European Journal of Geography Volume 10, Number 1:99-116, March 2019
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DEVELOPING AN ENVIRONMENTAL MONITORING PROGRAM BASED ON THE PRINCIPLES OF DIDACTIC REDUCTION

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Abstract

Environmental monitoring combines a large number of topics and interdisciplinary relations, which leads to a mandatory reduction of the learning content. This article presents the application of mathematical methods for the didactic reduction of the whole program and single topics of the environmental monitoring course. These methods include the selection of monitoring objects and partial components and indicators. Entropy, constructing regression models, clustering and application of graph theory are carried out. This article gives examples of applying the didactic reduction method in the monitoring of Ukrainian regions. The method can be interpolated to any geographic object. Implementation of this method leads to a flexible reduction of the learning time and better performance of future professional duties. It provides the development of theoretical skills in analysis and synthesis, determining essence from a large data set and the degree of influence of factors.

Keywords: *environmental monitoring, learning, teaching, didactic reduction*

1. INTRODUCTION

Teaching and learning methods of different courses acquire new forms, methods and tools under the development of information technologies. Therefore, a transformation of the learning content takes place.

The environmental monitoring program covers a large number of topics that students need to learn. They should be informed of the methods for implementing a variety of monitoring programs, as well as understand the economic efficiency and legal background for the implementation of various activities in this area. Students have to acquire this knowledge within the course which is not always achievable in a limited amount of study time. In more detail, according to Directive 2011/92/EU, the environmental impact assessment shall identify, describe and evaluate human beings, fauna and flora; soil, water, air, climate and the landscape; material assets and the cultural heritage and the interaction among the named factors. Additionaly, the course program includes a series of interdisciplinary links among geography, sustainable development, ecology, metrology, economics and law.

The key feature of the environmental monitoring course is that this area of knowledge determines numerical parameters of an environment. On the one hand, this presupposes working with complex formulas, programming, etc., on the other, numerical data is easier to reduce. The aforementioned complexity of planning and taking measurements, processing the results, and planning appropriate steps can be simplified through the reduction of quantitative variables.

2. BACKGROUND

In the area of geography teaching and learning, different approaches are used. In the process of teaching glocal issues with geographical principles "... due to their complexity as a result of the didactic reduction these issues are often taught too simple in geography classes…" (Fögele, 2016). Instead, the scientist proposed to improve cumulative learning. Glocal issues are characterized by qualitative variables or information units that are a part of the sustainability quadrangle, inquiry on different scale levels, subjectivity and values, intergenerational perspectives etc.

Their structuring can be considered as a classic example of didactic reduction (Hering, 1958). According to the classification of methods of didactic reduction (Grüner, 1967), such structuring reflects the horizontal nature of the reduction, which does not lead to a direct decrease in the amount of information.

In the continuation of this idea, it has been reviewed that well-prepared material through quantitative and qualitative reduction is a good path in geography teaching (Maier & Budke, 2016). In order to implement this, it is necessary to avoid the distortion of the subject material.

Environmental monitoring in a greater extent is characterized by availability of information units with quantitative variables. These variables are a part of the methods and tools of measurement and evaluation, processing of results, and calculation of the economic effect of the implementation of activities. All these aspects can cause difficulties for students and can only be considered fragmentarily by them, which is likely to negatively affect achievement of learning goals. Restructuring of the material should be a subject for specific justification.

The methods of didactic reduction specially developed for measurement sciences are well-known. Environmental monitoring mostly belongs to such sciences. These methods of didactic reduction may include consideration of knowledge in the projection of the model "system" with "signals" (Ruhm, 2011), which serves to represent a qualitative and / or a quantitative type of knowledge. Also, it is possible to implement aspects of semantic modeling in the teaching of environmental monitoring (Shmatkov, 2016) which may also be a means for representing a qualitative and / or a quantitative type of knowledge.

Both methods in between the vertical (content amount reduction) and the horizontal (content quality reduction) nature of didactic reduction. Their application requires significant additional teachers` and students` training. Scientists point out the importance of using the methods of didactic reduction in the process of teaching the measurement sciences at all levels of education (Mesch, 1994; Ruhm, 2011; Shmatkov, 2016), which is difficult to disagree with in regard to the complexity of these courses.

We need to represent any learning content in such a way that content mastering could provide the development of key competencies that could be provided by didactic reduction (Knecht, 2007). In this context, phenomena of cognitive complexity of learning, for instance, reified into the fact that professionals reduce their knowledge to a degree that is sufficient and necessary to perform specific professional tasks in the shortest amount of time (Lehner, 2012). Additionally, the use of didactic reduction in the process of teaching environmental monitoring can provide students with the ability to identify factors that have the greatest impact on the monitoring indicator, quickly identify the main focus of attention from the reams of data and affect the aspects that are now in need of such influence.

Taking into account the limited time experts have to work with the service product, a vertical reduction in the form of reflection of essentials is proposed as a high priority when developing the web-atlas (Preuschmann et al., 2017). Although the method depicted here is simple for the content developer (lecturer), its implementation is mediated by the specific task – developing the web-atlas.

In the present article we aim to develop a vertical didactic reduction method for the environmental monitoring program, which will set priorities within each module and enable their study in accordance with the degree of their influence on the overall scope. Within the course, we want to propose a quantitative transformation of such qualitative variables as “sufficient”, “important” and “necessary”.

3. METHOD

3.1 General description

During the development of the method, we relied on the fact that the reduced content of the environmental monitoring teaching should be subordinate to specific criteria, namely, the importance of substance for students, practical significance, exemplary value, structuralism and accessibility (Kaulbach, 2018).

A five steps method to reduce the learning content of the environmental monitoring course is proposed. The method based on a theoretical analysis of literature, the studying and generalization of the experience of developing didactic reduction methods and using methods of mathematical statistics and graph theory, which has been carried out. It covers matters of the utmost importance of the environmental monitoring course.

At the first step, a sample of monitoring objects and a set of partial indicators of the environmental assessment are formed; the components of an environment are determined.

At the second step, assessment of the components of the environment is made by calculating the integral indicators for each component, taking into account entropy of the environment.

At the third step, partial indicators, which have the greatest influence on the variations of integral indicators, for each component of the environment are determined. It is implemented through the construction of regression models.

At the fourth step, clustering of monitoring objects is conducted, cluster characteristics are formed and their typical representatives are determined; graph theory is used.

At the fifth step, the conclusions are formulated and the vertical reduction of the environment monitoring environment teaching is implemented.

3.2 The theoretical basis of the method

Monitoring objects can be any country, region, city or other territories that have distinct features of their environment. To the set of partial indicators of the environment monitoring assessment, the following requirements are put forward:

- to be available for measurement or be displayed in statistical sources;
- to assess the processes in statics and dynamics;
- to be informative – to characterize the maximum number of components of an environment;
- to have no multicollinear relations.

Partial indicators may have different units of measurement, to eliminate this problem, a standardization algorithm can be used. When substantiating the structure of the components of environment, it is necessary to consider it as an ecological system. Therefore, the components that affect the quality of human life must be included in the overall assessment of the environment. The calculation of the integral indicators of the assessment for each component must take into account its entropy: the scale of chaos and disorder of elements (attributes) of this system. Since an environment is a complex ecological system, the following factors influence its condition and development:

- manufacturing, transport, housing and communal services through the generation of emissions into the atmosphere, various classes of dangerous waste, etc.;
- agricultural activity – through deforestation, fertilization in soil, etc.;
- natural factors – through natural fires in forests, reducing the salinity of sea water.

These factors operate integrally. In addition, within the ecological system there are interconnections among elements which are in disorder. Using the entropy method, the integral value of the object in general is not a simple arithmetic sum of its features. It is the following integrated sum (Vasylev et al., 2004):

$$R(S_i) = \sum_{j=1}^{n} H_j b_{ij}, \quad i = \overline{1, m}, \tag{1}$$

$R\ (S_i)$– integral value of the object S_i;
H_j – the entropy of j-th feature;
b_{ij} – quantitative assessment of j-th feature of i object;
m – number of objects;
n – number of features.

For the purpose of this study, the steps presented in Fig. 1 for the calculation of the integral indicators for assessing components of an environment were proposed.

This approach presupposes fact that the greater the entropy of any partial indicator, which describes a certain attribute through any component of an environment, the more disordered the environmental system is in general. If the entropy of the feature expressed through a partial indicator is insignificant, then its importance in the general set of features is negligible. Thus, the integral value of the assessment of each component of an environment is always greater than the sum of its inputs due to the identification of the increase of the system qualities or of the integral effect of functioning of ordered and disordered elements.

To find such an increase, we need to make the following transformations: determine the numerical value of the entropy of each feature and determine the numerical integral value of each system object.

It is seen in Fig. 1 that the vector w_{ij}^k takes into account the entropy of each standardized partial indicator at the k-th level, as stipulated by the method, which is represented by formula (1). The calculation of the vector w_{ij}^k takes into account both the importance of each feature of the system and the range of distribution (disorder) of features and in this way classical approaches (Wilson, 2013) to the evaluation of the entropy of systems are simplified.

To determine the level of influence of partial indicators on the variations of the integral indicators of the environment assessment, it is suggested to construct regression models for each component using the following formula:

$$y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \dots \beta_n x_n, \quad (2)$$

α – the free coefficient, which shows the influence of external factors that are not included in the model;

$\beta_1, \beta_2, \beta_n$ – coefficients reflecting the influence of partial indicators on the variations of the integral indicator of the environment assessment;

y – dependent variable (the integral indicator of the environment assessment);

x_1, x_2, x_n – independent variables (partial indicators of the of the environment assessment).

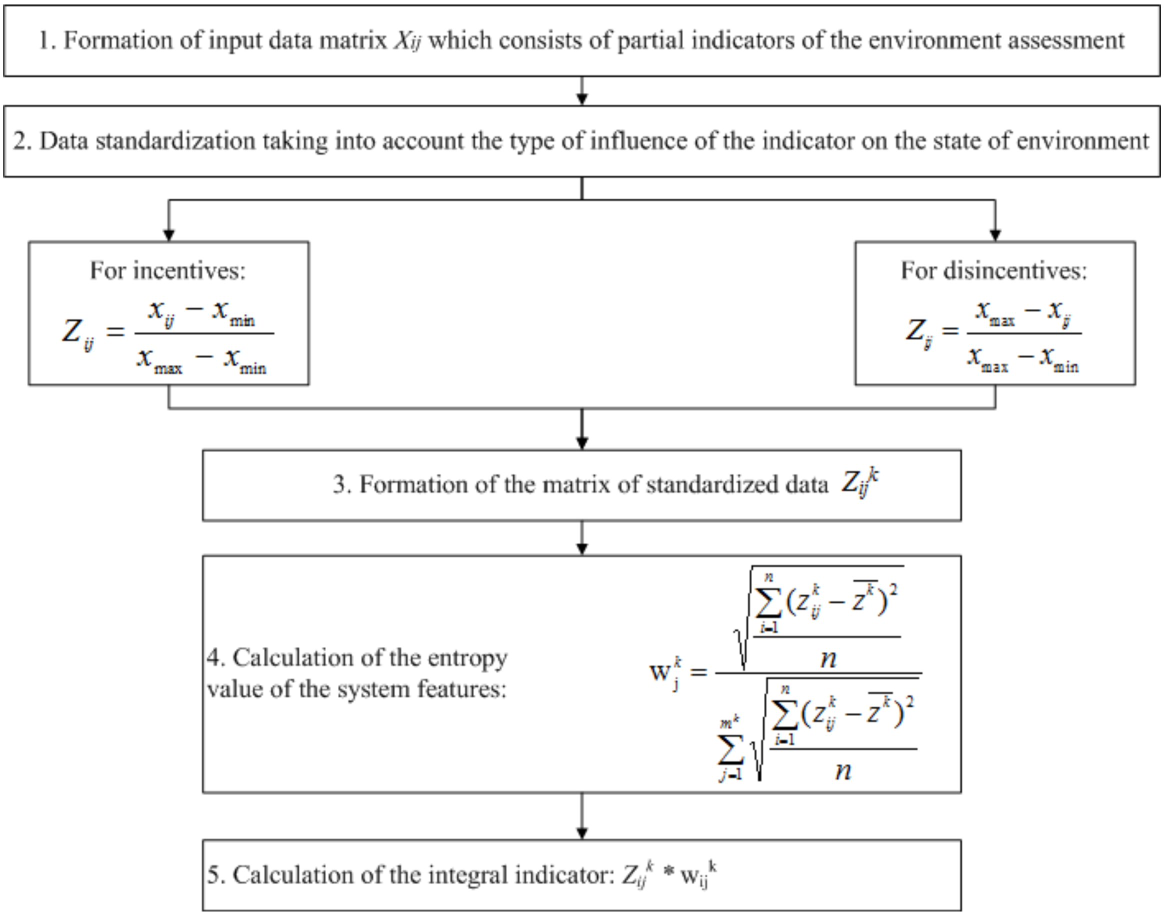

Figure 1. The algorithm for calculating integral indicator of the environment assessment for each component: incentives – partial indicators the growth of which improves the state of an environment; disincentives – partial indicators, the growth of which worsens the state of an environment.

The k-means clustering is proposed for grouping monitoring objects. This method provides significant elimination of the subjective approach in interpreting the findings.

As a typical cluster representative, it is proposed to choose one or more objects that have the smallest Euclidean distance from the center of the cluster.

4. RESULTS

This section describes in details the implementation of the method in accordance with the developed structure: monitoring objects sampling; assessment of the components of the environment; regression models construction; monitoring objects clustering and implementation of graph theory; formulating conclusions and implementing a vertical reduction. It is necessary to take into account that conclusions can be reached and the content reduction can be applied at every step of the method implementation, to a certain extent.

4.1 Monitoring objects sampling

In order to reflect the specifics of the method implementation in the presented article, Ukraine and its regions which have different characteristics of the environment associated with different natural and climatic conditions, industrial development, state policy of conservation of the environment, etc. are defined and a set of partial indicators (n = 56) is formed. The indicators that are widespread among the methods of environmental monitoring are included to this set.

In the study, the main documents that determine the indicators of the environmental monitoring have been analyzed. As mentioned above, according to Directive 2011/92/EU it is stipulated to monitor the four groups of indicators. The Environmental Performance Index (EPI) ranks 180 countries with 24 performance indicators across ten issues categories covering environmental health and ecosystem vitality. This index has the following categories: Air Quality, Water & Sanitation, Heavy Metals, Biodiversity & Habitat, Forests, Fisheries, Climate & Energy, Air Pollution, Water Resources, Agriculture.

Within each category, the partial indicators of the environmental assessment are studied. For example, the chapter Forests uses the tree cover loss indicator. The chapter Air Pollution uses sulfur oxides (SOX) and nitrogen oxides (NOX) indicators. The indicators in Water Resources include wastewater treatment. The chapter Agriculture uses sustainable nitrogen management index as a gauge of efficiency, this indicator uses nitrogen use efficiency and crop yield to measure the environmental performance of agricultural production.

Within the specificity of the implementation of the developed method, the list of the partial indicators of the index can be combined within the categories, for example, Air Quality and Air Pollution; Water & Sanitation and Water Resources. In addition, some components according to the sources of information may not be considered within the content of school and / or university education.

In the presented study, in order to reflect the specifics of the implementation of the developed method, several such indicators are widely used, which are widespread in the methods of environmental monitoring.

These indicators can be classified into the following groups (components):

- the atmosphere indicator characterized by the level of air pollution by different types and sources of pollution;
- water resources characterized by the level of pollution, purification and use of water resources;

- soil characterized by the application of various types of fertilizers and use of pesticides;
- wastes characterized by generation of wastes and handling of them;
- costs characterized by the level of financing for measures and actions to improve the condition of the habitat;
- forest recourses characterized by the condition of forest resources and their restoration.

This list is not exclusive. The teacher and students can implement the developed method in any other group of indicators of the environment in order to provide quantitative variables.

The indicators of the "Costs" group are presented in monetary units and cannot be fully measured by measurement tools. In spite of this, the inclusion of this component into the content of the environmental monitoring course is justified by the effect of costs on the environmental measures in particular and the quality of habitat in general.

Under the condition of an effective state policy towards financing environmental protection, the correlation coefficient between the integral indicators, which characterize these areas, should be high and have positive value.

Under the condition of an ineffective state policy towards financing environmental protection, the correlation coefficient between the integral indicators, which characterize these areas, should be high and have negative value as exemplified by Ukraine (Fig. 2).

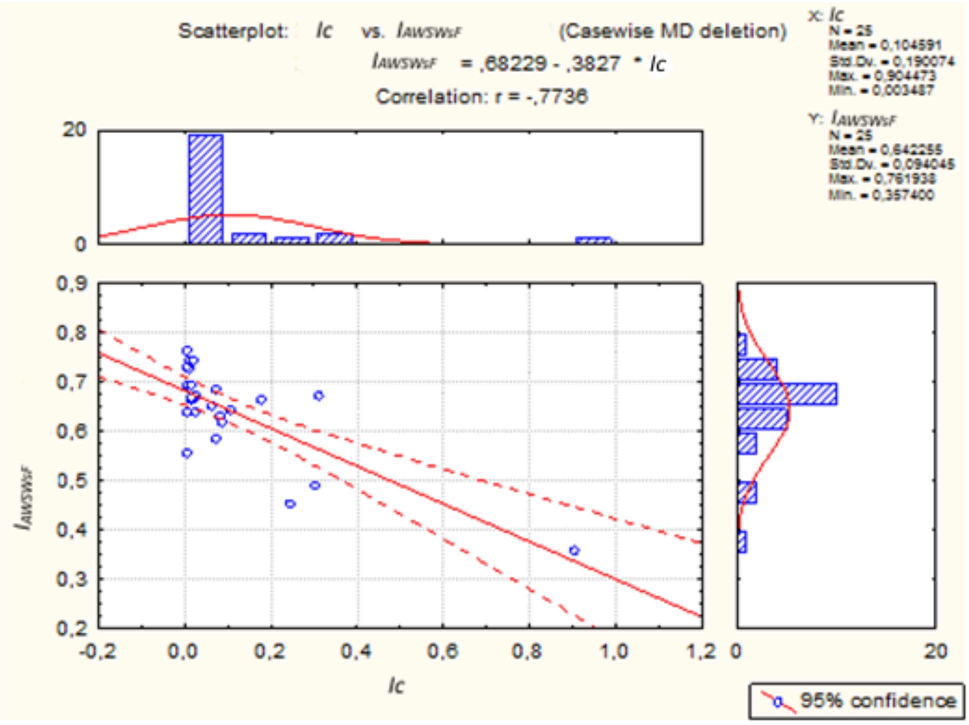

Figure 2. Scatter plot of the correlation between the integral indicator of the assessment of the component "Costs" and the integral indicator of the assessment of the quality of the habitat.

Cost-benefit analysis is one of the central topics of environmental monitoring in general (Glasson & Therivel, 2013) and of the environmental monitoring education in particular (Silva Villanueva, 2011). This allows us to achieve the following goals in the learning process:

- improving the understanding of the relations among elements of a habitat and understand the need for managerial action to improve environment condions;
- planning measures and other actions to protect an environment, taking into account their economic efficiency;
- determining the correlation between the environmental expenditures of the state and business entities;
- determining the direction of environmental policy.

4.2 Assessment of the components of the environment

On the basis of the first step, as an example of the method implementation, the environment was assessed according to the scheme (Fig. 3).

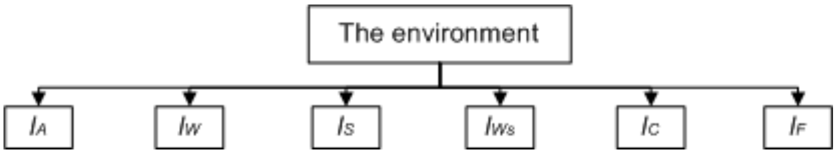

Figure 3. Component composition of the environment assessment.

In Fig. 3 the following symbols are adopted:

I_A – integral indicator of the atmosphere assessment;
I_W – integral indicator of the water resources assessment;
I_S – integral indicator of the soil assessment;
I_{Ws} – integral indicator of the wastes assessment;
I_C – integral indicator of the costs assessment;
I_F – integral indicator of the forest resources assessment;

The composition of the indicators and their details may vary depending on the monitoring objectives, measurement tools, and methods implemented by the organization etc. This in no way affects the possibility of the method interpolation. Integral indicator is formed according to the logical scheme presented in Fig. 4.

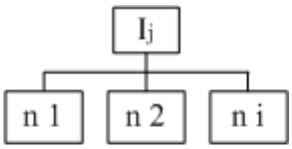

Figure 4. The logic of the formation of the integral indicator of the environment assessment, where I_j is the integral indicator of the assessment of its constituents; j = 6; n 1 ... n i are the partial indicators of the environment condition.

According to Figs. 1, 3, 4 the set of partial indicators (n = 56) of environmental monitoring within each of the components was formed. For the assessment of the component “The atmosphere” the following partial indicators (n 1 – n 11) are offered, for example:

- n 1 – emissions of carbon dioxide into the air from stationary sources of pollution, thousand tons (disincentive);
- n 5 – emissions of suspended solids into the atmosphere from stationary sources of pollution, thousand tons (disincentive);

- n 6 – emissions of sulfur dioxide into the air from stationary sources of pollution, thousand tons (disincentive);
- n 7 – emissions of nitrogen dioxide into the atmosphere from stationary sources of pollution, thousand tons (disincentive);
- n 9 – emissions of non-methane volatile organic compounds into the atmosphere from stationary sources of pollution, thousand tons (disincentive);
- n 10 – emissions of ammonia into the atmosphere from stationary sources of pollution, thousand tons (disincentive);
- n 11 – emissions of methane into the air from stationary sources of pollution, thousand tons (disincentive).

For the assessment of the component “Water resources” the following partial indicators (n12 – n24) are offered, for example:

- n 12 – drawing of water from natural water objects, million m3 (disincentive);
- n 14 – water loss during transportation, million m3 (disincentive);
- n 17 – water saving drawing through the circulating and recycling water supply, million m3 (incentive);
- n 21 – discharge of contaminated return water without purification into the surface water objects, million m3 (disincentive);
- n 24 – wastewater treatment facilities, million m3 (incentive).

For the assessment of the component “Soil” the following partial indicators (n25 – n29) are offered, for example:

- n 25 – application of mineral fertilizers per hectare of acreage, kg (disincentive);
- n 26 – application of organic fertilizers per hectare of acreage, tons (incentive);
- n 29 – areas where pesticides were used, thousand hectares (disincentive).

For the component “Wastes” assessment partial indicators (n 30 – n 42) are offered, for example:

- n 32 – waste generation per square kilometer, tons (disincentive);
- n 33 – waste generation per capita, kg (disincentive);
- n 37 – waste disposal in dedicated places and facilities, thousand tons (incentive);
- n 39 – waste disposal in fly-tipping, thousand tons (disincentive).

For assessment of the component “Costs” the following partial indicators (n 42 – n 46) are offered, for example:

- n 45 – investments into overhaul of main means of environmental protection, millions of Ukrainian hryvnia (incentive);
- n 46 – current expenditures on environmental protection, millions of Ukrainian hryvnia (incentive).

For the assessment of the component “Forest resources” the following partial indicators (n47 – n56) are offered, for example:

- n 47 – area of forest destruction, hectares (disincentive);

- n 48 – number of forest fires, units (disincentive);
- n 51 – area of reforestation, hectares (incentive);
- n 52 – area of afforestation, hectares (incentive);
- n 56 – damage caused to forestry, millions of Ukrainian hryvnia (disincentive).

The values of integral indicators of the assessment of components of the environment for the previously specified objects according to statistical data for 2017 (Prokopenko, 2018) are presented in table 1. The exemplary histogram of the distribution of values of the integral indicator of the water resources assessment is shown in Fig. 5. The current condition of the water resources in each region can be analyzed and compared with additional sources to determine the quality of the integral indicator. The exemplary histogram of the distribution of values of the integral indicator of the soil assessment is shown in Fig. 6. The histograms of the distribution of values of the integral indicators of the condition of the components "The atmosphere", "Wastes", "Costs" and "Forest Resources" were constructed in the same way. Such an analysis showed that there are significant differences among the monitoring objects in terms of values of integral indicators, and of the assessment of the environment condition.

Table 1. The values of the integral indicators

The monitoring object	Components											
	I_A	Rank	I_W	Rank	I_S	Rank	I_{Ws}	Rank	I_C	Rank	I_f	Rank
Ukraine (average)	0,851	-	0,752	-	0,379	-	0,653	-	0,105	-	0,579	-
Vinnytsia region	0,761	20	0,848	5	0,171	23	0,655	15	0,024	13	0,761	1
Volyn region	0,993	3	0,840	8	0,477	6	0,616	20	0,012	18	0,714	3
Dnipropetrovsk region	0,274	23	0,457	22	0,269	17	0,449	24	0,904	1	0,337	23
Donetsk region	0,199	24	0,368	24	0,448	8	0,716	2	0,244	4	0,534	18
Zhytomyr region	0,981	5	0,827	10	0,449	7	0,675	10	0,007	20	0,730	2
Transcarpathian region	0,999	1	0,841	7	0,541	4	0,696	4	0,009	19	0,637	8
Zaporizhya region	0,711	21	0,436	23	0,237	20	0,666	12	0,302	3	0,395	22
Ivano-Frankivsk region	0,656	22	0,848	4	0,671	1	0,611	21	0,070	9	0,635	9
Kiyiv region	0,914	13	0,742	19	0,531	5	0,684	9	0,313	2	0,491	20
Kirovograd region	0,975	8	0,825	12	0,194	21	0,541	23	0,006	22	0,669	6
Lugansk region	0,878	16	0,838	9	0,444	9	0,626	18	0,026	12	0,547	17
Lviv region	0,854	17	0,759	18	0,430	10	0,660	14	0,061	10	0,550	16
Mykolayiv region	0,969	9	0,782	16	0,308	16	0,578	22	0,082	7	0,522	19
Odessa region	0,946	12	0,724	20	0,153	24	0,663	13	0,086	6	0,607	14
Poltava region	0,824	19	0,827	11	0,397	13	0,617	19	0,176	5	0,651	7
Rivne region	0,979	6	0,863	1	0,603	2	0,638	16	0,022	14	0,629	10
Sumy region	0,953	10	0,818	13	0,251	18	0,737	1	0,027	11	0,611	13
Ternopil region	0,976	7	0,841	6	0,343	14	0,700	3	0,004	23	0,615	12
Kharkiv region	0,904	15	0,768	17	0,188	22	0,628	17	0,074	8	0,449	21
Kherson region	0,985	4	0,461	21	0,420	11	0,673	11	0,003	24	0,252	24
Khmelnytsky region	0,953	11	0,863	3	0,335	15	0,684	8	0,017	15	0,628	11
Cherkasy region	0,834	18	0,802	15	0,409	12	0,694	6	0,015	17	0,579	15
Chernivtsi region	0,997	2	0,863	2	0,586	3	0,686	7	0,006	21	0,678	5
Chernihiv region	0,908	14	0,812	14	0,246	19	0,694	5	0,017	16	0,679	4

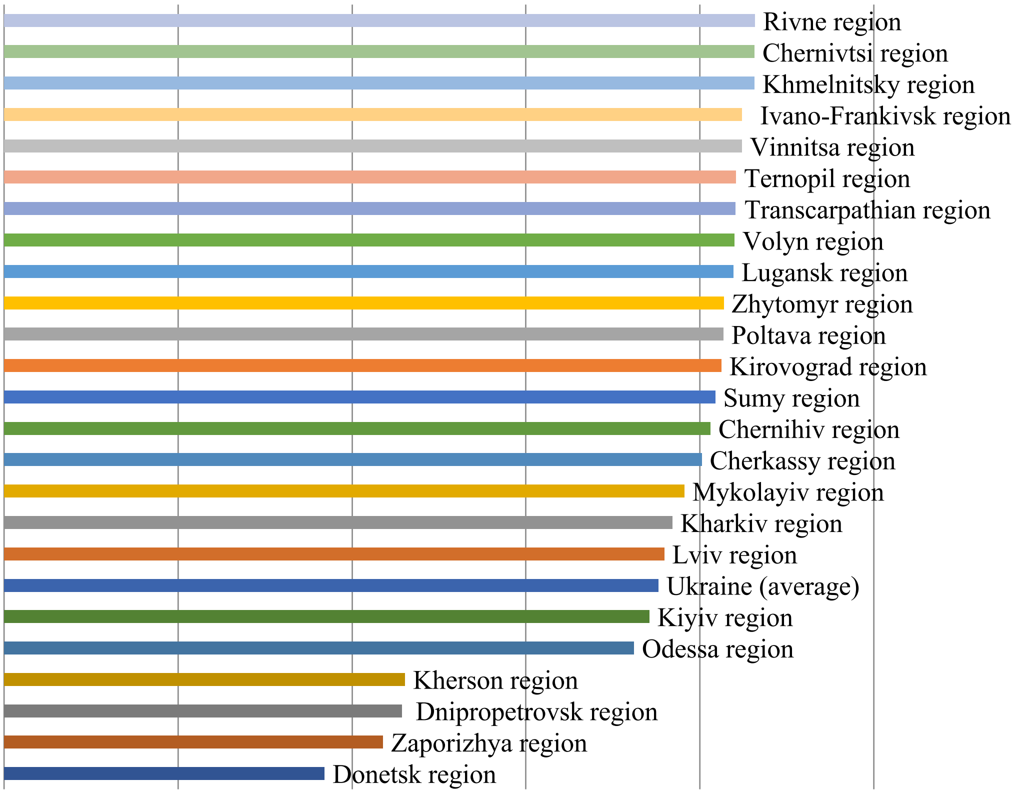

Figure 5. Distribution of the monitoring objects in terms of the values of the integral indicator of the assessment of the current condition of the component "Water Resources".

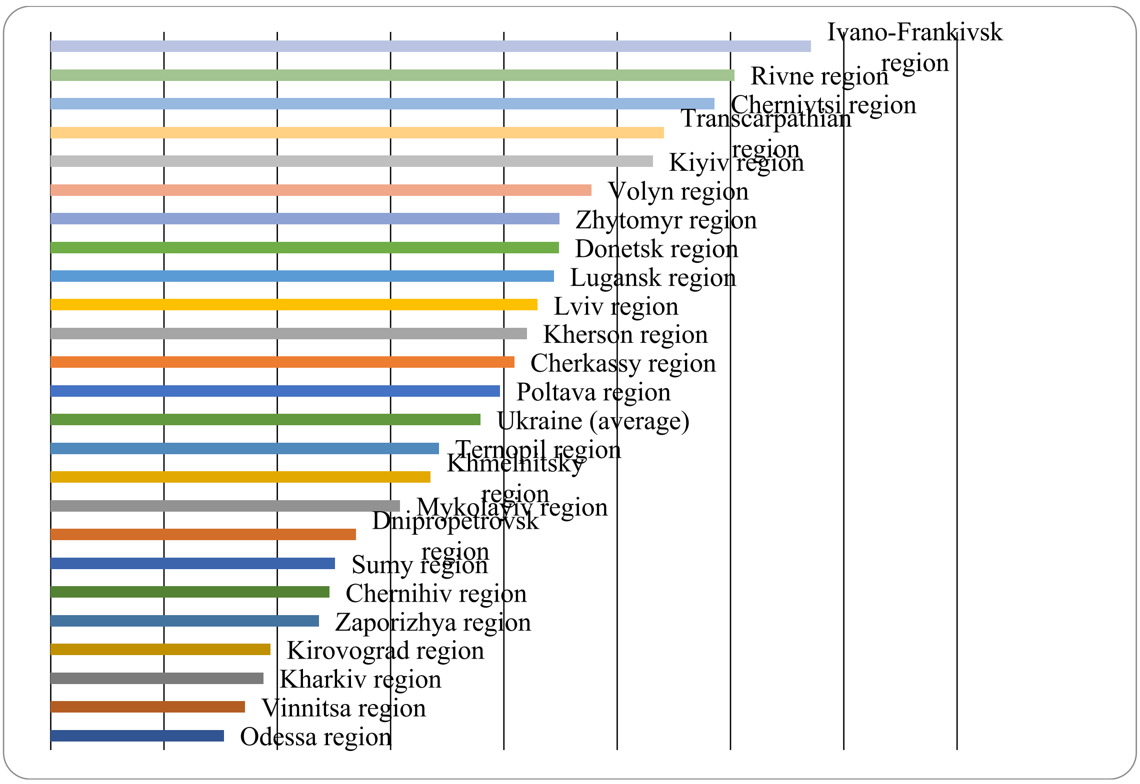

Figure 6. Distribution of the monitoring objects in terms of the values of the integral indicator of the assessment of the current condition of the component "Soil".

4.3 Regression models construction

To determine the list of partial indicators that have the most significant influence on the variations of the integral indicators, regression models (Table 2) were constructed.

Table 2. Parameters of the regression models for the determination of the influence of partial indicators on the variations of the integral indicators

Components	List of partial indicators before modeling	Coefficients β in the regression model		List of partial indicators after modeling	Reliability of the model (R^2)
The atmosphere	n 1 – n 11	n 1	0,1251	n 1, n 2, n 3, n 4	0,999
		n 2	0,4765		
		n 3	0,1450		
		n 4	0,1006		
Water resources	n 12 – n 24	n 12	0,2630	n 12, n 14, n 16, n 17, n 18, n 20, n 24	0,999
		n 14	0,1364		
		n 16	0,0261		
		n 17	0,1101		
		n 18	0,4541		
		n 20	0,3745		
		n 24	0,1580		
Soil	n 25 – n 29	n 25	0,2850	n 25, n 27, n 28, n 29	0,967
		n 27	0,9100		
		n 28	0,5030		
		n 29	0,1740		
Wastes	n 30 – n 42	n 30	0,2352	n 30, n 31, n 32, n 33, n 34, n 35, n 36, n 37, n 38, n 39, n 41	0,999
		n 31	0,3741		
		n 32	0,2364		
		n 33	0,2872		
		n 34	0,1528		
		n 35	0,3174		
		n 36	0,3378		
		n 37	0,1854		
		n 38	0,2678		
		n 39	0,4466		
		n 41	0,5554		
Costs	n 43 – n 46	n 43	0,3188	n 43, n 45, n 46	0,996
		n 45	0,3573		
		n 46	0,4489		
Forest resources	n 47 – n 56	n 49	0,6136	n 49, n 50, n 51, n 52, n 53, n 55	0,975
		n 50	0,1783		
		n 51	0,1226		
		n 52	0,3778		
		n 53	0,4953		
		n 55	0,3293		

The reliability of the models is verified by the high values of R^2 and by the model residues distribution for each component, which are closely related to the distribution. The example is shown in Fig. 7. At this step, the partial indicators that have the greatest influence on the integral indicators were determined.

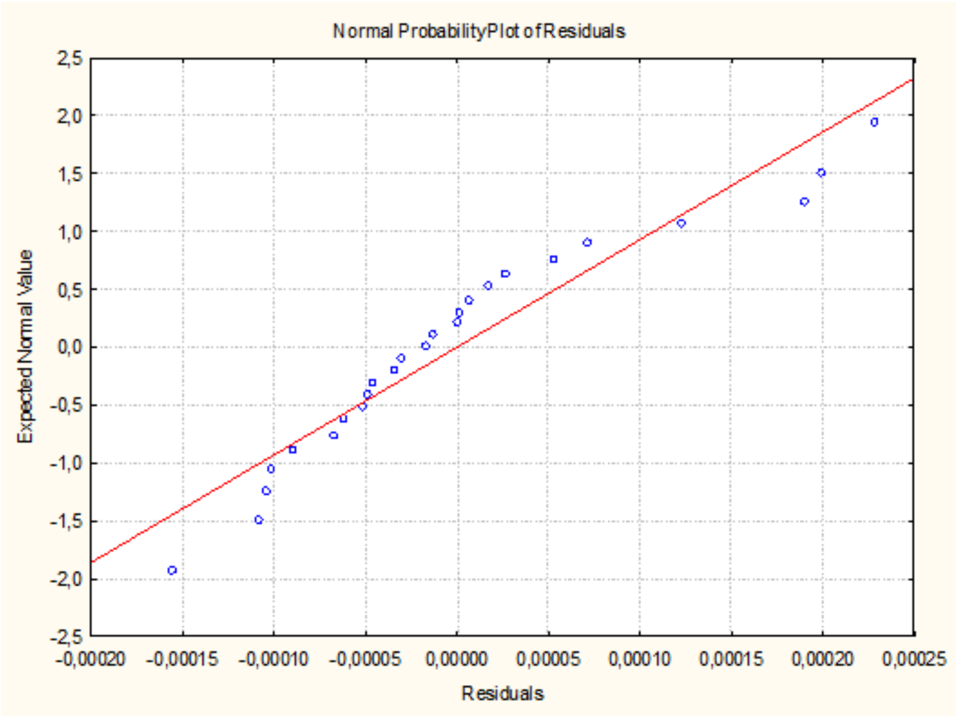

Figure 7. The distribution of residues of the regression model for the determination of the influence of partial indicators on the integral indicator of the atmosphere assessment.

The partial indicators that have the greatest impact on the integral indicator of the atmosphere assessment are the following:

- emissions of carbon dioxide into the air from stationary sources of pollution – 0,1251;
- emissions of pollutants into the air from stationary sources of pollution – 0,4765;
- emission of pollutants into the air from stationary sources of pollution per square kilometer – 0,1450;
- emission of pollutants into the atmosphere from stationary sources of pollution per capita – 0,1006.

The partial indicators that have the greatest impact on the integral indicator of the water resources assessment are the following:

- drawing of water from natural water objects – 0,2630;
- total water discharge – 0,4541;
- discharge of contaminated return water into surface water objects – 0,3745;
- use of fresh water per capita by region, including fresh water and seawater which are used for the needs of the national economy and population – 0,0261;
- saving of drawing of water through the circulating and repeated-successive water supply – 0,1101;
- capacity of wastewater treatment facilities – 0,1580;
- water losses during transportation – 0,1364.

The partial indicators that have the greatest impact on the integral indicator of the soil assessment are the following:

- application of mineral fertilizers per hectare of acreage – 0,2850;

- area of agricultural crops fertilized with mineral fertilizers – 0,9100;
- area of agricultural crops fertilized with organic fertilizers – 0,5030;
- areas where pesticides were used – 0,1740.

The partial indicators that have the greatest impact on the integral indicator of the wastes assessment are the following:

- generation of waste of I–III classes of hazard – 0,3741;
- waste generation per square kilometer – 0,2364;
- waste generation per capita – 0,2872;
- total waste generation – 0,2352;
- total waste utilization – 0,1528;
- utilization of waste of I-III classes of hazard – 0,3174;
- waste incineration – 0,3378;
- waste disposal in dedicated places and facilities – 0,1854;
- removal of waste of I-III classes of hazard into dedicated places and facilities – 0,2678;
- disposal of waste in fly-tipping – 0,4466;
- total amount of waste accumulated during operation in waste disposal sites per square kilometer – 0,5554.

The partial indicators that have the greatest impact on the integral indicator of the costs assessment are the following:

- investments into environmental protection – 0,3188;
- investments into overhaul of main means of environmental protection – 0,3573;
- current expenditures on environmental protection – 0,4489.

The partial indicators that have the greatest impact on the integral indicator of the forest resources assessment are the following:

- area of forests fueled by fires – 0,6136;
- volume of burnt and damaged forest – 0,1783;
- areas of forests reproduction – 0,1226;
- forest harvesting area – 0,3778;
- area of the transformation of forest areas of natural renewal into the covered with forest vegetation areas – 0,4953;
- the number of illegal cuts – 0,3293.

Other indicators do not have a statistically significant effect on the integral indicators of the assessment and in the learning process can be analyzed after the indicators that have such an effect in random order under condition of study time availability. Based on the findings, a teacher can develop a training program. Students will collect and / or analyze the environmental indicators in the learning process or in their future professional activity in a sequence according to the level of impact of the partial indicators on the integral indicator. These actions ensure a reduction in the time for teaching, learning, and in the time for professional monitoring. At the same time, it ensures it ensures the ability to obtain approximate results with statistically small errors in order to stay at the forefront of the modern knowledge. It allows us to maximize the information on the results obtained under time constraints for teaching / learning and as well as for its direct implementation.

4.4 Monitoring objects clustering and implementation of graph theory

For further didactic reduction, we distinguished groups of the monitoring objects with the use of the k-means clustering (Table 3) which allows us to eliminate the subjective approach in result interpretation. As can be seen in Fig. 8, the average values of the partial indicators within the defined clusters are differentiated and the distances among the centers of the clusters are statistically significant.

Table 3. Results of clustering of the monitoring objects by values of integral indicators

Cluster 1		Cluster 2		Cluster 3	
The cluster's composition	Euclidean distance among the objects	The cluster's composition	Euclidean distance among the objects	The cluster's composition	Euclidean distance among the objects
Dnipropetrovsk region	0,195208	Vinnytsia region	0,112553	Volyn region	0,060816
Donetsk region	0,152102	Kirovograd region	0,071503	Zhytomyr region	0,064213
Zaporizhya region	0,154674	Mykolayiv region	0,050081	Transcarpathian region	0,052434
		Odessa region	0,054614	Ivano-Frankivsk region	0,123114
		Sumy region	0,041044	Kiyiv region	0,120389
		Ternopil region	0,053473	Lugansk region	0,045351
		Kharkiv region	0,065380	Lviv region	0,053017
		Kherson region	0,197665	Poltava region	0,072933
		Khmelnytsky region	0,053609	Rivne region	0,057688
		Chernihiv region	0,048350	Cherkasy region	0,057222
				Chernivtsi region	0,064913

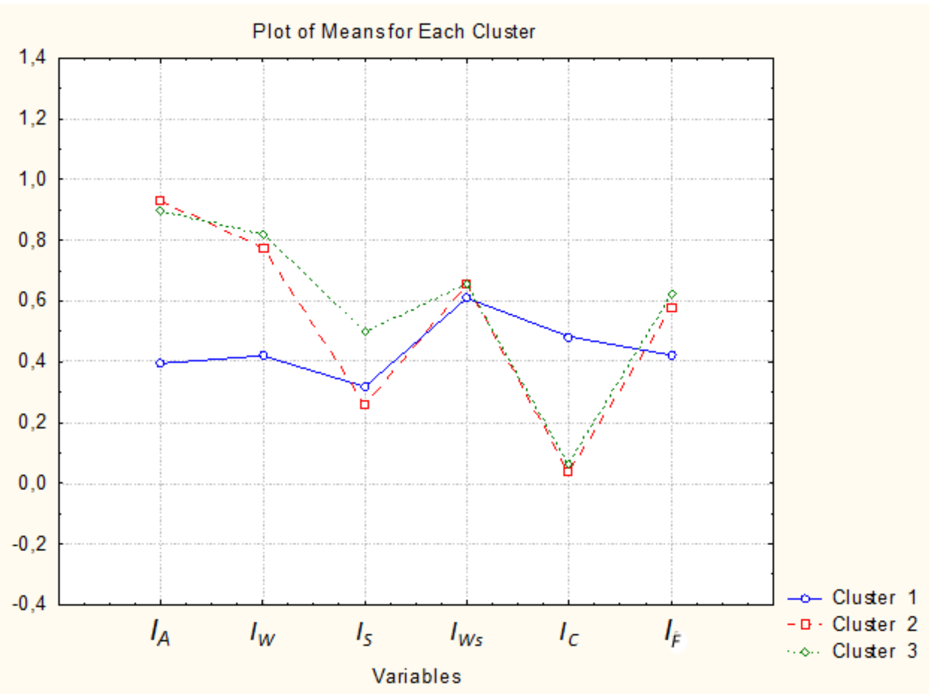

Figure 8. Distribution of values of the clusters of the monitoring objects.

Thus, three monitoring objects were located in Cluster 1. These objects are characterized by the worst condition of the habitat in Ukraine. Within the framework of content reduction of the environmental monitoring course, it is possible to determine the typical representatives of the cluster trough the smallest values of the Euclidean distance from the object to the center of the cluster. For instance, the typical representative of Cluster 1 is the Donetsk region. Cluster 2 includes representatives. which have middle environmental level. There are ten monitoring objects here. The typical representative of Cluster 2 is the Sumy region. There are 11 regions in Cluster 3 where the environmental level can be defined as high.

On the basis of the data obtained on the cluster representatives, other objects can be analyzed. This can be a tool for study time reduction. The reflection of the results of clustering is well coordinated with the use of graphs. The application of graph theory in the framework of didactic reduction is known (Costa, D'Ambrosio & Martello, 2014; Shmatkov, 2016). The results indicate simplification of the comprehension of the subject area. Variations in the representation of cluster analysis on the basis of graph theory are shown in Fig. 9 (A, B) where shading shows possible reduction volumes.

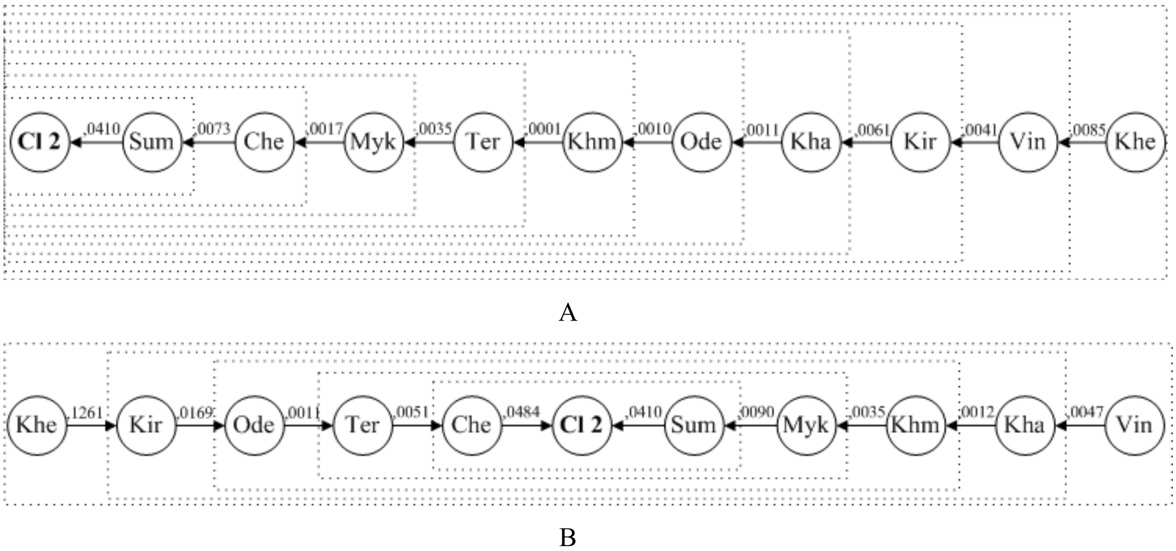

Figure 9. Didactic reduction through the representation of Euclidean distances from the center of Cluster 2 (Table 3) among the monitoring objects.

For greater visual clarity, it is possible to coordinate the length of the arrows which link the vertices of the graph with the Euclidean distances. In accordance with the existing requirements (Kaulbach, 2018), the proposed didactic reduction tool reflects present and future value of environmental monitoring for students. They continue to keep abreast of learning content developments despite the reducing content within the frame of the program. It shows the effect of factors on the result and provides forecasting. The method of didactic reduction can be applied to the entire course program or to a specific topic that is exemplary. Structuring that prioritizes the reduction of cognitive complexity in regards to the learning subject is a key attribute of didactic reduction.

6. CONCLUSIONS

Thus, in the article, the environmental monitoring program reduction method has been adopted. The method is based on the principles of vertical didactic reduction (Grüner, 1967; Mesch, 1994; Ruhm, 2011) in the realm and provides improved directions for mathematical models implementation. Ukraine and its regions as the objects under study have various characteristics of habitats that provide ample opportunities for interpolation of the method. It can be applied to different geographic objects – areas, cities, regions, countries, etc.

We understand that the developed method can only be applied to quantitative variables. However, we see the possibility of analyzing qualitative variables in terms of their quantitative form or quantitative variables as interconnected with them. Moreover, monitoring by its very nature implies planning, measuring and processing the results, which falls closely in line with the developed didactic reduction method. The implementation of the method is not complex or specific. It can be implemented with the use of free software within a short period of time. Using the math methods combined in this study, a teacher can form a course program or separate topics of the environmental monitoring course and coordinate them with the available study time. Students can apply their knowledge through the didactic reduction when performing their professional duties in the future. The adequacy of the chosen math methods is confirmed in the study. We fully agree that all aspects of the environment are important. However, it is impossible to cover all current developments in the learning process. On the other hand, prompt assessment of the situation and quick decision-making is often important in the process of professional activity, which will inevitably be accompanied by certain mistakes. The developed method is aimed to minimize such mistakes, in addition to the teaching and learning advantages it provides. In general, the method allows students to learn how to identify the decisive factors from a large data set, how to cover central tenets, how to structure data, and how to carry out their analysis and synthesis.

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