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The assessment algorithm for sustainable development goals in the Hukiv, Dereluy, and Vyzhenka river basin systems of Chernivtsi oblast

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Abstract: The study deals with an integral assessment of hydromorphological and geoecological conditions of the Hukiv (flatland type of river), Dereluy (foothill type of river), and Vyzhenka (mountainious type of river) river basin systems (Figure 1). The indicators characterizing the river basin in the best way as a holistic system, the channel, floodplain, and watershed altogether, in natural reference conditions and in terms of human economic activity are addressed.
The assessment hydromorphological test and geoecological monitoring of small rivers (SWOT-analysis) in accordance with the developed universal algorithm for hydromorphological assessment of small river basins for the sustainable development goals are generated and fulfilled. Interpretation maps for the sustainable development of the Hukiv, Dereluy and Vyzhenka rivers are created. The practical importance and relevance concerns the potential application of the proposed monitoring and the algorithm to solve methodological and applied problems related to the functioning of the systems "basin–river–human" and "basin–river–riverbed" in terms of modern human activity and needs; the need to modify consumer-type stereotypes for the use of natural resources, as well as to provide recommendations for enhancing the resource-efficient and sustainable activities in basin systems and small rivers.

1. Introduction

The problem of sustainable development planning is not new, but for many years it remains relevant and in demand in scientific circles of specialists in various fields – economists, politicians, strategists. In recent years, there has been a tendency to identify opportunities for sustainable development for natural systems, as these are primarily resources so necessary to humanity (Chen et al., 2005; Gadzalo et al., 2018; Skoulikaris, Zafirakou, 2019; Islam, 2020). Scientists have not ignored basin systems, transboundary river systems and are trying to develop a common vision of sustainable development of this dynamic system (Everard, Powell, 2002; Dombrowsky et al., 2014; Spiliopoulos, 2014; Gerlak, Saguier, 2015; Krengel et al., 2018; Strokal, 2021).

A significant number of works are devoted to the sustainable development of Ukraine in general and in terms of its individual regions, in which attempts are made to develop planning for their optimal development (Kotykova et al., 2017; Kozlovskyi et al., 2017; Kvasha et al., 2017; Semenenko et al., 2019; Savitska et al., 2020).

Most of these studies were performed at the Institute of Geography of the National Academy of Sciences of Ukraine (Rudenko et al., 2015).

To obtain the most generalized conclusions, to make appropriate strategic decisions in development management, the Balance of Development Index has been developed, which is calculated on the basis of 8 separate indices. For the Chernivtsi region this index is 1.007.

Based on these data – Chernivtsi region can be described as relatively balanced in economic, environmental and social dimensions. However, these figures do not give a complete picture of the situation in specific administrative boundaries. We offer an option to assess the readiness of the region for balanced development and development of planning and management decisions based on the basin principle.

One of the priorities of regional development concerning water resources to further develop the basin principle in resource management, restoration of the natural mode of operation of small rivers and limitations of economic activities in catchment areas, especially in the river sources and within the protection zones.

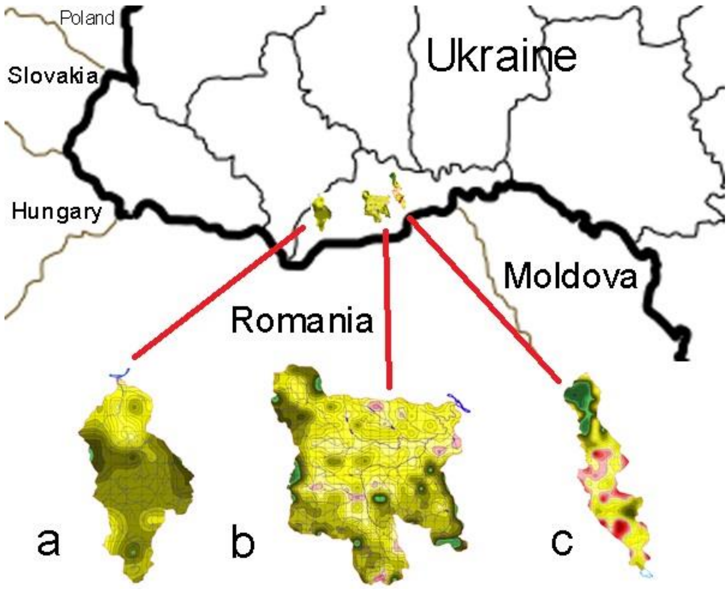

Figure 1. River basins: **(a)** Vyzhenka, **(b)** Dereluy, **(c)** Hukiv.

2. Materials and Methods

Previous studies in the field and relevant mathematical calculations contributed to developing an algorithm for the ecological and hydromorphological assessment of basins for the sustainable development goals (Kyryliuk, 2016). The latter enables to critically delimit the river basins areas according to the need for sustainable development. The diverse indicators forming its basis characterize small river basins in various ways. The algorithm operation principle is the sequential summation of indicators of individual blocks: transformation of the river network (by length and number of tributaries of different order), anthropogenic transformation, conflicts of the nature use types (quantitative, dynamic indicator and intensity), erosion hazard, floodplain assessment (in response to the land use type), the riverbed processes hazards, hydromorphological assessment of the riverbed state and coastal vegetation (according to the quality classes), the assessment of land use and the degree of the basin territory study (Kyryliuk, Kyryliuk, 2015). The points of the algorithm blocks are arranged in an ascending order in relation to the component intensity of the block. The minimum possible number of points is 14, the maximum is 57. This algorithm may be considered universal in relation to the assessment of the hydrological factor of the natural environment not only in the study areas, but also in the similar ones. The algorithm does not consider the economic and social components of potential sustainable development.

It is proposed to use SWOT-analysis for the studied basins in order to analyze their geoecological problems and preconditions for sustainable development. This method is used in strategic planning and is expressed in the division of factors and phenomena into four categories: Strengths, Weaknesses, Opportunities, Threats. SWOT-analysis does not contain any economic categories, so it can be used to build strategies in various areas of human activity – In our case in particular (Table 1).

Table 1. SWOT analysis of geoecological problems and prerequisites for sustainable development of the Hukiv, Dereluy and Vyzhenka basin systems.

Basin system	SWOT analysis				
		Positive influence		Negative influence	
Hukiv	*Internal environment*	**Strengths**		**Weaknesses**	
		S1	Reserved natural boundaries in the upper reaches, the park is a monument of landscape gardening art	**W1**	Lack of a basin plan and actions to improve the state of the environment
				W2	Transport accessibility
		S2	Joining the Upper Prut Euroregion	**W3**	High density of rural population – over 100 people/km^2
				W4	Large volumes and rates of accumulation of household and construction waste
	External environment	**Opportunities**		**Threats**	
		O1	Improvement of environmental legislation	**T1**	Flooding
		O2	Strengthening control over compliance with environmental legislation	**T2**	Low ecological culture, good breeding and education of the population
				T3	Poor funding for research and expeditionary work in the basin
Dereluy	*Internal environme*	**Strengths**		**Weaknesses**	
		S1	Natural monuments, parks – monuments of landscape gardening art	**W1**	Large volumes and rates of accumulation of household and construction waste
		S2	Joining the Upper Prut Euroregion	**W2**	Transport accessibility
		S3	The presence of mineral waters		
	External environment	**Opportunities**		**Threats**	
		O1	Improvement of environmental legislation	**T1**	Poor funding for research and expeditionary work in the basin
				T2	Low ecological culture, good breeding and education of the population
		O2	Strengthening control over compliance with environmental legislation	**T3**	Landslide processes
				T4	Air pollution from vehicle emissions
Vyzhenka	*Internal environment*	**Strengths**		**Weaknesses**	
		S1	Joining the Upper Prut Euroregion	**W1**	Large volumes and rates of accumulation of household and construction waste
		S2	Conservation area		
		S3	Unique natural complexes and objects		
		S4	Recreational attraction		
		S5	Reproduction of valuable fish species		
		S6	The density of the rural population is less than 50 people/km^2		
		S7	Transport accessibility		
		S8	Sources of mineral waters		
	External environment	**Opportunities**		**Threats**	
		O1	Improvement of environmental legislation	**T1**	Poor funding for research and expeditionary work in the basin
		O2	Significant tourist and recreational potential	**T2**	Low ecological culture, good breeding and education of the population
				T3	Seismic activity
		O3	Strengthening control over compliance with environmental legislation	**T4**	Mudflows
				T5	Windthrows

The analysis identifies the factors that, in our opinion, are the most informative about the state of the basin system from the point of view of the prospects for its sustainable development (taking into account its natural component). These include transformation of the river network (by length and number of tributaries of different order), anthropogenic transformation, conflicts of the nature use types (quantitative, dynamic indicator and intensity), erosion hazard, floodplain assessment (in response to the land use type), the riverbed processes hazards, hydromorphological assessment of the riverbed state and coastal vegetation (according to the quality classes), the assessment of land use and the degree of the basin territory study.

3. Results and Discussion

3.1. Components of the algorithm

The algorithm enables to identify specific problems in the functioning of the system "riverbed–floodplain–basin–human" and respond in a timely manner to these challenges, minimizing the influence of the factor from the outside or inside. The work involves constant monitoring of indicators and, if necessary, mapping of the possible development ways for the timely response measures.

The following characteristics have become the basis of the algorithm **Ecological and hydromorphological assessment of river basin for sustainable development** (Figure 2). The assessment of the territory in conventional points can be carried out for any river basin. The minimum possible number of points is 14, the maximum is 57. In view of this, a division into three categories (equivalent distribution of points by categories) has been made relatively the prospects for sustainable development in conjunction with a SWOT analysis: areas of significant (adverse) problems of sustainable development, areas of moderate problems of sustainable development, areas favorable for sustainable development.

Transformation of the river network. Rivers of different orders and their length (at different stages of its development) and the main characteristics of the functioning of the river system at a certain time interval characterize the state of the river system and the intensity of changes in the geoecological state of the river basin. Changes in the structure and parameters of the functioning of the river network occur under the influence of natural and anthropogenic factors. With the help of the ordinal classification of river systems, it is possible to obtain information on the hydrological, geomorphological and ecological characteristics of small rivers. This category was assessed on a 4 point system: absent – 4 points, insignificant – 3, moderate – 2 and significant – 1 point.

The anthropogenic transformation of the basins is assessed as follows: low transformed; transformed; moderately transformed; strongly transformed; very heavily transformed. We associate the predominance of territories with a high degree of anthropogenic load with intensive plowing of lands confined to slope surfaces and with territories occupied by settlements, medium and low – with the use of poorly dissected territories (mainly hayfields and natural pastures).

The nature management's conflicts. The process of rationalizing nature management is currently being carried out in a rather contradictory manner, which leads to numerous conflicts between various types of nature management. Most of the conflicts in the nature management are observed for the agricultural and settlement type. Within the basin, we single out such conflicts of nature management – industrial, agricultural, transport, settlement, water management, and recreational. Each of them has a different dynamics, intensity, manifestation and possible solutions. The assessment of conflicts was carried out taking into account the number of conflicts in a specific kilometer square (2–3 conflicts – 3 points, 4–5 – 2 points, more than 6 – 1 point), their dynamics (decreasing – 4 points, unstable – 3, stable – 2, increasing – 1 point) and intensity (low – 4 points, moderate – 3 points, strong – 2 points, very strong – 1 point).

Erosional hazard. The assessment consists in the additional impact of hydrographic objects on the erosion situation: there is no erosion hazard (absent) – 5 points; minimum erosion hazard – 4 points (temporary streams, tributaries of rivers and rivers do not affect the territory) low erosion hazard – 3 points (influence of rivers and tributaries) average erosion hazard – 2 points (influence of temporary streams, rivers and their tributaries) strong erosion hazard – 1 point (influence of ponds, enhanced by the actions of temporary streams, tributary and main river).

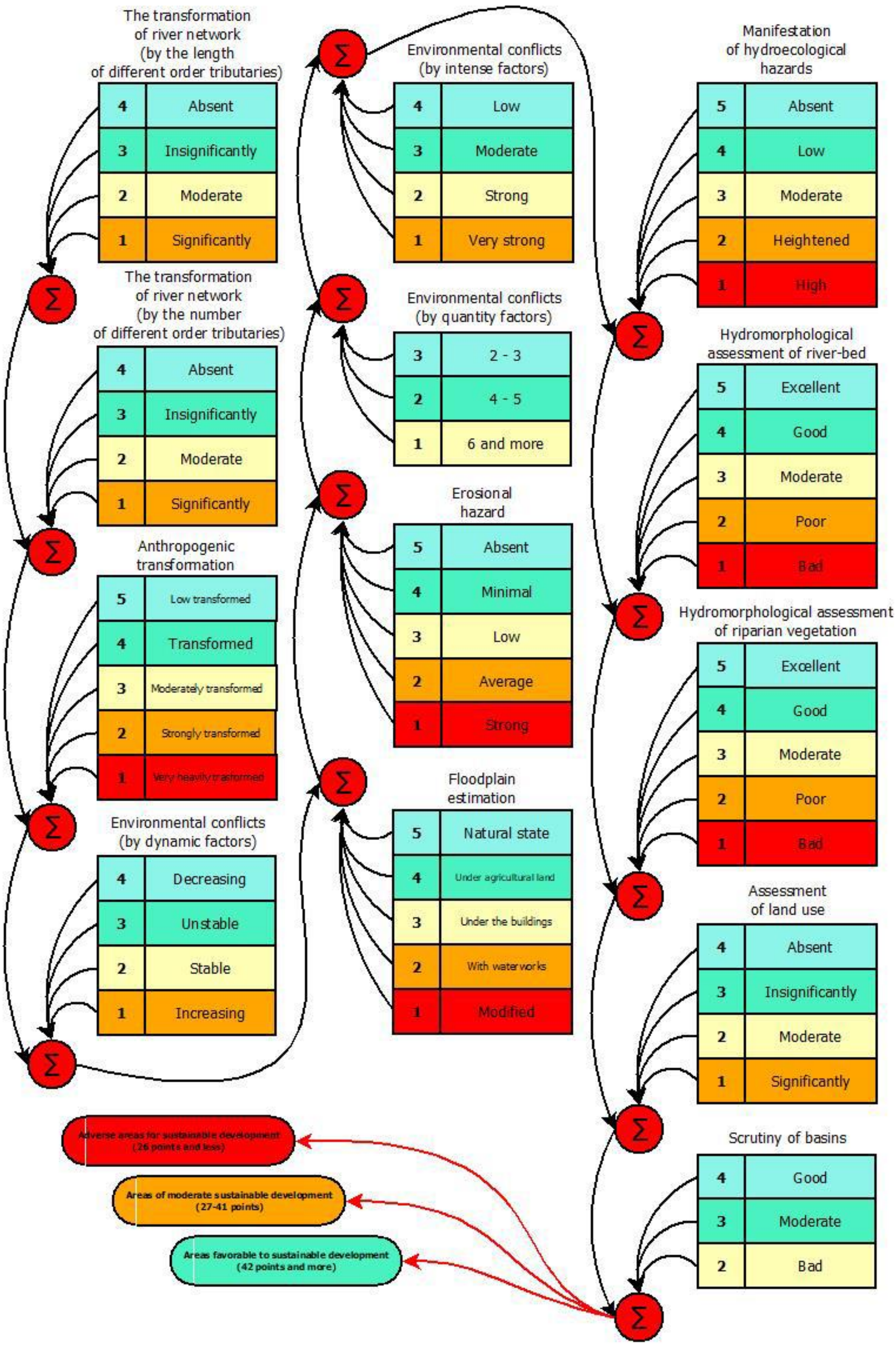

Figure 2. Algorithm of ecological and hydromorphological assessment of the river basin for the perspective sustainable development.

Floodplain assessment. The floodplains that are in their natural state meet the primary conditions according to the Water Framework Directive (WFD 2000).The plowing of the floodplain changes the water runoff and sediment, which, when entering the riverbed, determine the direction of riverbed deformations. Longitudinal dams compress the flow at a considerable distance during floods, which dramatically changes their impact on the channel.

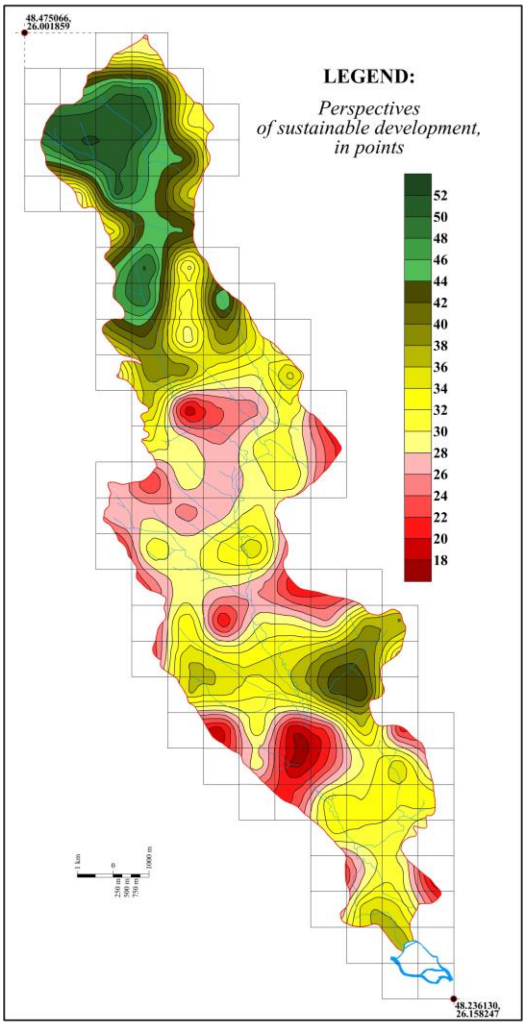

Figure 3. Differentiation of the Hukiv river basin according to the perspective for sustainable development.

Manifestation of hydroecological hazards. The risk of developing a dangerous situation under the action of any hydroecological hazard is assessed. This includes both the danger of the manifestation of riverbed processes and the consequences of such a manifestation.

Hydromorphological assessment of the state of the riverbed and coastal vegetation. Assessment of the hydromorphological quality of rivers is carried out in accordance with the WFD requirements: by quality classes – excellent (5 points), good (4 points), moderate (3 points), poor (2 points), bad (1 point). For riverbed and coastal vegetation, the quality of the class depends on the characteristic conditions in the catchment area.

Land use assessment is carried out taking into account the types of vegetation under which the lands in the basin system are located: natural vegetation (absent) – 4 points, lands of moderate agricultural use (insignificant) – 3 points, lands of intensive agricultural use (moderate) – 2 points, land under construction (significant) – 1 point.

The degree of knowledge of the basin is a specific category, it is proposed not only from the standpoint of hydrological knowledge, but also includes the availability of data on any natural component in periodicals and scientific publications, Internet resources, and etc. In this regard, the Hukiv basin has been studied well (Figure 3), Dereluy basin – well (Figure 4), Vyzhenka basin – satisfactory (Figure 5).

3.2. Testing of the algorithm

Areas with significant (adverse) conditions sustainable development (less than 26 points). For sustainable development, in accordance with the SWOT analysis, geoecological problems and prerequisites for sustainable development are characterized by a practically absence of strengths and opportunities with overcoming weaknesses and threats.

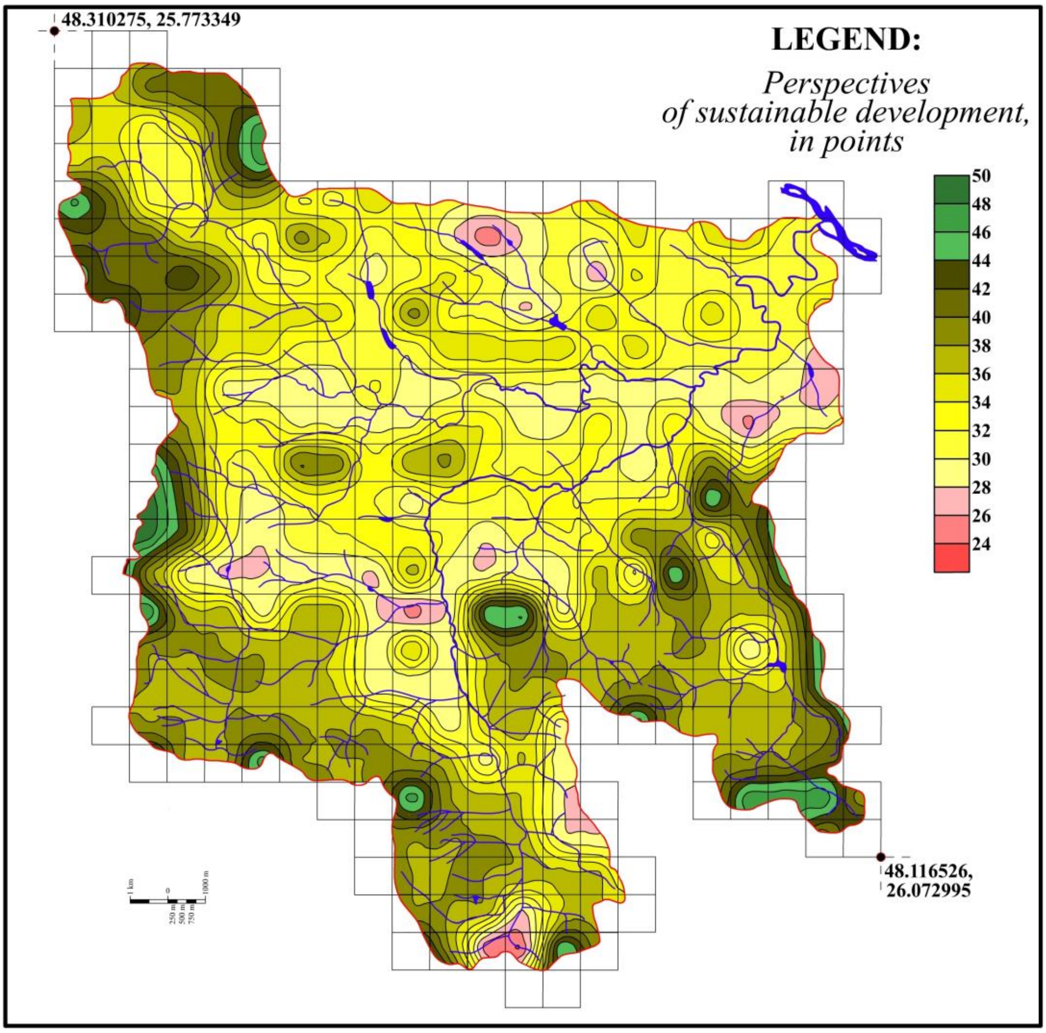

Figure 4. Differentiation of the Dereluy river basin according to the perspective for sustainable development.

The transformation of the river network, both in terms of quantity indicator and length, is characterized as moderate and significant. Anthropogenic transformation is determined by the concentration of strongly transformed and very heavily transformed territories. Conflicts of land use are characterized as stable and increasing in dynamics, strong and very strong in intensity with a number of 4–5 (on a relatively small area, settlement, transport, agricultural and recreational types of land use conflict). The hazard from the manifestation of erosion processes is average and strong. The floodplains are predominantly built up, with hydraulic structures and modified.

There is an increased and high hazard from riverbed processes, manifested in the washout of valuable lands, a decrease in productivity and a deterioration in the quality of floodplain lands, waterlogging of the floodplain, flooding of settlements, activation of landslide and erosion processes, an increased risk of breakthrough of pond dams, and ect.

In hydromorphological terms, poor and bad quality classes prevail. In land use, the main place is occupied by arable land and built-up areas.

Areas with moderate conditions sustainable development (points from 27 to 41). The transformation of the erosional-riverbed network is dominated by significantly and moderately transformed territories. The consequence of anthropogenic activity is the transformed and moderately transformed areas. Conflicts of land use manifest as unstable and low with the number of 3–4 (in terms of dynamics, intensity and number, respectively).

Erosion hazard is minimal and low. The floodplain is predominantly under agricultural land. Manifestation of riverbed processes is characterized as low and moderately hazardous. Among the hydromorphological indicators, good and moderate quality classes dominate. The land use is dominated by meadow vegetation, forbs and ruderal associations with an insignificant share of cultivated land.

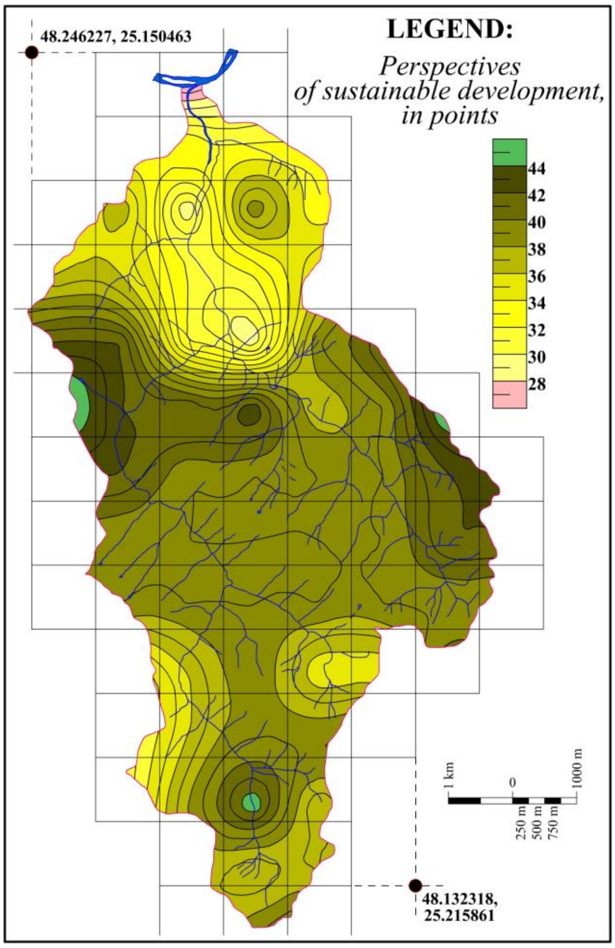

Figure 5. Differentiation of the Vyzhenka river basin according to the perspective for sustainable development.

Areas favorable for sustainable development (more than 42 points). They have many strengths regarding the internal environment and the opportunities for the external. Weaknesses of the internal and hazards of the external environment are practically absent. Transformational processes in the river network are absent or there is a slight change in comparison with previous years. Territories with insignificant anthropogenic transformation prevail. Conflicts manifest as decreasing (in dynamics), low (in intensity) and 2–3-component (in number). The manifestation of erosion processes in the network of temporary and permanent streams is absent or minimal. The floodplain is in its natural state. The hazard of manifestation of riverbed processes is absent or low.

The observed hydromorphological parameters are of excellent and good quality classes. In land use, a significant share is occupied by natural vegetation.

The main directions of optimization of nature management for unpromising and little promising areas and further territorial development are: reclamation of degraded territories; development of ecological tourism; increasing the level of environmental education and upbringing of the population; establishment of warning and prohibition signs. The presence of landscapes unaltered by anthropogenic activity within promising areas prompts the creation of nature conservation areas of local importance and the provision of a special regime for their use.

4. Conclusions

The proposed algorithm made it possible to identify 3 types of areas for perspective sustainable development: adverse areas for sustainable development; areas of moderate sustainable development; areas favorable to sustainable development. For each of the identified areas, a characteristic is given according to the SWOT analysis – a classic economic method that we have applied to solve geoecological problems and perspective for sustainable development. According to this analysis, one of the real threats to the external environment (relative to the environment of the basin system) is poor funding for research and expeditionary work in the studied basins and low ecological culture. At the same time, the entry of the territory into the Upper Prut Euroregion is important.

The zoning of the Hukiv, Dereluy and Vyzhenka basin systems provides grounds for future similar work within the Chernivtsi region, the Upper Prut system, and other small basins with perspective for improving environmental and water legislation and strengthening control over its implementation.

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