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Complex investigations of the state, functioning and transformation processes development in the river basin systems

***A. Kovalchuk, I. Kovalchuk** (*National University of Life and Environmental Sciences of Ukraine*), **A. Mykhnovych, O. Pylypovych**, (*Ivan Franko National University of Lviv*), **B. Zhdaniuk**, (*Volynian Lesia Ukrainka National University*)

SUMMARY

The paper deals with the essence and main directions of the complex analysis of the river systems state in mountain and highland regions of Ukraine. Their functioning (as water, sediments and dissolved substance runoff riverbed morphology changes under influences of the riverbed and slope processes) and long-term changes in the morphology and geoecological state of the rivers and their catchments due to natural and man-made factors are characterized. The investigations were based on comparative morphometric analysis of the river systems structure, field and stationary observations of the nature components state within the catchments, determination of the anthropogenic pressure on the landscapes. As the result the tendencies, scales and intensity of transformation and degradation processes development in different parts (subbasins) of the river basin systems in the Polissia, Volyno-Podillia, Precarpathians, and Ukrainian Carpathians have been ascertained. The measures for improvement of the river basin systems state and optimization of nature use have been proposed.

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Introduction

River systems are the subject of matter for many sciences – geomorphology, hydrology, landscape studies, ecology etc. Everyone uses the overall methods as well as many special methods and approaches to the river systems studying. Every scientific branch studies its own specific problems spectrum. First of all these problems concern the genesis, forming mechanisms, dynamics, structure of the river systems as well as the factors, scales of changes, actual state etc. At the same time not enough attention is paid to the functioning of rivers as the complicated organized systems, to riverbed and watershed flows of the water, sediments, dissolved matter, organisms and human, to different reaction on the climate change, tectonic movements, economic activities and so on. That is why the urgent and actual task is substantiation of the algorithms for river systems complex researches which include the state assessment, functioning, transformation and degradation processes development analysis as well as the changes projecting, elaboration and implementation of the optimizing management decision.

Methods and Theory

The main idea is to combine in certain order the approaches and methods of geomorphology (structural, dynamical, climatic, anthropogenic, engineering, biogenic, ecological), morphometry, soil studies, hydrology, hydraulics, hydrodynamics, hydrochemistry, hydroecology, hydrobiology, landscape studies, riverbed studies, erosion studies, water management planning and engineering, nature protection etc by the river system research. Every science (or its branch) studies different aspects of the structure, state, functioning of a river system, and its changes under the impacts of natural and man-made factors in the order defined by the research algorithm. And the results are transferred to other scientists. Certain science conducting its own investigations and generalizing results of previous researches transfer the information to the next science or its branch. As finite result of a research some complex system of knowledge, models, concepts and syntheses on the studied river and basin systems is created. Based on such system the schemes (plans) of different oriented economical, nature protective, recreational use of the river system resources within the catchment as well as processes regulation and renaturalization measures are worked out. The results of our investigations of the river basin systems (Kovalchuk & Kovalchuk, 2018; Kovalchuk, 1994; 1997; 2007; Kovalchuk & Dubis 1998; Kovalchuk & Mykhnovych 2006; Kovalchuk & Pavlovs'ka, 2008; Kovalchuk & Shtoyko, 1989; 1992; Pylypovych & Kovalchuk, 2017; Bug River valley..., 2002; Kovalchuk et al., 2018; 2020), generalization of the experience and results of other scientists (Aleksieyevskiy, 1998; Dang Minh Hai et al, 2019; Rossa O'Briain, 2019) allow to formulate the concept (main directions) and to propose the general algorithm of the complex research of the river systems and catchment systems state, their functioning regime, scale of transformation and degradation processes development.

This algorithm is following:

1. visual analysis of the river network pattern (realized on the base of large-scale topographic maps);
2. studying of genesis of the river systems and their structural elements (based on the river valley and river bed morphology analysis as well as geologic-geomorphologic structure studying);
3. river systems and terrace complexes dating (applying sediments dating methods), evaluation of the erosion-accumulation processes intensity);
4. morphometric analysis of the river system structure. It is realized by the river ordering, the portion of every order calculation, every order length and amount counting, the different order catchment areas determining as well as their proportions and so on. These parameters are calculated for different time periods;
5. calculation and analysis of another morphometric parameters (riverbed and watershed inclination, river network density, river order increasing etc); theses parameters are calculated for different time moments (based on the morphometric analysis of the different time topographical maps);
6. calculation of the different order catchment state parameters (forestry, agricultural reclamation, arable lands portion, settlement, industrial and transport load etc). These parameters are calculated for the different time moments applying the large-scale topographical maps, space images, statistical information etc;
7. determination of the scales and trends of the transformation processes development within the river system structure and the catchment geosystems (realized by the comparative analysis of the river and catchment systems morphometric parameters for different time moments);

8. ascertaining of the causes, factors, conditions of the transformation and degradation processes development in the river and catchment systems and assessment of the relations between them and their consequences;
9. investigation of the functioning regime of the river or river basin systems. It includes studying of water, sediments, dissolved and biogenic substances runoff, riverbed deformations development during long-term period. It is based on the data of hydrometeorological stationary observations in the river basins;
10. ascertaining of man-made component in the changes of the river basin system state and functioning regime (by the methods of modeling, comparative and factor analyses etc);
11. ascertaining the correlation between the scales of the river and basin systems state and functioning regime changes and climate changes;
12. analysis of hydromorphological and hydroecological effects of riverbed and watershed processes development, impacts of human activity upon the rivers and the catchments (realized applying field hydromorphologic and geomorphologic investigations, water sampling and laboratory analysis, using aero and space images for different time moments and so on);
13. creating of cartographic (or GIS) models of the river system structure, occurring and intensity of transformation and degradation processes development, changes in ecological state of floodplain-riverbed complexes and catchment systems;
14. creating of the forecast models reflected the prospects of changes in the state of river systems, riverbed and watershed processes development with different periods (10 – 20 – 50 years);
15. creating of cartographic (or GIS) models of optimization-recommendation measures (antierosion, riverbed regulating, soil protection, water protection, nature reservation etc). They are based on the digital terrain model (DTM) and factor maps (of the soils, hydrographic, hydrologic, climatic, forests, land use, ecologic);
16. substantiation and realization of the monitoring program on the rivers state, riverbed and slope processes, man-made transformation of the river basin systems, creating of the gauging stations network, providing observation;
17. substantiation of the concept of river basin nature use as well as implementation of the measures directed upon practical realization this concept (creating the authorities for integrated river basin management, GIS providing of their activity, supporting measures directed on sustainable nature use and river basin geosystems development).

Results and Discussion

River system transformation. Transformation processes are those of them that cause the changes in riverbed morphology, morphometric parameters and functioning regime of the river systems. They are represented by the riverbed straightening and deepening, drainage channels networks, hydrotechnical engineering and constructing, water runoff regulating in the riverbeds and within the watersheds as well. The main consequences of the transformation processes are: a) changes in the amount of different order rivers in the system (increasing due to drainage channels network construction; decreasing due to headwaters silting and drying off); b) changes in the river length (partial and overall) (usually increasing of the total length, especially within the wet lowlands, concerns to drainage channels constructing; decreasing can be explained by the riverbed straightening and headwaters drying off); c) changes of the stream direction, water runoff regime, ratio between surface and underground water runoff, chemical composition (mineralization), riverbed depth, sediments transportation, ratio between river bank and bottom erosion, sediments accumulation; d) changes in the trends of so called bioecological processes development, hydroecological state of the system. Experience in the river systems transformation in Ukraine (Kovalchuk, 1997; 2007; Kovalchuk & Dubis 1998; Kovalchuk & Mykhnovych 2006; Kovalchuk & Pavlovs'ka, 2008; Kovalchuk & Shtoyko, 1989; 1992; Pylypovych & Kovalchuk, 2017; Bug River valley..., 2002; Kovalchuk et al., 2020) testifies that during last 50-90 years the total amount of different order rivers in some river systems of the Ukrainian Polissia and other wetlands has increased in 1,5 – 4,3 times due to the drainage channels constructing. At the same time the total length of different order rivers has increased 1,2–2,9 times. By comparison of different time (XIX – XXI centuries) large-scale (1:25 000 – 1:100 000) topographical maps (Kovalchuk & Kovalchuk, 2018; Kovalchuk, 1997) the scales of forest and bog ecosystems transformation into agricultural have been determined. Also inverse transformation has been ascertained as well as changes in road network, settled lands (rural, urban and suburban), unused lands changes and so on.

Degradation processes analysis. Degradation processes are those of them which cause silting and shallowing of the river bodies, their growing up by hygrophilous vegetation, river amount and river length decreasing, worsening of the surface and underground waters quality, soil and vegetation cover state worsening, biodiversity decreasing and other natural components changes in the river systems and watershed landscapes. Assessment of the scales and intensity of the degradation processes development were carried out by the methods of comparative analysis of different time (1855, 1925, 1955, 1978, 2008) cartographic, remote sensing and statistical data, GIS modeling and field investigations. The main results of these work are following: a) ascertaining of the facts of the highland river systems large-scale degradation (from 15 to 64% of all I-II order rivers within the Podillia Highland have disappeared during last 150 years; similar situation is observed in the river systems of the Donets'k Ridge, Volyn' Highland, Dnipro Highland and Precarpathians where noticeable changes in river order structure occur (mostly decreasing); b) ascertaining of the soil cover degradation parameters – increasing of eroded agricultural lands area on 20–36 % for the last 40 years, damage of the lands by ravine erosion (increasing on 3–12 % for the last 60 years), landslides, suffosion, karst processes (Kovalchuk, 1997; Kovalchuk & Pavlovs'ka, 2008; Bug River valley..., 2002). Most intensive degradation of the agricultural land have been revealed in the Precarpathians, Carpathian Mountains, Podillia, Volyn' and Dnipro Highlands and Donets'k Ridge; c) determination of the parameters of vegetation cover changes (forestry, specific and age structure of the forests, pests and diseases affects etc (Kovalchuk, 1997). For example, forestry of several river basins of the Volyn'-Podillia Highland in XX century has decreased on 14–22 %, locally – up to 40–70 % (Kovalchuk, 1997; Kovalchuk & Pavlovs'ka, 2008; Bug River valley..., 2002); d) ascertaining of the surface and underground waters quantity decreasing and quality worsening. It is established that end of XX century is characterized by intensive pollution of the small rivers of Ukraine. Their water runoff has decreased on 11–17 % and even more. Several facts of the runoff increasing have been observed. The runoff increasing was caused mostly by discharged waste waters; e) establishing of the parameters of biotic and landscape diversity changes (it has decreased on 12–33 % and continue to considerably decrease). The main causes of these processes are determined.

Studying of the river basin system functioning. The functioning is understood like the changes of river system by which this system keeps autochthonal features, relative stability of the structure and system-forming functions. By diverse words the essence of the functioning is that in the conditions permanent mass exchange with environment, neighboring systems and subsystems conducted by water, lithodynamical, air and biotical streams the river basin systems keep their invariant state and regime. They are relatively and dynamically stable (Aleksieyevskiy, 1998; Kovalchuk, 1994; Kovalchuk & Pavlovs'ka, 2008; Bug River valley..., 2002). When these conditions are disturbed we observe transformation of the state and functioning regime. Stability is provided by the processes of riverbed and river basin relief transforming and is characterized by the balance of material and energy usually. The material and energy is taken out of the watershed, deposited within the system and inflow inside. At that the functioning can be realized in certain regime – modal, approximately to modal and extreme (drought, flood). By determination of the functioning regime the water runoff dynamics, sediment load, dissolved and biogenic substances runoff, the tendencies and intensity of riverbed and river basin processes development, factors and conditions impacts are analyzed. Such analyses allow to evaluate the state of riverbed, floodplain and the river basin as whole as well as to determine the level of changes (Aleksieyevskiy, 1998; Kovalchuk, 1997; 2007).

Conclusions

The results of investigations of the river basin structure, transformation-degradation processes development in these basins of Ukraine, their functioning regime and geoecological state changes under impact of natural and man-made processes and factors are presented in the raw of monographs (Kovalchuk & Kovalchuk, 2018; Kovalchuk 1997; Kovalchuk & Pavlovs'ka, 2008; Pylypovych & Kovalchuk, 2017; Bug River valley..., 2002) and scientific papers (Kovalchuk & Mykhnovych, 2006; Kovalchuk & Shtoyko, 1989; 1992; Kovalchuk, 2007; Kovalchuk et al, 2018; 2020). In Ukraine researches of these problems different aspects are carried of by Professors V. Vyshnevs'kyi, V. Hrebin', I. Kovalchuk, S. Kostrikov, N. Loboda, Y. Molchak, O. Obodovs'kyi, O. Svatlychnyi, I. Chervaniiov, Y. Yushchenko and their followers. The important task for nearest perspective is continuing of these researches and taking into account the global climate change influences upon the state and functioning regime of the river basin systems (Kovalchuk, 2007; Kovalchuk et al, 2018; Rossa O'Briain, 2019),

elaborating of the digital large-scale geoecological atlases of the river basin systems with high level of economic activity and heavy ecological situation (Kovalchuk & Kovalchuk, 2018).

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