ISSN 1995-4255, Contemporary Problems of Ecology, 2012, Vol. 5, No. 7, pp. 621–632. © Pleiades Publishing, Ltd., 2012.
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Diversity and Protection of Korean Pine Broad-leaved Forests in the Manchurian Natural Area

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Received June 16, 2011

Methods for the ecological-geographical analysis of the Manchurian Natural Area are discussed to perform estimation of the contemporary state, monitoring, and conservation of the biodiversity of Korean pine broad-leaved forests. The models used for conservation of the mountain Korean pine broad-leaved forests in the transboundary areas of Russia, China, the Democratic People's Republic of Korea (DPRK), and the Republic of Korea should be based on the coordinated management of national resources. Estimating the ecological potential of Korean pine broad-leaved forests and the state and role played by forest ecosystems in the contemporary structure of the vegetation cover of the Manchurian Natural Area is significant for a more successful management of forests and scientifically grounded distribution of the nature reserves to conserve biodiversity. The united ecological-geographical system taking into account the regional peculiarities of forests can serve as a key in the development of the conservation of the biome.

Keywords: biome, biota, Manchurian Natural Area, Korean pine broad-leaved forests, geography of biodiversity, conservation of ecosystems

DOI: 10.1134/S1995425512070062

The specific features of the plant vegetation of southern Russian Far East were first observed in the second half of 19th century by K.I. Maksimovich [21, 22]. He generalized the results of the long-term studies of flora and vegetation of Manchuria and singled out the Manchurian Floral Region. This finding was later justified by V.L. Komarov [6], who paid much attention to studying the specific features of flora and vegetation, finding the boundaries of this phytogeographical area. In the contemporary system of phytogeographical subdivision, it is called the Manchurian Floral Province, which is included in the diverse Forest Japan–China Subarea within the East Asian Floral Area. The latter was singled out by A.L. Takhtadzhyan [27] in the Boreal Realm of the Holarctic Realm. According to the natural zoning of Siberia suggested by V.B. Sochava, this territory lies within the Amur-Sakhalin Natural Area [13]. It has the Manchurian complex (Manchurian phratry of formations) of nemoral plant formations reflecting the genetic homogeneity of the Manchurian flora and the vegetation of the regions, as well as similar landscape-geographical relationships between them [13]. The Korean pine broad-leaved forests of the mountain part occupy the central place in the Manchurian complex of formations.

In the monograph of Ma Ji [9], the Korean pine broad-leaved forests in China are related to the Boreal Forest Region, influenced by the monsoon climate. According to the phytogeographical zoning of China, pine broad-leaved forests are included in the category of temperate coniferous and mixed deciduous forests [28], which allows relating this territory to the United Manchurian Natural Area. Here, the following three regions are singled out: northern temperate oak (*Quercus mongolica*), Korean pine (*Pinus koraiensis*), and Korean pine broad-leaved forests, as well as three regions of southern Korean pine broad-leaved and broad-leaved forests with southern Manchurian elements and evergreen species of the subtropical flora.

All the above-given schemes provide similar specific features of the territory that arise, because it is located near the ocean in the Pacific monsoon zone. The northern border of the Manchurian Natural Area starts from Sovetskaya Gavan (49° N), then runs along the places where the habitats of the major Manchurian flora are mixed (Korean pine, Manchurian walnut, Amur cork tree, Manchurian ash, magnolia-vine, Amur grape, etc.). The southern border runs between 41° and 42° N along the shore, then falls up to 39° N in the mountain ranges, where the Manchurian deciduous forests gradually turn into the Japan-China forests. In the east, the area is limited by the Pacific shore [10] (Fig. 1).

The Manchurian natural area is physiogeographically homogenous. Here, the subdued and low roof-

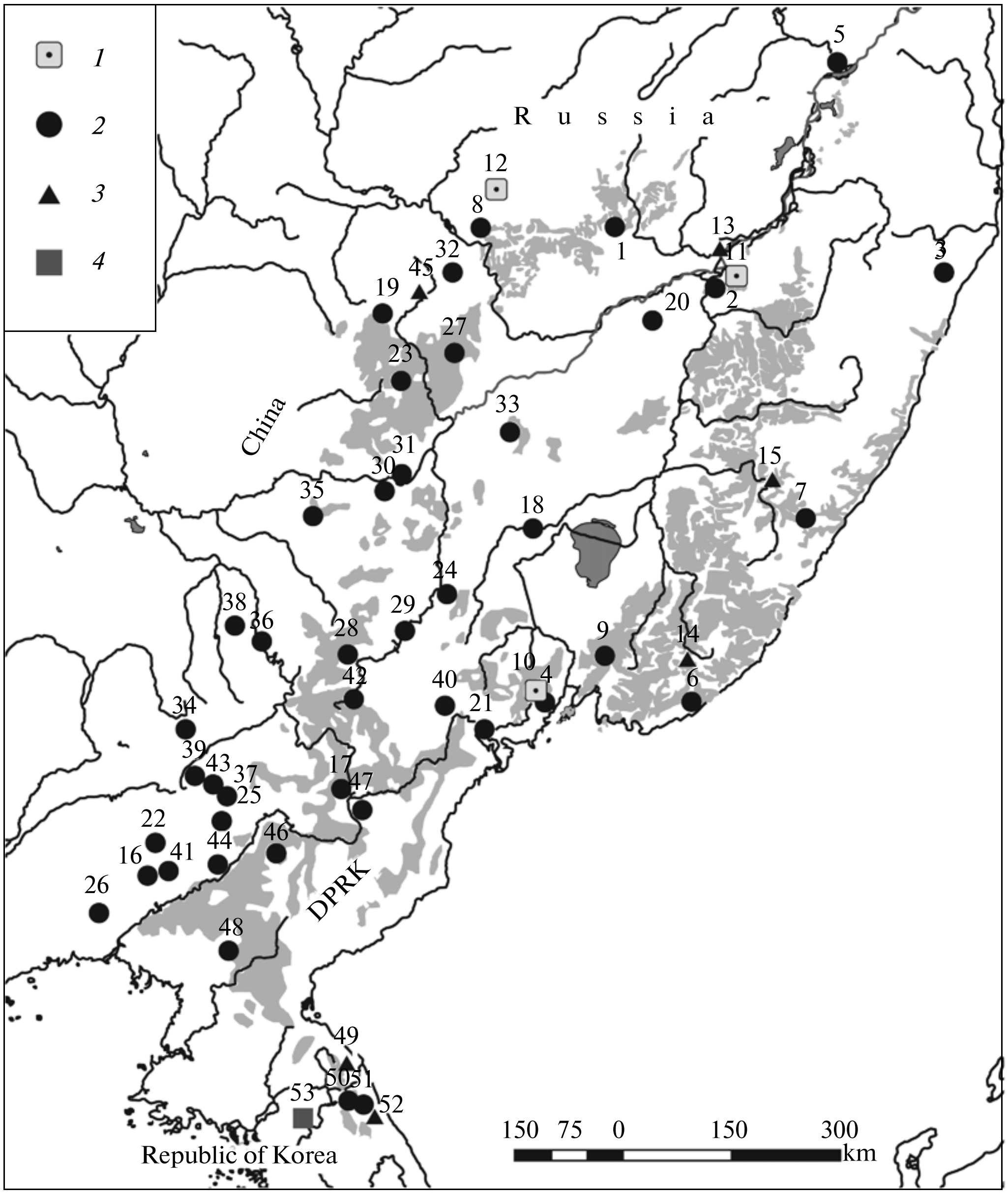

Fig. 1. Range of the Korean pine broad-leaved forests of the Manchurian Natural Area (according to [4] and [28]) and the natural protected areas protecting the forest ecosystems of the Manchurian complex of formations: (*1*) preserves, (*2*) reserves, (*3*) national parks, (*4*) landscape reserves.

block mountains (from 500 to 1500 m in absolute altitude) are combined with the accumulation-denudation plains and the intermontane depressions. In Russia, this area includes the following territories: the Sikhote-Alin mountain range with an average altitude of the hills of 650–800 m (the highest summit is Tordoki Yani, 2078 m), southern spurs of the Bureya Plateau, the Malchan-Kukanskaya mountain group to the south of the Badzhal Range with the summits of about 1000 m in elevation, the Pogranichnyi Range, and the Black Mountains. In China, the area involves the Lesser Khingan with an average elevation of the hills of 400–600 m (Pingdingshan, 1060 m) and the Eastern Manchurian mountain system with medium-altitude mountain ranges up to 1500–1800 m (Changbai (Baitoushan, 2747 m), Laolin, Zhanguankan, southern part of the Bureya Mountains, etc.). In the DPRK, it covers the Kvanmobong Mountains (Puksubeksan, 2520 m).

The climate of the Manchurian Natural Area is determined by the relationship between the air masses of Continental Eurasia and the vast water areas of the Pacific Ocean; it is humid. The area is a monsoon territory: in winter, it is influenced by the East Asian monsoon of northwestern direction for seven or eight months; in summer, it becomes influenced by the Pacific monsoon bringing moisture from the sea. The average annual amount of precipitation (maximum in summer) regularly falls in a westerly direction and ranges from 700–1000 mm in the southern mountains to 500 mm in the northern mountains. The average annual air temperature varies from –1.5°C to +6°C. The average temperatures in January are from –5°C in the south to –26°C in the north. The average temperatures in July are +20–24°C. The location near the ocean smooths over the temperature differences between the north and the south regions. The duration of the growing season and the production processes are significantly dependent on the effective heat sum ($\Sigma t > 10$°C from 1600 to 3200°C) and the number of days with the average daily temperature of >10°C (150–180) [23].

BIOTA

The rich and multiple floral and faunal structures of the Manchurian Area are determined by the repeated reorganizations in the natural complexes caused by the fall of temperature in the Pleistocene, on the one hand, and the tectonic processes (lowering of the edge-zone of the Asian Continent followed by the sea transgressions), on the other hand. In the Holocene, the mountain relief of the area helped to preserve the species of the tertiary thermophilic flora in the refuges.

The flora of the Manchurian Area includes about 2000 species [25]. There are many relict species that make it look archaic. The endemic species make up about 4%. The number of rare and endangered plant species is close to 300 [14]. The forests of the area are characterized by a diverse species composition. Thus, the number of tree and shrub species in the coniferous broad-leaved forests is about 350. This value is much higher than in the neighboring regions with boreal forests. The center of dendrofloral diversity lies within the southern complex of coniferous broad-leaved forests. Therefore, it determines their complex structure, high closure, and vertical species saturation [14].

The flora of Korean pine broad-leaved forests is dominated by the species belonging to the genera of the Asian temperate zone including southern regions of Siberia, Northeastern China, North Korea, and some regions of Japan [30]. The specific feature of this flora is the combination of nemoral and boreal value elements and the high number of relict species from either of these groups. The southern part of the habitat of the Korean pine broad-leaved forests is dominated by the species of the ancient Middle Tertiary China-Japan flora that survived during the Pleistocene glaciations in the refuges of the Far East, Southeast Asia, and western part of North America. Among them, the highest abundance is observed in the family Araliaceae. Common are *Shizandra chinensis*, *Phellodendron amurensis*, and *Syringa amurensis*. Among lianes, the species of *Actinidia* and *Dioscorea* are found. The relict species of the second group inhabited everywhere Europe, Siberia, the Far East, and South America. However, when the temperature fell, they migrated to the south, and some populations even became extinct. For this reason, many of these species either have disjunctive habitats or, inhabiting the Western Europe, are represented by specific forms and vicarious species (*Carpinus cordata—C. betulus, Quercus mongolica—Q. robur*, etc.). Some species have disjunctive habitats between the temperate latitudes of North America and East Asia (amphi-Pacific habitats of the genera *Weigela*, *Hydrangea*, *Deutzia*, *Jeffersonia*, *Magnolia*, etc.).

The fauna of the area under study is also diverse. A.I. Kurentsov [8] singled out five types of terrestrial fauna in the Amur River region. In his classification, the Amur River (or Manchurian) fauna was a special category. In general, the total number of endangered and protected species of vertebrate and invertebrate animals in Primorsky krai reaches 283 species, and 102 of them are endemic species. The Siberian and Okhotsk species inhabit the taiga and high-mountain belts. They are distributed in northern parts of the area and invade southern territories along the mountain ranges. Here, the most common mammals are the following: moose, brown bear, wolverine, sable, Siberian weasel, chipmunk, squirrel, and mountain hare. Among the Manchurian species, some predators (Siberian tiger, Amur leopard, Asian black bear, dhole, and Amur cat) and even-hoofed ungulates (Sakhalin musk deer, Ussuri sika deer, and Amur goral) occur. The insectivores inhabiting this territory are large mole (mogera) and Amur hedgehog. The reptiles and amphibians are not numerous in the forests; Sakhalin adder, Siberian salamander, and Siberian tree frog are found. Tiger keelback, Russian rat snake, and Far Eastern turtle are common in southern Primorye.

The following bird species are widespread in the forests: nutcracker, black-billed capercaillie, Siberian jay, and hazelhen. From the Okhotsk fauna, the following bird species inhabiting spruce forests are found: Siberian grouse, black hazelhen, and brown dipper. Willow ptarmigan inhabits the mountain regions of tundra. Coniferous broad-leaved forests are a habitat of many birds: Japanese nightjar, European roller, azure-winged magpie, Indian golden oriole, mandarin duck, Siberian grouse, Amur hazelhen, chestnut-cheeked starling, Oriental scops owl, leaf warblers, etc. In summer, herons, cranes, and black stork come back to the water bodies from the south. Insects are very important for the biodiversity of the region. Many of them are included in the Red Data Books.

Therefore, the biome of Korean pine broad-leaved forests is developed under certain zonal and altitude-zonal, bioclimatic and landscape conditions. Its specific features are determined by the dominance of the life forms mostly adapted to the inimitable combina-

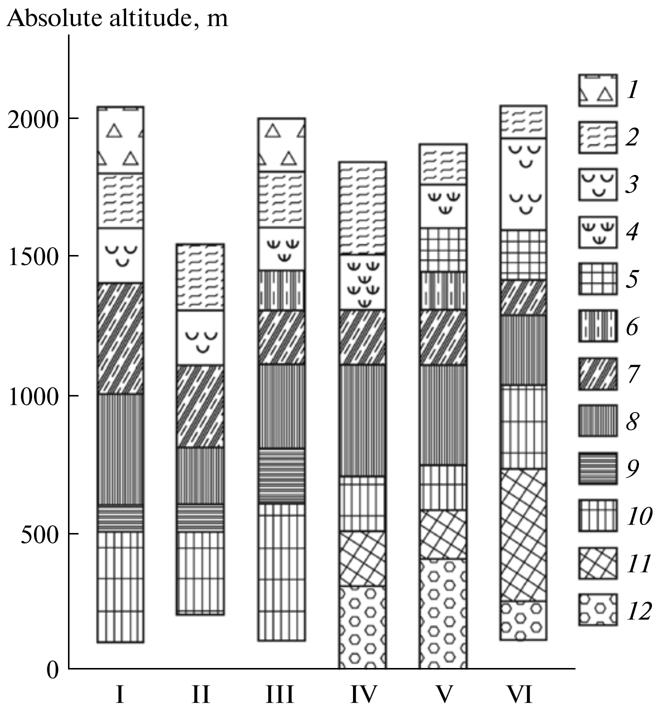

Fig. 2. Types of high-altitude vegetation belts of the Manchurian Natural Area: (I) Lesser Khingan, (II) Northern Sikhote-Alin, (III) Western Sikhote-Alin, (IV) Eastern Sikhote-Alin, (V) Southern Sikhote-Alin, (VI) Northern Changbaishan; altitudinal belts: (*1*) goltsy, (*2*) mountain tundra, (*3*) elfin wood, (*4*) microbiota, (*5*) high-mountain tree-shrub communities, (*6*) light birch forests, (*7*) light spruce, fir, larch forests and parks, (*8*) dark coniferous taiga, (*9*) Korean pine broad-leaved forests of high altitude, (*10*) Korean pine broad-leaved forests, (*11*) polydominant broad-leaved forests, (*12*) oak forests.

tion of climatic and landscape conditions that were either historically formed or transformed by humans. Among the complex of forest formations, the central position is held by the Korean pine broad-leaved forests with a compound multispecies composition of stand, as well as compound vertical and horizontal structure. The Korean pine (*Pinus koraiensis* Sieb. et Succ.) is the main edificator plant. Even though it is not dominant in forest communities, it is still of key value in the biocoenotic connections within the ecosystems of the Korean pine broad-leaved forests. The Korean pine is often mixed with the following broad-leaved trees: *Acer mono*, *A. tegmentosum*, *A. pseudosieboldianum*, *A. barbinerve*, *Tilia mandshurica*, *Phellodendron amurense*, *Ulmus macroparpa*, *U. montana*, and many other representatives of the Manchurian flora. The forest communities are dense and highly shaded owing to the broad-leaved species and have from five to seven layers, including the multispecies shrub layer, grass cover, and nonlayered vegetation. The forest composition along the valleys of mountain rivers is enriched through the plants that are common to the habitats with a higher moisture content: *Populus maximoviczii*, *P. koreana*, *Ulmus propinqua*, *Maakia amurensis*, *Padus maackii*, *Acantopanax sessiliflorum*, etc.

RANGE OF KOREAN PINE AND KOREAN PINE FORESTS

The Korean pine is a mountain tree growing at moderate and low altitudes of the mountain ranges (Fig. 1). A detailed description of its range is provided in several publications [5, 20, 23]. In general, the distribution of *Pinus koraiensis* in the north (continental mountainous areas) is limited to a great extent by the thermal conditions. In the south, the limiting factor is the moisture content [5]. The upper boundary of its distribution goes to an altitude of about 600 m. At the coast of the Strait of Tartary, *Pinus koraiensis* grows at altitudes not higher than 400–500 m. At the Khekhtsir and Samurskii ranges, it grows at the altitude of about 100 m and not higher. In the southern part of Primorye, the upper distribution boundary of *Pinus koraiensis* near the sea goes to the altitude of 900–1200 m. In moving away from the coast, it rises to 1100–1250 m. In the southern part of the range (East Manchurian mountains), it reaches 1500 m.

The belt of Korean pine broad-leaved forests at the Lesser Khingan occurs from the altitude of 600 m, in the basins of the Kura and Urmi rivers from 500 to 600 m, and in the basins of the Khungari and Anyuy Rivers up to the altitude of 200–250 m. However, some forests of *Pinus koraiensis* can grow higher, i.e., at an altitude of 400–500 m. Within the Sikhote-Alin, the belt of Korean pine broad-leaved forests is observed from the bottom of the mountain ranges to 500–600 m; on the southern sides of the hills, these forests grow at 900–1000 m (Fig. 2, table).

Within the range (from 39° to 52° N), the Korean pine broad-leaved forests are influenced by various bioclimatic conditions determined by the heat and moisture contents that are distributed in the mountains. Thus, every region has different types of Korean pine forests substituting for each other with respect to the climatic conditions; i.e., there are three types of climatic facies defined by B.P. Kolesnikov [5]: *northern Korean pine forests* with the share of Siberian coniferous trees and depletion of the Manchurian floral elements; *typical Korean pine forests* (without hornbeam) with the optimal conditions for the development of Korean pine broad-leaved forests; and *southern Korean pine forests* with the most thermo-mesophilic floral representatives, such as hornbeam (*Carpinus cordata*), prickly castor oil tree (*Kalopanax septemlobum*), Manchurian fir (or needle fir) (*Abies holophylla*), and yew (*Taxus cuspidata*). V.B. Sochava [13] placed great emphasis on the fact that the area under study is located near the ocean and is influenced by the summer monsoon. He singled out three important biogeographical borders. The first border demarcates the southern extremity of Primorsky krai and then

Natural protected areas protecting Korean pine broad-leaved and broad-leaved forests of the Manchurian Natural Area

No.	Natural protected areas	Year of foundation	Area: thous. ha	Object of conservation	Belt of Korean pine broad-leaved forests, m a.s.l.
				Russia Reserves	
1	Bastak	1997	91.8	Oak, Korean pine broad-leaved (Korean pine-linden) forests of the northern geographical facies with the Manchurian, Okhotsk, East Siberian elements in flora and fauna	200–250
2	Bolshekhekhtsirsky	1963	45.4	Korean pine broad-leaved forests of the northern geographical facies and their specific floral and faunal endemics	200–550
3	Botchinskii	1994	267.4	Korean pine broad-leaved forests of the northern facies, spruce-fir forests—habitats of the northern population of the Amur tiger, spawning areas of the salmons	50–300
4	Kedrovaya Pad	1916	18.0	Oak, broad-leaved, Korean pine broad-leaved forests with hornbeam, Manchurian fir broad-leaved forests of the southern complex of formations with diverse flora and fauna of rare and endemic species (more than 50 species)	300–400
5	Komsomol'skii	1963	64.4	Northern outpost of Korean pine broad-leaved forests of the northern facies and their specific complex of Manchurian, Okhotsk, and East Siberian flora and fauna	350–400
6	Lazovsky, named after L.G. Kaplanov	1957	121.0	Oak forests, liana coniferous broad-leaved and broad-leaved forests of the southern type, sometimes with hornbeam, yew, as well as rare and valuable species of animals and plants inhabiting this area, fir-spruce forests	200–800
7	Sikhote-Alin	1935	398.3	Oak, Korean pine broad-leaved forests of the typical geographical facies: mountain, valley, seaside Korean pine-spruce forests with broad-leaved species	200–600
8	Khingan	1963	97.1	Amur River forest steppe with wet meadows, oak forests, Korean pine broad-leaved forests of the northern geographical facies	350–400
9	Ussuri, named after V.L. Komarov	1932	40.4	Manchurian fir, Korean pine-spruce broad-leaved, and liana Korean pine broad-leaved forests of the southern geographical facies with the southern complex of relict floral and faunal species	200–600
				Preserves of federal significance	
10	Leopardovyi (union of preserves Barsovyi, 1979, and Borisovskoe Plato, 1996)	2008	169.4	Natural complexes of southern Primorye and habitats of the endangered Amur snow leopard and Amur wildcat. Oak, broad-leaved, Korean pine broad-leaved with hornbeam, Manchurian fir broad-leaved forests of the southern complex of formations with diverse flora and fauna consisting of rare and endemic species (more than 50 species)	300–400
11	Khekhtsirsky	1959	102.0	Rare and endangered animal species (Manchurian wapiti, musk deer, sable, Asiatic black bear, etc.) inhabiting the forests of the Lesser and Greater Khekhtsir, Korean pine broad-leaved of the northern geographical facies and spruce-fir forests	200–500
12	Khingan-Arkhara	1958	52.8	Rare and endangered species of animals (roe, Manchurian wapiti, Indian marten, Ussuri boar, sable, brown and black bears, etc.); Korean pine broad-leaved forests of the northern facies (western outpost), spruce-fir forests of the Southern Okhotsk complex of formations	350–400

Table. (Contd.)

No.	Natural protected areas	Year of foundation	Area: thous. ha	Object of conservation	Belt of Korean pine broad-leaved forests, m a.s.l.
				National parks	
13	Anyuiskii	2007	429.4	Oak, Korean pine broad-leaved forests of the typical geographical facies (mountain, valley), Korean pine-spruce forests with broad-leaved species. Habitats of the Siberian tiger, dhole, Amur wildcat, Asiatic black bear, spawning areas of red fishes	200–600
14	Zov Tigra	2008	82.2	Oak forests, Korean pine broad-leaved forests of the southern geographical facies. Protected species of the fauna; Siberian tiger, lynx, Amur wildcat, sika deer, roe, musk deer, Manchurian wapiti, boar, etc.	150–700
15	Udegeiskaya Legenda	2007	88.6	Oak, Korean pine broad-leaved forests of the typical geographical facies, mountain, valley, seaside Korean pine-spruce forests with broad-leaved species	200–600
				People's Republic of China	
				National reserves	
16	Baishilazi	1995	7.5	Broad-leaved forests, oak forests, and shrub communities of hazel and bush clover of the southern Manchurian complex of formations	400–1000
17	Changbaishan	1960	196.5	Virgin broad-leaved Korean pine (the age of Korean pine is about 500 years), oak forests of the southern Manchurian complex of formations	600–1100
18	Fenghuangshan (Heilongjiang)	2006	26.6	Oak, broad-leaved forests with Korean pine, mountain shrubs with meadowsweet and hazel-hornbeam of the Manchurian complex of formations	200–250
19	Fenglin	1958	18.4	Primary *Pinus koraiensis* and Korean pine broad-leaved forests of the typical geographical facies	280–680
20	Honghe	1984	21.8	Marsh lands in the Songhua River valley, valley broad-leaved forests	No data
21	Hunchun	2001	88.9	Oak, broad-leaved, and Korean pine broad-leaved forests with the Manchurian fir, shrub communities of hazel and bush clover of the southern Manchurian complex of formations	250–620
22	Laotudingzi	1981	15.2	Broad-leaved forests, oak forests, and shrub communities of hazel and bush clover of the southern Manchurian complex of formations	820–1200
23	Liangshui	1996	12.1	Coniferous broad-leaved forests of the typical geographical facies; plantations of cultures	300–700
24	Mudanfeng	1994	19.6	Broad-leaved, Korean pine broad-leaved, spruce-fir forests mixed with broad-leaved species of the southern complex of Manchurian formations; conservation of valuable bird species	350–600
				Provincial reserves	
25	Beidadingzi	1993	1.4	Oak, broad-leaved forests, and their industrial plantations	No data
26	Fenghuangshan (Liaoning)	2003	2.6	Korean pine broad-leaved forests of the typical goegraphical facies	250–450
27	Hebeihongsong-mushulin	1981	11.9	Korean pine broad-leaved forests of the southern geographical facies	300–600
28	Huangnihe (Jilin)	2000	23.5	Forest ecosystems of the Manchurian type of formations (oak, broad-leaved forests, fragments of Korean pine plantations)	800–1300

Table. (Contd.)

No.	Natural protected areas	Year of foundation	Area: thous. ha	Object of conservation	Belt of Korean pine broad-leaved forests, m a.s.l.
29	Jingbohu	1980	126.0	Primary Korean pine broad-leaved forests of the typical geographical facies	250–350
30	Lianhyachi	1997	190.0	Korean pine broad-leaved forests of the typical geographical facies, oak forests	250–350
31	Longkou	2002	28.0	Oak, Korean pine broad-leaved forests of the typical geographical facies	300–560
32	Maolangou	2003	47.2	Oak, Korean pine broad-leaved forests of the typical geographical facies, shrub communities of the Asian hazel, bicolor lespedeza, geological natural monuments	200–300
33	Qixinglazi	1990	33.0	Oak forests and communities of hazel and bush clover; habitats of the Siberian tiger, boar (numerous), roe, European red deer, lynx, etc.	200–400
34	Sanjiaolong	1990	8.1	Korean pine broad-leaved forest of the typical geographical facies at the western border of distribution and geological natural monuments	200–400
35	Songfengshan	1984	1.5	Oak and broad-leaved forests, fragments of Korean pine plantations	150–300
36	Songhuajiangsanhu	1990	1144.7	Oak and broad-leaved forests	No data
37	Tonghuashihu	1993	1.5	Oak forests and communities of hazel and bush clover	No data
38	Zuojia	1982	5.5	Oak and broad-leaved forests	No data
				District reserves	
39	Daxicha	1984	0.5	Oak, broad-leaved, Korean pine broad-leaved with hornbeam, Manchurian fir broad-leaved forests of the southern complex of formations	200–500
40	Fengwu Gou	1991	4.2	Marsh ecosystems	No data
41	Foyegou	1981	6.8	Coniferous broad-leaved, broad-leaved forests of the southern complex of Manchurian formations	300–400
42	Liudingshan	1991	0.3	Oak and broad-leaved forests	300–400
43	Luchang	1984	0.4	Oak, Korean pine broad-leaved forests, and their secondary forests	350–500
44	Wenziling	1992	6.9	Oak, broad-leaved forests, fragments of Korean pine plantations	No data
				National parks	
45	Tangwanghe	2009	20.9	Korean pine broad-leaved, fir-spruce, oak forests of the typical complex of Manchurian formations	200–400
				Democratic People's Republic of Korea	
				Reserves	
46	Ogasan	1959	6.0	Korean pine broad-leaved forests with subtropical species	400–800
47	Paektusan	1959	132.0	Coniferous broad-leaved, Korean pine broad-leaved forests of the southern complex of Manchurian formations with subtropical species	500–1100
48	Myohyangsan	1959	16.1	Coniferous broad-leaved, Korean pine broad-leaved forests of the southern complex of Manchurian formations with subtropical species	No data
				National parks	
49	Kumgangsan	1959	60.0	Coniferous broad-leaved, Korean pine broad-leaved forests of the southern complex of Manchurian formations with subtropical species	No data

Table. (Contd.)

No.	Natural protected areas	Year of foundation	Area: thous. ha	Object of conservation	Belt of Korean pine broad-leaved forests, m a.s.l.
				Republic of Korea	
				Reserves	
50	Daeamsan-Daewoosan	1973	4.6	Forest ecosystems and floral and faunal complexes peculiar to them	850–1150
51	Soraksan	1965	13.4	Ecosystems of coniferous broad-leaved forests and their floral and faunal complexes	850–1150
				National parks	
52	Seoraksan	1970	39.8	Ecosystems of coniferous broad-leaved forests and their floral and faunal complexes	850–1150
				Landscape reserves	
53	Myeongjisan-Cheonggyesan (Upper Stream of Jojongcheon)	1993	2.2	Ecosystems of deciduous forests and rare species of flora and fauna	850–1150

stretches into China and the Korean Peninsula. It limits the distribution of the most thermophilic and temperate wet coniferous broad-leaved forests. The second border limits the distribution of the subcontinental Korean pine broad-leaved forests to the west. It runs along the Lesser Khingan and borders the zone of influence of the summer monsoon. The third border goes in the Upper Amur, then runs along the Greater Khingan to the south. It coincides with the border of the range of Mongolian oak and some other broad-leaved species of the Manchurian Natural Area.

Mountain coniferous broad-leaved forests are the basis of the altitudinal-belt spectra of the mountain part of the Manchurian Natural Area; they determine their regional peculiarities (Fig. 2). In the *northern geographical facies*, the stand of Korean pine forests is based on the following trees: Manchurian fir (*Abies nephrolepis*), Jezo spruce (*Picea ajanensis*), and Dahurian larch (*Larix gmelinii*). In addition, the share of small-leaved species (Manchurian and yellow birches, aspen, etc.) increases. The taiga species are also numerous [5]. Korean pine forests of the northern geographical facies are common to the high altitudes of the Middle Amur basin [2].

Korean pine broad-leaved forests of the *typical facies* (*Pinus koraiensis*, *Quercus mongolica*, *Acer mono*, *A. ukurunduense*, *A. tegmentosum*, *Betula costata*, *Tilia amurensis*, and *Fraxinus mandshurica*) occur at medium altitudes of the mountains of the Manchurian Natural Area. The eastern slopes of the Sikhote-Alin are covered with Korean pine broad-leaved forests at the altitude of 150–170 m, after the lower belt of xeromesophilic oak forests (*Quercus mongolica*). The following zones are well defined within this belt: 200–500 m—cedar-oak forests; 500–700 m—Korean pine and spruce broad-leaved forests (most diverse in the composition of broad-leaved tree species, shrub layer, and grass cover); 500–800 m—transitional Korean pine broad-leaved forests with fir, spruce, and boreal forms in the grass cover. At the altitude of 700–800 m, Korean pine forests are replaced by fir-spruce forests. At the altitude of 1100 m, spruce and birch (*Betula lonata*) light and crooked forests become dominant. The upper border of forest at the western macroslope goes to the altitude of 1350–1500 m, and at the eastern one, it is 1000–1200 m, depending on the distance from the coast, geological material, exposition and gradient of slopes. At an altitude above 1200 m, the dominant plants are Siberian dwarf pine and microbiota tangle (*Microbiota decussata*) reaching here the northern border of its range [2].

In running toward the south, the number of the altitudinal belts in the Sikhote-Alin and the northern branches of the East Manchurian Highland (Changbai Mountain Range) gradually increases. The lower border of Korean pine broad-leaved forests of the *southern geographical facies* with Manchurian fir and hornbeam, as well as the tertiary thermophilic relict species (*Abies holophylla*, *Carpinus cordata*, *Tilia amurensis*, *T. mandshurica*, *Acer mono*, *A. pseudosieboldianum*, *Fraxinus rhynchophylla*, *Actinidia kolomikta*, and *Vitis amurensis*), is at the altitude of up to 300–500 m. In the lower belt, to the altitude of 500–600 m, polydominant broad-leaved forests with thermophilic elements (*Castanea crenata*, *Betula schmidtii*), hornbeam, and Manchurian fir, and xeromorphous communities with pine (*Pinus densiflora*, *P. funebris*) and oak (*Quercus dentata*) forests are developed. Here, the endemics are represented by the formations of the Manchurian spruce broad-leaved forests with Korean spruce (*Picea koraiensis*). Korean pine broad-leaved forests form a belt of southern Manchurian forests at the altitude of 400–750 m. Korean pine-spruce broad-leaved and fir-spruce forests lie higher. The upper border of the forest at the coastal macroslope goes to the altitude of 1200–1300 m; at the western one, 1500 m. The subgoltsy shrubs are represented by the tangle of Siberian dwarf pine (1450–1800 m), devil's club (*Oplopanax elatus*), and microbiota at the altitudes of 1100–1500 m [2].

The western border of the distribution of Korean pine broad-leaved forests is associated with a more continental climate and goes along the edge of the Pacific zone of influence on the Asian continent. At the left bank of the Amur River, the natural border is the Bureya-Zeya Plain, and they do not grow outside it (Fig. 1). In China, their border is determined by the Lesser Khingan ranges, which make these forests grow further west. Despite being located away from the sea, the Lesser Khingan is significantly influenced by the summer monsoon, because the air masses do not encounter any obstacles in the form of meridional ranges in their main direction (southeast). The Manchurian fir grows at the northern branches of the Lesser Khingan to the Bureya Mountains [14]. In general, all the climatic facies of Korean pine forests are represented in the Lesser Khingan.

The southern part of the range of Korean pine broad-leaved forests lies within the East Manchurian Highland. Here, the characteristics of the altitudinal zonality change: the belt of Korean pine broad-leaved forests is displaced upwards and occupies the middle of the slopes at the altitudes of 500–600 m. The southern border of the Korean pine broad-leaved forests coincides with the northern border of subtropical forests with evergreen elements. Thus, the Korean pine broad-leaved forests are enriched with thermophilic species in the lower belts. The northern branches of the East Manchurian Highland go into Russia (Pogranichnyi Range), and the Korean pine broad-leaved forests here belong to the southern forest facies with hornbeam and Manchurian fir (Fig. 2).

CONSERVATION OF THE GENE POOL OF KOREAN PINE BROAD-LEAVED FORESTS IN THE MANCHURIAN NATURAL AREA

Korean pine broad-leaved forests hold the gene pool of the Manchurian flora and fauna. According to estimates by specialists, the potential range of Korean pine broad-leaved forests is about 50 million hectares [20]. However, this area has now significantly decreased.

According to the Russian Federal Forestry Agency, Korean pine broad-leaved forests occupied 2.94 million hectares of Russian territory in 2007 [7]. This constitutes 1.1% of the total area of all forests growing in the Far East. In 1950, this value was 4.4% [5]. In 1990, the prohibition on any commercial cuttings of Korean pine broad-leaved forests was imposed. It had positive results. Their area increased by 2.1% over a seven-year period (2000–2007), which is evidence of efficient changes in the forest management. In V.N. Koryakin's [7] opinion, it can be suggested to a certain degree that the contemporary area of Korean pine broad-leaved forests is two times larger, including the areas of the industrial forests, where the Korean pine is still the major tree species or young growth. In 2010, Russia listed the Korean Pine in Appendix III of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). These measures should help to protect the Korean pine forests in Primorye.

The range of Korean pine broad-leaved forests lies mainly in the northeastern provinces of China (Heilongjiang, Jilin, and Liaoning). Nevertheless, the large primary forest stands were almost totally cut down by the middle of the 20th century owing to age-old extensive agricultural activities [3]. In 1950s, the environmental problems became aggravated and China adopted a program on forest restoration with many human resources involved. Now, the northeastern territories of China not suitable for agriculture are occupied by well-attended plantations of coniferous and broad-leaved trees. In addition, significant investments are being made to save the seed gene pool. According to the estimates by researchers from China, the area of Korean pine broad-leaved forests in China was 1.68 million hectares in 1999 [17].

On the Korean Peninsula, the Korean pine broad-leaved forests were significantly destroyed during military operations. Only small forests have remained. In the DPRK, they occupy about 356000 ha (http://www.unep.org/PDF/DPRK_SOE_Report.pdf). In the Republic of Korea, the areas with natural forests can be found only in the hard-to-reach mountain regions. In 1962, a national program on forest restoration was started, and the area of Korean pine forests reached 320 000 ha by 2008 [29].

According to WWF, only about 30% of the Korean pine forests were not cut ((http://www.wwf.ru/data/ /news/2832/kedrvcifrah.doc). For this reason, they need extensive conservation, which should be of countrywide character. Now, Russian Korean pine broad-leaved forests are protected in nine nature reserves, three national parks, and three preserves of federal significance (Fig. 1, table). In China, the conservation is performed in nine nature reserves and one national park, where natural Korean pine broad-leaved forests grow, as well as in 20 provincial and district nature reserves. There are also several scientific stations aimed at protecting the Korean pine forests. Data on the natural areas of preferential protection in the DPRK are restricted. Here, these forests are protected in two nature reserves and two national parks. In the Republic of Korea, the southern forests are protected in two nature reserves and one national park.

In Russia, Korean pine broad-leaved forests of all three climatic types are protected in the nature reserves. According to the data of WWF [12], they are quite fully represented in the natural areas of preferential protection. Investigation, monitoring, and restoration of Korean pine broad-leaved forests of the northern type are performed by five nature reserves, two preserves, and the Anyuiskii National Park. There are almost no primary stands of Korean pine broad-leaved forests in the nature reserves. In the Komsomol'skii Nature Reserve, the most "successful" one, only 20% of forests were not cut or exposed to fires. In the other nature reserves, this value is even lower [1]. Slightly destroyed typical Korean pine broad-leaved forests are protected in the largest nature reserve of the Amur River region (the Sikhote-Alin Nature Reserve) and the Udegeiskaya Legenda National Park adjacent to it. Forests of the southern facies are protected in three nature reserves, Leopardovyi Preserve, and Zov Tigra National Park. The Korean pine broad-leaved forests occupying about 40% of the Ussuri Nature Reserve are considered to be almost undisturbed [1].

In China, the virgin forests under reservation conditions have remained in the mountain systems of the Changbai Mountain Range, Vandashan, and the Lesser Khingan. The forests of the typical facies are found in nine reserves. Three of them are considered to be the most important for the conservation of Korean pine broad-leaved forests [15, 18, 19]. At the Lesser Khigan in the Fengling Biosphere Reserve and in the Liangshui State Reserve, the Korean pine broad-leaved forests of the typical facies occupy 80 and 91.3% of the area, respectively. The forests grow in the lower forest belt at the altitude of 280–450 (sometimes up to 700) m and develop without any human interference. The old-aged Korean pine broad-leaved forests pose the highest interest as the models of Manchurian forests that have remained until now. Both long-term observations of the natural development of the forest ecosystems, as well as dynamics of their components and some investigations of the possible forest recovery during artificial planting, are performed under the laboratory conditions.

In the Changbaishan Biosphere Reserve [26] and the Paektusan Reserve, which borders it from the side of the DPRK, the biodiversity of the Manchurian fir forests and the Korean pine broad-leaved forests of the southern facies are protected. Here, the Korean pine broad-leaved forests grow at the altitude of 500–1100 m. In this reserve, long-term observations of the state of forest ecosystems and investigation of the influence of climatic changes and anthropological activities on them are performed. In general, the Korean pine broad-leaved forests of the southern facies in China and the Korean Peninsula include more than 25 reserves with different conservation statuses (Fig. 1, table).

In May 2010, the Chinese government said that they were planning to create nine more reserves with the total area of 38 000 km^2 along the border with Russia and the DPRK in order to protect the Siberian tiger (http://russian.china.org.cn/environment/txt/2010–05/30/content_20146972.htm).

Nevertheless, it is not enough to protect the forest communities in the reserves and preserves. A certain scientifically based program is needed to rehabilitate the secondary plant communities lying in the area near the potential range of the Korean pine, as well as to introduce a well-grounded adaptive and stable forest management providing a balance of all the components on the basis of consideration of the environmental peculiarities of the regions. The Chinese government has paid much attention recently to the restoration and conservation of the forest ecosystems in the northeastern territories of the country (http://russian.china.org.cn/environment/txt/2010–04/21content_19876048.htm). In the east of the Heilongjiang Province (Vandashan Range), a number of preserves have been formed to protect the elite seminal Korean pine forests. In addition, there are several permanent study areas and forest experiment stations investigating Korean pine broad-leaved and broad-leaved forests in the northeast of China.

One of these scientific stations where the investigations of the forest ecosystems are performed (Maoershan/Lingshui Forest Ecosystem Research Station) is located at the foothills of the Lesser Khingan (Dailing District). The station was founded in 1974. The Korean pine broad-leaved and broad-leaved forests of the Manchurian complex grow at the altitude of 300–600 m. Here, the observations of ecology and functioning of the ecosystems of primary old-aged Korean pine (*P. koraiensis*), oak (*Q. mongolica*), and walnut (*Juglans mandshurica*) forests are carried out. The long-term investigations of how various components of the forest ecosystems develop under changing climate conditions are performed. Attention is paid to physiology and population genetics of the species. The biodiversity of forests is high and indicative of the richness of biota in the Lesser Khingan [19]. In the Lingshui Reserve with the area of 12000 ha, 578 mushroom species, 90 lichens, 95 mosses, 36 ferns, 9 gymnosperms, and 445 plants were registered. It is the habitat of 491 insect species, 252 bird species, 44 mammal species, and 12 amphibian species. Experiments are performed on the cultures of the main trees, including plantations of Korean pine, larch, and spruce.

CONCLUSIONS

The search for optimal models favoring the stable development of the mountain regions of Russia, China, the DPRK, and the Republic of Korea should be based first on a coordinated national policy in the area of conservation and exploitation of natural resources. The basis for sound ecological decisions should be the consideration of ecological-ethnological-geographical peculiarities of particular territories. Planning and organization of the network of ecological stations and new natural areas of preferential protection should be based on the ecological-geographical approach with the application of remote sensing and geoinformational technologies.

The ecological differentiation of the territory based on the bioclimatic model of relationships between vegetation types and worldwide climatic conditions is illustrated on the map "Ecoregions of the World" [24]. According to the moisture regime, the Manchurian Natural Area globally belongs to the humid sector. The bioclimatic values determine the biotic complexes of plants and animals developed throughout history. The maps of Russian [11] and Chinese [16, 30–32] ecoregions are based on these principles. There are five ecological regions that can be singled out within the Manchurian area. Each of them has its own regional complexes of Manchurian formations, including Korean pine broad-leaved forests, which occur as mountain ecosystems only in four of them: in Russia, the *Amur-Sakhalin* and *southern Sikhote-Alin* ecological regions; in China, the *Manchurian* and *Changbaishan* ecological regions with mixed forests. They have particular types of Korean pine forests, including climatic facies, which are characterized by the regular complex of the tree species mixed with the Korean pine and the floral structure of the stable components at the lower layers. This presupposes the unity of their ecological view and is reflected in the peculiarities of age and recovery alternations and in the directions and phases of age-old alternations. On the basis of ecological regions, it is possible to acquire comparative data for the inventory and estimation of the biodiversity and creation of databases of alpha, beta, and gamma diversity and to obtain information about geography and ecology of the species and their communities with establishment of background, rare, and unique biological objects in order to elaborate the strategy of their successful development. This will ensure a required scientific base for the development of the system of ecological monitoring, balanced use of national natural resources, and elaboration of the optimal plan of forest management, including the conservation of biodiversity of the regions.

We hope that the above-discussed experience in studying the biome of Korean pine broad-leaved forests of the Manchurian Natural Area will be useful not only for knowledge of the regional diversity of forest ecosystems on the territories of the four neighboring countries, but that it will also allow estimating their contemporary state and responses to the global environmental changes.

ACKNOWLEDGMENTS

We are grateful to V.M. Neronov (Severtsov Institute of Ecology and Evolution, Moscow), Professor Ge Jianping (College of Life Sciences, Beijing Normal University), and Professor Guo Qingxi (Northeast Forestry University, Harbin) for the opportunity to visit two stations where investigations of the protected forest ecosystems of China are performed, and to Professor Mao Zijun (Northeast Forestry University, Harbin) and Minsun Kim (National MAB Committee of RK) for the help in obtaining the materials on the protected areas of China and the Republic of Korea.

The work was supported by the Russian Foundation for Basic Research, project no. 11-05-00088-a.

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