Fire risk insurance model for forest stands growing in the area of Slovak Paradise

Jan Holecy[1], Jaroslav Skvarenina[1], Jan Tucek[1] & Jozef Mindas[2]

[1]Technical University of Zvolen, Masarykova 24, 960 53 Zvolen, Slovakia
Phone: +421/48-5206 318, Fax: +421/48-5332 654,
e-mail: holecy@vsld.tuzvo.sk, jarosk@vsld.tuzvo.sk, tucek@vsld.tuzvo.sk
[2]Forest Research Institute, Masarykova 22, 960 92 Zvolen, Slovakia
Phone: +421/48-5314 206,
e-mail: mindas@fris.sk

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Abstract

The submitted paper presents the proposal of the forest property fire insurance model based on the results of the statistical analysis of the forest fire occurence in the territory of the Slovak Paradise National Park during the period of years 1991-2000. The description of fire vulnerability concerning particular tree-species groups according to the age of forest stands was carried about using the Weibull probability distribution W(c; γ).The insurance model consists of 2 components. The first component presents the net insurance premium for 1 ha of a forest stand belonging to the particular age class. The second component informs about the risk premium necessary for an insurance company to avoid the situation that it would not be able to pay off the all expected insurance claims completely. Presented gross insurance premiums inform about prices for the insurance of 1 ha of forest stand according to its age for the period of 1 year. The model has been experimentally tested at the policy rating concerning particular tree-species insurance in relation to the scale of areas insured.

Introduction

The fire risk insurance of forest property belongs among the most imoportant tools how to dare the financial consequences of a forest fire occurence. The territory of the Slovak Paradise National Park with its wildland – urban interface (W-UI) area represents one of the most fire endangered regions in Slovakia. The interest of forest owners for the fire insurance of their property was not very high even in the recent past. The main reason of neglecting the financial aftermaths of the fire occurence in the Slovak forestry were the direct subsidies provided by the government to all forest owners as a compensation, when forest fire had occurred. But, the situation has already changed, at present. As the state budget becomes more and more limited year by year, these subsidies are not available at the scale as they used to be. So, many forest owners have realized that to insure their property under conditions when forest fire often occures, is the only way how to maintain the woodland management sustainable and financially stable. In this sense, a well developed system of the regular fire insurance is needed.

The objective of this paper is to propose the forest property fire risk insurance model that would meet all necessary requirements for efficient fire insurance of forests within the W-UI of the Slovak Paradise.

Statistical analysis of burnability concerning particular tree-species

As the basic measures of the burnability observed at particular tree-species were used the point estimates of the mean annual fire occurence rates ($\hat{p}$):

$$\hat{p} = \frac{\sum h_i}{\sum H_i} \; ; \qquad \sum h_i = h \quad \text{and} \quad \sum H_i = H \tag{1}$$

where:

(h_i) is the area of the particular tree-species destroyed by fire during the (i-th) year

(H_i) is the total observed area of the particular tree-species within the experimental area during the (i-th) year

These fire occurence rates were mutually compared and tested whether their differences are significant or not by the following null hypothesis (H_0):

$$H_0 : \hat{p}_1 - \hat{p}_2 = 0 \tag{2}$$

At these tests we used the (z) test statistic as proposed by Triola (1989) and also by Klein at al. (1997):

$$z = \frac{(\hat{p}_1 - \hat{p}_2)}{\sqrt{\frac{\hat{p}_1(1-\hat{p}_1)}{H_1} + \frac{\hat{p}_2(1-\hat{p}_2)}{H_2}}} \tag{3}$$

The null hypothesis (H_0) was rejected at the significance level of (α) when ($z > z_\alpha$). Symbol (z_α) denotes the critical value of the standard normal distribution N(0;1). The significance level of (α = 0.05) these tests was used. According to the results of this testing procedure the following 5 groups of tree-species were distinguished as presented in TABLE 1.

TABLE 1:Particular groups of tree-species with the same annual fire occurrence rates (p}

Numbers of gropups	**Groups of particular tree-species**	**Total observed areas**	**Total destroyed areas**	**Fire occurrence rates**
		(ha)	(ha)	(p)
1.	Pine	21295,7010	29,3281	0,001377186
2.	Spruce	106028,2990	83,5258	0,000787769
3.	Larch	12572,0470	7,9200	0,000629969
4.	Fir	16204,7570	5,6986	0,000351664
5.	Broadleaved	51673,6420	13,8583	0,000268189
TOTAL		207774,4460	140,3309	0,000675400

The observed data pointed out the obviously higher fire occurence rates at the younger forest stands than the older ones.
The obtained empirical distribution functions describing the observed destruction of the forest stands by fire at particular tree-species in relation to their age were modelled using the Weibull probability distribution W (c; γ) with the given probability distribution function F (t):

$$F(t) = 1 - e^{-ct^{\gamma}} \qquad (4)$$

where (t) denotes the age of a forest stand.
The parameters (c) and (γ) related to the assumed distribution W (c; γ) were estimated from each of the analyzed empirical distribution functions using the method of quartiles, as proposed by Kouba (1997, 2002), developed by Kouba and Kasparova (1989) and applied also by von Gadow (2000). This procedure was used due to the fact, that the Kolmogorav-Smirnov test had pointed out the very significant goodness of fit ($\alpha = 0.05$) between the empirical and the corresponding a ssumed Weibull probability distribution functions describing the destruction of forest by fire in relation to its age, at all analysed tree-species. The vulnerability of forest stands by fire in relation to their age was then estimated by probabilities p (t) calculated by using the relation:

$$\frac{p(t)}{u} = \frac{\Delta F(t).h}{H}, \quad \text{it means that} \qquad (5)$$

$$p\ (t) = u\ .\ \Delta\ F\ (t)\ .\ \hat{p} \qquad (6)$$

where:
is the number of assumed age classes at particular tree-species (1 age class spans the period of 10 years)
Δ F (t) is the expected increment of the Weibull probability distribution function F (t) corresponding to the increment of (Δ t) = 10 years

The obtained probabilities of p (t) inform about the expected destruction of a (t) years old forest stand during a common year. They refer to the possibility how to calculate the expected loss in terms of forest land management risk as presented by Hanewinkel (2002), Hanewinkel and Oesten (1998) and by Sisak and Pulkrab (2001). Also van Wagner (1979) proposed the very similar approach.

Valuation of forest stands for purposes of insurance

The value of forest property in the territory of the Slovak Paradise belongs among the essential inputs of the proposed fire insurance model. The valuation of forest stands for the purposes of insurance was carried out by using the officially stated prices of standing timber in Slovakia. The forest stands expectation values were taken from the Governmental Decree no. 465/1991 also presented by Tutka et al. (1992) for the mean yield classes and the modal stocking of particular tree-species growing in the area of Slovak Paradise. All these values correspond to the mean hauling distance that in the experimental territory approaches about 1 km. The values of forest stands concerning particular tree-species obtained by this procedure are presented in TABLE 2 and TABLE 3.

TABLE 2: Values of the fully stocked pine, spruce and larch stands V(t) and their values reduced by a modal stocking

Age	PINE Yield class 24 Mod.stocking 0,76		SPRUCE Yield class 29 Mod.stocking 0,77		LARCH Yield class 26 Mod.stocking 0,765	
(t)	Value V(t)	Value H(t)	Value V(t)	Value H(t)	Value V(t)	Value H(t)
years	(€ * ha^{-1})	(€ * ha^{-1})	(€ * ha^{-1})	(€ * ha^{-1})	(€ * ha^{-1})	(€ * ha^{-1})
10	1112,80	845,72	1004,74	773,65	2687,14	2055,66
20	1135,04	862,63	1052,41	810,36	2748,15	2102,34
30	1222,31	928,96	1265,10	974,12	3016,87	2307,90
40	1477,29	1122,74	1669,68	1285,65	3679,85	2815,09
50	1792,16	1362,04	2152,50	1657,42	4470,74	3420,11
60	2104,09	1599,11	2645,09	2036,72	5240,50	4008,98
70	2403,80	1826,89	3659,61	2817,90	5979,76	4574,52
80	2685,18	2040,74	5253,51	4045,20	6663,86	5097,86
90	2942,36	2236,19	6786,29	5225,44	7397,25	5658,90
100	3270,42	2485,52	8242,07	6346,39	8526,08	6522,45
110	3868,14	2939,78	9633,06	7417,46	10391,83	7949,75
120	4453,87	3384,94	10928,71	8415,11	12109,71	9263,93
130	5098,27	3874,69	12146,14	9352,53	13760,72	10526,95
140	5720,19	4347,34	13302,45	10242,89	15365,96	11754,96
150	6309,10	4794,92	14387,86	11078,66	16883,20	12915,64
160	6875,76	5225,58	15401,16	11858,90	18334,72	14026,06
170	6875,76	5225,58	15401,16	11858,90	18334,72	14026,06
180	6875,76	5225,58	15401,16	11858,90	18334,72	14026,06

Close this chapter

TABLE 3: Values of the fully stocked fir, oak and beech stands V(t) and their values reduced by a modal stocking H(t)

Age	FIR Yield class 26 Mod.stocking 0,73		OAK Yield class 22 Mod.stocking 0,78		BEECH Yield class 24 Mod.stocking 0,79	
(t)	Value V(t)	Value H(t)	Value V(t)	Value H(t)	Value V(t)	Value H(t)
years	(€ * ha^{-1})	(€ * ha^{-1})	(€ * ha^{-1})	(€ * ha^{-1})	(€ * ha^{-1})	(€ * ha^{-1})
10	937,27	684,21	1396,62	1089,36	1060,97	838,17
20	969,54	707,76	1484,38	1157,82	1161,20	917,35
30	1114,26	813,41	1691,93	1319,70	1525,45	1205,10
40	1479,00	1079,67	2126,58	1658,73	2058,38	1626,12
50	1951,79	1424,81	2555,86	1993,57	2640,20	2085,76
60	2450,01	1788,51	2966,07	2313,53	3212,24	2537,67
70	3093,65	2258,37	3348,16	2611,57	3752,51	2964,48
80	4512,79	3294,33	3706,30	2890,92	4713,25	3723,46
90	6096,91	4450,74	4032,66	3145,47	6363,37	5027,06
100	7605,24	5551,83	4329,68	3377,15	7817,92	6176,16
110	9070,06	6621,15	4626,95	3609,02	9028,02	7132,13
120	10445,41	7625,15	5123,70	3996,48	9991,20	7893,05
130	11734,22	8565,98	5954,38	4644,42	10697,70	8451,18
140	12978,54	9474,33	6732,75	5251,55	11135,29	8796,88
150	14138,76	10321,29	7483,01	5836,75	11335,75	8955,24
160	15236,88	11122,93	8185,60	6384,77	11159,73	8816,19
170	15236,88	11122,93	8185,60	6384,77	11159,73	8816,19
180	15236,88	11122,93	8185,60	6384,77	11159,73	8816,19

Formulation of the fire insurance model

Similary as the most of non-life insurance model also the proposed fire risk insurance for forest stands takes in account the two fllowing kinds of risk:

1. The risk of a forest owner informing about the expected loss induced by the forest fire occurrence in the area of 1 ha during a common year [€ . ha^{-1} . $year^{-1}$].
2. The risk of an insurer informing about his expected loss in relation to the scale of the total insured area of forest.

This fire risk insurance model is the enhanced version of the simplier model described by Holecy (2000 b).
Thus, in this sense, our proposed insurance model consists of these essential components:

$$G_m (t) = N(t) + R_m (t) \qquad (5)$$

where:
G_m (t) is the gross insurance premium (€ . ha^{-1} . $year^{-1}$) for 1 ha of (t) years old forest stand
N(t) refers to the net insurance premium for 1 ha of (t) years old forest stand (€ . ha^{-1} . $year^{-1}$)
R_m(t) refers to the risk premium (€ . ha^{-1} . year⁻s¹) dependent on the total insured area of (m) ha.

The model regards the revealed higher risk of the forest destruction in younger forest stands already mentioned by Martell (1980). The net premiums N(t) were calculated as the products of values with the obtained destruction probabilities p(t):

$$N(t) = H(t) . p(t) \quad (6)$$

where V(t) are expected values of the (t) years old forest stands presented in TABLES 2 and 3.

The risk premiums $R_m(t)$ were calculated using the standard error of insurance (S_m) as the measure of risk concerning an insurance in the following way:

$$R_m(t) = H(t) . u . \Delta F(t) . s_m . z_\alpha \quad (7)$$

where:
H(t) is the modal expected value of the forest stands (t) years old (€ . ha^{-1})
z_α is the score of the standard normal distribution that refers to the reliability (1- α).

The standard error of insurance (s_m) was calculated as follows:

$$s_m = \sqrt{\frac{\hat{p}(1-\hat{p})}{m}} \quad (8)$$

The value of (α) = 0.05 at all these calculations was used.

Results

The application of the proposed insurance nodel brought results shown in TABLES 4,5,6,7,8 and 9. Due to the lack of space, the corresponding risk premiums R_m (t) are not presented here, in the paper. But their values can be obtained simply by the subtracting the values of net premiums N(t) from coresponding values of $G_m(t)$ at each particular tree-species.

However, the presented gross insurance premiums $G_m(t)$ do not include overheads expenses of an insurance company.

TABLE 4: : Gross premiums $G_m(t)_{0,95}$ for insuring 1 ha of pine stands according to the scale of (m) insured ha

PINE	Net premiums	Gross premiums $G_m(t)_{0,95}$ at the scale of (m) ha insured			
Years	N(t)	m = 18	m = 180	m = 1 800	m = 18 000
(t)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)
10	4,26	52,21	19,42	9,05	5,77
20	2,95	35,99	13,40	6,26	4,00
30	2,48	29,82	11,13	5,22	3,35
40	2,42	28,59	10,69	5,03	3,24
50	2,40	27,98	10,49	4,96	3,21
60	2,33	26,77	10,06	4,78	3,11
70	2,23	25,12	9,47	4,52	2,95
80	2,09	23,19	8,76	4,20	2,75
90	1,93	21,09	7,99	3,84	2,53
100	1,81	19,54	7,42	3,59	2,38
110	1,82	19,32	7,36	3,57	2,38
120	1,79	18,65	7,12	3,48	2,32
130	1,75	17,95	6,87	3,37	2,26
140	1,68	16,97	6,51	3,21	2,16
150	1,59	15,80	6,08	3,01	2,04
160	1,49	14,57	5,62	2,79	1,90
170	1,28	12,34	4,78	2,39	1,63
180	1,10	10,47	4,07	2,04	1,40

TABLE 5: Gross premiums Gm(t)0,95 for insuring 1 ha of spruce stands according to the scale of (m) insured ha

SPRUCE	Net premiums	Gross premiums $G_m(t)_{0,95}$ at the scale of (m) ha insured			
Years	N(t)	m = 18	m = 180	m = 1 800	m = 18 000
(t)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)
10	2,40	38,35	13,76	5,99	3,53
20	1,62	28,20	10,03	4,28	2,46
30	1,49	28,32	9,98	4,17	2,34
40	1,56	30,25	10,63	4,43	2,47
50	1,64	31,26	11,01	4,60	2,57
60	1,65	30,99	10,93	4,59	2,58
70	1,90	30,01	10,78	4,71	2,78
80	2,27	31,40	11,48	5,19	3,20
90	2,47	35,06	12,77	5,73	3,50
100	2,53	35,84	13,07	5,86	3,58
110	2,51	34,62	12,66	5,72	3,52
120	2,42	32,17	11,83	5,39	3,36
130	2,29	29,03	10,75	4,97	3,14
140	2,15	25,56	9,55	4,49	2,89
150	1,99	22,07	8,34	4,00	2,63
160	1,83	18,52	7,11	3,50	2,36
170	1,58	15,69	6,04	2,99	2,02
180	1,36	13,32	5,14	2,55	1,74

Close this chapter

TABLE 6: Gross premiums $G_m(t)_{0,95}$ for insuring 1 ha of larch stands according to the scale of (m) insured ha

LARCH	Net premiums	Gross premiums $G_m(t)_{0,95}$ at the scale of (m) ha insured			
Years	N(t)	m = 18	m = 180	m = 1 800	m = 18 000
(t)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)
10	1,31	117,87	38,17	12,97	5,00
20	1,25	81,76	26,71	9,30	3,80
30	1,25	69,16	22,72	8,04	3,39
40	1,37	67,01	22,13	7,93	3,45
50	1,50	65,72	21,80	7,92	3,53
60	1,57	62,84	20,95	7,70	3,51
70	1,61	58,94	19,74	7,34	3,42
80	1,60	54,31	18,27	6,87	3,27
90	1,59	50,08	16,93	6,44	3,13
100	1,64	48,14	16,34	6,29	3,11
110	1,78	49,10	16,75	6,51	3,28
120	1,85	48,01	16,45	6,47	3,31
130	1,88	45,90	15,80	6,28	3,27
140	1,87	43,21	14,94	6,00	3,18
150	1,83	40,12	13,94	5,66	3,04
160	1,77	36,88	12,87	5,28	2,88
170	1,58	31,27	10,96	4,54	2,51
180	1,40	26,55	9,35	3,92	2,20

TABLE 7: Gross premiums $G_m(t)_{0,95}$ for insuring 1 ha of fir stands according to the scale of (m) insured ha

FIR	Net premiums	Gross premiums $G_m(t)_{0,95}$ at the scale of (m) ha insured			
Years	N(t)	m = 18	m = 180	m = 1 800	m = 18 000
(t)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)
10	0,44	20,05	6,64	0,06	1,06
20	0,42	14,12	4,75	0,04	0,85
30	0,44	12,54	4,27	0,04	0,82
40	0,53	13,25	4,55	0,04	0,93
50	0,62	14,15	4,90	0,05	1,05
60	0,70	14,52	5,07	0,05	1,14
70	0,79	15,10	5,32	0,05	1,25
80	1,04	18,26	6,48	0,07	1,58
90	1,25	20,53	7,35	0,08	1,86
100	1,39	21,41	7,72	0,08	2,03
110	1,48	21,41	7,79	0,09	2,11
120	1,53	20,73	7,60	0,08	2,13
130	1,53	19,64	7,25	0,08	2,10
140	1,51	18,35	6,83	0,08	2,04
150	1,46	16,93	6,35	0,07	1,95
160	1,40	15,48	5,85	0,07	1,85
170	1,25	13,15	5,01	0,06	1,63
180	1,11	11,19	4,30	0,05	1,43

TABLE 8: Gross premiums $G_m(t)_{0,95}$ for insuring 1 ha of oak stands according to the scale of (m) insured ha

OAK	Net premiums	Gross premiums $G_m(t)_{0,95}$ at the scale of (m) ha insured			
Years	N(t)	m = 18	m = 180	m = 1 800	m = 18 000
(t)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)
10	1,15	28,42	9,78	3,88	2,01
20	0,83	20,40	7,02	2,78	1,45
30	0,72	17,87	6,15	2,44	1,27
40	0,72	17,80	6,12	2,43	1,26
50	0,70	17,23	5,92	2,35	1,22
60	0,66	16,27	5,60	2,22	1,15
70	0,61	15,06	5,18	2,06	1,07
80	0,56	13,75	4,73	1,88	0,97
90	0,50	12,40	4,27	1,69	0,88
100	0,45	11,08	3,81	1,51	0,79
110	0,40	9,88	3,40	1,35	0,70
120	0,37	9,16	3,15	1,25	0,65
130	0,36	8,94	3,07	1,22	0,63
140	0,34	8,50	2,92	1,16	0,60
150	0,32	7,96	2,74	1,09	0,56
160	0,30	7,35	2,53	1,00	0,52
170	0,25	6,22	2,14	0,85	0,44
180	0,21	5,27	1,81	0,72	0,37

TABLE 9: Gross premiums $G_m(t)_{0,95}$ for insuring 1 ha of beech stands according to the scale of (m) insured ha

BEECH	Net premiums	Gross premiums $G_m(t)_{0,95}$ at the scale of (m) ha insured			
Years	N(t)	m = 18	m = 180	m = 1 800	m = 18 000
(t)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)	(€ * ha^{-1} * $year^{-1}$)
10	0,89	21,87	7,52	2,98	1,55
20	0,66	16,17	5,56	2,21	1,15
30	0,66	16,32	5,61	2,23	1,16
40	0,71	17,45	6,00	2,38	1,24
50	0,73	18,02	6,20	2,46	1,28
60	0,72	17,85	6,14	2,44	1,26
70	0,69	17,10	5,88	2,33	1,21
80	0,72	17,72	6,09	2,42	1,26
90	0,80	19,82	6,82	2,71	1,41
100	0,82	20,26	6,97	2,77	1,44
110	0,79	19,53	6,72	2,67	1,38
120	0,73	18,10	6,22	2,47	1,28
130	0,66	16,26	5,59	2,22	1,15
140	0,58	14,24	4,90	1,94	1,01
150	0,50	12,22	4,20	1,67	0,87
160	0,41	10,15	3,49	1,39	0,72
170	0,35	8,59	2,95	1,17	0,61
180	0,29	7,27	2,50	0,99	0,52

Conclusions

The brand-new forest property fire insurance model was proposed and experimentally evaluated on the example of the W-UI belonging to the area of the Slovak Paradise National Park. The obtained results point out that the amounts of the gross premiums $G_m(t)$ are about 3 times lower, if the scales of the insured areas (m) increase 10 times. To decrease the mentioned gross premiums and make them acceptable for the most of forest owners, the insurance company should enlarge the insured areas of the all forest stands of assumed tree-species as much as possible.

References

Gadow, K.v.2000. Evaluating risk in forest planning models. Silva Fennica vol. 34(2): 181-191.

Hanewinkel, M. 2002. Comparative economic investigations of even-aged and uneven aged silvicultural systems: a critical analysis of different methods. Forestry, vol 75(4): 473-481.

Hanewinkel, M.- Oesten, G. 1998. Ökonomischer Modellvergleich risikobeinflusster Alterklassen und Plenterwald betriebsklassen. All. Forstz. Wald 53:427–430.

Holecy, J. 2000 a. Preliminary results of the analysis concerning forest fire occurrence in Slovakia. pp. 117–127. In Proc. 4th International Scientific Conference „Wood & Fire Safety“, May 14–19, 2000, High Tatras, Strbske Pleso, Technical University of Zvolen, Slovakia, 395 pp.

Holecy, J. 2000 b. Forest property fire insurance problem in Slovakia and its solution by methods of elementary statistics. pp. 53-60. In Proc. Int. conf. on „Development Trends of Processes Management in Wood Processing Industry and in Forestry“ June 21–23, 2000, Zvolen, Technical University of Zvolen, Slovakia. 313 p.

Klein, T. – Bahyl, V. – Vacek, V. 1997. Basics of Probability and Mathematical Statistics. Publishing House of the Technical University of Zvolen, Zvolen. 224 p. (in Slovak).

Kouba, J. 2002. Das Leben des Waldes und seine Lebensunsicherheit (Forest Life and its Temporal Uncertainty) German Journal of Forest Science. vol. 121:211–228.

Kouba, J. – Kasparova, I. 1989. Steuerungs theorie des Ausgleichs prozesses zum Normal Wald auf Grund der Stochastischen Processe. Res. Report, Czech. Agriultural University. Prague, Czech Republic. 64 pp.

Kouba, J. 1977. Markov chains and modelling the long – term development of the age structure and production of forests. Proposal of a new theory of the normal forest. Scientia Agriculturae Bohemslovaca, vol. 26(3):179-193.

Martell, D.L. 1980. The optimal rotation of a flammable forest stand. Can. J. For. Res. 10:30-34.

Sisak, L. – Pulkrab, K. 2001. Damaging factors and their influence on forestry in the Czech Republic. pp. 125-132. In Proc. IUFRO Division 4 Conference ”The Economics of Natural Hazards in Forestry“, June 7-10, 2001, Solsona, Catalonia, Spain, Padua University Press, Italy. 164 pp.

Tutka, J. – Hladik, M. – Durkovic, J. – Linderova, R. 1992. Forest valuation. (Ocenovanie lesov). Zvolen, The Institute for Education and Training of Employees in Forestry and Water Management. (in Slovak) 215 pp.

Triola, M.F. 1989. Elementary statistics. 4th ed. Redwood City, California, Benjamin Cummings Publishing Company. 784 pp.

Van Wagner, C.E. 1978. Age class distribution and the forest fire cycle. Can. J. For. Res. 8:220-227.