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Articole de cercetare

Technical harvesting ages of the main forest species in Romania

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Abstract. Technical harvesting ages were calculated for the main wood species in Romania: Norway spruce, silver fir, Austrian pine, European larch, European beech, sessile oak, pedunculated oak, Turkey oak, Hungarian oak, European hornbeam, silver birch, silver linden, willow, black locust, silver poplar and black poplar. Target wood assortments considered in the study were established based on dimensional assortments presented in the Romanian sorting tables. The actuality and the relevance of this study is given by several factors, such as the diversification of ownership structure over the forest lands in Romania and the necessity of technical harvesting ages established for a wider range of wood assortments than those presented in the Romanian technical norms for forest management planning. Since the current technical harvesting ages are based on the old Romanian yield tables and taking into account the numerous changes of the Romanian forest laws,an upgrade of harvesting ages was necessary.
Keywords: technical harvesting age, forest rotation, high forest, coppice

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Introduction

Harvesting moment indicate the state a stand (in the case of regular high forest or coppice) or an individual tree (in the case of single tree selective system) should have in order to be achieved, to the greatest extent, the forest management goals (Drăgoi 2004). Establishing the harvesting moment of a forest stand takes into account the fulfilment of various forest management objectives, such as: maximizing the value of the forest or the expected value of the land covered with forest vegetation (Faustmann 1849), maximizing the volume growth either for the total production or for the production of a certain target assortment (Rucăreanu 1967, Drăgoi 2004, Bettinger et al. 2009); improving the stability of forest ecosystems against disturbing factors by optimizing the stands' diversity (Giurgiu 1988, Duduman 2009); improving the forests capacity to store carbon (Kaipainen et al. 2004).

This state is established within the forest management plan according to the production/protection goals adopted for each individual stand and can be expressed by age or diameter (Anonymous 1986, 2000).

The moment at which the stands with production functions are to be harvested depends on the longevity of the species that compose them and, implicitly, on their development stages. For this reason, under normal conditions, one forest stand should not be replaced by another until it has reached physiological maturity. Productive maturity is established by the forest manager in relation to the production goals adopted for each stand and, as a rule, cannot be dissociated from the stage of physiological maturity characterized by the ability of the trees to naturally regenerate by seeds. Physiological maturity is the longest stage in the life cycle of trees (Florescu and Nicolescu 1996). Productive maturity generally corresponds to the first part of physiological maturity, when tree growth is still active. Corresponding to the period of productive maturity, forest managers can opt for obtaining a diverse range of wood assortments and, in turn, in relation to the assortments transposed into production goals, the harvesting age can differ significantly.

Depending on the management goal aimed by the forest manager, the harvesting age is differently established and several types can be distinguished (Faustmann 1849, Pressler 1860, Williams 1988, Giurgiu 1988, Leahu 2001, Bettinger et al. 2009): physical, biological, technical, silvicultural, financial, economic, protection, etc.

The production sustainability of a certain target assortment is ensured by means of technical harvesting age, this being the main type of harvesting age adopted when drawing up the forest management plans in Romania (Anonymous 1986, 2000).

The technical harvesting age indicates the moment at which the maximum volume growth of the total production of a target wood assortment is achieved, and is established at the stand level, depending on the species in its composition, their yield class and the management goals (Leahu 2001). The identification of tree species and the determination of the yield class are carried out by the forest engineer. Establishing the target wood assortment should be an option expressed primarily by the forest owner. However, the target wood assortments are usually taken over from the technical norms in force (Anonymous 1986, 2000) for an extremely limited range of assortments. For the main wood species in Romania, the technical harvesting ages have been established and modified over time on the basis that the forests are managed on large areas, being owned by a single owner - the state. The last update of these ages is presented in the Technical Norms for forest management planning (2000), without any changes being made to take into account the changes that took place in Romania regarding the diversification of the property structure. In these technical norms, the technical harvesting ages are presented for the main species in Romania, but only for the timber assortment. Moreover, in 2004 the new Romanian yield tables (Giurgiu and Drăghiciu 2004) and dimensional sorting tables for forest stands (Giurgiu et al. 2004) were published. These tables bring important changes to the biometric parameters describing the woody species, compared to the previous tables (Giurgiu et al. 1972), reflected on the volumes and volume growths (for the same species, yield classes and ages), but also changes in the dimensional sorting indices.

Furthermore, establishing the harvesting age represents an optimization problem in relation to social-economic needs and allows the selection of a single type of harvesting age from a multitude of possible variants (Giurgiu 1988). Lately, at the global level, there has been a shift from the management of wood production to the management of forest ecosystems, from ensuring the continuity of wood production to sustainable forest management (SFM) and, implicitly, from management by exclusion to management by including user groups (Kant, 2003).

Mingers and Brocklesby (1997) describe the components of a planning process and show the importance of having a balance between the significances given to them: i) the material component that indicates what is possible in a planning situation; ii) the individual (personal) component that primarily reflects the objectives of the forest owner; iii) the social component that indicates what is acceptable for society. The material component is described in very detail in the Romanian forest management plans, and the social component led to an extremely dense and restrictive legislative framework for the forest owner in Romania (Nichiforel and Schanz 2009). For this reason, the role of the forest owner (the personal component) in the timber production planning process in Romania is that of a spectator, although the forest production process is considered complete only when the desired physical result is available to the legal owner (Kant 2000).

Diversification of the ownership structure in Romania, including the forests, requires the adaptation of management methods by taking into account the requirements of small-scale forest owners. For small-scale forestry, some regulations established for state-owned forests are very difficult to comply with and cannot lead to results like those expected by managing forests on large areas. Forest owners must be given the opportunity to participate in setting management goals for the forest areas they own.

Thus, the main goal of this paper is to calculate the technical harvesting ages for the main tree species in Romania and for a varied range of dimensional wood assortments, offering small forest owners properly substantiated alternatives.

Materials and methods

To determine the technical harvesting age in relation to the species, the yield class (CLP) and the target wood assortment, secondary data were used, taken from the yield tables for relative yield classes (Giurgiu and Drăghiciu 2004) and from the dimensional sorting tables for forest stands (Giurgiu et al. 2004). Qualitative analysis was used, the technical harvesting ages being determined according to the method proposed in literature (Giurgiu and Drăghiciu 2004), a method taken from Russian forestry in 1958 (Giurgiu 1988), but adapted to Romanian forests and improved later (Giurgiu 1962, Giurgiu and Drăghiciu 2004).

Thus, the wood assortments were proposed (Table 1), taking into account the dimensional assortments (Table 2) and the correspondence with the target assortments established when drawing up the forest management plans, according to species and yield classes for the production forests (Anonymous 1984).

After establishing the wood assortments, for each species the proportion of working wood corresponding to each assortment was determined by summing the related sorting indices (Giurgiu et al. 2004) of each category of diameters corresponding to the characteristic d_g (average diameter of the basal area). The same dimensional sorting was used for: 1) spruce (*Picea abies* (L.) H. Karst) in the natural range and spruce outside the natural range; 2) European beech (*Fagus sylvatica* L.) from seed and European beech from shoots. For the silver linden (*Tilia tomentosa* Moench) the dimensional sorting from the small-leaved lime (*Tilia cordata* Mill.) was used. In the case of larch (*Larix decidua* Mill.), the data in the yield table are provisional, and for willow (*Salix* sp.) from shoots, since the dimensional sorting does not include the G1 assortment, the following assortments have been fixed: 5-12 cm, 5-16 cm, 5-20 cm, 5-24 cm, 12-24 cm, over 5 cm, over 12 cm, over 16 cm, over 20 cm and over 24 cm. Only species for which yield tables are complete (contain data on primary production after interventions and secondary production) and for which dimensional sorting tables exist were considered in the study.

After calculating the sorting indices related to the established assortments, the volume of the respective assortment was determined, for the ages presented in the yield tables (Giurgiu and Drăghiciu 2004), first for the primary production, then for the cumulative secondary production, and by summing them up, we obtained the total production of the target wood assortment at different ages. Dividing

Table 1 Target wood assortments considered in the study

Dimensions of the proposed assortment (cm)	Corresponding dimensional assortments*	Corresponding target assortments, according to Anonymous (1984)
Coniferous		
5-10	S	Thin: cellulose
5-14	S+M2	Thin and medium: pulp, constructions
5-20	S+M2+M1	Medium and thin: pulp, constructions
10-20	M2+M1	Medium: pulp, constructions
5-24	S+M2+M1+G3	Thin, medium and thick: timber, pulp, constructions
5-34	S+M2+M1+G3+G2	Thin, medium and thick: timber, pulp, constructions
>5	S+M2+M1+G3+G2+G1	Thick, medium and thin: timber, pulp, constructions
>10	M2+M1+G3+G2+G1	Thick and medium: timber, pulp, constructions
>14	M1+G3+G2+G1	Thick and medium: timber, pulp, constructions
>20	G3+G2+G1	Thick and very thick: timber
>24	G2+G1	Very thick and thick: timber
>34	G1	Very thick: timber, soundboard
Deciduous		
5-12	S	Thin: pulp, constructions
5-16	S+M3	Thin and medium: pulp, constructions, timber
5-20	S+M3+M2	Medium and thin: timber, pulp, constructions
5-24	S+M3+M2+M1	Medium and thin: timber, pulp, constructions
12-24	M3+M2+M1	Medium: timber
5-40	S+M3+M2+M1+G2	Thin, medium and thick: pulp, constructions, timber
>5	S+M3+M2+M1+G2+G1	Thick, medium and thin: timber, pulp, constructions
>12	M3+M2+M1+G2+G1	Medium and thin: timber
>16	M2+M1+G2+G1	Thick and medium: timber
>20	M1+G2+G1	Thick and medium: timber
>24	G2+G1	Very thick and thick: high quality timber, veneer
>40	G1	Very thick: veneer, high quality timber

Note. * The dimensional assortments are detailed in Table 2.

this volume by the related age allowed determining the volume growth of the target assortment. The technical harvesting age for each assortment was identified next to the maximum value of the average growth of the production corresponding to the target assortment.

Knowing that the most resilient forests in front of disturbing factors and also able to ensure a wide range of ecosystem services are those resulted through natural regeneration (Strassburg et al. 2016), if the target wood assortments considered in this study lead to technical harvesting ages lower than the masting/fructification ages of the tree species in stand composition (table 3), such wood assortments will not be established through the forest management plans.

In this sense, all harvesting ages lower than the maximum ages mentioned in the literature (table 3) for the first abundant fructification in the forest are highlighted in the paper in red, being presented only for informational purposes, indicating when the maximum volume growth of the respective dimensional assortments is achieved. The maximum thresholds of the ranges mentioned in the literature were taken into account, to avoid underestimations which may occur due to different site conditions, that might lead to different fructification ages inside the forest. These thresholds are

Table 2 Dimensional sorting of working wood in relation to the group of species and considering the diameter of wood logs at the thin end (cm) (Giurgiu et al. 2004)

Coniferous					
Thick wood (G)			Medium wood (M)		Thin wood
G1	G2	G3	M1	M2	S
>34 cm	24-34 cm	20-24 cm	14-20 cm	10-14 cm	5-10 cm
Deciduous					
Thick wood (G)		Medium wood (M)			Thin wood
G1	G2	M1	M2	M3	S
>40 cm	24-40 cm	20-24 cm	16-20 cm	12-16 cm	5-12 cm

also considered appropriate for stands regenerated from shoots, for which it is known that abundant fruiting in the forest begins earlier than in the case of those regenerated from seed (Florescu and Nicolescu 1996), but no more detailed information is provided in the Romanian literature.

Negulescu et al (1973) state that the poplar (*Populus alba* L. and *Populus nigra* L.) begins to fruit at 15-20 years in the forest, the willow begins to fruit in isolation at 5-15 years, and the Scots pine (*Pinus sylvestris* L.) begins to bear fruit in the forest at 30-40 years. In this study, the fructification age in the black pine (*Pinus nigra* J.F. Arnold) forests was assimilated to that of Scots pine. According to Damian (1978) the birch (*Betula pendula* Roth) begins to fruit abundantly in the forests between the ages of 20 and 30 years. The Turkey oak (*Quercus cerris* L.) fruits abundantly at the age of 30-40 years (Constantinescu 1963), which is why, in case of this species, the age of 40 years for the beginning of abundant fruiting in the forest was taken into account, corroborated with the studies on the biology of fruiting in oak species (Tomescu 1965) carried out for Turkey oak in stands at least 45 years old.

Due to the lack of information in the litera-

Table 3 The ages of first abundant fructification in the forest

Species – the age considered in this study	Age of the first abundant masting in the forest (years), according to ...			
	Haralamb (1956)	Florescu (1981)	Stănescu et al (1997)	Clinovschi (2005)
Norway spruce in its natural range – 70 years	60-70	40-50	-	60
Silver fir – 70 years	60-70	60-70	50-70	60-70
Austrian pine – 40 years	-	-	-	20-30*
European larch – 40 years	30	20-40	30	30
European beech – 80 years	60-80	60-70	70-80	70-80
Sessile oak – 80 years	60-70	60-70	60-70	60-80
Pedunculate oak – 80 years	60-70	50-60	70	70-80
Turkey oak – 40 years	-	-	-	25-30*
Hungarian oak – 50 years	-	-	-	-
Hornbeam – 40 years	30-35	30-40	15-20*	15-20*
Silver birch – 30 years	20	-	10*	10*
Lime – 45 years	20-25*	25-45	20-30*	-
Willow – 15 years	-	-	10*	early
Black locust – 20 years	-	10-20	early (5-7 years isolated)	**
Silver and black poplar – 20 years	-	-	at relatively young ages	-

Note. * without specifying the ecological context: isolated or in the forest. ** In Romania, it does not regenerate naturally from the seed.

ture regarding the beginning of the abundant fruiting inside the forests of the Hungarian oak (*Quercus frainetto* Ten.) under the conditions in Romania, however knowing that, among the oak species from Romania, fruiting begins earlier in case of Turkey oak (Stănescu et al. 1997), in this study the age of the first abundant fruiting for Hungarian oak was considered to be 50 years. For the spruce outside the natural range, the age of abundant fruiting inside the forest as not taken into account because in such forest stands it is desirable to came back to the natural forest type through artificial regeneration.

Results

Table 4 shows the technical harvesting ages calculated for coniferous. The ages for which there is no certainty that the maximum value of mean volume growth of the production corresponding to the target assortments has been identified have been highlighted in yellow, due to the fact that they correspond to the ages at which the species description stops in the yield tables.

Compared to small wood assortments, in the case of large-sized assortments, a sharp flattening of the variation curves of the mean volume growths of the wood production corresponding to the respective assortment is observed in the upper yield classes, while in the case of the lower yield classes, this tendency is also observed in the case of small wood assortments (Figure 1). Also, once the productivity of a stand decreases, the data provided by the yield tables become insufficient for identifying the maximum value of mean volume growth of the production of the target assortment. The technical harvesting ages for which deviations occur from the general variation trend in relation to the yield class for the same target assortment were highlighted in green.

In the case of European beech (table 5), the only deviation from the normal trend of variation in the technical harvesting age occurs for the wood assortment „>20 cm" where, in the second yield class, a lower harvesting age is obtained than in case of the first yield class. Similar situations also occur: i) in case of pedunculated oak (*Quercus robur* L.) from seed, third yield class, target assortment „>20 cm"; respectively ii) for Hungarian oak, the second yield class, target assortments „>16 cm" and „>20 cm".

Except for the sessile oak (*Quercus petraea* (Matt.) Liebl.) and the pedunculated oak regenerated from seed, the same maximum growths were obtained for all the Quercus sp., but also for the European beech regenerated from the shoots, at the same ages, for the wood assortments „5-40 cm" and „> 5 cm" (values highlighted in orange). This is due to the identical sorting indices up to the ages at which the maximum value of the mean volume growth of the respective assortment is obtained. In this case, the difference between the two target assortments is given by the participation of the dimensional assortment G1 in the „>5 cm" assortment, compared to the „5-40 cm" assortment.

In the highlighted cases, this participation produces changes in the average growth at ages older than those at which the maximum growth in volume of the target assortment is obtained. In the case of the Turkey oak from the seed, in the second yield class, the „>24 cm" target assortment, a first maximum of the average growth was obtained at the age of 105 years, with the decrease of the average growth up to 120 years, however, it was found that after 120 years, the average volume growth of wood production of this assortment shows an upward trend, which is why it was considered that the data in the yield tables are not sufficient to identify with certainty the technical harvesting age for this assortment.

In Figure 1 (Supplementary material), for the main tree species in Romania (Norway spruce, silver fir, European beech, sessile oak and pedunculated oak), the variation graphs of the average volume growth are presented comparatively for some target assortments with

Table 4 Technical harvesting ages for coniferous

Species	Yield class	Technical harvesting ages (years) for the target wood assortment … (cm)											
		5-10	5-14	5-20	10-20	5-24	5-34	> 5	>10	> 14	>20	> 24	> 34
Norway spruce – natural range	I	20	25	30	35	35	45	70	75	90	95	130	140
	II	25	30	35	40	40	55	75	80	90	115	140	DI
	III	25	35	45	45	50	65	85	90	100	140	DI	DI
	IV	35	40	55	60	60	85	90	115	120	140	DI	DI
	V	45	50	70	75	80	105	105	120	140	DI	DI	DI
Norway spruce – outside its natural range	I	15	20	25	25	30	40	55	60	65	85	100	DI
	II	20	25	30	35	40	40	60	65	75	100	DI	DI
	III	25	30	40	40	45	60	75	75	80	100	DI	DI
Silver fir	I	25	25	35	35	40	55	80	85	90	115	115	140
	II	25	30	40	40	45	60	85	90	100	135	135	140
	III	30	35	45	45	55	65	90	100	115	140	DI	DI
	IV	35	40	55	55	60	80	100	120	120	140	DI	DI
	V	40	50	65	65	75	100	105	120	130	140	DI	DI
Black pine	I	20	25	30	35	40	50	50	60	70	90	DI	DI
	II	20	25	35	40	40	50	55	65	75	90	DI	DI
	III	25	30	40	45	45	55	55	70	80	90	DI	DI
	IV	30	35	50	60	55	65	65	85	90	DI	DI	DI
	V	40	50	65	80	75	75	75	90	DI	DI	DI	ns
European larch	I	20	20	25	30	30	40	50	55	60	80	85	115
	II	20	25	30	30	35	45	50	60	65	90	100	120
	III	25	30	35	35	40	55	60	60	70	105	120	DI
	IV	25	35	40	45	50	55	70	75	85	120	DI	DI
	V	35	40	50	55	60	70	70	95	105	120	DI	DI

Note. Abbreviations: DI – insufficient data in the yield tables to confirm the achievement of the maximum value of the mean volume growth of the wood production corresponding to the target assortment; ns – wood assortment that cannot be obtained. The values in red represent technical harvesting ages lower than the age of the first abundant fruiting in the forests, those in yellow are ages for which there is no certainty that the maximum value of the mean volume growth of the production corresponding to the target assortment has been identified, and those in orange are technical harvesting ages similar for different target wood assortment but for the same species and yield class.

technical harvesting ages higher than the age of abundant fruiting in the forest.

Table 6 shows the technical harvesting ages for the other deciduous species for which the yield tables allowed the application of the described method and for which the dimensional sorting table for forest stands also exists. The similarity between the target assortments „5-40 cm" and „>5 cm" is much more obvious, the only difference being obtained in case of willow regenerated by seeds, for the first yield class.

Deviations from the normal variation of the harvesting age in relation to the yield class are recorded for: hornbeam (*Carpinus betulus* L.), 5th yield class, target assortment „>12 cm"; willow from seed, yield classes IV and V, target assortments „5-40 cm" and „>5 cm",

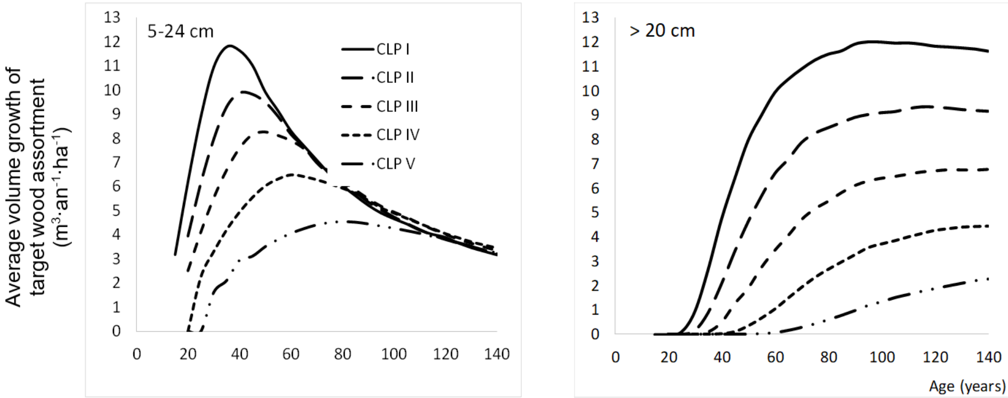

Figure 1 Variation of mean volume growth against age for the wood production corresponding to target assortment – example for Norway spruce (natural range)

respectively third yield class, target assortment „> 16 cm"; white and black poplar, yield class III, target assortments „5-16 cm" and „>24 cm"; willow from shoots, second yield class, target assortment „>20 cm", respectively third yield class, target assortment „> 16 cm".

Together with the technical harvesting ages, the maximum volume growths that led to the respective ages are presented in tables 1, 2 and 3 from the supplementary material. The growths highlighted in red correspond to situations where the technical harvesting age is lower than the age of abundant fruiting in the forest.

In the case of coniferous species (table 1 – Supplementary material) the highest volume growths are obtained for the „> 5 cm" and „5-34 cm" target assortments. The first includes the entire range of dimensional assortments and assumes that the beneficiary of the wood will be able to efficiently capitalize on all the obtained dimensional assortments.

If the aim is to obtain a larger amount of thick and very thick wood assortments, the volume growth of the other assortments will remain a secondary objective, and the establishment of a harvesting age of 130 or even 140 years for spruce in its natural range, first yield class, it is worth considering, since the volume growths corresponding to the „> 24 cm" or „> 34 cm" target assortments register high values: 10.7 $m^3 \cdot year^{-1} \cdot ha^{-1}$, respectively 7.77 $m^3 \cdot year^{-1} \cdot ha^{-1}$.

In the case of European beech and species of the *Quercus* genus, the largest volume growths are recorded by the target assortments „> 5 cm" and „5-40 cm" (Table 2 - Supplementary material). Based on the research methodology and the data used, it was not possible to identify the harvesting age for the beech regenerated by seeds in case of very thick and thick wood assortments, even in the first yield class, while in the fifth yield class, at the age of 115 years, it is barely possible to obtain medium wood assortment for timber (target assortment „12-24 cm"), but the maximum growth of this assortment does not exceed 2.22 $m^3 \cdot year^{-1} \cdot ha^{-1}$, which is why it becomes advisable that at this yield class the harvesting age not to exceed 100 years.

In the case of deciduous species regenerated from shoots, technical harvesting ages below the age at which abundant fruiting begins in the forest should be avoided when conversion to high forests is considered, in order to favour so the natural regeneration from the seeds. If the management objectives assume the maintenance of the coppice, the trees could be harvested even at younger ages, but when adopting the target assortments, it is worth considering the maximum volume growths presented in tables 2 and 3 from the supplementary material.

In case of oak species, the volume growths of target assortments are smaller than in case

Table 5 Technical harvesting ages for European beech and oak species

Species	Yield class	Technical harvesting ages (years) for the target wood assortment … (cm)*											
		5-12	5-16	5-20	5-24	12-24	5-40	>5	>12	>16	>20	>24	>40
European beech (from seeds)	I	25	30	35	45	45	70	90	110	130	140	DI	DI
	II	30	35	45	50	55	85	105	125	135	135	DI	DI
	III	35	45	55	60	70	105	110	135	140	DI	DI	DI
	IV	45	55	70	80	90	130	140	DI	DI	DI	DI	DI
	V	55	75	85	100	115	140	DI	DI	DI	DI	DI	ns
European beech (from shoots)	I	25	30	40	45	60	70	90	115	120	DI	DI	DI
	II	30	40	45	55	70	85	100	120	DI	DI	DI	DI
	III	35	50	60	70	85	105	120	DI	DI	DI	DI	DI
	IV	45	60	75	90	110	120	120	DI	DI	DI	DI	ns
	V	65	80	100	115	120	DI	DI	DI	DI	DI	DI	ns
Sessile oak (from seeds)	I	25	35	40	45	50	80	85	105	110	110	140	DI
	II	30	40	45	55	60	80	95	105	125	130	140	DI
	III	35	45	55	65	70	95	115	125	140	DI	DI	DI
	IV	45	55	65	75	85	110	135	140	DI	DI	DI	DI
	V	50	65	80	90	100	135	135	140	DI	DI	DI	ns
Sessile oak (from shoots)	I	25	35	40	50	55	70	70	90	95	120	DI	DI
	II	30	40	45	55	65	70	70	105	110	120	DI	DI
	III	35	45	50	65	75	75	75	105	120	DI	DI	DI
	IV	40	50	60	75	90	80	80	115	120	DI	DI	ns
	V	50	60	70	80	100	80	80	120	DI	DI	DI	ns
Pedunculated oak (from seeds)	I	20	25	30	40	40	65	80	95	100	130	140	DI
	II	25	30	35	45	45	75	90	105	110	140	DI	DI
	III	25	35	40	50	55	75	105	120	130	130	DI	DI
	IV	30	40	45	55	60	85	105	140	DI	DI	DI	DI
	V	35	45	55	60	70	100	120	140	DI	DI	DI	DI
Pedunculated oak (from shoots)	I	20	25	35	40	50	55	55	85	90	115	120	DI
	II	25	30	35	45	55	65	65	85	105	120	DI	DI
	III	30	35	40	55	65	70	70	100	120	DI	DI	DI
	IV	35	40	50	65	75	80	80	115	120	DI	DI	ns
	V	40	50	60	75	90	100	100	120	DI	DI	DI	ns
Turkey oak (from seeds)	I	20	25	30	35	35	60	65	75	85	85	115	130
	II	20	25	35	40	45	65	65	80	95	105	DI	DI
	III	25	30	40	50	50	65	65	90	105	130	DI	DI
	IV	30	40	45	55	65	80	80	100	115	130	DI	DI
	V	40	45	55	70	80	80	80	115	130	DI	DI	DI
Turkey oak (from shoots)	I	15	20	25	30	35	45	45	60	65	95	95	110
	II	20	25	30	35	40	50	50	70	75	85	120	DI
	III	25	30	35	45	50	55	55	70	95	105	120	DI
	IV	30	35	45	50	60	55	55	80	100	120	DI	ns
	V	35	40	50	60	75	60	60	85	120	DI	DI	ns
Hungarian oak (from seeds)	I	25	35	45	50	60	75	80	100	130	DI	DI	DI
	II	30	40	50	55	65	80	80	110	120	130	DI	DI
	III	35	45	55	65	70	90	95	125	130	DI	DI	DI
	IV	35	50	60	70	80	105	105	120	130	DI	DI	DI
	V	40	55	65	80	95	120	120	130	DI	DI	DI	DI

Note. Abbreviations: DI – insufficient data in the yield tables to confirm the achievement of the maximum value of the mean volume growth of the wood production corresponding to the target assortment; ns – wood assortment that cannot be obtained.
* in the case of provenances from shoots, the technical harvesting ages lower than the age of the first abundant fruiting in the forest were highlighted (in red), in order to be avoided if the conversion to high forest is aimed. The values in red represent technical harvesting ages lower than the age of the first abundant fruiting in the forests, those in yellow are ages for which there is no certainty that the maximum value of the mean volume growth of the production corresponding to the target assortment has been identified, the values in green indicate technical harvesting ages with deviations from the general variation tendency in relation to the species and yield class for the same assortment, and those in orange are technical harvesting ages similar for different target wood assortment but for the same species and yield class.

Table 6 Technical harvesting ages for other deciduous species

Species	Yield class	Technical harvesting ages (years) for the target wood assortment … (cm)**											
		5-12	5-16	5-20	5-24	12-24	5-40	>5	>12	>16	>20	>24	>40
Hornbeam	I	25	30	40	45	55	50	50	75	100	120	DI	DI
	II	25	35	40	45	60	55	55	80	110	120	DI	DI
	III	30	40	45	50	70	65	65	90	120	DI	DI	DI
	IV	35	45	55	60	75	75	75	120	DI	DI	DI	DI
	V	40	50	60	70	85	85	85	115	DI	DI	DI	ns
Silver birch	I	15	25	25	35	40	45	45	55	70	DI	DI	ns
	II	20	25	30	40	50	45	45	70	DI	DI	DI	ns
	III	25	35	40	50	60	55	55	70	DI	DI	DI	ns
	IV	30	45	55	55	70	65	65	DI	DI	DI	DI	ns
	V	40	60	70	DI	DI	70	70	DI	DI	DI	ns	ns
Silver lime	I	20	25	30	35	45	45	45	65	85	105	110	DI
	II	25	30	35	45	50	50	50	75	100	110	DI	DI
	III	25	35	40	50	60	60	60	80	110	DI	DI	DI
	IV	30	40	50	60	70	65	65	100	110	DI	DI	ns
	V	40	50	55	70	85	75	75	110	DI	DI	DI	ns
Willow from seeds	I	8	10	12	14	14	20	22	24	34	36	36	36
	II	8	12	14	16	16	22	22	26	38	40	DI	DI
	III	10	12	14	18	18	24	24	30	36	40	DI	DI
	IV	10	14	16	20	22	20	20	30	38	40	DI	DI
	V	12	16	18	22	24	22	22	38	40	DI	DI	ns
Black locust from seeds	I	8	12	14	20	24	26	26	40	DI	DI	DI	DI
	II	10	14	18	26	32	30	30	40	DI	DI	DI	ns
	III	14	18	24	30	40	36	36	40	DI	DI	DI	ns
	IV	18	28	34	40	DI	40	40	DI	DI	DI	ns	ns
	V	30	40	DI	DI	DI	DI	DI	DI	DI	ns	ns	ns
White poplar and black poplar	I	10	10	15	15	20	20	20	25	30	35	50	65
	II	10	15	15	20	20	25	25	30	35	40	50	70
	III	10	10	15	20	20	25	25	30	35	40	45	70
	IV	15	20	20	25	30	30	30	35	45	50	70	ns
	V	15	20	25	30	35	30	30	40	50	65	70	ns
Willow from shoots*	I	6	8	10	10	14	-	12	16	22	34	DI	ns
	II	8	10	10	12	16	-	12	18	28	32	DI	ns
	III	8	12	14	14	22	-	14	24	26	34	DI	ns
	IV	10	14	16	16	30	-	16	30	34	DI	DI	ns
	V	14	18	20	20	30	-	20	30	34	DI	DI	ns

Note. Abbreviations: DI –insufficient data in the yield tables to confirm the achievement of the maximum average volume growth of the wood production corresponding to the target assortment; ns – wood assortment that cannot be obtained.

* - the G1 dimensional assortment cannot be obtained for willow from shoots, which is why the target assortments „>5", „>12", „>16", „>20" and „>24" do not include this dimensional assortment, and the „5-40" and „>5" assortments are identical.

** - in the case of provenances from shoots, the technical harvesting ages lower than the age of the first abundant fruiting in the forest were highlighted, in order to be avoided if the conversion to high forest is aimed. The values in red represent technical harvesting ages lower than the age of the first abundant fruiting in the forests, those in yellow are ages for which there is no certainty that the maximum value of the mean volume growth of the production corresponding to the target assortment has been identified, the values in green indicate technical harvesting ages with deviations from the general variation tendency in relation to the species and yield class for the same assortment, and those in orange are technical harvesting ages similar for different target wood assortment but for the same species and yield class.

of beech, but their variation is also smaller. In the case of target assortments that include large dimensional assortments, among the oak species, the largest volume growths for the same assortments and yield classes are recorded for pedunculated oak from the seed, followed by the sessile oak from the seed and Turkey oak from the seed. In case of target assortments that do not include large dimensional assortments, the growth of coppice stands is sometimes higher than that recorded in the high forest stands, except for pedunculated oak, where the growth of the high forest is for all the analysed assortments larger than the growth of the coppices.

From the category of the other analysed deciduous species, the largest volume growths are recorded by willow (e.g. 21.6 $m^3 \cdot year^{-1} \cdot ha^{-1}$ in the first yield class, target assortment „> 5 cm”), followed by poplar, black locust and hornbeam (Table 3 – Supplementary material). At the same time, poplars and willows also allow obtaining large-sized wood assortments, unlike birch and black locust (*Robinia pseudoacacia* L.), where the management of stands aiming to obtain such type of wood assortments would require high ages, similar to species longevity and, consequently, very much reduced volume growths. The very small volume growths of black locust and silver birch in the lower yield classes (IV and V) justify including such forest stands under special protection, especially since only small sizes wood assortments can be achieved.

Discussion

The re-evaluation of the technical harvesting ages for Romanian forests, carried out in relation to the species, the yield class and the target assortment, allows highlighting the aspects that require improvements through future research, in order to better substantiate the technical decisions adopted during forest management planning.

Several studies have been carried out in Romania on the fruiting of some forest species such as: pedunculated oak, sessile oak, hornbeam (Enescu et al. 1966, Bolea et al. 1982a, Scutareanu et al. 1984, Bolea 1989), silver fir (Lalu 1993), European larch, Scots pine (Bolea et al. 1982b). It is noted, however, that there is a lack of detailed information in the Romanian literature regarding the ages at which forest species begin to abundantly fruit in the forest, in relation to the site conditions. Knowing these ages is necessary to avoid adopting technical harvesting ages lower than the silvicultural harvesting age.

It was also found that in many situations, even for higher yield classes, for long-lived species, it was not possible to identify the maximum value of mean volume growth of the production corresponding to large-size wood assortments due to the fact that the data in the current yield tables (Giurgiu and Drăghiciu 2004) stop at ages lower than the ages at which these maxima are reached. In addition, there are a number of situations highlighted in tables 5 and 6 (for beech from seed – second yield class, pedunculated oak from seed – third yield class, Hungarian oak from seed – second yield class, hornbeam – fifth yield class, willow from seed – yield classes III, IV and V, white poplar and black poplar – third yield class, willow from shoots – yield classes II and III) where the obtained technical harvesting ages do not fall within the normal variation trends in relation to the yield class, which implies a revision of the information from the yield tables and/or the dimensional sorting tables (Giurgiu et al. 2004).

In order to widen the range of species for which the technical harvesting ages could be determined, another aspect that should be taken into account when drawing up the new biometric tables for forests stands refers to their completion with information for those species that are lacking either form the yield tables drawn-up on relative yield classes (e.g. maple, alder, aspen, cherry tree, ash, etc.), or from the dimensional sorting tables (e.g. Scots pine) and, eventually, the addition of other species of forestry interest for which we have not yet such tables.

Depending on the changes that will appear in the new yield tables and dimensional sorting tables, this study can be completed in the future with technical harvesting ages for other species or target assortments. Also, the analysis is worth continuing to determine the economic harvesting ages (Drăgoi and Duduman 2006) since, although for species of high economic value (e.g. pedunculated oak, sessile oak, beech), for thick and very thick wood assortments, these maximum growths record lower values than in the case of small-size wood assortments, the selling price will certainly produce a change in the outlook of the forest manager or owner.

In addition, we should not neglect the secondary species in the compositions of the even-aged stands which, in most cases, due to their reduced longevity (e.g. cherry tree), do not reach the harvesting ages proposed for the main species for large-sized assortments (Nicolescu 2002), with the risk that, over time, the species diversity of these stands to decrease. For such species, the harvesting ages are not presented in the technical norms, and maintaining the trees belonging to these species until too old ages is accompanied by a significant wood quality depreciation.

Greater attention is needed for the stand-level forest management, in order to ensure the continuous presence of these species in the future compositions of the stands (preferably through natural regeneration), but also their proper economic exploitation. For this reason, the establishment of harvesting ages at stand level, differentiated by species category, can be considered an option, without the risk of disrupting the planning of wood production as long as it is carried out in relation to the harvesting ages established for the main species in stand composition.

Concerns for knowing the characteristics of forest ecosystems in order to scientifically substantiate forest management methods should not be neglected. These allow deepening the aspects related to establishing the optimal moment of harvesting the stands. For example, through the technical instructions for forest management planning from 1950 and 1951 (Anonymous 1950, Anonymous 1951), it was mentioned about harvesting age only that it must „express the dimensions and quality of the materials to be produced and is determined according to the achievement of a maximum useful production", and the minimum rotation for high forests were indicated as 100 years for Norway spruce, silver fir, beech and 120 years for pedunculated and sessile oaks. The instructions from 1959 (Anonymous 1959) introduced the term of „management goal", being established target assortments by species and yield classes in relation to the minimum diameter at the thin end of the logs. Obtaining large-sized assortments was recommended only for the high productivity stands, the technical harvesting ages varying for spruce between 100 and 115 years, for silver fir and beech between 100 and 120 years, and for pedunculated and sessile oaks between 110 and 130 years.

A more thorough presentation of the technical harvesting ages is made by Giurgiu (1988) for Norway spruce in the natural range, silver fir, beech, sessile oak from the seed, sessile oak from shoots, being indicated age thresholds between which it is recommended to harvest the stands. The ages identified in this paper based on the new yield tables and the new dimensional sorting tables for stands are generally comparable or higher than the maximum thresholds of the intervals proposed by Giurgiu for the same species, yield classes and target assortments (table 7). The largest positive differences are reported in the case of the sessile oak regenerated from seeds, for the „>5 cm" target assortment and in the case of the sessile oak from the shoots, for the „>12 cm" target assortment. These differences further argue for the necessity of the present study.

Compared to the technical harvesting ages indicated in the technical norms for forest management planning (Anonymous 1986, 2000) for timber assortment, the ages in this paper have values either comparable or 10-20 years higher if only the "thick" and "very thick" dimensional wood assortments are considered, or up to 40 years lower if the medium wood assortments are also considered.

Establishing the target assortment becomes an extremely important stage in the planning process of wood production (Duduman and Drăgoi, 2008), and this study provides the necessary arguments for correctly informing forest owners and explaining the economic losses that occur in the case of adopting too low harvesting ages, especially in the case of high and medium productivity stands.

In the case of Norway spruce outside the natural range, its natural regeneration from seed must be carefully analysed. Practical experiences have shown that these cultures were strongly affected by biotic and abiotic factors (Duduman et al. 2011, Duduman and Olenici 2015), in most situations the best management option being represented by artificial regeneration with tree species corresponding to the natural forest type.

Conclusions

Technical harvesting age offers great flexibility to the forest manager, allowing him to opt,

Table 7 Differences (years) between technical harvesting ages achieved and those presented by Giurgiu (1988)

Species	Target wood assortment	Yield class				
		I	II	III	IV	V
Norway spruce (natural range)	>5	0	0	5	0	5
	>10	5	0	0	15	10
	>14	15	0	0	15	20
	>20	0	5	35	20	-
	>24	30	25	-	-	-
	>34	10	-	-	-	-
Silver fir	>5	5	0	-5	-5	-5
	>10	5	0	-10	10	0
	>14	5	10	15	10	-
	>20	5	25	20	20	-
	>24	0	15	-	-	-
	>34	5	5	-	-	-
European beech	>5	5	15	15	30	-
	>12	15	25	25	-	-
	>16	30	30	20	-	-
	>20	30	30	-	-	-
	>24	-	-	-	-	-
	>40	-	-	-	-	-
Sessile oak (from seeds)	>5	15	20	30	45	25
	>12	15	5	10	20	5
	>16	5	15	15	-	-
	>20	-10	0	-	-	-
	>24	0	-10	-	-	-
	>40	-	-	-	-	-
Sessile oak (from shoots)	>5	-	-	-	-	-
	>12	30	40	35	45	40
	>16	0	10	10	10	-
	>20	10	0	-	-	-
	>24	-	-	-	-	-
	>40	-	-	-	-	-

both at the level of each individual tree and at the level of the growing stock, for an optimal management system in relation to all three components of the planning process: material, individual and social.

It is important to ensure a common framework for planning timber production, respecting the principles of forest management and ensuring the continuity of timber production where possible, with the appropriate application of established management methods, but the right of the forest owner to sets its own management goals, following the legislative framework imposed by society, must in turn be respected.

The improvement of the way of establishing the harvesting ages in Romania constitutes an element of forest policy and involves a stochastic approach to the social, economic and ecological aspects that affect the forest management. The differences that currently exist in timber production planning between large and small forest owners cannot be ignored, just as it is not fair for society to be indifferent to the management objectives the owners of the small forest areas wish to achieve.

Thus, the updating of the harvesting ages can be a step forward in the activity of revising the technical norms for the management of forests in Romania, at the same time meeting the requirements arising from the current socio-economic context, reflected by the diversification of the ownership structure on forestlands and materialized by the need of forest owners to sometimes establish production goals different from those presented in the current technical norms or those established for forests owned by the state.

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Supplementary material

The online version of the article contains supplementary material.

Fig. 1. The dynamics of the mean volume growth corresponding to wood production of the target assortment against age (e.g. Norway spruce, silver fir, European beech, sessile oak and pedunculated oak)

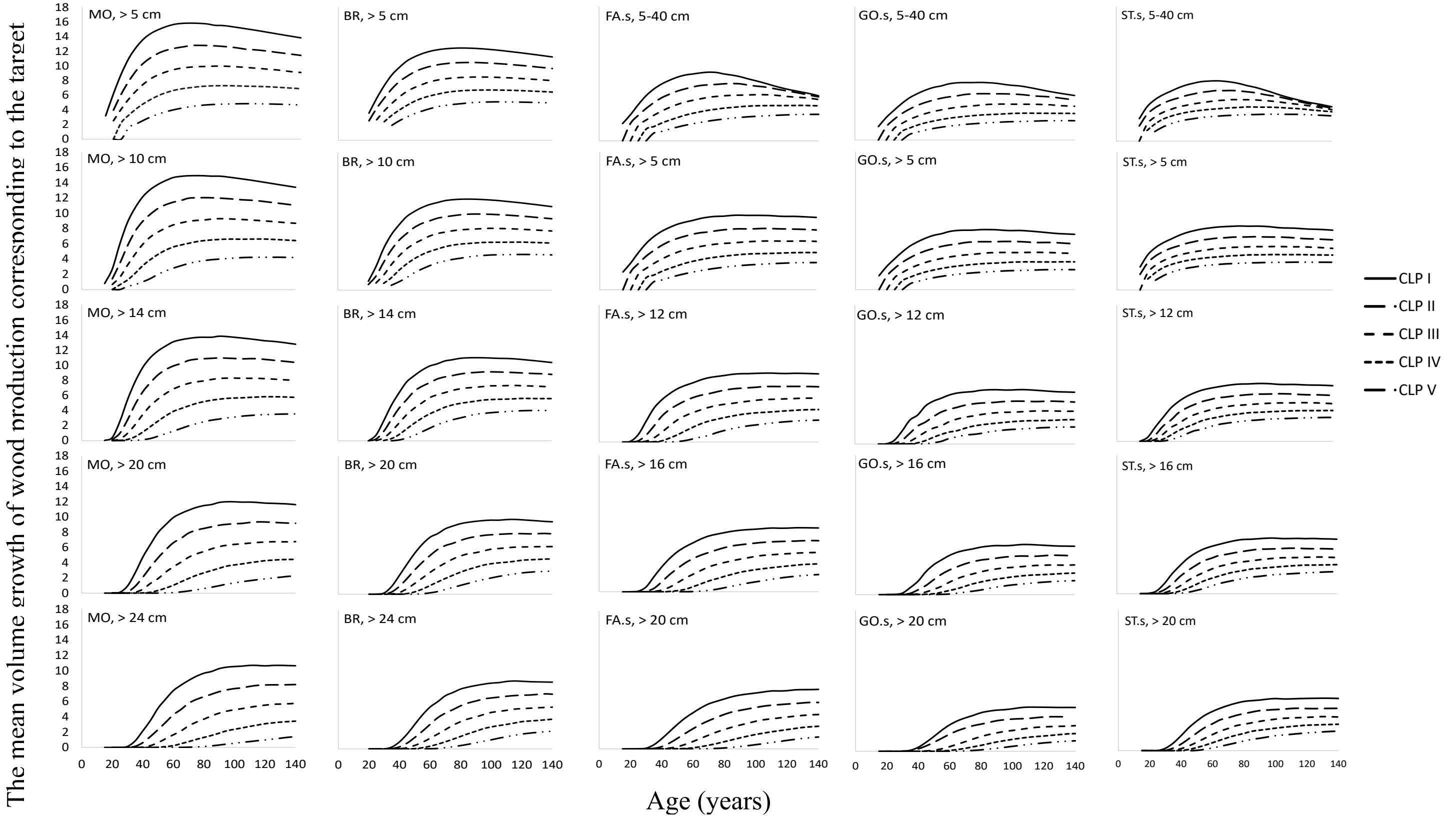
Table 1. Maximum value of average volume growth corresponding to wood production of target assortment, against species and yield class, for coniferous

Table 2. Maximum value of average volume growth corresponding to wood production of target assortment, against species and yield class, for European beech and oak species

Table 3. Maximum value of average volume growth corresponding to wood production of target assortment, against species and yield class, for other deciduous species

Supplementary material

Cotos A., Duduman G., 2017. Technical harvesting ages of the main forest species in Romania. Bucovina Forestieră 17(2): 115-129.



MO – Norway spruce, BR – silver fir, FA.s – European beech from seed, GO.s – sessile oak from seed, ST.s – pedunculated oak from seed; CLP – yield class.

Fig. 1. The dynamics of the mean volume growth corresponding to wood production of the target assortment against age (e.g. Norway spruce, silver fir, European beech, sessile oak and pedunculated oak)

Table 1. Maximum value of average volume growth corresponding to wood production of target assortment, against species and yield class, for coniferous

Species	Yield class	Maximum value of mean volume growth ($m^3 \cdot an^{-1} \cdot ha^{-1}$) for the target wood assortment …											
		5-10	5-14	5-20	10-20	5-24	5-34	> 5	>10	> 14	>20	> 24	> 34
Norway spruce – natural range	I	3.08	5.89	10.15	8.05	11.79	14.40	15.84	14.91	13.85	11.99	10.70	7.77
	II	2.69	5.22	8.56	6.88	9.88	11.97	12.79	12.03	10.97	9.34	8.20	-
	III	2.48	4.58	7.28	5.78	8.26	9.66	9.97	9.28	8.29	6.76	-	-
	IV	2.07	3.82	5.78	4.56	6.49	7.24	7.30	6.62	5.83	4.43	-	-
	V	1.67	2.94	4.17	3.20	4.55	4.84	4.84	4.23	3.54	-	-	-
Norway spruce – outside its natural range	I	3.14	6.13	10.79	8.88	12.63	15.72	17.09	16.16	15.04	12.96	11.39	-
	II	2.68	5.47	9.51	7.84	11.81	13.97	14.86	14.05	12.76	10.61	-	-
	III	2.44	5.02	8.87	7.19	10.24	12.17	12.59	11.79	10.46	8.21	-	-
Silver fir	I	2.55	4.88	7.79	6.19	8.97	11.09	12.49	11.91	11.08	9.76	8.82	6.42
	II	2.45	4.42	6.91	5.47	7.91	9.66	10.52	9.96	9.19	7.93	7.15	4.84
	III	2.00	3.73	5.90	4.67	6.70	8.08	8.56	8.09	7.38	6.21	-	-
	IV	1.76	3.27	5.03	3.98	5.64	6.61	6.79	6.29	5.65	4.61	-	-
	V	1.57	2.86	4.20	3.21	4.56	5.13	5.19	4.66	4.04	3.02	-	-
Black pine	I	3.55	5.48	7.71	5.81	8.52	9.25	9.30	8.26	7.07	4.57	-	-
	II	2.70	4.16	5.90	4.36	6.48	6.70	7.01	6.17	5.21	3.28	-	-
	III	2.16	3.23	4.44	3.21	4.80	5.07	5.07	4.33	3.56	2.05	-	-
	IV	1.55	2.27	3.06	2.17	3.25	3.33	3.33	2.72	2.11	-	-	-
	V	1.13	1.58	1.98	1.31	2.04	2.04	2.04	1.46	-	-	-	-
European larch	I	2.47	5.27	9.00	7.38	10.96	13.30	13.85	13.05	11.86	9.65	8.16	5.22
	II	2.36	4.72	7.81	6.23	9.18	10.81	11.18	10.44	9.36	7.50	6.30	3.89
	III	2.00	3.96	6.36	4.98	7.32	8.39	8.60	7.91	7.01	5.49	4.60	-
	IV	1.76	3.24	4.87	3.72	5.43	5.99	6.11	5.52	4.81	3.69	-	-
	V	1.49	2.50	3.43	2.50	3.71	3.96	3.96	3.45	2.93	2.15	-	-

Note. The red colour highlights the volume growths corresponding to the technical harvesting ages lower than the age of first abundant fruiting in the forest.

Table 2. Maximum value of average volume growth corresponding to wood production of target assortment, against species and yield class, for European beech and oak species

Species	Yield class	Maximum value of mean volume growth ($m^3 \cdot an^{-1} \cdot ha^{-1}$) for the target wood assortment …											
		5-12	5-16	5-20	5-24	12-24	5-40	>5	>12	>16	>20	>24	>40
European beech (from seeds)	I	3.88	5.41	6.43	7.30	5.51	9.22	9.75	9.06	8.44	7.77	-	-
	II	3.42	4.68	5.56	6.27	4.64	7.68	8.01	7.31	6.75	6.06	-	-
	III	2.90	3.88	4.62	5.18	3.82	6.19	6.37	5.76	5.19	-	-	-
	IV	2.26	3.13	3.64	4.09	3.00	4.75	4.86	-	-	-	-	-
	V	1.90	2.47	2.85	3.13	2.22	3.55	-	-	-	-	-	-
European beech (from shoots)	I	4.32	5.53	6.35	6.81	4.86	7.60	7.66	6.73	6.01	-	-	-
	II	3.35	4.38	4.91	5.32	3.70	5.89	5.93	5.15	-	-	-	-
	III	2.43	3.23	3.70	4.02	2.81	4.47	4.50	-	-	-	-	-
	IV	1.64	2.27	2.66	2.92	2.08	3.26	3.26	-	-	-	-	-
	V	1.14	1.61	1.91	2.11	1.46	-	-	-	-	-	-	-
Sessile oak (from seeds)	I	3.56	4.81	5.76	6.48	4.95	7.77	7.83	7.06	6.48	5.63	4.74	-
	II	3.10	4.05	4.76	5.32	3.92	6.25	6.28	5.57	5.08	4.41	3.61	-
	III	2.44	3.22	3.74	4.15	3.04	4.84	4.86	4.29	3.84	-	-	-
	IV	1.88	2.46	2.85	3.15	2.25	3.63	3.63	3.16	-	-	-	-
	V	1.40	1.81	2.08	2.30	1.61	2.61	2.61	2.20	-	-	-	-
Sessile oak (from shoots)	I	4.25	5.46	6.21	6.73	4.85	7.20	7.20	6.03	5.23	4.39	-	-
	II	3.30	4.23	4.80	5.19	3.67	5.45	5.45	4.50	3.90	3.16	-	-
	III	2.70	3.41	3.76	4.01	2.75	4.16	4.16	3.27	2.70	-	-	-
	IV	2.03	2.54	2.74	2.86	1.92	2.94	2.94	2.20	1.73	-	-	-
	V	1.44	1.77	1.88	1.91	1.21	1.92	1.92	1.32	-	-	-	-
Pedunculated oak (from seeds)	I	4.06	5.21	5.85	6.44	4.59	8.08	8.36	7.66	7.22	6.73	6.15	-
	II	3.57	4.54	5.11	5.56	3.88	6.78	6.96	6.30	5.90	5.43	-	-
	III	2.96	3.75	4.29	4.65	3.21	5.56	5.67	5.11	4.76	4.37	-	-
	IV	2.62	3.27	3.67	3.94	2.64	4.58	4.62	4.08	-	-	-	-
	V	2.08	2.70	2.97	3.18	2.11	3.61	3.65	3.16	-	-	-	-
Pedunculated oak (from shoots)	I	3.77	4.90	5.68	6.17	4.45	6.70	6.70	5.60	4.87	4.09	3.27	-
	II	3.28	4.23	4.77	5.12	3.65	5.50	5.50	4.50	3.90	3.25	-	-
	III	2.60	3.51	3.92	4.20	2.94	4.46	4.46	3.59	3.09	-	-	-
	IV	2.15	2.77	3.10	3.29	2.28	3.46	3.46	2.76	2.28	-	-	-
	V	1.73	2.16	2.40	2.52	1.71	2.64	2.64	2.05	-	-	-	-
Turkey oak (from seeds)	I	3.03	4.27	5.17	5.98	4.26	7.38	7.46	6.62	6.00	5.31	4.48	1.38
	II	2.63	3.67	4.40	5.04	3.55	6.02	6.06	5.26	4.66	4.08	-	-
	III	2.40	3.21	3.76	4.19	2.91	4.80	4.80	4.01	3.46	2.96	-	-
	IV	1.98	2.63	3.02	3.32	2.23	3.63	3.63	2.90	2.42	1.96	-	-
	V	1.59	2.09	2.34	2.51	1.62	2.65	2.65	1.99	1.59	-	-	-
Turkey oak (from shoots)	I	2.98	4.42	5.33	6.09	4.36	6.97	6.97	5.99	5.17	4.41	3.64	0.60
	II	2.79	3.78	4.52	5.02	3.48	5.49	5.49	4.52	3.82	3.12	2.47	-
	III	2.32	3.13	3.63	3.96	2.67	4.17	4.17	3.24	2.63	2.07	1.49	-
	IV	1.83	2.44	2.74	2.92	1.91	3.00	3.00	2.14	1.64	1.19	-	-
	V	1.56	1.99	2.16	2.25	1.39	2.27	2.27	1.49	1.04	-	-	-
Hungarian oak (from seeds)	I	2.93	4.48	5.41	6.08	4.42	7.02	7.04	6.12	5.27	-	-	-
	II	2.43	3.64	4.41	4.94	3.62	5.67	5.67	4.89	4.18	3.50	-	-
	III	1.85	2.84	3.44	3.86	2.84	4.41	4.41	3.78	3.22	-	-	-
	IV	1.37	2.11	2.57	2.90	2.14	3.28	3.28	2.78	2.31	-	-	-
	V	0.93	1.46	1.79	2.02	1.50	2.27	2.27	1.92	-	-	-	-

Note. The red colour highlights the volume growths corresponding to the technical harvesting ages lower than the age of first abundant fruiting in the forest.

Table 3. Maximum value of average volume growth corresponding to wood production of target assortment, against species and yield class, for other deciduous species

Species	Yield class	Maximum value of mean volume growth ($m^3 \cdot an^{-1} \cdot ha^{-1}$) for the target wood assortment …											
		5-12	5-16	5-20	5-24	12-24	5-40	>5	>12	>16	>20	>24	>40
Hornbeam	I	5.64	7.00	7.69	8.04	4.83	8.27	8.27	5.59	4.27	3.20	-	-
	II	4.86	5.98	6.57	6.83	4.05	7.01	7.01	4.68	3.55	2.57	-	-
	III	4.10	4.99	5.48	5.70	3.33	5.84	5.84	3.85	2.89	-	-	-
	IV	3.16	3.90	4.32	4.50	2.68	4.64	4.64	3.12	-	-	-	-
	V	2.55	3.14	3.46	3.58	2.11	3.69	3.69	2.41	-	-	-	-
Silver birch	I	4.14	5.57	6.38	6.90	4.90	7.26	7.26	5.81	4.60	-	-	-
	II	3.80	4.85	5.41	5.71	3.90	5.84	5.84	4.45	-	-	-	-
	III	3.05	3.88	4.27	4.39	2.96	4.46	4.46	3.20	-	-	-	-
	IV	2.38	2.93	3.16	3.22	1.85	3.24	3.24	-	-	-	-	-
	V	1.74	2.15	2.29	-	-	2.31	2.31	-	-	-	-	-
Silver lime	I	5.67	6.88	7.55	7.87	4.97	8.16	8.16	6.10	5.03	4.04	3.13	-
	II	4.34	5.52	6.12	6.42	4.10	6.65	6.65	4.97	4.04	3.12	-	-
	III	3.78	4.69	5.16	5.35	3.30	5.50	5.50	3.94	3.08	-	-	-
	IV	2.92	3.66	4.01	4.19	2.56	4.29	4.29	3.01	2.26	-	-	-
	V	2.40	2.91	3.17	3.25	1.89	3.31	3.31	2.16	-	-	-	-
Willow from seeds	I	11.93	15.63	17.99	19.71	13.74	21.54	21.58	18.33	15.97	13.78	11.35	1.97
	II	10.70	13.26	15.19	16.32	11.21	17.43	17.43	14.32	12.21	10.42	-	-
	III	8.50	10.74	11.79	12.61	8.55	13.11	13.11	10.55	8.72	7.14	-	-
	IV	7.00	8.34	8.94	9.28	6.05	9.48	9.48	7.12	5.66	4.38	-	-
	V	4.88	5.48	5.78	5.96	3.55	6.02	6.02	4.06	3.20	-	-	-
Black locust from seeds	I	7.73	9.96	11.29	12.51	9.19	13.05	13.05	10.79	-	-	-	-
	II	6.41	7.96	8.88	9.63	6.91	9.86	9.86	7.81	-	-	-	-
	III	4.81	5.83	6.45	6.85	4.89	6.97	6.97	5.09	-	-	-	-
	IV	3.23	3.84	4.23	4.40	-	4.40	4.40	-	-	-	-	-
	V	2.00	2.38	-	-	-	-	-	-	-	-	-	-
White poplar and black poplar	I	7.55	11.03	12.81	14.77	11.15	16.32	16.32	14.42	12.54	10.28	7.92	1.20
	II	6.47	7.97	10.10	10.97	8.72	12.19	12.19	10.48	8.85	7.03	5.11	0.47
	III	4.40	4.51	6.26	7.17	5.86	8.57	8.57	7.60	6.50	5.08	3.50	0.11
	IV	3.27	4.18	5.04	5.46	3.99	5.62	5.62	4.49	3.49	2.42	1.51	-
	V	1.82	2.61	3.07	3.23	2.36	3.29	3.29	2.49	1.79	1.11	0.54	-
Willow from shoots*	I	12.08	16.90	18.87	19.91	12.70	-	20.29	13.97	10.20	7.18	-	-
	II	10.87	14.14	15.52	15.93	9.46	-	16.03	10.26	7.10	4.57	-	-
	III	8.81	10.94	11.60	11.75	6.45	-	11.75	6.86	4.37	2.55	-	-
	IV	6.96	8.00	8.25	8.27	3.79	-	8.27	3.95	2.25	-	-	-
	V	4.28	4.69	4.77	4.77	1.80	-	4.77	1.80	0.56	-	-	-

Note. The red colour highlights the volume growths corresponding to the technical harvesting ages lower than the age of first abundant fruiting in the forest.