

# Formation of European beech stands (*Fagus sylvatica* L.) that involve Scots pine (*Pinus sylvestris* L.) in tree species composition in the Ukrainian Roztochie

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## ABSTRACT

Productive European beech stands (*Fagus sylvatica* L.) involving Scots pine (*Pinus sylvestris* L.) are formed in Ukrainian Roztochie. Considering value and limited distribution of beech stands involving pine in tree species composition, it is necessary to work out and implement measures for their natural restoration in connection with the climate change and the efficient use of raw materials and non-wood products. Main forestry and management indices of beech stands that include pine in tree species composition were analysed. Forestry activities that are currently carried out in middle-aged and maturing stands significantly reduce their relative completeness and growing stocks, as determined by comparing growth particularities of productive beech stands from different sources.

## KEY WORDS

forest management, forest typology, site conditions, beech (*Fagus sylvatica* L.) stands, tree species composition

## INTRODUCTION

Long-term studies of European beech (*Fagus sylvatica* L.) forests in the Ukrainian Roztochie have been stipulated by the unique composition of the mountain species which are rare for the region (Buteiko 1975; Kosets 1953; Koziy 1963; Myklush 1986; Soroka 1998, 2003, 2008). Soroka M.I. (Soroka 2003) noted that beech stands of Roztochie are characterised by a high degree of self-regulation and restoration.

Pure beech in Roztochie and beech mixed with Scots pine, common oak (*Quercus robur*), hornbeam (*Carpinus betulus*) and other concomitant tree species

typical for the region form productive natural stands. Mixed beech and pine stands are the most productive. While analysing the restoration of pine and beech stands on Roztochie almost 50 years ago, Buteiko A.I. (Buteiko 1972) noted that on Roztochie, these stands and their derivatives occupy about 9000 ha. She also pointed out that the contradictory nature of the interaction of pine and beech is observed, and in most cases, it is expressed in mutual assistance, but in the process of restoration, there is intense competition between these species.

The formation of indigenous forest stands in a natural way has not been always successful. Special attention is required for natural restoration and the formation

of valuable and highly productive forest stands with the participation of light-loving and shade-tolerant tree species that create forest types. As studies show (Gerushinsky and Zarubenko 1996; Krinitsky et al. 2010; Mazepa and Krinitskaya 2012), by timely implementation of the techniques of gradual felling, appropriate care of undergrowth and thinning in young age, it is possible to get indigenous forest with the above-mentioned characteristics.

The aim of the study is to characterise the structure of beech stands that involve pine in tree species composition depending on the origin and to propose approaches for their natural efficient restoration.

## MATERIAL AND METHODS

The study was performed by using field inventory data of Ukrainian State Forest Management Planning Organization (Ukrderzhlisproekt) as of 1 January 2019 for beech forests involving pine in tree species composition in the Ukrainian Roztochie and by materials of five sample plots. The sample plots were used to confirm the reliability of the indices indicated in the management descriptions of forest management association. The materials of the electronic stratum database included data of educational, nature protection, and forestry enterprises and institutions of Roztochie, in which beech stands with the participation of Scots pine grow on 603 plots with a total area of 2097 ha.

The main forestry and management indices were calculated in accordance with the requirements of the forest management instruction (Forest management... 2014) and the provisions of forest inventory (Anuchin 1982; Grom 2007). Forest type was determined as a complex forest management index currently used in Ukraine that defines both typology of tree species (Ostapenko et al. 1978; Ostapenko and Tkach 2002; Vorobiov 1953) and site conditions (Pohrebniak 1963). Due to significant difference in the growing stocks of stands of a particular age and often a small number of plots of a certain age, it is not possible to form a sample to obtain reliable averages; therefore, the productivity of the studied stands was followed by the largest values of growing stocks at a particular age.

The processing of the database of forest management materials and the formation of forestry and man-

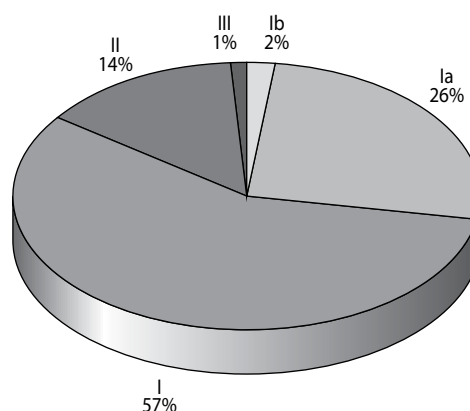
agement indices of stands were carried out in Microsoft Excel.

## RESULTS AND DISCUSSION

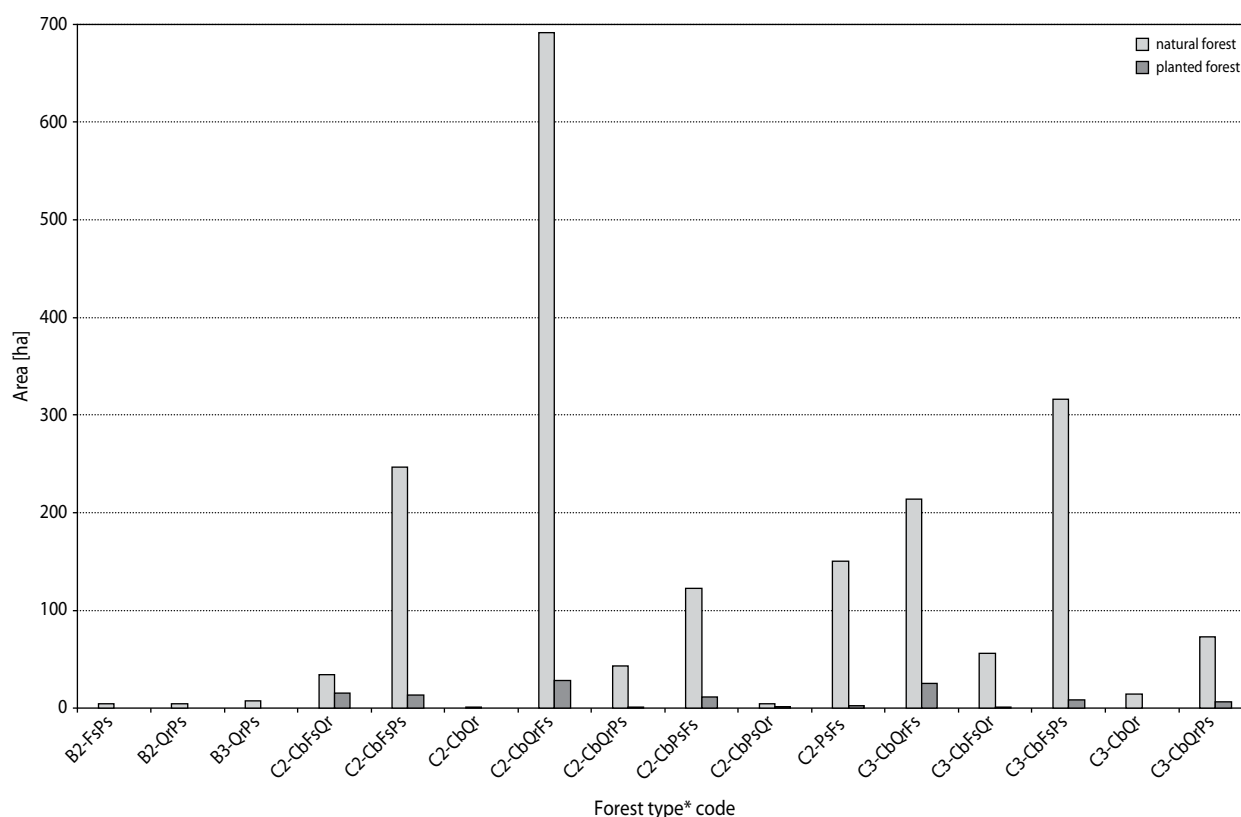
The share of the beech stands that involve pine on Roztochie is nearly 20%. Their average age is 79.1 years, average relative completeness equals 0.66 and average growing stock is 287 m<sup>3</sup>/ha. According to the materials of the sample plots, the European beech is somewhat inferior in growth intensity compared to Scots pine, but together with the pine forms the upper tier of the tent.

The biggest share of beech stands involving pine in tree species composition is represented in recreational and health-improving forests (40.4%). The smallest share of these forests is classified as protective and defensive forests (only 3.9%). More than 21% of mixed pine and beech forests are located in the national park 'Yavorivskyi National Park', nature reserve 'Roztochie', wildlife reserves, regional landscape park and protected tracts.

Beech stands involving Scots pine of natural seed origin prevail in Ukrainian Roztochie and occupy 1983.5 ha, which is 94.6% of the total area of interest. Planted forest was created on an area of 113.5 ha. The studied stands are characterised by high productivity. On an area of almost 1200 ha (56.8%), the stands are characterised by the I site index, according to the scale of Orlov M.M. (Shvidenko et al. 1987) (Fig. 1).



**Figure 1.** Distribution of beech stands involving pine in tree species composition by site indices



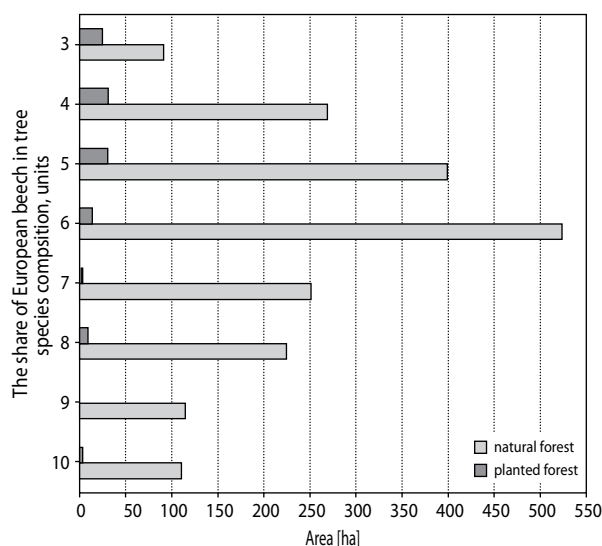
**Figure 2.** Distribution of beech stands involving pine in tree species composition by forest type

\* See section Material and methods.

B2 – fresh, relatively pure condition; B3 – moist, relatively pure condition; B4 – boggy, relatively pure condition; C2 – fresh, relatively rich condition; C3 – moist, relatively rich condition; Qr – *Quercus robur* L.; Ps – *Pinus sylvestris* L.; Fs – *Fagus sylvatica* L.; Cb – *Carpinus betulus* L.

Beech stands with the participation of pine in composition on the area of interest grow mainly in relatively rich forest types. Stands in fresh and moist relatively pure forest types are represented by only six plots on an area of 15.8 ha, which is 0.75% of the area of the studied stands. Most of the stands in relatively rich and rich conditions grow in fresh forest types, in particular, fresh, relatively rich condition occupies more than 65% of the area. The most common forest type of beech stands involving pine in tree species composition is fresh hornbeam–oak–beech relatively rich type (Fig. 2). This type of forest is represented by 179 plots of natural origin and 11 plots of planted forests.

Forest stands that have six units of beech in tree species composition occupy the biggest area (537 ha or 25.6% of the total area). Planted stands that have four and five units of beech in tree species composition occupy 31 and 30.5 ha, respectively (Fig. 3).



**Figure 3.** Distribution by the share of European beech in tree species composition

Mainly four or five tree species are involved in the tree composition of planted beech forests with the participation of pine, but in some cases, there can be up to 10 different tree species. Most often, areas of planted forest were created with the participation of common oak (*Q. robur* L.), red oak (*Quercus rubra* L.), Norway spruce (*Picea abies*) and European larch (*Larix decidua*) and less often with wild cherry (*Prunus avium*). Natural forests are predominantly formed with the participation of three or four tree species in composition (Tab. 1). Stands involving beech and pine with tree species composition 6Fs4Ps are formed on 16 plots in an area of more than 100 ha. Stands with tree species composition 8Fs2Ps grow on 25 plots with an area of 66 ha. Planted pine–beech stands with an insignificant share of accompanying tree species are formed only on six plots. It is noteworthy that pine–beech stands with an insignificant share of accompanying species prevail among ripening forests.

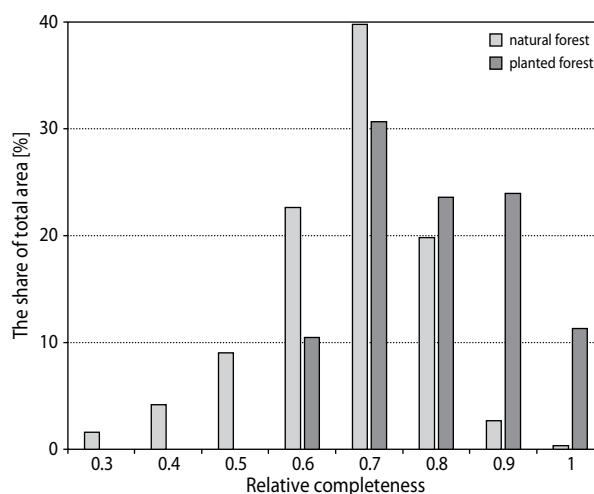
**Table 1.** Number of plots and area of mixed beech and pine stands

| Tree species composition | Natural forest |                       | Planted forest |                       |
|--------------------------|----------------|-----------------------|----------------|-----------------------|
|                          | area [ha]      | number of plots [pcs] | area [ha]      | number of plots [pcs] |
| 5Fs5Ps                   | 22.4           | 7                     | 1.9            | 2                     |
| 6Fs4Ps                   | 104.0          | 16                    | –              | –                     |
| 7Fs3Ps                   | 6.0            | 3                     | 1.4            | 1                     |
| 8Fs2Ps                   | 66.0           | 25                    | 2.6            | 3                     |
| 9Fs1Ps                   | 36.4           | 11                    | –              | –                     |

Ps – *Pinus sylvestris* L.; Fs – *Fagus sylvatica* L.

Forestry activities carried out in the studied stands affect, first of all, their relative completeness. Stands of natural origin are formed with a relative density within 0.3 and 1.0, while stands of artificial origin grow at a higher relative density within 0.6 and 1.0 (Fig. 4). More than 40% of the areas (823.8 ha) of beech stands with the participation of pine are characterised by a relative density of 0.7, and stands with a relative density of 0.8 and 0.6 grow on almost twice smaller area (419 and 460 ha, respectively). Stands with a relative density of 0.9 and 1.0 are formed on a small area, only 99.9 ha, of which 59.9 ha are formed of natural forest. A relative density of 0.95 and more was recorded on seven plots (19.6 ha) of young and middle-aged stands, of which four plots on

an area of 12.8 ha are occupied by planted forests, which is 11.3% of the total area of planted stands.



**Figure 4.** Distribution of beech stands involving pine in tree species composition by relative completeness and area

Various types of forestry activities and measures, depending upon age and conditions which affect stand's growing stocks, are carried out for productive stands to form an expedient structure and composition. According to the forest inventory materials, the growing stocks of stands of a specific age can vary significantly, depending on the time elapsed after certain types of felling and their intensity. The maximum and minimum values of growing stocks of a certain age may differ by 1.5–2 times; for example, at 20 years, the minimum value of the stock on one of the plots was 45 m<sup>3</sup>/ha and on the other one equaled 90 m<sup>3</sup>/ha; at 50 years, the values 160 and 300 m<sup>3</sup>/ha were recorded and at 100 years, they were 260 and 380 m<sup>3</sup>/ha, respectively.

The main management indices are shown in Table 2 only for stands of natural origin, taking into account the small area of stands of artificial origin and the uneven representation of plots within them by age. Stands with the participation of Scots pine in Roztochie are characterised by high-growing stocks, for example, already in 60 years, it reaches 400 m<sup>3</sup>/ha.

It should be noted that at a young age, the studied stands do not sparkle by intensive growth in height and at 20 years are characterised by a II site index according to the scale of Orlov M.M. (Shvidenko et al. 1987). Gradually, the growth rate increases and at the age from

**Table 2.** The main management indices of stands with the highest growing stocks

| Age [years] | Site index     | Forest type code       | Relative completeness | Stock [m <sup>3</sup> /ha] | Stand composition        |
|-------------|----------------|------------------------|-----------------------|----------------------------|--------------------------|
| 20          | II             | C <sub>3</sub> -CbQrFs | 0.9                   | 90                         | 6Fs1Ps1Bp2Cb             |
| 30          | I              | C <sub>3</sub> -CbQrFs | 0.6                   | 150                        | 5Fs1Ps1Bp3Pt + Cb        |
| 40          | I <sup>a</sup> | C <sub>2</sub> -CbPsFs | 0.81                  | 200                        | 10Fs + Ps + Cb + Pt + Bp |
| 50          | I <sup>a</sup> | C <sub>3</sub> -CbFsPs | 0.7                   | 270                        | 4Fs2Ps4Bp + Cb           |
| 60          | I <sup>a</sup> | C <sub>3</sub> -CbQrFs | 0.8                   | 400                        | 8Fs2Ps + Bp + Pt         |
| 70          | I <sup>a</sup> | C <sub>2</sub> -CbQrFs | 0.7                   | 350                        | 8Fs2Ps + Qr + Cb         |
| 80          | I              | C <sub>3</sub> -CbFsPs | 0.8                   | 400                        | 7Fs3Ps + Qr + Cb         |
| 90          | I              | C <sub>2</sub> -CbPsQr | 0.7                   | 380                        | 8Fs1Ps1Qr + Cb           |
| 100         | I              | C <sub>2</sub> -CbFsPs | 0.7                   | 380                        | 8Fs2Ps + Qr + Cb         |
| 110         | I              | C <sub>2</sub> -CbQrFs | 0.7                   | 320                        | 8Fs2Cb + Ps + Qr         |
| 120         | I              | C <sub>2</sub> -CbQrFs | 0.64                  | 408                        | 8Fs2Qr + Ps + Bp + Cb    |

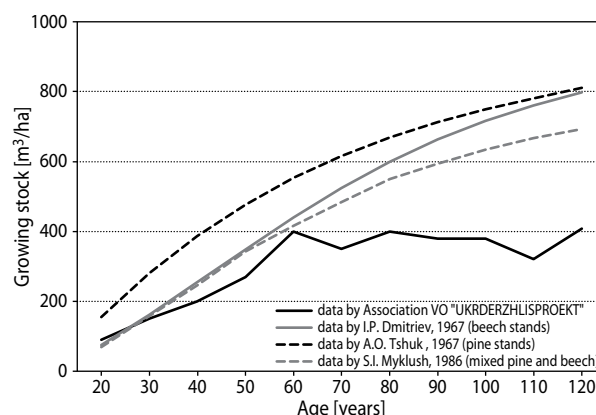
Qr – *Quercus robur* L.; Ps – *Pinus sylvestris* L.; Fs – *Fagus sylvatica* L.; Cb – *Carpinus betulus* L.; Bp, *Betula pendula*; Pt – *Populus tremula*.

40 to 70, stands are characterised by I<sup>a</sup> site index. After 80 years, the stands are again characterised by the I site index, which may not necessarily be due to a decrease in energy and growth, but is often due to the influence of forestry activities, which can be justified by a gradual decrease in relative completeness.

A significant share of beech, mainly eight units, is relevant for stands with the highest growing stocks at different ages. At a young age, the share of European beech is different; it can vary from 5 to 10 units, obviously depending on the time and nature of the thinning performed. This is also justified by the share of accompanying species, namely, silver birch (*Betula pendula*) and aspen (*Populus tremula*).

The potential of beech stands involving Scots pine in tree species composition is pointed out by a comparison of the highest values of growing stocks of full (in regards of completeness) beech stands (Dmitriev 1967), the natural pine stands (Tshuk 1967) and pine-beech stands (Myklush 1986) of western Ukraine (Fig. 5). The studied productive stands in terms of the trend of the accumulation of growing stocks approach the values of stocks of beech and pine-beech stands and are naturally inferior compared to stocks of pure pine stands up to 60 years old. Thinning in young age insignificantly

reduces the growing stocks of the studied stands, but forestry measures used after 60 years significantly affect the growing stocks.



**Figure 5.** Comparison of growing stocks of stands from different sources

The difference in growing stocks of the studied productive forest stands in comparison with beech and pine-beech stands of different origin indicated on figure above with age increases from 30% to 55% and in comparison with pine stands increases from 40% to 59%. Obviously, in order to ensure natural regeneration, it is necessary to moderately reduce the relative completeness of stands, but it is also advisable to carry out such measures in an integrated manner, ensuring the possibilities of fruiting and promoting natural renewal through soil mineralisation and additional lighting under the forest canopy. Buteiko A.I. (Buteiko 1975) noted that the optimum condition for the emergence of undergrowth and protection of seedlings is a relative density of 0.7 when compressing the stand in the seed year.

It is noteworthy that according to the data by the association VO 'UKRDERZHLISPROEKT', beech undergrowth aged from 5 to 25 years was recorded only on 28 plots with a total area of 80.5 ha, which is less than 5% of the total area.

## CONCLUSIONS

According to the inventory data of Ukrainian State Forest Management Planning Organization (Ukrderzhlisproekt) for the Ukrainian Roztochie as of 01.01.2019,

beech stands, with the participation of Scots pine, grow on 603 plots in a total area of 2097 ha. Their average age is 79.1 years, the average relative completeness is 0.66 and the average stock is 287 m<sup>3</sup>/ha. The forest stands of natural seed origin predominate, occupying 1983.5 ha (94.6% of the area of interest). Areas of planted forest were created on an area of 113.5 ha.

Using such types of final felling that ensure natural restoration and measures to promote natural regeneration is an important task due to climate change in order to preserve the forest environment and face the significant economic costs needed for creating areas of planted forest. As emphasised by Buteiko A.I. (Buteiko 1972), only European beech is successful in natural regeneration in congested coeval pine–beech stands taking into cuttings that promote seeds emergence guarantee its restoration and preservation. In most cases, pine is advisable to be injected by biogroups after final felling.

Experience of long-term research in relatively rich forest type by Gorshenin M.M. (Gorshenin 1972) in Lviv (western Ukraine) region on permanent plots is recommended to be followed in order to secure formation of the productive beech stands with Scots pine in tree species composition. As noted by his followers (Krinitzky et al. 2010), two-step gradual felling in ripe hornbeam–pine stands combined with forehanded care of self-seeding and undergrowth, and regular thinning allows the formation of indigenous stands of seed origin.

Taking into account the value and limited distribution of beech stands involving pine in tree species composition, it is necessary to work out and implement measures for their natural restoration in connection with climate change and for the efficient use of raw materials and non-wood products. Therefore, in the expected seed years, in order to increase the number of seeds and improve their quality and germination, it is necessary to illuminate the crowns of trees by cutting individual trees of concomitant species or the worst specimens of European beech and Scots pine. To preserve the undergrowth, it is recommended to carried out tree fellings in winter with a significant snow cover.

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