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Research of the geomorphologic objects and processes dynamics

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SUMMARY

The problem of getting information on the geomorphologic objects and processes dynamics, visualization of this information on digital map models is a topical task of geomorphology and adjoining sciences. The paper deals with the substantiation of the geomorphologic processes classification with defining of the relatively incessant and interrupted natural and man-made, exogenous and endogenous, flat and linear their types. This classification has to be used by the planning and implementation of the geomorphologic objects and processes dynamics research. The scheme of the criteria (parameters) is proposed to use by the investigations of the geomorphologic processes dynamics (Table 1). During working out of the field stationary and cartometrical investigations the spectrum of the parameters of the main kinds of exogenous processes development intensity in the different regions of Ukraine and river basin systems have been determined.

Keywords: Geomorphologic processes, dynamics, classification

Introduction

Dynamical changes that take place in the environment, economy and society under the wide rage of factors demand their adequate cadaster, systemizing of obtained information, synthesis and map visualization. In this aspect the problem of getting information on the geomorphologic objects and processes dynamics, visualization of this information on digital map models is a topical task of geomorphology and adjoining sciences.

Method and Theory

Most intensive the methods of the geomorphologic processes research are used in geomorphology, landscape studies, hydrology, meteorology, soil sciences (Bairak, 2018; Dynamical…, 2022; Kovalchuk, 2016; Recent…, 2005). These methods also get into social geography, are used in ecology, geoecology, cartography (ecological mapping). In the case of geomorphologic objects and processes dynamics assessment day by day more often the methods and data of remote sensing and GIS are applied (Kovalchuk, 2016; Bairak, 2018). However, the problem of geomorphologic objects and processes dynamics research is still far from solving and need to implement a row of stationary, semi-stationary and field investigation. Results of these investigations are needed for solving theoretical, methodical and practical problems of geomorphology, cartography, environment protection, engineering, protecting natural and economical objects against destroying by geomorphologic processes, sustainable development providing, natural resources management etc.

Results

1. Theoretic-methodical base of the geomorphologic objects and processes dynamics investigations. By the research it is necessary to base on the processes classification. The first criterion is unceasing of development. Among the recent geomorphologic processes the two groups are defined: 1) *relatively incessant processes* – they develop nonstop, and the intensity can change in wide rage in short-term and long-term aspects. These processes include weathering, denudation (erosion, abrasion, karst, buckling, man-made processes) and accumulation of denudation products. As result the weathering crust is forming, ground surface lowering, slope slighting, destroying, cutting, negative relief forms forming and sedimentation, surface shifting, accumulative relief forming; 2) *interrupted processes* – their development is usually cyclic and concern to Sun activity, climate changes, seasonality, geodynamics (landslides, mudflows, aeolian processes, floods, earth crakes, volcanoes).

By the *genesis of the processes* the two groups are defined: *natural* and *man-made*. The natural processes dynamics investigations have some specifics: endogenous processes are studied mostly with geodetic, astronomic-geodetic, geophysical, geological-geomorphologic methods, and the exogenous processes are studied by the methods of field, stationary and semi-stationary, experimental, remote sensing, geodetic investigations and GIS mapping. The recent relief-forming processes dynamics research includes determination of the quantity parameters, space distribution (drawing areal of denudation, transfer and accumulation), and development intensity (single case, seasonal, yearly average, long-term etc). The main parameters of the geomorphologic processes are intensity (tempo) of their development and frequency of activization. The measurement units of the recent relief forming processes are the following parameters (*Table 1*): *Increasing/decreasing of the length, height, depth, volume of the relief forms* (m, mm, m^3); *Increasing/decreasing of the mass or volume of the transported material* (ton, dm^3 (m^3) per ha or km^2 per year or season); *Duration (t) of process activization and development* (years, seasons, days); *processes area per time unit* (m^2, ha, km^2/year or season); *velocity* (intensity of the process development): $V = X/t$, where X – total increase of area, volume, mass of denuded, transported or accumulated material; t – time period of activization or development of the process; *Acceleration of the process*: $a = X / t^2$, where X – any form of the material transportation under impact of the recent geomorphologic processes; t – time period (Kovalchuk, 2016; Bairak, 2018). By determination of the *unceasing geomorphologic processes* dynamics the following intensity parameters are used: m/year, mm/season, m^3/ha•year, t/km^2•year, m^3/km^2•year etc. For example, the intensity of the gullies growing in length is defined in m/year; tempo of the slope divergence under impact of gravity and weathering – mm/season, mm/year; intensity of the surface denudation – mm/year. By investigation of the *interrupted processes* the parameters of appearing frequency are used – amount of cases per 1-3, 10-15, 50 or 100 years (floods, landslides). Other intensity parameters are also often used, such the

area and volume of the accumulated sediments – m^2 and m^3 per one case (mudflow, for instance); volume of the sediments transported by a landslide – m^3 per one single case etc.

Table 1. *Parameters of the geomorphologic processes dynamics (fragment)*

Group of processes	**Type of process**	**Process dynamics parameters**		
		areal	**linear**	**volume**
Geomorpho-logic exogenous: a) erosion-accumulation	Flat erosion;	Eroded area increase, m^2, ha/year;	Layer of soil washing mm/year; mm/season;	Washed material, m^3/year;
	Linear erosion;	Eroded area increase, m^2, ha/year;	Gully length increase, m/year;	Gully volume increase, m^3/year;
	Bottom erosion;	Eroded area increase, m^2, ha/year;	Depth of cutting, cm/year;	Cutting material increase, m^3/year;
	Side erosion;	Gully area increase, m^2, ha/year;	Velocity of gully bank digression, m/year;	Washed material, increase m^3/year;
	Sediments accumulation	Accumulated area increase, m^2, ha/year	Layer of sediments accumulation, mm/year	Accumulated sediments, m^3/year
b) landslides	Denudation;	Landslide area increase, m^2, ha/year;	Tearing wall length increase, m/year;	Moved material increase, m^3/year;
	Accumulation	Landslide body area increase, m^2/year	Landslide body length increase, m/year	Accumulated landslide body increase, m^3/year
c) stone fall-stone-peel	Falling;	Falling area increase, m^2/year;	Felled body length increase, m/year;	Felled body increase, m^3/year;
	Peeling	Peel area increase, m^2/year	Peeled body length increase, m/year	Peeled body increase, m^3/year
d) karst	Karst denudation;	Denudation area increase, m^2/year;	Cavity depth / length increase, m/year;	Karst cavity increase, m^3/year;
	Karst accumulation	Accumulation area increase, m^2/year	Layer of accumulation increase, cm/year	Accumulation form increase, m^3/year
e) aeolian	Aeolian denudation;	Denudation area increase, m^2/year;	Denudation intensity increase, mm/year;	Denudation intensity (ΔV), m^3/ha•year;
	Aeolian accumulation	Accumulation area increase, m^2/year	Accumulation intensity increase, mm/year	Accumulation intensity (ΔV), m^3/ha•year
f) mudflow	Mudflow denudation;	Mudflow nidi areas increase, m^2, ha/year;	Cutting down intensity, mm/year;	Denudation intensity (ΔV), m^3/year;
	Mudflow accumulation	Mudflow cone areas increase, m^2, ha/year	Accumulation intensity increase, mm/year	Accumulation intensity (ΔV), m^3/year
g) weathering	Physical;	Increase, m^2/year;	Intensity, mm/year;	Intensity, m^3/year;
	Chemical;	Increase, m^2/year;	Intensity, mm/year;	Intensity, m^3/year;
	Biotical	Increase, m^2/year	Intensity, mm/year	Intensity, m^3/year;

The processes dynamics investigations by their development duration are divided on *single* (the scale per one case is evaluated) and *regime (systematic)* (periodically repeating, are observed within the stationary or semi-stationary sites). Single measurements usually are carried out by studying of the interrupted processes. The regime measurements are carried out by studying of the unceasing processes with the aim to determine their fluctuation and intensity in time and space. Simultaneously the natural and man-made factors influenced on the studied process development are analyzed as well (for example, precipitation per one rain, season, year). The important direction of the geomorphologic processes research are morphometric and cartometrical investigations (using large-scale topographical maps and remote sensing materials which illustrate studied objects (length of the river or gully, amount of karst forms within the area etc) at the moment of mapping (different time cutting). Comparing the measurements on the different time maps or satellite images, we receive the parameters of the scales and intensity of their state changes for studied period. Also important in the relief forming processes dynamics studying is providing needed recurrent of some measurements of the relief forms state and dynamics which is satisfied for statistical proceedings of the obtained observation results and providing high data reliability as well as optimal measurements frequency which depends on the aim of research. When the aim is assessment of the

factors influence upon the relief forming, the single measurements are done, or the data sets are analyzed (for example hydrometeorological data sets). If the aim is obtaining data on the geomorphologic process's development intensity, periodical and systematical observations are carried out for longer period (once per decade, monthly, seasonally, or yearly for many years period (depending on duration of the fluctuation cycles and development intensity). Optimal duration of the data sets depends on the aim of research, changeability of the process and the impacted factors, their cycles and development.

By determination of the recent relief forming processes dynamics parameters it is needed to keep the following principles: *equivalence of the measurements carried out in different regions by different scientists* (providing of comparability of the obtained results); *using of mutual controlled methods during the measurements* (it is needed to use one basic method and two controlled); *passporting (certification) of the field investigation results* (fixation of the locality by the maps and satellite images, geological-geomorphologic localization, downloading of the geodetic survey and other measurements results in the electronic tables and databases etc); *GIS mapping of the processes and comparison of the results with the data of the stationary and semi-stationary investigations.* Concerning the last principle, it is important to note that the necessary component of the geomorphologic objects and processes dynamics research is visualization of their results on the digital map models. Traditionally the intensity of the geomorphologic objects and processes is presented on the map models by the manners of so-called quantitative background, isolines, located diagrams, histograms, signs, letter-number indexes. The mentioned map models are useful by the territorial planning and implementation of the raw of process regulating and protecting measures, as well as optimization of the land use and nature protection.

2. *The results of the geomorphologic processes and the river systems structure dynamics research.* During the stationary and cartometrical investigations within the Podillia, Roztochchia, Precarpathians and Transcarpathian it is ascertained that the tempo of soil wash out in the different segments of the slopes and watersheds amounts: 0,14 – 7,1 mm/season from certain slope elements, 0,001 – 3,5 mm/year in average from the slope, 0,06 – 0,8 mm/season from the elementary tillage catchments, 0,06 – 0,23 mm/season from the catchments of the rivers of the I order, 0,009 – 0,07 mm/year from the catchments of the medium-sized rivers. The extreme quantities can exceed the average 2 – 10 times and more (Klapchuk, 2012; Kovalchuk, 2016). The average tempo of the gully erosion varies from centimeters to 2,6 m/year per one gully apex, and the extreme parameters amount 10 m/year and more (Kovalchuk, 2016). The modules of chemical denudation, which were calculated according to the content of dissolved matter, which was washed out by the river water runoff, fluctuate from 0,0005 – 0,006 mm/season from the slopes to 0,015 – 0,07 mm/year from the river basins (Kovalchuk, 2016). According to the data of O. Obodovskyi, tempo of vertical riverbed deformations within the flat rivers fluctuates from 0,2 – 3,05 cm/year (cutting down) to 0,02 – 1,35 cm/year (sediment accumulation). The average intensity of the riverbed horizontal deformations is changed within 0,01 – 5,65 m/year. By the research results the horizontal deformations of the Dnister riverbed along the 100 km segment between the towns Halych and Zalishchyky during 66-years period and 107-years period amount according 13,7 m/year and 3,8 m/year (Burshtynska et al. 2017). The trends of analyzed erosion-accumulation processes correlate with the long-term water runoff changes (Figure 1). The tempo of defluction movements of the slope sediments layer amounts 0,1 – 0,3 mm/year on the slopes of Roztochchia, 2,7 – 3,2 mm/year in the Transcarpathian and 10,0 – 30,0 mm/year in the Carpathians (Strzyżowski et al., 2021) and up to 15,4 – 110,4 mm/year in Crimea (by the data of Kliukin). Tempo of the karst denudation in the Crimean Mountains amounts 0,025 – 0,05 mm/year and more, sometimes up to 0,14 mm/year. In the Volyn Highlands and Polissia it is from 0,008 to 0,051, in average – 0,018 mm/year. The important parameters of the long-term dynamics of the river systems are the changes of the amount and length of the different order (classification rank) rivers and their density (Kovalchuk A. et al., 2020). The research results testify that the amount of the smallest rivers in the catchment systems of the Carpathians and Precarpathians during the last more than 150 years decreased in 15,1 – 21,7%, and in the river catchments of the Podillia Highlands these parameters were almost two times higher. The causes of changes were human activity within the river basins: deforestation, tillage, riverbeds straightening, drainage, water intake, climate change.

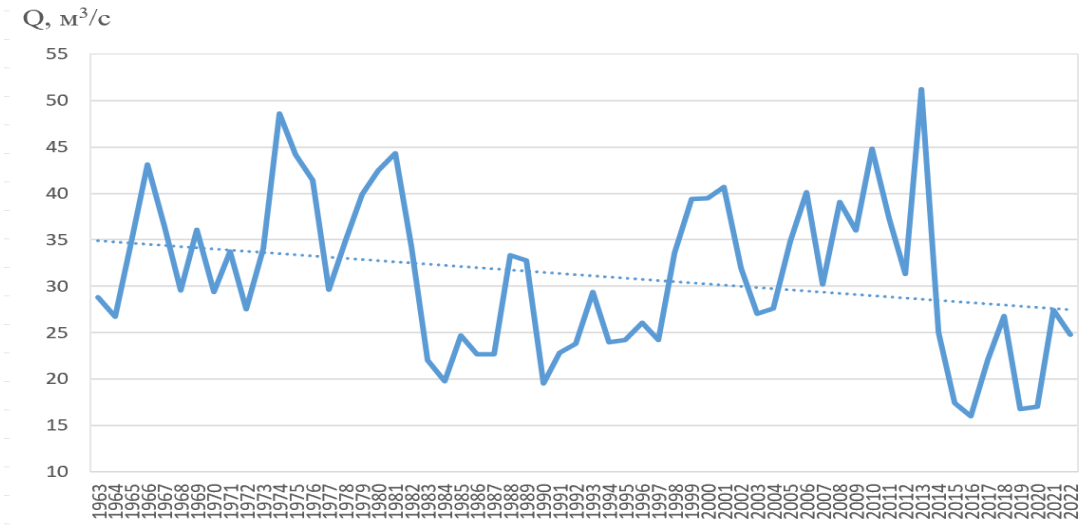

Figure 1. *Long-term (1963–2022) dynamics of the average water runoff and the trend line in the Styr River (Lutsk) (worked out by T. Pavlovska on the base of hydrometeorological observations data.*

Conclusions

During working out of the field stationary and cartometrical investigations the spectrum of the parameters of the main groups, types and kinds of exogenous processes development intensity in the different regions of Ukraine have been determined. Proposed in the presented paper scheme of classification and criteria (parameters) may be used by planning and implementation of the geomorphologic objects and processes dynamics research (*Table 1*).

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