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Risk evaluation of the climatic change impact on secondary Norway spruce stands as exemplified by the Křtiny Training Forest Enterprise

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ABSTRACT: The paper proposes a method of assessing the potential risks of the future development of stands in relation to a climatic change. To assess risks of the future development of a stand simple point scales have been worked up based on primary properties of a site and a stand according to data of the forest management plan (FMP). In assessing the health condition, the risk of damage to stands by *Armillaria* sp. in the felling age was evaluated on the basis of a present attack by *Armillaria* sp. and also defoliation of the crown primary structure assessed during a simple field examination. The evaluation was carried out in the region of the Křtiny Training Forest Enterprise (TFE) Masarykův les, ranger district Proklest, in 2002. The study was conducted in 118 Norway spruce stands aged more than 20 years. The majority of evaluated stands ranked among the category of high and medium risk from the viewpoint of site and stand risks and among the category of high *Armillaria* sp. attack.

Keywords: climatic change; Norway spruce; risk evaluation; health conditions

According to the global scenarios of the climate development, viz. both the scenario of Business as Usual developed by IPCC or other global (e.g. Goddard Institute of Space Studies or Geophysical Fluids Dynamics Laboratory) and regional scenarios, in the region of the Czech Republic in 2030, it is possible to expect annual mean temperatures higher by 1.9–2.6°C as compared with 1990. In addition to the increased mean temperature it is possible to expect also higher irregularity in the course of precipitation and changes in some other climatic characteristics (KALVOVÁ et al. 1995). Naturally, all these factors will cause marked changes in the possibility to grow spruce particularly at lower and medium locations.

From the viewpoint of a forest manger, it is important to know potential risks of management and to have a possibility to specify them at least partially for particular units of the forest-management classification of forests. Thus, we tried to find criteria and to propose a method of the evaluation of potential risks of the future development of forests with spruce in relation to the climatic change (CC). We also tried to verify the use of some parameters for assessing the present health condition of Norway spruce in these stands. Evaluation which should be available for larger units in usual forest practice has to be based on easily detectable parameters. We selected, therefore, standard parameters contained in forest management planning, i.e. included in a "forest management book" of the FMP (evaluation of risks) or parameters which can be determined by simple field examinations (evaluation of the present health condition). The objective of the evaluation is to make possible to rationalize management in terms of priority measures and to increase care of stands with higher risks in relation to CC or worse health conditions.

MATERIAL AND METHODS

In 2002, we tried to evaluate the present health condition and potential risks of stands with Norway spruce in the region of the Proklest ranger district, Forest District Křtiny, TFE Křtiny Masarykův les. The Proklest ranger district belongs to the 4th forest vegetation zone (FVZ) (93% of the stand area) and to the 3rd FVZ (7% of the stand area). Spruce covers about 60% of the stand area (see Tables 1 and 2). Stands parts (parts of a stand demarcated in regenerated stands only where part of the original stand is delimited from the regenerated one) aged over 20 years

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Table 1. Species composition in the Proklest ranger district according to the FMP

Species	Area (%)
Beech	17.23
Birch	0.41
Oak	3.23
Red oak	0.05
Hornbeam	1.77
Goat willow	0.01
Rowan	0.02
Ash	0.36
Sycamore maple	1.02
Linden	0.41
Alder	0.33
Cherry	0.01
Total broadleaves	**24.85**
Scots pine	1.78
Douglas fir	2.75
European larch	9.61
Silver fir	0.64
Norway spruce	60.37
Total conifers	**75.15**

Table 2. The percentage of forest type groups in the Proklest ranger district according to the FMP

Forest type group	Area (%)
3A	0.07
3B	5.99
3H	0.45
3L	0.12
3S	0.42
4A	2.60
4B	64.02
4H	4.82
4S	21.50

with the proportion of spruce (according to FMP) > 50% were evaluated. Generally, it refers to 118 stand parts, 36 of them in the 3rd and 92 in the 4th FVZ.

To assess risks of the stand future development we proposed simple point scales based on primary properties of a site (forest vegetation zone and ecological series) and a stand (species composition and age structure) according to the FMP (see Table 3). Evaluation of site factors results from a forest vegetation zone which describes most markedly climatic characteristics of a site. The smallest degree of risk of the 6th forest vegetation zone (FVZ) is based on our present findings on vitality and adaptability of spruce stands in various regions of the Czech

Table 3. Evaluation of site and stand risks (values in the form × number are coefficients which are used for the multiplication of initial factors)

Factor	Characteristics	Value
Forest vegetation zone	1–2 FVZ	5
	3 FVZ	4
	4 FVZ	3
	5 and 7 FVZ	2
	6 FVZ	1
Ecological series	extreme	× 1.3
	gleyed, waterlogged, nutrient-rich	× 1.2
	acid	× 1.1
	enriched	× 1.0
Total value for site factors		1.0–6.5
Species composition	spruce monoculture (spruce over 95%)	5
	spruce 80–95%, 5% and more other autochthonous species	4
	spruce 70–79%, 20% and more other autochthonous species	3
	spruce 60–69%, 30% and more other autochthonous species	2
	spruce 50–59%, 40% and more other autochthonous species	1
Age structure	even-aged stand	× 1.1
	two-storied or all-aged stand	× 1.0
Age	up to 60 years	× 1.2
	over 60 years	× 1.0
Total value for stand factors		1.0–6.6
Total value for site and stand factors		2.0–13.1

Table 4. Stand classification according to the evaluation of site and stand risks

Risk rate	Point range
Very low risk (1)	2.0–4.0
Low risk (2)	4.1–6.0
Medium risk (3)	6.1–8.0
High risk (4)	8.1–10.5
Very high risk (5)	10.6–13.1

Republic. The findings were obtained within surveys for the National Climatic Programme as well as within other studies. Spruce stands in the 6th FVZ appeared to be by far most vital, with the highest potential for a response to the global change of climate. As a correction factor a coefficient was used based on an ecological series in terms of the UHÚL (Institute for Forest Management Planning) typological system (taking into consideration the trophic and hydric regime of soils in relation to potential risks). The extreme series is considered to be most risk especially with respect to the expected higher frequency of climatic extremes which will significantly affect the already existing high stress load of spruce at these localities. It refers to consequences of short-term droughts in particular. Moreover, communities of extreme series are generally very sensitive to changes in ecological conditions (VINŠ et al. 1996). Series affected by water and a nutrient-rich series with the high risk of stand disintegration follow.

Another scale specifies stand risks and represents the way of stand establishment and its basic properties. Species composition was selected as a basic determining factor (proportion of spruce and autochthonous species). The stand age structure and its age were chosen as parameters specifying risks through coefficients. Classification of stands according to age into two different categories, viz. ≤ 60 years and > 60 years comes from present findings and the capability of spruce stands to adapt to unfavourable conditions (JANKOVSKÝ, CUDLÍN 2002). About 60 years of age, marked impairment in the health condition and symptoms of premature senescence occur as noticed for example by MADĚRA et al. (1999). We suppose, therefore, a little smaller risk of unfavourable development in younger stands which should have a possibility to use their adaptation potential better than older stands.

Results consist in a "point evaluation" which is a relative measure of risks of the stand future development under a CC. Although it refers to the rough general expression only of the rate of risks it makes possible to formulate an idea on the relative danger to particular stand parts within the given management unit. Based on the evaluation of site and stand risks the stand parts were classified into 5 categories (Table 4).

Table 6. Classification of stands according to the risk evaluation of damage to stands by *Armillaria* sp. in the felling age

Attack intensity	Point range
Stands with low damage	0.9–2.0
Stands with medium damage	2.1–3.0
Stands with high damage	3.1–10.0

Table 5. Risk evaluation of the damage to stand by *Armillaria* sp. in the felling age and evaluation of the primary structure defoliation (values in the form × number are coefficients which are used for the multiplication of initial factors)

Factor	Characteristics	Value
Attack by *Armillaria* sp.	more than 75% trees show evident symptoms of *Armillaria* attack	5
	50–75% trees show evident symptoms of *Armillaria* attack	4
	25–50% trees show evident symptoms of *Armillaria* attack	3
	0–25% trees show evident symptoms of *Armillaria* attack	2
	symptoms of *Armillaria* attack are not evident	1
Age	up to 19 years	× 2.0
	20–29 years	× 1.8
	30–39 years	× 1.5
	40–49 years	× 1.4
	50–59 years	× 1.3
	60–69 years	× 1.2
	70–89 years	× 1.1
	90 and more years	× 1.0
Total value of *Armillaria* attack		1.0–10.0
Assessment of the primary structure defoliation	defoliation 80–100%	5
	defoliation 60–80%	4
	defoliation 40–60%	3
	defoliation 20–40%	2
	defoliation to 20%	1

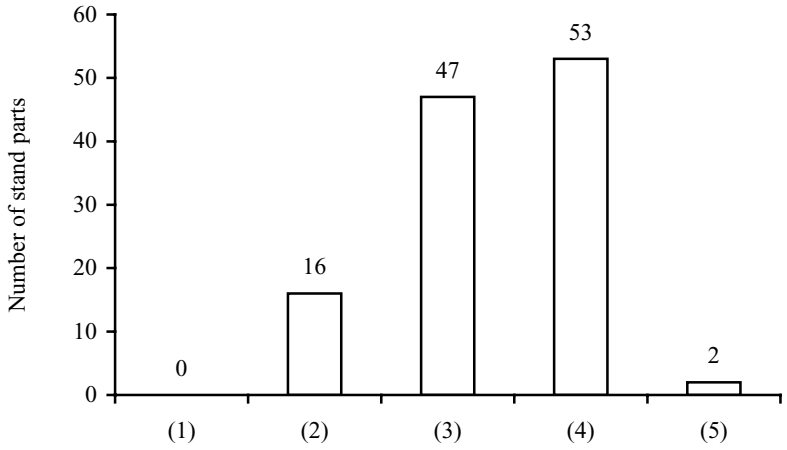

Fig. 1. Numbers of stands with a various degree of site and stand risk: (1) – very low risk, (2) – low risk, (3) – medium risk, (4) – high risk, (5) – very high risk

In the same stand parts, the present health condition of spruce was assessed during field inspections, viz. attack by and degree of the primary structure defoliation. Stands were classified into visually assessable categories for particular parameters of evaluation.

In assessing the present attack of stands by *Armillaria* sp. the percentage was estimated of attacked trees in categories given in Table 5; every tree with any symptoms of attack was considered to be an attacked tree (butt swelling, fruit bodies, syrrocium, rhizomorphs). For the purpose to compare estimates of risks of *Armillaria* damage in the felling age for stand parts of various age the point value of an attack is multiplied by coefficients according to age. In a young stand, a certain percentage of attacked trees can indicate a critical health condition in the future while in an old stand, the same percentage of attacked trees appears to be a manifestation of ageing and will not be increased. The correction of age thus takes into account the progressive course of decay, i.e. a fact that e.g. at the attack of 60% trees at an age of about 40 years it is possible to expect attack of 80–100% trees at an age of about 80–100 years. According to the risk of damage to stands by *Armillaria* sp. at the felling age we propose to classify stand parts into three categories (Table 6).

In assessing defoliation of the crown primary structure (CUDLÍN et al. 2001) the defoliation was estimated for the whole stand in categories given in Table 5 in the course of an inspection round to stands. A total defoliation was not determined with respect to the fact that it reached relatively low average values (up to 20–30%) in all stands not differing noticeably even in stands of different age.

RESULTS

In the region under evaluation, stands with high and medium potential risk predominate (see Table 4), generally 93%, in detail see Fig. 1. A higher risk is shown by stand parts in the 3rd FVZ (mean point value 9.2) than stand parts in the 4th FVZ (mean point value 7.7). Of 36 stand parts included into the 3rd FVZ, 31 (86%) show a high risk and 5 a medium risk.

In assessing the risk of damage to stands by *Armillaria* sp. in the felling age, the lowest point value of 2.6 was found in one stand part aged 54 years, the highest point

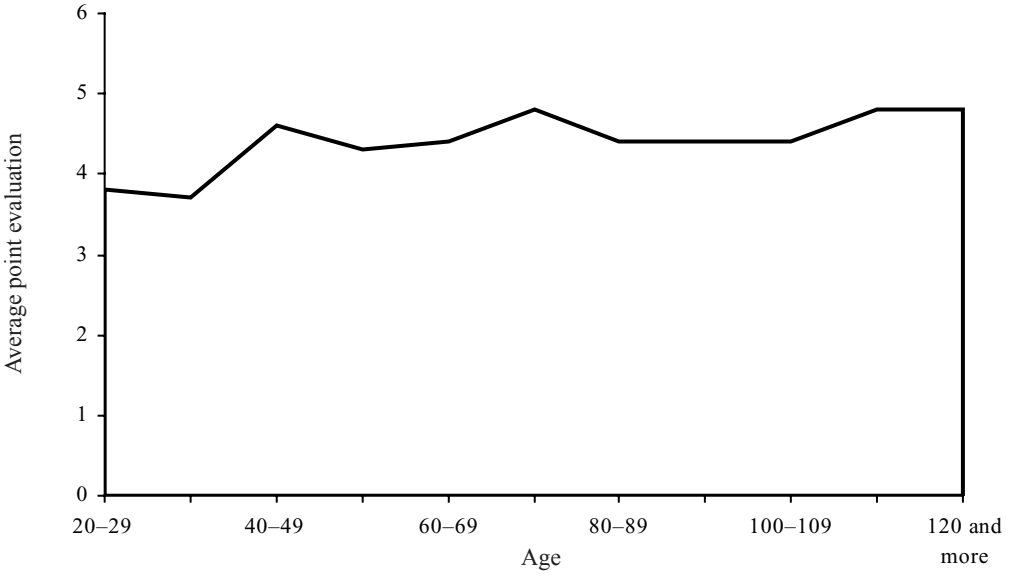

Fig. 2. Results of the *Armillaria* attack evaluation according to the stand age

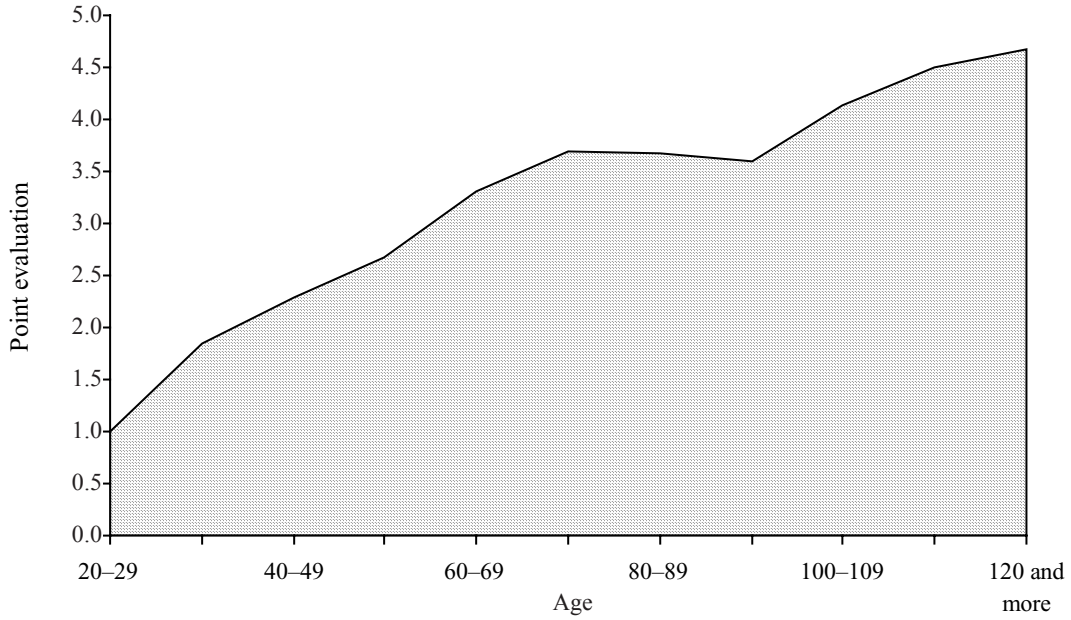

Fig. 3. Results of the evaluation of the primary structure defoliation of stand parts according to the stand age

value of 6.0 was found in three stand parts at an age of 30 to 39 years. At present, evaluation of the risk does not show any significant differences between particular age categories (see Fig. 2); values of attack in younger stands up to 40 years of age only (20–29 years – 3.8; 30–39 years – 3.7) are slightly lower. None of stand parts under investigation ranks among the category of low damage by *Armillaria* sp. (see Table 6), 19 stand parts rank among the category of medium damage and remaining 99 stand parts rank among the category of high damage to stands.

Relationships have not proved between the risk of *Armillaria* damage and FVZ (the 3rd FVZ as against the 4th FVZ) and to compare ecological series, the material is not sufficient with respect to the evident dominance of a nutrient-rich series.

Results of evaluation of the primary structure defoliation of spruce crowns according to age categories are given in Fig. 3. The primary structure defoliation increases with the stand age and a dependence has not been proved on the proportion of spruce in a stand or on site conditions (the 3rd as against the 4th FVZ). The material is not, however, sufficiently numerous for more detailed comparisons of particular age categories. At an age between 60 and 70 years, it reaches on average a point evaluation of 3 corresponding to 40–60% defoliation, in older stands average defoliation of the primary structure is higher than 50% the internal tolerance of trees to stress impacts being exceeded (CUDLÍN et al. 2001).

DISCUSSION AND CONCLUSIONS

From the viewpoint of the future development of stands, the predominant majority of stand parts with spruce in the studied locality is evaluated as medium to high risk parts. At present, spruce in the 3rd and the 4th FVZ is already out of its optimum (according to various sources, mean temperatures up to 6°C and precipitation over 800 mm can be considered to be an optimum). Further unfavourable changes in conditions will result in significant increase in its threat. Nevertheless, high threat to spruce in relation to expected increase in temperatures by about 2°C in localities with a mean annual temperature over 7°C (i.e. roughly the present mean temperature in the 4th FVZ in the Křtiny TFE) was noticed even sooner (THOMASIUS 1992 in VINŠ 1996).

The proposed methodology of risk evaluation of the further development of stands based on data from a FMP makes possible simple comparisons of particular stand parts within the selected unit of forest division (in our case for a ranger district – RD). Its application in the region of the Proklest RD resulted in assumed conclusions corresponding to outcomes from previous surveys in the given area (JANKOVSKÝ, CUDLÍN 2002; MADĚRA et al. 1999) and elsewhere under comparable conditions (GRABAŘOVÁ, MARTÍNKOVÁ 2000, 2001). Methods used in the study were proposed with special reference to conditions occurring at medium altitude condition; to compare stands under different spectrum of conditions it would be suitable to elaborate similarly structured systems of evaluation separately for particular types of natural conditions and methods of management preferably for management sets of stands (made up for forest management purposes and based on principles of forest typology; basic units of general planning). These methods should be based on parameters used in the presented methodology possibly completed by some other parameters. Such a methodology will make possible to set more precisely particular parameters and better to compare risks of the stand disintegration under situation without or with the effect of a CC.

In the monitored region, *Armillaria* sp. occurs as a marked biotic factor decreasing vitality and reducing competition possibilities of spruce in relation to other species. The high predisposition for attack is formed particularly by the stress load of spruce owing to summer droughts and also high temperatures in the growing season. It is possible to expect that *Armillaria* sp. will occur in possible destabilization and disintegration of spruce stands due to the climatic change. Authors of the monitoring of stands in the Křtiny TFE in 12 ICP plots in 2001 (JANKOVSKÝ, CUDLÍN 2002) came to the same conclusions. The proposed methodology of assessing the risk of damage to stands by *Armillaria* sp. in the felling age eliminates a marked dependence of the damage on the stand age making possible to compare stands of various age. With respect to simplicity it can become one of parameters for areal assessing the further development of the health condition of spruce particularly in the 3rd and 4th forest vegetation zones.

Monitoring the primary structure defoliation has demonstrated its marked relationship to the stand age. Therefore, the monitoring is important in older stands only where together with other parameters (total defoliation, the crown transformation degree) it shows evidence of the present response of spruce stands to the integrated effect of stress factors and their expected response to other changes in site conditions (CUDLÍN et al. 2001).

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Hodnocení rizik dopadu klimatické změny na porosty se smrkem na příkladu ŠLP Křtiny

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ABSTRAKT: Příspěvek navrhuje způsob hodnocení možných rizik budoucího vývoje porostů v souvislosti s klimatickou změnou (KZ). Pro hodnocení rizik budoucího vývoje porostu byly zhotoveny jednoduché bodové stupnice, které vycházejí ze základních vlastností stanoviště a porostu podle údajů LHP. U hodnocení zdravotního stavu bylo hodnoceno riziko poškození porostu václavkami v mýtním věku na základě současného napadení václavkami a dále defoliace primární struktury koruny při jednoduchém terénním šetření. Hodnocení probíhala v roce 2002 na území ŠLP Masarykův les Křtiny, LÚ Proklest, ve 118 porostech se smrkem starším 20 let. Většina hodnocených porostů patřila do kategorií vysokého a středního rizika z hlediska stanovištních a porostních rizik a do kategorie vysokého napadení václavkami.

Klíčová slova: klimatická změna; smrk; hodnocení rizik; zdravotní stav

Podle globálních scénářů vývoje klimatu, ať již jde o scénář Business as Usual, vypracovaný IPCC, či o další scénáře globální (např. Goddard Institute of Space Studies či Geophysical Fluids Dynamics Laboratory) i regionální, lze v roce 2030 očekávat roční průměr teploty na území ČR o 1,9–2,6 °C vyšší ve srovnání s rokem 1990.

Z pohledu lesního hospodáře je důležité znát možná rizika hospodaření a mít možnost je alespoň rámcově speci-

fikovat pro jednotlivé celky hospodářskoúpravnického rozdělení lesů. V roce 2002 jsme se pokusili o hodnocení současného zdravotního stavu a možných rizik porostů se smrkem na území lesního úseku Proklest, polesí Křtiny, ŠLP Masarykův les Křtiny.

Pro hodnocení rizik budoucího vývoje porostu jsme navrhli jednoduché bodové stupnice, které vycházejí ze základních vlastností stanoviště (vegetační stupeň a ekologická řada) a porostu (dřevinná skladba a věková struktura) podle údajů LHP (tab. 3). Výsledkem je bodové hodnocení, které je relativním měřítkem rizik dalšího vývoje porostu při KZ. Na základě hodnocení stanovištních a porostních rizik byly porostní skupiny zařazeny do pěti kategorií (tab. 4).

Při hodnocení současného napadení porostů václavkami bylo na pochůzce porosty odhadováno procento napadených stromů v kategoriích uvedených v tab. 5; za napadený strom byl považován každý strom s jakýmikoliv příznaky napadení (zbytnění oddenku, plodnice, syrocium, rizomorfy). Podle rizika poškození porostů v mýtním věku václavkami navrhujeme rozdělit porostní skupiny do tří kategorií (tab. 6).

Při hodnocení defoliace primární struktury koruny (CUDLÍN et al. 2001) byla defoliace odhadována pro celý porost v kategoriích uvedených v tab. 5 při pochůzce porosty. Celková defoliace nebyla zjišťována vzhledem k tomu, že dosahovala ve všech porostech poměrně nízkých průměrných hodnot (do 20–30 %) a nelišila se znatelně ani u různě starých porostů. Pro statistické hodnocení možných závislostí byla použita běžná korelační analýza.

Na hodnoceném území jednoznačně převažují porosty s vysokým a středním rizikem (podle tab. 4) – souhrnně 93 %, podrobně viz obr. 1. Větší riziko vykazují porostní skupiny ve 3. lvs (průměrná bodová hodnota 9,2) než porostní skupiny ve 4. lvs (průměrná bodová hodnota 7,7). Ze 36 porostních skupin zařazených do 3. lvs vykazuje 31 (86 %) vysoké riziko, 5 střední riziko.

Při hodnocení rizika poškození porostu václavkami v mýtním věku byla nejmenší bodová hodnota 2,6 zjištěna u porostní skupiny staré 54 let, nejvyšší bodová hodnota 6,0 u tří porostních skupin ve věku 30–39 let. Z hodnocení tohoto rizika nevyplývají v současné době žádné významné rozdíly mezi jednotlivými věkovými kategoriemi (obr. 2), mírně nižší jsou pouze hodnoty napadení u mladších porostů do 40 let (20–29 let – 3,8; 30–39 let – 3,7). Defoliace primární struktury vzrůstá s věkem porostu, nebyla prokázána závislost na zastoupení smrku v porostu či na stanovištních podmínkách (3. lvs proti 4. lvs). Materiál je ovšem málo početný pro podrobnější srovnání odděleně pro jednotlivé věkové kategorie, tak jak by to bylo žádoucí.

Převážná většina porostních skupin se smrkem na sledované lokalitě je hodnocena jako středně až vysoce riziková z hlediska dalšího vývoje porostů. Smrk je ve 3. a 4. lvs již v současné době mimo své optimum (za optimum lze podle různých pramenů považovat průměrnou teplotu do 6 °C a srážky nad 800 mm). Další nepříznivá změna podmínek povede k významnému zvýšení jeho ohrožení.

Navržená metodika hodnocení rizik dalšího vývoje porostu na základě údajů z LHP umožňuje jednoduché srovnání jednotlivých porostních skupin v rámci vybrané jednotky rozdělení lesa.

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