FOREST FIRE WEATHER INDICES DURING TWO LARGEST FOREST FIRE EVENTS IN THE SLOVAK PARADISE NATIONAL PARK

APLIKÁCIA POVETERNOSTNÝCH INDEXOV LESNÝCH POŽIAROV V NÁRODNOM PARKU SLOVENSKÝ RAJ

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Abstract
Paper gives the analysis of the two largest forest fire events in the W-UI of Slovak Paradise National Park (July 1976 and October 2000). There are analysed the geological, soil and topographical conditions of the fire occurrence, here. Thoroughly were evaluated the meteorological factors influencing the ignition and propagation of the fire occurrence (air temperature, relative humidity, wind speed). Three forest fire weather indices were calculated (Baumgartner, Angstrőm and Nesterov indices). As the most sensitive measure of the fire occurence risk forecasting seems to be the Angstrőm index.

Introduction

The climate, topography and vegetation (forest types) are considered to be the key factors accounting for fuel load and its flammability and for evaluating fire potential in the forest. In mountains, topography determines both vertical (zonal) climatic changes as elevation changes and a great variety of site climates as slopes change. Zonal and site climates in turn cause corresponding vertical vegetation zones and forest types. Fuel load is determined by vegetation structure (forest type) and climate.

Within a given fuel type, fire behavior is regulated largely by the state of the weather. Meteorological factors play a key role in affecting wildfire occurrence and behaviour. Weather variables are often combined in specific meteorological fire danger indices, that provide estimations of fire danger level at a given time. Weather variables are often combined in specific meteorological fire danger indices, that provide estimations of fire danger level at a given time. A number of indices have been developed so far, and many of them are currently applied in operational conditions. Some indices are more suited to rate the probability of fire occurrence, while others are also related to the conditions for fire spreading; the fire danger concept refers to both the fire occurrence probability and the expected fire severity (Bovio and Camia 1997).

The fuel flammability is evaluated by using the weather indices like the Nesterov index widely used in Russia, or the Baumgartner and M 68 Index in Germany. A fire-danger rating system, the Angstrom index, was devised in Sweden and has been used all over Scandinavia (Langholz and Schmidtmayer 1993). The occurrence of the great forest fire events in Slovakia has been documented only by the values of meteorological elements (air temperature, relative humidity, precipitation wind speed etc.), so far. There have not been calculated any specific meteorological fire danger indices, here yet. Weather national fire danger rating system still has been in the stage of preparation only.

The paper is focused on the analysis of the natural and meteorological conditions during these two largest forest fire events in the Slovak Paradise National Park:

- The first fire occured at the Kysel Rift in the morning on July 17th to July 22th 1976. The forest of 29.22 ha was completely burned out.
- The second fire occured recently on October 23th, to November 7th 2000 as the consequence of incinerating rests of timber after its extraction by forest workers, at the place called Tri Kopce (Three Hills). Area of 64 ha belonging to the unique natural forest was completely destroyed. This event required the lives of 6 forest workers.

Analysis of the natural conditions

The territory of the Slovak Paradise is characterized by the low precipitation totals (570 – 650 mm per year) due to the rain shadow of the Tatra Mts, in which is the whole area situated. The geological ground of wild-land area mainly consists of limestone and partly of dolomite. The karst relief together with the mentioned subterranean caves and rifts act as a good drainage of the whole terrain and serve as the excellent air-conditions promoting the propagation of fire, if it occures. Rendzinas which have developed as the main types of soil here, are rocky and very shallow. These types of soil are not able to keep larger amounts of water. Due to its properties, soil here quickly gets rid of any water and dries soon after rain. During a dangerous summer or drought periods, this soil contains very small amount of water. The continual cover of dense grass is represented by plant communities consisting of rather higher and very combustible species. Natural forests growing on steep slopes and rocky ridges consist of the “relict” pine and pine – larch stands with the spruce and the beech at bottoms of numerous rifts and valleys. Due to the lack of soil water, the coniferous litter here is very difficult to disintegrate and so represents the highly flammable stock of fuel. Extraordinary dangerous from the fire propagation point of view are young pine and spruce stands (up to 20 years of age). They contain a lot of dry branches that are growing very closely to the land surface that is often covered by grass.

There are several reasons why is the all W-UI territory of the Slovak Paradise National Park susceptible to burn and so strongly vulnerable from the forest fire occurence point of view.

- Shallow soils on steep slopes of limestone and karst fields which are often dry especially during the vegetation period.
- Mostly coniferous natural uneven aged fully stocked forest stands which can act (under favourable conditions) as the excellent medium of fire propagation.

- Nearly inaccessible terrain due to the lack of convenient road network, which makes extinguishing works extremely difficult.
- Rain shadow of the High Tatras Mountains influencing mostly northern part of the park.

Analysis of meteorological conditions

This analysis was carried out using the daily fire weather data, recorded at the meteorological station Poprad – airport (695 m a.s.l.). These data enabled to track the development of fire danger conditions in the region of Slovak Paradise National Park from the beginnings of the 1976 and 2000 fire seasons.

For the evaluation of the mentioned two largest fire events the following 3 indices were used:

German Baumgartner Index (BI):

$$BI = P - PE \text{ (sum of 5 days)}$$

Where:
P- precipitation (mm)
PE – potential evapotranspiration (mm)
The system is divided into the following fire danger classes as follows:

Fire danger classes/ Month	1	2	3	4	5
	(mm)				
March	+ 5 >	+ 5 to - 3	- 3 to - 9	- 9 to - 15	- 15 <
April	+ 3 >	+ 3 to - 8	- 8 to - 16	- 16 to -27	- 27 <
May	- 3 >	- 3 to - 16	- 16 to - 25	- 25 to - 35	- 35 <
June	- 12 >	- 12 to - 24	- 24 to - 32	- 32 to - 41	- 41 <
July	- 12 >	- 12 to - 24	- 24 to - 31	- 31 to - 40	- 40 <
August	- 8 >	- 8 to - 20	- 20 to - 28	- 28 to - 37	- 37 <
September	- 6 >	- 6 to - 18	- 18 to - 26	- 26 to - 35	- 35 <
October	- 6 >	- 6 to - 18	- 18 to - 26	- 26 to - 35	- 35 <

Nesterov ignition index (N), Russian fire-rating system, there was devised in the former Soviet Union in 1949 and is calculated as follows:

$$N = \sum_{i=1}^{W} (t_1 - D_i) \times t_i$$

Where:
N -Nesterov Index
W - number of days since the last rainfall > 3mm

t - temperature (°C)
D - dew point temperature (°C)

Its computation begins on the first spring day when the height of temperature is above freezing after the snow melting and continues until the rainfall of 3 mm.

Five different fire danger classes are used depending on the value of the index (Shetinsky1994):

1) N<300 no fire risk,
2) 301<N<1 000 low risk,
3) 1 001<N<4 000 medium risk,
4) 4 001<N<10 000 high risk,
5) N>10 000 extremely high risk

Angstrőm index (I): was devised in Sweden and has been used all over the Scandinavia. The index, **I**, is given by:

$$I = \left(\frac{R}{20}\right) + \left(\frac{27 - T}{10}\right)$$

Where:
R - relative humidity (%)
T - air temperature (°C)

The values for I translate into fire danger as follows:

1) I > 4.0 fire occurrence unlikely
2) 4.0 < I < 3.0 fire conditions unfavourable
3) 3.0 < I < 2.5 fire conditions favourable
4) 2.5 < I < 2.0 fire conditions more favourable
5) I < 2.0 fire occurrence very likely

Results concerning the mutual comparison of weather indices

The information value of the presented indices concerning the classification of the weather suitability to the fire occurrence is, however, limited in the intensively managed agricultural areas. Usually, forest fire does not occure even during the periods of extreme drought unless the influence of human element.

During the vegetation period of **1976,** there was the dry weather with a deficit of precipitation. The meteorological situation before this fire event: Southern anticyclonic situation, warm, dry weather (30 °C), southern hot wind (6-8 m/s), climate water balance deficit –42 mm of water. Figure 1 shows the curse of meteorological measures: precipitation, temperature, relative humidity, wind speed from the 1st April till the 31st

August 1976. Figure 2 depicts the course of the all 3 applied indices the date of the beginning and the duration of fire at the locality of Kysel, as well.

The second fire event that took place in the year **2000** started in the not typical season of the year, on the 22nd of October. This event was preceded by the extremely dry and warm vegetation period and the autumn with the long – lasting deficit of precipitation. Meteorological situation before fire event: Southeastern anticyclonic situation, warm, dry weather (26 °C) southern dry wind (5-7 m/s). Climate water balance deficit –12 mm of water. Figure 3 depict the course of meteorological measures: precipitation, temperature, relative humidity, wind speed from the 1st August till the 31st November 2000. Figure 4 presents the course of the all 3 applied indices, the date and the duration of fire at the locality of Tri Kopce, as well.

The comparison of terms concerning the beginnings of both these fire events with the meteorological data points out the fact that both these events are connected with the decline of the relative humidity beneath 40 % (Figure 1 and Figure 3). Wittich (1998) explains this phenomenon by the very close correlation between the content of water in litter and values of the relative air humidity.

Both these fire events are essentially related to the high values of the meteorological fire danger indices. For the better comparison of the mentioned indices Table 1 and Table 2 present both the absolute and the relative frequencies of fire danger classes. The analysis shows the different inertias and sensibilities of particular indices. For example, the Angstrőm index shows quick time fluctuations, while the Baumgartner index shows the undisturbed course with the moderate inertia. The Nesterov index and partly also the Baumgartner index only seldom approach the highest fire danger levels (class 5). During the summer season (July 1976), the Russian-continental Nesterov index preliminary seems to be the less sensitive indicator of the fire danger levels under conditions of the low humid-temperate climate of the Slovak Paradise National Park. Inspite of this fact, the Nesterov index in comparison with the German Baumgartner index, has approached the higher fire danger levels during the dry continental weather in October 2000.

Table 1: The absolute values (abs.) and relative frequencies (rel.%) of particular fire danger classes concerning meteorological fire indices for the period from the 1st April till the 31st August, 1976.

1976										
fire danger classes/ index	1		2		3		4		5	
	abs.	rel.%	abs.	rel.%	abs.	rel.%	abs.	rel.%	abs.	rel.%
Baumgartner	55	37	49	33	22	15	22	15	1	1
Nesterov	37	24	40	26	57	37	19	13	0	0
Angstrőm	42	28	42	28	28	18	28	18	13	8

Table 2: The absolute values (abs.) and relative frequencies (rel.%) of particular fire danger classes concerning meteorological fire indices for the period from the 1st August till the 31st November, 2000.

2000										
fire danger classes/ index	1		2		3		4		5	
	abs.	rel.%	abs.	rel.%	abs.	rel.%	abs.	rel.%	abs.	rel.%
Baumgartner	54	44	41	34	19	16	8	7	0	0
Nesterov	32	26	18	15	26	21	39	32	7	6
Angstrőm	53	43	36	30	12	10	9	7	12	10

Conclusions

The submitted analysis includes only the periods of the two largest forest fire events in the territory of the Slovak Paradise National Park. We are aware, that only a more detailed evaluation of the all other recorded historical forest fire events and corresponding meteorological data can provide the more exact results and consequences for the choice of the most suitable weather fire index for the forest fire danger forecast within the W-UI of the Slovak Paradise National Park. According to the presented preliminary results, as the most efficient seems to be the future combined use of the index based on the water balance (Baumgartner index) and the index that includes also measure of the relative air humidity (Angstrőm index).

Acknowledgement

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Figure 1: Air temperature, relative humidity, wind speed and precipitation totals for the period from the 1st April till the 31st August, 1976 (Fire Kysel Rift)

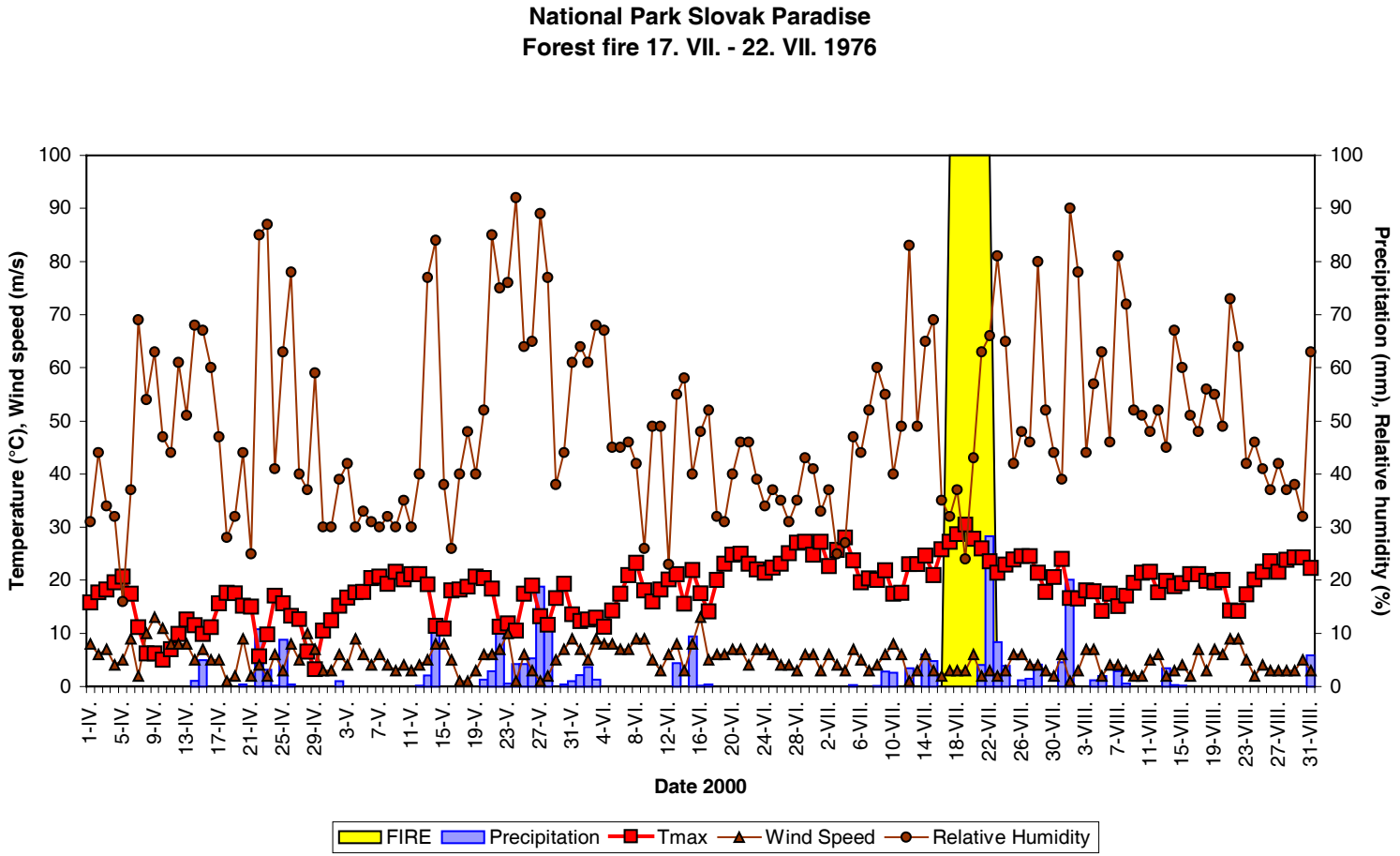

Figure 2: The comparison concerning the performance of the Baumgartner, Angstrőm and Nesterov indices for the period from the 1st April till the 31st August, 1976 (Fire Kysel Rift)

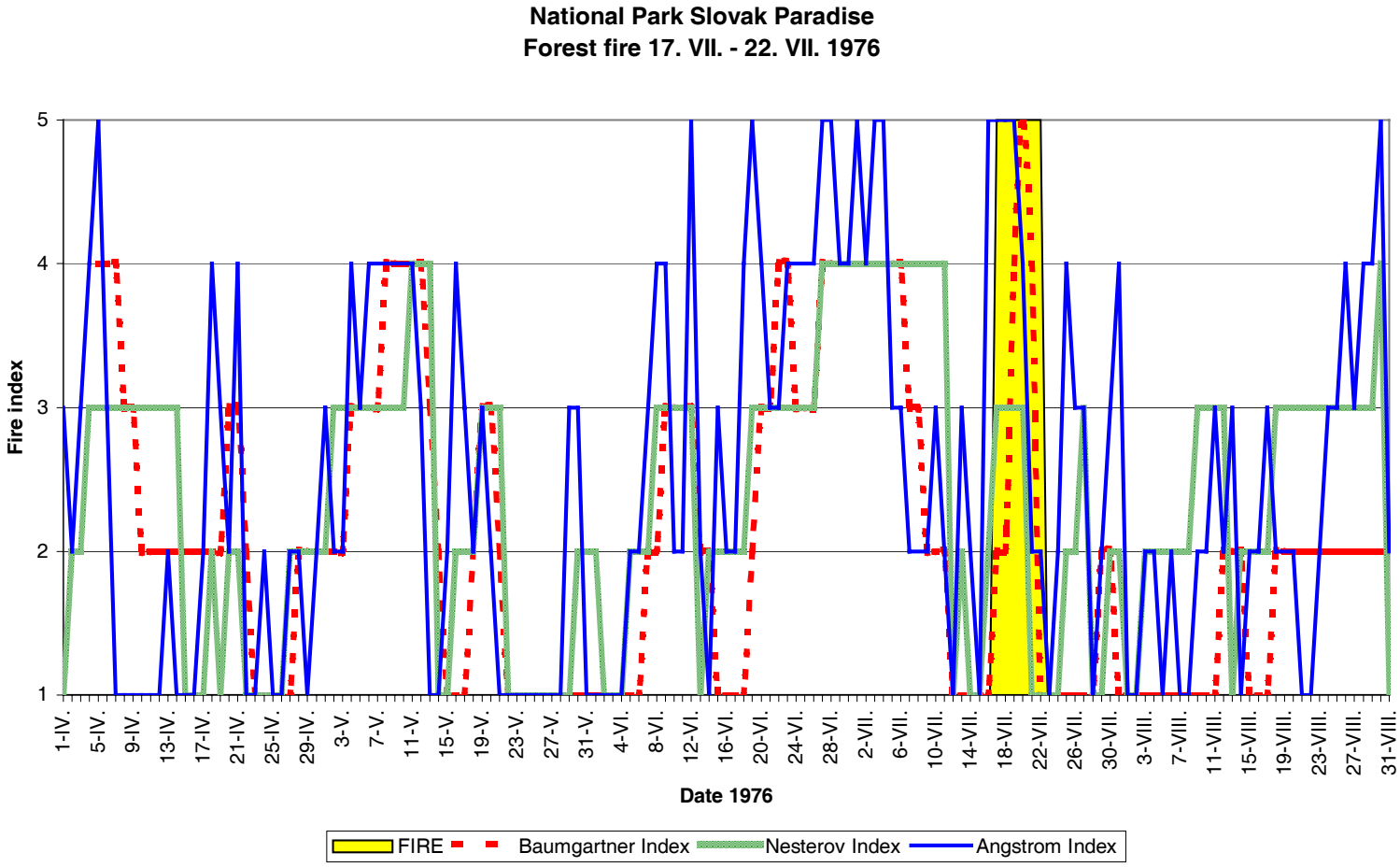

Figure 3: Air temperature, relative humidity, wind speed and precipitation totals for the period from the 1st August till the 31st November, 2000 (Fire Three Hills).

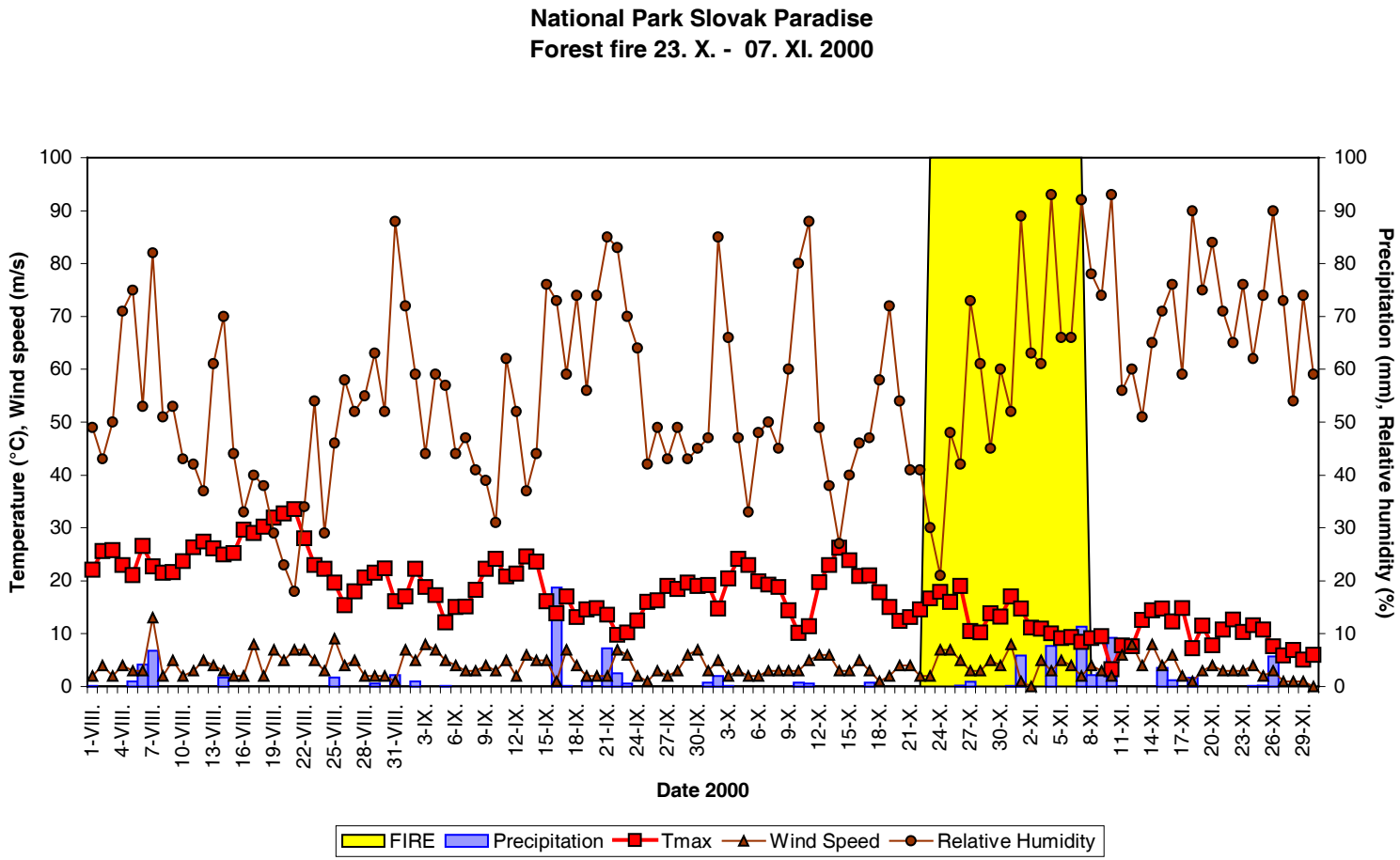

Figure 4: The comparison concerning the performance of the Baumgartner, Angstrőm and Nesterov indices for the period from the 1st August till the 31st November, 2000 (Fire Three Hills).