

# Characteristics of coniferous and mixed forest types in the basins of Belaya and Malaya Laba rivers (North-Western Caucasus)

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**Abstract.** Based on the results of the studies conducted in the forest areas of the basins of the rivers Belaya and Malaya Laba, there has been compiled a typological scheme of the coniferous and mixed forests of North-Western Caucasus (NWC) which included 21 forest types, that are distributed into 12 groups. The forest stands of the studied forests types is predominantly complex in composition: mixed-age groups, multi-tiered, medium to high productivity, medium to high-density. The forest regeneration is weak or very weak, according to the scale proposed by S. M. Bebia. The data obtained during the research can be used for assessing the dynamics of the forest biogeocenoses, biodiversity, as well as successional processes.

## 1 Introduction

Coniferous and coniferous-broadleaved forests of the Northwest Caucasus (NWC) are unique ecosystems that cover relatively small areas. In addition dark coniferous forests growing on the territory of the Caucasus State Nature Biosphere Reserve are classified as rare plant communities, with some unique plant species that are included in the Russian Red Book, including endemic and relict species.

As an integral part of the belt spectrum of the mountain ecosystems, forests perform the most important ecological function such as protection and preservation of biodiversity and protection of the mountains themselves. But the majority of coniferous forests are severely degraded, due to economic activities and recreational pressure, and their present distribution is only a fraction of their potential natural area.

In this regard, the issues of assessment of the current state and typological structure of coniferous and coniferous-broadleaved forests of the NWC, which is of particular interest in connection with the complex terrain, are of particular relevance.

Many works have been devoted to issues of coniferous forest diversity [1-4]. For example, in Turkish forests, with *Abies nordmanniana* (Steven.) the authors [4] distinguish fir-pine – *Abieti nordmannianae-Pinetum sylvestris* Eminağaoğlu et Anşin 2007, *Lilio ciliati-Pinetum sylvestris* Quézel et al. 1992; *Abieti nordmannianae-Piceetum orientalis* Eminağaoğlu et Anşin 2007, *Vaccinio myrtilli-Piceetum orientalis* Quézel et al. 1992; fir-beech forests – *Pyrolo secundae-Fagetum orientalis* Akman et al. ex Quézel et al. 1992; maple-fir forests – *Acerio tauricoli-Abietetum cilicicae* Quézel et al. 1992.

Many researchers [5-9] have studied forests in the NWC. In particular, the work done by K.Yu. Golgofskaya is focusing specifically on the forest typology of the Caucasus State Nature Biosphere Reserve [10, 11], which was mainly based on the study of the basin of the river Belaya. In our opinion, the typological diversity of coniferous forests in the Malaya Laba River basin has been insufficiently studied. Due to this circumstance, the study of the current state of coniferous and mixed forests, their species and typological diversity is particularly relevant and requires more detailed and thorough elaboration.

In relation to everything described above, the aim of this specific work is to analyze the current state and characterize the types of coniferous and mixed forests of the Northwest Caucasus.

## 2 Materials and methods

Studies were conducted by route method in 2014, 2018 on the territory of 2 sites: 1) the Belaya River basin within the height of 600-1900 m above sea level; 2) the Eastern section of the Caucasus Reserve, located in the upper reaches of the Malaya Laba River, within the height of 600-2200 m above sea level (Figure).

Soils under coniferous and broad-leaved forests are thick and dense brown mountain-forest, brown mountain-forest loamy [10]. The study area is located along the northern and southern macro-slopes of the Main Caucasian Range. A significant part of the sample area is located within the territory of the Caucasus Nature Reserve which is included in the World Heritage List and is the largest specifically protected subject of the North Caucasus by its area..

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The climate is humid and moderately cold. The average annual amount of precipitation is around 600-1500 mm, summers are warm, and winters are cold. According to the Roshydromet meteorological stations

"Krasnaya Polyana" and "Guzeripl" the average air temperature during 1960-1990 on the territory of the Caucasus Nature Reserve was decreasing, but since then started gradually increasing [16].

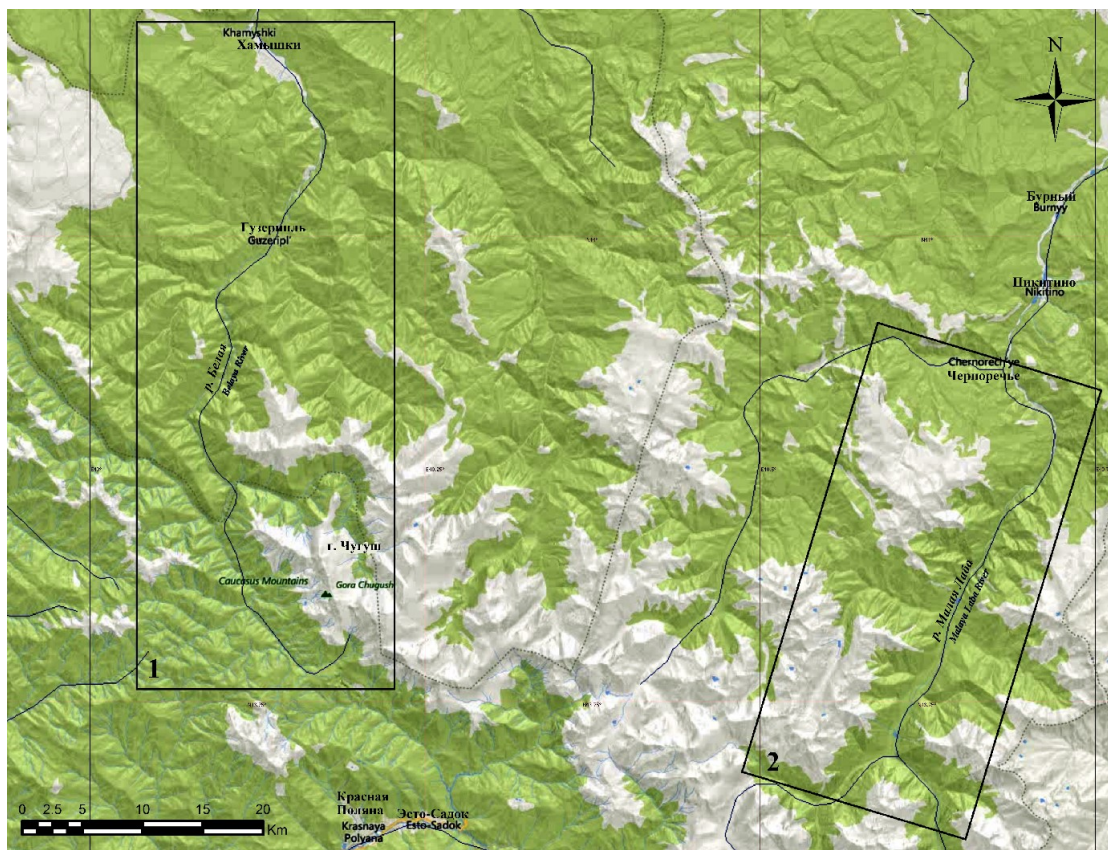


Fig. 1. Location and schematic map of the research area. 1 – basin of river Belaya, 2 – basin of river Malaya Laba

When classifying forest vegetation, it has been used the ecological-phytocenotic; the type of the forest was determined by the type of the forest biogeocenosis. Groups of forest types were distinguished by the species composition of the stand, as well as by a group of dominant species in the herb-dwarf shrub layer. Phytocenoses similar in the species composition of stand tiers and ground cover were considered to be of the same forest type [12, 13].

Geobotanical descriptions and taxonomic characteristics of forest stands were carried out in the forest areas of the study area. During field surveys, traditional research methods and norms accepted in forest taxation were used [12-14]. Forest biocenoses were studied by tiers. For the forest stand, we determined the stand structure, species composition, bonitet, crown closure, fullness, average height, average diameter, and cross-sectional area. We assessed the species composition of the undergrowth, its projective cover, average height, and the amount of specimens per sampling area.

For the herb-dwarf shrub layer it has been determined its species composition, total projective cover, and projective cover of each species [15]. The size of the examined area was 900 m<sup>2</sup>. There were laid

126 sample plots in total. The study of the young growth regeneration of the forest-forming species on the studied area was done by placing 3×3 m plots after every other diagonally along the sampled area, about 40-45 per 1 hectare. At the same time we recorded the quantity, height, diameter and age of the young growth [17]. When young growth and sprouts were recorded, they were distributed by height into four groups: I – 0 - 0.50 m; II – 0.51 - 1.00 m; III – 1.01-1.50 m; IV – more than 1.50. We made a visual assessment of the sampled area, as well as its qualitative condition. When assessing the natural regeneration, the scale proposed by S.M. Bebiya [18] has been used.

The vascular plant species were identified according to A.I. Galushko [19]. Latin names of vascular plants and mosses given according to PlantList [20].

The data collected became the basis for constructing a typological scheme of the coniferous and coniferous-broadleaved forests in the Northwest Caucasus.

### 3 Results and Discussion

The results of our research revealed that in fir forests the most characteristic groups of forest types are fir forests with herb-rich vegetation cover, fir forests with

rhododendron undergrowth, fir forests with tallgrass vegetation cover, fir forests with fescue grass vegetation cover, and fir forests with fern vegetation cover. The forest taxation characteristics of the identified forest types typical for fir forests are given in table 1.

Group of fir forests with herb-rich vegetation covers. Its represented by the mixed tree stands and mixed age groups of the trees. The dominant species in this group is *Abies nordmanniana* (Steven.) Spach, with *Fagus orientalis* Lipsky, *Pinus sylvestris* var. *hamata* Steven, *Ulmus glabra* Huds. In this group there were drawn up four distinctive forest types.

*Fageto-Abietum oxalidosum*. Occupies the largest areas, is distributed at the altitude of 600-2200 m a.s.l on the slopes with a moderate steepness (15-20°) of northern and north-western exposition.

*Abies nordmanniana* is a dominant species among the forest stand of this forest type, with *Fagus orientalis* being a co-dominant one. In addition to the above there can be found *Picea orientalis* (L.) Peterm., *Acer platanoides* L., *Alnus incana* (L.) Moench. Where *Fraxinus excelsior* L. sporadically among the trial plots. The forest stands are highly productive, II class of bonitet. Crown closure in the range of is 0.8-0.9.

The shrub layer is sparse and is represented by *Sambucus nigra* L., *Corylus avellana* L. Forest regeneration is very weak. The total amount of young growth is 505 pcs./ha. The young growth is presented by *Populus tremula*, *Fagus orientalis*, *Sorbus aucuparia* L., *Carpinus betulus* L. Undergrowth on the sample plots grows in clumps and is confined to more illuminated areas.

**Table 1.** Taxation characteristics of forest stands of fir forests in the Northwest Caucasus

Forest type	Layer	H mean, m	D mean, cm	Stand density
Group of fir forests with herb-rich vegetation cover				
<i>Fageto-Abietum oxalidosum</i>	I	26±0.9	65±14	0.8
	II	15±1.9	24±2	
	III	9±0.6	14±0.6	
<i>Fageto-Abietum impatientiosum</i>	I	27±0.6	73±11.5	0.6
	II	17±0.6	28±4.5	
	III	9±0.6	12±0.6	
<i>Pineto-Abietum calamagrostoso-hylocomiosum</i>	I	20±2.7	39±8.5	0.6
	II	10±1.5	11±1.2	
<i>Fageto-Abietum rubosum</i>	I	30±4.5	64±12.7	0.4-0.5
	Group of fir forests with rhododendron undergrowth			
<i>Fageto-Abietum rhododendrosom</i>	I	27±2.8	33±11.5	0.7
	II	9±1.5	9±0.5	
Group of fir forests with tallgrass vegetation cover				
<i>Abietum senecioso-calamagrostosum</i>	I	30±4.0	44±16.4	0.4
Group of fir forests with fescue grass vegetation cover				
<i>Abietum festucosum</i>	I	36±2.8	55±13.1	0.7-
	II	10±1.5	15±2.5	0.8
Group of fir forests with fern vegetation cover				
<i>Abietum galioso-dryopteridosum</i>	I	23±1.7	51±5.7	0.7
	II	13±2.1	15.3±7.6	

The dwarf shrub-herb layer is well developed, the total projective cover (TPF) is 60%. It is dominated by mesotrophic species: *Asarum caucasicum* (Duch.) N. Busch, *Oxalis acetosella* L., as well as *Paris incompleta* M. Bieb., *Geranium robertianum* L., *Milium effusum* L., *Salvia glutinosa* L., *Dryopteris filix-mas* (L.) Schott and others. Projective coverage of the moss layer is 15%.

*Fageto-Abietum impatientiosum*. It is widespread on the southern and south-eastern slopes of medium steepness (15-20°).

*Abies nordmanniana* and *Fagus orientalis* are dominant species in this forest stand of this forest type. *Picea orientalis* is found sporadically in the sampling areas. Forest stands of class II bonitet. The canopy crown closure is 0.8.

The shrub layer is sparse, represented by *Sambucus nigra*. Forest regeneration is very weak. Total amount of young growth is 389 pcs./ha. The young growth is represented by *Fagus orientalis*, *Fraxinus excelsior*, *Abies nordmanniana*, *Acer pseudoplatanus* L.

The dwarf shrub-herb layer is 50%. It is dominated by the megatrophic species *Impatiens noli-tangere* L.

*Asarum caucasicum*, *Oxalis acetosella*, *Lapsana communis* subsp. *grandiflora* (M. Bieb.) P.D.Sell., *Geranium robertianum*, *Milium effusum* L., *Salvia glutinosa*, *Veronica gentianoides* Vahl, *Dryopteris filix-mas*, *Thlaspi macrophyllum* (Hoffm.) and others are also noted in its composition. Projective coverage of the moss layer is 10-15 %.

*Pineto-Abietum calamagrostoso-hylocomiosum*. The forest stand are of various ages with medium productivity. It is dominated by *Abies nordmanniana*, with *Pinus sylvestris* var. *hamata*. Also in the composition of the forest stand are marked *Populus tremula* L., *Betula raddeana* Trautv. Stands of class III bonitet. The canopy crown closure is 0.8.

*Aruncus dioicus* (Walter) Fernald, *Frangula alnus* Mill. and *Sorbus aucuparia* L. occur in the undergrowth with a projective cover of 10%.

Forest regeneration in the forest areas of the selected forest type is very weak. The total amount of young growth is 250 pcs./ha. It includes *Abies nordmanniana*.

The dwarf shrub-herb layer is 20-40%. It is formed by *Calamagrostis arundinacea* (L.) Roth with projective cover up to 30%, *Rubus caucasicus* Focke, *Geranium robertianum*, *Galium odoratum* (L.) Scop., *Dolichorrhiza renifolia* (C.A. Mey) Galushko, *Vaccinium myrtillus* L. and others are also noted. Moss layer – 35%.

*Fageto-Abietum rubosum*. Forest stands of this specific forest type formed by *Abies nordmanniana* and *Fagus orientalis*. The stand are of mixed age group, predominantly highly productive, of bonitet class I. The canopy crown closure is 0.4-0.6.

Forest regeneration is very weak, up to 700 pcs./ha. The young growth is confined to stand windows and includes *Abies nordmanniana* and *Fagus orientalis*.

The dwarf shrub-herb layer is 50-70%. Mesotrophic species dominate in the ground cover: *Rubus caucasicus*, *Calamagrostis arundinacea*, also *Oxalis acetosella*,

*Fragaria vesca* L., *Geum urbanum* L., *Dryopteris filix-mas* and others. Moss layer – 15%.

Group of fir forests with rhododendron undergrowth. In this group is there is one forest type – *Fageto-Abietum rhododendrosom*. Plantation is of different age groups, bi-level, grade II bonitet. *Abies nordmanniana* dominates the forest stand, *Fagus orientalis* is co-dominant species with occasional occurrence of *Ulmus glabra* in some areas. Crown closure is 0.9.

*Rhododendron ponticum* dominates in the undergrowth with projective cover of 20-35%, additionally singularly noted is *Ilex colchica* Pojark. Mesotrophic species dominate in the grass-dwarf shrub layer, *Rubus caucasicus* with projective coverage up to 10%, as well as *Vaccinium arctostaphylos* L., *Polygonatum glaberrimum* K. Koch., *P. verticillatum* (L.) All., *Dryopteris filix-mas*. Moss layer – 5%.

Forest regeneration is weak; the total amount of young growth is 1480 pcs./ha. In its composition in the forest plots, there are *Acer platanoides* L., *Abies nordmanniana*, and *Fagus orientalis*.

Group of fir forests with tallgrass vegetation cover. There is a single forest type in this group – *Abietum senecioso-calamagrostosum*. Its forest taxation characteristics are presented in Table 1. The forest stands are pure, formed by *Abies nordmanniana*, single-tiered, highly productive, grade I bonitet. Occasionally in some forest, plots can found *Fagus orientalis*.

The shrub layer is practically absent. Forest regeneration in this forest type is weak. Total amount of young growth is 1200 pcs./ha.

The dwarf shrub–herb layer is 80%. It is dominated by mesotrophic species *Senecio macrophyllus* Humd.-Bonpl. et Kunth, *Calamagrostis arundinacea*, also *Betonica macrantha* C. Koch, *Astrantia trifida* Hoffm., *Poa annua* L. and others. Moss layer – 10%.

Group of fir forests with fescue grass vegetation cover. Includes one forest type – *Abietum festucosum*. The forest stands are multi-tiered, of different age groups, highly productive, appraisal class Ia. Formed by *Abies nordmanniana*. Crown closure of the canopy is 0.6.

Shrub layer is practically absent. *Frangula alnus*, *Sorbus aucuparia* singled out. Forest regeneration on is very weak. Total amount of young growth is 380 pcs./ha.

The dwarf shrub–herb layer is 30%. Mesotrophic species – *Festuca drymeja* Mert. et W. D. J. Koch. – predominate here, also noted *Sanicula europaea* L., *Carum meifolium* Boiss., *Dolichorrhiza renifolia*, *Astrantia trifida*, *Galium rotundifolium* L., *Poa remota* Forselles, *Prunella vulgaris* L. etc. Moss layer – 10%.

Group of fir forests with fern vegetation cover. The group in the studied area includes *Abietum galiosodryopteridosum*. It grows on steep slopes (about 30°) of north-western exposition. Forest stand are multi-tiered, of different age groups, grade II bonitet. Crown closure is 0.6-0.8. *Abies nordmanniana* dominates. *Fagus orientalis*, *Tilia begoniifolia* Steven, *Acer platanoides*, *Picea orientalis* found occasionally.

Undergrowth is not developed. The dwarf shrub–herb layer is 20-30%. It is dominated by megatrophic species

– *Dryopteris filix-mas*, *Athyrium filix-femina* (L.) Roth, *Galium odoratum* also present *Galega orientalis* Lam, *Senecio vulgaris* L., *S. propinquus* Schischk, *Festuca drymeja*, *Polygonatum glaberrimum*, *Oxalis acetosella*, *Geranium robertianum*, *G. sylvaticum* L., *Salvia glutinosa*, *Erysimum aureum* M. Bieb., *Milium effusum*, *Aconitum nasutum* Fisch. ex Rchb., *Lapsana communis* subsp. *grandiflora*, *Campanula latifolia* L., *Viola mirabilis* L., *Platanthera chlorantha* (Custer) Rchb. Moss layer – 10%.

In pine forests, two groups of types distinguished: group of pine forests with herb-rich vegetation cover, group of mixed pine forests (Table 2).

Group of pine forests with herb-rich vegetation cover. *Pinetum herbosum*. The forest stands are pure, formed mainly by *Pinus sylvestris* var *hamata*. *Betula raddeana* with *Abies nordmanniana* occasionally appearing in the mix. Crown closure of the tree canopy is 0.3-0.4. Forest stand is of different age groups, grade III bonitet.

The shrub layer with projective cover of 10-15%, here can be found *Lonicera caucasica* Pall., *Rubus caucasicus* L., *Salix caprea* L. and others.

Forest regeneration is practically absent. The total amount of young growth is 150 pcs./ha.

The dwarf shrub–herb layer is 25-30%. It is formed by *Valeriana tiliifolia* Troitsky, *Fragaria vesca*, *Poa annua*, *Carum meifolium* (M. Bieb) Boiss, *Lathyrus pratensis* L., *Calamagrostis arundinacea* and others. Moss layer is 5-10%.

**Table 2.** Taxation characteristics of forest stands of pine forests in the Northwest Caucasus

Forest type	Layer	H mean, m	D mean, cm	Stand density
Group of pine forests with herb-rich vegetation cover				
<i>Pinetum herbosum</i>	I	19±0.9	39±4.6	0.3-0.4
<i>Pinetum astrantiosum</i>	I	18±1.5	38±4.5	0.3
Group of mixed pine forests				
<i>Querceto-Pinetum herbosum</i>	I	22±0.5	59±4.1	0.5
	II	16±0.7	13±1.7	
<i>Querceto-Pinetum rhododendrosom lutei</i>	I	21±3.0	29±7.1	0.5
	II	10±0.5	15±1.9	
<i>Carpineto-Pinetum herbosum</i>	I	25±0.8	58±8.3	0.6
	II	17±1.1	27±10.4	
	III	9±0.6	6±1.0	
<i>Populo tremulae-Pinetum herbosum</i>	I	24±0.5	43±10.4	0.4
	II	16±1.5	21±1.0	

*Pinetum astrantiosum*. The forest stands of this forest type are medium-aged, medium-productive, III class of bonitet. Plantation is monodominant, formed by *Pinus sylvestris* var. *hamata*, with single records of *Betula litwinowii* Doluch., *Abies nordmanniana*, *Fagus orientalis*.

Shrub layer with projective cover of 15%. It includes *Sorbus aucuparia* L., *Lonicera caucasica*. Undergrowth is practically absent on the sampled plots, its total amount of young growth is 125 pcs./ha.

The dwarf shrub–herb layer is 40%. The main species represented by *Astrantia trifida*, *Aconitum nasutum*, *Valeriana tiliifolia*, *Dryopteris filix-mas*, *Geranium robertianum*, *Polygonatum glaberrimum* and others. Moss layer – 5%.

Group of mixed pine forests. Mixed forest stands formed by *Pinus sylvestris* var *hamata* and small-leaved or broad-leaved tree species. Here it has been identified the following forest types: *Querceto-Pinetum herbosum*, *Querceto-Pinetum rhododendrosum lutei*, *Carpineto-Pinetum herbosum*, *Populo tremulae-Pinetum herbosum*.

*Querceto-Pinetum herbosum*. Forest areas are spread on slopes of medium steepness (20-25°) of south-eastern exposure.

Forest stands are two-tiered, mixed-age groups, III class of bonitet. Crown closure is 0.6. The first tier represented by *Pinus sylvestris* var *hamata*, the second formed by *Quercus robur* L.

The shrub layer is weakly expressed (10%), with *Sorbus torminalis* (L.) Grantz., *Prunus spinosa* L., *Spiraea hypericifolia* L. being the most common species here.

The forest regeneration is very weak, the total amount of young growth is 400 pcs./ha. It includes *Quercus robur*, *Carpinus betulus* L., *Fagus orientalis*, *Acer cappadocicum* Gled.

The dwarf shrub–herb layer is 40%. It is formed by *Vicia cracca* L., *Lithospermum officinale* L., *Campanula alliariifolia* Willd. Brandza et al. Moss layer – 5%.

*Querceto-Pinetum rhododendrosum lutei*. This forest type form complex two-tier forest stands structures. They grow on slopes of medium steepness (30°) with a southern exposure. The stands are of the III class of bonitet and of different age groups.

The first tier is represented by *Pinus sylvestris* var. *hamata*, the second by *Quercus robur*. The canopy crown closure is 0.5. The shrub layer is pronounced, with a projective coverage of up to 40%, formed by *Rhododendron luteum* Sweet. Forest regeneration is very weak, the total amount of young growth is 317 pcs./ha. The young growth includes *Quercus robur*, *Carpinus betulus*, *Fagus orientalis*, *Picea orientalis*, *Abies nordmanniana*.

The dwarf shrub–herb layer at different sites is 5-20%. It is formed by *Calamagrostis arundinacea*, *Thalictrum minus* L., *Vicia cracca*, *Campanula alliariifolia*, *Poa nemoralis*, *Clinopodium menthifolium*, *Poa annua*, *Geranium robertianum* etc. Moss layer – 2%.

*Carpineto-Pinetum herbosum*. The forest areas are located on moderately steep slopes (20°) of eastern and south-eastern exposition. The stands of this forest type are predominantly mixed-age groups, of bonitet class II.

The tree layer is formed by *Pinus sylvestris* L. and *Carpinus betulus* L. Companion species are *Picea orientalis*, *Fagus orientalis*, *Populus tremula*. The shrub layer is sparse and includes *Corylus avellana*, *Ribes*

*aureum* Pursh, *Sambucus nigra*. Forest regeneration is very weak, the total amount of young growth is 560 pcs./ha. The young growth includes *Carpinus betulus*, *Acer pseudoplatanoides*, *Pinus sylvestris*, *Fagus orientalis*, *Picea orientalis*.

Dwarf shrub–herb layer of the forest floor is 50-60%. It is formed by mesotrophic species – *Vicia cracca*, *Campanula alliariifolia*, *Poa nemoralis*, *Lapsana communis* subsp. *grandiflora*, *Galium odoratum*, *Milium effusum*, *Poa remota*, *Aconitum nasutum*, *Urtica dioica* L., *Asarum caucasicum*, *Salvia glutinosa*, *Cyanus triumfettii* (All.) Dostal ex A. Löve et D. Löve. Moss layer – 5%.

*Populo tremulae-Pinetum herbosum*. Forest areas are distributed on slopes of medium steepness (20°) of south-eastern exposure. The forest stands are of different age groups, II class of bonitet.

The tree layer formed by *Pinus sylvestris* var. *hamata* and *Populus tremula*. Associated species are *Quercus robur*, *Acer campestre* L., and *Fagus orientalis*. Closure of canopy crowns is 0.5-0.6.

Total projective cover of shrub layer is 5-10%. It includes *Corylus avellana*, *Ribes aureum*. Forest regeneration is very weak, the total amount of young growth is 400 pcs/ha. The young growth includes *Carpinus betulus*, *Quercus robur* and *Fagus orientalis*.

The dwarf shrub–herb layer well developed, with a growing stock of up to 80%. The layer formed by mega- and mesotrophic species *Cyanus triumfettii*, *Dryopteris filix-mas*, *Paris incompleta*, *Vicia cracca*, *Aconitum orientale*, *Campanula alliariifolia*, *Poa nemoralis*, *Galium odoratum*, *Festuca drymeja*, *Persicaria bistorta* (L.) Samp., *Dactylis glomerata* L. *Polygonatum glaberrimum*, *Pilosella officinarum* Vaill. Moss layer – 5%.

In addition also conducted of the sampling plots with predominance *Fagus orientalis* in stands and with participation of conifers in the quantity of three or more units. Because of conducted researches in the spruce-beech and fir-beech forests, the following groups identified group of beech forests with herb-rich vegetation cover, group of beech forests with fern vegetation cover, group beech forests with rhododendron undergrowth (Table 3).

Group of beech forests with herb-rich vegetation cover. In the group of the studied area, it has been identified two forest types: *Piceeto-Fagetum oxalidosum*, *Abieto-Carpineto-Fagetum calamagrostosum*.

*Piceeto-Fagetum oxalidosum*. Forest areas formed by this forest type distributed on the slopes with moderate or gentle steepness (10-20°) of western exposition. Plantation of different-age, highly productive, I class of bonitet.

The forest stand is two-tiered. The canopy crown closure is 0.8. It is dominated by *Fagus orientalis*, *Picea orientalis*. *Alnus glutinosa* (L.) Gaertn also found in the forest stand.

The shrub layer is not developed. Forest regeneration is very weak. Total amount of young growth is 310 pcs./ha. On the studied plots there observed the

following young growth species *Fagus orientalis*, *Picea orientalis*.

**Table 3.** Taxation characteristics of stands of spruce-beech, fir-beech forests North-Western Caucasus

Forest type	Layer	H mean, m	D mean, cm	Stand density
Group of beech forests with herb-rich vegetation cover				
<i>Piceeto-Fagetum oxalidosum</i>	I	31±1.2	55±16.5	0.7
	II	16±3.2	29±5.5	
<i>Abieto-Carpineto-Fagetum calamagrostosum</i>	I	29±0.7	47±24.7	0.6
	II	19±2.5	33±12.4	
Group of beech forests with fern vegetation cover				
<i>Piceeto-Fagetum filicosum</i>	I	29±2.1	59±22.6	0.7
	II	18±1.9	24±8.3	
	III	10±0.6	17±8.2	
<i>Abieto-Fagetum galioso-filicosum</i>	I	26±1.5	62±16.6	0.7
	II	18±3.7	31±6.9	
	III	9±0.8	15±5.3	
Group of beech forests with rhododendron undergrowth				
<i>Abieto-Fagetum rhododendroso-filicosum</i>	I	26±1.3	67±1.8	0.6
	II	17±0.9	23±6.1	

The dwarf shrub–herb layer is 15%. Most often mesotroph – *Oxalis acetosella*, also present *Galium odoratum*, *Polygonatum verticillatum*, *Pulmonaria mollis* Wulfen ex Hornem., *Daphne mezereum* L., *Valeriana tiliifolia*, *Paris incompleta*, *Dryopteris filix-mas*, *Platanthera chlorantha*, *Phegopteris connectilis* (Michx.) Watt. Moss layer – 12%.

*Abieto-Carpineto-Fagetum calamagrostosum*. The identified forest type is formed by mixed forest stands of I class of bonitet, represented by *Fagus orientalis*, *Abies nordmanniana*, *Carpinus betulus*. *Alnus glutinosa* also found in the sample plots. The canopy crown closure is 0.8.

The shrub layer is practically not existent. Forest regeneration is very weak; the total amount of young growth is 530 pcs./ha.

The dwarf shrub–herb layer is 30%. The mesotrophic species *Calamagrostis arundinacea* dominates with projective cover of 10-15%. Moss layer is 7%.

Group of beech forests with fern vegetation cover. It is widespread in the North-West Caucasus.

*Piceeto-Fagetum filicosum*. Forest areas of the presented forest type are distributed on the elevated slopes (5° on average) of western and north-western exposition. The forest stands are mixed, of mixed age groups, highly productive, of bonitet class I. The forest stands are complex in structure and composition, with many tiers. They dominated by *Fagus orientalis*, *Picea orientalis*. *Acer platanoides*, *Alnus incana*, *A. glutinosa*, *Abies nordmanniana* occasionally occurs as well. Closure of canopy crowns – 0.8.

The shrub layer is not developed. Forest regeneration is weak. Total amount of young growth is 1300 pcs./ha. Main species are *Picea orientalis*, *Abies nordmanniana*, *Fagus orientalis*, *Fraxinus excelsior*, *Ulmus glabra* which participate in undergrowth.

The dwarf shrub–herb layer is 50-65%. It is dominated by megatrophic species – *Dryopteris filix-mas*, *Athyrium filix-femina*, also present *Oxalis acetosella*, *Galium odoratum*, *Paris incompleta*, *Phegopteris connectilis*, *Impatiens noli-tangere*, *Asarum caucasicum*, *Clinopodium menthifolium*, *Geranium robertianum*, *Salvia glutinosa*, *Telekia speciosa* (Schreb.) Baumg, *Solidago virgaurea* L. Moss layer – 15%.

*Abieto-Fagetum galioso-filicosum*. Forest areas of this forest type are located on gentle slopes (10°) of the southern exposition.

The forest stands are of mixed-age groups, three-tiered, grade II bonitet. The canopy crown closure is 0.9. *Fagus orientalis*, *Abies nordmanniana* are dominant here.

The shrub layer cannot be identified on either of the sample plots. Forest regeneration on the plots of the selected forest type is very weak – 160 pcs./ha. The following young growth species are part of the undergrowth: *Fagus orientalis*, *Picea orientalis*. *Acer pseudoplatanoides*, *Ulmus glabra*.

The dwarf shrub–herb layer at different sites is 20-60%. It is dominated by megatrophic species – *Dryopteris filix-mas* and *Galium odoratum*. *Oxalis acetosella*, *Paris incompleta*, *Asarum caucasicum*, *Clinopodium menthifolium*, *Geranium robertianum*, *Salvia glutinosa*, *Polygonatum glaberrimum*, *Thlaspi macrophyllum*, *Milium effusum*, *Aconitum nasutum* is also noted. Moss layer – 12%.

Group of beech forests with rhododendron undergrowth. In the group, there has been selected *Abieto-Fagetum rhododendroso-filicosum*. The forest stands are complex, mixed age groups, of bonitet class II, formed by *Abies nordmanniana* and *Fagus orientalis*. The canopy crown closure is 0.7-0.8.

The shrub layer with pre-active cover up to 60% is represented by *Rhododendron ponticum*, as well as *Prunus laurocerasus* L. Forest regeneration is very weak, the total amount of young growth is 100 pcs./ha. *Abies nordmanniana* is identified as part of it.

The dwarf shrub–herb layer is 50-70%. It includes mega- and mesotrophic species – *Geranium robertianum*, *Dryopteris filix-mas*, *Calamagrostis arundinacea* and others. The moss layer is 15%.

According to the conducted research, there can be spruce forests the following groups are distinguished according to surveys: group of spruce forests with fern vegetation cover, group of spruce forests with herb-rich vegetation cover.

Group of spruce forests with fern vegetation cover. High-density, mixed-age groups, two-tier forest stands, characterize this group of forest types. A single forest type was identified here (Table 4).

*Fageto-Piceetum filicosum*. The forest stands grow on gentle slopes of the south-eastern exposition. The stands are mixed-age groups, highly productive, of the class II of bonitet. The vertical structure of the plantation is two-tiered. Crown closure is 0.9. *Picea orientalis* and *Fagus orientalis* dominate in the tree layer. *Alnus*

*incana*, *Abies nordmanniana*, *Carpinus betulus*, *Acer platanoides* are part of this structure as well.

**Table 4.** Taxation characteristics of forest stands of spruce forests in the North-Western Caucasus

Forest type	Layer	H mean, m	D mean, cm	Stand density
Group of spruce forests with fern vegetation cover				
<i>Piceeto-Fagetum filicosum</i>	I	26±1.2	72±21.6	0.8
	II	15±0.6	23±2.6	
Group of spruce forests with herb-rich vegetation cover				
<i>Abieto-Fagetum galioso-filicosum</i>	I	25±1.5	63±12.9	0.8
	II	16±1.5	29±6.0	
	III	9±1.2	14.66±3.5	

The shrub layer is not pronounced. Forest regeneration on forest plots is very weak – 910 pcs./ha. The young growth is represented by *Picea orientalis*, *Fagus orientalis*, *Ulmus glabra* and *Abies nordmanniana*.

The dwarf shrub–herb layer is 30%. Megatrophic species – *Dryopteris filix-mas* and *Galium odoratum* are the most abundant. *Athyrium filix-femina*, *Poa remota*, *Oxalis acetosella*, *Paris incompleta*, *Asarum caucasicum*, *Clinopodium menthifolium*, *Geranium robertianum*, *Polygonatum glaberrimum*, *Impatiens noli-tangere*, *Veronica gentianoides* are present as well. Moss layer – 10%.

Group of spruce forests with herb-rich vegetation cover. This group of forest types is defined by the complex forest stands of many trees of different age groups. A single forest type has been identified here (Table 4).

*Fageto-Piceeta geranioso-oxalidosum*. Forest areas are located on gentle slopes of south-eastern exposition. The forest stands are three-tiered, of different age groups, of the class II of bonitet. Crown closure is 0.9. *Fagus orientalis* and *Picea orientalis* dominate in the tree canopy.

The shrub layer is sparse, with a projective coverage of up to 10%. It includes *Grossularia uva-crispa* L., *Ribes aureum* L., *Euonymus europaeus* L. Forest regeneration is very weak. The total amount of young growth on the forest plots is 440 pcs./ha and is represented by *Picea orientalis*, *Fagus orientalis*, and *Abies nordmanniana*.

The dwarf shrub–herb layer is 0-10%. Mega- and mesotrophic species – *Dryopteris filix-mas*, *Athyrium filix-femina*, *Polygonatum glaberrimum*, *Oxalis acetosella*, *Geranium robertianum*, *Carum meifolium* are noted. Moss layer – 10%.

Thus, according to the research results, it found that stands in the selected forest types of the Belaya and Malaya Laba river basins have a complex multi-tier structure; stands are predominantly of different age. Group of spruce forests with fern vegetation cover, group of spruce forests with herb-rich vegetation cover, group of fir forests with herb-rich vegetation cover belong to high-density stands.

It should be noted that *Abietum festucosum*, *Fageto-Abietum rubosum*, *Abietum galioso-dryopteridosum*,

*Abietum senecioso-calamagrostosum*, *Piceeto-Fagetum oxalidosum*, *Abieto-Carpineto-Fagetum calamagrostiosum*, *Piceeto-Fagetum filicosum* are also characterized by the most optimal conditions of growth; stands in these forest types are highly productive (I class of bonitet).

An assessment of the forest regeneration potential of the selected forest types showed that in the forest areas of the Belaya and Malaya Laba river basins, regeneration is weak or very weak, according to the scale proposed by S. M. Bebia [18]. The young growth in the selected forest types is predominantly benign, grows in groups and is confined to more light areas.

## 4 Conclusions

Based on our own data obtained from surveys of forest areas in the Belaya and Malaya Laba river basins, we present floristic, geobotanical and taxation characteristics of the most common forest types with the participation of conifers: *Picea orientalis*, *Abies nordmanniana*, *Pinus sylvestris* var *hamata*.

Based on the results of surveys of forest areas in the Belaya and Malaya Laba river basins, a forest typology scheme of coniferous and mixed forests of the Northwest Caucasus was compiled, which includes 21 forest types distributed into 12 groups. The most common are forest types with the participation or dominance in the forest stand of *Abies nordmanniana*. Group of spruce forests with fern vegetation cover and group of spruce forests with herb-rich vegetation cover are least represented in the study area, and we found small areas in the Malaya Laba River basin.

Forests with coniferous species are confined to slopes of northern, western, south-eastern exposures, distributed within heights of 600 to 2200 m above sea level.

The groups of forest types identified by our studies were compared with existing literature data on the typological diversity of coniferous forests in the Western Caucasus. For example, Golgofskaya [10, 11] has developed a detailed classification scheme for the Belaya River basin, which includes about 60 forest type groups, including 24 groups with conifers in their stands. A comparative analysis showed that the following groups are not included in our study: calamagrostis pine forests, stony pine forests, rock fir forests, sabrefied beech fir forests, rock spruce forest, moss spruce forests, spruce forests with fescue grass vegetation cover.

Applying Brown-Blanke method K. O. Korotkov and E.A. [21] identified two associations of the dark coniferous forests. The association *Ilici colchicae* - *Abietetum nordmannianae* Korotkov et Belonovskaya 1987 corresponds to the following forest types described according to our research results: *Abieto-Fagetum rhododendroso-filicosum*, *Fageto-Abietum rhododendrosom*.

A.A. Frantsuzov (2006) 4 associations of beech-fir forests in the basins of Belaya River using Brown-Blanke floristic classification, 3 of which are consistent with the results of our research. Thus, the association *Rhododendro pontici* - *Fagetum orientalis* Frantsuzov

2006 corresponds to *Abieto-Fagetum rhododendroso-filicosum*, *Fageto-Abietum rhododendrosom*; *Festuco drimejiae - Abietetum nordmannianae* Frantsuzov 2006 – *Abietum festucosum*; *Petasito albae – Abietetum nordmannianae* Frantsuzov 2006 – *Abietum galiosodryopteridosum*, *Abieto-Fagetum galioso-filicosum*. The following forest types were described for the study area for the first time in the present study: *Fageto-Abietum impatientosum* and *Abietum seneciosocalamagrostosum*.

The given forest typology scheme can serve as a basis for assessment of successional changes in forest cover and dynamics of vegetation diversity in the future.

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