ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LIX 33 Number 1, 2011

FORESTRY ADAPTATION MEASURES AT THE DECLINE OF NORWAY SPRUCE (*PICEA ABIES* KARST.) STANDS AS EXEMPLIFIED BY THE SILESIAN BESKIDS, CR

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Received: May 18, 2010

Abstract

ČERMÁK, P., HOLUŠA, O.: *Adaptation measures at the decline of Norway spruce (Picea abies Karst.) stands as exemplified by the Silesian Beskids, Czech Republic.* Acta univ. agric. et silvic. Mendel. Brun., 2011, LIX, No. 1, pp. 293–302

At the beginning of this century, particularly after 2003, decline of *Picea abies* occurred at Forest District Jablunkov in the Silesian Beskids. This decline is of the complex character disease caused by the synergetic effects of abiotic, biotic and anthropogenic factors. Under conditions of climatic changes, it is possible to expect that similar episodes will repeat and appear also in other regions. Forestry will have to respond to them by changes in forest management. Measures proposed and discussed in this paper can be a starting point in their basic principles for other similar regions. Fundamental spheres of possible measures are as follows: chemical adaptations of the soil environment, i.e. liming or fertilization (if to realise them or not), changes in the species composition (particularly the rate of the decrease of *Picea abies*, participation of *Fagus sylvatica* and increasing the diversity of tree species), modification of the rotation (decrease) and regeneration period (increase).

decline disease, Silesian Beskids, *Picea abies*, liming, tree species composition, rotation period

Since the 90s of the 20th century, the area decline of *Picea abies* occurs in European regions, which has not been brought about by one evident reason but is of the character of a complex disease caused by synergetic effects of abiotic, biotic and anthropogenic factors. The complex of factors changes also in the course of time, however, symptoms and impacts of these decline disease episodes are very similar. Climate or its changes and sudden variations can be considered to be one of main stressors. In the Czech Republic, decline of this type was noted particularly in the Orlické hory Mts. (ČERMÁK *et al.*, 2005; ŽID, ČERMÁK, 2007) and the Silesian Beskids.

In the Polish side of the Silesian Beskids, the decline of spruce stands occurred already at the beginning of the 1990's. At the beginning of this century, its symptoms began to appear also in the Jablunkov Forest District, which is directly connected with this Polish area. Basic symptoms are as follows: yellowing and defoliation, decreasing the radial increment and the dieback of particular trees and groups of trees in stands of various ages, in some cases with the effect of final biotic mortality factors (*Armillaria* spp., *Ips typographus, Ips duplicatus, Pityogenes chalcographus* etc.), in other cases without an identifiable mortality factor).

Present findings on the course and reasons of the decline can be briefly resumed. In the second half of the 1990's and at the beginning of the 21st century, gradual increasing the radial increment occurred in the Jablunkov Forest District. It was interrupted in 2000. This increase was made possible by mild winters without marked temperature extremes, high temperatures in the growing season, more or less normal precipitation and the decline of air pollution. In 2003, the radial increment markedly decreased (another fall in 2006) remaining at the substandard level (ČERMÁK *et al.*, 2010). Within the same period, more marked symptoms of decline started to appear. Damage to spruce determined by monitoring as yet differs only insignificantly in various age classes. Naturally, in average values, the health condition of stands gets worse with increasing age. The intensity of damage to stands is not primarily dependent on site conditions, i.e. forest type group, altitude or slope orientation. No situation illustrating a biotic agent acting simultaneously the role of a predisposition, initiation and mortality stress factor was identified. The rate of using biotic mortality factors mentioned above markedly changes in particular stands or parts of the region.

On the basis of the comparison of dendrochronological dates of limed and unlimed stands (ŠRÁMEK *et al.*, 2008), notable differences did not result in the tree increment between limed and unlimed areas effects of the site classes being evidently marked. At the damaged stand, an increment did not follow after the increment fall as in comparable undamaged stands. Naturally, this fact can be interpreted as the logical result of defoliation and generally lower condition. Determined depositions of acidifying and eutrophying basic cations, fluorides and chlorides (ŠRÁMEK *et al.*, 2008) do not reach critical values being comparable with other mountain localities in the CR. On the other hand, they are not by far unimportant co-creating the total load.

Climatic factors, particularly shorter and longer spells of drought and temperatures in the growing season and in autumn, significantly affected the radial increment (ČERMÁK *et al.*, 2010). Dry and warm weather in 2003 has to be considered an initiation stressor acting a fundamental and perhaps a key role in the present health condition of forest stands.

Under conditions of climatic changes, it is possible to expect that similar episodes of the *Picea abies* decline will repeat in other European mountain ranges. Thus, forest management will have to respond to them urgently. To ensure the sustainable and safe production of forests as well as to ensure the fulfilment of non-wood producing functions it will be necessary to define and implement a number of adaptation measures.

General measures proposed (see Tab. I) and discussed in this paper can be a starting point for other regions in their fundamental theses.

Area adaptations of the soil environment

The supply of nutrients in soil throughout the Beskids is low in the long term, the lack of nutrients is documented at least since the 1980's of the last century (e.g. KLIMO, VAVŘÍČEK, 1991) and later papers prove the deficiency of Ca, Mg or P (KULHAVÝ, KLIMO (1998); BARSZCZ, MAŁEK (2008); NOVOTNÝ *et al.* (2008)). Higher contents of sulphur in soil were also demonstrated (BARSZCZ, 1990; BARSZCZ, MAŁEK, 2008). The soil environment of the Beskids is markedly heterogeneous. Even on small areas, different soil types with markedly differentiated trophic conditions can change. It is documented both by surveys carried out in the Silesian Beskids (MLČOUŠEK *et al.* 2008; TUREK *et al.*, 2009) and surveys coming from other parts of the Beskids (VAVŘÍČEK, BETUŠOVÁ 1996; VAVŘÍČEK, 2001). This differentiation can become evident more markedly in the general characteristics of soil profiles than in factors resulting from the various species composition. Results of surveys within the Czech Terra project (MLČOUŠEK *et al*, 2008; TUREK *et al.*, 2009) show that reserves of nutrients are generally higher in forest floor than in underlying horizons. The highest values of bivalent exchangeable bases were detected in humus of beech stands although total reserves of bases in mineral soil horizons were relatively balanced regardless of the stand species composition. ŠRÁMEK *et al.* (2008) note that in soils with the generally higher content of nutrients there is marked depletion of nutrients from upper soil layers in spruce stands. In beech stands, however,

I: *Fundamental principles of adaptation measures proposed for the Beskids within the Czech Terra project and their comparison with the present measures – Regional Plans of Forest Development of Moravian-Silesian Beskids Natural Forest Region (Holuša et al., 2000)*

Type of measures	Present measures	Proposed measures
Liming and fertilization	At present not realized; carried out in the past	Not to realize – potential risks are higher than benefits
Proportion of *Picea abies* in the target species composition	In the 4th FVZ up to 50%, in the 5th FVZ up to 70%	In the 4th FVZ up to 10%, in the 5th FVZ 10–20%
Proportion of *Fagus sylvatica* in the target species composition	Markedly lower than in the natural species composition	To increase slightly compared to the present condition: in the 4th FVZ 20–50% (at exposed sites even up to 60%), in the 5th FVZ 10–40% and in the 6th FVZ 10–30%
Proportion of other species	Very low	To increase
Spruce rotation period	According to sites 90 to 160 years (extremely unfavourable sites of the 6th and the 7th FVZ	According to sites 70 to 120 years with a possibility to decrease operatively down to about 60 years according to the condition of stands
Regeneration period in spruce stands	According to sites 20 to 40 years	According to sites 30 to 40 years with a possibility to extend operatively

Note: FVZ – forest vegetation zone

there is higher uptake of nutrients from deeper horizons. In stands with the most intense symptoms of decline, minimum contents of nutrients were found both in spruce and beech stands, namely within the whole soil profile depth. Thus, it is possible to say that differences between spruce and beech stands were much smaller than it was supposed.

The present condition of the soil environment is a predisposition stressor for forest stands. Linear correlations showed that various soil properties had different effects on the health condition of spruce stands (TUREK *et al.*, 2009). While in some factors, this effect changed with the soil depth, at other factors, this effect was the same regardless of the monitored horizon. In the forest floor, the forest health condition was most affected by the OVB/Al ratio (the content of exchangeable bases to the content of aluminium) in relation to the rate of defoliation and BS (basic saturation) concerning the abundance of discoloured trees. If the OVB/Al ratio was <1, the stand was also affected by medium or heavy defoliation. The occurrence of discoloured trees occurred if BS was lower than 36%.

In interpretations of the soil environment conditions and opinions resulting from them on measures aimed at the area treatment of soil, i.e. fertilization and liming, authors differ very often (FORMÁNEK, VRANOVÁ, 2003). A number of authors states the increasing content of Ca, Mg and also P and K in the soil or needles of spruce on limed plots as compared with unlimed plots, namely with various time distances from application at various European localities including the Beskids (e.g. IRGESLEV, 1999; IRGESLEV, HALBÄCKEN, 1999; BONNEAU *et al.*, 2000; ROSBERG *et al.*, 2006; KULHAVÝ *et al.*, 2009). On the other hand, some studies from Germany (HUBER *et al.*, 2006a, 2006b) or Scandinavia (NILSEN, 2001; SIKSTRÖM, 1997, 2002, 2005) revealed that liming in medium-term and long-term criterion showed none or only small effect on the content of nutrients in spruce needles or on its nutrition. HUBER *et al.* (2006b) state that increasing the Ca content after liming had no physiological response. In case of P, its concentration in needles was even lower twenty years after liming than before liming. The absence of the more marked improvement of soil properties and the quality of nutrition was detected even at long-term monitoring (18 years) the limed plots in the Moravian-Silesian Beskids. In organomineral (humus) horizons A or in E horizons, a marked difference was not demonstrated between the initial and current values of the exchangeable soil response (VAVŘÍČEK, BETUŠOVÁ, 1996). At higher locations of the flysch zone, the exchangeable soil response increased from the initial mean value 2.74 pH/KCl in 1983 to a value 3.00 pH/KCl in 1994. In the further period 1996 and 1997, a fall occurred again to a value of 2.82 pH/KCl. The content of available magnesium markedly increased. However, a fivefold value compared to the original value in 1988 (229 $mg.kg^{-1}$) significantly decreased to about 100 $mg.kg^{-1}$ Mg in further years. The content of magnesium in soil, values of soil reaction and thus the content of calcium or even the amount of applied limestone did not demonstrate significant effects on the growth, development and health conditions of spruce stands. Different characteristics of site defined by the group of forest types and soil type (eg the soil skeleton) always decided.

Positive effects of liming on basic saturation are often related to negative impacts on the dynamics of nitrogen in acid soils with spruce stands (FORMÁNEK, VRANOVÁ, 2003). The short-term but rather high content of Mg and luxury nutrition with a marked disproportion to the content of potassium can cause ecological risks because of significant antagonism of this bivalent element in consequence of the deficit nutrition by K (VAVŘÍČEK, 1998, 2001). On the basis of these facts, it is probable that more permanent improvement of soil conditions after the realization of liming cannot be considered a priori. Nevertheless, the short-term improvement of the condition of available nutrients can be expected.

In addition to the supply of nutrients, the hydrological regime of soils appears to be an important problem in the Silesian Beskids. With respect to the particle-size distribution when soils are sandy to sandy-loam (particularly in the eastern part) and thus subject to drying up, it is not possible to affect this regime by any measure.

In case of the application of fertilizers or liming it refers to the marked change of the environment of heavily stressed tree species, which is necessarily connected with risks of undesirable impacts. It is possible to expect negative consequences of the soil environment homogenization or acceleration of the raw humus decomposition. At aerial liming, above all horizons of forest floor are affected. They create important specific forms of humus particularly at higher locations. As a mechanical and buffering barrier they prevent from the higher effect of surface-applied limestone on changes in parameters of organomineral horizons A (VAVŘÍČEK, BETUŠOVÁ, 1996). For these reasons, substantially more marked growth and development of the root system occurs in upper organic layers. With respect to the higher intensity of climatic stressors (in connection with global changes of climate) this stimulation effect can show negative impacts on the health condition of stands treated in this way (VAVŘÍČEK, 2001). The stands can respond more frequently and intensely to spells of drought, marked changes in temperatures etc. In addition, more intensive growth of fine roots in forest floor is accompanied by the reduction of fine root penetration in mineral soil (FORMÁNEK, VRANOVÁ, 2003). Generally, it is possible to state that the "regradation" of soils should not consist in pH modifications but in the recovery of the humus supply cycles. However, these can be rather realized by the change of forest management than by measures such as fertilization or liming. Decision making on possible modifications of the soil environment is problematic being related to a number of uncertainties. It is necessarily based on subjective estimates of uncertain future benefits on the one hand and risks on the other hand.

ŠRÁMEK *et al.* (2008) propose the application of Silvamix PMC fertilizer at a rate of 300 kg.ha^{-1} or the combination of fertilization by dolomitic limestone with the high content of Mg (2 t.ha^{-1}) with the subsequent application of Silvamix K3 fertilizer. Authors of this paper consider measures to the soil environment to be too risk or even dangerous bringing only short-term potential benefits.

Species composition

Present studies (both from regions affected or unaffected by the *Picea abies* decline) are consistent that at the expected changes of climate the area of forests suitable for growing spruce will decrease markedly in Central Europe (KOPECKÁ, BUČEK, 1999; HANEWINKEL *et al.*, 2010). The decline of *Picea abies* and the increased proportion of broadleaved species can be expected even in boreal and boreonemoral forests (KOCA *et al.*, 2006). In the 4th beech (*Fageta* s. lat.) and to a great extent also in the 5th firbeech (*Abieti-Fageta* s. lat.) forest vegetation zone (FVZ), it will not be possible to preserve the present high proportion of *Picea abies*, namely even in regions not affected by the decline yet.

The basis of proposed changes in the species composition for the Silesian Beskids or for the whole natural forest region of the Moravian-Silesian Beskids consists in the decreased proportion of *Picea abies*. Particular recommendations differ in the rate of this reduction and which species (and at what rate) should replace Norway spruce. ŠRÁMEK *et al.* (2008) mention the recommended target proportion of *Picea abies* in the 4th FVZ 0–20% and explain it particularly by economic reasons. Also KULLA *et al.* (2009) suggest the proportion of 20% for the Slovakian part of the Beskids. Authors of this paper assume that to preserve spruce in such a proportion will be probably very difficult or even quite impossible. Primarily, Norway spruce should be quite absent at these locations. For the prospective origin of the quality natural regeneration of present stands in places where the regeneration of other species is problematic we propose the proportion of *Picea abies* for the target species composition in the 4th FVZ up to 10%. For the 5th FVZ, we propose the proportion of *Picea abies* within the limits 10–20%, ŠRÁMEK *et al.* (2008) suggest 10–30%, KULLA *et al.* (2009) 10–40% (over 30% only at moist sites). In the 6th FVZ, we recommend the proportion of *Picea abies* up to 50% according to the site type (ie edaphic categories), KULLA *et al.* (2009) propose 30–40%.

It is evident that it will be necessary to extend particularly the species spectrum of trees. The higher number of species creates a condition for the broader use of natural adaptation processes and thus also for the generally higher resistance of stands. The rich species composition increases the possibility to replace a species, which has actually unfavourable conditions for its growth. The species will decline or recede from stands from other reasons. Following species should be represented in the target composition: *Fagus sylvatica*, *Abies alba*, *Quercus robur* (3rd–4th FVZ, taking into account climate changes perhaps also the existing 5th FVZ), *Acer pseudoplatanus, Acer platanoides, Fraxinus excelsior, Carpinus betulus* (3rd–4th FVZ), *Cerasus avium* (mesotrophic sites of the 3rd–5th FVZ), *Ulmus glabra* (mesotrophic and enriched sites), *Sorbus aucuparia* and to a certain extent also *Betula pendula*, *Populus tremula* or *Larix decidua*. *Larix* can be used as admixture (to 10%, especially in mesotrophic and extreme edaphic series). *Larix* has stabilization function and their litter fall has high content of Ca and Mg. And, of course, it has important production function.

A number of the species can occur in stands only as an admixture. There is a question, which species should be used as main stand-forming species instead of Norway spruce, particularly in the 4th and 5th FVZ where the proportion of spruce will be mostly reduced. With respect to the high reproduction potential and relatively wide ecological valence European beech (*Fagus sylvatica*) is logically offered. Nevertheless, it is necessary to take into account possible risks in considerations concerning its proportion in the target species composition. The risks are connected with growing beech under considered potential climatic changes. GEßLER *et al.* (2007) deal, for example, with these risks.

Effects of the increased content of CO_2 on beech are uncertain. There are studies demonstrating the increase of growth of the aboveground and underground biomass (e.g. MEDLYN *et al.*, 2001). However, other studies do not suppose such a growth or mention the conditionality of the growth response on the character of a substrate, the stand mixture composition etc. (EGLI, KÖRNER, 1997; SPINNLER *et al.*, 2002; KÖRNER *et al.*, 2005; KOZOVITS, 2005). MEDLYN *et al.* (2001) and KÖRNER (2003) mention a possibility of the decreased LAI in maturity. Because of this decreased LAI, beech could lose a basic competition advantage, i.e. the suppression of competition species by shading. It could result in problems concerning its role as a main stand species on acid substrates. On the other hand, some papers from Scandinavia demonstrate a general idea that because of climatic changes beech can be more used in mixed stands with Norway spruce thanks to its higher resistance to abiotic and biotic stressors accompanying climatic changes as well thanks to the increased competitive capacity with Norway spruce (BOLTE *et al.*, 2009).

With respect to differences in results of studies mentioned above it is possible to state that responses to climatic changes can be different in various ecotypes of European beech. Thus, differences can occur not only between beech trees from various geographical regions but also from various altitudes, i.e. vegetation zones. Results of modelling growth responses of European beech (MÁTYÁS *et al.*, 2008) suggest that in intermediate geographical latitudes and in the north of Europe climatic changes could result in the increase of beech production. Under stressed conditions (particularly at dry sites), growth depressions are predicted and the loss of beech vitality. Validity of these conditions is demonstrated by studies recapitulating the response of beech on dry and warm episodes demonstrating its rather high sensitivity (CIAIS *et al*., 2005; FRIEDRICHS *et al*., 2009). On the other hand, e.g. DITTMAR *et al.* (2003) suppose on the basis of the evaluation of annual rings that European beech shows high resilience and will be able to cope with periods characterized by the decreased availability of water. It is not known so far if the increased input of CO_2 manages at least partly to compensate for effects of water stress. Other risks of growing European beech are connected with biotic factors. Since the 90s of the last century, records occur on the presence of fungi of the genus *Phytophthora* (*Phytophthora citricola, P. cambivora, P. cactorum*) on beech trees in Europe (e.g. WERRES, 1995; SCHMITZ *et al*., 2007). Their occurrence on declining beech is related to climatic extremes, such as in Bavaria after the very humid year 2002 and extremely dry year 2003 (JUNG 2004, 2009). Increased sensitivity of roots to *Phytopthora citricola* at increased CO_2 detected FLEISCHMANN *et al.* (2010). Generally, it is assumed that activities of fungal and bacterial pathogens (particularly sugar-dependent parasites) as well as of some insect parasites (especially sucking insect) will increase with the increased CO_2 concentration and related climatic changes (e.g. MANNING, TIEDEMANN, 1995). However, in partial studies, conclusions also appear demonstrating decreased activities of some biotic agents on beech. For example, HENN *et al.* (2000) note reduced feeding of *Lymantria dispar* under conditions of increased CO_2. Changes caused by the increased CO_2 can be related not only to the intensity of feeding of herbivores associated with the quality of food but also to the growth of their larvae or food preferences (HÄTTENSCHWILER, SCHAFELLNER, 2004). The change of food preferences (i.e. the change of intensities of damage to particular species) can significantly affect competition relationships in stand mixtures.

In general terms, it is not possible to say unambiguously if the increase of CO_2 and implicit changes of climate can result in the general increasing the effect of biotic stressors or rather changes in the demonstration of particular species (groups of species) of pests and pathogens. Thus, general effects on the health condition of forest stands can be predicted only with difficulties (CHAKRABORTY *et al*., 2000; GARRETT *et al*., 2006).

The target proportion of beech should take into account risks mentioned above. On the other hand, it is evident that in case of the marked decline of spruce it will be difficult to avoid the certain increase of the beech proportion in production forests (particularly from silvicultural reasons). ŠRÁMEK *et al.* (2008) propose not to increase the proportion of beech because it is able to fulfil its reclamation function only in limited extent being not advantageous even from the aspect of production. Therefore, they recommend 20–40% proportion in the 4th FVZ and 20% in the 5th FVZ. Authors of this paper assume that the increased proportion of beech is acceptable and necessary also with respect to a fact that beech is the main edificator in the 3rd to the 6th FVZ. Considering the problematic regeneration and growth of other species creating the target species composition (moreover, their response to climatic changes is uncertain or complicated) it is realistic that the increased proportion of beech (at least for a transition period) would occur in any case. Thus, we propose to use the proportion of beech in the target species composition 20–50% in the 4th FVZ (at exposed sites up to 60%), 10–40% in the 5th FVZ and 10–30% in the 5th FVZ. For the Slovakian part of the Beskids, KULLA *et al.* (2009) propose the proportion of beech in commercial forests 30–40% in the 4th FVZ, 20–30% in the 5th FVZ and 10–30 % in the 6th FVZ.

The rotation and regeneration period of spruce

Present studies suggest that under changes environmental conditions, Norway spruce grows older at medium altitudes. For example, MADĚRA *et al.* (1999) dealt in detail with the situation of a spruce stand in the 3rd FVZ (mesotrophic sites) in the Drahanská vrchovina Upland (Southern Moravia). They found out that because of already created and unadapted short and narrow crowns symptoms of unhealthy conditions became evident in a spruce stand, namely low LAI and LAD, the low number of needle age classes, small dimensions of needles and the permanent progressive depression of the height and diameter growth. At the physical age of 85 years, sample trees (mean trees of a stand) reached a good site class 1+ (mesotrophic soils, long growing season), however, since their age of 60 years, they exhibited symptoms of the beginning of senescence. Authors of the paper assume that permanently unfavourable precipitation and temperature conditions are the main reason of this fact. Thus, the monitored stand reached as a whole only 82% tabular growing stock. Moreover, spruce trees aged over 60 years are generally more endangered by biotic pests and wind. In case the trees were infected by wood-destroying fungi (both by root decay such as *Armillaria* sp. and *Heterobasidion annosum* or wound decays such as *Stereum sanguinolentum*) the part of wood attacked by decay increased with age. It results in increasing losses in wood realization and increased risk of breakages or windthrows. With respect to these facts it appears to be ineffective and heavily risk growing Norway spruce using existing rotation periods, which are about 90 to 110 years at medium altitudes, at higher altitudes even more (Tab. I.). Authors of the paper propose to reduce the rotation period in general directions of management by about 10 to 20 years and particularly a possibility of the operative reduction of rotation according to the condition of a stand up to 60 years. Also ŠRÁMEK *et al.* (2008) propose the reduction of rotation, namely differently in variously damaged stands. In the most damaged stands (the proportion of damaged individuals 31% and more), the rotation is not determined and regeneration is carried out according to the order of urgency using underplanting and advance planting.

Reduced rotation is substantiated both from silvicultural and environmental aspects but also from economic reasons. HANEWINKEL *et al.* (2010) note the highest land expectation values are at spruce at an age of 80 years (according to their model evaluations of economic impacts on spruce and beech under conditions of a climatic change in SW Germany). Thus, this age appears to be optimal for the rotation period and also DIETER (2001) reached the same conclusion.

With respect to the target species composition of subsequent stands when not only richer species composition is taken into consideration but preferably the richer vertical and horizontal structure of stands, it is also desirable to extend the existing regeneration periods (20–40 years according to a site) of spruce stands. According to the authors the regeneration period should take 30 to 40 years with a possibility to extend this period in case of reasoned need. ŠRÁMEK *et al.* (2008) propose a 30-year regeneration period and KULLA *et al.* (2009) a 20 to 40-year period. TUREK *et al.* (2009) propose for extreme edaphic series and for damaged stands a permanent regeneration period. The permanent regeneration period lead to vertical and horizontal differentiation of stands and it make possible of selection silvicultural system.

SUMMARY

The aim of the paper is to summarize present proposals for forestry adaptation measures in a typical region affected by the decline of Norway spruce (the Silesian Beskids) and to synthesize and confront them with literature sources. Under conditions of climatic changes it is possible to expect that similar episodes of decline will repeat in other regions. Forestry will have to respond to them by changes in management and measures mentioned above can be a starting point in fundamental principles for other similar regions.

In the Polish part of the Silesian Beskids, the decline of spruce stands began already at the beginning of the 90s. At the beginning of this century, its symptoms began to appear at the Jablunkov Forest District. This district is directly connected with this Polish region. Basic symptoms are as follows: yellowing, defoliation, decrease of radial increment and dieback of particular trees and groups of trees in stands of various ages, in some cases using final biotic mortality factors (*Armillaria* spp., *Ips typographus, Ips duplicatus, Pityogenes chalcographus* etc.), in other cases without identifiable mortality factors.

Basic forestry adaptation measures are generally summarized in Tab. I. Authors of this review assume that affecting the soil environment is too risk or even dangerous bringing only potential short-term benefits. It is evident that at lower vegetation zones it will not be possible to preserve the existing high proportion of *Picea abies* even in regions not affected by the spruce decline yet. The tree species composition should be modified in such a way the proportion of spruce to be minimized in the 4th and 5th FVZ and the composition of tree species to be as rich as possible. The higher number of species creates conditions for the wider use of natural adaptation processes and thus for the generally higher resistance of forest stands. An increase in the proportion of *Fagus sylvatica* is problematic. In literature, a number of risks related to beech are mentioned, namely in situations of the elevated content of CO_2 in the atmosphere and related to climatic changes. Present findings are, of course, often contradictory or with conditioned applicability. Generally, it is very complicated to predict summary effects on the health condition. The target proportion of beech should take into account risks mentioned above. On the other hand, it is evident that in case of the marked reduction of the proportion of spruce it will be rather complicated to avoid a certain increase (particularly from silvicultural aspects) in the proportion of beech in commercial forests.

Spruce stands aged over 60 years are more endangered by biotic pests and wind, their increment culminates earlier under conditions of chronic stress than it was calculated at the determination of the rotation period under present general instructions for management. With respect to these facts growing spruce under present rotation periods, which are about 90 to 110 years at medium locations, appears to be ineffective and considerably risk. Authors of this paper propose to reduce the rotation period in general directions of management by about 10 to 20 years and particularly a possibility of the operative reduction of rotation according to the stand condition up to 60 years.

The paper was prepared under the support of the CR Ministry of Environment "Czech Terra" VaV SP/2d1/93/07 project.

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