

Main forestry and management indices of pine (*Pinus sylvestris* L.) stands involving beech (*Fagus sylvatica* L.) in composition of Ukrainian Roztochchia

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ABSTRACT

As of 2019, the total area of forest stands with the varying proportion of Scots pine (*Pinus sylvestris* L.) and beech (*Fagus sylvatica* L.) in composition on the Ukrainian Roztochchia was 11,251.3 ha and the area of pine stands involving European beech in composition was 6879.5 ha. Pine stands involving beech in composition are formed on the fresh, moist and boggy relatively pure and relatively rich soil condition. Pine forest stands (average share of pine exceeds 56%), which include beech in composition occupy more than 80% of the total area of interest. Mature and overmature forest stands dominate most of the landscape. More than 85% of stands are characterized by an average relative completeness.

Undergrowth of deciduous tree species, which is mainly formed by European beech or hornbeam (*Carpinus betulus* L.) and rarely by common oak (*Quercus robur* L.) or sycamore maple (*Acer pseudoplatanus*), is available under a canopy of middle-aged, ripening and mature stands. The study points to the need to rethink forest management approaches and eventually to use such methods of forest cuttings that ensure natural regeneration not only of a European beech and common oak, but primarily of a pine. The practice of creating pine plantations in such conditions favourable for its growth and development should be used only in those cases when it is impossible to achieve natural regeneration of pine.

KEY WORDS

forest typology, site conditions, pine stands, *Pinus sylvestris* L., beech stands, *Fagus sylvatica* L., tree species composition

INTRODUCTION

Forest management on the basis of sustainable development aims at efficient use of forest typology capacity and formation of highly productive and biologically sustainable stands. Such stands are usually formed using high quality natural regeneration providing optimal mixture of tree species in a composition. Along with this, specific reasonable stand structure, which is determined by optimal trees allocation within the area and their forestry and management indices, should be provided within concrete site conditions.

Particularities of landscape and vegetation of Roztochchia, which is located in the Ukraine and Poland, are well described in the literature (Koziy 1963; Silvicultural research 1972; Buraczyński 2002; Debrynyuk 2003; Soroka 2008; Danchuk et al. 2015). Forest structures prevailing in Roztochchia are typical hornbeam-oak (*Carpinus betulus* L.-*Quercus robur* L.), hornbeam-beech (*Fagus sylvatica* L.), pine (*Pinus sylvestris* L.) and black alder (*Alnus glutinosa*) phytocoenoses.

Numerous geobotanical, silvicultural and forest management studies (Koziy 1963; Silvicultural research... 1972; Buteiko 1975; Myklush et al.1998; Debrynyuk 2003; Soroka, 2003, 2008; Myklush 2011; Gadow K. et al. 2012) establish and describe: features of the formation, growth and productivity of stands involving pine and beech in Roztochchia; common patterns of distribution of trees by the degrees of thickness; basic forestry and management indices of pine and beech forests and their mutual influence on each other.

Analysis of the formation of mixed forests involving pine and beech has both theoretical value due to combining heliophilous tree species – pine and shade-tolerant beech and practical importance since it allows to grow highly productive stands with two important tree species. In addition, cultivation of mixed stands more efficiently uses site conditions and ensures higher biological stability and maximum yield and productivity of stands at the age of final cutting.

The aim of the study is to analyse particularities of formation of pine stands that involve beech in a tree species composition of natural and artificial origin in the Ukrainian Roztochchia and to propose options for natural restoration of mixed stands.

MATERIAL AND METHODS

Study was performed based upon materials of electronic database of forest units of public, state and military forest enterprises, educational and protected institutions of Ukrainian Roztochchia (data was actualized as of 01.01.2019).

Processing of forest inventory database and forming of forestry and management indices was carried out using Microsoft Excel capacities based upon the generally accepted in forest inventory (dendrometry) methods (Instruction 2014). Forest management indices of natural and planted (artificial) stands established (averaged) over decades on the basis of all available data with a minimum number of at least 8 values. Seventy-year-old natural stands have a maximum number of forest management units, namely 31.

In young stands to ensure adequate sample size and accuracy of calculation of average value not less than 5%, values of management units from the closest age were included, in particular, for young ten-year planted stands, data was calculated as the arithmetic average of forest management indices of stands aged 9, 10 and 11.

Forest type was determined by a complex forest management index currently used in Ukraine that defines both typology of tree species (Vorobiov 1953; Ostapenko et al. 1978; Ostapenko and Tkach 2002) and site conditions (Pohrebniak 1963).

RESULTS

As of 2019, the total area of forest stands with the varying proportion of pine and beech in composition on the Ukrainian Roztochchia was 11,251.3 ha and the area of pine stands involving European beech in composition

Table 1. Distribution of pine stands involving beech in composition by origin

Categories	Area (ha)	Number of plots (pcs)	The average area of a plot (ha)
Planted forest	2630.9	975	2.70
Natural forest	4203.0	1270	3.30
Unclosed planted forest	34.8	24	1.45
Sparse growth of trees	10.8	6	1.80

was 6879.5 ha. Natural pine stands involving European beech in composition occupy the largest area, namely 4.2 thousand ha (Tab. 1).

The areas of pine stands involving European beech in composition exceeds the area of planted stand by 1.6 times. Six plots with sparse growth of trees, which have an area of 10.8 ha, left with the relative completeness of less than 0.3. It is noteworthy that on certain areas, natural pine stands involving European beech in composition with an average area of 3.3 ha grow on area over 30 ha, in particular in Yavorivskyi National Park.

In Ukrainian Roztochchia, pine stands involving European beech in composition are formed in the fresh, moist and boggy site conditions and mainly in fresh and moist pine forest types (Tab. 2). Stands with a predominance of pine are growing in pine, oak and beech forest types. It should be noted that the number of plots and the mean area of the site, which varies from 1.4 to 3.8 ha, mainly correlate with the area of the plot of the relevant forest type.

Table 2. Distribution of pine stands involving beech in composition by area and number of plots

Forest type* code	Area (ha)	Number of plots (pcs)	The average area of a plot (ha)
B ₂ -FsPs	246.0	100	2.46
B ₂ -QrPs	723.5	228	3.17
B ₃ -QrPs	326.7	91	3.60
B ₄ -QrPs	3.3	2	1.65
C ₂ -CbFs	11.4	6	1.90
C ₂ -CbFsPs	1313.1	533	2.50
C ₂ -CbQr	5.6	3	1.87
C ₂ -CbQrF	103.6	53	2.00
C ₂ -CbQrPs	1765.4	546	3.23
C ₂ -CbPsFs	63.9	17	3.80
C ₂ -CbPsQr	7.2	5	1.44
C ₃ -CbFsPs	767.9	277	2.80
C ₂ -CbFsPs	9.5	6	1.60
C ₃ -CbQr	30.2	12	2.50
C ₃ -CbQrPs	1490.8	394	3.78
C ₃ -CbPsQr	26.6	10	2.66
C ₃ -CbQrFs	26.0	13	2.00

* See chapter 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.).

Buteiko (1975), during 60s through 80s of the last century, allocated large areas of pine and beech forest types extended over Ukrainian Roztochchia, but recently, forestry inventory has defined less than 65 ha covered by beech-pine stands and less than 160 ha covered by pine-beech stands.

Even though middle-aged stands occupy 34% of area of Ukrainian Roztochchia, general tendency of age distribution of Ukrainian forests, where middle-aged forests are dominating, is not followed in Ukrainian Roztochchia taking into account the area covered by ripening stands (38%; Fig. 1). The oldest overmature stands aged over 150 are preserved in the recreational and health improving forests of Lviv city. The area occupied by the young stands is 516.4 ha, representing 7.5% of the studied area.

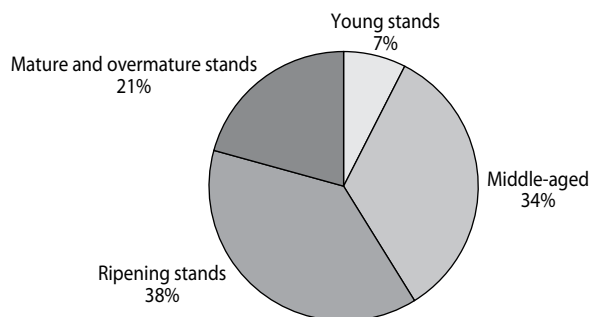


Figure 1. Distribution of pine stands involving beech in composition by age groups

In Ukrainian Roztochchia, the planted stands occupy 38.9% of the area. These stands are mainly formed by pine and beech trees, rarely by adding other tree species, such as coniferous: European larch (*Larix decidua* Mill.), Norway spruce (*Picea abies* L.), rarely black pine (*Pinus nigra* Arn.) and deciduous: mainly common oak or very rarely northern red oak (*Quercus rubra* L.).

Area occupied by the pine stands of natural origin for a certain share of pine in the composition are in most cases bigger than those occupied by the planted stands; exceptions are stands involving 2 and 3 units composed of pine (Tab. 3). We observe from Table 3 that stands that have 8 and 10 units of pine in composition dominate in both origins of natural forests and planted.

Table 3. Distribution of pine stands involving beech in composition by origin depending on the pine share in general tree species composition

The share of pine in the composition	Natural forest		Planted forest	
	area (ha)	percent (%)	area (ha)	percent (%)
10 Ps	728.1	10.6	496.3	7.2
9 Ps	704.1	10.2	391.2	5.7
8 Ps	951.9	13.8	487.3	7.1
7 Ps	671.8	9.8	425.2	6.2
6 Ps	464.9	6.8	322.3	4.7
5 Ps	277.1	4.0	265.0	3.9
4 Ps	332.9	4.8	201.2	2.9
3 Ps	72.2	1.0	81.3	1.2
2 Ps	–	–	6.7	0.1

According to forest inventory data, the vast majority of studied stands are mixed and single-tier in form. Two age groups of pine were allocated only in some areas composed of middle-aged and ripening stands.

Values of forestry and management indices of pine stands with the participation of beech in the composition of Ukrainian Roztochchia of natural and planted origin (Tab. 4) points out some differences in their formation. At a young age, up to 50 years, natural stands are formed with the larger share of pine in composition

in comparison to planted stands. In middle-aged stands, significant impact of forest management on the formation of the stands is observed, in particular increasing the share of pine in their composition.

Differences in the relative completeness of stands of natural and planted origin are most significant among other forestry and management indices. Higher values of relative completeness are traced in plantations over a 100-year study period. At a young age, up to 50 years, planted stands are formed at a relative completeness of 0.08–0.13 higher than natural stands. Only after the age of 70, the values of relative completeness of stands of different origin gradually converge and eventually the difference does not exceed 0.03.

Despite some differences in the tree species composition and relative completeness of stands of natural and artificial origin, their average heights and diameters differ slightly. The largest differences are relevant for values of average heights up to 50 years old, where tree stands of natural origin are smaller by 2.5 m (15%) as compared to the planted stands (Fig. 2). In older age, the difference in values of the average heights of plantations and natural forests does not exceed 3%.

The formation of stands of natural and artificial origin with different relative completeness directly affects their growing stocks (Fig. 5). The most significant differences are observed between the ages of 30 and 60, when the difference in growing stocks reaches

Table 4. Forestry and management indices of pine stands involving beech in composition of natural and planted origin

Age [years]	Natural forest					Planted forest				
	average share of pine in tree species composition	average		relative completeness	growing stock [m ³ /ha]	average share of pine in tree species composition	average		relative completeness	growing stock [m ³ /ha]
		height [m]	diameter [cm]				height [m]	diameter [cm]		
10						6.4	3.5	4.5	0.80	25
20	7.8	8.2	10.0	0.72	76	6.7	7.4	9.8	0.81	67
30	8.2	12.6	16.2	0.65	129	5.4	14.9	18.7	0.78	148
40	6.2	16.9	18.8	0.72	187	6.6	18.6	20.7	0.8	242
50	7.5	19.9	25.5	0.63	230	5.6	22.5	27.1	0.85	317
60	6.8	22.7	28.7	0.64	261	7.3	22.5	29.0	0.77	319
70	8.3	25.2	32.3	0.71	357	8.1	25.8	32.3	0.73	362
80	6.7	26.5	33.9	0.67	326	8.9	27.2	33.8	0.69	372
90	7.2	27.3	36.7	0.66	342	7.6	27.3	36.7	0.67	346
100	7.9	28.0	29.0	0.63	353	7.0	28.7	42.2	0.66	380

19–87 m³/ha, which is 12–28% respectively. In the age of final cutting, the values of growing stocks of 90–100 years old stands are values converging and do not exceed 10%.

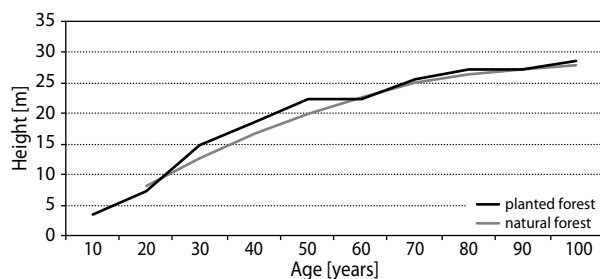


Figure 2. Change in average heights of stands of natural and artificial origin

Middle-aged, ripening and mature stands of natural and artificial origin have growing stocks more than 500 m³/ha. The highest stocks of 550–580 m³/ha are relevant to ripening stands that have tree species composition 9Ps1Fs of both natural and artificial origin.

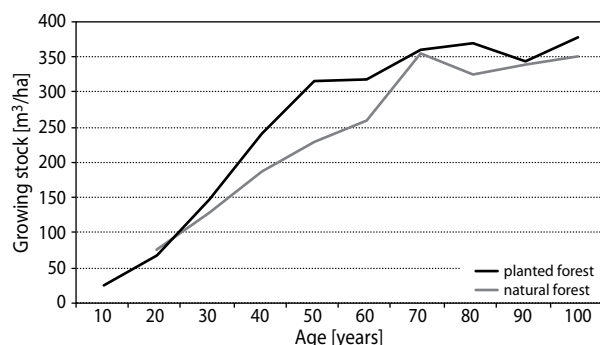


Figure 3. Change of average stocks of stands of natural and artificial origin

It should be noted that a significant proportion of competitive concomitant tree species and shrubs do not contribute to the emergence of self-sowing pines and also cause their inhibition. On an area of 630.9 ha, a pure beech undergrowth of 3 to 30 years old develops under the shelter of pine stands. Undergrowth of oak with a density of 1–4 thousand pieces/ha up to 5 m in height is recorded only on seven plots in the conditions of fresh and wet pine forest type on a relatively pure soil conditions on an area of 36.4 ha. However, undergrowth

of pine with a normal density of up to 2 thousand pieces/ha and up to 15 years of age were recorded only on two plots of total area of 7.6 ha. Mixed undergrowth involving different amounts of beeches and hornbeams, rarely oaks and other deciduous species predominate under the pine stands.

DISCUSSION

As of 2019, the total area of forest stands with the varying proportion of pine and beech in composition on the Ukrainian Roztochchia was 11251.3 ha (3548 plots) and the area of pine stands involving European beech in composition was 6879.5 ha (2275 plots). Natural pine stands with the participation of beech in composition occupy the largest area, namely 4.2 thousand ha. Pine stands involving beech in composition are formed on the fresh, moist and boggy relatively pure and relatively rich soil condition.

Pine stands involving European beech in composition are represented in 14 categories of protection, but the largest areas are still belonging to operational forests (36.3%) and the production part of the forests of green areas (30.5%). Large areas of beech-pine forests are preserved in the Yavorivskiy National Park, and the smallest part of them belongs so called in Ukraine scientific category of forests (less than 0.1%).

Large areas of ripening and mature stands require a sound approach to the efficient use of valuable timber and to ensure the natural regeneration of beech and pine. It is advisable to use the experience of close-to-nature forestry of the pine forests of north-eastern Germany to carry out logging and restore indigenous productive beech-pine stands (Lavnyy and Spathelf 2016). Moreover, Tkach and Meshkova (2019) note that in Ukraine, on average, the area of natural pine stands is decreased by 4 thousand hectares annually, which is due to the fact that gradual and selective fellings that aim at natural reproduction of pine forests are carried out in unreasonably small amounts.

While analysing the experience of forming pine stands, researchers note that mixing of different ages pine stands with the participation of beech in composition have several advantages, in particular, the creation of beech forests under the canopy of mature pine stands reduces the number and diversity of insect pests. As

well as several decades after the introduction of beech to stand, soil fertility and humus type of former pure pine stands have improved.

As noted by Lavnyy and Spathelf (2016), among the types of final fellings, German foresters use the following three methods to promote natural regeneration of pine: (1) uniform-gradual felling, (2) group-graded felling with a diameter of a 'gap' of 20–30 m and (3) a narrow continuous felling on area of 0.5–1 ha. A uniform-gradual felling is applied most often, depending on a relative completeness of a stand it may be two or three interventions. Felling time is within 15–20 years. The influence of gradual fellings, as noted by Krynytska (2015), appears on the accumulation of sediments and the ability of forest stands to naturally regenerate given that high intensity of felling improves light nutrition of deciduous trees that form the second tier of a stand.

It is well known that a forest canopy protects the undergrowth from competition against grasslands, but obscured undergrowth does not contribute to own development. This should be taken into account while undertaking forest management activities in mature and overmature stands to ensure the natural regeneration of economically valuable species in order to form new stands of natural origin.

CONCLUSIONS

At a young age, up to 50 years old, natural stands are formed with the larger share of pine in the composition than stands of artificial origin. In middle-aged stands, a significant influence of forest management measures on the formation of stands was observed, in particular share of pine in their composition increased. Most of the studied forest stands are mixed and single-tiered.

Differences in the relative completeness of stands of natural and artificial origin are the most significant taking into account all the studied forestry and management indices of pine stands that involve European beech in composition.

Despite some differences in the composition and relative completeness of plantations of natural and artificial origin, their average heights and diameters differ slightly. It was determined that middle-aged, ripening and mature stands of natural and artificial origin have relatively high growing stocks. The highest stocks of

550–580 m³/ha that were observed belong to the ripening stands with the tree species composition 9PsIFs of both natural and artificial origin.

The undergrowth of deciduous tree species is mainly formed under the canopy of middle-aged, ripening and mature stands. The absence of pine undergrowth under the canopy of the investigated stands points out the necessity of elaboration and application of such methods of forest cuttings that could ensure natural regeneration not only of a beech or oak, but primarily of a pine. To this end, it is necessary to take measures to promote natural regeneration taking into account the more frequent fruitful years of pine as compared to beech and oak. The practice of creating pine plantations in such favourable for its growth and development conditions should be used only in those cases when it is impossible to achieve natural regeneration of pine.

REFERENCES

- Buteiko A.I. 1975. Pine-beech forests of the West of the Ukrainian SSR (In Russian). Ph. D thesis, Lviv, Ukraine
- Danchuk O.T., Korol M.M., Chaskovskyy O.G., Tsunyak A.M. 2015. Forest monitoring of Roztochchia as a system component of multifunctional sustainable forestry (in Ukrainian with English summary). *Proceedings of Forest Academy of Sciences of Ukraine*, 13, 64–69.
- Debrynyuk Y.M. 2003. Silvicultural zoning of Ukrainian western steppe (in Ukrainian with English summary). Monography. Kamula, Lviv, Ukraine, 248.
- Gadow K.V., Zhang C.Y., Wehenkel C., Pommerening A., Corral-Rivas J., Korol M., Myklush S., Hui G.Y., Kiviste A., Zhao X.H. 2011. Forest Structure and Diversity. In: *Continuous Cover Forestry, Managing Forest Ecosystems* (eds. T. Pukkala, K.V Gadow). Springer, Dordrecht, 23, 29–84.
- Instruction 2014. Instruction for the management of the forest fund of Ukraine. Cameral works. (in Ukrainian) Available at http://dklg.kmu.gov.ua/forest/control/uk/publish/article?art_id=119323&cat_id=104547 (accessed 1 March 2020).
- Koziy G.V. 1963. Flora and vegetation of western regions of Ukraine (in Ukrainian). *Proceedings of the Botanical Garden of Lviv*, 7–20.

- Krynytska O. 2015. Features of litter accumulation in hornbeam-pine-oak stands, formed after gradual fellings in conditions of Lviv Roztochia (in Ukrainian with English summary). *Proceedings of the Forestry Academy of Sciences of Ukraine*, 13, 76–82. DOI: 10.15421/411510
- Lavnyy V., Spathelf P., 2016. Close to nature forestry practices in pine forests in northeast Germany (in Ukrainian with English summary). *Proceedings of the Forest Academy of Sciences of Ukraine*, 14, 52–57. DOI: 10.15421/411606
- Myklush S.I., Busko, N.M., Chaskovskyy O.G. 1998. Models of management structure of plain beech stands of western Ukraine (in Ukrainian with English summary). *Scientific Bulletin of UNFU*, 9 (2), 159–163.
- Myklush S.I. 2011. Plain beech forests of Ukraine: productivity and organizing sustainable forestry in them. (in Ukrainian with English summary). Monography. Wucts, Lviv, Ukraine.
- Ostapenko B.F., Fedets I.F., Ulanovsky M.S. 1978. Forest vegetation zoning and classification of forest types of the Ukrainian and Moldavian USSR (in Russian). *Works of the Kharkiv Institute of Agriculture*, 258, 6–27.
- Ostapenko B.F., Tkach, V.P. 2002. Forest typology (in Ukrainian). KhDAU, Kharkiv, Ukraine.
- Pohrebniak P.S. 1963. General forestry (in Russian). Agricultural Publishing House, Moscow, Russia.
- Buraczyński, J. 2002. Roztocze. Środowisko przyrodnicze (in Polish). Wyd. Lubelskie, Lublin, Poland.
- Silvicultural research. 1972. Silvicultural research on Roztochia: Collection of scientific works. 1972. Kameniar, Lviv, Ukraine.
- Soroka M.I. 2003. Beech forests of Roztochia – syn-taxonomy and genesis (in Ukrainian with English summary). *Scientific Bulletin of UNFU*, 13 (3), 106–116.
- Soroka M.I. 2008. Vegetation of Ukrainian Roztochia. Monography. Svit, Lviv, Ukraine.
- Tkach V.P., Meshkova V.L. 2019. Current problems of formation and reproduction of biologically stable pine forests of Ukraine under the conditions of climate change. In: Proceedings of the international scientific-practical conference ‘Pine forests: current status, existing problems and ways to solve them’ (eds. V. Tkach et al.), 12–13 June 2019, Kyiv, Ukraine, 67–74.
- Vorobiov D.V. 1953. Forest types of the European part of the USSR (in Russian). Ukrainian Academy of Sciences, Kyiv, Ukraine.