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ASSESSMENT OF ENVIRONMENT OF AN AREA'S SOCIAL VULNERABILITY: ECOLOGICAL ASPECT

Purpose. The purpose of the current research is identification and integral estimation of ecological determinants of forming environment of an area's social vulnerability (on the example of the oblasts of the Carpathian region of Ukraine).

Methodology / approach. The empirics of environment of the social vulnerability based on the identification of ecological components is carried out by construction of commensurate series of indicators' values through the normalizing for each group of parameters, in particular, within the selected set of areas (oblasts of the Carpathian region). The construction of time series of significance coefficients (calculation of weight coefficients) stipulates the use of the theory of sensitivity, while the calculation of the integral coefficient of the social vulnerability natural environment requires the multiplicative approach.

Results. The calculated integral coefficients of the natural environment of social vulnerability contributed to determining the living standards of the population of the natural resource sector and showed a significant socio-ecological divergence among the oblasts of the Carpathian region and Ukraine. In 2019, the highest values of integral coefficients of social vulnerability natural environment in the Carpathian region of Ukraine were observed in Ivano-Frankivsk (0.574) and Chernivtsi (0.391) oblasts. Ivano-Frankivsk oblast was the leader in that regard throughout the studied period.

Originality / scientific novelty. The methodological approach for analyzing the social vulnerability of the area has been improved, which, unlike the traditional ones based on determinants of the social, economic, and political environment, provides for a comprehensive analysis of the sensitivity of changes in the social vulnerability of the territory regarding the changes in the natural environment determinants.

Practical value / implications. The paper offers and substantiates a methodological approach to the estimation of ecological determinants as the indicators of an area's vulnerability growth, which serves as the information-analytical base for the development of the initiative-taking social vulnerability reduction policy.

Key words: ecology, determinant, Carpathian region, social vulnerability, sensitivity, area.

Introduction and review of the literature. Humanization and socialization are the mainstreams in current scientific research and its scientific-practical results. A person is in their focus. A decent quality of life is an integral characteristic of the society's development level. The present existential challenges increasingly escalate and bring to the fore the problems of the economy and society ecologization, resource management, and protection of biodiversity (EU4Environment launched for the

Eastern Partnership countries for 2019–2022, European Green Deal for 2030 and 2050), as well as their combination with the priorities of social stability and cohesion (EU social policy).

The natural environment is among the major quality of life factors and the determinant of social vulnerability growth. Yet, there is a range of environmental problems that increase social vulnerability both in Ukraine and the Carpathian region, namely contamination of surface and ground waters, the release of pollutants into water, air pollution and the change of its composition due to industrial and other emissions, disruption of ecological balance caused by the depleting extraction of minerals and mineral waters, illegal logging in the Carpathians, the change of land resources structure due to construction, negative physical-geographic processes, falling soil fertility, etc. Meanwhile, environmental specifics of the Carpathian region are related, first of all, to the problems of deforestation and degradation of forest ecosystems, violation of a hydrological regimen of mountain rivers often leading to floods and other dangerous natural processes, depletion of agricultural areas, and contamination of the region with the waste of different hazard class. These conditions and factors generate the socio-ecological vulnerability environment in the region and determine the perspectives of its further economic growth and wellbeing of the population, so they should be considered by planning the regional development.

The difficult socio-economic situation in Ukraine and the regions, strengthened by macroeconomic stagnation, military conflict, the Covid-19 pandemic, job cuts, rising unemployment and high migration activity, price instability and rising energy tariffs, lead to the expansion of a socially vulnerable segment of the population, unable to meet their needs independently and exercise their rights due to limited resources or falling into particularly difficult social conditions. This threatens the development of a systemic social crisis both in certain territories and in social groups of the population.

Timely identification of trends in the spread of social vulnerability of the population of the region and implementing mechanisms and tools of active socio-economic policy can prevent the development of crisis phenomena and prevent the implementation of systemic social threats. In our opinion, social vulnerability needs to look through the prism of the population's readiness for environmental threats. Therefore, environmental determinants are one of the key indicators of the forming environment of social vulnerability of the population and territory.

Dependence of social development and human well-being on environmental conditions has recently become an extremely critical issue discussed by many outstanding scholars, country leaders, environmental groups, and individual activists worldwide. The main point of discussion and research concerns not only the global environmental change but also natural resource potential and natural hazards for separate territories, especially those defined as socially vulnerable ones. Such effects are the result of both the frequency and extent of the hazard, and the susceptibility or resilience of the society against environmental risks, e.t. the assessment of social vulnerability is particularly complicated because of the variety of factors shaping it (Lee, 2014; Medvedeva et al., 2021; Sebesvari, 2016). Most of these assessments

concern negative outcomes from natural hazards and challenges, such as limits of resources (Beroya-Eitner, 2016), climate change (Kazakova, 2016), floods (Fekete, 2008) or other extreme events and disasters (Birkmann et al., 2008).

Some of the research focus on temporal and spatial changes in social vulnerability determined by environmental conditions (Cutter and Finch, 2008). In this context, many scholars (Berrouet, Machado and Villegas-Palacio, 2018; Kok, 2016; Sowman and Raemaekers, 2018) consider and analyse a socio-ecological vulnerability, which still needs more attention in respect of developing the methods for its assessment. Moreover, the factors and forces determining the vulnerability of the society are associated with the volatile nature of the environment and, therefore, their dynamics in time and space should be considered. Fuchs and Glade (2016) make a crucial point thereon claiming that such dynamics might be caused by natural variations (e.g. climate changes, modifications in terrestrial ecosystems, biodiversity loss) but can also be determined by social and economic transformations such us urbanization, industrialization, excessive natural resource consumption, etc. Thus, the hardest task is to assess a variety of ecological determinants of social vulnerability based on a comprehensive approach and specificity of the territory. Given this point, a few regional case studies have been found (Eakin, 2005; Rudel, 2008; Sietz, 2014).

For instance, Eakin (2005) discusses ethnographic data collected in three communities in Central Mexico to argue the rural population capacities to manage environmental risks. Different livelihood strategies are analyzed to improve risk management capacity. The study by Sietz (2014) presents a new method of refining global insights into vulnerability at a regional scale (on the example of dryland in Northeast Brazil). It is based on a link between broad patterns of vulnerability and modelled regional smallholder development. These studies confirm that, when reflecting sub-national differences, regional variations in the underlying conditions of social vulnerability should be considered. Therefore, the analysis of the context-specific processes can facilitate vulnerability reduction. Hence, the composition of indicators determining social vulnerability depends on a specificity of a particular territory (spatial perspective).

In terms of dynamics, vulnerability analysis focuses on present-day conditions that determine the way a person or community is affected by hazards, as well as on the projections of affects in the future considering the capacities of people and communities to cope with environmental hazards and adapt to them (Breil et al., 2018). There is also a concept of differentiated vulnerability, which lies in different impacts of environmental changes on different social groups. One of the recent research projects (Wolch et al., 2014; Boiko et al., 2021) standing for this concept proves that extreme events cause worse effects on more vulnerable groups. These groups, according to the mentioned research, include people living in areas with low environmental qualities, people with low socio-economic status, and people with physical conditions that present greater difficulties in preparing for, and in recovering from, environmental change impacts. The difficulties in coping with ecological factors might be caused by the lack of economic resources or physical conditions like poor health or suffering from other social

disadvantages. Thus, the capacities to confront ecological challenges, ensure social stability and, as a result, provide sustainable development of the territories are becoming increasingly influential factors shaping the well-being and quality of life of the population, especially of the most vulnerable segments of the people.

A lot of scientific groups in Ukraine, e.t. by E. Libanova, S. Doroguntsov, V. Heyets, B. Burkynskyi and other prominent scientists, investigate environmental factors and their impact on social development of the territories. At the present stage of Ukraine's development, research on social vulnerability and its determinants are of a significant importance at the regional and local levels. Thus, in the Carpathian region of Ukraine there are significant social problems, as well as threats to environmental security. The problem of providing social stability is relevant here given such specifics as: high migration activity of the population given the closeness to EU borders causing human outflows and human potential reduction (Mulska et al., 2020), which leads to socio-cultural imbalances, loss of generations, family dramas, the narrowing of population development due to structural distortions in the human reproduction (Tsybulska and Demedyuk, 2015), the deepening of imbalances and problems in the labor market (Sytnyk et al., 2020); inequalities in the socio-economic development of the territories, in particular, industrialized territories of both the region and the whole Ukraine (Pysarenko, 2014); the presence of a significant part of the mountainous areas of the Ukrainian Carpathians, which have a much lower level of social infrastructure and security (Chervinska, 2015).

At the same time, the ecological specifics of the Carpathian region are primarily related to deforestation and degradation of forest ecosystems, disruption of the hydrological regime of mountain rivers, which often leads to floods and other dangerous natural processes, depletion of agricultural land, pollution of the region, etc. (Kravtsiv, 2013; Semiv et al., 2021). Such conditions and factors form the environment of the socio-ecological vulnerability of the region, determine the prospects for its further economic growth and welfare of the population, and therefore should be considered by planning the region's development. Moreover, the environment determining social vulnerability in the Carpathian region is volatile and must be constantly monitored. However, at the regional level, the amount of comprehensive analytical and empirical studies ascertaining the role and impact of ecological factors is insufficient.

The purpose of the article. The purpose of the current research is identification and integral estimation of ecological determinants of forming environment of an area's social vulnerability (on the example of the oblasts of the Carpathian region of Ukraine).

The conducted analysis can help suggest relevant measures for minimizing environmental risks and challenges, propose tools for regulating ecological factors of social welfare in the region, as well as seek for responses to emerging vulnerabilities.

Results and discussions. *The state and tendencies in the development of problematic aspects of the natural environment of social vulnerability in the Carpathian region.* A system of indicators that describe the state and development of the natural environment, as well as the level of environmental safety in the region

determine the natural environment of social vulnerability of the population in the region. In terms of sustainable growth, these environmental factors primarily determine the level of social vulnerability of the population. The ecological situation in the oblasts of the Carpathian region of Ukraine affects, on the one hand, the general well-being of people and society, and, on the other hand, the quality of the environment and, respectively, the desire of people to live in this territory, to fulfil their human capital and intellectual and personnel potential here.

Problematic aspects of the natural environment of social vulnerability of the population in the Carpathian region of Ukraine are as follows (statistical assessment of selected indicators of the natural environment in the region is given in Table 1):

1) In the oblasts of the region, the volume of freshwater consumption is significantly less (compared to the average state value). While an average indicator for other oblasts of the country in 2019 was 174.6 m^3 per capita, it was 2.9 times less in Ivano-Frankivsk oblast, 3.2 times less in Chernivtsi oblast, and 3.6 times less in Lviv oblast. The lowest volumes of freshwater consumption is a typical situation for Zakarpattia oblast (23.9 m^3 per capita), it is 7.3 times less than the average state value in the country.

2) The oblasts of the Carpathian region are characterized by a lower level of general water drain. The providing of the oblasts of the Carpathian region of Ukraine with general water drain per capita is on average less than 2.0 times for Lviv oblast, 2.9 times for Chernivtsi oblast, 3.0 times for Ivano-Frankivsk oblast and more than 4.0 times for Zakarpattia oblast.

3) There are significant imbalances between the oblasts of the Carpathian region in terms of the level of contamination of water bodies. In Zakarpattia, Ivano-Frankivsk and Chernivtsi oblasts, the volumes of polluted recycled waters discharged into surfaced water bodies are low (1–4 mln m^3), which is 1–3 m^3 per capita. Instead, the value of this indicator in Lviv oblast is higher than the national average. In 2019, the corresponding indicators amounted to 17.9 and 17.6 m^3. Annually, over 40 mln m^3 of polluted recycled waters is being discharged into surfaced water bodies in Lviv oblast. Despite a sufficiently high capacity of treatment plants in the oblast (more than 280 m^3), the efficiency of their functioning is low.

4) The level of air pollution is high, especially in Ivano-Frankivsk and Lviv oblasts, with a tendency to further worsen the situation. For instance, in 2010, the volume of pollutant emissions into the air from stationary pollution sources amounted to 169.2 thsd. t, and by 2019, this indicator increased to 205.0 thsd. t. The main air pollutants are enterprises producing and distributing electricity, and stationary pollution sources, contributing about 90 % of total regional emissions into the atmosphere.

Other oblasts of the Carpathian region of Ukraine are characterized by satisfactory air purity conditions. Thus, in Chernivtsi oblast in 2019, the volume of emissions of pollutants into the air from stationary pollution sources amounted to only 2.4 thsd. t and in Zakarpattia oblast – 3.7 thsd. t, which constituted 0.25 % of total emissions in Ukraine. During 2019, relative indicators (per 1,000 people) in these oblasts amounted to 2.7 and 3.0 t, respectively, and had a clear tendency to further decrease.

Table 1

State of natural environment in the Carpathian region of Ukraine, 2010, 2015–2019

Indicators	Oblasts	Period						2019/2010	
		2010	2015	2016	2017	2018	2019	+/-	%
Consumption of freshwater per capita, m³	Zakarpattia	26.5	23.8	23.0	17.5	19.1	23.9	-2.6	90.2
	Ivano-Frankivsk	62.3	56.4	53.6	54.4	60.4	59.9	-2.4	96.1
	Lviv	68.8	47.4	47.0	48.6	49.6	48.6	-20.2	70.6
	Chernivtsi	75.2	53.9	57.3	55.1	56.4	54.3	-20.9	72.2
	Ukraine	214.4	166.6	168.3	161.7	174.7	174.6	-39.8	81.4
General water drain, per capita, m³	Zakarpattia	34.5	25.4	27.8	29.4	29.4	31.9	-2.6	92.5
	Ivano-Frankivsk	66.7	42.0	42.8	43.6	45.9	44.6	-22.1	66.9
	Lviv	94.3	86.8	85.6	70.4	69.4	66.9	-27.4	70.9
	Chernivtsi	58.6	46.2	46.3	45.2	47.5	46.6	-12.0	79.5
	Ukraine	177.8	130.5	131.8	116.1	128.4	133.0	-44.8	74.8
Discharge of polluted recycled waters into surfaced water bodies, per capita, m³	Zakarpattia	6.4	1.6	3.2	3.2	3.2	2.4	-4.0	37.5
	Ivano-Frankivsk	10.9	0.7	0.7	0.7	0.7	0.7	-10.2	6.4
	Lviv	23.2	17.8	18.2	28.1	16.7	17.9	-5.3	77.2
	Chernivtsi	7.7	2.2	2.2	2.2	2.2	1.1	-6.6	14.3
	Ukraine	38.1	20.5	16.4	23.5	22.6	17.6	-20.5	46.2
Emissions of pollutants into the air from stationery pollution sources, per 1,000 people, t	Zakarpattia	13.9	3.5	3.9	2.5	3.2	3.0	-10.9	21.6
	Ivano-Frankivsk	122.6	162.0	142.5	144.0	161.2	149.8	27.2	122.2
	Lviv	44.5	40.4	40.7	43.1	42.3	35.4	-9.1	79.6
	Chernivtsi	4.2	3.5	3.3	3.6	3.0	2.7	-1.5	64.3
	Ukraine	90.3	66.8	72.3	61.0	59.5	58.7	-31.6	65.0
I-III hazard class waste generation, per unit area, t	Zakarpattia	0.6	0.2	0.1	0.1	0	0.1	-0.5	16.7
	Ivano-Frankivsk	0.2	0.2	0.2	0.5	0.3	0.4	0.2	2.0 p.
	Lviv	0.1	0.1	0.1	0.1	0.1	0.2	0.1	2.0 p.
	Ukraine	2.8	1	1.1	1	1.1	1	-1.8	35.7
IV hazard class waste generation, per unit area, t	Zakarpattia	14.2	10.3	12	13.5	14.6	11.9	-2.3	83.8
	Ivano-Frankivsk	91.6	152.6	139	139.4	141.2	214.4	122.8	2.3 p.
	Lviv	119	135.4	127.1	113.6	97.9	93.6	-25.4	78.7
	Chernivtsi	31	49.1	48	45.6	38	39.4	8.4	127.1
	Ukraine	703	540.6	512.1	633.8	610	764.8	61.8	108.8
Coefficient of utilization of IV hazard class waste	Zakarpattia	0.07	0.01	0.00	0.00	0.00	0.00	-0.1	-
	Ivano-Frankivsk	0.47	0.27	0.35	0.33	0.28	0.29	-0.2	61.7
	Lviv	0.02	0.11	0.17	0.24	0.17	0.16	0.1	8.0 p.
	Chernivtsi	0.13	0.17	0.31	0.30	0.30	0.37	0.2	2.8 p.
	Ukraine	0.34	0.30	0.29	0.27	0.29	0.24	-0.1	70.6
Capital investment for environmental protection, per 1,000 people, thsd. UAH	Zakarpattia	7.9	6.2	4.7	11.0	36.5	11.2	3.3	141.8
	Ivano-Frankivsk	99.2	65.5	86.7	268.9	213.9	181.6	82.4	183.1
	Lviv	34.4	23.8	41.0	95.4	112.8	88.1	53.7	2.6 t.
	Chernivtsi	9.4	20.6	15.2	26.2	23.7	33.4	24.0	3.5 t.
	Ukraine	60.3	179.5	314.4	260.1	239.0	387.9	327.6	6.4 t.
Operating costs for environmental protection, per 1,000 people, thsd. UAH	Zakarpattia	36.9	70.5	102.6	130.5	180.0	214.1	177.2	5.8 t.
	Ivano-Frankivsk	107.6	169.3	183.1	229.5	400.1	463.1	355.5	4.3 t.
	Lviv	60.2	134.8	151.3	176.5	233.6	207.3	147.1	3.4 t.
	Chernivtsi	47.0	75.6	77.3	95.8	112.1	135.4	88.4	2.9 t.
	Ukraine	226.5	395.6	448.5	482.9	576.9	655.8	429.3	2.9 t.
Share of operating costs for environmental protection to GRP, %	Zakarpattia	0.30	0.31	0.40	0.38	0.43	0.51	0.2	x
	Ivano-Frankivsk	0.73	0.51	0.49	0.49	0.70	0.73	-	x
	Lviv	0.37	0.36	0.33	0.30	0.33	0.24	-0.1	x
	Chernivtsi	0.43	0.37	0.33	0.30	0.30	0.36	-0.1	x
	Ukraine	0.96	0.85	0.80	0.69	0.68	0.74	-0.2	x

Note: t – times.
Source: calculated by the authors based on State Statistics Service of Ukraine, 2010, 2015–2019.

5) Operating costs and capital investment for environmental protection are low and insufficient. It is noteworthy that the share of capital investment in four oblasts is only about 2–3 % of the total capital investment for environmental protection in Ukraine. In 2019, relative investment indicators in the Carpathian region were as follows: 11.2 thsd. UAH per 1,000 people in Zakarpattia oblast, 33.4 thsd. UAH per 1,000 people in Chernivtsi oblast, 88.1 thsd. UAH per 1,000 people in Lviv oblast and 181.6 thsd. UAH per 1,000 people in Ivano-Frankivsk oblast. Meanwhile, the average regional value of the indicator was 387.9 thsd. UAH per 1,000 people. Instead, a bigger share of capital investment for environmental protection was in Ivano-Frankivsk oblast (3.13 % in 2010; 3.82 % in 2017; 3.13 % in 2018; 2.67 % in 2019). The corresponding indicators exceeded the average regional values in Ukraine.

Empirical research and forecasting of the natural environment of social vulnerability of the Carpathian region of Ukraine. 20 determinants were selected to estimate the natural environment of social vulnerability in the Carpathian region. They were grouped (Table 2) by the criteria of (1) availability of water resources, (2) contamination of an area and air quality, (3) investment framework of nature management, and (4) availability of land resources. The research of natural determinants of an area's social vulnerability, same as other subjective factors, has informational-analytical limits related to insufficiency and lack of consolidated statistical information on the components of the socio-economic and natural environment, as well as significant gaps in the methodological framework in the regional dimension.

The commensurable series of indicators' values are constructed at the initial stage of implementing the methodology for the research of social vulnerability natural environment by the normalization for each group of parameters, including within the selected set of areas (the oblasts of the Carpathian region). The maximum values of parameters in the data range are the threshold values for indicators-stimulators, while the minimum values – for indicators-destimulators. Calculation of weight coefficients stipulates the use of the theory of sensitivity that allows constructing the time series of significance coefficients (1):

$$w_{it}^{nk} = \frac{\left|\mu_i^{kn}\Delta x_{it}^n\right|}{\sum_{i=1}^{j}\left|\mu_i\Delta x_{it}^n\right|}, \tag{1}$$

where μ_i^k is the sensitivity coefficient of the *i* indicator in the *k* group of the *n* oblast;

Δx_{it}^n is the coefficient of the variability of the *i* indicator of the *n* oblast in the *t* time period;

w_{it}^{nk} is the weight coefficient of the *i* indicator in the *k* group of the *n* oblast in the *t* time period;

j is the number of *i* indicators in each group of parameters.

The integral coefficient of social vulnerability natural environment is calculated based on the multiplicative approach.

The weight coefficients of the indicators of social vulnerability natural

environment in the Carpathian region are inertial and do not have wavy dynamics. Chernivtsi and Lviv oblasts had the minimum values of weight coefficients of the discharge of contaminated return waters into the surface waters (6.62 % and 6.33 % in 2019, respectively) in the group of availability of water resources. Yet, Ivano-Frankivsk and Zakarpattia oblasts had consistent dynamic weight coefficients in the entire period under research. Water extraction from natural sources and general water disposal had the highest weight values for the oblasts of the Carpathian region. Meanwhile, in Ukraine, treatment facilities capacity (18.0 % in 2019) and the use of fresh water (18.55 % and 18.15 % in 2010 and 2019, respectively) had much weight significance in the group.

Table 2

Determinants of the natural environment of social vulnerability in the Carpathian region

Determinants	Quantification	Nature of impact
Availability of water resources		
Water extraction from natural sources		−
Consumption of fresh water		+
The volume of circulating and reused water		+
General water drain	per capita, m^3	+
Discharge of polluted recycled waters into surfaced water bodies		−
Treatment facilities capacity		+
Contamination of territories and air quality		
Emissions of pollutants into the air from stationery pollution sources	per 1,000 people, t	−
I–III hazard class waste generation	per unit area, t	−
IV hazard class waste generation	per capita, kg	−
I–III hazard class waste treatment coefficient		+
IV hazard class waste treatment coefficient		+
Index of wastes accumulated during exploitation in the designated places or facilities	% of previous year	−
Investment framework of nature management		
Capital investment for environmental protection	per capita, €	+
Operating cost for environmental protection		+
The share of operating cost for environmental protection in GRP	%	+
The share of capital investment in environmental protection in total capital investment	%	+
Availability of land resources		
The share of built-up areas		−
The share of agricultural land areas	%	+
The share of nature reserve fund areas		+
Forests, forest-covered areas, and land under water areas	per 1,000 people, thsd. ha	+

Note. The indicators were divided into stimulators (+) and destimulators (−) by the expert method.
Source: the authors' interpretation.

The obtained results indicate acute ecological problems related to securing the rational management of water resources and their protection from depletion and pollution in the oblasts of the Carpathian region. Between 2010 and 2019, the region faced the challenge of water supply. Water resources are used irrationally in some oblasts of the region, they are contaminated by industrial and agricultural wastewaters and waste. Thermal power stations in Burshtyn and Dobrotvir, as well as agribusinesses and farms lacking treatment facilities and sewerage are the largest pollutants of surface and ground waters. The concentration of some pollutants in water bodies of the oblasts of the Carpathian region exceeded the maximum allowable rates tens of times.

There are a lot of major air pollutants in the Carpathian region affecting the quality of life, namely road transport, woodworking and food enterprises, construction corporations, and farms. The causes of territory and air pollution include outdated technology and gas purification equipment, in some cases – the lack of gas purification and automatic control of devices, low technological discipline, and lack of necessary funds to purchase modern purification equipment. These challenges affect the implementation of measures in environmental protection, which is aggravated by inefficient economic tools and leverages designated to encourage enterprises to introduce environmentally friendly technologies and innovative purification equipment and to secure the proper functioning of treatment facilities, etc.

For that matter, the dynamics of growth in the weight significance of I–III hazard class waste generation was observed in all oblasts of the Carpathian region of Ukraine, for instance, in Chernivtsi oblast from 13.92 % in 2010 to 21.47 % in 2019, in Lviv oblast from 14.44 % in 2010 to 20.98 % in 2019. Meanwhile, significant growth in the weight of IV hazard class waste treatment coefficient was observed in Ukraine from 17.65 % in 2010 to 20.53 % and 20.06 % in 2014 and 2019, respectively, indicating the need to construct waste processing plants in the region. It is worth mentioning that the determinant of wastes accumulated during exploitation in the designated places or facilities acquired much significance in Zakarpattia oblast in the crisis period (2014–2015), while the index weight was the least significant in Ivano-Frankivsk oblast in 2010–2019. The treatment weight coefficients were high in Lviv oblast compared to other oblasts of the Carpathian region as it has substantial problems with waste treatment. For comparison, the weights of the I–III hazard class waste treatment coefficient in Lviv and Zakarpattia oblasts in 2019 were 28.6 % and 9.05 %, respectively. Interestingly, the region needs the establishment and development of financial funds to reproduce and protect some types of natural resources and the development of the waste treatment industry, since untimely disposal and treatment of industrial and household waste affects the natural environment and health of the local population.

The reduction of social vulnerability in the Carpathian region depends on the ecological situation, which correlates with the efficiency of regional nature management policy and investment volumes. Local budget revenues from rent payments for the use of forest resources, special water use, and subsoil use, land fee, and environmental tax constitute the prospective source of funding the integrated

nature management projects in the Carpathian region. The analysis shows that capital investment in environmental protection was most significant for the oblasts of the Carpathian region (in 2019, for Zakarpattia oblast – 42.8 %, Lviv – 28.45 %, Ivano-Frankivsk – 32.55 %, and Chernivtsi – 25.9 %). The trend is the same for Ukraine, namely capital investment and operating cost of environmental protection had the highest weight values in 2019 (29.18 % each).

A significant variability scope of weight coefficients of the share of environmental protection operating cost in GRP is observed in four oblasts of the Carpathian region. An upward trend in operating cost was outlined in Zakarpattia oblast in 2013–2014 and 2016–2017, while the weight significance of the indicator increased to 36.55 % and 38.76 %, respectively, in Lviv oblast in this period. The weights of the share of environmental protection operating cost in GRP were the lowest in Ivano-Frankivsk and Zakarpattia oblasts in 2019 and amounted to 16.21 % and 10.11 %, respectively. Remarkably, the significant growth of environmental protection and natural resources development expenditures in Ivano-Frankivsk oblast since 2016 is the positive aspect of financial resourcing of integrated nature management in the Carpathian region. It is worth emphasizing that the maintenance of integrated nature management depends on local budgets' expenditures on environmental protection and the development of the tourism and recreation industry.

Lviv oblast differs by powerful economic capacity and a higher level of urbanization from the other oblasts of the Carpathian region, which is reflected in the normative monetary evaluation of lands of different categories and the level of nature management integrity. The results of the analysis of the indicators' weight significance confirm it in the availability of land resources group. A share of built-up areas (38.79 % in 2019) and forest areas (27.06 %) had the highest weight significance in 2010–2019. The share of agricultural lands was most significant in Zakarpattia and Ivano-Frankivsk oblasts (29.67 % and 30.06 % in 2019).

The revenues from environmental taxes related to the rational use of natural resources and nature protection should be targeted to local budgets. It is quite necessary in terms of authorities' decentralization and local governance reform that stipulate the transfer of nature management regulation center to the level of territorial communities. It will boost the processes of natural resources capacity reproduction in the Carpathian region (Table 3). Namely, the weight significance of determinants of investment framework of the nature management group was growing by 0.2 % a year on average in all oblasts of the Carpathian region in 2010–2019.

The natural environment of social vulnerability in the Carpathian region in 2010–2019 substantially differs from the average national rate by the component of availability of water resources. In 2010, the highest coefficient value was in Ivano-Frankivsk oblast (0.398) and the lowest – in Zakarpattia oblast (0.156). Meanwhile, in 2019, the quality of life in terms of availability of water resources was the best in Ivano-Frankivsk and Chernivtsi oblasts (0.561 and 0.492, respectively) (Table 4). Significant growth of the group coefficient is observed in Chernivtsi and Ivano-Frankivsk oblasts – almost twofold.

Table 3

Average annual growth paces of weight coefficients of social vulnerability natural environment determinants in the Carpathian region, 2010–2019, %

Determinants	Ukraine	Chernivtsi	Lviv	Zakarpattia	Ivano-Frankivsk
Availability of water resources					
Water extraction from natural sources	0.073	0.039	-0.103	-0.073	-0.075
The use of fresh water	0.106	0.222	-0.030	-0.157	-0.045
The volume of circulating and reused water	0.084	0.089	0.205	0.206	0.061
General water disposal	0.031	0.173	0.006	0.086	-0.004
The discharge of contaminated return waters into the surface waters	-0.320	-0.651	0.025	-0.296	-0.051
Treatment facilities capacity	0.027	0.128	-0.103	0.233	0.114
Contamination of territories and air quality					
Emission of pollutants from stationary sources into the atmosphere	-0.148	-0.298	-0.809	0.117	-0.498
I-III hazard class waste generation	-0.322	0.839	0.726	0.056	0.146
IV hazard class waste generation	0.318	0.001	-0.670	-0.116	0.453
I-III hazard class waste treatment coefficient	-0.200	-0.234	1.719	-0.336	0.580
IV hazard class waste treatment coefficient	0.268	-0.276	-0.448	0.258	-0.417
Index of wastes accumulated during exploitation in the designated places or facilities	0.084	-0.033	-0.518	0.021	-0.264
Investment framework of nature management					
Capital investment in environmental protection	-0.036	-0.317	0.001	1.607	0.371
Operating cost of environmental protection	-0.036	0.139	-0.370	-1.778	-0.518
The share of operating cost of environmental protection in GRP	0.391	0.157	0.218	-1.752	-0.184
The share of capital investment in environmental protection in capital investment	-0.318	0.021	0.151	1.923	0.332
Availability of land resources					
The share of built-up areas	0.057	0.271	0.254	-0.487	-0.247
The share of agricultural land areas	0.022	-0.062	-0.060	0.199	0.107
The share of nature reserve fund areas	-0.086	-0.130	-0.081	0.120	0.082
Forests, forest-covered areas, and land under water areas	0.007	-0.079	-0.112	0.168	0.058

Source: calculated by the authors.

The group coefficients of environment of social vulnerability reflected the deteriorating situation in all oblasts of the Carpathian region by the availability of the land resources component. Since 2017, the coefficient has declined by 15 % in Lviv oblast and by 18 % in Zakarpattia oblast. Chernivtsi and Lviv oblasts had the lowest values of group coefficients in 2019 (0.475 and 0.498, respectively).

The received empirical estimations of natural environment of social vulnerability by the contamination of territories and air quality component demonstrated a substantial variability scope between the oblasts of the Carpathian region and Ukraine.

Table 4

The natural environment of social vulnerability in Ukraine and the Carpathian region: availability of water and land resources, 2010–2019

Oblasts	Years									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Availability of water resources										
Chernivtsi	0.239	0.496	0.525	0.543	0.494	0.535	0.517	0.517	0.316	0.492
Lviv	0.338	0.369	0.400	0.332	0.338	0.370	0.342	0.324	0.347	0.311
Zakarpattia	0.156	0.160	0.180	0.219	0.164	0.173	0.190	0.185	0.168	0.171
Ivano-Frankivsk	0.398	0.532	0.572	0.597	0.593	0.562	0.545	0.553	0.578	0.561
Ukraine	0.797	0.825	0.839	0.809	0.890	0.806	0.836	0.760	0.765	0.800
Availability of land resources										
Chernivtsi	0.461	0.581	0.615	0.577	0.576	0.575	0.575	0.479	0.474	0.475
Lviv	0.507	0.507	0.562	0.537	0.536	0.534	0.534	0.497	0.491	0.498
Zakarpattia	0.862	0.867	0.867	0.864	0.861	0.859	0.859	0.773	0.779	0.745
Ivano-Frankivsk	0.759	0.757	0.775	0.773	0.788	0.789	0.789	0.728	0.733	0.721
Ukraine	0.764	0.780	0.810	0.807	0.838	0.850	0.849	0.878	0.900	0.851

Source: calculated by the authors.

The worst situation with the contamination of territories and air quality in 2010 was observed in Lviv oblast (0.131), while Chernivtsi oblast had the highest values of the group coefficient (Table 5). In 2019, the situation did not change. The lowest coefficient value was in Lviv oblast (0.118) and the highest – in Chernivtsi (0.413).

Table 5

The natural environment of social vulnerability in Ukraine and the Carpathian region: contamination of territories and investment framework, 2010–2019

Oblasts	Years									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Contamination of territories, air quality										
Chernivtsi	0.357	0.310	0.265	0.272	0.306	0.383	0.330	0.329	0.435	0.413
Lviv	0.131	0.116	0.127	0.124	0.109	0.217	0.202	0.141	0.188	0.118
Zakarpattia	0.169	0.169	0.183	0.216	0.193	0.368	0.410	0.216	0.264	0.398
Ivano-Frankivsk	0.186	0.140	0.114	0.138	0.139	0.196	0.188	0.149	0.128	0.135
Ukraine	*0.463*	*0.485*	*0.472*	*0.459*	*0.460*	*0.417*	*0.496*	*0.480*	*0.467*	*0.406*
Investment framework of nature management										
Chernivtsi	0.117	0.196	0.081	0.051	0.079	0.237	0.136	0.213	0.172	0.235
Lviv	0.201	0.215	0.166	0.283	0.275	0.147	0.262	0.350	0.390	0.306
Zakarpattia	0.096	0.080	0.116	0.070	0.051	0.102	0.061	0.196	0.329	0.174
Ivano-Frankivsk	0.475	0.467	0.269	0.398	0.426	0.290	0.409	0.664	0.819	0.772
Ukraine	*0.703*	*0.824*	*0.895*	*0.814*	*0.759*	*0.641*	*0.648*	*0.608*	*0.590*	*0.755*

Source: compiled based on the authors' calculations.

The lowest values of investment framework of nature management group coefficients in 2010–2019 were in Zakarpattia oblast. They were extremely low in the crisis period (0.051–0.079). There was an upward trend in the dynamics of expenditures

on environmental protection and natural resources sector in Zakarpattia oblast, namely the group coefficient increased in 2017 compared to 2012. The expenditures of local budgets on capital investment increased in 2019 compared to 2010–2014. Natural resources framework of innovation-based and environmentally friendly development of regional economies fosters the creation of additional opportunities to frame favorable natural environment of social vulnerability in the region.

The significance of the components of natural environment of the social vulnerability has stable dynamics. Low value of weight coefficient in the availability of water resources group was observed only in 2019 in Zakarpattia oblast. The weight significance of this component for social vulnerability of the population in Ukraine was at 20–22 %. The weight coefficient of "Contamination of territories and air quality" group in 2010–2019 was the highest in Ukraine and in Chernivtsi oblast (Table 6). Investment framework of nature management played the most significant role in framing the social vulnerability environment in Zakarpattia (55.02 %) and Ivano-Frankivsk oblasts (37.16 %) in 2019. The weight significance of availability of land resources group was the highest in Chernivtsi oblast among other oblasts of the Carpathian region, amounting to 42.86 % in 2013 and 36.26 % in 2019.

Table 6

Weight significance coefficients of natural environment of social vulnerability components in the Carpathian region and Ukraine, 2010–2019, %

Compo-nents	Regions	Years									
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Availability of water resources	*Ukraine*	20.7	21.4	21.0	22.3	18.8	21.6	20.1	21.5	20.4	21.0
	Lviv	27.2	25.6	24.0	35.2	26.0	20.5	33.3	28.4	27.7	25.2
	Chernivtsi	13.6	8.4	8.4	10.9	17.5	18.1	10.7	14.9	21.3	20.4
	Zakarpattia	10.4	9.5	10.7	7.1	11.6	14.0	7.8	10.8	13.9	8.1
	Ivano-Frankivsk	13.4	9.8	9.7	15.0	13.9	12.5	15.2	14.2	13.5	13.5
Contamina-tion of territories and air quality	*Ukraine*	32.5	33.7	34.1	29.9	28.6	28.8	33.4	31.2	32.7	37.0
	Lviv	13.7	16.0	12.0	15.2	15.2	5.7	16.8	19.6	11.2	18.2
	Chernivtsi	28.8	42.3	21.9	23.3	29.9	33.1	25.4	31.6	32.2	28.6
	Zakarpattia	22.5	21.1	24.2	16.0	21.1	16.7	16.6	43.4	22.5	11.8
	Ivano-Frankivsk	14.2	18.5	13.7	13.7	14.6	8.9	16.4	19.4	17.5	13.1
Investment framework of nature management	*Ukraine*	31.5	28.8	29.8	32.0	37.8	35.3	31.2	31.7	32.1	26.0
	Lviv	34.5	33.1	42.7	21.8	34.6	53.4	21.9	25.7	33.8	36.5
	Chernivtsi	35.6	27.2	56.2	46.3	26.9	17.2	47.2	24.8	24.4	23.1
	Zakarpattia	36.8	41.0	29.7	51.4	41.9	26.1	50.7	11.5	26.8	55.0
	Ivano-Frankivsk	35.9	35.8	48.7	28.4	34.6	46.5	28.1	23.8	30.7	37.2
Availability of land resources	*Ukraine*	15.3	16.1	15.2	15.9	14.7	14.3	15.3	15.6	14.8	16.0
	Lviv	24.7	25.3	21.3	27.8	24.1	20.4	28.0	26.3	27.3	20.2
	Chernivtsi	21.9	22.2	13.5	19.4	25.7	31.6	16.7	28.7	22.2	27.9
	Zakarpattia	30.4	28.4	35.4	25.5	25.5	43.2	24.9	34.3	36.8	25.1
	Ivano-Frankivsk	36.5	35.9	27.9	42.9	37.0	32.2	40.3	42.6	38.3	36.3

Source: compiled based on the authors' calculations.

The integral coefficients of natural environment of social vulnerability calculated based on the theory of sensitivity allowed determining social vulnerability natural environment components in dynamics with maximum precision (Figure 1). The highest

values of integral coefficients of natural environment of social vulnerability in the Carpathian region of Ukraine in 2019 were observed in Ivano-Frankivsk (0.574) and Chernivtsi (0.391) oblasts. Ivano-Frankivsk oblast was the leader in that regard in the entire period under research. Yet, the oblasts of the Carpathian region are differentiated relative to the average rate in Ukraine.
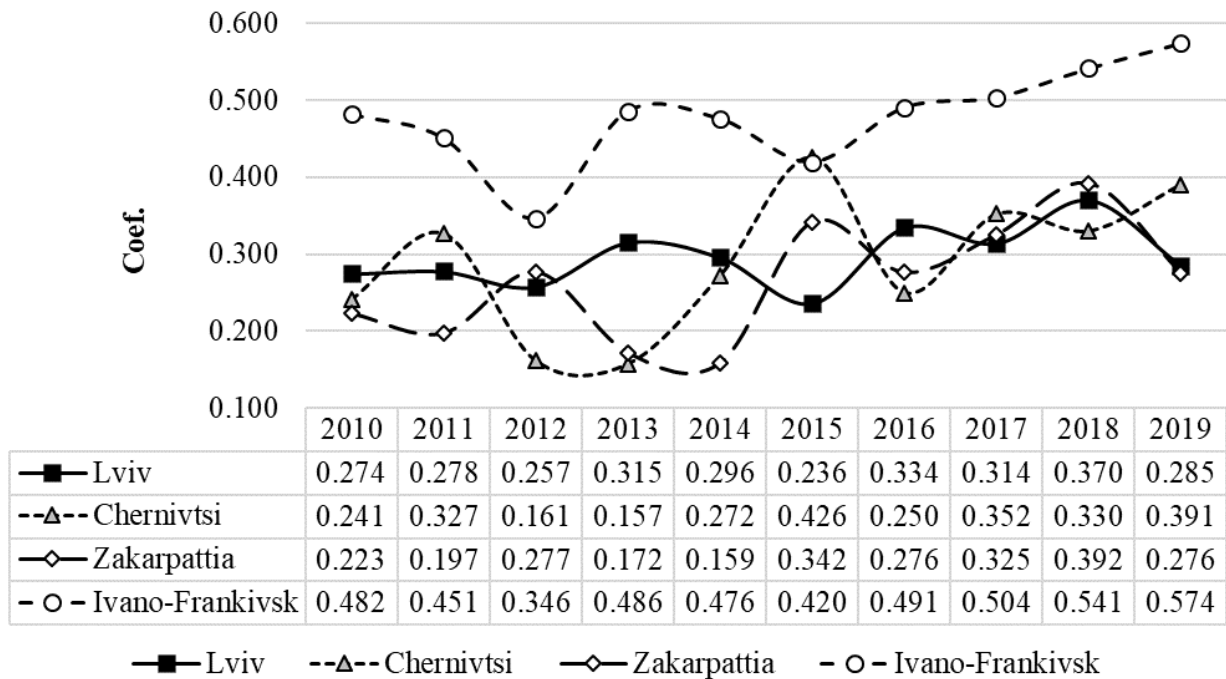

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
■ Lviv	0.274	0.278	0.257	0.315	0.296	0.236	0.334	0.314	0.370	0.285
△ Chernivtsi	0.241	0.327	0.161	0.157	0.272	0.426	0.250	0.352	0.330	0.391
◇ Zakarpattia	0.223	0.197	0.277	0.172	0.159	0.342	0.276	0.325	0.392	0.276
○ Ivano-Frankivsk	0.482	0.451	0.346	0.486	0.476	0.420	0.491	0.504	0.541	0.574

■ Lviv   △ Chernivtsi   ◇ Zakarpattia   ○ Ivano-Frankivsk

Figure 1. Integral coefficients of natural environment of social vulnerability in the Carpathian region, 2010–2019

Source: compiled based on the authors' calculations

The problem of diversification of sources to secure financial-investment framework for integrated nature management through introducing amendments to inter-budgetary relations in terms of the distribution of rent payment for the use of natural resources, land fee, and environmental tax is gaining special relevance for the Carpathian region as it stipulates the increase of the share of these payments in the budgets of local governments.

To substantiate applications for levelling environmental threats to the spread of social vulnerability of the population, it is advisable to forecast the empirical values of the natural environment of social vulnerability in the Carpathian region based on the creation of models according to the scenario approach. To construct a forecast for pessimistic and optimistic scenarios, the Polynomial function to the Third Power (Formula 2) and the Exponential function (Formula 3) were conducted, and for the tendentious scenario, the Power function (Formula 4) was used.

$$FC_p = -0.0009 * t^3 + 0.016 * t^2 - 0.071 * t + 0.372 ,$$ (2)

$$R^2 = 0.873$$

$$FC_O = 0.266 * e^{0.039*t} ,$$ (3)

$$R^2 = 0.706$$

$$FC_T = 0.270 * t^{0.131} ,$$ (4)

$$R^2 = 0.500$$

where FC_p, FC_T, FC_O are predictive values of the natural environment of social vulnerability in the Carpathian region according to pessimistic, tendentious and optimistic scenarios, respectively;

t is period.

With an active regional policy for reducing the social vulnerability due to the improvement of the natural environment, a significant effect can be obtained, as evidenced by forecast calculations of the levels of the environment according to the optimistic scenario (0.440 in 2022 compared to 0.381 in 2019). Instead, the lack of effective mechanisms for solving the problematic issues of the natural environment in the Carpathian region will lead to a deepening of the problem of social vulnerability in the territory (Figure 2). It is noteworthy that, according to the forecast model in 2023, it could be expected a decrease in the level of the natural environment of social vulnerability to a point of 0.138, which is 2.2 times less than in 2010.
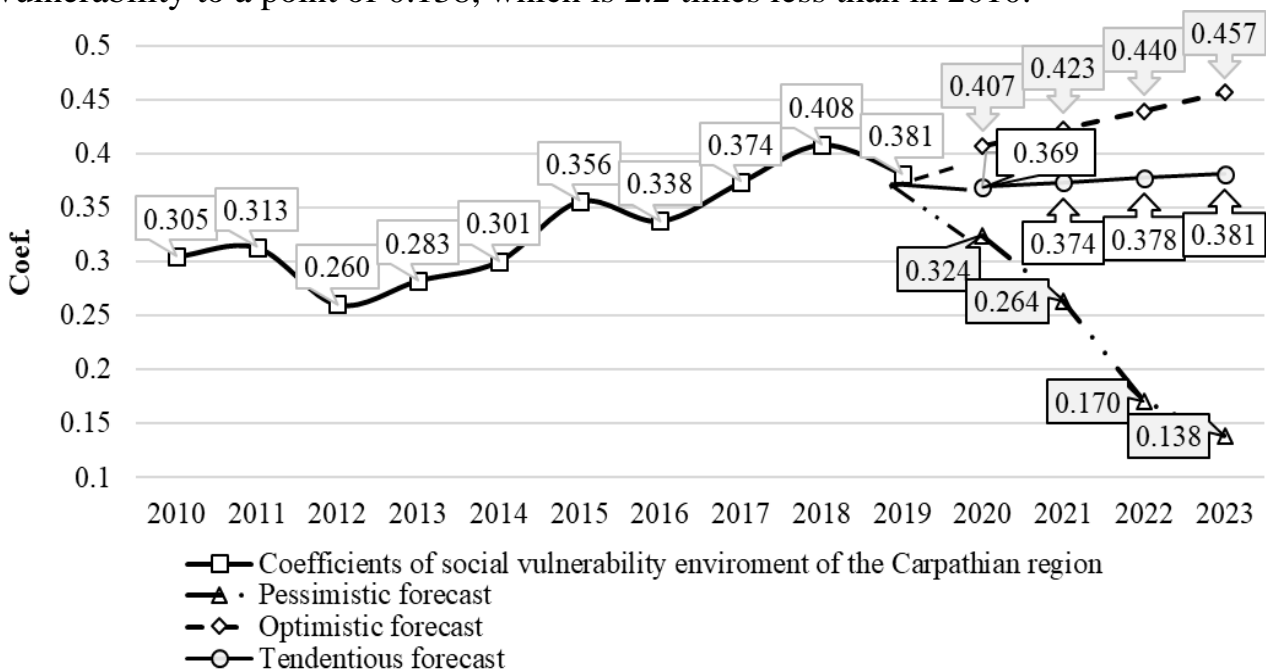
Figure 2. Forecast of the levels of the natural environment of social vulnerability in the Carpathian region of Ukraine by 2023: a scenario approach

Source: compiled based on the authors' calculations.

According to the results of empirical research on the natural environment in the Carpathian region of Ukraine, there are grounds for the following conclusions, regarding three vectors of regional policy for minimization of social vulnerability:

1. Troubleshooting critical problems. The task of this policy is to proactively resolve the expressed problematic aspects like factors of strengthening the social vulnerability of the territories that lead to exacerbation of the issue of social vulnerability due to the impact on public health from air pollution caused by emissions of industrial enterprises, as well as rivers and reservoirs, soils by solid waste landfills and spontaneous landfills, sewage, which actualizes the problem of high-quality drinking water.

According to this vector of regional policy, the objects of regulation are, first of

all, a critically high level of contamination of territories and low air quality (emissions of pollutants into the air from stationary sources in Ivano-Frankivsk oblast and especially carbon dioxide and methane in Lviv oblast, accumulation of waste of all hazard classes in these areas and especially low level of their disposal in Lviv oblast) and, secondly, low level of investment providing of nature management in Zakarpattia and Chernivtsi oblasts.

To implement the initiative-taking directions for regional policy, it is necessary to focus on using the following measures:

- rational consumption of freshwater, creation of water protection zones and coastal protective strips of water bodies, reconstruction of existing, and if necessary, creation of new systems of centralized water supply and drain, modernization of existing and arrangement of new water treatment facilities and sewerage networks;

- strengthening control over compliance with legislation and standards of industrial emissions by business entities and increasing liability for violation of environmental legislation;

- modernization of treatment plants of industrial enterprises in the oblasts in general and directly the main air pollutants like enterprises for the production and distribution of energy, gas and water, mining industry; transition to the use of renewable energy sources to gradually replace traditional resource-intensive and environmentally polluting energy production;

- implementation of the projects for the initiation and distribution of separate collection systems, sorting of household waste and packaging containers, recycling, and processing of industrial and household waste, increasing the level of an ecological culture of the local population (which is particularly important for mountainous and rural areas).

2. Aligning disparities. The task of this policy is to improve the natural environment of social vulnerability of the population in the oblasts of the Carpathian region of Ukraine, which increases the differentiation in the standards and quality of life, as well as the social vulnerability of the population and some territories due to the deterioration of the quality of flora and fauna, natural and recreational resources and zones, neglect of territories, loss of resting places, etc.

According to this vector of regional policy, the objects of regulation are, firstly, the deterioration of the availability of water resources (low level of water intake from natural water bodies and the consumption of freshwater, significant volumes of discharge of contaminated return waters into the surface waters and a lower level of provision of drain) in Lviv and Zakarpattia oblasts and, secondly, a poor land fund (large volumes, including illegal deforestation and forest plantations, a greater share of contaminated land and a smaller share of the lands of the nature reserve fund) in Lviv and Chernivtsi oblasts.

To improve the situation in these aspects, the regional authorities should direct their efforts to:

- reforming the environmental control system in terms of expanding the powers of state environmental inspections and the possibilities of the public control system,

improving the efficiency of their response to offences, expanding the range of persons who can initiate inspection and control measures, increasing in fines for deforestation and pollution of water bodies, as well as obstructing the work of inspectors, simplifying procedures for proving to law enforcement agencies the facts of environmental violations and crimes;

- protection and restoration of forests, parks and other green spaces, as well as small rivers and lakes;

- creation of unified state digital systems and platforms for accounting of objects (resources) of land and water funds;

- strengthening the protection of sanitary zones around known fields and the introduction of rational extraction of medicinal waters, the prohibition of their overtime pumping, which leads to pollution and depletion of sources.

3. Realization of benefits. The task of this policy is to use the potential and natural resource capabilities of the region to minimize natural threats to social vulnerability of the population.

According to this vector of regional policy, the object of regulation is a more rational, economical, and effective use of the natural environment, including the forest fund of Zakarpattia, Ivano-Frankivsk, Lviv oblasts, water resources of Ivano-Frankivsk, Chernivtsi and Zakarpattia ones, clean air and territories of Chernivtsi and Zakarpattia ones, effectivization of the costs of nature management and environmental protection in the region. The full realization of the potential will contribute to improving the quality of life, and consequently weakening the social vulnerability of the population and territories. The strategic priorities of regional policy should be smart space development, increasing the role of sectors of the green economy, compliance with the principles of security of consumption and social responsibility, the formation of clean and safe living space, and the key measures are:

- transition to smart space development of cities and territories with specialization in smart infrastructure technologies, smart waste management and environmental protection, smart technologies in transport, preservation and efficient use of alternative energy for the sake of full maintenance of all utility subsystems;

- stimulating the development of a green economy (green energy, agriculture, industry, transport ecology, sustainable tourism and waste management) to preserve the natural ecosystem, and biological diversity and minimize the risks of intensive, often irrational, use of natural resources, anthropogenic impact on the environment, development of private environmentally friendly and socially responsible business;

- stimulating the construction, production and purchase of smart, environmentally friendly, safe housing with autonomous resource support and maximum energy efficiency;

- introduction of a competitive electricity market, implementation of Smart Grid pilot projects containing operational and energy-saving measures, including smart meters, smart consumers, renewable energy sources and energy efficiency resources;

- development of smart systems for ensuring public safety in a person's living space through financial and budget support for developing local projects of digital

security technologies, such as smart street lighting, facial and license plate scanning technologies, emergency and acoustic sensors for identifying emergency and/or dangerous situations, fixing and informing about them, etc.

The improvement of natural resources and efficient use of economic capacity is among the major preconditions for improving the natural environment of social vulnerability in the Carpathian region in structural economic deformations. The problem of diversification of sources to secure a financial-investment framework for nature management is especially important. A broad range of forms and types of public-private partnerships should be institutionalized to increase the attraction of private investment to the projects in ecologization and environmental protection, especially by public and municipal entities, and secure the combination of investment capacity of private businesses and organizations and property resources of the state and local governments. The Carpathian region as a border area should be an active participant in implementing cross-border projects in the socio-ecological domain funded by the EU.

Conclusions. The main parameters of the natural environment in the oblasts of the Carpathian region, in general, correspond to average national rates, while having certain specifics shown in comparatively smaller amounts of freshwater consumption, lower level of general water disposal, high level of air pollution (especially in Ivano-Frankivsk and Lviv oblasts), problems with the I–II hazard class waste treatment (namely environmentally friendly storage and treatment of refinery waste), accumulation of low-risk waste and low level of its treatment, poor investment in environmental protection, high social vulnerability and limited access of the population (including mountain, old industrial, remote areas) to social infrastructure facilities, growing external migration activity, low official income and expenditures of the population, resulting in the deterioration of the life quality of in the region.

The calculation of natural environment of social vulnerability coefficients shows significant ecological differentiation between the oblasts of the region and Ukraine. The time series of integral indices constructed based on the theory of sensitivity (dynamic weight significance parameters) contributed to determining the levels of natural environment of social vulnerability in the region from 2010 to 2019. Ivano-Frankivsk oblast had the highest integral coefficients of the natural environment of the quality of life in the entire period under research.

The proposed methodological approach to assessing the natural environment of social vulnerability in the oblasts of the Carpathian region has some methodological vacuum, in particular, concerning (1) the generation of information and analytical basis for research based on the principles of validity, comparatives and universality; (2) restrictions on the division of indicators into stimulators and destimulators (for example, the indicator 'Share of agricultural land area' can simultaneously be considered as a stimulant of the deterioration of the natural situation in the region, which leads to the spread of social vulnerability of the population, and a destimulator, in which an increase in the share of agricultural land contributes to the growth of the country's food security and minimization of the consequences of social vulnerability

of the territory).

Scenario modeling of the level of social vulnerability of the population in the Carpathian region under socio-economic and other shocks, as well as reducing the quality of life as the key determinant of environmental and social sustainability may be the direction of further research.

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