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# Comparison of the approach to determination of the rotation period of forest stands in the Czech Republic and in the Slovak Republic

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**Abstract:** The exact determination of the rotation period is still a current and important essential issue of forestry. It attracts the attention of forest economists, managers and owners worldwide, not only of forest economists but also of forest managers. The rotation period is defined by physical, technical or financial parameters of forest management. Therefore, it is necessary to distinguish between the biological and the economic optimal rotation period. A fundamental challenge in forest management is the need for appropriate determination of the rotation period. The primary interest of our research was to compare the effective legislation for the determination of the rotation period in the Czech Republic and in the Slovak Republic. Scientific methods such as document analysis and questionnaire survey were applied. The results of the legislation analysis and other related documents were compared with the expert opinions of the relevant stakeholders. Those who affect the decision process related to the problem and those where are "affected" by the problem were involved in the study. Results show that respondents do not agree with the regulation of rotation period according to effective law. Moreover, they consider it as not usable as the conditions in forest ecosystems have changed recently, which is not considered in the legislation.

**Keywords:** cutting age; expert opinions; forest legislation; forest management practices; forest policy

One of the oldest issues in forestry is determining the best age at which forest stands should be harvested (Pearse 1967) and this paradigm has not changed yet (Hartman 2018). Forest economists, forest managers, and other stakeholders consider the determination of the rotation period to be one of the most critical issues in forest economics, forest management, silviculture, and nature conservation (Samuelson 1976; Yousefpour et al. 2012). The rotation period of forest stands, or rotation forest age, is in general characterised as "the planned number of years (period) between the time when the stand regenerates and its final cut at a specified stage of maturity" (Nyland 1996).

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Basically, a summary of different types of rotation for forest stands was presented by Williams (1988), who distinguished the following types of rotation:

(*i*) Physical: based on the life expectancy of individual tree species according to their characteristics (e.g. different for beech, linden or for example alder, etc.).

(*ii*) Technical: similar to what Konšel (1931) defined; it is understood as the time required for the growth of expected assortments according to current market demand.

(*iii*) Growing: age at which maximum seed production is achieved to facilitate natural regeneration.

(*iv*) Biological: harvesting of stands is allowed only at the time of reaching the highest growth increase (the culmination of the growth).

(*v*) Generating income: the expected income from the forest is evaluated (see above).

(*vi*) Economic: such a time when the growth produces maximum profit. Harvesting based on the value of the growth percentage: based on the principle that in a similar way like in the evaluation of the current and future values (prices) of individual trees and the subsequent decision whether to cut them down or leave them standing. In this way, the growth rate of the prices of individual trees in the stand can also be evaluated.

The biological rotation period approach determines the optimum time (in years) at which a forest stand can be harvested to maximize timber/wood production (Stokland 2021). A biological cutting age is dependent on the habitat productivity (Hartman et al. 2018). However, this approach does not consider the costs and benefits that can be obtained from the forest.

Calculations of the optimal rotation period from the economic point of view include the value of the stand, timber benefits, costs, and interest rates, and are based on sustainable use of the forest. The right methods to determine the optimal rotation period can assist forest owners and managers in making decisions about forest investment (Chladná 2007; Nakajima et al. 2017).

The basis for the calculation of such a rotation period was generalised Faustmann's formula (Faustmann 1849), which was later used by Fernow (1902) as a calculation for determining the optimal rotation period. More recently, the forestry literature has mapped countless suggestions for improving the calculations of an optimal rotation period using Faustmann's study (e.g. Huang, Kronrad 2001; Zhang 2001).

Other studies (Lippke et al. 2011) have shown that the age of the physical rotation period, which is based on the life span of a tree, varies among species considerably. The technical rotation age is therefore based on the tree size (diameter, length, volume) and quality required by a given market (that concerns particular raw timber assortments).

The rotation period is important especially within the forest management because it determines harvesting intervals and can dramatically affect stand growth conditions (Bettinger et al. 2009), e.g. changes in the length of the rotation period can affect the age distribution of stands and their quality as well. Lindenmayer and Franklin (2002) reported that the use of longer rotation periods could have direct and significant consequences for biodiversity conservation (at the landscape level) and the forest management itself. Longer rotation periods reduce the rate of timber harvesting in each planning horizon and thus help to reduce some of the negative impacts of short rotation periods, while it still allows to obtain forest products (Moning, Muller 2008).

The issue of the correct determination of a rotation period has become the topic of discussion not only in the Czech Republic (CZ) and in the Slovak Republic (SK) but also in other European countries (Holušová 2021). Although these two countries have a common history, and often forest management practices based on the same platform, the goal of the study is to compare approaches to the rotation period length determination in the Czech Republic and in the Slovak Republic. The comparison is based on the analysis of relevant legislation and expert opinions.

## MATERIAL AND METHODS

**Study area.** The CZ and SK are landlocked countries in Central Europe and they used to be two parts of one country. Both countries were part of the Austro-Hungarian Monarchy. After its disintegration, independent Czechoslovakia was established in 1918, which was split into two individual states on January 1, 1993 (Ivanová, Koišová 2014).

The natural conditions of both countries are very similar. The CZ is located mainly in the Hercynian biogeographical region. Almost half of the territory lies in the Carpathian biogeographical region. According to the Ministry of Agriculture of the CZ (2021), the area of forest land covers 2.677 mil ha. The

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percentage of forest cover is close to 34 %. In the CZ coniferous tree species predominate in forest stands (70.4%). The most common tree species is Norway spruce (48.8%), followed by Scots pine (16.1%), European larch, and silver fir (1.2%), and other conifers. Of the broadleaved tree species, European beech (9.0%), oak (7.5%) and birch (2.8%) occur naturally, along with other broadleaved tree species (maple, wild cherry, lime, hornbeam, etc.).

The nearly entire territory of the SK belongs to the Carpathian biogeographical region, where the Tatra Mountains are situated. According to the Summary Information on the State of Forests (Ministry of Agriculture and Rural Development of Slovak Republic 2020), the area of forest land in the SK in 2020 consisted of 2.025 mil. ha, when forest stands covered the area of 1.952 mil. ha. The forest cover of this country approaches 41.3%. Broadleaved tree species predominate, accounting for 63.9% of their total. European beech (34.6%), Norway spruce (21.8%), oak (10.4%) and Scots pine (6.6%) have the highest representation. The proportion of coniferous tree species (36.1%) is decreasing, especially due to the increasing vulnerability of Norway spruce to the manifestations of ongoing climatic change.

Table 1. Survey questions and concerns

| Id. | Questions | Response options |
|---|---|---|
| Q1 | Is the RP of forest stands regulated/assessed by legislation in your country? | Yes, the RP is exactly determined by the law<br>No, the RP is not exactly determined by the law<br>Do not know |
| Q1a | If Yes, please name the specific laws and regulations: | Narrative |
| Q1b | If Yes, would you welcome the possibility of setting the length of RP on your own (based on the expert opinion)? Please justify: | Yes, please justify (narrative)<br>No, please justify (narrative) |
| Q2a | What is the average length of rotation period (in years) for Norway spruce in your country? | Years |
| Q2b | According to your opinion, is this RP optimal? | Yes, please justify (narrative)<br>No, please justify (narrative)<br>Do not know |
| Q3a | What is the average length of rotation period (in years) for European beech in your country? | Years |
| Q3b | According to your opinion, is this RP optimal? | Yes, please justify (narrative)<br>No, please justify (narrative)<br>Do not know |
| Q4a | What is the average length of rotation period (in years) for fir species in your country? | Years |
| Q4b | According to your opinion, is this RP optimal? | Yes, please justify (narrative)<br>No, please justify (narrative)<br>Do not know |
| Q5a | What is the average length of rotation period (in years) for oak species in your country? | Years |
| Q5b | According to your opinion, is this RP optimal? | Yes, please justify (narrative)<br>No, please justify (narrative)<br>Do not know |
| Q6a | What is the average length of rotation period (in years) for poplar species in your country? | Years |
| Q6b | According to your opinion, is this RP optimal? | Yes, please justify (narrative)<br>No, please justify (narrative)<br>Do not know |

RP – rotation period length

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To achieve the set of research goals a combination of qualitative methods was applied, i.e. the document analysis was carried out and the elaborated qualitative questionnaire survey was evaluated.

**Document analysis and expert opinion mapping.** The document analysis is a systematic process of reviewing or evaluating documents – both printed and electronic materials. Like other analytical methods in qualitative research, the document analysis requires that data be examined and interpreted to make meaning, gain understanding, and develop empirical knowledge (Bowen 2009). The analytical procedure included the search, selection, evaluation, and synthesis of the data contained in the various legislative norms and regulations with related annexes.

Secondly, the questionnaire survey method with qualitative research questions (Gibowski 1994) to collect data in bulk by "querying" or "asking" stakeholders about their knowledge, preferences, or their opinions and attitudes about a particular issue was used (attitude to a particular problem).

The questionnaire was divided into two main sections. The first section was focused on general information about the respondent, i.e. questions on the institution/organisation. The second section was focused on specific closed and open-ended questions related to the given issue (Table 1). The questions were designed according to the existing laws and were based on the goals of a national research project: The influence of rotation period on the health condition of forest stands: the possibilities of determining the optimal rotation of forest stands with regard to the economy of management and the diversity of ecosystems (2021–2023). This research project is implemented for the needs of the performed contract research.

The closed-ended questions were analysed using a simple frequency analysis. The open-ended questions mapped the estimated length of rotation periods in decades (years). The narratives from supplementary closed-ended and open-ended questions, as well as the texts from effective legislation were analysed using MAXQDA Analytics Pro software (Version for Windows and Mac, 2020). The results were systematically processed with the aim to obtain common opinions among respondents about the optimal length of rotation periods of chosen tree species. The gathered opinions were compared with effective legislation.

The expert institutions on the national level were identified based on the stakeholder categorisation as those who "can affect the decision process" and "are affected by the decision made" (Reed et al. 2009). The experts involved in the study were representatives from state and non-governmental organisations/institutions and associations of forest owners (Table 2).

Table 2. Institutions and organisations considered in the study

| Group | | SK | | CZ | |
|---|---|---|---|---|---|
| | | Institution | *N* | Institution | *N* |
| Can affect the decision process | legislative state/governmental institutions (power in legislation process) | Ministry of Agriculture and Rural Development | 1 | Ministry of Agriculture | 3 |
| | | Ministry of Environment | 1 | Ministry of Environment | 1 |
| | research and educational institutions (provide knowledge/expertise) | Forest Management Planning Institute of National Forest Centre | 3 | The Forest Management Institute | 4 |
| | | Technical University of Zvolen | 3 | Czech University of Life Sciences Prague | 1 |
| | | Slovak University of Agriculture in Nitra | 0 | Mendel University in Brno | 2 |
| | | Institute of Forest Ecology (Slovak Academy of Sciences) | 1 | Czech Academy of Agricultural Sciences | 1 |
| Affected | forest owners' associations | state and private | 2 | state and private | 3 |
| | other | NGOs interested in forestry or environmental sciences | 0 | NGOs interested in forestry or environmental sciences | 0 |

NGO – non-governmental organization; *N* – number of respondents

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We contacted 8 groups of stakeholders from the SK and 7 from the CZ. We received positive feedback from 11 SK respondents, four of them provided more detailed answers. Accordingly, the total number of respondents from CZ was 15 and three of them provided more detailed answers (Table 2).

## RESULTS

**Determination of rotation period according to effective forest legislation.** The rotation period of forest stands in the CZ is regulated by Decree No. 298/2018 on the preparation of regional forest development plans and on the definition of forest management units. The Decree defines the rotation period as "the planned framework period of production of forest stands for particular forest management units and is indicated by the number of years rounded to tens (for each decade)". The determination of the length of the rotation period is based on the values set out in Annex 3 of this Decree. The methods for determining are laid down in Decree No. 84/1996 on forest management planning (as amended by Decree No. 186/2022). However, these methods do not specify the optimum length of the rotation period.

In the SK, the length of the rotation period is determined by a combination of a decree of the Ministry of Agriculture (Decree No. 537/2021) and Forest Management Plans (FMP) for a specific forest management unit. The regulation is based on the cutting maturity of the stands included in forest management models used in particular forest stands. The rotation maturity of individual trees is determined based on site class and stand density according to the publication by Halaj et al. (1990). The rotation period is thus determined for the forest management units as the area-weighted average of the ages of the tree maturity (Bavlšík et al. 2008). However, we must point out that with the thus determined rotation period of forest stands, it is so-called physical (volume) optimal rotation period. This is applicable to both countries. A list of the legislation concerning the rotation period in the CZ and in the SK is shown in Figure 1.

**Length of the rotation period by specific tree species.** In the CZ, the rotation period is determined for the forest management unit (basic management unit defined based on similarity of natural conditions, required forest functions, declared through forest categorization), predominant tree species (forest stand type), health status (endangered, poor quality, quality, common quality, resonant, etc.) and silvicultural system (coppice forest, coppice-with-standards, high forest).

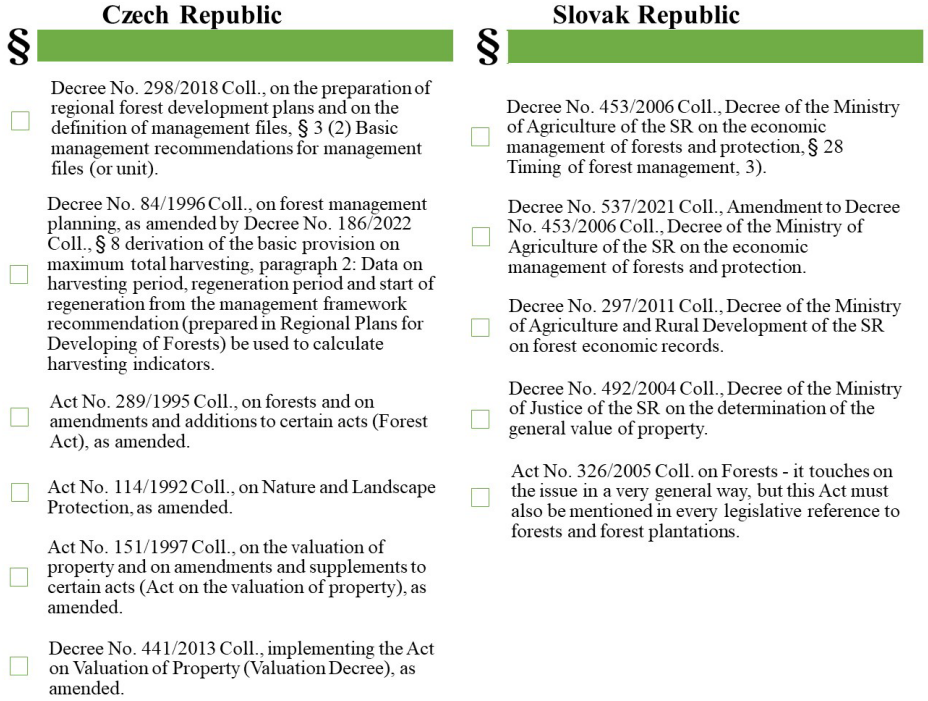


Figure 1. List of legislation tools concerning the rotation period of forest stand determination in CZ and SK

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In the SK, the average rotation period of forest stands is determined by the used forest management model/method, which is specified in the valid FMP for each area (forest management unit). The exact lengths of the rotation period (RP) for tree species are laid down in Appendix 14 of Decree No. 492/2004, but it has an informative pattern and was determined on the basis of the average rotation periods used in forests in the SK. The latest appendix of Rural Development Programme of SK 2014–2020 lists an amplified edition of the abovementioned Appendix 14 (Ministry of Agriculture and Rural Development of Slovak Republic 2013). In the SK, when determining the rotation period of individual tree species, it is possible to request the prolongation of rotation period, or its shortening according to current needs. As one respondent revealed: "For example, in Slovak conditions, it is possible to adjust the RP according to the real state of the stand, i.e. particular spruce has a prescribed rotation period of 120 years, but the stand is currently decaying, then there is a possibility of reducing the RP, for example to 90 years." A summary of the rotation periods for individual tree species can be found in Table 3.

The optimal rotation period also differs related to forest categories. In both countries there are three main categories of forests according to their primary function: (*i*) productive forests; (*ii*) special-purpose forests and (*iii*) protective forests (Ministry of Agriculture and Rural Development of Slovak Republic 2020; Ministry of Agriculture of Czech Republic 2021). The optimal rotation period described above is related to productive forests. In the CZ, the rotation period in special-purpose forests and in protected areas is based on the needs of specific nature conservation/protection objectives. The suggested rotation period for these forests is proposed in the elaboration process of forest management plan/management plan of the protected area. If the rotation period differs from Decree No. 298/2018, an exception may be requested, which must be approved by the nature conservation/protection authority, etc.

Table 3. Summary length of the rotation period of forest stands in years by tree species in the CZ and SK

| Tree species (groups) | Rotation period (in span of years) | |
|---|---|---|
| | CZ | SK |
| Norway spruce (and other spruce species) | 70–130 (170 for a resonant timber production; 60 for damaged stands) | 70–110 |
| Silver fir (and other fir species) | 90–140 | 90–120 |
| Scots pine (and other pine species) | 90–130 | 90–100 |
| European beech | 100–140 | 100–120 |
| Oak (all groups of oak species) | 100–180 | 120–160 |
| Poplar (all group of poplar species) | 30–60 | 15–30 |

Source: Relevant legislation

In the SK, the RP for special-purpose forests is derived from the stage of decay of natural forests based on the physical maturity of the trees and the growing conditions of forest stands – which is the time from the RP used within common management/forest management as usual/up to the required physical age of trees. Therefore, generally it is longer than in commercial forests. In the case of protective forests, the rotation period is shifted from physical maturity to the state of stands when the ability to fulfil their protective function and the capacity for natural regeneration ceases.

**Expert opinions towards laws and regulation of rotation period.** The results of the questionnaire survey from both countries (closed and open questions) with some selected answers are shown in Table 4.

Based on the comparison of legislation and experts' results, there is a difference between the rotation period recommended by legislation and the actual rotation period in both countries. In the CZ it is probably so because the legislative regulation is relatively new and has not yet been fully adopted. In the SK, it is caused by the fact that legislation has a recommendatory character and is based on the average rotation period used in the whole SK. The actual rotation maturity of the given tree species under its natural conditions is also considered.

Respondents in both countries agreed on comparatively long rotation periods mostly for all tree species, when compared to other European countries. Also, the forest owners and managers would accept more decision space related to determination of the rotation period.

To conclude, CZ respondents point to significant pressure from nature conservation agents to prolong the rotation period. These demands, however, are in no way supported by arguments as to how much the prolongation of the rotation period will

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Table 4. Results of a questionnaire survey

| Questions and answers | CZ | SK |
|---|---|---|
| | (% of respondents) | |
| **Q1: Is the RP of forest stands regulated/assessed by legislation in your country?** | | |
| Yes, the RP is exactly determined by the law | 100 | 60 |
| No, the RP is not exactly determined by the law | 0 | 40 |
| Do not know | 0 | 0 |
| **Q1a: If Yes, please name the specific laws and regulations:** | | |
| A correct answer | 90 | 85 |
| An incorrect answer | 10 | 25 |
| **Q1b: If Yes, would you welcome the possibility of setting the length of RP on your own (based on the expert opinion)? Please justify:** | | |
| Yes, please justify | 70 | 80 |
| No, please justify | 30 | 20 |
| **Q2a: What is the average length of rotation period (in years) for Norway spruce in your country?** | | |
| An average most common answer | 80–120 | 80–120 |
| **Q2b: According to your opinion, is this RP optimal?** | | |
| Yes, please justify | 30 | 20 |
| No, please justify | 70 | 75 |
| Do not know | 0 | 5 |
| **Q3a: What is the average length of rotation period (in years) for European beech in your country?** | | |
| An average most common answer | 90–120 | 100–120 |
| **Q3b: According to your opinion, is this RP optimal?** | | |
| Yes, please justify | 80 | 30 |
| No, please justify | 10 | 65 |
| Do not know | 10 | 5 |
| **Q4a: What is the average length of rotation period (in years) for fir species in your country?** | | |
| An average most common answer | 90–140 | 100–200 |
| **Q4b: According to your opinion, is this RP optimal?** | | |
| Yes, please justify | 80 | 50 |
| No, please justify | 20 | 45 |
| Do not know | 0 | 5 |
| **Q5a: What is the average length of rotation period (in years) for oak species in your country?** | | |
| An average most common answer | 100–180 | 60–160 |
| **Q5b: According to your opinion, is this RP optimal?** | | |
| Yes, please justify | 60 | 55 |
| No, please justify | 30 | 40 |
| Do not know | 10 | 5 |
| **Q6a: What is the average length of rotation period (in years) for poplar species in your country?** | | |
| An average most common answer | 30–60 | 20–100 |
| **Q6b: According to your opinion, is this RP optimal?** | | |
| Yes, please justify | 100 | 80 |
| No, please justify | 0 | 20 |
| Do not know | 0 | 0 |

RP – rotation period

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increase the diversity of forest stands. The current adjustment of the length of the rotation period used in the CZ still comes from the times when this was artificially prolonged with the aim to preserve forest stands for the needs of solving the state's economic crisis (before 1991), when most of the forest property was owned by the state.

## DISCUSSION

The presented results show considerable similarities in both countries related to the analysed issue. The length of rotation periods for specific tree species in the Czech Republic and in the Slovak Republic is similar. This is caused by their common history (Ivanová, Koišová 2014) and similar forest policy applied (Krykorková et al. 2022). The main difference was spotted in a decision process related to the determination of rotation period. In the SK the rotation period could be reduced/prolonged according to the growing conditions of forest stands. Foresters and forest owners in the CZ have more limited management options, i.e. less variability, which is more regulated by the legislation (Decree No. 298/2018; Holušová 2021). In some parts of the CZ territory – e.g. the Hercynian part (from a biogeographical point of view), forest owners are also forced to a longer harvesting period. The lengths of average rotation periods in the Czech Republic and in the Slovak Republic are similar.

In the territory of the former Czechoslovak Republic, the rotation period was shortened from 250 years to 150 years in oak forests, from 150 years to 120 years in beech and fir forests, and from 120 years to 100–80 years in spruce forests. In contrast, pines, for which King Frederick of Prussia prescribed 60 years, have a coppicing period of 80 years to 100 years. Special purposes lead to deviations. Thus, for example, the desire to supply the industry with softwoods imposes a cutting period of 50 years to 60 years on spruces in Germany. In Czechoslovakia, the coppicing period was prescribed by law in 1928 as temporarily irreducible (Konšel 1931).

At present, the rotation period in the two countries compared is still comparatively long in relation to previous years. The longer rotation periods give organisms more time to re-establish after harvest and provide habitats for species that depend on old-growth forests, such as large-diameter trees, large thickets, and logs (Brockerhoff et al. 2005) and help achieve biodiversity conservation goals (Lindenmayer, Franklin 2004). However, if we look at other European countries, e.g. Austria or Poland, in CZ and SK the average rotation period is approximately by about 10–30 years longer (Holuša et al. 2021). Shorter rotation periods are suggested as better for decreasing the specific forest management risks like occurrence of disturbances (Holécy, Korená Hillayová 2020; Zimová et al. 2020).

According to the outlined legislation and procedures, the issue of finding the optimal rotation period from the economic point of view is closer in SK than in CZ. The Czech legislation does not recognize the economic optimal rotation period and works more with the biological rotation period.

If we look back at the definition of the rotation period, it is true that initially, the approach was more focused on identifying the length of the felling season in order to maximize the timber production. Thus, the rotation period is referred to as the biologically optimal age (Avery, Burkhart 2015; Nyland 2016) suitable for harvesting the stand.

Within the concrete suggestions from the respondents, there is most often a tendency to focus on the definition of the rotation period, which could be defined as the technical rotation. And that is the choice of the target diameter at breast height (hereinafter DBH) of trees. That is, allowing the growth to be felled when the required DBH is reached. Which are rather methods that are more commonly used for fast-growing trees or trees cultivated on plantations (e.g. Magagnotti et al. 2021; Latterini et al. 2022).

There are also frequent tendencies to reduce the currently valid rotation period established by legislation. This applies in particular to forest stands of Norway spruce.

**Possible proposals for changes in legislation and suggestions how to change the rotation period from an economic point of view.** In the case of the Czech Republic, based on the research results, opinions focus on the possibility of shortening the rotation period for most tree species (probably in the order of decades or so). The authors of the study also suggest allowing for a more sophisticated choice of the rotation period than simply subtracting from the legislation. The choice of the technical rotation period and the method of target DBH of trees are completely revolutionary; which would result in very significant legislative changes in the CZ.

As part of the proposal on how to change the rotation period from an economic point of view, a number

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of questions arise, which would, for example, mean a number of complex changes for the CZ, e.g. in view of economic management of forests, the introduction of economic indicators into forest management plans, their monitoring and evaluation, which places higher demands on foresters in practice.

These aspects also require the creation of economic information systems (Matějíček, Dudík 2011) or the creation of suitable accounting procedures that would allow working with such data on forest stands (Sekot 2007). In the case of changing the Slovak Republic legislation, the proposals are similar. The rotation periods for the chosen tree species should be shorter and the determination should be based more on the preferences of forest owners and managers. The need for shorter rotation periods arises also from actual climate change impacts in the SK. Climate change increases the specific risk of forest management which causes economic losses for forest owners/managers in the case of forest destruction. As Holécy and Korená Hillayová (2020) calculated, the inclusion of specific risk into forest management plans shortens the optimal rotation period.

## CONCLUSION

The determination of rotation period in the Czech Republic and in the Slovak Republic is a discussed issue. The results of the comparison showed some similarities and differences in the given topic. The effective legislation exists in both countries but it has mainly a commendatory character.

The opinions on an optimal rotation period and rotation period defined by legislation vary in both countries. In the Czech Republic, there are significant pressures from the side of nature protection agents to extend the rotation period of forest stands. But forestry experts would like to reduce the length of the rotation period. This is because the quality of wood with the age of trees significantly decreases, and the health condition of forest stands deteriorates. Czech forest owners (and administrators) would welcome more sophisticated options for determining the rotation period of forest stands than just deriving it from the legislation, more economic criteria and the health status of forest stands should be taken in account. In Slovakia, the determining of rotation period is wider and could be slightly changed according to the natural conditions of particular forest stands. Like in the CZ, respondents agreed with the idea of shortening the optimal rotation period in general. In both countries, the focus is slowly shifting towards identifying the optimal rotation period from the economic point of view, considering the value of time and investment.

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