PHYTOCOENOSES UNDER DIFFERENT PHYSICAL-GEOGRAPHIC CONDITIONS: INTERZONAL, INTERHEIGHT BELTS, EXTRAZONAL ONES, ECOTONES AND PARAGENESE (LAKE BAIKAL REGION)

Alexander Sizykh[1*]

[1*]*Siberian Institute of Plants Physiology and Biochemistry of RAS SB, 664033 Irkutsk, 132 Lermontova str., Russia;*

[*]Corresponding Author Alexander Sizykh e-mail: alexander.sizykh@gmail.com;

Received May 2023; Accepted June 2023; Published July 2023;

DOI: https://doi.org/10.31407/ijees13.303

ABSTRACT

This paper presents information on the vegetation of concrete environments - zonal, interzonal, interheight belts and extrazonal ones as a result of studies done by numerous vegetation researchers for different regions during many years. As this information is separate statistics in the characteristics of the vegetation cover for environmental zones and height belts, it is necessary to take it into account while characterizing the heterogeneity of vegetation structure under different physical-geographic conditions of the vast Baikal Region: this is an important aspect of such studies. Taking into account of opinions of different researchers concerning the characteristics of the structure of different territories favors the understanding of structural peculiarities of the coenoses under concrete physical-geographic conditions at a concrete territory. Stating of typological diversity of phytocoenoses as of proxies of vegetation modern state and formation trends allows to perform in a more concrete way assessments and forecasts of the development of different environments at a regional-topologic level of their spatial and temporal organization.

Key words: phytocoenoses, physical-geographic conditions, interzonal, interheigth belts, extrazonal, ecotones, paragenese, Lake Baikal region

INTRODUICTION

Revealing of the intensity and of the rate of structural-dynamic changes in vegetation under different physical-geographic conditions under definite climatic conditions favoring a concrete vegetation type [1, 2] allows to judge about the range of such changes in vegetation cover structure with time and space.

In the system of geographic zonality, by heat and moisture ratio and radiation balance, the latitudinal zonality is always primary, and height belts are secondary. Due to variations of solar radiation at the boundary of atmospheric moistening transition (from oceans deep into a continent), the latitudinal zonality in well developed mountain systems is replaced by heat belts, which are situated in a definite belt of solar radiation. It means that in the mountains, the height belts are determined by the intensity of solar radiation in a definite radiation belt on a common background of heat and moisture ratio in the aspect of latitudinal zonality [3].

Phytocoenoses–ecotones

After the notion "ecotone" was accepted for the characteristics of natural phenomena, it onbtained a very vast use, and any transitional areas were called «ecotone" if, on a researcher's opinion, there is "a boundaries blur" between phytocoenoses and whole environmental systems. The ecotones have a specific structure reflecting coenoses transitional between different communities, but there is no concrete definition, as any phytocoenoses of transitional type are called ecotones meaning both interzonal (and interheight belts) and intrazonal heterogeneities of vegetation cover structure. Ecotones have particular features and structure different from zonal environmental systems or height belts.

It is to notice here that the problem of ecotones establishment in the spatial stratigraphy is presented in papers by numerous researchers worldwide starting from first publications by B.E. Livingston [4], F. Clements [5], J. Weaver, F. Clements [6] where they show that an ecotone is a transitional community between two different phytocoenoses. Further the term "ecotone" while characterizing the heterogeneities of vegetation structure was used as well by other researchers such as Valter, Box [7], Davis [8], Hansen-Bristow et al. [9], Naiman [10], Kullman [11], Holland et al., [12], Rusek [13], Korner [14], Bugman, Pfister [15], Holtmeier [16], Bossuyt, Hermy and Deckers [17], Royce, Barbour [18], Knight, Maddux [19], Chen [20], Sjogersten et al. [21], Leffer and Caldwell [22], Holtmeier and Broll [23], Camarero et al. [24], Wiegand et al. [25], etc.

It is known that the ecotones result from formation of continuity of a coenotic cover functioning as membranes, as buffers and partly as refugia and can present very important information concerning the assessment of the state of adjacent ecosystems as these environmental zones are very rich in information. The elevated activity of environment formation on transitional territories makes ecotones play an important role in species evolution, adaptation and hybridization with formation of spatially and genetically particular systems. Structural-functional organization of ecotones formed due to evolution is very important for the studies of global environmental changes. Main tasks in ecotones systems studies nowadays are: typology, zoning and mapping with revealing of processes of biogeocoenotic cover ecotonization, landscapes structure and biospheric processes dynamics.

It is to notice that ecotones establishment is not connected with any different characteristics of the environment, i.e., this term characterizes interzonal, sub-zonal, intrazonal and interheight belts heterogeneities of the vegetation structure. The ecotones are found out at the junction of forest, steppe zones and under the conditions of vertical belts at the regional level. Probably it is necessary to take into account as well historical-genetic peculiarities of the formation of vegetation in a concrete region, actual physical-geographic conditions of a territory, actual state and dynamic trends of the coenoses while division of them onto types and classifying in order to increase impartiality while describing environmental phenomena and objects.

There is recently a new ecological branch positioned as ecotones ecology with establishment of ecotones systems of different organization level. However, there are no principles of subdivision of ecotones systems i.e., either these are genetic differences or division by heterogeneities of territorial subdivision of a geographic environment. For example, on the base of studies of evolution processes and of anthropogenic impact onto the development of sub-Arctic landscapes, a forest northern boundary is considered as a "regional geoecotone". Structural and functional organizations of ecotones systems resulted thanks to evolution is very important for the studies of global environmental changes. Main tasks of the studies of these systems nowadays are: typology, zoning and mapping with revealing process of ecotonization of biocenotic cover and of biospheric processes dynamics

The term "ecotone" is actively used in biogeography, biocenology, geobotany, ecology and geoecology. There are ecotones of different order and size – from marginal and interzonal to transcontinental ones. The problem of ecotones in interheight belts under the conditions of height belts for vegetation structure is considered rather in detail in the paper by P.L. Gorchakovsky, S.G. Shiyatov [26], which deals with phytoindication of the environmental conditions and natural processes illustrated by Ural mountain system. While analyzing the approaches for ecotones establishment presented by numerous researchers the authors state a wide rabge of opinions concerning the problem of classification of the vegetation at environmental contacts in mountains. As, in his opinion, transitional belts can consist of vegetation territorial units of different rank but always by one rank lower than boundary units, ecotone is interpenetration and combination of elements appropriate to contacting coenoses. An ecotone under mountainous conditions is a belt with any width but less that the width of boundary vegetation units.

The use of the term "ecotone" to reveal vegetation spatial organization for different physical-geographic conditions – zonal (interzonal), interheight belts and intrazonal ones is doubtfully an optimal solution for the characteristics of phytocoenoses in contrast environments. In this case, an attempt to reveal the dynamics and to determine a vector of environmental processes via vegetation structure as of an ecotone, as is presented in interpretations cited above, is very conventional.

Phytocoenoses reflecting paragenese (object) in vegetation structure

The notion "paragenesis" is used for characteristics of different environments from temporal viewpoint rather for a long time. For example, minerals paragenesis should be understood as a way of their coexistence [27, p. 21] due to their common origin [27, p. 9]. In the field of geography, "paragenetic" landscapes are mentioned first of all by F.N. Mil'kov [28], although this notion was used initially in the field of geology and concerned rocks, geological facies and formations. According to D.S. Korzhinsky [29], minerals paragenesis is regularly repeating under definite geological conditions "…minerals coexistence in a closed contact with each other" [29, p. 7].

Mastering this notion as a new knowledge field for characteristics of new phenomena (objects) causes some difficulties in understanding of matter, which a researcher is dealing with. It results partly in confusion, partly in misunderstanding of a process essence. For example, in the field of geography these difficulties are nor resolved yet. As there are discrepancies in the term sense, it is difficult to determine what are "paragenetic landscapes", "paragenetic landscape units", etc., and geographers paid to this phenomenon not enough attention. It is to notice here that in geology, where this notion just appeared, there were discrepancies as well. Geologists noticed that paragenesis determination has ambiguous term sense, for example, regular combination, generality, simultaneity, contiguity, etc. So, these definitions cannot explain unambiguously if any phenomen is a paragenesis or not. The attempts to resolve this problems often depend on the competence of researchers and on their ability to formulate and justify the regularities of combination, generality and simultaneity of origin. Construction of formal-logic schemes does not exclude any uncertainty but within strict aims limit and at concrete objects, such schemes can have positive results. Essence and specific of geographic paragenesis are presented in papers by F.N. Mil'kov [28], I.V. Krut' [30], A.Yu. Reteyum [31], D.L.Varleugin, Bazilevich [32] S.V. Vasilyev [33]. Determination of paragenesis as of common location and combination is an epistemological phenomenon as it implies common activity of "an object" and "a subject" [33].

Practical importance of this phenomena is a possibility to forecast availability and properties of some objects according to availability and properties of other ones. Paragenese is characteristic for different environments [31, 34, 35]. For example, paragenese of modern exogenic processes is understood as combination of several simultaneously occurring adjacent, adjoining or conjugate processes with a common boundary. There is genetic interlink of regional and local paragenesis resulting in formation of soils geochemical specifics – "paragenese" promoting formation of concrete biogeocoenoses manifesting biogeocoenotic function of a geological environment. Availability of paragenetic interlinks of direct and reverse interaction of conjugate environmental units is not denied either.

Principles of parageneses (object) characteristics we studied to characterize the structure of different environments allowed us to propose such interpretation for vegetation paragenese: "Paragenese represents systems of spatially conjugate regionally and topologically (or typologically) different phytocoenoses connected by common origin within vegetation zonal types (or height belts) during a definite time period on a concrete territory". This definition of paragenese (object) served as methodology of performed studies of a complex structural-dynamic organization of phytocoenoces of transitional type within vegetation types (often reflecting environmental zones) in the Baikal Region.

RESULTS

According to the studies results, we marked on a space photograph position of key sites where we found out phytocoenoses-ecotones and coenoses reflecting paragenese (object) in the structural-dynamic organization and spatial stratigraphy of vegetation in the Baikal Region (Fig.1).

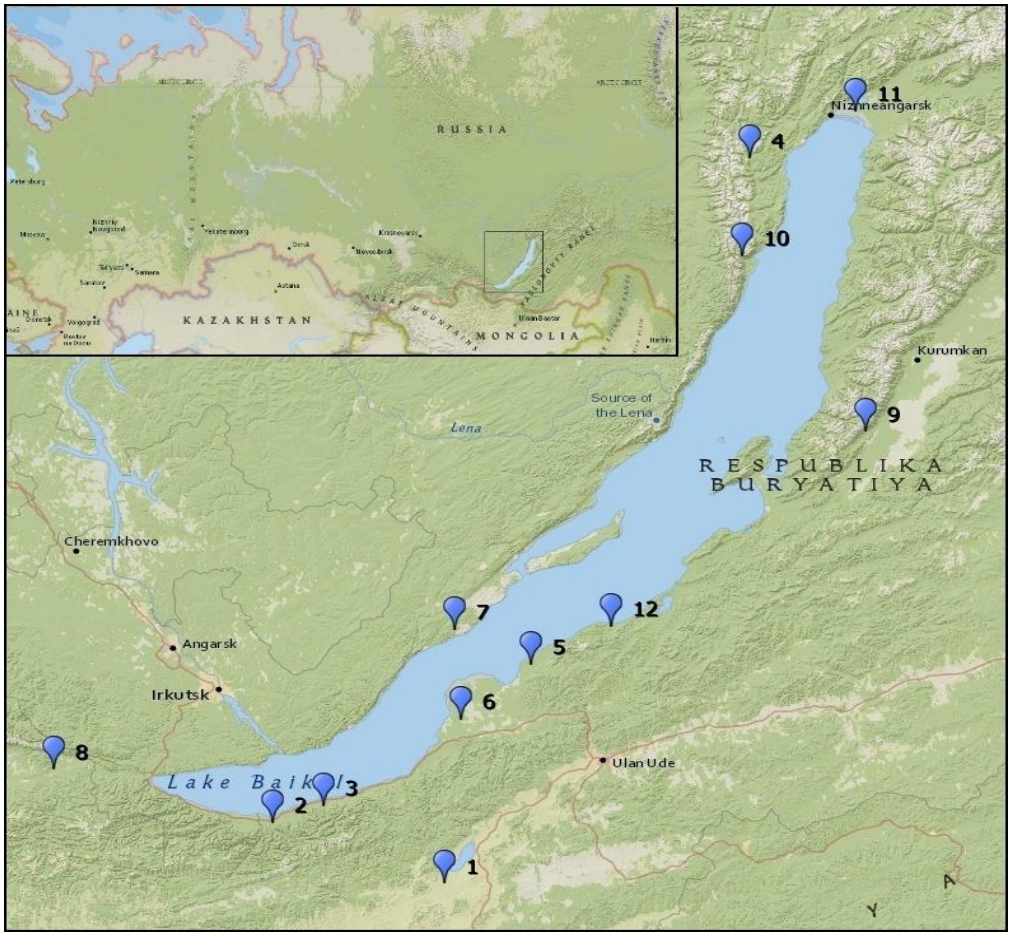

Figure 1. The studied areas: Ecotones: 1 – middle part of the Selenga R. basin, 2 – surrounding area of Osinovka mountain, 3 – surrounding area of Lysaya mountain, 4 – Davan pass, 5 – the Bol'shaya Sukhaya R. basin, 6 – the Bol'shaya Rechka R. basin. Paragenese: 7 – Pre-Ol'khon (western shore of Lake Baikal), 8 – Tunka Depression, 9 – Barguzin Depression, 10 – the Rel' R. basin (north-western shore of Lake Baikal), 11 – bar – Yarki Island (northern shore of Lake Baikal), 12 – central part of Lake Baikal shore.

Ecotones (basic characteristics of phytocoenoses-ecotones): The coenoses of the key site (Fig. 1, No 1) – middle part of the Selenga R. basin, South-Western Pre-Baikal, a territory at the junction of mountain forest-steppes and steppe zone of Central Asian (Daurian-Mongolian) sub-area of steppe area reflect an interzonal ecotone. This is seen from the results of the analysis of geoelemental, ecotypologycal (ecotypes) compositions, of belt-zonal groups of plant species and from composition of dominant families. By species composition the coenoses from the key site are more related to the forest-steppe zone but with presence of species from North Asian steppes. The territory of the studied area is characteristic by zonal forest-steppe soils. Climate changes during last decades in this region is manifested by humidity and temperature increase, and decrease of anthropogenic pressure favors both forestation of steppe areas within the forest-steppe zone (this is manifested on the territory around Monostoy Ridge, terrain Euy-Sutoy and Lake Gusinoye Depression) and expansion of trees into steppes zone. Thus, there are trends of forest-steppe zones shifting latitudinally with formation of light-coniferous forests of zonal type to this or that degree.

Phytocoenoses of the key sites around Osinovka mountains (Fig. 1, No 2), Lysaya mountain (Fig. 1,No 3) and upstreams of the Goudzhekit R. (Fig. 1, No 4) illustrate height belts ecotones characterizing variation of forest upper boundary due to climatogenic successions of vegetation under transitional environmental conditions in the region during last decades resulting from humidity and temperature change. This favors expansion of trees species into sub-goltsy belt and mountain tundra with formation of ecotones at the contact "forest – sub-goltsy belt", "firest – mountain tundra". Vegetation of the key sites – middle current of the Bol'shaya Sukhaya R. (Fig. 1, No 5) and the Bol'shaya Rechka R. (Fig. 1, No 6) illustrates formation of interheight belts ecotones and mountain systems

vegetation at well-developed height belts resulted from climatogenic successions of last decades and reflecting spatial differentiation of the belt of polydominant dark-coniferous – light-coniferous forests at the contact with the dark-coniferous highland belt. Humidity and temperature changes during last decades favors activation of replacement of polydominant dark-coniferous – light-coniferous taiga by dark-coniferous one. This is characteristic as well for the vegetation from other areas around Lake Baikal – Primorsky Ridge (Lake Baikal western shore), Onot upland and Olkha plateau (Southern Pre-Baikal), as well as for the boards of Barguzin and Tunka Depressions. The ecotones in the vegetation structure are coenoses reflecting the character of the relationship of vegetation zonal types (or height belts). Considerable variation of heat and moisture ratio results in change of the boundaries of environmental zones (or height belts) as of definite environments with spatial "widening" or "convergence" (under definite environmental conditions) of ecotones as interzonal (or interbelts) formations.

Paragenese (basic characteristics of coenoses reflecting paragenese (object)): Major part of plants species presented in geobotanical description of different years and of phytocoenoses from key sites reflecting paragenese in the vegetation structure and vegetation periods belong to dominant families (*Asteraceae, Poaceae, Cyperaceae, Fabaceae, Apiaceae, Brassicaceae, Ranunculaceae, Caryophyllaceae*). Such set of dominant families is characteristic for boreal floras and is similar with families spectrum for the East Siberian flora. The whole Holarctic area is characterized by dominant position of the families *Asteraceae* and *Poaceae.* Boreal floras are very characteristic by a considerable role of *Cyperaceae* and important one of *Ranunculaceae*. Floras continental features are manifested in the considerable role of the families *Brassicaceae, Rosaceae, Fabaceae*. A relative abundance of the species of *Caryophyllaceae* increases northward and reaches its maximum in the Arctic belt of Siberia. The families spectrum represents the most common peculiarities of the flora due to its zonal position (taiga zone). Genera spectrum in the whole shows as well the boreal character of the flora in the coenoses at the contact between taiga and zonal steppes in the Baikal Region. And a high position (number of species in the coenoses) of such genera as *Allium* and *Astragalus* increases towards the south of Siberia and reflects the specifics of regional-topological conditions of the environment of phytocoenoses formation in the region.
Soils compositions (in all the listed areas the soils are extrazonal - kryoarid) do not reflect any direct connection with phytocoenoses species composition and types. Both forest and steppe coenoses develop on the same soils, this was revealed at combined soil-geobotanical profiling of the key sites (Fig. 1, No 7-12). During last decades, the areas occupied by extrazonal steppe coenoses in the forests zone decreased, this suggests rather considerable climate changes and anthropogenic impact in the region. Forest coenoses with a rather sustainable reproduction, often with mosses synusia characteristic for polydominant dark-coniferous – light-coniferous taiga actively form among steppe areas (Fig. 1, No 7).

Particular coenoses, which are to be called taiga-steppe ones form under the conditions of steppes extrazonality and weakly manifested mountain-steppe and mountain-forest-steppe belts in the studied areas. Taking into account the peculiarities of the modern state and the vector of development of taiga-steppe coenoses in the studied area, we have to expect formation of light-coniferous taiga with further inclusion of dark-coniferous species as there are trends of activation of their positions (considerable presence of dark-coniferous species in the second synfolium and undergrowth) in the light-coniferous forests on the studied territories. However, these processes will be constrained by anthropogenic impact on the background of climate dynamics, mainly of moisture (Fig. 1, No 7).

Paragenese (object) occurs in the vegetation structure of the Baikal Region, it is manifested in two forms. First one occurs within of a definite vegetation type, when steppe coenoses consisting of plant species characteristic for two zonal vegetation types – forest (taiga) and steppe – form in the taiga zone. In the considered case this is the territory of the key sites – Pre-Ol'khon (Fig. 1, No 7), north-western shore (Fig. 1, No 10) of Lake Baikal, as well as Tunka (Fig. 1, No 8) and Barguzin (Fig. 1, No 9) Depressions. The second one occurs within a definite type of zonal vegetation, phytocoenoses of which include plants characteristic for numerous vegetation types (and height belts) of different environmental zones of Central Siberia. These are phytocoenoses characterizing paragenese in the vegetation structure of two key sites – bar of Yarki Island (Fig. 1, No 11) and the near-shore belt of the central part of the eastern shore of Lake Baikal (Fig. 1, No 12).

Light-coniferous forests together with steppe coenoses in the studied areas (Pre-Ol'khon, central part of the western shore of Lake Baikal; the Rel' R. basin, north-western shore of Lake Baikal; Tunka Depression, South-Western Pre-Baikal; Barguzin Depression, North-Eastern Pre-Baikal) are essentially common in the phytocoenogenese. The dynamics of such coenoses manifests the peculiarities of the development of vegetation at environments contact

(contrast environmental conditions) as reflection of paragenese in the regional vegetation structure. Under the conditions of paragenese (object), within environmental zones (or height belts) as of definite environments differing by heat and moisture ratio, a "restraint" of a natural object (for example, forestation of extrazonal steppes within a zonal taiga) during a concrete period in a concrete area when climate changes. This was noticed on the key sites of vegetation in the Baikal region such as Pre-Ol'khon (Fig. 1, No 7), Tunka (Fig. 1, No 8) and Barguzin (Fig. 1, No 9) Depressions, the Rel' R. basin (Fig. 1, No 10). Spatial "widening" of any natural object well occur as well in the case of increase of xerophytization (if the climate becomes drier) of vegetation in taiga zone as illustrated by coenoses of the northern shore (Fig. 1, No 11) and central part of the eastern shore of the lake (Fig. 1, No 12). Here among the coenoses of zonal mountain polydominant taiga there are plants species characteristic for the sub-goltdy belt (*Pinus pumila, Rhododendron aureum*), mountain tundra (*Phyllodoce coerulea, Cassiope ericoides, Empetrum nigrum*) and dry psammophytic (*Achnatherum splendens, Festuca lenensis*) steppes of North Asian type in integrated way.

Paragenese in the vegetation structure are coenoses reflecting the structure and the dynamics of environmental conditions at regional-topological level of environment organization within vegetation zonal types (or height belts) during a definite time period on a concrete territory.

CONCLUSION

Ecological and biocoenotic importance of the ecotones and the cenoses eflecting paragenese (object) in the vegetation structure means revealing of phytocoenotic and typological diversity of the coenoses, indication of structural-dynamic organization and forecast of vegetation development under concrete physical-geographic conditions on vast territories including zonal, height belts and intrazonal differences of the environments determining different degree of natural and anthropogenic resistence of the vegetation cover in general. Further studies of the vegetation structure under contrast environmental conditions (the coenoses at environments contact respond more rapidly to all climate changes and anthropogenic impact) on other territories adjacent to the Baikal Region and the whole territory of Central Siberia will allow to reveal the peculiarities of structural-dynamic organization of the coenoses at environments contact at the continental level. This will allow to forecast the vegetation development under different conditions of climate dynamics in space and time. A timely forecast of the trends in vegetation development allows to avoid probable degradation processes both in the vegetation cover and in the environments of different organization levels and will be useful for optimizing nature management in general.

Acknowledgement. The research was done by financial support of the grant no. 075-15-2020-787 of the Ministry of Science and Higher Education of RF for implementation of large scientific projects of priority directions of scientific and technological development (project title "Bases, methods and technologies for digital monitoring and forecasting of the ecological situation on the Baikal natural territory").

REFERENCES

1. Chebakova N.M., Renyfeild J., Parfyonova Ye.I. Re-distribution of vegetation zones and population of Siberian larch and pine in Central Siberia at climate warming // Sib. Ecol. Journal. – 2003. – Iss. 6. – PP. 677-686;
2. Holdrige L.R. The life zone system // Adansonia. – 1966. – T. 6. – fasc. 2. – PP. 199-203;
3. Bezdelova A.P. The peculiarities of Trans-Baikal zonal position as a base for development of the steppification of vegetation cover in the region // Steppes of North Eurasia. – Orenburg: "Gazprompechat'" Co., "Orenburggazpromservice" Ltd, 2006. – PP. 99-102;
4. Livingston B.E. The Distribution of the Upland Societies of Kent Country. – Michigan: Bot. Gas., 1903. – 35 p;
5. Clements F. E. Natural and structure of the climax // Journal of Ecology, 1936. – Vol. 24. – Iss. 1. – PP. 252-284;
6. Weaver J. Clements F. Plant Ecology. – New-York, 1929. – 601 p;

7. Walter H., Box E. Global classification of natural terrestrial ecosystems // "Vegetatio". – 1976. – Vol. 32. – Iss.2. – PP. 75-81;
8. Anthony M. Davis. The Prairie-Deciduous Forest Ecotone in the Upper Middle West // Annals of the Association of American Geographers. – 1977. – Vol. 67. – P. 204;
9. Katherine J. Hansen-Bristow., Jack D. Ives, John P. Wilson. Climatic Variability and Tree Response within Forest-Alpine Tundra Ecotone // Annals of the Association of American Geographers. – 1988. – Vol. 78. – PP. 505;
10. Naiman R., Decamps H., Fournier F. Role of Land/Inland Water Ecotones in Landscape Management and Restoration. Proposals for Collaborate Research. – MAB-Digest.4. UNESCO: Paris,1989.– 94 p;
11. Kullman L. Dynamics of altitudinal tree-limits in Sweden: A Review // Nor. Georg. Tidsskrift. – 1990. – Vol. 44. – PP. 103-116;
12. Holland M.M., Risser P.G., Naiman R.J. Ecotones. The Role of Landscape Boundaries in the Management and Restoration of Changing Environment. – N.Y., L., 1991. – 142 p;
13. Rusek J. Air-pollution-mediated changes in alpine ecosystems and ecotones // Ecological Application. – 1993. – Vol. 3. – P. 406-416;
14. Korner Ch. A re-assesment of high elevation tree line position and their explanation // Oecologia. – 1998. – Vol. 115. – PP. 445-459;
15. Bugmaqnn H., Pfister C. Impacts of inter annual climate variability on past and future forest composition // Reg. environ. Change. – 2000. – Iss. 1. – PP. 112-125;
16. Holtmeie F.-K. Mountain Timberlines: Ecology, Patchiness and Dynamics. – N.-Y.: Springer, 2009. – 438 p;
17. Bossuyt B., Martin Hermy and Jozef Deckers. Migration of herbaceous plant species across ancient-recent forest ecotones in central Belgium // Journal of Ecology. – 1999. – Vol. 87. – P. 629;
18. Royce, E.B. Mediterranean climate effects. Conifer water use across a Sierra Nevada ecotone / E.B. Royce, M.G. Barbour // American Journal of Botany. – 2001. – Vol. 88. – PP. 911-918;
19. Kharuk V.I. Tree vegetation climate-driven changes within ecotones in Siberia // Proceeding of the Intern Confer. "Boreal forests in a changing world: challenges and needs for actions", 2011. – PP. 219-222;
20. Chen X.-W. Modeling the effects of global climate change at the ecotone of boreal larch forest and temperate forest in Northeast China // Climate Change. – 2002. – Vol. 55. – PP. 77-97;
21. Sofie Sjogersten., Benjamin L. Turnert, Nathalie Mahieut, Leo M. Condrons, Philip A. Wookey. Soil organic matter biochemistry and potential susceptibility to climatic change across the forest-tundra ecotone in the Fennoscandian mountains // Global Change Biology. – 2003. – Vol. 9. – PP. 759;
22. A. Joshua Leffer., Martyn M. Caldwell. Shifts in depth of water extraction and photosynthetic capacity inferred from stable isotope proxies across an ecotone of *Juniperus osteosperma* (Utah juniper) and *Artemisia tridentate* (big sagebrush) // Journal of Ecology. – 2005. – Vol. 93. – P. 783;
23. Friedrich-Karl Holtmeir., Gabriele Broll. Sensitive and response of northern hemisphere altitudinal and polar tree lines to environmental change at landscape and local scales // Global Ecology and Biogeography. – 2005. – Vol. 14. – PP. 395;
24. Julio Camarero., Emilia Gutierrez, Marie-Josee Forth. Spatial patterns of plant richness across tree line ecotones in the Pyrenees reveal different locations for richness and tree cover boundaries // Global Ecology and Biogeography. – 2006. – Vol. 15. – PP. 182;
25. Thorsten Wiegand, J. Julio Camarero, Nadja Ruger, Emilia Gutirrez. Abrupt population changes in tree line ecotones along smooth gradients // Journal of Ecology. – 2006. – Vol. 94. – PP. 880;
26. Gorchakovsky P.L., Shiyatov S.G. Phytoindication of Environmental Conditions and Processes in High Mountains. – Moscow: Nauka, 1986. – 209 p;
27. Fersman A.Ye. Geochemistry. – Leningrad: Onti-Khimtheoret, 1937. – V. 3. – 503 p;
28. Mil'kov F.N. Natural zones of USSR. – Mysl', 1964. – 325 p;
29. Korzhinsky D.S. Theoretical Basis of the Analysis of Minerals Paragenesis. – Moscow: Nauka, 1973. – 288 p;
30. Krut' I.V. Introduction in Common Earth Theory. Levels of Geosystems Organization. – Moscow: Mysl', 1978. – 367 p.
31. Reteyum A.Ye. About paragenetic landscape units // All-Union Geographic Society Publishing House. – 1972. – V. 104. – Iss. 1. – PP. 17-20;
32. Verlygin D.L., Bazilevich N.I. Links of production of zonal vegetation formation worldwide with some climate parameters // News of USSR AS. Series geogr. – 1992. – Iss. 1. – PP. 23-32;

33. Vasilyev S.V. Paragenesis // Forest and Swamp Landscapes of West Siberia. – Tomsk: RAS SB Scientific and Technical Literature Publishing House, 2007. – PP. 24-29.
34. Grishankov G.Ye. Paragenetic systems of environmental zones (illustrated by Crimea) // Systematic Studies of Nature. – Moscow: Nauka, 1977. – PP. 128-139.
35. Kulikov A.I., Bazhenov V.S., Ivanov N.V. Soils Paragenesis and paradynamism. – Ulan-Ude: RAS SB BSC Publishing House, 2006. – 280 p.