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**RESEARCH ARTICLE**

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# Changes in mixed forest plantations after snow damage in the Northwest Rhodopes

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**ABSTRACT**

The changes in diameter structure of *Pinus sylvestris* (L.) in addition to a similar previous study on *Pinus nigra* (Arn.) in mixed Austrian black pine – Scots pine plantations after damages from abundant wet heavy snow in the region of Velingrad – Northwest Rhodopes were studied. A period without significant abiotic influences (1997-2007) and following one (2007-2017) were compared, in which small-scale natural disaster caused by snowfalls was observed (2015). The analysis was made with variation distribution curves of the stems according to natural degrees of thickness. It is confirmed that the reason for deviations from the normality of the distribution of the trees is their right asymmetry as a consequence of trees with smaller diameters loss as a sum result of the natural loss and the heavy snow. This is proved by the analysis of the curves of mean variation rows for percent stem distribution according to natural degrees of thickness and Skewness and Kurtosis coefficients. The dynamics in the tree number distribution of both species forming the composition by Gini index was investigated as well as the diameter, height, basal area, volume, and assortment structure.

**Key words:** Dynamics of the dendrobiometrical indicators, thickness structure, timber assortment structure, Gini index, Scots pine, Austrian black pine

## Introduction

Influence on the forest development realized the large (scale) and the small (scale) disturbances in the plantations. These disturbances could be with a natural or anthropogenic origin, large ones being windfalls, snowthrow, forest conflagration destructed areas, erosion, volcanoes, landslides, calamities, group shelterwood cuttings (cutting areas), or forestless areas due to different causes. For small disturbances, it is usually considered about the loss of solitary or small tree groups, no matter the causes. The disturbances could be with different forms and dimensions depending on the origin (due to phenomenon or activity) and the way of realization. In all cases, to the disturbances should be added the places in which forestry activities were performed including tree cuttings (Rafailov, 2003).

Numerous investigations have shown that the disturbances in forest ecosystems have a significant influence on the forest structure, its tree composition, and dynamics (Pickett & White, 1985). Different disturbances most frequently are accepted as a negative factor for the forest, as they take it out of the temporary ecological balance. In reality, in most cases, they are a necessary ecological process, due to which the forest ecological systems, not subject to active management, maintain their stability and productivity. This way, due to small-scale natural disturbances, the biodiversity, heterogeneity, and the renovation process are maintained (Rafailov, 2003). Higher ecological stability and productivity helps to reach a condition named ‘ecological health’ of a forest ecosystem, in which its complexity is maintained – composition, structure, and dynamics in the process of usage to meet the human needs (McCarthy, 2001; Alexandrov, 2014). White (1979) studied the dynamics of the natural disaster as a factor for the natural forest development.

In case of natural disturbances investigation in the natural and artificial stands and due to development of diseases and insects after them, and in relation with mitigation of the damages, it is convenient to direct them not only on measurement of the description of separate trees and tree groups but also to investigate their structure (Wolter et al., 2009), as well as to study the changes in different dendrobiometrical indicators of stands.

In the region of Velingrad (Northwest Rhodopes), during the first decade of March 2015, abundant wet snow was observed and this lead to disturbances in the form of many snowbreakage and snowthrown trees mainly in coniferous plantations established in the 1940s in the lands of the villages Chepino bania, Ludzhene, and Kamenitsa (Shikov, 1972).

As a result of the wet heavy snowfall, the general condition of forest ecosystems was disturbed, the natural succession processes and development were stopped, and the composition, structure, and characteristics of the stands were disturbed.

In relation to the disturbance due to the wet snowfall in the area and plantations, a study on the changes in the thickness structure of Austrian black pine was carried out and published (Ferezliev, 2019), and widening of its scope is needed in order to the prognosis of development of these stands.

The working hypothesis/aim of the investigation is to study the changes in the thickness structure of Scots pine as an addition to recorded ones for the Austrian black pine mentioned during the investigation of the diameter dynamics, height, volume, and assortment structure of the trees in mixed Austrian black pine – Scots pine plantation after a natural disaster in the region of Velingrad, Northwest Rhodopes.

## Materials and Methods

The region under investigation covers part of the mountain landscape of northwest branches of the Rhodopes in the transitional-continental subarea of the European-continental climate area (Sabev & Stanev, 1963).

The object of investigation is in the subarea West Rhodopes of Thracian forest area and the middle mountain forest belt of beech and coniferous (Zahariev et al., 1979).

The investigation was carried out in 5 still existing from ten sample plots (SP) the established in 1972 in mixed Austrian black pine – Scots pine plantations afforested in 1942, aiming at studying the growth and productivity of both pine species at similar conditions (Shikov, 1972).

No forestry activities were carried out in SP1, SP3, and SP4. In SP2 and SP5 were carried out commercial thinnings with 10% intensity in 1997.

After full callipering in SPs and measuring two perpendicular DBH (every 0.5 cm), the trees were distributed separately for species as independent parts of the mixed stands according to number and thickness degrees (every 2 cm), and the mean diameters were established via the mean arithmetic basal area.

After 2015, the plantations are with a uniform structure, stocking rate of 0.8, and medium condition.

In consequence of the abundant wet and heavy snowfall in the spring of 2015, part of the trees were damaged by snowbreakage and snowthrown, and in order to prevent investment by bark beetles, cutting was carried out during the next 2 years (in 2016 in SP1, SP2, and SP3, and 2017 in SP4 and SP5) to remove the damaged trees, which suggests changes in the tree composition and structure in plantations (Ferezliev, 2017).

As it was mentioned, the changes in the thickness structure of Austrian black pine trees after the damages on the studied mixed plantations as a result of the wet snowfall were the object of a previous publication (Ferezliev, 2019). To investigate the peculiarities resulting from the changes in thickness structure of Scots pine, the data from diameter measurements in 2007 and 2017 were used.

**Table 1.** *Location and characteristics of the sample plots.*

| N of SP | division/ subdivision | Location | Coordinates | Area (ha) | Composition | Age | Altitude (m) | Exposure | Slope (°) | Soil type |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 25 / p | SGS Alabak | 41°59.699'N<br>23°57.665'E | 0.135 | *P. nigra* - 51.6%<br>*P. sylvestris* - 48.4% | 75 | 900 | S-slope upper part | 11 | Distric, Eutric Cambisols |
| 2 | 346 / h-I variant | SGS Alabak | 42°02.066'N<br>23°58.113'E | 0.135 | *P. nigra* - 87.1%;<br>*P. sylvestris* - 12.9% | 75 | 850 | S-slope upper part | 7 | Distric, Eutric Cambisols |
| 3 | 346 / h-II variant | SGS Alabak | 42°02.069'N<br>23°58.098'E | 0.135 | *P. nigra* - 77.8%;<br>*P. sylvestris* - 22.1% | 75 | 850 | S-slope upper part | 7 | Distric, Eutric Cambisols |
| 4 | 346 / l-I variant | SGS Alabak | 42°02.008'N<br>23°58.212'E | 0.135 | *P. nigra* - 91,9%;<br>*P. sylvestris* - 8.1% | 75 | 800 | S-slope upper part | 4 | Distric, Eutric Cambisols |
| 5 | 346 / l-II variant | SGS Alabak | 42°02.004'N<br>23°58.212'E | 0.135 | *P. nigra* - 88.0%;<br>*P. sylvestris* - 12% | 75 | 800 | S-slope upper part | 4 | Distric, Eutric Cambisols |

The direct influence of snowfall was studied in SP2 where comparisons were made based on the diameters measured in 2007, those just before the abiotic influence in 2014, and in 2017 after eliminating the snowbreakage and snowthrown specimens (Table 3).

Scots pine trees are distributed according to natural degrees of thickness- NDW (relations of thickness degrees to mean diameter) and variation rows for tree number in the degrees in percentage from the total tree number from all SPs are obtained (Tyurin, 1931; Krastanov et al., 1965; Tsakov, 1980; 1998; Ferezliev et al., 2017; Ferezliev et al.,2018a; Ferezliev, 2019).

Variation rows from SP are united according to years and based on calculated mean variation rows curves of mean variation rows for percentage distribution of Scots pine stems are obtained according to relative thickness degrees (Kyulev, 1969; Ferezliev et al., 2018b).

The characteristics of the frequency distribution is done according to Skewness and Kurtosis coefficients (Ferezliev, 2009; Ustabashiev & Ferezliev, 2013). For this purpose, descriptive statistical analysis is carried out with Statistica 12-Trial version.

The characterization and comparison of the tree distribution from both species forming the composition according to diameter are realized applying the Gini index (Lexerød & Eid, 2006) for the basal area, which is used for evaluation of population heterogeneity (Weiner & Solbrig, 1984).

Gini coefficient calculator (https://shlegeris.com/gini.html) was used. Graphically the level of Gini index is presented with the relation between the area locked between straight line (Lorenz curve-diagonal), which expresses cases of trees with similar dimension, and line (perfect equality), and is a case with determined diversity in the dimensions to the total area under the diagonal. Calculating the Gini index does not require the establishment of diameter in thickness degrees or classes.

$GS = (\Sigma^n{}_1\,(2j\text{-}n\text{-}1)g_j\,)/\,(\Sigma g_j(n\text{-}1))$,

where:

$g_j$ – is the tree basal area with rank j;

j – is the tree rank according to DBH ordered upwards from 1 → n;

n –is the total tree number.

Comparison between basal areas of Austrian black pine in the SPs is also done with the suggested parabolic dependence II degree for the mean leading curve in case of change of the basal area per ha depending on stands age (Tsakov, 1983):

$G\ (ha) = -0.012.A^2 + 1.3256.A+8.315$.

Calculation of volume and assortments was done with FET 1.11 (Demo) (Evangelov, 2012), whose mathematical model for Austrian black pine is based on the table of Nedialkov et al. (1978), and for Scots pine – on those of Krastanov et al. (1976), published in ‘Handbook of the dendrometric worker’ (Poriazov et al., 2004) and ‘Reference book in dendrobiometry’ (Krastanov & Raykov, 2004).

## Results

To compare the changes in the thickness structure of Scots pine and according to the applied methods, variation curves of distribution of Scots pine trees were used. The data are shown in Table 2.

The curves of the mean variation rows of percentage distribution according to natural thickness degrees in plantations investigated before and after the natural disaster are presented in Table 7.

To study the changes in the mixed Austrian black pine – Scots pine as a sequence of the abundant wet heavy snowfall, some dendrometric indicators and timber assortment structure were established for each species – for a period without significant abiotic influences (1997-2007) and for following one (2007-2017), during which the natural disaster took place (Tables 3, 4, 5).

**Table 2.** *Variation curves for percentage distribution of the number of trees by natural degrees of thickness.*

| Number of SP | Year | Natural degrees of thickness | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 |
| | | Number of trees (%) | | | | | | | | | | | | | |
| SP1 | 2007 | 1.7 | 3.1 | 7.8 | 16.3 | 15.6 | 20.8 | 19.6 | 8.7 | 4.3 | 1.7 | 0.2 | | | |
| SP2 | | | 7.1 | 10.0 | 10.0 | 7.1 | 28.6 | 21.4 | 15.7 | | | | | | |
| SP3 | | | | 9.1 | 18.3 | 13.7 | 13.7 | 13.7 | 4.6 | 5.0 | 9.1 | 8.7 | 4.1 | | |
| SP4 | | | | 18.1 | 21.9 | 16.7 | 5.2 | 22.9 | 12.4 | 2.9 | | | | | |
| SP5 | | 4.6 | 4.6 | 7.4 | 14.4 | 20.8 | 23.1 | 25.0 | | | | | | | |
| SP2 | 2014 | | 8.5 | 8.5 | 15.3 | 8.5 | 15.3 | 23.7 | 20.3 | | | | | | |
| SP1 | 2017 | | | 12.1 | 4.9 | 23.7 | 34.8 | 16.1 | 4.0 | 4.5 | | | | | |
| SP2 | | | | 15.2 | 12.7 | 0.0 | 17.7 | 41.8 | 12.7 | | | | | | |
| SP3 | | | 16.1 | 18.9 | 15.0 | 11.1 | 6.1 | 8.9 | 5.6 | 13.9 | 0.0 | 0.0 | 0.0 | 0.0 | 4.4 |
| SP4 | | | | 12.4 | 22.2 | 17.0 | 5.7 | 24.7 | 11.9 | 6.2 | | | | | |
| SP5 | | 4.7 | 4.7 | 1.4 | 15.6 | 23.6 | 20.8 | 29.2 | | | | | | | |

**Table 3.** *Dendrometric indicators for P. nigra of the investigated sample plots for the period 1997-2017.*

| Number of sample plot (SP) /Year of measurement | Number of trees *Pinus nigra* | DbH (cm) | Average height H av. (m) | Basal area ($m^2$) per SP | Basal area ($m^2$) per ha | Volume ($m^3$) per SP | Volume ($m^3$) per ha |
|---|---|---|---|---|---|---|---|
| SP1 | | | | | | | |
| 1997 | 176 | 17.5 | 19.5 | 4.2086 | 31.1748 | 43.885 | 325.071 |
| 2007 | 146 | 19.5 | 20.3 | 4.3502 | 32.2237 | 41.805 | 309.667 |
| 2017 | 38 | 25.2 | 22.4 | 1.8979 | 14.0585 | 20.969 | 155.324 |
| SP2 | | | | | | | |
| 1997 | 222 | 17.6 | 20.3 | 5.3955 | 39.9667 | 58.667 | 434.567 |
| 2007 | 142 | 21.1 | 20.8 | 4.9848 | 36.9244 | 54.489 | 403.619 |
| 2014 | 140 | 21.2 | 21.0 | 4.9485 | 36.6556 | 54.877 | 406.496 |
| 2017 | 110 | 22.9 | 23.5 | 4.5110 | 33.4148 | 54.894 | 406.626 |
| SP3 | | | | | | | |
| 1997 | 290 | 14.9 | 17.6 | 5.0601 | 37.4822 | 47.751 | 353.712 |
| 2007 | 181 | 18.7 | 20.5 | 4.9880 | 36.9481 | 46.940 | 347.706 |
| 2017 | 157 | 20.2 | 20.6 | 5.0165 | 37.1593 | 54.875 | 406.483 |
| SP4 | | | | | | | |
| 1997 | 490 | 11.8 | 17.7 | 5.3601 | 39.7044 | 46.814 | 346.772 |
| 2007 | 388 | 14.3 | 15.3 | 6.1872 | 45.8311 | 52.946 | 392.190 |
| 2017 | 302 | 14.9 | 15.4 | 5.2413 | 38.8244 | 44.803 | 331.876 |
| SP5 | | | | | | | |
| 1997 | 257 | 14.7 | 17 | 4.3507 | 32.2274 | 40.207 | 297.830 |
| 2007 | 254 | 16.5 | 18.7 | 5.4366 | 40.2711 | 51.157 | 378.940 |
| 2017 | 223 | 17.6 | 16.8 | 5.3965 | 39.9741 | 53.954 | 399.657 |

**Table 4.** *Dendrometric indicators for Pinus sylvestris of the investigated sample plots for the period 1997-2017.*

| Number of sample plot (SP) /Year of measurement | Number of trees *Pinus sylvestris* | DbH (cm) | Average height H av. (m) | Basal area ($m^2$) per SP | Basal area ($m^2$) per ha | Volume ($m^3$) per SP | Volume ($m^3$) per ha |
|---|---|---|---|---|---|---|---|
| SP1 | | | | | | | |
| 1997 | 77 | 21.5 | 21.8 | 2.7998 | 20.7393 | 32.094 | 237.736 |
| 2007 | 70 | 24.0 | 23.5 | 3.1571 | 23.3859 | 38.384 | 284.324 |
| 2017 | 33 | 27.6 | 21.8 | 1.9665 | 14.5667 | 22.050 | 163.331 |
| SP2 | | | | | | | |
| 1997 | 17 | 22.2 | 20.2 | 0.6561 | 4.8600 | 6.876 | 50.932 |
| 2007 | 17 | 24.0 | 22.0 | 0.7671 | 5.6822 | 8.778 | 65.024 |
| 2014 | 15 | 24.4 | 21.7 | 0.7029 | 5.2067 | 7.084 | 52.473 |
| 2017 | 12 | 26.2 | 21.8 | 0.6486 | 4.8044 | 7.197 | 53.314 |
| SP3 | | | | | | | |
| 1997 | 24 | 20.1 | 19.4 | 0.763 | 5.6519 | 8.307 | 61.533 |
| 2007 | 23 | 20.1 | 19.3 | 0.9473 | 7.0170 | 7.458 | 55.247 |
| 2017 | 23 | 24.3 | 20.9 | 1.0640 | 7.8815 | 11.737 | 86.941 |
| SP4 | | | | | | | |
| 1997 | 23 | 14.5 | 16.0 | 0.3313 | 2.4541 | 2.785 | 20.629 |
| 2007 | 23 | 15.9 | 16.4 | 0.3968 | 2.9393 | 3.572 | 26.461 |
| 2017 | 23 | 16.5 | 17.1 | 0.4278 | 3.1689 | 3.989 | 29.548 |
| SP5 | | | | | | | |
| 1997 | 25 | 17.2 | 17.0 | 0.5549 | 4.1104 | 4.965 | 36.774 |
| 2007 | 25 | 18.9 | 18.0 | 0.6703 | 4.9652 | 6.980 | 51.703 |
| 2017 | 25 | 19.2 | 18.1 | 0.6932 | 5.1348 | 7.173 | 53.059 |

To precise the evaluation of snow influence the data from 2014 is available – the year just before the disturbance.

The basal areas calculated per ha according to the suggested correlation dependence of the change of this dendrobiometrical indicator with the age (Tsakov, 1983) for the corresponding ages of the investigations realized and compared for Austrian black pine are as follows:

1997 (55 years)- G(ha)= 44.93 m2; 2007 (65 years)- G(ha)= 43.78 m2;

2014 (72years)- G(ha)= 41.55 m2; 2017 (75years)- G(ha)= 40.24 m2.

Results from Gini indexes (Gini, 1912) calculated for the basal areas of SPs trees are presented in Table 6.

**Table 5.** *Assortment of Pinus sylvestris and Pinus nigra in sample plots.*

| № of sample plot - year | ASSORTMENTS OF TREE TRUNKS - *Pinus sylvestris* (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Large construction timber (LCT) | | | | Middle sized construction timber (MCT) | | | | SUM (LCT+MCT) % | Small construction timber (SCT) class VI % | Total construction timber % |
| | class Ia % | class I % | class II % | Total LC % | class III % | class IV % | class V % | Total MCT % | | | |
| SP1 -1997 | 0.0 | 0.0 | 36.7 | 36.7 | 20.7 | 15.7 | 8.4 | 44.9 | 81.6 | 3.5 | 85.1 |
| SP1-2007 | 0.0 | 0.9 | 47.4 | 48.2 | 18.0 | 9.7 | 7.2 | 35.0 | 83.2 | 2.0 | 85.2 |
| SP1-2017 | 0.0 | 7.2 | 55.7 | 62.9 | 9.8 | 6.1 | 4.4 | 20.3 | 83.2 | 2.0 | 85.2 |
| SP2-1997 | 0.0 | 0.0 | 38.4 | 38.4 | 22.2 | 11.5 | 11.0 | 44.7 | 83.1 | 2.1 | 85.1 |
| SP2-2007 | 0.0 | 0.0 | 49.3 | 49.3 | 15.1 | 11.3 | 6.9 | 33.4 | 82.7 | 2.5 | 85.2 |
| SP2-2014 | 0.0 | 0.0 | 51.8 | 51.8 | 14.4 | 11.1 | 4.2 | 29.7 | 81.5 | 3.6 | 85.2 |
| SP2-2017 | 0.0 | 0.0 | 57.4 | 57.4 | 13.6 | 8.1 | 2.9 | 24.6 | 82.0 | 3.2 | 85.2 |
| SP3-1997 | 0.0 | 0.0 | 31.7 | 31.7 | 21.9 | 15.4 | 13.3 | 50.7 | 82.4 | 2.7 | 85.1 |
| SP3-2007 | 0.0 | 0.0 | 27.5 | 27.5 | 22.5 | 17.6 | 14.2 | 54.4 | 81.9 | 3.2 | 85.1 |
| SP3-2017 | 0.0 | 0.0 | 51.6 | 51.6 | 15.7 | 9.0 | 6.3 | 31.0 | 82.6 | 2.6 | 85.2 |
| SP4-1997 | 0.0 | 0.0 | 0.0 | 0.0 | 10.5 | 22.0 | 42.5 | 75.0 | 75.0 | 9.7 | 84.7 |
| SP4-2007 | 0.0 | 0.0 | 3.5 | 3.5 | 17.7 | 25.3 | 31.9 | 74.9 | 78.4 | 6.6 | 85.0 |
| SP4-2017 | 0.0 | 0.0 | 9.0 | 9.0 | 18.7 | 23.8 | 26.6 | 69.1 | 78.1 | 6.8 | 84.9 |
| SP5-1997 | 0.0 | 0.0 | 9.8 | 9.8 | 21.5 | 23.2 | 25.4 | 70.1 | 79.9 | 5.1 | 85.0 |
| SP5-2007 | 0.0 | 0.0 | 23.7 | 23.7 | 23.5 | 19.4 | 13.9 | 56.8 | 80.5 | 4.6 | 85.0 |
| SP5-2017 | 0.0 | 0.0 | 23.1 | 23.1 | 22.9 | 20.2 | 14.3 | 57.4 | 80.5 | 4.5 | 85.0 |
| ASSORTMENTS OF TREE TRUNKS - *Pinus nigra* (%) | | | | | | | | | | | |
| SP1 -1997 | 0.0 | 0.0 | 11.6 | 11.6 | 21.4 | 22.0 | 20.7 | 64.1 | 75.7 | 5.7 | 81.4 |
| SP1-2007 | 0.0 | 0.0 | 16.5 | 16.5 | 22.2 | 21.0 | 17.1 | 60.3 | 76.8 | 4.7 | 81.6 |
| SP1-2017 | 0.0 | 1.2 | 48.7 | 49.9 | 15.0 | 8.7 | 6.2 | 29.9 | 79.8 | 2.3 | 82.1 |
| SP2-1997 | 0.0 | 0.0 | 13.5 | 13.5 | 20.9 | 21.7 | 20.6 | 63.1 | 76.6 | 4.8 | 81.4 |
| SP2-2007 | 0.0 | 0.0 | 31.9 | 31.9 | 21.5 | 15.2 | 9.8 | 46.5 | 78.4 | 3.4 | 81.8 |
| SP2-2014 | 0.0 | 0.0 | 32.5 | 32.5 | 21.6 | 14.4 | 10.3 | 46.3 | 78.8 | 3.1 | 82.0 |
| SP2-2017 | 0.0 | 0.5 | 40.7 | 41.2 | 18.0 | 12.3 | 7.9 | 38.2 | 79.4 | 2.6 | 82.1 |
| SP3-1997 | 0.0 | 0.0 | 2.3 | 2.3 | 13.3 | 20.2 | 34.8 | 68.3 | 70.6 | 9.7 | 80.4 |
| SP3-2007 | 0.0 | 0.0 | 19.8 | 19.8 | 22.9 | 19.3 | 15.9 | 58.1 | 77.9 | 3.8 | 81.7 |
| SP3-2017 | 0.0 | 0.0 | 26.5 | 26.5 | 22.8 | 16.5 | 12.4 | 51.8 | 78.3 | 3.6 | 81.9 |
| SP4-1997 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 9.5 | 45.3 | 56.5 | 56.5 | 22.1 | 78.6 |
| SP4-2007 | 0.0 | 0.0 | 1.4 | 1.4 | 11.2 | 19.4 | 37.5 | 68.1 | 69.5 | 10.5 | 80.1 |
| SP4-2017 | 0.0 | 0.0 | 2.6 | 2.6 | 13.9 | 21.0 | 33.4 | 68.4 | 71.0 | 9.6 | 80.5 |
| SP5-1997 | 0.0 | 0.0 | 1.7 | 1.7 | 12.3 | 20.7 | 35.3 | 68.2 | 69.9 | 10.4 | 80.4 |
| SP5-2007 | 0.0 | 0.0 | 5.3 | 5.3 | 17.3 | 22.9 | 28.2 | 68.4 | 73.7 | 7.2 | 81.0 |
| SP5-2017 | 0.0 | 0.0 | 12.1 | 12.1 | 21.9 | 20.0 | 21.9 | 63.8 | 75.9 | 5.6 | 81.4 |

## Discussion

The method of variation curves of stem distribution according to thickness degrees allows comparison of their form calculating tree number of different degrees in percent from the total tree number (Ferezliev et al., 2018a) (Table 2).

The analysis of the mean variation curves obtained characterizing the percentage distribution of Scots pine trees during the years (starting for the revision period in which the natural disturbance was realized (2007), and the following with which the next begins (2017), (Table 7) showed that there is no significant difference in the thickness structure which was obtained for Austrian black pine (Ferezliev, 2019).

Observation of the curves of mean variation rows for percent distribution of tree stems according to natural thickness degrees for the period before, immediately after, and after abiotic influence (Table 7), allows establishing the changes in the diameter structure as a sequence of the natural loss and abiotic influence.

Both mean variation curve (for 2007 and 2017) and the variation curve for 2014 are with typical asymmetric form, with well-detected maximums which, as a difference for the Austrian black pine, are presented after the mean diameter, e.g., tree distribution is evident with positive (right) asymmetry in the three of the studied cases, and this is visible from the maximums obtained – at NDW 1.1, to the right from the mean diameter. This is also confirmed by statistical investigation of the distributions with coefficients of Skewness and Kurtosis.

**Table 6.** *Results of calculated Gini indices for basal areas by sample plots*

| № of Sample plot / year | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| 1997 | Gini index | | | | | |
| *Pinus sylvestris* | 0.224 | 0.208 | 0.368 | 0.269 | 0.219 | |
| *Pinus nigra* | 0.299 | 0.281 | 0.311 | 0.356 | 0.276 | |
| № of Sample plot / year | 1 | 2 | 3 | 4 | 5 | |
| 2007 | Gini index | | | | | |
| Gini index for *Pinus sylvestris* | 0.215 | 0.201 | 0.362 | 0.244 | 0.186 | |
| Gini index for *Pinus nigra* | 0.316 | 0.223 | 0.237 | 0.319 | 0.277 | |
| № of Sample plot / year | 2 | 1 | 2 | 3 | 4 | 5 |
| | Gini index | Gini index | | | | |
| | 2014 | 2017 | | | | |
| *Pinus sylvestris* | 0.206 | 0.177 | 0.190 | 0.340 | 0.251 | 0.175 |
| *Pinus nigra* | 0.225 | 0.293 | 0.601 | 0.252 | 0.318 | 0.283 |

Those of Skewness are higher than 0, which is an argument for the fact that the distributions are mainly to the right (curve benched left). For 2007 the Skewness (As) = +0.3531 (standard error of Skewness, Std.err.As = 0.6607); for 2017- As = +0.4226 and Std.err.As = 0.7521.

Such deviations are often established in uniform-to-age forest plantations (Ferezliev et al., 2018a; Tsakov et al., 2018). Kurtosis of distribution is negative anyway. This means that the diameter distribution is realized to curves decreasing in the top parts the normal distribution curves, criteria for which are the negative values of the Kurtosis (Kurt. = -1.6730, Std.err.Kurt. =1.2794 and Kurt. = -0.3567, Std.err.Kurt. = 1.4809, for 2007 and 2017 resp.), but without a big difference from the possible for normal distribution. This means we can accept here as a cause for deviation from the normal Scots pine trees distribution (to difference with Austrian black pine) is their right skewness as a sequence from trees with smaller diameter loss as a sum result from the natural elimination and heavy snow dropped, which was observed on spot during the registration of fallen trees (numbered) in SPs.

The situation is different in comparison with Austrian black pine for the length of the variation interval, which is relatively widen after the abiotic influence (from NDW 0.5-1.6 in 2007 to NDW 0.5-1.8 in 2017). For Scots pine, in both variations (before dropping of heavy wet snow and after sanitary cuttings) some movement to wider stems was observed (maximums 20.5% in 2007 and 24.1 % in 2017 at NDW 1.1). The end of the curves shows that relatively larger diameters are present after the snow damage (in 2017)- to 1.8 from mean diameter, which confirms the registered loss of smaller Scots pine trees.

For direct registration of influence of snow in 2015 on thickness structure comparison of the variation curves of distribution of Scots pine stems in SP2 was made on the base of measurements done in 2014 (just before the natural disaster) and in 2017 just after sanitary cutting realized during which all snowbreakage and snowthrown trees were removed (Table 7).

There is some difference in the variation curves as follows:

**Table 7.** *Mean percentage distribution of the number of trees of Pinus sylvestris by natural degrees of thickness*

| | Natural degrees of thickness | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | Total |
| *Pinus sylvestris* number of trees 2007 (N %) | 1.3 | 3.0 | 10.5 | 16.2 | 14.8 | 18.3 | 20.5 | 8.3 | 2.4 | 2.2 | 1.8 | 0.8 | | | 100.0 |
| aggregate-N (%) | 1.3 | 4.3 | 14.7 | 30.9 | 45.7 | 64.0 | 84.5 | 92.8 | 95.2 | 97.4 | 99.2 | 100.0 | | | |
| *Pinus sylvestris* number of trees 2017 (N %) | 0.9 | 4.2 | 12.0 | 14.1 | 15.1 | 17.0 | 24.1 | 6.8 | 4.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 100.0 |
| aggregate-N (%) | 0.9 | 5.1 | 17.1 | 31.2 | 46.2 | 63.2 | 87.4 | 94.2 | 99.1 | 99.1 | 99.1 | 99.1 | 99.1 | 100.0 | |
| *Pinus sylvestris* number of trees-SP2, 2014 (N %) | | 8.5 | 8.5 | 15.3 | 8.5 | 15.3 | 23.7 | 20.3 | | | | | | | 100.0 |
| aggregate-N (%) | | 8.5 | 16.9 | 32.2 | 40.7 | 55.9 | 79.7 | 100 | | | | | | | |
| *Pinus sylvestris* number of trees SP2, 2017 (N %) | | | 15.2 | 12.7 | 0.0 | 17.7 | 41.8 | 12.7 | | | | | | | 100.0 |
| aggregate-N (%) | | | 15.2 | 27.8 | 27.8 | 45.6 | 87.3 | 100 | | | | | | | |

Asymmetry of both curves is identical as a phenomenon, but drastically differs in terms of the values of the variations especially in the interval NDW 0.8-1.2, where the curve before the disaster marks smaller variation compared to that after carrying out of the sanitary cutting. Both curves sharply decrease after NDW 0.8 (from 15.3% to 8.5% of the Scots pine trees in 2014 and from 12.7% to 0% of stems in 2017). After NDW 0.9, the stroke is increasing for both curves until peak values are reached at ESD 1.1- to the right of the mean diameter.

Here the variation in 2017 is significant (from missing (0%) to 41.8% number of trees), as it was relatively smoother before the snowfall - from 8.5% to 23.7%. The conclusion made for the mean variation curves about some movement to the thicker stems is confirmed.

The last one is also confirmed during statistical validation of the data with the obtained for both cases positive (right) asymmetry ($As_{2014} = 0.4636$ and /Std. err. $As_{2014}$/ = 0.7937; $As_{2017} = +1.2802$ and /Std. err. $As_{2017}$/ = 0.8452).

As for Kurtosis manifestation for the year before the natural disaster, there is a decrease in the variation curve (Kurt. = -1.3345, std. err. Kurt. = 1.5875). On the contrary – after the sanitary cutting in 2017, there is a significant increase in variation (Kurt. = +3.0936, std. err. Kurt. = 1.7408). Both cases confirm the ascertainments for the Austrian black pine (Ferezliev, 2019).

A possible reason for the right asymmetry of the curves is the fall of trees with smaller diameters after a significant amount of wet snow (although in this statement there is a high dose of the convention having in mind the removal of the small number of Scots pine trees).

In contrast to what was found about the Austrian black pine, the variation curve in 2014 is in the wider interval (for NDW from 0.6 to 1.2), moreover in the central thickness degrees (similar to Austrian black pine) nearly half of the stems (47.5%) are concentrated.

In 2017, the variation is in the relatively narrower interval (for NDW from 0.7 to 1.2), and despite the absence of trees in ESD 0.9, the largest number of trees (59.5%) was concentrated in the central thickness degrees. This is due to the large representation in ESD 1.1.

As it is also mentioned in other publications, the fact of a presence of a higher percentage of trees in the central thickness degrees has determined practical value, because the average thickness degrees, which are represented by the highest number of trees, increase the quantity of large- and middle-sized construction timber (LCT and MCT) assortments in the stand (Logvinov,1956; Ferezliev et al., 2018a), which is visible from Table 5. It is evident that the disaster does not influence significantly as the sum of the LCT and MCT (for Scots pine in %) for SP2, from 82.7% in 2007, decreases to 81.5% in 2014 and increases again to 82.0% in 2017.

Some authors (Dimitrov, 2003; Petrin & Markoff, 2018) recommend during the analysis of Skewness not to use statistical asymmetry of the curve itself towards itself maximum but the asymmetry towards mean diameter ($d_{av.}$) established by Weisse (1880) (approximately 58% from the sum percent of tree number (thin) towards mean diameter). This approach requires determining the location of the Scots pine stem with average diameter by the thickness (so-called rank, aggregate-N (%)). To determine its rank, half of the percentage of stems at NDW 1.0 (Tyurin, 1938; Ferezliev et al., 2017) is added to the total percentage for natural thickness 0.9 (Table 7). Using this approach, the found right (positive) asymmetry is confirmed in a smaller part (5) of the studied 11 cases (for $OP4_{2007}$-59.3%; for $OP5_{2007}$-63.4%; for $OP1_{2017}$-58.0%; for $OP3_{2017}$-64.2% and for OP $5_{2017}$-60.4%).

When checking the information about dead or damaged and cut Scots pine trees, it can be seen that for the period 2007-2014 and 2014-2017, respectively, there is absence of trees with dimensions less than the average diameter. This fact is a reason in this particular case to use as an additional argument the analysis based on statistical asymmetry of the obtained curves according to their maximums.

From the analysis of data shown in Tables 3 and 4, it can be seen that the average height of the Scots pine (45.5 %) exceeds that one of the Austrian black pine, which is a change from the established situation until the 45th year of age (Shikov, 1972) when in all sample plots the mean Scots pine height was with higher values. It is confirmed the established until this age priority of Scots pine on Distric Eutric Cambisols average diameters as well.

Deviation ranges of basal area per ha for Austrian black pine in the plantations investigated towards the values calculated according to the dependence suggested by Tsakov (1983) are within the intervals from 0.7 to 0.9 at 55 (1997), from 0.7 to 1.1 at 65 (2007), 0.9 at 72 (2014, before the natural disaster) and from 0.3 to 1.0 at 75 (in 2017). Actually, except SP1, in which high number of Austrian black pine was lost during the last decade (108) and at this age for the rest of SPs, the range in the differences according to basal areas is from 0.8 to 1.0 and does not differ significantly from the obtained for the rest of ages (Table 3). A significant difference is not observed before and after the snowfall, similarly to the percentage distribution of Austrian black pine stems investigated as an independent part of the plantations with different composition and conditions of growth (habitat) (Ferezliev, 2019).

Excluding again SP 1, where the difference in the volumes calculated for Austrian black pine between 2007 and 2017 is -49.8% (due to 3.6 times more lost trees in comparison with the natural loss for the period 1997-2007), for all other cases and regardless of the trend of increasing average diameter and average height (the exception is in SP4) for all other cases and independently from the increasing mean diameter and mean height, the differences in the volumes is from -15.4% (SP 4, 2007-2017) up to nearly full coincidence - + 0.7% (for the volume of SP 2 (2007-2017) and to +27.2% (SP 5, 1997-2007). Even more insignificant (0.03%) is the difference in the volumes of Austrian black pine in SP 2 before and after a natural disaster where 2-year growth compensated the volume loss of the trees lost (Table 3).

For the Scots pine (as it was established for the Austrian black pine), a solid decrease in the volume is present again (-42.6%), due to the large number of trees lost in SP 1 for the period 2007-2017, which compared with the natural loss (1997-2004), is with 5.3 times more (Table 4). With close relation but positive (+40.6%) increased the volume in SP 5 for the period 1997-2007, without a change in tree number. For the rest of the cases, the differences in the volumes within the years in the beginning and the end of the revising period are within the range from -18% to +28.3%. Similarly, to the Austrian black pine, there is either a significant difference in the volumes (+1.3%) for the year before the natural disaster (2014) and after the removal of 2 damaged Scots pine specimens during the sanitary culling in 2016.

From a point of view of forestry dendrobiometry it is interesting to establish the assortment structure according to categories of formed wood, in particular, according to tree species (Tsakov et al., 2006). Analyzing the assortment structure (Table 5), it is evident that with increasing the age and independently from the natural loss the forestry activities did commercial thinning in SP2 during the period 1997-2007 and sanitary cuttings during 2016-2017 in all areas, as a result from the natural disturbance), in predominant cases for both species increases the percent of the large construction timber (LCT) concentrated mainly in II class, at predominant part of middle-sized construction timber (MCT), except SP1 and SP2 in 2017 for the Austrian black pine and SP1 (in 2017), SP2 (in 2007, 2014 and 2017) and SP3 (in 2017) for the Scots pine. Despite the elimination of all snowbreakage and snowthrown trees (priority with less than the mean diameter for the Scots pine and with different dimensions but prevailing again for the thinner than a medium for Austrian black pine), for both species in SP2 $_{2017}$ was detected increased percent of LCW (for Scots pine from 49.3% in 2007, 51.8% in 2014 to 57.4% in 2017 and for Austrian black pine from 31.9% in 2007, 32.5% in 2014 to 41.2% in 2017).

Summarized assortment structure of the studied stands showed that for both tree species predominate LCT and MCT (from 75% in 1997 in SP4 to 83.2% in 2007 and 2017 in SP1 for Scots pine and similarly from 56.5% in 1997 in SP4 to 79.8% in 2017 in SP1 for Austrian black pine). The total quantity of construction wood is nearly equal from 85.0% to 85.2% for Scots pine and 78.6% to 82.1 % for Austrian black pine, for both species without changes or increase since the year preceding the natural disturbance (2014) till the moment following the sanitary cuttings (in 2017 - 85.2% for Scots pine and from 82.0% to 82.1% for Austrian black pine).

Graphical presentation of the tree number distribution according to thickness degrees is widely used in the past but it cannot be directly analyzed and compared as subjective evaluations. Indirect characterization of the tree number distribution according to diameter via indexes gives objective evaluation, which could be easily interpreted (Alexandrov, 2014).

One of the indexes suitable for the evaluation of the influence of different impacts (such as natural disturbances) on the structure of plantations is the Gini index. It could be used as an indicator for direct comparison of wood-size variation of the plantations and stands, for evaluation of the time-dependent change at plantation or landscape level, to evaluate the influence of forestry activities on the wood-size variation (Karamfilov, 2016), as well as for the classification of wood-size variation (Weiner,1990).

In general, the Gini index evaluates the declination from the perfect size and is min.= 0, when all trees are with equal dimension and equality, and max.= 1. The interval from 0 to 1 presents a situation with determined trees' diversity.

As it is clear, the Gini coefficient is a measure for the non-uniformity of the given statistical distribution. If we presume that all trees in a plantation are with same diameters, then the Gini coefficient is = 0. The higher the coefficient than 0 towards the maximal value 1, the bigger the heterogeneity of the plantation and vice versa – smaller values are criteria for expressed homogeneity of the studied indication.

Gini index is used to determine plantation structure. At values ≤0.35, the structure is considered to be homogenous – typical for even-aged forests, and the higher values are criteria for uniform (GS=0.35-0.43, at two- storey stands), heterogenic (GS=0.44-0.51, at different age), and balanced GS ≥0.51. Though this index could be used while planning the cuttings (Karamfilov, 2016).

The indexes calculated for the studied SPs in corresponding years for both tree species are <0.43, which is normal having in mind the fact that the plantations are of the same age (Table 6). An exception is Austrian black pine in SP2 for 2017 – in which the snowbreakage and snowthrown trees are removed, which is considered as an exception from the disturbed structure as the following effect and not as balanced one at all. On the other hand, increasing the age, another phenomenon for higher structural homogeneity for both species, which is a tendency and is not changed as a result of the natural disaster.

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