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Salvage felling in the Slovak forests in the period 2004–2013

Náhodná ťažba v lesoch Slovenska v období rokov 2004–2013

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Abstract

Salvage felling is one of the indicators of the forest health quality and stability. Most of the European Union countries monitor forest harmful agents, which account for salvage felling, in order to see trends or functionality between factors and to be able to predict their development. The systematic evidence of forest harmful agents and volume of salvage felling in Slovakia started at the Forest Research Institute in Zvolen in 1960. The paper focuses on the occurrence of the most relevant harmful agents and volume of salvage felling in the Slovak forests over the last decade. Within the 10 years period (2004–2013) salvage felling in Slovakia reached 42.31 mil. m^3 of wood, which was 53.2% of the total felling. Wind and European spruce bark beetle *Ips typographus* damaged 78.4% of salvage wood, i.e. they were the most important pest agents. Norway spruce (*Picea abies*) was the most frequently damaged tree species that represented the amount of 35.6 mil. m^3 of wood (81.2% of total volume of salvage felling). As Norway spruce grows mostly in mountains, these regions of Central and Northern Slovakia were most affected. At the damaged localities new forests were prevailingly established with regard to suitable ecological conditions for trees, climate change scenarios and if possible, natural regeneration has been preferred. These approaches in forest stand regeneration together with silvicultural and control measures are assumed to gradually decrease the amount of salvage felling over long term perspective.

Keywords: salvage felling; pest agents; windstorms; bark beetles; *Ips typographus*

Abstrakt

Náhodná ťažba je jedným z indikátorov zdravotného stavu lesov a jeho stability. Niektoré štáty Európskej únie monitorujú škodlivé činitele, ktoré sú príčinou náhodnej ťažby, aby zisťovali vzťahy medzi činiteľmi a prognózovali ich vývoj. Systematická evidencia škodlivých činiteľov a objemu náhodných ťažieb začala v 1960 v Lesníckom výskumnom ústave Zvolen. Tento príspevok sa zameral na výskyt najzávažnejších škodlivých činiteľov a objem náhodných ťažieb v slovenských lesoch počas ostatného desaťročia. V priebehu 10-ročného obdobia (2004–2013) náhodná ťažba na Slovensku predstavovala 42,31 mil. m^3 kalamitnej hmoty, čo je 53,2 % podiel na celkovej ťažbe. Vietor a lykožrút smrekový *Ips typographus* zapríčinili až 78,4 % náhodnej ťažby a týmto patrili k najvýznamnejším škodlivým činiteľom v lesoch Slovenska. Smrek obyčajný (*Picea abies)* bol najčastejšie poškodzovanou drevinou, pričom jeho kalamitná hmota predstavovala objem 35,6 mil. m^3, čo bol 81,2 % podiel na celkovej náhodnej ťažbe. Smrek obyčajný rastie predovšetkým v horských oblastiach Slovenska, práve tieto regióny stredného a severného Slovenska boli najviac poškodzované. Na obnovovaných plochách po kalamitách sa lesy zakladajú prevažne s ohľadom na ekologickú vhodnosť pre vybrané dreviny, čiastočne aj na klimatickú zmenu a preferuje sa pritom prirodzené zmladenie. Takéto postupy v rámci porastovej obnovy spolu s pestovno-ochrannými opatreniami by mali v dlhodobom výhľade znížiť rozsah náhodných ťažieb.

Kľúčové slová: náhodná ťažba; škodlivé činitele; vietor; podkôrny hmyz; *Ips typographus*

1. Introduction

Slovakia is considered a well afforested country. Forests cover about 2 mil. ha, which is over 40% of the total area of the country. The European beech (*Fagus sylvatica* L.) is the most common forest tree species with 31.6% coverage. The next most common forest tree species are Norway spruce (*Picea abies* L. [Karst.]), oaks (*Quercus* spp.), pines (*Pinus* spp.) and silver fir (*Abies alba* Mill.) with the coverages of 25.5%, 10.7%, 7.0% and 4.1%, respectively (Anonymous 2011).

In Central Europe, where forests have been managed for many decades and industrialisation have been developing very fast within the last 70 years, the susceptibility of forest tree species have been changing. Nevertheless, there is a rule that forest management cultivates trees up to the age of about 100 years, when they are not only the most productive, but unfortunately often also more susceptible to pest agents. Some studies show that the emissions from 50s to 90s of the 20th century changed the soils so dramatically that soil ecosystems cannot recover within several last years, when

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the emissions were dramatically reduced (Crippa et al. 2015). Climate change, presently the major environmental factor influencing natural processes, can be not only measured and modelled by climatologists (Hlásny et al. 2014), but it can also be indirectly visible by the changed behaviour of certain susceptible organisms, which include forest trees as well as other organisms living in forests. As forest ecosystems belong to most natural ecosystems at least in Central Europe, they show more natural signs of these climatic change trends than other ecosystems (Zúbrik & Kunca 2006; Santini et al. 2013).

These are just several predisposing factors which may be taken into consideration in connection with large scale forest damage events in Slovakia as well as in many other European countries. The paper sums up the processed wood from salvage felling and the major forest disturbance events which occurred in Slovakia in the last 10 years. Besides, it also shows up some pest agents which are much more important for forest ecosystems than others.

2. Methods and data collection

The systematic evidence of forest pests in Slovakia started at the Forest Research Institute in Zvolen in 1960. At that time, an annual statistical form named L116 was created and it was in practice with just little adjustments up to 2012, when a new law on forest evidence has come into force (Kunca et al. 2014b). The adjustments mostly referred to upgrades of the list of pest agents. From 2004 to 2011 (8 years), there were 71 pest agents in L116 report that were divided into three major groups:

– abiotic (12 agents): wind, snow, icing, late spring frost, early autumn frost, other damages by frost, drought and sun scorch, flooding, waterlogging, a landslide, a complex of abiotic agents, other abiotic agents,
– biotic (52 agents): *Ips typographus* L., *Pityogenes chalcographus* L., *Trypodendron lineatum* Olivier, Scolytinae on fir, Scolytinae on pines, *Ips cembrae* Heer, *Scolytus intricatus* Ratzeburg, other Scolytinae, *Lymantria dispar* L., Tortricidae on oaks, *Calliteara pudibunda* L., Geometridae on oaks, Diprionidae on pines, *Pristiphora abietina* Christ, *Coleophora laricella* Hubner, beetles of Melolontha, other leaf-eating insects, *Dreyphusia nordmannianae* Eckstein, Adelgidae on *Picea* spp. and *Larix* spp., other sucking insects, *Hylobius abietis* L., *Hylastes cunicularius* Erichson, Curculionidae, larvae of Buprestidae, larvae of Melolontha, *Gryllotalpa gryllotalpa* L., other root pests, needle cast, powdery mildew, rusts, *Phytophthora cactorum* (Lebert & Cohn) J. Schröt., *Botrytis cinerea* Pers., other diseases of leaves and needles, cankers, necrosis, other canker diseases, *Armillaria* sp., *Heterobasidion annosum* s.l. (Fr.) Bref., wood rots, other wood destroying fungi, tracheomycosis, seed rot, damping-off of seedlings, root rot of seedlings, other similar damping-off of seedlings, tree bark peeling by game, bitten off by game, other damages by game, rodents, nematodes, weeds, other biotic damages,
– anthropogenic agents (7 agents): imissions, fire, wood stealing, grazing of domestic animals, tourism, pesticides, other anthropogenic agents.

The volume of salvage felling was measured only once. Each volume of wood cut in salvage felling had to be assigned a pest agent and sometimes even two or more pest agents. Hence, in our analysis the total volume of salvage felling is smaller than the total volume of certain pest agents. This rule was changed in 2012 and from that time on each volume of salvage felling could be assigned only to one pest agent.

The new law on forestry evidence has become effective in 2012, and the salvage felling realised in 2012 was already evaluated by the new method. The major change of the pest agents evidence is that the evidence has become obligatory for all forestry subjects. Second, the data are collected first by regional state district administrations who do the first formal control of the data, and the reports are subsequently centralised at the National Forest Centre in Zvolen. The third change regards the set of pest agents. There were 53 pest agents (by 18 less than before in L116 form), out of them there were:

– 5 in the group of abiotic agents: wind, snow, drought and sun scorch, flooding and waterlogging, other abiotic agents,
– 42 in the group of biotic agents: *Ips typographus* L., *Pityogenes chalcographus* L., *Trypodendron lineatum* Olivier, Scolytinae on fir, Scolytinae on pines, *Ips cembrae* Heer, *Scolytus intricatus* Ratzeburg, other Scolytinae, *Lymantria dispar* L., Tortricidae on oaks, Geometridae on oaks, Diprionidae on pines, *Pristiphora abietina* Christ, *Coleophora laricella* Hubner, beetles of Melolontha, other leaf-eating insects, *Dreyphusia nordmannianae* Eckstein, Adelgidae on *Picea* spp. and *Larix* spp., other sucking insects, *Hylobius abietis* L., Curculionidae, larvae of Buprestidae, larvae of *Melolontha*, *Gryllotalpa gryllotalpa* L., other root pests, needle cast, powdery mildew, rusts, diseases of leaves and needles, cankers and bark necrosis, tracheomycosis, *Armillaria* sp., *Heterobasidion annosum* s.l. (Fr.) Bref., wood rots, damping-off of seedlings, other fungal diseases, tree bark peeling by game, bitten off by game, rodents, nematodes, weeds, other biotic damages,
– 6 in the group of anthropogenic agents: imissions, fire, a wood stealing, grazing of domestic animals, damages by pesticides, other anthropogenic agents.

The analysis below considers 8 years out of 10 years by the set of 71 pest agents. In the last 2 years, 53 pest agents are considered. All 53 pest agents also occurred in the set of 71 pest agents.

The salvage felling is the felling of wood that was damaged by pest agents. Wood volume of salvage felling mentioned in the analysis means the processed volume of wood. In the statistical reports foresters have to estimate the volume of salvage felling named as the estimated salvage felling. The estimated wood volume of salvage felling can be processed in the same year or in the following year. In order to avoid the duplicity of the wood volume of the estimated salvage felling from one year into the following year, only the processed salvage felling was considered.

The proportion of salvage felling was calculated as the absolute volume of salvage felling divided by the total felling volume in a certain year and multiplied by 100 (to express it as a percentage). The proportion of salvage felling serves as a mean to compare the annual salvage felling among years.

However, salvage felling is not the same as disturbances. Disturbances are mostly quantified with predicted volume of wood damaged by a major natural event, while salvage felling is given as a volume of annually processed wood damaged by pest agents and stated in the statistical report at the end of the year. Information on disturbances come from a different source of a consultancy service for foresters provided by the National Forest Centre - Forest Research Institute Zvolen, settled at the Department of Forest Protection and Game Management. The service has been active since 1959, when it was called the Control and Prognostic Service. In 1962, it changed its name to the Laboratory of Forest Protection Control, and in 1994 it was renamed to the Forest Protection Service (Kunca et al. 2014b). Specialists on biotic, abiotic and anthropogenic agents have been involved in national and international research projects and the knowledge and experiences obtained in the research have been passed to foresters. If a major disturbance damaged a larger forest area, foresters have been obliged to send that information to both the state administration and to the Forest Protection Service specialists. Foresters have to report the pest agents, the damaged volume, the damaged area and the main damaged trees species. This information is just the early estimation of salvage felling. That is the main source of data about the sudden natural disturbances such as wind-throw (Kunca et al. 2014b).

The data in the analyses were processed with simple statistical methods of Microsoft Excel. The variation of the three major groups of pest agents over 10 years was simplified by the linear trend function in Microsoft Excel. As there were only 10 years of the analysed input data, it was not appropriate to use other types of curve lines. Statistically significant differences of averages were evaluated by one-factorial ANOVA analysis in the STATISTICA program at 5% level of the significance ($p < 0.05$)

3. Results

3.1. Salvage felling

The current total wood volume stock in Slovak forests is 452 mil. m^3 (Anonymous 2011). Over the period of 10 years (2004–2013) the total felling reached 79.50 mil. m^3, i.e. 17.6% of the total wood volume stock. Total annual felling varied between 6.61 and 9.51 mil. m^3 with an annual average of 7.95 mil. m^3, i.e. 1.76% of the total wood volume stock (Table 1).

Table 1. Volume of total felling and salvage felling in Slovakia within the period 2004 – 2013.

Felling	Sum	Annual average	Standard deviation	Minimum	Maximum	Number of years
	[mil. m^3]					
Total felling	79.50	7.95	0.79	6.61	9.51	10
Salvage felling	42.31	4.23	1.08	2.67	6.27	10

Salvage felling reached 42.31 mil. m^3 over the period of 10 years, i.e. 53.2% of the total felling of that period (Table 1). The annual salvage felling varied between 2.67 and 6.27 mil. m^3, which was from 38.8% to 65.9% of the total annual felling (Fig. 1). The average annual salvage felling was 1.0% of the total wood volume stock.

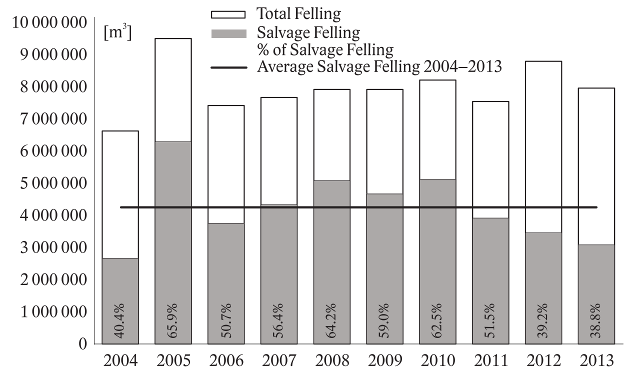

Fig. 1. Development of both total and salvage felling in Slovakia over the period 2004–2013.

3.2. Pest agents

The salvage felling was caused by the three major groups of pest agents. Abiotic and biotic pest agents were the most serious, followed by anthropogenic pest agents with the proportion of damaged wood of 48.6%, 48.5% and 2.9%, respectively. The greatest variation occurred within the anthropogenic pest agents, the smallest variation was in the group of total salvage felling (Table 2).

Table 2. Wood volume affected by major groups of pest agents in Slovak forests within the period 2004–2013.

Major group of pest agents	Sum	Average and statistical sign. ($p < 0.05$)	Standard deviation	Variation
	[mil. m^3]			[%]
Abiotic Pest Agents	21.32	2.13a	1.22	57.2
Biotic Pest Agents	21.23	2.12a	0.94	44.1
Anthropogenic Pest Agents	1.28	0.13b	0.08	60.4
Total	43.83	4.38	1.17	26.8

The anthropogenic and abiotic pest agents have clear decreasing linear trends, while the damages caused by the biotic pest agents have an increasing linear trend (Fig. 2).

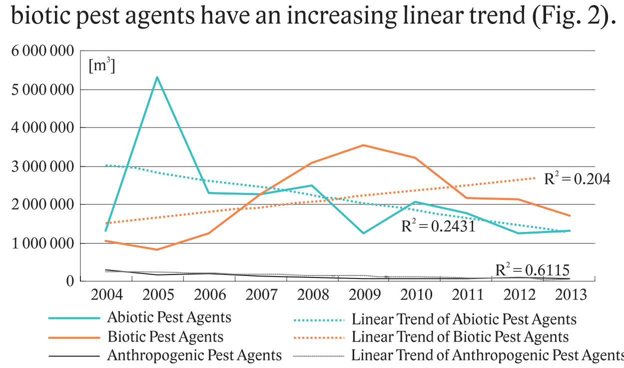

Fig. 2. Development of volume of processed wood from salvage felling caused by the three major groups of pest agents.

In every group of major pest agents (abiotic, biotic and anthropogenic) there was one pest agent that damaged more wood than the rest of pest agents in that group. From the abiotic pest agents it was wind, from the biotic pest agents it was *Ips typographus*, and imissions were the most damaging from the anthropogenic pest agents (Table 3–5). Wind was the most damaging agent from all pest agents evaluated within the last 10 years followed by *Ips typographus* (Table 6).

Table 3. Processed volume of wood from salvage felling due to selected abiotic pest agents in Slovak forests within the period 2004–2013.

Major group of pest agents	Sum	Average and statistical sign. (p < 0.05)	Standard deviation	Variation
		[mil. m^3]		[%]
Wind	18.47	1.85a	1.20	64.9
Snow	1.10	0.11b	0.13	120.2
Black Ice	0.05	0.005b	0.007	144.1
Rest of abiotic pest agents	1.70	0.17b	0.07	43.4

Table 4. Processed volume of wood from salvage felling due to selected biotic pest agents in Slovak forests within the period 2004 – 2013.

Major group of pest agents	Sum	Average and statistical sign. (p < 0.05)	Standard deviation	Variation
		[mil. m^3]		[%]
Ips typographus	16.37	1.64a	0.75	45.6
Armillaria spp.	2.18	0.22b	0.07	30.2
The rest of biotic pest agents	2.69	0.27b	0.31	114.4

Table 5. Processed volume of wood from salvage felling due to selected anthropogenic pest agents in Slovak forests within the period 2004–2013.

Major group of pest agents	Sum	Average and statistical sign. (p < 0.05)	Standard deviation	Variation
		[mil. m^3]		[%]
Imissions	1.10	0.11a	0.08	68.3
The rest of anthropogenic pest agents	0.18	0.02b	0.009	50.4

Table 6. The selected major pest agents in Slovak forests within the period 2004–2013.

Pest agents	Total volume of processed wood from salvage felling	
	[mil. m^3]	[%]
Wind	18.47	41.1
Ips typographus	16.37	37.3
Imissions	1.10	2.5
The rest of pest agents together	7.89	18.0
Total	43.83	100.0

The amount of wood of Norway spruce that was damaged by pest agents reached 35.6 mil. m^3 (81.2%), the rest belonged to European beech (3.3 mil. m^3 or 7.5%), pines (1.4 mil. m^3 or 3.2%), silver fir (1.2 mil. m^3 or 2.7%), oaks (0.7 mil. m^3 or 1.6%), and other forest tree species (1.63 mil. m^3 or 3.7%). As Norway spruce is spread over the mountainous regions of Central and Northern Slovakia, these regions are most affected by pest agents (Fig. 3 and Fig. 4).

3.3. Major disturbances

There were four heavy windstorms (one in 2004, two in 2007 and one in 2010), one heavy snowfall (in 2006), and a serious long-term European spruce bark beetle outbreak which accelerated after the large-scale windstorm in 2004 with the gradation in 2009. There was a major honey fungus calamity with high levels of damage from 2004 to 2011. These seven major disturbances damaged together 26.3 mil. m^3 (Table 7), i.e. 60.0% of the total wood volume of salvage felling, or 33.1% of the total felling. Windstorm disturbances damaged 7.2 mil. m^3, i.e. 27.4% of disturbances (Table 7) or 16.4% of wood volume of salvage felling (Table 2).

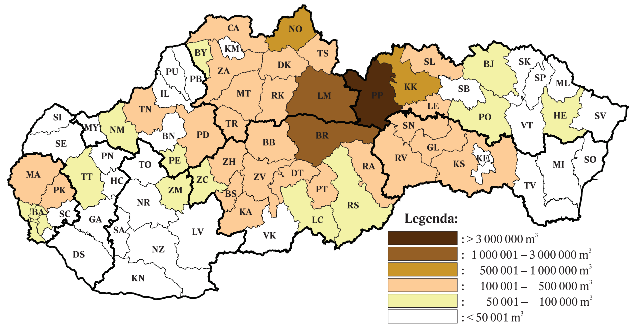

Fig. 3. Distribution of wood volume processed in the salvage felling caused by wind over 10 years period from 2004 to 2013.

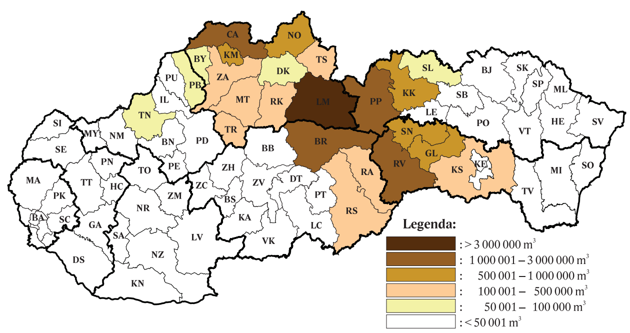

Fig. 4. Distribution of wood volume processed in the salvage felling caused by *Ips typographus* over 10 years period from 2004 to 2013.

It is clear that there were also smaller disturbance events with 40.0% proportion on wood volume of salvage felling, but they were not big enough to be mentioned separately.

Table 7. Summary of major disturbances in Slovakia from 2004 to 2013.

Type of disturbance (date of its occurrence)	Estimated disturbance volume [mil. m^3]	Most damaged tree species (its proportion on total calamity volume)	Affected region in Slovakia
Windstorm "Alžbeta" (November 19, 2004)	5.3	*Picea abies* (90%)	from North-Central to South-Central
Snowfall "Tamara" (January 2006)	0.5	*Picea abies* (87%)	Northern
Windstorm "Kiryll" (January 18 to19, 2007)	0.4	*Picea abies* (90%)	Central
Windstorm "Filip" (August 23 to 24, 2007)	1.0	*Picea abies* (60%)	South-Central
Windstorm „Gizela" (May 17 – 19, 2010)	0.5	*Fagus sylvatica* (80%)	South-Western
Ips typographus (from 2004 to 2013)	16.4*	*Picea abies* (100%)	North and Central
Armillaria spp. (from 2004 to 2013)	2.2*	*Picea abies* (90%)	West-Northern
Total	26.3	—	—

* Processed (not estimated) wood volume in the salvage felling.

Ips typographus was the most important disturbing pest agent as it damaged 62.4% of the wood affected by disturbances. The windstorm was the second most important disturbing pest agent (27.4%). The remaining 2 major disturbing agents damaged 10.2% of the wood affected by disturbances. Norway spruce was the most affected tree species by major disturbing pest agents (93.3%), and most of these disturbances occurred in Central and Northern Slovakia.

4. Discussion

Wood volume of salvage felling belongs to indicators of forest health in some countries (Grodzki et al. 2015; Knížek et al. 2015; Kunca 2015). This kind of felling is also known as sanitary or sanitation felling and is initiated by disturbances that could be caused by three main groups of abiotic, biotic and anthropogenic agents (Schelhaas et al. 2003; Spiecker 2003). Obviously, many pest agents could be included in these groups. In Slovakia, there are presently 53 monitored pest agents, in Poland (Grodzki et al. 2015) 109 pest agents are monitored (5 abiotic pest agents, 102 biotic pest agents, 2 anthropogenic agents), and in the Czech republic (Knížek et al. 2015) 16 pest agents are monitored (5 abiotic pest agents, 10 biotic pest agents, and 1 anthropogenic pest agent). Because of the same geographical region that is by Schelhaas et al. (2003) "Central Pannonic Ecological Zone", the number and the variability of the presently monitored pest agents should be critically reviewed.

According to the presented analysis, there was 1 significantly more important pest agent in every major group of pest agents (wind, *Ips typographus* and imissions) in Slovakia, the rest did not play a big role in damaging the forests within the 10 years period. It does not mean that the rest of the pest agents should be monitored as one cumulative group of "other pest agents", but maybe the list of the pest agents could be shortened and more harmonised within the European regions by natural conditions (Schelhaas et al. 2003; Spiecker 2003; Zúbrik et al. 2013).

The short term analysis of pest agents in Slovakia pointed out that a group of abiotic pest agents was the most important factor influencing volume of salvage felling. Moreover, from the point of the specific pest agents, the wind was the factor that damaged the largest amount of wood (Table 6). Similarly, wind affected the largest proportion of wood volume of salvage felling in many Central European countries, as well as in other parts of Europe for the several last decades (Schelhaas et al. 2003; Spiecker 2003; Zach et al. 2008; Grodzki 2010; Zach et al. 2010; Grodzki et al. 2015; Knížek et al. 2015).

The proportion of salvage felling from total felling in Slovakia ranged between 38.8% and 65.9%, with an average of 53.2%. The volume of salvage felling in the neighbouring mountainous countries of the Central Pannonic Ecological Zone was also quite variable and high. Knížek et al. (2015) stated that in the Czech Republic the average volume of salvage felling within the analysed 10 years period was 41%, and varied between 20% (in 2012) and 75% (in 2007).

Schelhaas et al. (2003) stated that major disturbances in the European region reached 8.1% over the years 1950–2000. If we selected only our major disturbances (Table 7), their proportion on total felling was 33.1%, which is 4.1 times more than the European long term annual average of disturbances.

In spite of the high proportion of salvage felling or major disturbances on the total felling in Slovakia, previous major disturbances at the European level did not affect Slovakia. The windstorm Vivian in 1990 damaged 120 mil. m^3 in the Western Europe (König et al. 1995). At the end of 1999 there were three windstorms (Anatol, Lothar and Martin) that damaged 180 mil. m^3 of wood in the forests of different European regions (Sacre 2002). One of the biggest windstorms in Europe occurred on January 8, 2005 in southern Sweden and Denmark and on January 9, 2005 in Estonia. It is known as Gudrun and only in southern Sweden it damaged 75 mil. m^3 of wood (Schlyter et al. 2006; Langström et al. 2009). None of them reached Slovakia except for the windstorm Kyrill in 2007, which was considered a minor windstorm disturbance in Slovakia with only 0.4 mil. m^3 of damaged wood. However, in the Western Europe it damaged 55 mil. m^3, predominantly in Germany and the Czech Republic (Kunca et al. 2014a). The directions of low pressure paths and storm damages in the European region are demonstrated on maps by Gardiner et al. (2008, 2011); at the regional level of Slovakia wind directions are described by Konôpka et al. (2008).

Schelhaas et al. (2003) stated that windstorms represent 53% of disturbances in Europe, while in Slovakia it was just 27.4%, i.e. a half of the European average. That results from the very high proportion of the second most important pest agent in Slovakia, the European spruce bark beetle that damaged 62.4% of wood affected by disturbances. It has been long well-known that European spruce bark beetle is the secondary pest agent and often follows wind-throws and last decades driven also by climate change (Christiansen & Bakke 1988; Pfeffer & Skuhravy 1995; Blennow & Olofsson 2008; Gardiner et al. 2008; Grodzki et al. 2010; Marini et al., 2013; Mezei et al. 2014; Sproull et al. 2015). Moreover, there are several examples that bark beetles following wind, fire, drought or snow were more dangerous pests than previous primary agents (Christiansen & Bakke 1988; Kunca et al. 2011; Nikolov et al. 2014). Catastrophic bark beetle outbreaks after windstorms occurred in the Czech Republic in the Šumava Mountains after the windstorms of 1868 and 1870 (Pfeffer & Skuhravy 1995), in Sweden in 1969 (Nilsson et al. 2004) or recently in Sweden in 2005 or 2007 (Langström et al. 2009), in Lithuania (Zolubas & Dagilius 2009) or in Far East Russia (Soukhovolsky 2009; Tarasova 2009). The windstorm Alžbeta from November 19, 2004 in Slovakia can be added to that list of examples. When Windstorm Alžbeta in 2004 damaged 5.3 mil. m^3 (Koreň 2005; Kunca 2005; Kunca & Zúbrik 2006); the broken and uprooted trees were not completely processed by the beginning of the growing season 2005. The Slovak law prevented that kind of management of damaged wood, so secondary pest agents, mainly European spruce bark beetle, started to multiply their population abundance (Kunca et al. 2011; Nikolov et al. 2014). The attractive wood material for bark beetles was later replaced by newly damaged wood from the Snowfall Tamara in 2006 and Windstorms Kyrill and Filip in 2007. The European spruce bark beetle outbreak was predicted by researchers (Zúbrik et al. 2005, 2006) but those alerts were not accepted by the environmental state administrations as an argument for applying the management of damaged and surrounding forests. It was the nature protection which determined the forest management that finally resulted in the large-scale European spruce bark beetle outbreak in the natural, semi natural and artificial monocultures of Norway spruce. This is just another example how difficult it is to harmonise the management of natural resources with regard to their functions, climate change scenarios and scientific knowledge about it (Spiecker 2003). The global climate change concept expects the occurrence of weather extremes that will limit the life in the regions. Hence, drought is also supposed to be one of the most important stress factors influencing forests (Hlásny et al. 2014; Pešková et al. 2015). However, forests in Central Europe have resisted drought quite well. So far, there is no information on large-scale salvage felling due to drought stress.

The structure of forest pest agents is determined by several factors, one of them is forest tree species composition. The greatest proportion of damaged wood volume in Slovakia was ascribed to Norway spruce. The national ecological survey (Anonymous 2011) reports that Norway spruce originally grew on 4.9% of forest land instead of the present 25.5%. Out of this, 20.6% (412 th. ha) of Norway spruce has grown at unsuitable sites due to which they are highly predisposed to any pest agents. That is very clear that Norway spruce pest agents are more active than pest agents of other forest tree species with much lower proportion growing at unsuitable sites (Anonymous 2011). The artificial spread of Norway spruce in the Slovak territory, as well as in other Central European countries, is a heritage from 19th and 20th century. At that time, planting of forest trees was a state program, and Norway spruce stands provided wood of very valuable quality, although on the account of their ecological stability, which was not well known at that time. Anyway, since Norway spruce is still economically extremely important tree species under European conditions, it will be sustained in a reasonable proportion in a temperate zone over long term. However, this species must be managed with special attention to its specific threats; ergo implementing forest protection measures mitigating wind and bark beetle risks (Kunca et al. 2007; Konôpka & Konôpka 2008).

5. Conclusions

Wind and European spruce bark beetle were the most important pest agents in Slovakia within the decade 2004–2013. It was evaluated by the volume of salvage felling that was caused by forest harmful agents. The recent dramatic increase of forest damage caused by bark beetles relates to large-scale wind-break disasters after which wood was not soon enough processed (due to restrictions of forest management in protected areas). In general, Norway spruce is the most affected forest tree species. It is likely that Norway spruce proportion in Slovakia, as well as in Central European countries will decrease in the future due to climate change and nature protection preferences. Recently, at the damaged localities of Slovakia new forests have been established prevailingly with regard to suitable ecological conditions for trees, climate change scenarios, and where possible, natural regeneration has been preferred. These approaches of forest stand regeneration together with silvicultural and protection measures would gradually decrease the volume of salvage felling in long-term perspective (see for instance Konôpka & Konôpka 2011; Vakula et al. 2015).

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