimentation, intensive evaporation from the surface of small ponds → decrease in the number and length of the smallest streams in the river systems → increase in waste discharge without purification → worsening of water quality and of the ecological situation in the river valley systems.

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