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GEOCHEMICAL STRUCTURE LANDSCAPES AND SOILS

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Different types of lateral and radial geochemical structures have been considered in the framework of structural approach. The adduced technique of the geochemical diversity assessment is based on the account of numerous combinations of geochemical structures within elementary technogenic landscape. Their connection with landscape and biological diversity has been considered in the article.

Key words: landscape, geochemical structure, diversity.

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ГЕОХИМИЧЕСКАЯ СТРУКТУРА ЛАНДШАФТОВ И ПОЧВ

В рамках структурного подхода рассмотрены латеральные и радиальные геохимические структуры. Приведенная методика оценки геохимического разнообразия основана на учете множественных комбинаций геохимических структур в пределах элементарного техногенного ландшафта. В статье рассмотрена связь между ландшафтным и биологическим разнообразием.

Ключевые слова: ландшафт, геохимическая структура, разнообразие.

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ГЕОХІМІЧНА СТРУКТУРА ЛАНДШАФТІВ ТА ҐРУНТІВ

У межах структурного підходу розглянуто латеральні та радіальні геохімічні структури. Наведена методика оцінки геохімічного різноманіття ґрунтується на врахуванні чисельних комбінацій геохімічних структур у межах елементарного техногенного ландшафту. У статті розглянуто зв'язок між ландшафтним та біологічним різноманіттям.

Ключові слова: ландшафт, геохімічна структура, різноманіття.

European landscapes are permanently exposed to the intensive geochemical technogenic load owing to transborder and regional pollutants. They are transformed into oxides of elements with different toxicity level. Elements are concentrating in landscapes, carrying out from them or redistributing within their borders due to natural conditions, processes and geochemical barriers. Thus geochemical structure forms by mentioned factors. It may be an indicator of the landscape contamination level. We use it for the establishment of geochemical diversity of landscapes.

OBJECTS AND METHODS

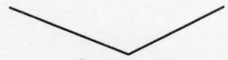
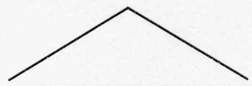
Geochemical structure is a regular lateral and radial distribution of chemical elements within landscape geochemical system and caused by their differentiation under the influence of external and internal migratory factors. Geochemical structure consists of radial and lateral structure, which characterize vertical (R-analysis) and horizontal or slope (L-analysis) redistribution migratory vectors of matter in landscapes (Chartko, 1981).

Owing to the absence of general definitions of different geochemical structures and their difficulty we developed primary concepts of structures kinds with the objective of systematization of the information about structural geochemical peculiarities of different landscapes. It allows describe and estimate diversity of landscapes and their technogenic transformation (tab. 1).

We have selected five type of lateral structures within landscape geochemical profile: ascended structure is differed by the increasing of element content within the catena from the top to the bottom; descended structure is identified by the reduction of element concentration; depressive structure is distinguished by low element concentrations in the middle part of the slope and its growth to the top and to the bottom; spike structure, conversely, has high amounts of element concentration in the middle of the slope, which are decreased to the top and to the bottom and uniform structure doesn't reveal any significant changes of concentration within the profile. The leading feature of radial structure identification is a set of regularities of chemical elements distribution by soil layers (tab. 2).

Table 1

The classification of lateral geochemical structure of landscapes

Kind of structure	Peculiarities of elements distribution	Structure form
Ascending (rising)	The element concentration increases from eluvial landscapes to superaqual	
Descending	The element concentration diminishes from eluvial landscapes to superaqual	
Depresive	The element concentration diminishes from eluvial landscapes to transeluvial and increases again to superaqual	
Peak-looked	The element concentration increases from eluvial landscapes to transeluvial with following decrease to superaqual	
Uniform	The element concentration is equal within catena	

There are following types of radial structures: uniform (chemical elements are distributed equally); humic (accumulation has occurred in a humic soil layer); humic-illuvial (accumulation has occurred in humic and illuvial layers); eluvial (elements has concentrated in humic and eluvial layers); eluvioilluvial (both eluvial and illuvial layers concentrate chemical elements) and lessivage structure is differed by leaching of elements to the lower layers with gradual concentration growth with the depth, i.e. bedrocks concentrate element more then overlying soil layers.

We shell consider the estimation procedure on the example of secondary fluvioglacial landscape of the Republic of Belarus. Its catena presented on the fig. 2 was built in the central part of the counry. This genus of landscapes is most common for the Belarusian ridge and Polessye. Their forming is connected with the activity of melted glacial waters. The sedimentation of anisomerous sands with gravel and pebble matter had been occurred. They covered by fluvioglacial loamy sands and loess-type loams. Their thickness is reached about 0,3–2,0 m.

Absolute altitudes are come to 150–190 m with relative excesses about 2–5 m. The relief is wavy, sometimes is flat or flat-wavy with separate hills achieving 5-7 m in height. Waterlogged depressions with lakes and shallow gullies have a subordinate significance. Sod-podzol loamy sandy and sandy soils are dominating in such landscapes. Surface wash is expressed weakly. Pine forests are prevailing on sandy rocks in dry places.

Arable lands have replaced deciduous forests with spruce, oak, lime-tree, somewhere with hornbeam and small-leaved species (birch, aspen andalder-tree). Different types of grasslands are spread in depressions (Klitsunova, Schstnaya, 2002). The share of arable lands is not exceeding 45% and the share of forests is varied from 20% to 30%.

Biogeochemical barrier is a basic in considering landscapes, because acidic and subacidic reaction of soils accelerates the transfer of chemical elements into mobile form and their carrying-out into local waterways. Redox conditions are changing more sharply and have an influence on the accumulation or on the acceleration of migratory processes for dome elements with changeable valency.

Table 2

The classification of radial geochemical structure of landscapes

Uniform	The element concentration is similar in all soil layers	
Humic (humic -accumulative); organogenic (for peat soils)	Accumulation of element in a humic (peat) soil layer	
Eluvial	Accumulation of element in an eluvial soil layer	
Illuvial	Accumulation of element in an illuvial soil layer	
Humic-illuvial	Accumulation of element in an illuvial and a humic soil layers	
Humic-eluvial	Accumulation of element in a humic and an illuvial soil layers	
Eluvioilluvial	Accumulation of element in an eluvial and an illuvial soil layers	
Lessivage or pseudolessivage (for peat soils)	Accumulation of element in lower soil layers	

RESULTS AND THEIR DISCUSSION

Lateral differentiation of chemical elements in secondary fluvioglacial landscape is considered on the example of mentioned catena. Superficial fluvioglacial coherent and mellow loamy sands are lying down on the substrate of fluvioglacial coherent and mellow sands with gravel and pebble matter. There are crops of barley in eluvial and superaqual landscapes of the catena. Sod-podzol sandy soils are combining with sod-podzol bogged soils (fig. 1). The thickness of loamy sand increases from 30 cm in eluvial landscapes to 60 cm in superaqual landscapes.

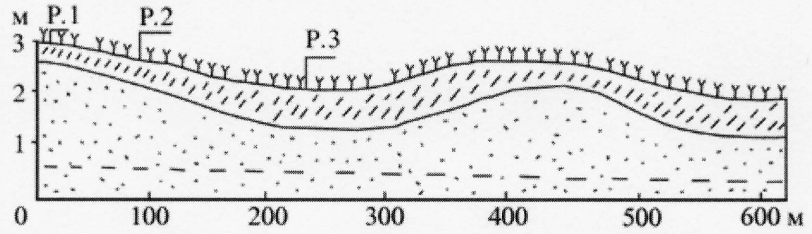
Lateral differentiation of chemical elements in soil catena is expressed weakly for major part of them because of slopes are slightly flat with relative heights 2–3 m. It is connected with the activity of biogeochemical and agritechnogenic factors.

The concentration of sustainable elements at hypergenic conditions (Si, Al) is not expressed in superaqual and transeluvial accumulative landscapes. Coefficients of local migration 1.0–1.15 are most common for this group of elements.

The monotonic accumulative type of lateral coupling is characteristic in conjugate series of facies for secondary fluvioglacial landscapes formed on the monolith superficial rock. Si and Al are excluded, because monotonic eluvial type of composition. They are well-drained. The acidity variability is not sufficient within the catena.

All listed circumstances are a cause of wide spreading of uniform lateral (Na, S, Cu, Co, Mo) and weakly expresses ascending (Ca, Mg, K, P, Mn, Zn, B) geochemical structures. Discending geochemical structure observes for elements sustainable to migration, i.e. Si and Al. Depressive structure is expressed for Fe.

Radial differentiation of chemical elements in secondary fluvioglacial landscapes indicates a presence of humic sorption barrier in a humic layer, which is almost not expressed.



	P.1	L	P.2	L	P.3	L
Particles	13,24	–	15,82	–	18,29	–
pH in KCl	5,45	–	2,45	–	3,10	–
Humus, %	2,30	–	5,56	–	5,63	–
Elements, %,						
Si	46,92	1,0	45,33	0,92	44,81	0,95
Al	3,12	1,0	2,90	0,99	2,60	0,83
Fe	1,10	1,0	0,92	1,19	1,15	1,04
Ca	0,32	1,0	0,40	1,14	0,52	1,62
Mg	0,26	1,0	0,33	1,10	0,39	1,50
Na	0,31	1,0	0,31	1,02	0,30	0,96
K	1,10	1,0	1,45	1,16	2,15	1,95
P	0,047	1,0	0,053	1,28	0,060	1,46
S	0,073	1,0	0,072	1,40	0,055	0,89
n 10^{-3}, %:						
Mn	37,00	1,0	39,4	1,11	40,34	1,09
Zn	2,40	1,0	2,57	1,15	2,79	1,15
Cu	0,90	1,0	0,99	1,14	0,99	1,01
B	1,92	1,0	1,87	1,12	2,11	1,15
Co	0,60	1,0	0,60	1,38	0,63	1,05
Mo	0,075	1,0	0,077	1,28	0,076	1,04

Fig. 1. **Geochemical profile of secondary fluvioglacial landscape**
P1–P3 – profile numbers within catena, L – coefficient of lateral geochemical differentiation

Agritechnogenesis influences on the radial differentiation weakly because the intensity of its impact within soil catena is equal, the infiltration is similar for all soil profiles. K and P have highest eluvial-accumulative coefficients and caused by the application of fertilizers (tab. 3). Geochemical structures are practically equal for all elementary landscapes.

Transeluvial and superaqual landscapes have the greatest similarity, which have following radial geochemic structures: humic-illuvial (Mg, K, P, S, Mn, Zn, Cu, B, Co, Mo), lessivage (Al, Fe) and uniform (Si) structures. Eluvial landscapes have a similar situation but humic accumulative structure observes for Ca, S, Cu, B, Co, Mo.

The spreading of lateral and radial geochemical barriers is insignificant for secondary fluvioglacial landscape. Humic sorption barrier is dominating. Other types of barriers have a subordinate significance.

Ground waters have been sampled from the profile 3 in superaqual landscape from the depth 130 cm. Their chemical composition is following, mg/l: Si 1,2, Fe 0,015, Ca 26,45, Mg 5,83, Na 2,50, K 3,60, N 0,5, C 65,3, P 0,016, S 8,5, Cl 12,31, Mn 0,025, Zn 0,005, Cu 0,012, B 0,0011, Co 0,009, Mo 0,0012, general mineralization 126,3, pH 5,8. Chemical elements have composed a following regulation of the water migration coefficient decrease: C 1288 > Cl 1214 > S 122 > Ca 52,2 > N 26,3 > Mg 14,4 > Mo 13,5 > Co 13,4 > Cu 12,9 > Na 8,9 > K 1,9 > Zn 1,7 > Mn 0,68 > B 0,54 > P 0,28 > Si 0,019 >Fe 0,008. Such elements as C, Cl, S, Ca, N, Mg are most active migrants in the landscape because a major part of them are bringing in with fertilizes on the background of high solubility of their compounds.

A chemical composition of barley biomass within the conjugate series of facies of secondary fluvioglacial landscape has been determined in samples of eluvial and superaqual landscapes. Total barley biomass in eluvial landscape is averaged to 95,12 centnes/ha at the grain harvest about 28,0 centners/ha. These values for super-aqual landscapes are equal to 100,14 and 30,10 centners/ha correspondingly. As far as general ash level is higher in superaqual landscape consequently concentrations of chemical elements are higher too (tab. 4). However the difference in the contents of chemical elements is not sufficient. Insignificant augmentation of their concentration is caused by higher humification of sod-podzol boggy soils. Geochemical conditions are similar within whole catena, but biogeochemical barrier is expressed better in superaqual landscape.

Biosorption coefficient (Kb) has also similar values and lowers in superaqual landscape excluding Kb of Si and S, which is caused by the difference f soil fertility.

Barley absorbed vastly such elements as N, P (Kb>100). A number of elements are adsorbing moderately K, Ca, Mg,S, Zn, Cu, Mo (Kb =10–100) and Si, Na, Mn, B (Kb=1– 10) are absorbed by barley weakly.

GEOCHEMICAL DIVERSITY

Geochemical diversity may be applied at the establishment of the grade of geo-chemical optimization of natural and technogenic landscapes, their differentia-tion by geochemical specialization, determination of the degree of their stability. Landscape diversity is a basis for the biodiversity preservation, which is considered as variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (The Convention …).

In this case landscape diversity is considered as an organizing and structuralizing system for the biodiversity realization where connection with its elements supports by flows of matter, energy and information exchange. The key definition at their study is a geochemical structure. Its account in the landscape diversity research may be considered as a basis for the analysis of environment-forming function of landscapes, for a number of ecological assessments and for the solution of applied problems of nature use.

Thereupon we are dealing with structural and functional elements of the diversity. Structural diversity demonstrates how elements of geochemical structure are correlated in spatial and temporal dimensions.

Among sizes and shapes of landscapes, disposition of lower rank units inside of it structural diversity includes a quantity and distribution of different geochemical structures correlated with them. It is concerning to combinations of radial and lateral structures.

Functional diversity is referred to the diversity of ecologically significant processes of migration and accumulation of chemical elements (erosion, deflation, sorption, biosorption etc.). Their spatial and temporal variability determines a geochemical structure balance and a geochemical balance of landscape as a whole.

As far as it is seeing from the fig. 2 (option 1) a diversity reaches a maximum in case of big number of individual geochemical structures at their equal and proportional availability inside of one landscape unit. If one of them is dominating in the presence of insignificant number of others then such diversity is should to be low. Model of low diversity is reflected on the fig. 2 (option 2).

Typical diversity occurs if one or several are dominated at about equal quantity of others. It is seeing on the fig. 2 (option 3).

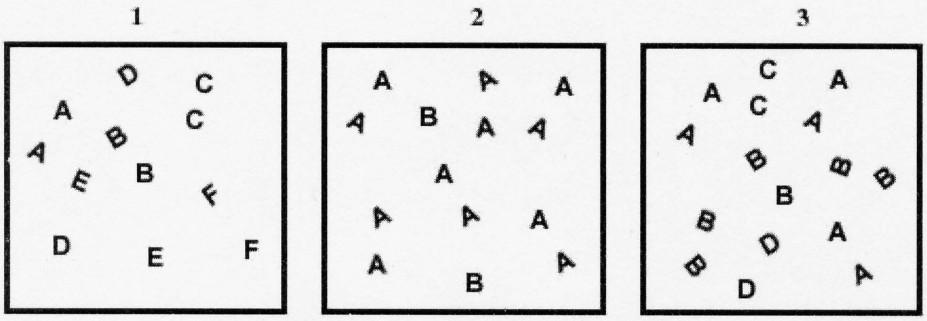


Fig. 2. **Examples of different degrees of geochemical structures**
1 – high; 2 – low; 3 – typical.

A geochemical structure of elementary landscape or estimation results of lower taxonomic level is taking into account during the assessment of diversity at the transition to higher landscape level. Diversity may be low in case of comparison of several elementary technogenic landscapes with identical diversities. As a whole a diversity of estimating landscapes couldn't be higher then diversity of their composing units. If each such elementary division is differed by either the type of structure or the diversity degree even in case of forming of landscape diversity by different units with lower diversity of geochemical structures and these structures are different, then landscape diversity may be high (fig. 3).

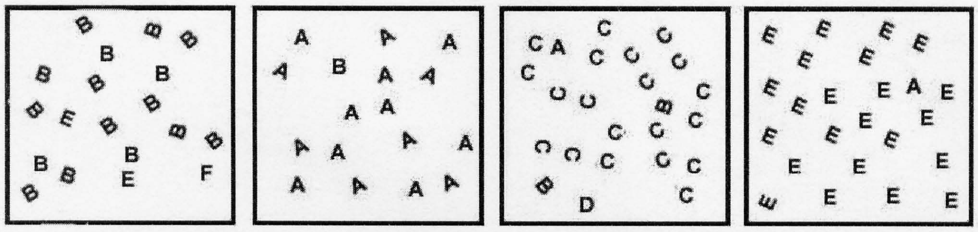


Fig. 3. **The model of high landscape diversity at low diversity of geochemical structures within elementary landscapes**

The main source of the information for the landscape geochemical diverdity analysis is a passport of geochemical structure of landscapes. Given documents are derived from the field information proceeding and presented in a view, which is convenient for following works.

The presence of landscape geochemical catena profile with points of soil profiles, tables of radial and lateral distribution of chemical elements within soil cover inside of considered catena as well as concentrations of chemical elements in phytomass and in waters. A kind of lateral and radial geochemical structure establishes for a one or another taxonomic units on the ground of this passport. Matrixes for the determination of the diversity degree are composed for each elementary landscape within soil profiles and catena. Analogous geochemical structures may be selected for the phytomass (roots, perennial ground-based part, branches and leaves) and for waters depending on the depth of their deposition. The frequency of occurrence for one or another kind of geochemical structure determines after the matrix construction. A diversity degree establishes according to adduced scheme (fig. 2). The example of such matrix is demonstrated on the fig. 4.

A matrix of lateral structure includes a list of following chemical elements: Si, Al, Fe, Ca, Mg, K, P, S, Mn, Zn, Cu, B, Co, Mo. The important thing for the studying of lateral structures diversity is that one geochemical structure is corresponding to a one chemical element within catena.

A process of the estimation of radial structure diversity is more difficult because it is necessary to know concentrations of elements within each soil profile. Chemical elements in the estimative matrix are situated in columns and appropriate soil profiles are in rows. Structural indices of occurred radial structures are input according to tab. 3 for each i-element within each j-profile.

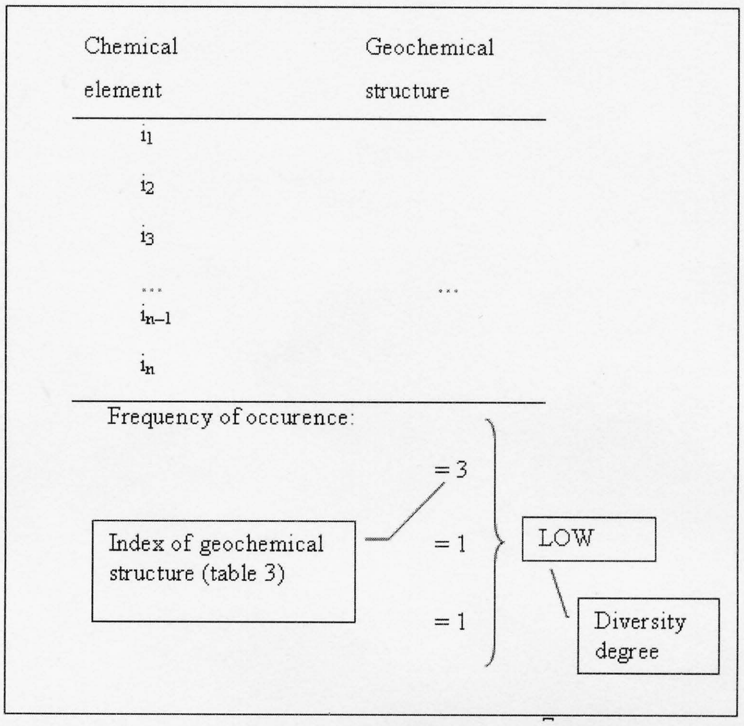


Fig. 4. **The scheme of an estimative matrix of the diversity of lateral geochemical structures**

The frequency of occurrence of individual geochemical structures is differed both for the whole facia (columns) and for each profile (raw). It is possible to assess a diversity of structures on the base of these data for both cases.

A diversity of radial geochemical structure for each chemical element estimates by the frequencies of occurrence of one or another kind of individual geochemical structures of elements and their quantity within soil profiles. As far as seeing from the fig. 6 indices of geochemical structures put down into cells are taken from the tab. 2–3. Thus, individual structure for each chemical element reflects within each profile.

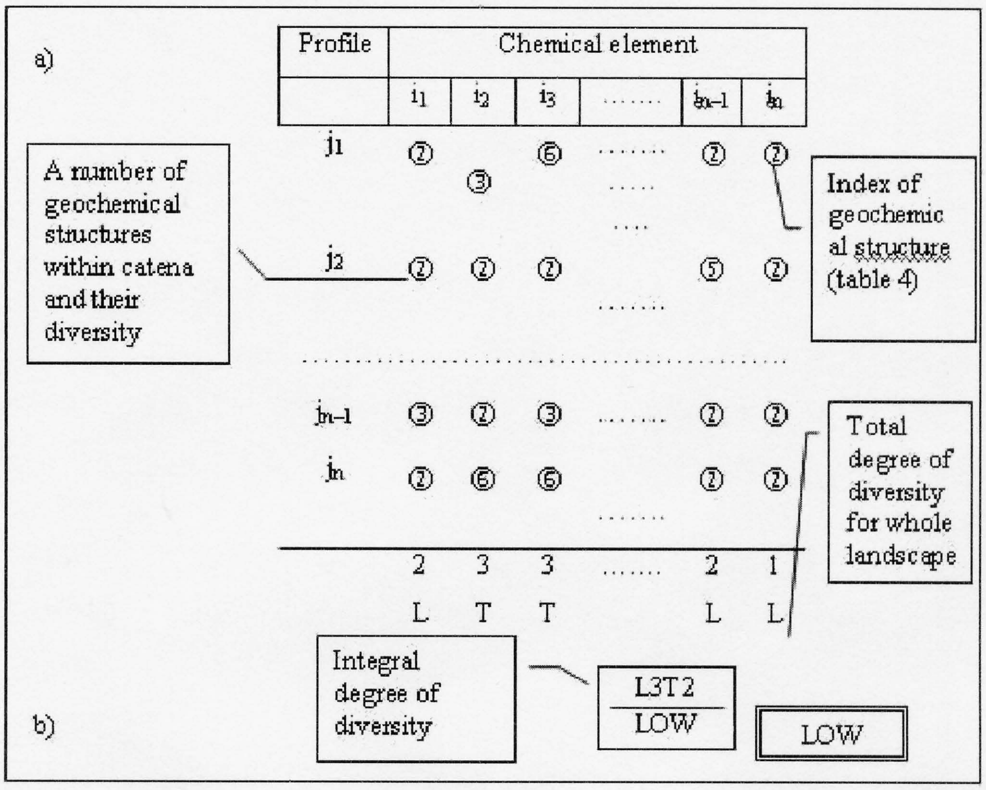
A number of structures in catena indicates in the total record line as far as seeing on the fig. 4 (option a). A degree of diversity is depending on this datum: L – low, T – typical, H – high. The formula of diversity for whole catena is written in the bottom from the right. Frequencies of occurrence of diversity degrees by elements are put down into the numerator and one degree with prevalent frequency is written into the denominator. It is expressed a geochemical diversity for whole catena.

Frequencies of occurrence of different kinds of geochemical structures in each profile are taking into account at the second stage. A matrix of frequencies of occurrence of geochemical structures is constructed as far as demonstrated on the fig. 5 (option b). Profiles are placed in rows and geochemical structures are written in columns. A frequency of occurrence of an appropriate kind of geochemical structure is put down for each profile. The assessment of diversity is proceeding by rows of matrix. A degree of diversity is indicated in the right end of each row of matrix. A degree of diversity for radial structures for a one elementary landscape is given by prevalent element structures within profile. Their frequencies are summarizing in rows (by kinds of geochemical structures) and sums should to be put down in the total record line where prevalent geochemical structure should be selected.

Table 3

Radial differentiation of chemical elements in soils of secondary fluvioglacial landscape according to R value

Elementary landscapes, profile №	Sampling depth from the layer, cm	Particles <0,01 mm	Chemical elements and R value													
			Si	Al	Fe	Ca	Mg	K	P	S	Mn	Zn	Cu	B	Co	Mo
Eluvial landscape with acidic oxidative medium, profile 1	A 5–15	13,24	0,99	0,6	0,9	1,14	1,4	1,37	1,34	1,2	1,3	1,14	1,15	1,2	1,2	1,2
	EB_1, 35–45	8,31	0,98	0,7	0,9	0,9	1,1	1,22	1,1	0,9	1,0	1,10	0,8	0,9	0,7	0,9
	B_2 78–85	6,89	0,99	0,8	1,1	1,0	1,2	1,15	1,0	0,95	1,1	1,0	0,9	1,0	0,9	0,9
	B_3C 130–140	6,32	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transeluvial accumulative with weakly acidic oxidative gley medium, profile 2	A 5–15	15,82	0,95	0,80	0,7	1,25	1,2	1,4	1,5	1,15	1,35	1,1	1,2	1,3	1,15	1,05
	EB_1 32–40	16,29	0,98	0,85	0,8		1,1	1,2	1,1	1,15	1,26	1,0	1,15	1,12	1,08	1,02
	B_2 63–70	8,91	0,96	0,88	1,2	1,18	1,0	1,03	1,05	1,0	1,3	1,05	1,08	1,05	1,0	1,0
	B_3C 120–130	7,56	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Superaqual with weakly acidic oxidative and reductive gley medium, profile 3	A 5–15	18,29	0,92	0,8	0,8	1,3	1,2	1,45	1,53	1,18	1,4	1,2	1,25	1,32	1,18	1,11
	EB_1 35–45	17,69	0,96	0,83	0,95	1,15	1,18	1,2	1,27	1,15	1,3	1,1	1,05	1,2	1,1	1,05
	B_2 10–80	9,39	0,98	0,95	0,99	1,0	1,02	1,01	1,1	1,03	1,1	1,0	1,0	1,03	1,04	1,0
	B_3Cg 97–105	7,80	1	1	1	1	1	1	1	1	1	1	1	1	1	1



	①	②	③	④	⑤	⑥	⑦	⑧		
j1		3	1			1			→	LOW
j2		4			1				→	LOW
....										
jn-1		3	2						→	TYPICAL
jn		3				2			→	LOW
		13	3		1	3			→	LOW

Degree of diversity

Fig. 5. **Estimative matrix of the diversity of radial geochemical structures**

Thus, we obtained three indices of radial geochemical structure diversity: 1) the diversity of element structures (for separate chemical elements); 2) the diversity of individual structures of elementary landscapes (facies) by soil profiles; 3) the diversity of frequencies of geochemical structures for whole landscape. They should be recorded in tables and map legends in such order as it is presented in the tab. 4, i.e. LLT, LTT, HTT etc.

This is an integral estimative index of the diversity of geochemical structures. It's derived from the results of synthesis of other mentioned indices and indicates a degree of diversity by three parameters simultaneously.

In case of combined estimation of structures total record has a view of fraction where structure is placed in a numerator and an integral parameter of radial structures diversity is put down in a denominator, for example: T/LTT.

Table 4

Combinations of degrees of radial geochemical structures diversity

Diversity of element structures for separate chemical elements	Diversity of individual structures of soil profiles within a facia	Total degree of frequencies of occurrences diversity of geochemical structures for whole landscape (urochishche)	Integral index of the diversity of geochemical structures
L	L	T	LLT
L	T	T	LTT
H	T	T	HTT

Thus the assessment of geochemical structures diversity has been realized in the Republic of Belarus on the level of landscape genera. Its results are reflected in the tab. 5.

Table 5

Landscape diversity of Belarus on the base of geochemical structures

Landscape	Diversity of lateral structures	Diversity of radial structures				Total index of landscape diversity for whole landscae
		Diversity of element structures	Diversity of individual structures of soil profiles	Diversity of frequencies of occurrences of geochemical structures for whole landscape	Integral index of the diversity of geochemical structures	
Hilly-moraine-erosive	L	L	L	L	LLL	L / LLL
Moraine lacustrine	L	H	L	L	HLL	L / HLL
Loess	L	T	T	T	TTT	L / TTT
Secondary moraine	T	T	T	T	T	T / TTT
Secondary fluvioglacial	L	T	L	T	TLT	L / TLT
Alluvial terraced	H	L	T	T	LTT	H / LTT
Nonsegmented with the prevalence of wetlands	L	T	T	H	TTH	L / TTH

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