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Assessment of the State of Vegetation and Prognosis of Its Anthropogenic Dynamics in Specially Protected Nature Areas on the Basis of Phytoecological Mapping

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Abstract—Methodological approaches to the construction of phytoecological maps are described regarding specially protected nature areas and their specific features. Such maps offer new possibilities for the assessment and analysis of current and predicted states of vegetation.

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Key words: nature reserves, vegetation, current state, anthropogenic transformation, phytoecological mapping.

Traditional measures to conserve phytodiversity by establishing a network of specially protected natural areas (SPNA)—nature and biosphere reserves, national parks, game reserves, etc.—do not offer a final solution to this problem. Since scientific research, economic activities, guided tours, etc., take place within these areas, their plant cover undergoes transformation accompanied by simplification of its structure, impoverishment of the flora, invasion of anthropophytes and apophytes, and increase in the proportion of secondary communities at the expense of primary communities. Therefore, it is necessary to perform a detailed study on trends in the anthropogenic transformation of vegetation in SPNA, to organize phytomonitoring, and, on this basis, to develop measures aimed at conserving phytodiversity at the floristic and cenotic levels and reducing the adverse effect on human activities on phytocenoses.

Phytoecological mapping is an effective method for revealing, imaging, and analyzing trends in the anthropogenic transformation of vegetation. It is based on the study of plant cover heterogeneity, environmental connections, and dynamic tendencies. Phytoecological maps provide information on the consequences of anthropogenic impact on the vegetation and environment of a certain area, the current state of various typological divisions and territorial complexes of vegetation, and conditions and tendencies of their transformation, which is presented in a concentrated and readily analyzable form (Gorchakovskii et al., 1995, 2000). To construct a phytoecological map, it is necessary to determine the composition of primary, secondary, and cultivated vegetation; estimate the degree of anthropogenic disturbance for different categories of plant communities; develop scales reflecting the degree of transformation; and perform a cartometric analysis of vegetation compartments.

In addition, phytoecological mapping of SPNA involves new tasks accounted for by specific features of these objects of nature. In the first place, this concerns the necessity to preserve unique plant communities, populations of rare plants, and phytodiversity in general by harmoniously combining the maintenance of the nature-conservation regime with scientific, educational, and economic activities.

METHODOLOGICAL APPROACHES TO PHYTOECOLOGICAL MAPPING

Methods and ways to construct phytoecological maps are considered here with regard to our studies in the Il'men Reserve, the Southern Urals. This reserve is of special interest from the nature-conservation standpoint, since it accommodates habitats of unique mountain steppe communities (Gorchakovskii and Zolotareva, 2004) and populations of rare plants, including endemic and relict species (Gorchakovskii et al., 2005).

The work on constructing phytoecological maps of the Il'men Reserve (more accurately, of a key plot within the reserve) may be used as an example illustrating methodological approaches to phytoecological mapping of SPNA.

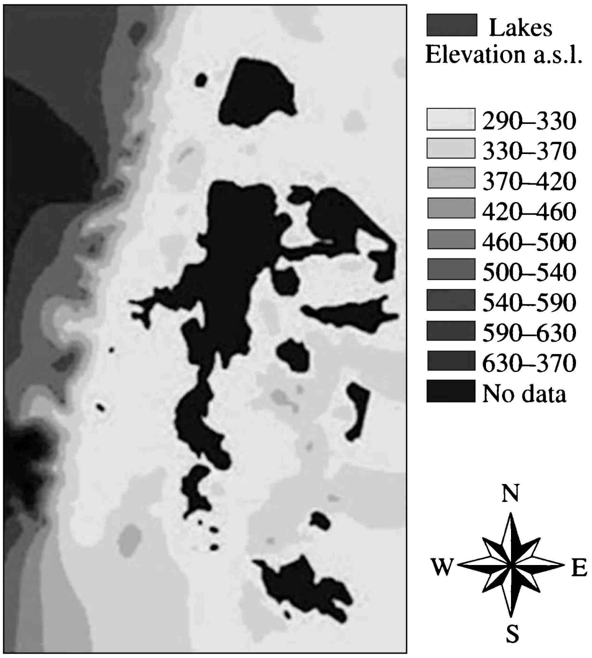

Fig. 1. Digital terrain model of the key plot in the Il'men Reserve.

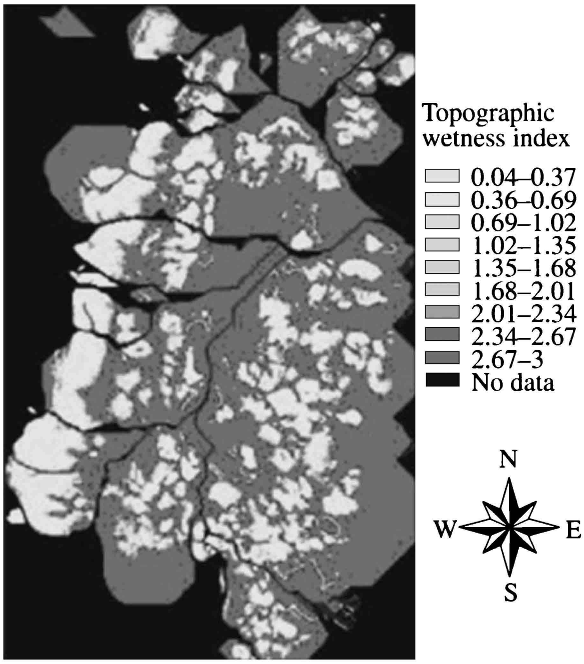

Fig. 2. Raster layer "Topographic wetness index."

Stage 1: Revealing the Dependence of Plant Community Distribution on Terrain and Moistening Conditions

With this purpose, a hydrologically correct digital terrain model of the study area was constructed with the ArcInfo 8.3 program (Fig. 1). We used the ArcView SINMAP application (Pack et al., 1996) intended for mapping the slope stability index on the basis of geographic information (mainly on the digital terrain model). The slope stability model takes into account that a high soil moisture tends to occur in convergent hollow areas. As a result, we obtained seven raster layers providing information on slope steepness, moisture supply in different topographic elements, etc. In our case, of special interest is the layer "Topographic wetness index" (Fig. 2). Its values below 1.02 and above 2.01 correspond to areas with low moisture content and to the saturation zone (permanently moistened areas), respectively; values between 1.02 and 2.01 indicate a saturation threshold (i.e., areas that can become saturated).

This raster layer provides evidence for segregation of the reserve area into compartments with different levels of moistening. By surveying this area in a west–east direction, five meridionally oriented compartments (plots) can be distinguished: (1) dry areas topographically coinciding with the Il'men Ridge; (2) a saturation zone topographically coinciding with the Zerkal'noe Bog and the Nyashevka River valley; (3) dry low-hill areas separated by the Nyashevka River and Shtannaya Kur'ya Bay; (4) a saturation zone occupied by Bol'shoi Tatkul' and Bol'shoe Miassovo and by the Klyukvennoe Bog; and (5) a broad, weakly moistened strip with scattered moisture-saturated sites between lakes Baraus, Bol'shoe Miassovo, and Malyi Kisegach.

On the basis of these data, we set up a network of transects for the study of vegetation. To take into account the entire diversity of plant communities and estimate their dependence on hydrologic factors, parallel transects (0.5 km apart from each other) were established so as to cross areas with different levels of moistening. They extended in a west–east direction in compartments 1–3, in a southwest–northeast direction in compartment 5, and from the periphery of lakes to their centers in compartment 4.

Stage 2: Constructing Maps of Present-Day and Potential Vegetation

Using ecophytocenotic criteria, we developed a classification of steppe, forest, meadow, bog, and riparian–aquatic vegetation, which was used to compile a provisional map legend. On this basis, a map of present-day vegetation was constructed (Fig. 3).

An analysis of tendencies in the dynamics of plant cover was based on the concept of epitaxon. According to Sochava (1978, 1979), the epitaxon is a dynamic whole that includes derivative components (states) subordinate to the maternal component (core), which has been formed under environmental conditions optimal for its development. Since the study area naturally segregates into two parts with different environmental con-

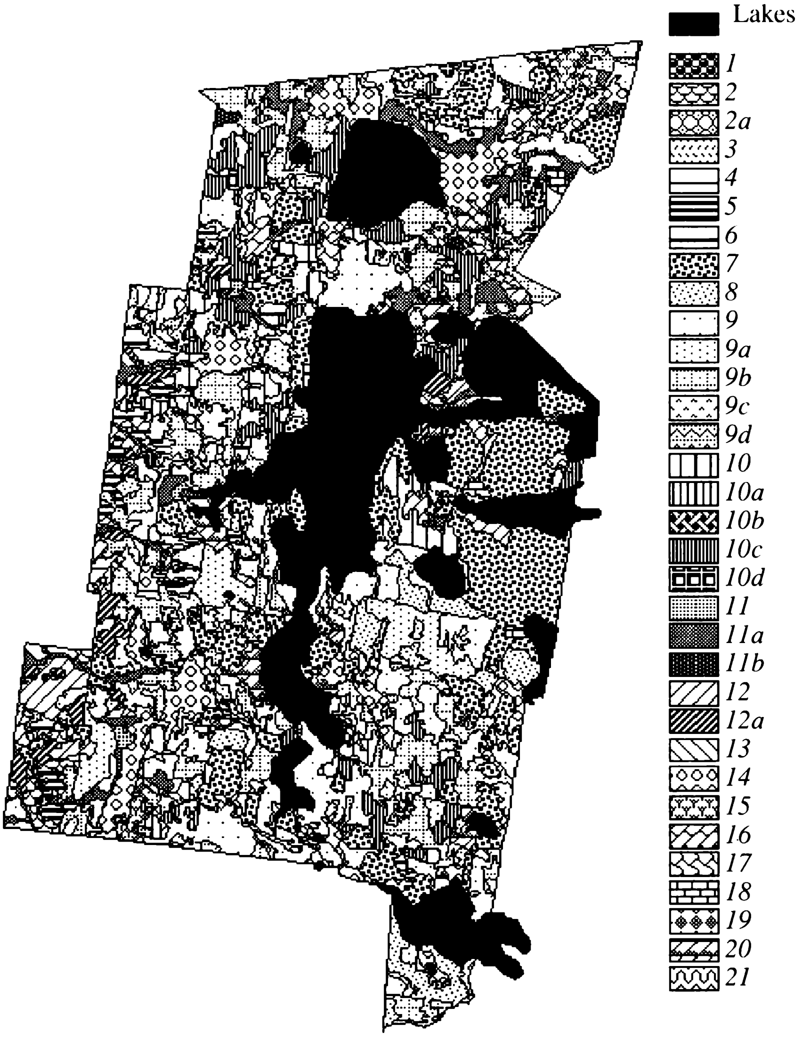

Fig. 3. Present-day vegetation map of the key plot in the Il'men Reserve: (*1–3*) steppes and steppificated meadows; (*4–11*) light conifer (*Pinus sylvestris, Larix sibirica*) forests, including open forests; (*12*) subtaiga broadleaf–conifer (*Pinus sylvestris, Tilia cordata*) forests; (*13*) broadleaf (*Tilia cordata*) forests; (*14, 15*) small-leaf (*Betula pubescens, Alnus incana*) forests; (*16–19*) bogs; (*20, 21*) riparian and aquatic communities. Secondary communities as subordinate to primary communities are designated in the legend by primary community numbers with alphabetic indices.

ditions (the foothill and mountain parts), an individual scheme of epitaxon was constructed for each part (Figs. 4, 5).

In the former part (the eastern foothills of the Il'men Ridge), the core of the epitaxon is formed by green moss pine forests (*Pinus sylvestris–Calamagrostis arundinacea + Vaccinium vitis-idaea + Vaccinium myrtillus–Pleurozium schreberi + Hylocomium splendens*), which are best represented in the region of Lake Baraus. In the mountain part, the core is represented by herbaceous pine forests (*Pinus sylvestris–Rubus saxatilis + Carex lasiocarpa + Calamagrostis arundinacea*), which occupy 20% of its total area.

Tendencies in the anthropogenic transformation of vegetation that are reflected in the schemes of epitaxa provide an idea how the recovery of anthropogenically disturbed plant communities would proceed under the same climatic conditions but without any anthropogenic load. This process would apparently follow the same transformation series but in reverse order, with secondary communities being replaced by corresponding primary communities. With regard to these tendencies, the map of the present-day vegetation was transformed into the map of future vegetation, a fragment of which is shown in Fig. 6.

Stage 3: Mapping the Levels of Anthropogenic Transformation of Plant Cover

The degree to which ecosystems in different parts of the study region are disturbed by human activities is reflected in the index of anthropogenic transformation of vegetation (*AT*). This index is calculated as the ratio

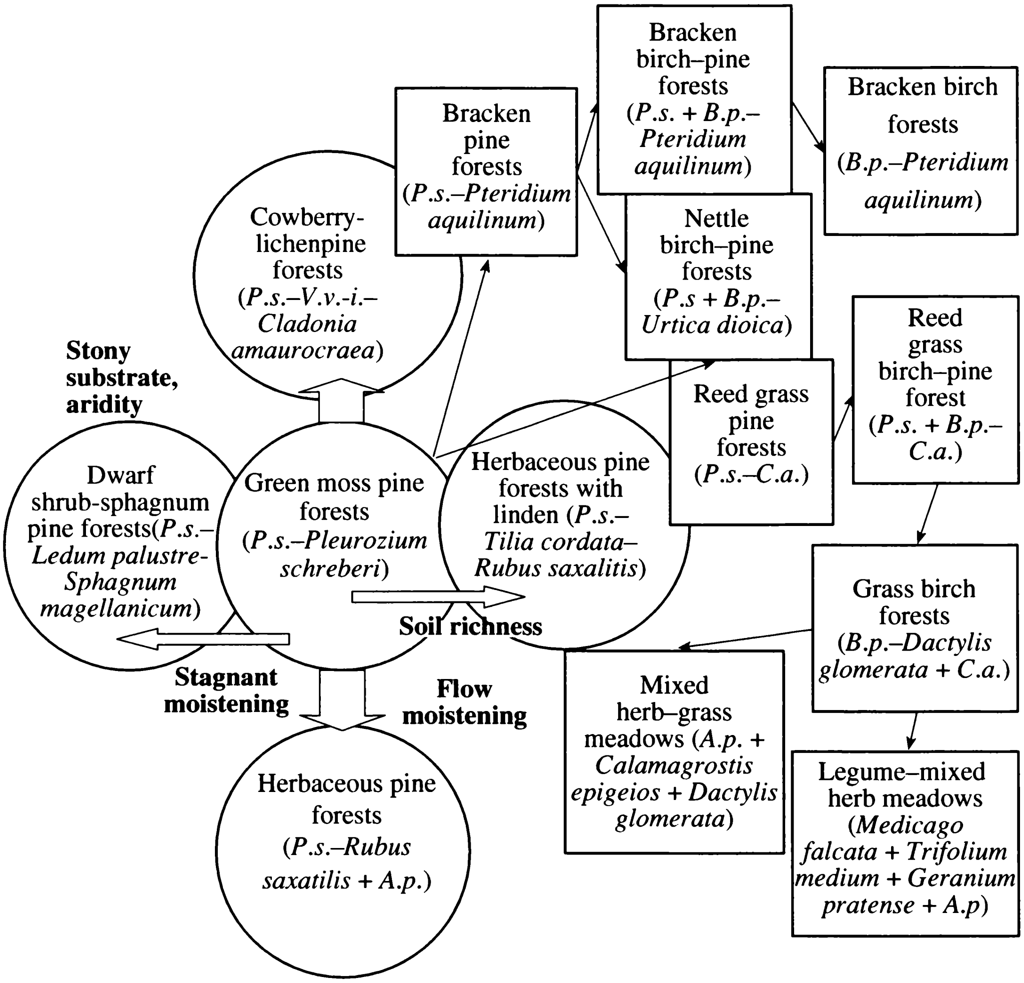

Fig. 4. Epitaxon of the eastern foothills of the Il'men Ridge, with serial variants placed in circles and anthropogenic transformation series in rectangles. Abbreviations: *P.s., Pinus sylvestris*; *B.p., Betula pendula*; *V.v.-i., Vaccinium vitis-idaea*; *C.a., Calamagrostis arundinacea*; *A.p., Aegopodium podagraria.*

of the area under transformed vegetation of any type, either secondary (*Ss*) or cultivated (*Sc*), to the total area of the region (*S*): $AT = (Ss + Sc)/S \times 100$ (Gorchakovskii et al., 2003).

The level of disturbance of natural vegetation is determined on the basis of phytoecological differentiation of the study area into territorial complexes or functional zones.

Estimating the Level of Vegetation Disturbance within the Framework of Territorial Complexes

After analyzing topographic and geological maps and the digital terrain model computed with the ArcInfo 8.3 program, we divided the study area into two meridionally oriented landscape regions, the Il'men Ridge and its eastern foothills. The Il'men Ridge within the study area was further divided into two parts, northern (with relatively flat slopes) and southern (with steep slopes). The eastern foothills, in turn, were divided into three parts: the Nyashevka River valley, lakes with lake depressions, and tall cliffs with steep slopes and rock outcrops. Thus, we identified a total of five territorial complexes (TCs), or groups of sites with distinctive landscape features.

(1) Severo-Il'menskii TC occupies low elevations (500–520 m a.s.l.) in the northern part of the Il'men Ridge with a relatively weakly dissected topography. Typical rocks are gneisses (biotitic, bimicaceous, and amphibolic) and granite gneisses accompanied by alkaline and biotitic syenites. Vegetation is characterized by the prevalence of steppificated open pine and larch–pine forests (*Larix sibirica + Pinus sylvestris–Artemisia sericea + Seseli libanotis + Calamagrostis arundinacea*), bracken pine forests (*Pinus sylvestris–Rubus saxatilis + Calamagrostis arundinacea + Pteridium aquilinum*), and mixed herb–reed grass pine forests (*Pinus sylvestris–Rubus saxatilis + Carex lasiocarpa + Calamagrostis arundinacea*), along with secondary

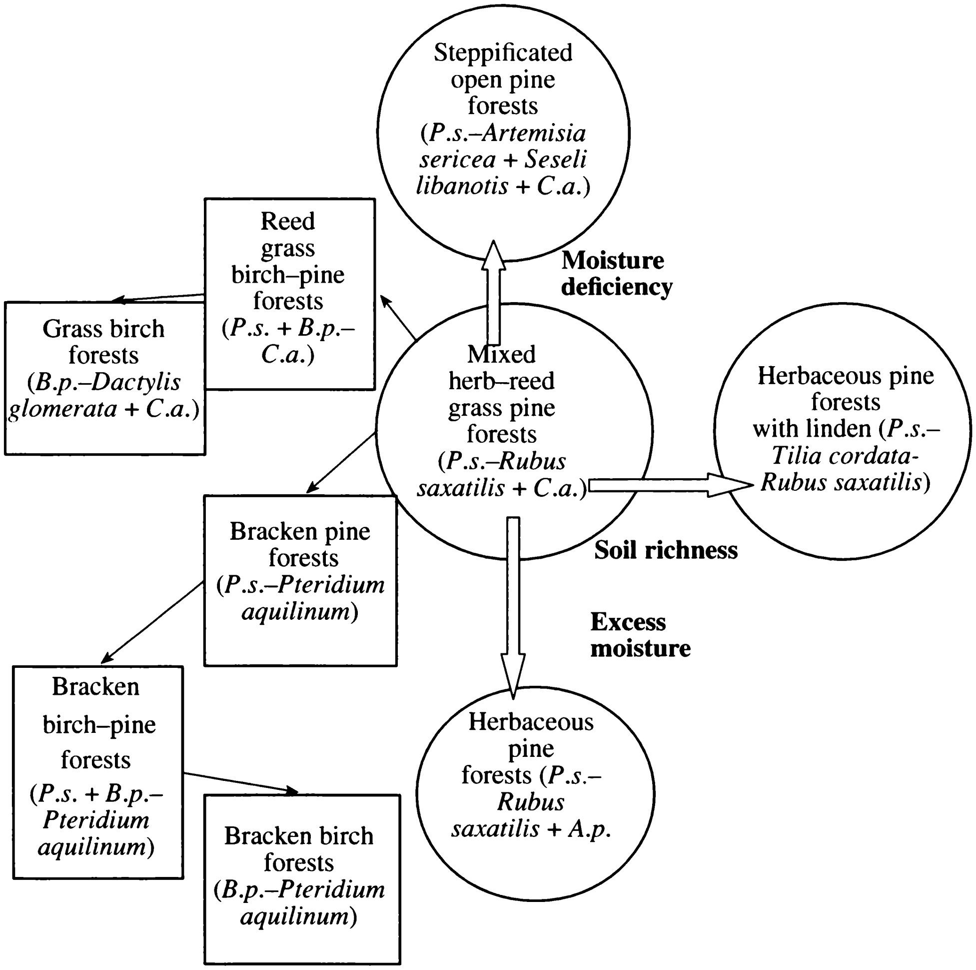

Fig. 5. Epitaxon of the Il'men Ridge, with serial variants placed in circles and anthropogenic transformation series in rectangles. For abbreviations, see Fig. 4.

(derivative) bracken birch forests (*Betula pendula–Aegopodium podagraria + Calamagrostis arundinacea + Pteridium aquilinum*) and mixed herb–grass birch forests (*Betula pendula–Rubus saxatilis + Dactylis glomerata + Brachypodium pinnatum + Calamagrostis arundinacea*).

(2) Yuzhno-Il'menskii TC occupies middle elevations (540–660 m a.s.l.) in the steep part of the Il'men Ridge composed of nepheline syenites and, along the margin, biotite syenites and syenite migmatites. In addition, this TC includes the Demidovskie Hills. The most widespread plant communities are herbaceous pine forests with linden (*Pinus sylvestris–Tilia cordata–Rubus saxatilis + Calamagrostis arundinacea + Aegopodium podagraria*), secondary herbaceous linden–birch forests derived from them (*Betula pendula + Tilia cordata–Lathyrus vernus + Calamagrostis arundinacea + Rubus saxatilis*), mixed herb–reed grass pine forests (*Pinus sylvestris–Rubus saxatilis + Carex lasiocarpa + Calamagrostis arundinacea*), and areas of meadow steppes (*Galium boreale + Artemisia sericea + Fragaria viridis* + mixed herbage) and steppificated meadows (*Inula hirta + Fragaria viridis + Artemisia sericea + Calamagrostis arundinacea*).

(3) Nyashevskii TC is in the intermontane depression (300–340 m a.s.l.) that narrows northward and is largely occupied by the Nyashevka River valley. Characteristic rocks are fieldspathic amphibolites, gneisses (amphibolic, amphibolic–biotitic, and quartzitic), and quartzites. In addition to sedge birch forests (*Betula pubescens–Carex cespitosa + Carex vesicaria + Carex elongata*), also widespread are mixed herb–reed grass pine forests (*Pinus sylvestris–Rubus saxatilis + Carex lasiocarpa + Calamagrostis arundinacea*) and secondary mixed herb–grass birch forests derived from them (*Betula pendula–Rubus saxatilis + Dactylis glomerata + Brachypodium pinnatum + Calamagrostis arundinacea*).

(4) Miassovskii TC (300–340 m a.s.l.) comprises lakes (Bol'shoi and Malyi Tatkul', Maloe and Bol'shoe

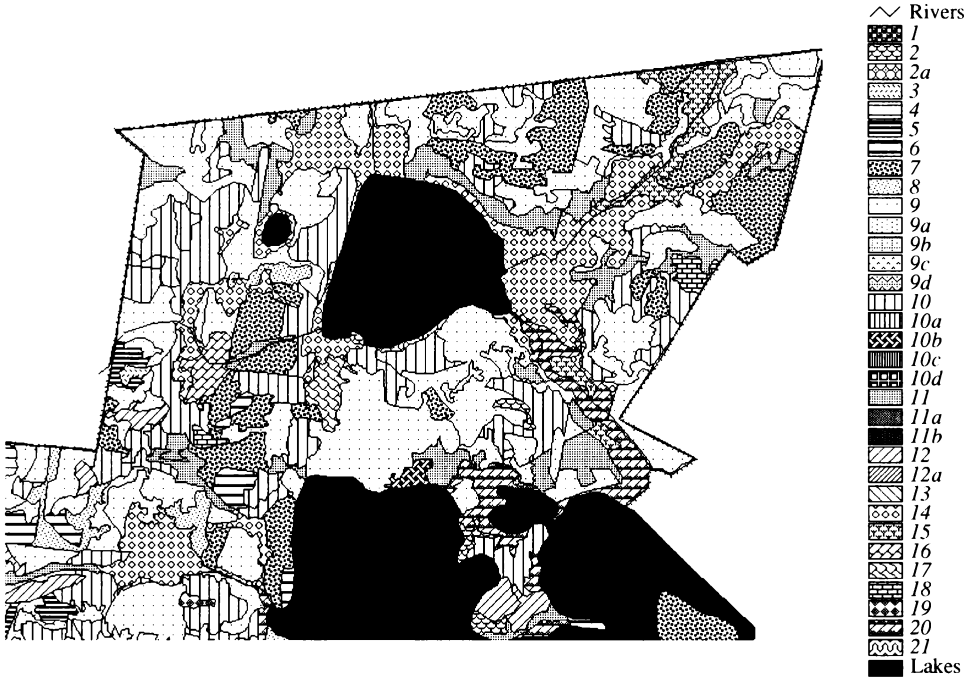

Fig. 6. Fragment of a map of potential vegetation. For designations, see Fig. 3.

Miassovo, Savel'kul', etc.) with lake depressions. Lacustrine–paludal and alluvial sediments such as quartz sands, shingle, and muddy clay (near Lake Tatkul') are typical of this TC. Prevailing plant communities include sedge birch forests (*Betula pubescens–Carex cespitosa + Carex vesicaria + Carex elongata*), reed beds (*Phragmites australis*), and herbaceous birch forests (*Betula pendula–Aconitum septentrionale + Heracleum sibiricum + Filipendula ulmaria + Aegopodium podagraria*).

(5) Vostochnyi (Eastern) TC comprises tall, steep cliffs (360–380 m a.s.l.) and rock outcrops in the eastern foothills of the Il'men Ridge. Main rock types include gneisses (biotitic, bimicaceous, muscovitic, and amphibolic), granite gneisses, quartzite gneisses, amphibolites, and, at the eastern margin, serpentinites. Characteristic plant communities are reed grass–dwarf shrub–green moss pine forests (*Pinus sylvestris–Calamagrostis arundinacea + Vaccinium vitis-idaea + Vaccinium myrtillus–Pleurozium schreberi + Hylocomium splendens*), mixed herb–reed grass pine forests (*Pinus sylvestris–Rubus saxatilis + Carex lasiocarpa + Calamagrostis arundinacea*), and mixed herb–grass birch forests (*Betula pendula–Rubus saxatilis + Dactylis glomerata + Brachypodium pinnatum + Calamagrostis arundinacea*).

A cartometric analysis of data on these TCs allowed us to determine the indices of anthropogenic transformation and propose a scale characterizing the level of vegetation disturbance in corresponding areas: weak ($AT < 10\%$), moderate ($AT = 10–33\%$), strong ($AT = 34–45\%$), or very strong ($AT > 45\%$). Figure 7 illustrates heterogeneity of the study region with respect to this parameter.

Estimating the Level of Vegetation Disturbance within the Framework of Functional Zones

The functional zoning of the study region was performed on the basis of a vegetation map with regard to the pattern and degree of anthropogenic impact on vegetation. As a result, three functional zones were identified: those of quietness, science–education activity, and economic activity. The quietness zone consists of six sites: the Il'men Ridge south of Mount Lysaya, within the Miassovskoe Forestry (for brevity, below referred to as Il'meny); the Demidovskie Hills (Demidovskie); the southern shore of Lake Tatkul' with steppe vegetation on Zmeinye Gorki hills and black alder forest on a quagmire (Zmeinye); the area with a high density of orchids northwest of Lake Bol'shoe Miassovo (Orchids); linden forest along the shore of Lake Bol'shoe Miassovo (Linden); and the north shore of Lake Malyi Kisegach (Kisegach), where unique plant communities grow. This zone accommodates part of the basic monitoring network and should be made accessible only to certified persons. The zone of economic activity comprises the vicinities of ranger stations Cheremshanka (two contours), Nyashevo, Savel'kul', Inyshko, Miassovo, and the Miassovo Field Station, with the last three sites being united into one contour.

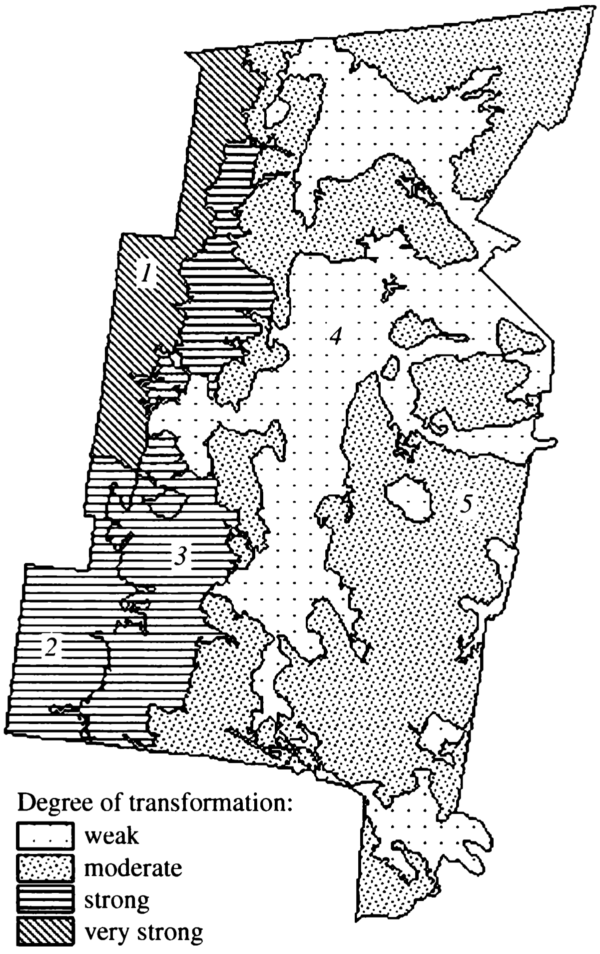

Fig. 7. Anthropogenic transformation of vegetation within territorial complexes (current state). For names of complexes (*1–5*), see the text.

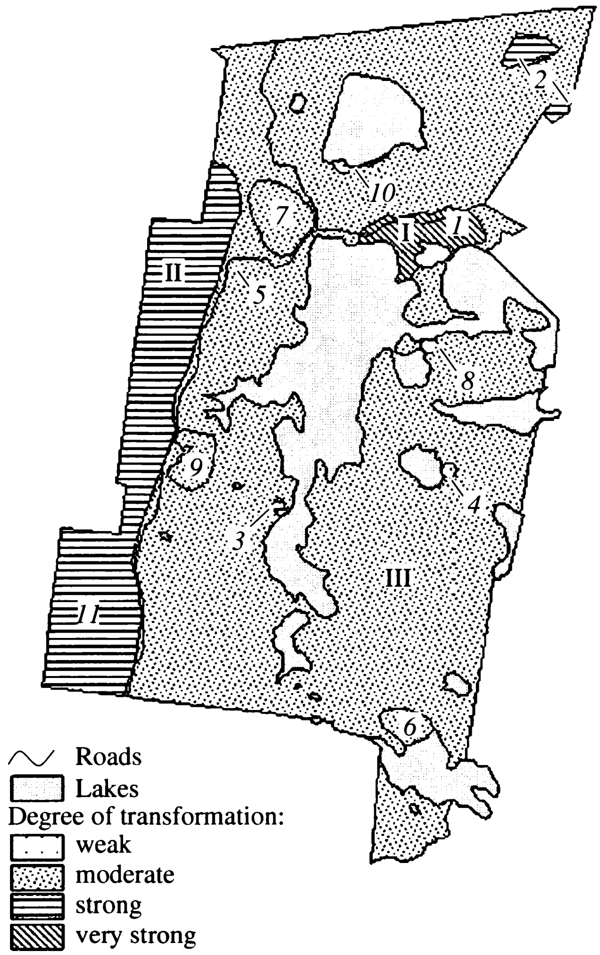

Fig. 8. Anthropogenic transformation of vegetation within functional zones (current state). Here and in Fig. 9, designations of zones and their fragments are the same as in the table.

Anthropogenic impact on this zone is considerable, as there are hay meadows, pastures, vegetable gardens, various buildings, etc. The remaining part of the study region is the zone of science–education activity, where scientific research is carried out and guided tours are allowed.

To estimate the state of vegetation in each functional zone, the index of anthropogenic transformation (*AT*) was used (Fig. 8). This index proved to have the lowest value (0) in the quietness zone, in Zmeinye and Linden, and the highest value (77%) in the economic activity zone near Miassovo. Demidovskie, Kisegach, and Orchids are transformed insignificantly (*AT* = 11–12%), and secondary communities occupying one-tenth of their area are represented by herbaceous birch forests with a pine understory. A low value of the *AT* index for Savel'kul' (9%) is explained by a relatively weak impact of fires and timber harvesting on the area between lakes Bol'shoe Miassovo, Baraus, and Savel'kul', where primary green moss pine forests have survived. Moreover, the Savel'kul' ranger station itself is small in area and remote from the boundary of the reserve, and the spectrum of synanthropic communities around it is scarce. The level of anthropogenic transformation is high in Nyashevo (37%), Cheremshanka (38%), and Il'meny (40%). In the last case, this is a consequence of timber harvesting prior to the establishment of the reserve. The necessity of including Il'meny in the quietness zone is explained by the fact that there are unique open larch and larch–pine forests and areas with steppe vegetation. Significant disturbances of plant cover in the science–education zone, where about 25% of communities are secondary, are also explained by timber harvesting prior to the establishment of the reserve.

Stage 4: Construction of Prognostic Maps and Other Maps Reflecting Specific Features of SPNA

Prognostic maps are made on the basis of data on trends in transformation of individual types of plant

Current and predicted states of vegetation

Functional zone	Current state			50-year prognosis under anthropogenic load								
				remaining unchanged			increasing by a factor of 2–3			increasing by a factor of 5–8		
	S, ha	incl. *Ss*, ha	*AT*, %	*S*, ha	incl. *Ss*, ha	*AT*, %	*S*, ha	incl. *Ss*, ha	*AT*, %	*S*, ha	incl. *Ss*, ha	*AT*, %
I. Economic activity	236.1	150.7	64	236.1	150.7	64	274.8	249.2	91	747.1	744.2	100
(1) Miassovo	161.8	124.3	77	161.8	124.3	77	199.8	183.3	92	340.7	340.7	100
(2) Cheremshanka	57	21.9	38	57	21.9	38	57	54.6	98	142	142	100
(3) Nyashevo	10.5	3.9	37	10.5	3.9	37	11.2	9.8	88	25.4	25.4	100
(4) Savel'kul'	6.8	0.6	9	6.8	0.6	9	6.8	1.5	22	6.8	3.9	57
(5) roads	0	0	0	0	0	0	0	0	0	232.2	232.2	100
II. Quietness	1520.2	529.4	35	1520.2	451.6	30	1520.2	451.6	30	1505.3	450	30
(6) Kisegach	50.8	5.8	11	50.8	5.8	11	50.8	5.8	11	50.8	5.8	11
(7) Orchids	131.5	16.1	12	131.5	16.1	12	131.5	16.1	12	127.9	16.1	13
(8) Linden	7	0	0	7	0	0	7	0	0	7	0	0
(9) Demidovskie	75.1	8.8	12	75.1	8.8	12	75.1	8.8	12	76.9	8.8	11
(10) Zmeinye	10.5	0	0	10.5	0	0	10.5	0	0	10.5	0	0
(11) Il'meny	1245.2	498.8	40	1245.2	420.9	34	1245.2	420.9	34	1232	419.4	34
III. Science–education activity	8678.1	2135.1	25	8678.1	1857.2	21	8639.4	1856.1	21	8182	1652.6	20

communities and their complexes depending on the intensity of external influences. They show probable states of vegetation in the SPNA after the next 50 years in the absence of significant climatic changes but at different anthropogenic loads: the same as today, two to three times greater, and five to eight times greater (table).

The first variant of the prognostic map, in which the anthropogenic load remains unchanged, shows that the *AT* index in the science–education zone and in Il'meny (the quietness zone) will decrease after 50 years due to the recovery of forest vegetation damaged due to previous timber harvesting.

The 50-year prognosis in the second variant is that a two- to threefold increase in anthropogenic load will result in expansion of the economic activity zone. In particular, a new contour (hay meadows) will appear at the bases of Demidovskie Hills (Nyashevo). These phytocenoses are not shown on the present-day vegetation map because of their small size, but they have been taken into account in calculating the *AT* index. The economic activity zone will also expand for 38.1 ha in the vicinity of Miassovo, with the majority of plant communities becoming secondary. The reduction of the science–education zone will be insignificant, and the quietness zone will remain unchanged.

A different picture will be observed upon a five to eightfold increase in anthropogenic load. As shown in the third variant of the prognostic map (Fig. 9), changes will occur in all three zones. In the economic activity zone, contours of main roads will appear; the areas of Miassovo and Nyashevo sites will increase by factors of 2 and 2.4, respectively; and contours in the Cheremshanka site will fuse. The *AT* index will reach 100% in most sites of this zone, except for Savel'kul' (57%). In the quietness zone, the area of the Orchids site will become 3.6 ha smaller under increasing impact from the nearby road. The same concerns Il'meny, where the road passes along the eastern boundary of the site. The Demidovskie Hills will also be affected by economic activity. To conserve unique steppe communities in this site, it is planned to expand the zone of quietness in its vicinities. Only Zmeinye, Kisegach, and Linden will remain unchanged. The *AT* index in the science–education zone will become lower, since not only secondary but also primary communities will enter the zone of economic activity.

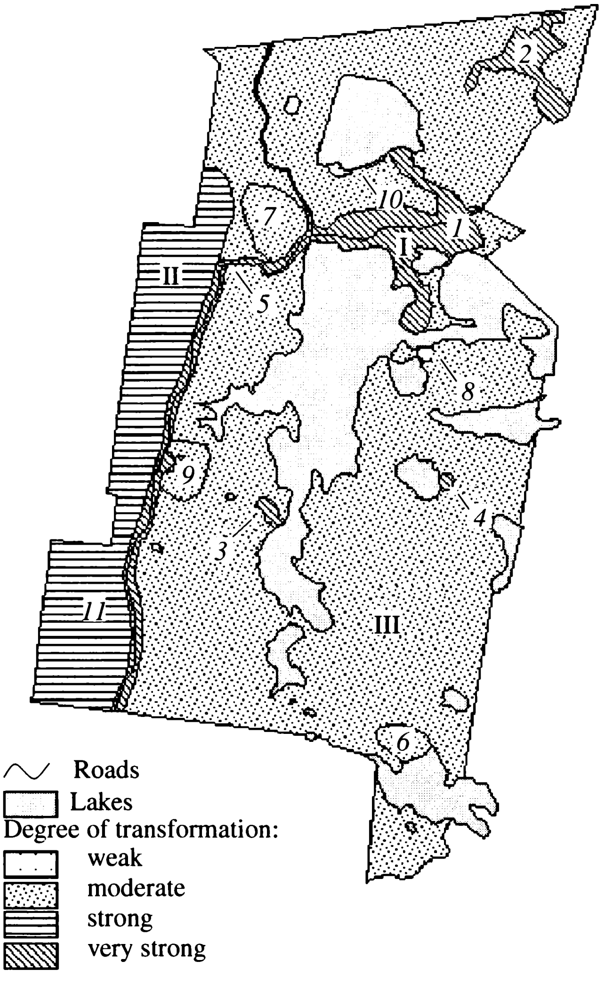

Fig. 9. Anthropogenic transformation of vegetation within functional zones (50-year prognosis with anthropogenic load increasing by a factor of 5–8).

Other maps (not shown here) provide additional information on the arrangement of the basic monitoring network, locations of unique plant communities and populations of rare species, migration pathways of anthropophytes, and plans for improving and developing research facilities and infrastructure of the reserve.

CONCLUSIONS

The construction of phytoecological maps is preceded by a detailed analysis of vegetation and relationships between plant communities and environmental factors such as topography, soil moisture conditions, etc. Special attention is devoted to anthropogenic transformation of plant communities, which is estimated from the proportions of apophytes and anthropophytes in phytocenoses. Geoinformation technologies are instrumental in studies on the distribution pattern of plant communities depending on environmental conditions.

Phytoecological mapping of SPNA involves construction of a series of maps reflecting the current and predicted states of vegetation with emphasis on the level of anthropogenic transformation of plant communities and their territorial complexes. In this process, the functional zoning of the study area is performed, and habitats of unique and reference plant communities and of rare and endangered plant species are identified and marked on the maps. The set of phytoecological maps contains ample information and provides a basis for planning and implementing measures to conserve the gene and cenosis pools of vegetation, laying foundations of phytomonitoring, reasonable arrangement of road networks, and developing research facilities and infrastructure of SPNA with the least possible disturbance to natural vegetation.

As follows from our studies, assessment of the state and dynamics of vegetation in SPNA yields more detailed and accurate information when performed within the framework of functional zones rather than territorial complexes.

REFERENCES

Gorchakovskii, P.L. and Zolotareva, N.V., *Reliktovaya stepnaya rastitel'nost' Il'menskikh gor na Yuzhnom Urale* (Relict Steppe Vegetation in the Il'men Mountains, Southern Urals), Yekaterinburg: Goshchitskii, 2004.

Gorchakovskii, P.L., Nikonova, N.N., Famelis, T.V., and Lyakhovich, E.M., *Fitoekologicheskaya karta Sverdlovskoi oblasti. Masshtab 1 : 1500000* (Phytoecological Map of Sverdlovsk Oblast, Scale 1 : 1500000), Yekaterinburg: AOZT UGSE, 1995.

Gorchakovskii, P.L., Nikonova, N.N., and Famelis, T.V., Phytoecological Map as a Means for Evaluating the State and Anthropogenic Transformation of Vegetation, *Ekologiya*, 2000, no. 6, pp. 411–418.

Gorchakovskii, P.L., Nikonova, N.N., and Famelis, T.V., Phytoecological Mapping: Methods, Principles, and Prospects, in *Botanicheskie issledovaniya v aziatskoi Rossii: Mat-ly XI s"ezda Russkogo bot. ob-va* (Botanical Studies in Asian Russia. Proc. XI Congr. Russ. Bot. Soc.), Barnaul: AzBuka, 2003, vol. 2, pp. 334–335.

Gorchakovskii, P.L., Zolotareva, N.V., Koroteeva, E.V., and Podgaevskaya, E.N., *Fitoraznoobrazie Il'menskogo zapovednika v sisteme okhrany i monitoringa* (Phytodiversity of the Il'men Nature Reserve in the System of Conservation and Monitoring), Yekaterinburg: Goshchitskii, 2005.

Pack, R.T., Tarboton, D.G., and Goodwin, C.N., SINMAP *User's Manual: A Stability Index Approach to Terrain Stability Hazard Mapping* (CD-ROM), Utah: Utah State Univ. Press, 1996.

Sochava, V.B., *Vvedenie v uchenie o geosistemakh* (Introduction to the Study of Geosystems), Novosibirsk: Nauka, 1978.

Sochava, V.B., *Rastitel'nyi pokrov na tematicheskikh kartakh* (Plant Cover on Thematic Maps), Novosibirsk: Nauka, 1979.