# Problems of natural restoration of forest and green spaces of the resort Caucasian Mineral Waters region

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**O Slepykh[1*], A Zubko[2], V Slepykh[3], M Zubko[2]**

[1] *Federal state institution of science Botanical Institute V L Komarova of the Russian Sciences Academy*, 2 Professor Popov Street, Saint Petersburg 197376, Russian Federation
[2] *Federal State Budgetary Educational Institution Novocherkassk engineering reclamation Institute A K Kortunov of the Donskoy state agricultural university*, 111 Pushkinskaya Street, Novocherkassk 346428, Rostov region, Russian Federation
[3] *Federal State Budgetary Institution "Sochi National Park",* 21 Moscovskaya Street Sochi, Krasnodar Region, 354000, Russian Federation

*Corresponding email: slepykh.olya@yandex.ru

**Abstract**. In the forests and green spaces of the Caucasian Mineral Waters resort region there are observed successions, leading to a decrease in their ecological potential. We defined the sanitary conditions and productivity of artificial and natural stands, collected data on species composition and abundance of trees in these stands and non-forested areas. We also determined the level of optimum illumination for the development of oak undergrowth.

## 1. Introduction

The Caucasian Mineral Waters region is located in the Central part of the North Caucasus. In 1992 the region was given the status of a specially protected ecological and resort region of the Russian Federation, in order to preserve and reproduce the natural resources of the Caucasian Mineral Waters region.

The total forested area of the Caucasian Mineral Waters region is 34.4 thousand hectares. Forests in the region have a diverse species composition. The main forest-forming species are birch (22.1%), oak (20.9%), ash (15.0%), hornbeam (13.7%), pine (12.1%), beech (4.8%), alder gray (2.7%), maple (1.7%) and others, whose share is less than 1% [3].

During the afforestation measures of mineral springs supply zones in the 60's and 70's of the last century, forests were established on the area of 9754.5 hectares. 5% of forest crops had unsatisfactory conditions. Stands of introduced species accounted for 24% of the total area of artificial forests - 2378.4 hectares [1].

The area of green spaces of the Caucasian Mineral Waters resort cities is not known due to the lack of their accounting.

There are city parks in the resort towns. One of them is given the status of a specially protected natural area of Federal importance – the Kislovodsk National Park, which covers an area of 966 hectares.

In the forests of the region there are intensive successional processes, which affect the overall environmental condition of the resort region by changing the balance of atmospheric carbon deposition by forests and environment specific changes due to the change of tree species. In natural

forests there is a change of oak species to hornbeam and beech to ash [1-7]. In the forests of artificial origin, the focus of successions has not been studied to date.

In order to identify the direction of the successional process in the most valuable region's forest formations, the characteristics of the renewable process under the canopy of English oak natural stands and artificial stands of introduced species were studied.

## 2. Methods and Materials

Permanent sample plots (PP) were laid in accordance with the provisions of the Industry standard [8]. On PP we defined indicators of forest stands, their sanitary condition [9, 10].

The undergrowth is considered on the grounds of size 4 m2 in quantity and high groups [11] of 25 pcs in PP. Evaluation of the resumption was given according to the established standards [12]. Healthy undergrowth was considered reliable at a height of 0.5 m and above At the same time, the illumination under the forest canopy space and in the open area was measured using a certified universal meter of meteorological parameters ATT-9508 with a light sensor ATA-1591 (Lutron Electronic Enterprise Co.), Ltd., Taiwan.)

Objects of research were a natural coppice stands of Quercus robur L., forest crops of *Quercus robur* L., *Quercus rubra* L., *Pinus pallasiana* D. Don, *Pinus kochiana* Klotzsch ex K. Koch, *Juniperus virginiana* L., *Fraxinus pennsylvanica* Marshall, as well as areas partially or completely devoid of woody vegetation with successful development of the oak undergrowth. Sample plots were laid on the territory of the Kislovodsk National Park and Beshtaugorsky and Essentuksky forest districts.

## 3. Results and Discussion

All the studied artificial stands have high productivity –class I forest site, with the exception of *Juniperus virginiana* and *Quercus robur* (class II) (Table. 1).

**Table 1.** Sample plots inventory characteristics of natural and artificial forests of the Caucasian Mineral Waters region.

| № | Forest stand | Tree species composition | Origin | Section | Age, years | Wood stock, $m^3$/ha | Density | Forest site | Index of sanitary condition |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *Quercus rubra* | 10QR | Forest crops | K[a] | 48 | 685,3 | 1,7 | I [b] | 1,8 |
| | | | | A[b] | 48 | 348,6 | 0,8 | I [b] | 1,8 |
| 2 | *Pinus pallasiana* | 9PP 1FE | -/- | - | 48 | 524,1 | 1,5 | I | 2,4 |
| 3 | *Pinus kochiana* | 10 PK | -/- | - | 48 | 350 | 1,3 | I | 1,4 |
| 4 | *Juniperus virginiana* | 10 JV | -/- | - | 37 | 153 | 0,8 | II | 2,9 |
| 5 | *Fraxinus pennsylvanica* | 10 FP | -/- | - | 43 | 317 | 0,9 | I[b] | 1,9 |
| 6 | *Quercus robur* | 7Q 3FE | Natural stand | - | 77 | 104,7 | 0,6 | V | 3,0 |
| 7 | *Quercus robur* | 8Q 2FE | -/- | - | 77 | 92,2 | 0,6 | IV | 3,1 |
| 8 | *Quercus robur* | 8Q 1FE 1CB | -/- | - | 77 | 109,5 | 0,6 | V | 3,7 |
| 9 | *Quercus robur* | 7Q 3FE | -/- | - | 77 | 61,2 | 0,4 | V | 2,1 |
| 10 | *Quercus robur* | 10 Q | Forest crops | - | 70 | 370,9 | 1,0 | II | 2,9 |
| 11 | *Betula pendula* Roth | 4Q 3BP 3FE 7PC 3QP | -/- | - | 60 | 27,3 | 0,2 | II V | 1,4 |
| 12 | *Quercus petraea* | 5QP 2UP 2OT 1PM | Natural stand | - | 60 | 13,8 | 0,1 | V[a] | 1,3 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13 | *Prunus armeniaca* | 7 PA 3PC | Orchard | - | 30 | 7,5 | - | - | 1,1 |
| 14 | No stand | - | Natural stand | - | - | - | - | - | - |
| 15 | *Quercus robur* | 10 Q | -/- | - | 15 | 0,34 | - | - | 1,6 |

[a] control section;
[b] section after environmental cutting

The sanitary condition of the stands varies from weakened to severely weakened, with the exception of *P. kochiana*, which has no signs of weakening. Weakened stands of *Q. rubra* and *P. pallasiana* have the same index of sanitary condition -1.8. Similar values have plantings of *F. pennsylvanica* index of the sanitary condition 1.9 and *P. pallasiana* index of the sanitary condition of 2.4. The planting of *J. virginiana* is severely weakened, the index of the sanitary condition corresponds to 2.9 points.

Under the canopy of all studied pure forest crops, maternal undergrowth, capable of providing natural reproduction of the growing species, is absent. The most common species reaching the values of reliable undergrowth are *F. excelsior* and *A. platanoides*. The number of reliable undergrowth of these native species provides a guaranteed restorative succession under the canopy of introduced crops.

The *Q. rubra* undergrowth in a small amount occurs in almost all the studied PP, except for the *F. pennsylvanica* stand. In the plantation *J. virginiana Q. rubra* occurs in a single instance. Considered an invasive species in the Caucasian Mineral Waters region, *Q. rubra* rarely reaches the size of a reliable undergrowth.

The studied coppice English oak (PP6-PP9) located on the territory of Beshtaugorsky forest district growing in forest-growing conditions of dry oak stand (C1), belong to the IV-V class of forest site. The sanitary condition of the stands varies from the category weakened to severely weakened with an index of 2.1 to 3.7 (Table. 1).

**Table 2.** The composition and size of trees in stands of artificial origin of the Caucasian Mineral Waters region

| PP /section | **Forest stand** | **Tree species composition** | Sidlings | **Undergrowth (m), pcs/ha** Small[a] | Medium[b] | Large[c] | Relaible[d] |
|---|---|---|---|---|---|---|---|
| PP-1, K[a] | *Quercus rubra,* section K | *Quercus rubra* L. | 25200 | 35600 | 100 | - | 100 |
| | | *Fraxinus excelsior* L. | 8600 | 41300 | 8500 | 1000 | 9500 |
| | | *Crataegus microphylla* C.Koch | - | 1600 | 200 | 200 | 400 |
| | | Other species | 100 | 900 | 200 | 300 | 500 |
| PP-1, A[b] | *Quercus rubra*, section A | *Quercus rubra* L. | 9800 | 25600 | 100 | - | 100 |
| | | *Fraxinus excelsior* L. | 5000 | 25200 | 2500 | - | 2500 |
| | | *Carpinus betulus* L. | 400 | 1500 | 1700 | - | 1700 |
| | | Other species | 300 | 1000 | 1500 | 400 | 1900 |
| PP-2 | *Pinus pallasiana* | Fraxinus excelsior L. | 39600 | 26800 | 9800 | 3000 | 12800 |
| | | Acer platanoides L. | 1600 | 2300 | 1200 | 800 | 2000 |
| | | *Crataegus microphylla* C.Koch | 100 | 400 | 900 | 500 | 1400 |
| | | *Quercus robur* L. | 800 | 500 | - | - | - |
| | | Other species | 100 | 500 | 200 | - | 200 |
| PP-3 | *Pinus* | *Abies nordmanniana* | 11000 | 11600 | 300 | - | 300 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | *kochiana* | (Steven) Spach | | | | | |
| | | *Fraxinus excelsior* L. | 200 | 6100 | 2900 | 1100 | 4000 |
| | | *Cerasus avium* (L.) Moench | - | 200 | 1300 | 1100 | 2400 |
| | | *Juglans regia* L. | - | 600 | 1300 | 500 | 1800 |
| | | *Acer pseudoplatanus* L. | 100 | 1000 | 900 | 300 | 1200 |
| | | *Tilia begoniifolia* Stev. | - | 500 | 700 | 200 | 900 |
| | | *Quercus rubra* L. | - | 1100 | 100 | - | 100 |
| | | *Acer platanoides* L. | - | 400 | 600 | 200 | 800 |
| | | Other species | 100 | 1800 | 800 | 1100 | 1900 |
| PP-4 | *Juniperus virginiana* | *Acer platanoides* L. | 200 | 3700 | 300 | - | 300 |
| | | *Robinia pseudoacacia* L. | - | 1400 | 500 | 100 | 600 |
| | | *Quercus rubra* L. | 100 | 1400 | 400 | - | 400 |
| | | *Thuja occidentalis* L. | - | 1500 | - | - | - |
| | | *Acer pseudoplatanus* L. | - | 800 | 200 | - | 200 |
| | | *Fraxinus excelsior* L. | - | 1000 | - | - | - |
| | | Other species | 100 | 400 | - | - | - |
| PP-5 | *Fraxinus pennsylvanica* | *Acer platanoides* L. | 10000 | 46300 | 4600 | 5100 | 9700 |
| | | *Fraxinus excelsior* L. | - | 300 | 500 | 1100 | 1600 |
| | | *Crataegus monogyna* Jacquin s.l. | 100 | 1100 | 400 | - | 400 |
| | | *Cerasus avium* (L.) Moench | 100 | 400 | 300 | - | 300 |
| | | Other species | 500 | 700 | 100 | 400 | 500 |
| PP-6 | *Quercus robur* | *Quercus robur L.* | 2300 | 16800 | 100 | 100 | 200 |
| | | *Fraxinus excelsior L.* | 46800 | 28500 | 100 | - | 100 |
| | | *Ulmus glabra* Huds. | 1900 | 6000 | 300 | - | 300 |
| | | *Carpinus betulus L.* | 4100 | 5800 | 500 | 100 | 600 |
| | | *Acer compestre L.* | 1500 | 1500 | 200 | 500 | 700 |
| | | *Pyrus communis L.* | - | 500 | 100 | 100 | 200 |
| PP-7 | *Quercus robur* | *Quercus robur L.* | - | 5600 | 300 | - | 300 |
| | | *Fraxinus excelsior L.* | 100 | 34400 | 800 | 700 | 1500 |
| | | *Ulmus glabra* Huds. | 200 | 600 | 300 | 100 | 400 |
| | | *Carpinus betulus L.* | 2200 | 10900 | 1300 | 800 | 2100 |
| | | *Acer compestre* | - | 1000 | 400 | 100 | 500 |
| | | Other species | - | 100 | 200 | 400 | 600 |
| PP-8 | *Quercus robur* | *Quercus robur L.* | 2100 | 39900 | - | - | - |
| | | *Fraxinus excelsior* | 35800 | 28000 | 500 | - | 500 |
| | | *Ulmus glabra* Huds. | 11500 | 10600 | 1900 | 1000 | 2900 |
| | | *Acer compestre L.* | 100 | 1000 | 100 | 100 | 200 |
| | | Other species | | 900 | 200 | 300 | 500 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PP-9 | *Quercus robur* | *Quercus robur L.* | - | 4500 | 1300 | 200 | 1500 |
| | | *Fraxinus excelsior L.* | 16700 | 49900 | 2000 | 800 | 2800 |
| | | *Ulmus glabra* Huds. | - | 100 | - | 100 | 100 |
| | | *Carpinus betulus L.* | 2300 | 16800 | 2400 | 3200 | 5600 |
| | | *Acer compestre L.* | 100 | 900 | 900 | 500 | 1400 |
| | | *Pyrus communis L.* | 100 | 900 | 300 | - | - |
| PP-10 | *Quercus robur* | *Quercus robur L.* | 100 | 2800 | - | 100 | 100 |
| | | *Fraxinus excelsior L.* | 5600 | 15100 | 1000 | - | 1000 |
| | | *Ulmus partifolia Jacq.* | 100 | 1400 | 100 | - | 100 |
| | | *Carpinus betulus L.* | - | 200 | - | 1500 | 1500 |
| | | *Acer compestre L.* | 900 | 7300 | 1000 | - | 1000 |
| | | Other species | - | 200 | 100 | - | 200 |
| PP-11 | *Betula pendula* | *Quercus robur L.* | 200 | 4100 | 2800 | 5800 | 8600 |
| | | *Ulmus partifolia Jacq.* | - | - | 200 | 400 | 600 |
| | | *Pinus sylvestris L.* | - | 100 | 200 | 400 | 600 |
| | | *Fraxinus excelsior L.* | - | 4600 | 1300 | 900 | 2200 |
| | | *Malus sylvestris (L.)* Mill. | | 400 | 300 | 2200 | 2500 |
| | | Other species | - | - | 300 | 700 | 1000 |
| PP-12 | *Quercus petraea* | *Quercus robur L.* | - | 2700 | 900 | 2100 | 3000 |
| | | *Ulmus partifolia Jacq.* | - | - | 1500 | 1400 | 2900 |
| | | *Pinus sylvestris L.* | - | 300 | 900 | 200 | 1100 |
| | | *Juglans regia L.* | - | 200 | 300 | 500 | 1000 |
| | | Other species | - | - | 200 | - | 200 |
| PP-13 | *Prunus armeniaca* | *Quercus petraea(Matt.) Liebl.* | - | - | 900 | 1400 | 2300 |
| | | | - | - | - | 2000 | 2000 |
| | | *Fraxinus excelsior L.* | - | - | 400 | 100 | 500 |
| | | *Prunus domestica L.* | - | 100 | 300 | - | 500 |
| PP-14 | No stand | *Quercus robur L.* | - | 100 | 200 | 1200 | 1400 |
| | | *Fraxinus excelsior L.* | - | 300 | 500 | 1300 | 1800 |
| | | *Malus sylvestris (L.)* Mill. | - | | | 900 | 900 |
| | | *Acer platanoides* L. | - | | | 100 | 100 |
| PP-15 | *Quercus robur* | *Quercus robur L.* | 500 | 4600 | 600 | 2800 | 3400 |
| | | *Carpinus betulus L.* | - | 600 | 500 | 1200 | 1700 |
| | | *Fraxinus excelsior L.* | 1900 | 1200 | 300 | 100 | 400 |
| | | Other species | 100 | 400 | 100 | - | 100 |

[a] height from 0.1 to 0.5 m.
[b] height from 0.6 to 1.5 m.
[c] height from 0.6 and more 1.5 m.
[d] height from 1.5 m.

The results of reliable undergrowth accounting in these areas showed that the amount of oak does not exceed 500 pcs/ha and can not be considered significant in the process of reforestation. The exception is the amount of reliable undergrowth of oak (1500 PCs/ha) on PP 9, which is also lower than standard, but significantly higher than in other areas.

The study of the forest crops characteristics on PP10 in the territory of Beshtaugorsky forest district showed that, in general, for the English oak stand artificial origin at the age of 70 years retained its

position. Forest in this area grows in the condition of fresh oak stand (D2), belong to IV class of forest site and has an index of the sanitary condition of 2.9. Reliable undergrowth in the amount of 3900 pcs/ha has the species composition with a predominance of hornbeam like in natural coppice oak stands (PP6-PP9).

Successful development in the oak forest conditions native deciduous tree species are: hornbeam and ash, and also related – *C. betulus, F.excelsior*, and also accompanying – *U. glabra, A. campestre* and *P. communis*. Their total number on all experimental plots corresponds to the norms of successful natural forest restoration.

On oak restoration research in the Caucasian Mineral Waters region, open areas were discovered immediately adjacent to the forest stands, glades with successful *Q. robur* and *Q. petraea* regeneration. Sample plots were laid in the Kislovodsk National Park and Essentuksky forest district. The species and quantitative undergrowth characteristics take into account (Table. 2).

In the studied open areas from 3 to 6 units of species composition is oak in the amount of 1400 to 8600 pieces/ha. Ash, elm and maple sycamore are up to 3 units of composition. In the open space, taking into account the small shading of the adjacent walls of the stand, the oak is not inferior in the success of the resumption of ash and other species.

## 4. Conclusion

Artificial stands of introduced species of the Caucasian Mineral Waters region possessing high productivity ($I^b$ - II class of a forest site) and having a satisfactory sanitary condition, are not provided with own reliable undergrowth. Successful renewal of predominantly *F. excelsior* under their canopy is the initial stage of regenerative succession of the native breed.

Natural coppice oak forests of the region belong to the IV-V class of forest type and the category of weakened and severely weakened by sanitary conditions. Oak forest crops are more productive - II class of forest site. Under the canopy of natural and artificial oak stands maternal undergrowth is not formed. In the regeneration process in the oak forest conditions the dominant positions are occupied by *Carpinus betulus* and *Fraxinus excelsior*, and also related *Ulmus glabra*, *Acer compestre* and *Pyrus communis*.

More successful oak undergrowth develops on the glades at the soil illumination at the level of 10 % of full lightening, where it occupies positions equivalent to ash and elm.

In order to prevent the change of species in the artificial and natural forests of the Caucasian Mineral Waters resort region, timely measures of care for the undergrowth and forest stands should be carried out according to special programs developed for this purpose.

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