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Geoecological monitoring of regional land use: definition and directions of formation

Andrii Bieliatynskyi[1*], *Kateryna* Sorokina[2], *Kostiantyn* Mamonov[3], and *Lyudmyla* Kovalenko[4]

[1]North Minzu University, School of Civil Engineering, Department of Road and Bridge, 204 Wenchang Road, Yinchuan, NingXia, 750021 P.R. China
[2]O. M. Beketov National University of Urban Economy in Kharkiv, Department of Water Supply, Sewage and Treatment Engineering, 17 Bazhanova str., 61002 Kharkiv, Ukraine
[3]O. M. Beketov National University of Urban Economy in Kharkiv, Department of Land Administration and Geoinformation Systems, 17 Bazhanova str., 61002 Kharkiv, Ukraine
[4]O. M. Beketov National University of Urban Economy in Kharkiv, Department of Higher

Abstract. It has been proven that modern trends in land formation and use require a rethinking of approaches to the development and implementation of monitoring tools, taking into account the ecological features of regional development. The need and relevance of solving issues related to the formation and use of geoecological monitoring of land use at the regional level has been established. The purpose of the study is to determine the directions and features of the formation and implementation of geoecological monitoring of land use in the regions. To achieve the goal, the following tasks are solved: systematization of theoretical provisions regarding the definition of geoecological monitoring of land use at the regional level; substantiation of the integral method of assessment of the formation and implementation of geoecological monitoring of land use; formation of the quantitative basis of geoecological monitoring. As a result of the study, a theoretical platform was developed for the definition of geoecological monitoring of land use, which is based on a systemic approach that includes interrelated stages and is formed on the basis of a quantitative basis for the construction of monitoring GIS maps in the context of informed decision-making. To form a quantitative basis for geoecological monitoring, the use of an integral method is proposed, which includes a set of interconnected elements that determine environmental and land use factors, which made it possible to improve the monitoring system and provide modeling of the presented factors to establish cause-and-effect relationships.

1 Introduction

Modern trends in the formation and use of land require a rethinking of approaches to the development and implementation of monitoring tools, taking into account the ecological features of regional development. In such conditions, the issue of creating information

* Corresponding author: beljatynskij@ukr.net

support for the implementation of geoecological monitoring of land use, balancing the parameters of its formation at the regional level is problematic.

At the same time, it is necessary to single out the factors of the formation and use of geoecological monitoring of land use and the possibilities of countermeasures, in particular, negative phenomena: degradation of natural ecosystems, loss of biodiversity, anthropogenic load on the natural environment, erosion, pollution, moistening and waterlogging of soils, chaotic land development of settlements, reduction of valuable characteristics.

At the legislative level, the need to apply ecological directions in the system of land relations is defined. Thus, in the Constitution of Ukraine, the Land and Civil Codes, the Law of Ukraine "On Environmental Protection", laws and other normative legal acts regulating the directions of the formation and use of land resources, the parameters and identified features of nature use, effective use of land, taking into account ecological aspects state and regional development. In international practices of land use, environmental directions and programs for ensuring environmental safety are of great importance, which are presented in the system of regulatory and legal support: the Stockholm Declaration, Agenda for the 21st century, the program "Man and the Biosphere", the European Strategy for the Protection of Nature, the European Network of Ecologically Vulnerable territories (EECONET), the Environment for Europe Programme, the Environmental Program for Europe, the Rio Declaration on Environment and Development, the Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Matters Concerning environment, All-European strategy for preservation of biological and landscape diversity, etc.

Along with this, the issues of theoretical substantiation regarding the definition of geospatial monitoring of land use, assessment of the level of its development and application, directions of its implementation at the regional level remain unresolved. Therefore, the research topic is relevant, and its development is timely.

2 Analysis of theoretical provisions

In the existing scientific developments, there are no unified approaches to the definition of geoecological monitoring of land use at the regional level. In particular, the Rio de Janeiro Declaration on the Environment and Development defines the directions for the development of territories with ecological aspects and features of the interaction of environmental factors [1].

In order to determine the geoecological monitoring of land use, a normative and legal framework has been formed, which is related to the ecological features of land use [2-5].

In some scientific developments, geoecological monitoring is considered through the prism of comprehensive observation of anthropogenic and natural sources of influence, the state of the environment, the dynamics of changes occurring in it are analyzed according to the forecast of the development of situations [6]. The areas of geoecological monitoring are determined:

- observation of environmental impact factors;
- forecast of the state of the biosphere;
- assessment of changes in this state [7].

The isolation of geoecological monitoring in the system of monitoring procedures is presented in the work of I. P. Gerasimov [8]. The characteristics of environmental monitoring from the standpoint of the levels of its use are defined in the work of E. Yu. Hnatchenko [9]. A systematic approach to determining environmental monitoring is implemented through a set of directions for its implementation:

- constructive and ecological assessment of territories;
- assessment of main components and implementation of spatial analysis of territories;

- application of methods and modern tools for carrying out analytical work on environmental monitoring;
- complex geoecological assessment of environmental components based on ecological-technogeochemical and component maps;
- development of nature protection measures.

The implementation factors of the system approach are based on the relevant principles of monitoring procedures:

- complexity – covers all components of the environment (atmospheric air, underground and surface waters, landscapes, soils, subsoil);
- intensity – characterized by the aggressiveness of the impact;
- regulation - provides for the definition of operations in accordance with the technological plan;
- spatio-temporal dimension – relevant spatial characteristics are taken into account, the changes of which are carried out over time;
- permanent analysis and control of the level of territory use and ecological condition [10].

As part of the system approach to determining the geoecological monitoring of land use, an algorithm for the formation of a geoecological atlas has been developed, which includes:

- editorial and preparatory work;
- formalization of letters of thematic maps;
- creating retrospective object layers;
- determination of deviations and changes in constructed object layers;
- formation of attributive layers of retroaspect layers;
- creation of object layers of the geoecological state and dynamics of nature use;
- geoecological mapping and modeling of the geoecological state;
- visualization of atlas mapping [11].

Representatives of the system approach define geoecological monitoring of land use from the standpoint of forming and applying a complex of actions, modern tools based on quantitative assessment for the implementation of monitoring procedures, taking into account the peculiarities of land relations [12-16].

The functional approach to the definition of geoecological monitoring is implemented through the prism of appropriate actions:

- study of natural features and anthropogenic changes of territories;
- identification of priority observation objects;
- selection of criteria for assessing the geoecological condition;
- definition of data collection methods;
- collection of data on the state of the natural environment and factors affecting it;
- processing of received data;
- analysis of information and interpretation of the obtained results;
- forecasting likely changes in the natural environment.

Modern systems and tools are important in the focus of the functional approach:

- geoinformation;
- Meteosat;
- NOAA/AVHRR; ORACLE [17];
- TNT-MIPS;
- ARC/INFO;
- SPRANS;
- GRADIS, PROSYS, EVCLID, KONSYS;
- WinGIS.

In the context of determining the geoecological monitoring of land use, directions and features of the formation and implementation of environmental monitoring procedures are of particular importance.

The importance of information support for geoecological monitoring of land use is indicated in the development by V. M. Bogolyubov and M. O. Klymenko [18]. At the same time, all the negative trends occurring in the development of the complex system "man - nature - society" increase the relevance of both ecological and socio-economic monitoring. Natural changes in the state of the environment are determined by geophysical services (hydrometeorological, seismic, gravimetric, etc.). To determine anthropogenic changes in the natural environment, special observations of changes in the state of the biosphere under the influence of human activity are organized [8]. In this context, developments where monitoring is formed on the basis of information and cadastral support, which is aimed at ensuring the efficiency of land use, deserve attention.

When defining geoecological monitoring, the main focus is on spatial provision and relevant factors [19].

Sokhnych A.Ya., Horlachuk V.V., Smirnov E.I., [20] focus on the tools of formation and implementation of geoecological monitoring of land use. Characterizing the features of geoecological monitoring of land use, international experience deserves attention (Table 1).

Table 1. International experience of geoecological monitoring of land use

Country	Characteristics of international experience
USA	carried out through a system of tools that are implemented by the Natural Resources Protection Service through a system of powers: detection of violations of established mandatory soil protection restrictions; appointment of fines and other sanctions; confiscation of land property or its forced sale [8].
France	state control of land plots is carried out to consolidate lands and preserve their intended use [8].
Germany	geoecological monitoring is related to directions and tools of environmental protection [11].
Italy	monitoring procedures are carried out, focusing attention on the features of the monitoring object, functional aspects of its implementation [8].
Japan	determined by the use of modern tools for monitoring through the prism of territorial zoning [11].

Geoecological monitoring is determined on the basis of the directions and features of observing land resources.

Dividing the provisions of the system approach, the definition of geoecological monitoring of land use is proposed as a system of directions for the development and implementation of monitoring procedures aimed at assessing and observing ecological and land use factors for the formation of a quantitative basis for decision-making regarding the increase in the efficiency of land use.

3 The purpose and objectives of the research

The purpose of the study is to determine the directions and features of the formation and implementation of geoecological monitoring of land use in the regions.

To achieve the goal, the following tasks are solved:

- systematization of theoretical provisions regarding the definition of geoecological monitoring of land use at the regional level;

- substantiation of the integral method of assessment of the formation and implementation of geoecological monitoring of land use;
- formation of the quantitative basis of geoecological monitoring.

4 Main part

For the formation and use of geoecological land monitoring, directions and features of land relations are of particular importance. In the structure of the lands of Ukraine, the largest specific weight is agricultural land, the structure of which includes (as of January 1, 2016): agricultural land - 68.8%; fallows - 0.4%; perennial plantations - 1.5%; haymakers - 4%; pastures - 9%; other agricultural land - 2%. The second place in the structure of land is occupied by forests and other wooded areas, which consist of: covered with forest vegetation - 16.1%; not covered by forest vegetation - 0.4%; other forest lands - 0.5%; shrubs - 0.7% [21].

In the structure of land, a significant specific weight is occupied by built-up land, which includes: under residential construction - 0.8%; industrial land - 0.4%; land under open development, quarries, mines and related structures - 0.3%; land for commercial and other use - 0.1%; public land - 0.499%; land of mixed use - 0.001%; land used for transport and communication - 0.8%; land used for technical infrastructure - 0.1%; land used for recreation and other open land - 1.2. Other lands occupy an insignificant specific weight in the structure of the land fund. It should be noted that land occupies 96%, surface water – 4% [21].

Thus, the presented structure testifies to the significant importance of agricultural land. In addition, the focus of attention is on built-up lands. In this context, monitoring procedures for the formation of a quantitative basis for land use are implemented on the basis of appropriate information-analytical, spatial and regulatory support.

For the formation and use of geoecological monitoring of land use, an analysis of the ecological state is carried out. The dynamics of waste generation and management for 1995-2020 is presented in the table. 2.

Table 2. Dynamics of waste generation and management for 1995-2020, thousand tons [21]

Years	Volume of generated waste	Volume of disposed waste	Volume of incinerated waste	The amount of waste removed to specially designated places and objects	The total amount of waste accumulated during operation in specially designated places and facilities
1995	3562,9	1915,7	-	1232,3	54841,0
1996	3150,9	1570,6	-	1262,9	46014,0
1997	3161,4	1794,9	-	1392,7	71551,2
1998	2454,1	1660,2	-	668,9	34337,5
1999	2820,4	1138,2	-	885,4	37098,9
2000	2613,2	1376,2	-	760,6	26244,1
2001	2543,3	2292,0	-	640,0	23002,0
2002	1728,8	1701,2	-	726,9	18728,5

2003	2436,8	1184,2	-	931,7	31304,0
2004	2420,3	840,1	-	1102,8	28349,0
2005	2411,8	863,4	71,4	948,5	21674,0
2006	2370,9	847,9	62,1	1057,0	20121,5
2007	2585,2	1031,2	39,6	990,6	20131,8
2008	2301,2	918,9	32,2	1066,3	21017,2
2009	1230,3	825,9	15,8	333,2	20852,3
2010	422549,9	144866,6	1056,8	311649,0	13219983,9
2011	443795,5	153368,2	1039,2	251352,0[3]	14372055,1
2012	446716,9	143110,3	1201,1	263562,6	14856638,5
2013	445262,1	146733,1	917,9	264665,6	15111636,2
2014	355000,4	109280,1	944,7	203698,0	12205388,8
2015	312267,6	92463,7	1134,7	152295,0	12505915,8
2016	295870,1	84630,3	1106,1	157379,3	12393923,1
2017	366054	100056,3	1064,3	169801,6	12442168,6
2018	352333,9	103658,1	1028,6	169523,8	12972428,5
2019	441516,5	108024,1	1059,0	238997,2	15398649,4
2020	462373,5	100524,6	1008,0	275985,3	15635259,6
Base index (2020/1995), relative unit	129,8	52,5	-	224,0	285,1

As a result of the analysis, an increase in the volume of generated waste was determined, the dynamics of which exceeds the level of disposed waste. This contributes to the growth of their level over the studied period, which reduces the level of environmental safety. There is an increase in the volume of household waste by 22%. Moreover, the dynamics of the volume of collected household waste exceeds the volume of collected, which indicates their accumulation. During the studied period, there is a decrease in the volume of emissions of pollutants and carbon dioxide into the atmospheric air (Table 3).

Table 3. Dynamics of emissions of pollutants and carbon dioxide into atmospheric air [21]

Years	Volumes of pollutant emissions			In addition, carbon dioxide emissions		
	total, thousand tons	including		total, million tons	including	
		fixed sources	mobile sources		fixed sources	mobile sources
1990	15549,4	9439,1	6110,3	-	-	59,9

1991	14315,4	8774,6	5540,8	-	-	45,5
1992	12269,7	8632,9	3636,8	-	-	37,2
1993	10015,0	7308,3	2706,7	-	-	23,8
1994	8347,4	6201,4	2146,0	-	-	21,1
1995	7483,5	5687,0	1796,5	-	-	20,3
1996	6342,3	4763,8	1578,5	-	-	20,8
1997	5966,2	4533,2	1433,0	-	-	18,3
1998	6040,8	4156,3	1884,5	-	-	15,5
1999	5853,4	4106,4	1747,0	-	-	17,0
2000	5908,6	3959,4	1949,2	-	-	15,4
2001	6049,5	4054,8	1994,7	-	-	17,2
2002	6101,9	4075,0	2026,9	-	-	19,6
2003	6191,3	4087,8	2103,5	-	-	20,7
2004	6325,9	4151,9	2174,0	148,8	126,9	21,9
2005	6615,6	4464,1	2151,5	173,6	152,0	21,6
2006	7027,6	4822,2	2205,4	201,9	178,8	23,1
2007	7380,0	4813,3	2566,7	213,3	184,0	29,3
2008	7210,3	4524,9	2685,4	204,3	174,2	30,1
2009	6442,9	3928,1	2514,8	180,3	152,8	27,5
2010	6678,0	4131,6	2546,4	193,2	165,0	28,2
2011	6877,3	4374,6	2502,7	229,9	202,2	27,7
2012	6821,1	4335,3	2485,8	226,6	198,2	28,4
2013	6719,8	4295,1	2424,7	225,8	197,6	28,2
2014	5346,2	3350,0	1996,2	193,0	166,9	26,1
2015	4521,3	2857,4	1663,9	161,2	138,9	22,3
2016	4686,6	3078,1	1608,5	173,9	150,6	23,3
2017	4230,6	2584,9	1645,7	148,2	124,2	24,0
2018	4121,2	2508,3	1612,9	150,5	126,4	24,1
2019	4108,3	2459,5	1648,8	147,2	121,3	25,9
2020	3675,3	2238,6	1436,7	131,9	109,1	22,8
2021	3788,8	2242,0	1546,8	-	111,8	-
Base index	0,24	0,24	0,25	-	-	-

The dynamics of emissions of pollutants into the atmosphere from mobile sources of pollution per person is presented in the table. 4.

Table 4. Dynamics of pollutant emissions into atmospheric air from mobile sources of pollution per person, kg [21]

Name of emissions	**The number of pollutant emissions per person, kg**						**Base index (2021 / 2016)**
	2016 p.	2017 p.	2018 p.	2019 p.	2020 p.	2021 p.	
That's all	37,7	38,7	38,2	39,2	34,4	37,4	0,99
sulfur dioxide	0,4	0,4	0,4	0,5	0,4	0,5	1,25
carbon monoxide	28,8	29,6	29,1	29,9	26,0	28,1	0,98
nitrogen dioxide	3,8	4,0	4,0	4,3	3,9	4,2	1,11
nitrous oxide	0,02	0,02	0,02	-	-	-	-
non-methane volatile organic compounds	4,0	4,0	3,9	3,9	3,4	3,8	0,95
ammonia	0,0002	0,0002	0,0002	-	-	-	-
methane	0,1	0,1	0,1	0,1	0,1	0,1	1
soot	0,5	0,6	0,6	0,6	0,6	0,6	1,2

The values of the presented indicator indicate its slight reduction by 1% over the studied period, which occurred due to the decrease in the volumes of carbon monoxide and non-methane volatile organic compounds. Sulfur and nitrogen dioxide inhibited this process. The dynamics of the volume of capital investments by types of environmental protection measures is presented in the table. 5.

Table 5. Dynamics of capital investment volumes by types of environmental protection measures, thousand hryvnias [21]

Years	**Total**	**Including on**				
		atmospheric air protection and climate change problems	**return water treatment**	**waste management**	**protection and rehabilitation of soil, underground and surface waters**	**other measures**

2006	2194188,5	762538,6	777924,5	339529,6	247695,4	66500,4
2007	3080687,6	1379250,6	809677,1	388386,6	393036,8	110336,5
2008	3731400,4	1476343,3	927352,9	422918,6	787303,8	117481,8
2009	3040732,7	1273789,4	882525,4	400016,9	401425,6	82975,4
2010	2761472,1	1139946,7	734663,4	475584,3	319922,0	91355,7
2011	6451034,6	2535632,6	721325,5	1183880,2	639123,1	1371073,2
2012	6589336,5	2462675,3	846955,4	730544,4	540516,8	2008644,6
2013	6038783,0	2411935,1	834114,8	713856,3	324980,1	1753896,7
2014	7959853,9	1915129,7	1122149,3	783965,4	359925,6	3778683,9
2015	7675597,0	1422946,6	848881,2	737498,9	388259,2	4278011,1
2016	13390477,3	2502805,8	1160029,1	2208676,6	419988,9	7098976,9
2017	11025535,2	2608027,4	1276530,2	2470969,5	1284502,0	3385506,1
2018	10074279,3	3505920,6	1692640,7	1182045,8	1444291,6	2249380,6
2019	16255671,8	4276767,6	1753869,1	5754260,9	1721924,9	2748849,3
2020	13239649,8	5595319,4	1578201,4	2899793,4	2554224,5	612111,1
Base index	6,03	7,34	2,03	8,54	10,31	9,2

During the studied period, there is an increase in the amount of capital investments by types of environmental protection measures. The volume of current costs for environmental protection by types of environmental protection measures is also increasing (Table 6). This is due to the growth of emissions and the need to respond to changes in the natural environment.

Table 6. Dynamics of the volume of current expenses by types of environmental protection measures, thousand hryvnias [21]

Years	Total	Including on				
		atmospheric air protection and climate change problems	return water treatment	waste manageme nt	atmospheri c air protection and climate change problems	other measure s
2000	2618375,0	350417,2	1715327,0	279210,6	66875,5	206544,7
2001	2903747,3	305105,2	1821837,3	327440,3	94106,9	355257,6
2002	3080131,5	416233,1	1941388,8	402946,5	83336,5	236226,6
2003	3361979,5	444661,5	2096224,5	477102,8	90681,6	253309,1

2004	4152245,6	606533,0	2349931,4	746664,8	111747,5	337368,9
2005	5313588,0	877357,8	2910905,3	925475,1	121704,4	478145,4
2006	5172413,1	826738,2	2598067,5	1330203,0	152942,8	264461,6
2007	6610318,0	1141918,4	3095147,2	1768850,0	222396,5	382005,9
2008	8444589,9	1349982,6	3989769,1	2315223,4	287331,4	502283,4
2009	8032734,5	1035156,0	4306516,3	1928302,3	240239,1	522520,8
2010	10366565,5	1314797,0	5035453,3	2599623,3	476253,5	940438,4
2011	12039439,5	1475396,9	5388363,2	3865909,7	592730,4	717039,3
2012	13924654,3	1341527,8	6195109,8	4756182,1	743467,1	888367,5
2013	14339060,4	1415795,5	6175917,3	4844304,8	923236,0	979806,8
2014	13965726,0	1238636,7	5611561,4	5416975,6	964737,0	733815,3
2015	16915535,2	1519827,8	6644284,7	6801931,2	1152701,9	796789,6
2016	19098224,8	1760613,4	7800088,3	6719577,7	1197194,3	1620751,1
2017	20466423,3	2104274,3	8065252,4	7508213,7	983781,8	1804901,1
2018	24317991,0	2897672,0	9623474,4	8830203,5	1288375,0	1678266,1
2019	27480190,3	2963889,1	10872744,2	10227144,3	1583926,5	1832486,2
2020	28092551,9	2375792,8	10746809,8	11197148,1	1577030,8	2195770,4
Base index	10,73	6,78	6,27	40,1	23,58	10,63

The development and implementation of geoecological monitoring of the use of the lands of the OTG is influenced by indicators of energy consumption and energy intensity (tables 7 - 8).

Table 7. Final energy consumption by spheres of activity for 2013 - 2020 [21]

№	Field of activity	Units of measurement	2013	2014	2015	2016	2017	2018	2019	2020	Base index (2020/2013)
1	Total final energy consumption	thousand tons AD	69557	61460	50831	51649	49911	51408	49665	47773	0,69
2	Industry	thousand tons AD	21864	20570	16409	14955	15098	16487	16122	15956	0,73
3	In % to the total	%	31,4	33,5	32,5	29,0	30,2	32,1	32,5	33,4	1,06

4	Transport	thousand tons AD	11280	10327	8750	9165	9624	9453	10026	8012	0,71
5	in % to the total	%	16,2	16,8	17,2	17,7	19,3	18,4	20,2	16,8	1,04
6	Household	thousand tons AD	23495	20384	16554	17588	16487	16201	14007	13601	0,58
7	gifts	%	33,8	33,2	32,6	34,1	33,0	31,5	28,2	28,5	0,84
8	in % to the total	thousand tons AD	5745	4663	3838	4856	4337	4742	4831	4863	0,85
9	Sector	%	8,3	7,6	7,6	9,4	8,7	9,2	9,7	10,2	1,23
10	services	thousand tons AD	2242	2016	1961	2143	1847	1880	1882	1662	0,74
11	in % to the total	%	3,2	3,3	3,9	4,1	3,7	3,7	3,8	3,5	1,09
12	Agriculture, forest and fishing economy	thousand tons AD	-	-	-	31	-	-	-	-	-
13	in % to the total	%	-	-	-	0,1	-	-	-	-	-
14	Other activities	thousand tons AD	4932	3500	3318	2910	2515	2645	2796	3679	0,75
15	in % to the total	%	7,1	5,7	6,5	5,6	5,0	5,1	5,6	7,7	1,08

It should be noted the decrease in final energy consumption as a whole, which is provided by the reduction of this consumption in industry, transport, households, the service sector, agriculture, forestry and fisheries, and non-energy use of energy. The largest specific weight of energy consumption occurs in industry and households.

Table 8. Energy consumption based on renewable sources by sphere of activity for 2013-2020 [21]

№	**Areas of activity**	**Units of measurement**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Base index (2020 / 2013)**

1	General supply of primary energy	thousand tons AD	115940	105683	90090	94383	89462	93526	89359	86363	0,74
2	Hydropower	thousand tons AD	1187	729	464	660	769	897	560	650	0,55
3	in % to the end	%	1,0	0,7	0,5	0,7	0,9	1,0	0,6	0,8	0,8
4	Biofuel energy and waste	thousand tons AD	1875	1934	2102	2832	2989	3209	3349	4243	2,26
5	in % to the end	%	1,6	1,8	2,3	3,0	3,3	3,4	3,8	4,9	3,06
6	Wind and solar energy	thousand tons AD	104	134	134	124	149	197	426	794	7,63
7	in % to the end	%	0,1	0,1	0,1	0,1	0,2	0,2	0,5	0,9	9,0
8	Total energy supply from renewable sources	thousand tons AD	3166	2797	2700	3616	3907	4303	4335	5687	1,8
9	Share of energy supply from renewable sources	%	2,7	2,6	3,0	3,8	4,4	4,6	4,9	6,6	2,44

Total energy supply is declining due to reduced hydropower, along with increased energy from biofuels and waste, wind and solar energy.

For the formation and implementation of geoecological monitoring of land use at the regional level, a quantitative basis was developed by applying the integral method in the following stages:

- formation of information-analytical and spatial provision of land use, taking into account ecological features at the regional level;
- development of a multi-level system of factors of formation and use of geoecological monitoring of land use;
- determination of local factors of the formation and use of geoecological monitoring of land use at the regional level using the method of expert assessments and the analytical method;
- assessment of rank coefficients characterizing intragroup influence of environmental and land use indicators;

- evaluation of system factors of formation and use of geoecological monitoring of land use;
- determination of weighting factors based on the application of the hierarchy analysis method;
- construction of an integral evaluation model of the generalizing indicator of the formation and use of geoecological monitoring of land use at the regional level;
- evaluation of the integral factor of formation and use of geoecological monitoring of land use at the regional level;

interpretation of the obtained results. The scheme of application of the integral method of assessment of the formation and use of geoecological monitoring of land use at the regional level is presented in fig. 1.

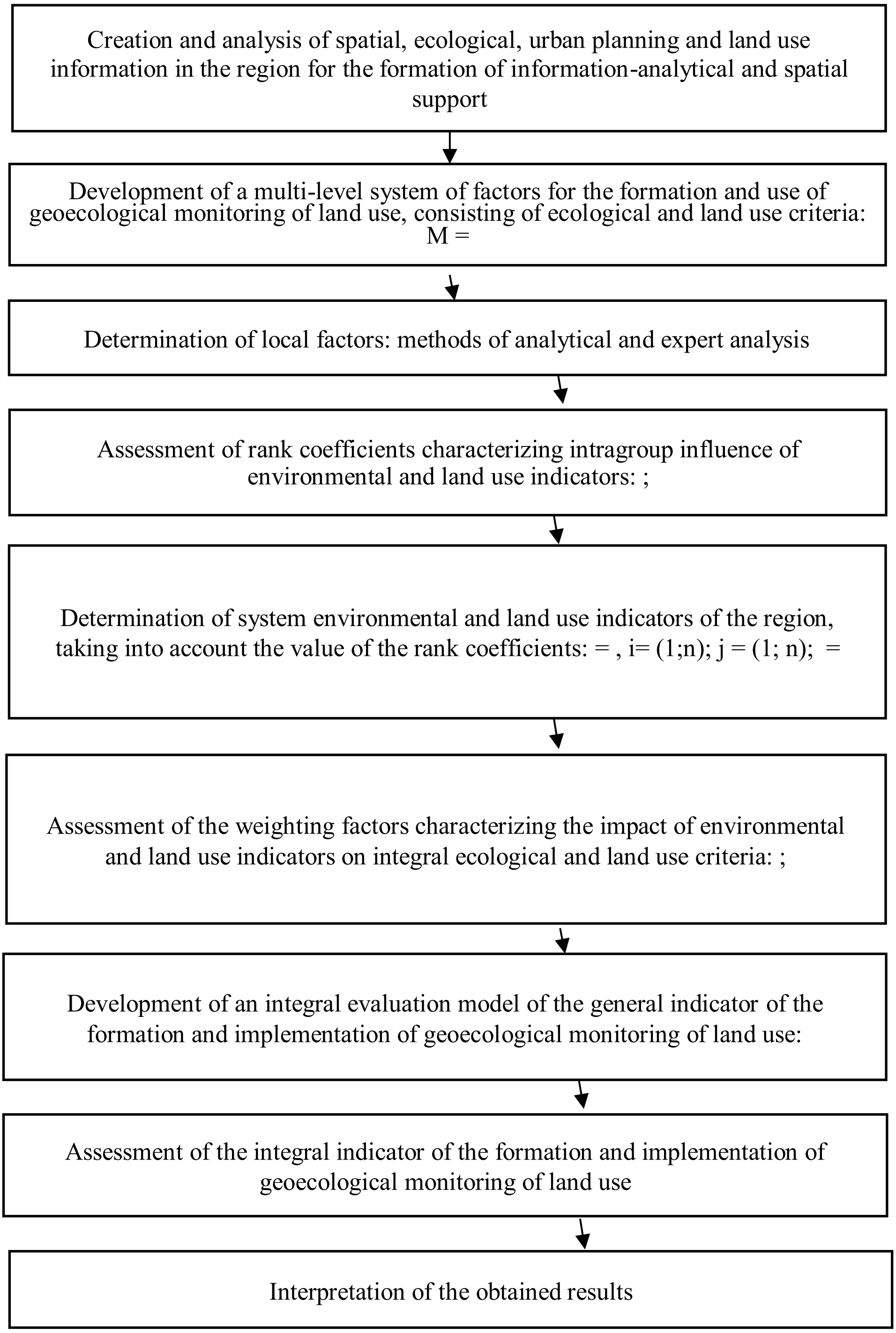

Fig. 1. Scheme of development and implementation of an integral method of assessment of the formation and application of geoecological monitoring of land use at the regional level

The developed scheme of formation and use of the method of assessing the level of geoecological monitoring of land use is determined by generalizing ecological and land use factors. In this context, it should be noted that generalizing environmental factors at the regional level are characterized by the state and directions of environmental protection, the level of formation and waste disposal, the level of formation and use of capital investments for the implementation of environmental measures, the level of completeness and opportunities the use of regulatory and legal support in the environmental sphere, the level of application of modern systems and technologies for the development of geoecological monitoring.

The generalizing factors of land use at the regional level are determined by functional indicators, the level of application of regulatory and legal support in the field of land relations, the level of information and spatial support, the level of technical and technological support of land relations.

Based on the values of the generalizing environmental and land use factors of the regions, an assessment of the relevant integral indicators was carried out (Fig. 2 - 3).

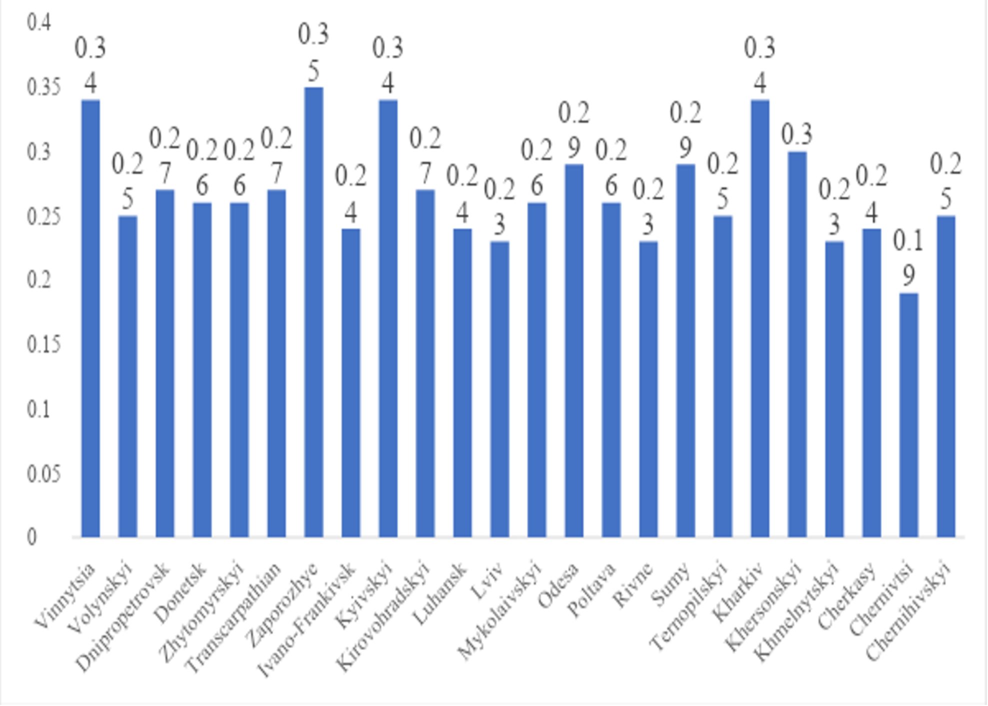

Fig. 2. Integral ecological indicator in the system of assessing the level of formation and use of geoecological monitoring of land use in regions, resp. unit

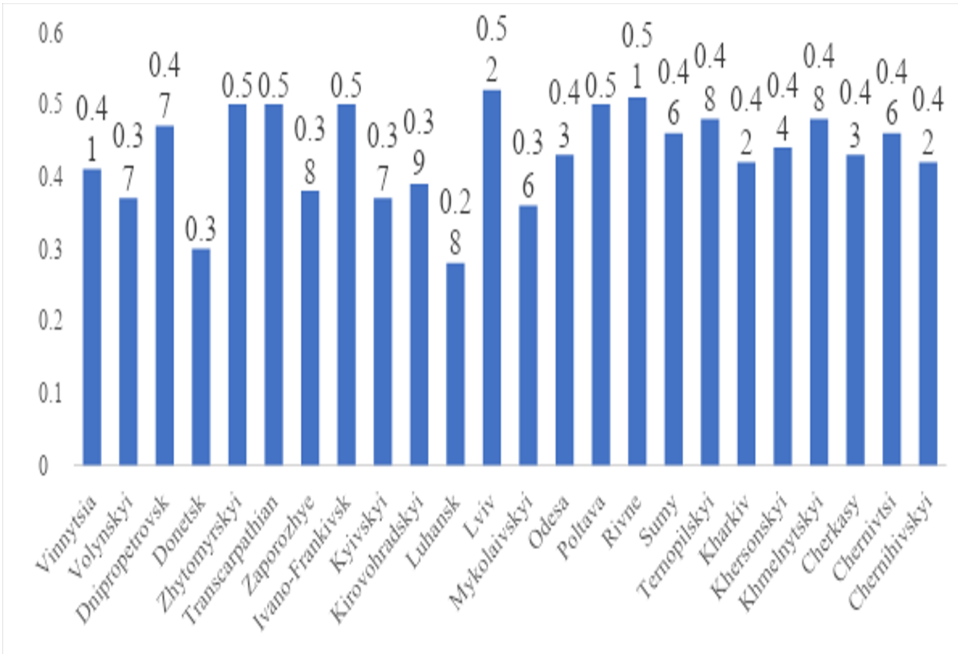

Fig. 3. Integral indicator of land use in the system of assessing the level of formation and use of geoecological monitoring of land use in regions, resp. unit

Taking into account the values of the presented integral indicators and weighting coefficients, an assessment of the integral factor of formation and use of geoecological monitoring of land use in the regions was carried out (Table 9).

Table 9. The results of the assessment of the integral indicator of the formation and application of geoecological monitoring of land use at the regional level, resp. unit

Regions	Value
Vinnytsia	0,75
Volynskyi	0,62
Dnipropetrovsk	0,74
Donetsk	0,56
Zhytomyrskyi	0,76
Transcarpathian	0,77
Zaporozhye	0,73
Ivano-Frankivsk	0,74
Kyivskyi	0,71
Kirovohradskyi	0,66
Luhansk	0,52
Lviv	0,75
Mykolaivskyi	0,62
Odesa	0,72
Poltava	0,76
Rivne	0,74
Sumy	0,75
Ternopilskyi	0,73
Kharkiv	0,76

Khersonskyi	0,74
Khmelnytskyi	0,71
Cherkasy	0,67
Chernivtsi	0,65
Chernihivskyi	0,67

As a result of the evaluation of the integral indicator, it was determined that the level of formation and implementation of geoecological monitoring of land use at the regional level is high or average due to the increase in the value of the ecological component while slowing down the efficiency of land use. The obtained values of the integral indicator at the regional level make it possible to build monitoring GIS maps as an element of geoecological monitoring for making informed decisions.

5 Conclusions and proposal

Thus, a theoretical platform has been developed for the definition of geoecological monitoring of land use, which is based on a systemic approach that includes interrelated stages and is formed on the basis of a quantitative basis for the construction of monitoring GIS maps in the context of informed decision-making.

To form a quantitative basis for geoecological monitoring, the use of an integral method is proposed, which includes a set of interconnected elements that determine environmental and land use factors, which made it possible to improve the monitoring system and provide modeling of the presented factors to establish cause-and-effect relationships.

References

1. O. H. Bilashenko, Vyznachennia heoekolohichnoho stanu tekhnohenno-navantazhenykh terytorii za kompleksom heofizychnykh danykh: avtoref. dys. d-ra heoloh. nauk: 04.00.22, Derzhavnyi Vyshchyi navchalnyi zaklad "Natsionalnyi hirnychyi universytet", 176
2. Pro zatverdzhennia Polozhennia pro derzhavnu systemu monitorynhu dovkillia Ukrainy. Postanova Kabinetu ministriv Ukrainy vid 30 bereznia, 391 (1998) zakon3.rada.gov.ua/laws/show/391-98-p (Last accessed 12.06.2023)
3. Pro zatverdzhennia Polozhennia pro monitorynh gruntiv na zemliakh silskohospodarskoho pryznachennia. Nakaz ministerstva ahrarnoi polityky vid 26.02.2004, 51 zakon5.rada.gov.ua/laws/show/z0383-04 (Last accessed 12.06.2023)
4. Pro zatverdzhennia polozhennia pro monitorynh zemel. Postanova Kabinetu ministriv Ukrainy vid 20.08.1993, 661 zakon2.rada.gov.ua/laws/show/661-93-p (Last accessed 12.06.2023)
5. Pro zatverdzhennia Poriadku zdiisnennia derzhavnoho monitorynhu vod» vid 20.07.1996, 815 search.ligazakon.ua/l_doc2.nsf/link1/KP960815.html (Last accessed 12.06.2023)
6. O. M. Krainiukov, A. N. Nekos, Monitorynh dovkillia (Monitorynh naftohazonosnykh terytorii): pidruch. dlia stud. vyshch. navch. zakl. Kharkiv: Folio, **203**, 11 – 12 (2015)
7. M. O. Hrek, Metody i modeli otsinky vplyvu mistobudivnykh faktoriv na vykorystannya zemel′ mist. Komunal′ne hospodarstvo mist. Ser. Tekhnichni nauky ta arkhitektura. Kharkiv, **137**, 9–12 (2017)

8. I. P. Herasymov, Ekolohichni problemy u mynuliy, teperishniy ta maybutniy heohrafiyi svitu, Moscow, Nauka, 247 (1985)
9. Ye. Yu. Hnatchenko, Konspekt lektsii z dystsypliny «Miskyi monitorynh» (dlia studentiv 6 kursu dennoi formy navchannia osvitno-kvalifikatsiinoho rivnia spetsialist, mahistr spetsialnosti 7.06010202, 8.06010202 «Mistobuduvannia»). Khark. nats. un-t misk. hosp-va im. O. M. Beketova. Kh.: KhNUMH, 63 (2013)
10. P. I. Kopach, N. V. Horobets, T. T. Danko, L. V. Bondarenko, Osnovni polozhennia metodolohii stvorennia systemy monitorynhu navkolyshnoho seredovyshcha hirnychodobuvnykh rehioniv. Ekolohiia i pryrodokorystuvannia, 12, 181 – 187 (2009)
11. A. Kovalchuk, I. Kovalchuk, Heoekolohichnyi atlas richkovo-baseinovoi systemy Bystrytsi: kroky zi stvorennia, otrymani rezultaty. geography.lnu.edu.ua/wp-content/uploads/2017/01/08-Kovalchuk.pdf (Last accessed 17.06.2023)
12. K. Mamonov, Methodological approach to the integral assessment of the regional lands use territorial development. Geodesy and Cartography. **45(3)**, 110–115 (2019)
13. K. Mamonov, A. Palamar, R. Viatkin, I. Kondratyuk, *Geoinformation support for monitoring the land of the ecological network of regions*. GeoTerrace, Eage: 7 – 9 December 2020, Lviv (2020)
14. K. Mamonov, W. Mingming, L. Chang, D. Jun, *Measurement of Coordinated and Coupled Development and Evaluation of Sustainable Development for Marine Economic-Ecological Complex System*. Hindawi Discrete Dynamics in Nature and Society, **2043635**, 12 (2021) https://doi.org/10.1155/2021/2043635
15. K. Mamonov, S. Nesterenko, Y. Radzinskaya, O. Dolia, City lands investment attractiveness calculation. Geodesy and Cartography, **68(1)**, 211–223 (2019)
16. K. Mamonov, S. Nesterenko, Y. Radzinskaya, The method for assessing the urban land investment attractiveness. Geodesy and Cartography, **68(2)**, 321–327 (2019) (Last accessed 17.06.2023)
17. http://kadastrua.ru/gis-tekh№logii/230-geoekologicheskij-monitoring.html (Last accessed 17.06.2023)
18. V. M. Boholiubov, M. O. Klymenko, V. B. Mokin, ta in. Monitorynh dovkillia: pidruchnyk. Vinnytsia: VNTU, 232 (2010)
19. L. D. Hrekov, H. Ya. Krasovskyў, O. M. Trofymchuk, Kosmichnyў monitorynh zabrudnennia zemel tekhnohennym pylom, 123 (Naukova dumka, 2007)
20. A. Ya. Sokhnych, V. V. Horlachuk, Ye. I. Smirnov, O. A. Sokhnych, Monitorynh zemel: tekhnolohichni zasady. Lviv: Ukr. tekhnolohiï, 116 (2005)
21. Ofitsiinyi sait Derzhheokadastru. http://land.gov.ua (Last accessed 17.06.2023)