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COMPARISON OF ANGSTROM FIRE INDEX FOR TBILISI (GEORGIA) AND KISLOVODSK (RUSSIA)

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Summary: *The results of a statistical analysis of the daily and mean monthly values of Angstrom Fire Index (AFI) for Tbilisi (Georgia) and Kislovodsk (Russian Federation) in the period 2011-2020 are presented. AFI = (R/20) + (27-T)/10, where R is the minimum relative humidity, T is the maximum air temperature. The gradations of the values of AFI are as follows*: *I. AFI ≥ 4.1 – Low, II. AFI = 4.0 ÷ 3.0 - Moderate, III. AFI = 2.9 ÷ 2.5 - High, IY. AFI = 2.4 ÷ 2.0 - Very High, Y. AFI = <2.0 - Extreme. In particular, it was found that a extreme fire hazard in Tbilisi is observed on average within 70 days a year and in Kislovodsk - within 42 days a year. Between the daily and monthly mean values of AFI in Tbilisi and Kislovodsk direct linear correlation is observed.*

Key Words: *Angstrom Fire Index, temperature, fire.*

Introduction

As you know, the problem of fires, including forest fires, is relevant for many countries of the world. [http://www.sasquatchstation.com/Fire_Weather.php; http://www.forestservice.gr/meteo/fwi1.html]. This problem is also important for Russia and Georgia, where forest fires are frequent [1-4].

In the last few decades, this problem has become even more urgent in connection with global and local climate warming [5,6], which affects the increase in fire hazard [7].

In different countries of the world, different indicators of forest fire hazard are used [1-4, 7-10]. These indices are mathematical formulas that formalize the influence of air temperature and humidity, atmospheric precipitation, forest fuel moisture, thunderstorm activity, etc. Along with climatological and operational information on the levels of forest fire hazard, their short-term and long-term forecast is carried out [1-4, 11].

In Georgia the works regarding the forests fire index hazard based on the example to Tbilisi began in 2019 year [2]. Analogous studies were continued for Telavi and Nalchik cities [3,4]. In these cases was used simple Swedish Angstrom Index [8,9] with four-range scale [http://www.forestservice.gr/meteo/fwi1.html].

This work is a continuation of previous research. The results of a statistical analysis of the daily values of Angstrom Fire Index (AFI) for Tbilisi (the capital of Georgia, large city with a population of over a million people) and Kislovodsk (Russian Federation, resort town with a population around 130 thousand people) with used of five-range scale [http://www.sasquatchstation.com/Fire_Weather.php] in the period 2011-2020 are presented below.

Study area, material and methods

Study area is Tbilisi and Kislovodsk cities. Data of the about daily maximum of air temperature T and minimum relative humidity R in the period 2011-2020 are used [http://www.pogodaiklimat.ru/archive.php?id=ru&region=07]. The Swedish Angstrom Index calculated from the formula: AFI = (R/20) + (27-T)/10 [8,9]. The gradations of the values of AFI are as follows [http://www.sasquatchstation.com/Fire_Weather.php]: I. AFI ≥ 4.1 – Low, II. AFI = 4.0 ÷ 3.0 - Moderate, III. AFI = 2.9 ÷ 2.5 - High, IY. AFI = 2.4 ÷ 2.0 - Very High, Y. AFI = <2.0 - Extreme.

The standard statistical methods are used. The following designations will be used below: Min – minimal values; Max - maximal values; St Dev - standard deviation; C_v - coefficient of variation (%); σ_m – standard error; 99%(+/-) - 99% upper and lower levels of the confidence interval of average; R – coefficient of linear correlation; α - the level of significance; a and b – linear regression equation coefficients.

Results and discussion

Results in table 1, 2 and fig. 1-4 are presented.

Table 1. Statistical characteristics of daily values of Angstrom Fire Index in Tbilisi and Kislovodsk for different months in 2011-2020.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Param	**Tbilisi**											
Min	2.9	1.5	1.0	1.0	0.9	0.1	-0.2	-0.2	0.3	1.0	1.4	1.6
Max	7.2	7.1	7.3	6.1	6.2	4.8	4.4	4.4	5.3	6.9	7.1	7.3
Mean	4.8	4.7	3.9	3.4	2.8	2.1	1.8	1.8	2.5	3.5	4.4	5.0
St Dev	0.91	1.06	1.00	1.09	0.94	0.86	0.83	0.87	0.89	1.07	1.05	0.85
Cv,%	18.7	22.7	25.5	32.3	33.3	41.4	45.8	49.5	36.1	30.6	23.5	17.1
σm	0.05	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.05
99%(+/-)	0.13	0.16	0.15	0.16	0.14	0.13	0.12	0.13	0.13	0.16	0.15	0.12
	Kislovodsk											
Min	2.1	1.4	0.8	0.4	0.6	0.8	0.2	0.4	0.5	0.3	1.1	1.6
Max	7.4	7.2	7.3	6.7	5.8	5.9	5.6	5.7	6.0	7.0	7.5	7.3
Mean	5.0	4.5	4.1	3.4	3.4	3.1	2.9	2.6	3.0	3.5	4.2	4.5
St Dev	1.30	1.46	1.54	1.42	1.07	0.87	0.86	0.92	1.16	1.51	1.53	1.41
Cv,%	26.1	32.5	37.2	42.2	31.2	28.7	30.1	35.8	38.9	43.5	36.4	31.0
σm	0.07	0.09	0.09	0.08	0.06	0.05	0.05	0.05	0.07	0.09	0.09	0.08
99%(+/-)	0.19	0.22	0.22	0.21	0.16	0.13	0.13	0.13	0.17	0.22	0.23	0.21
	The values of the correlation coefficient (**R**) and the coefficients of the linear regression equation between the AFI values in Tbilisi and Kislovodsk. (**AIF_Kisl=a·AFI_Tb + b)**											
R	0.40	0.47	0.44	0.56	0.54	0.53	0.51	0.43	0.41	0.60	0.50	0.37
a	0.5675	0.6503	0.6793	0.7364	0.6109	0.5381	0.5357	0.4589	0.5294	0.8417	0.733	0.614
b	2.2272	1.4643	1.4611	0.8892	1.6996	1.9341	1.8917	1.7744	1.6751	0.5212	0.949	1.4757

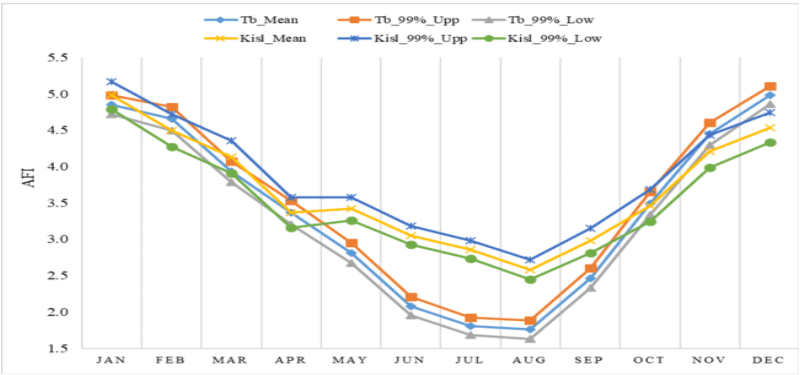

Fig. 1. The intraannual diatributions of mean monthly values of AFI in Tbilisi and Kislovodsk in 2011-2020.

In table 1 and fig. 1 the statistical characteristics of daily and mean monthly values of Angstrom Fire Index in Tbilisi and Kislovodsk for different months in 2011-2020 is presented. In particular, as follows from table 1 in Tbilisi values of AFI changes from -0.2 (July and August, fire occurrence is extreme) to 7.3 (March and December, fire occurrence is low). The greatest variations in the values of AFI are observed during August (C_v = 49.5%), smallest - in December (C_v = 17.1%). The mean monthly values of Angstrom Fire Index (table 1, fig. 1) changes from 1.8 (July and August, fire occurrence is extreme) to 5.0 (December, fire occurrence is low).

In Kislovodsk daily values of AFI changes from 0.2 (July, fire occurrence is extreme) to 7.5 (November, fire occurrence is low). The greatest variations in the values of AFI are observed during October (C_v = 43.5 %), smallest - in January (C_v = 26.1%). The mean monthly values of Angstrom Fire Index changes from 2.6 (August, fire occurrence very is high) to 5.0 (January, fire occurrence is low).

Coefficient of linear correlation between daily values of AIF in Tbilisi and Kislovodsk (table 1) changes from 0.37 (December) to 0.60 (October) – $\alpha < 0.05$. In table 1 the coefficients of the linear regression equation between the daily AFI values in Tbilisi and Kislovodsk (AIF_Kisl=a·AFI_Tb + b**)** are presented also.

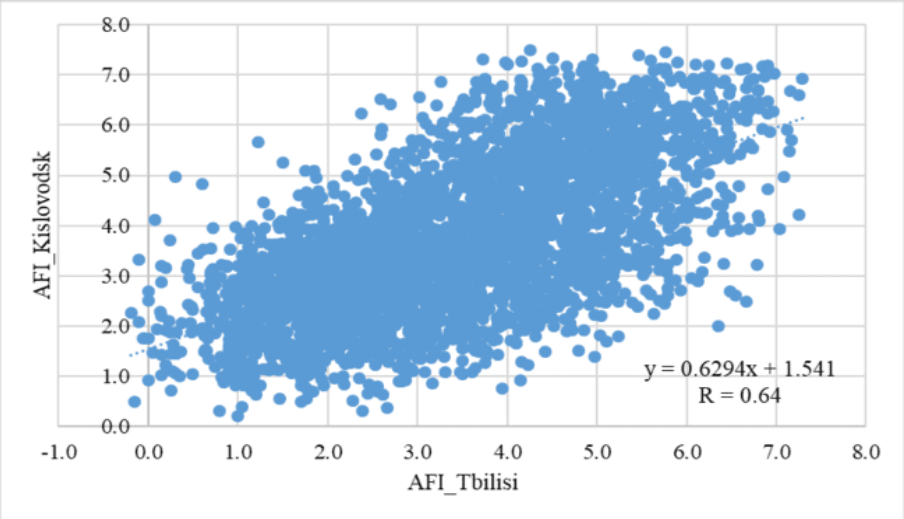

Fig. 2. Linear correlation and regression between daily values of AIF in Tbilisi and Kislovodsk (full data).

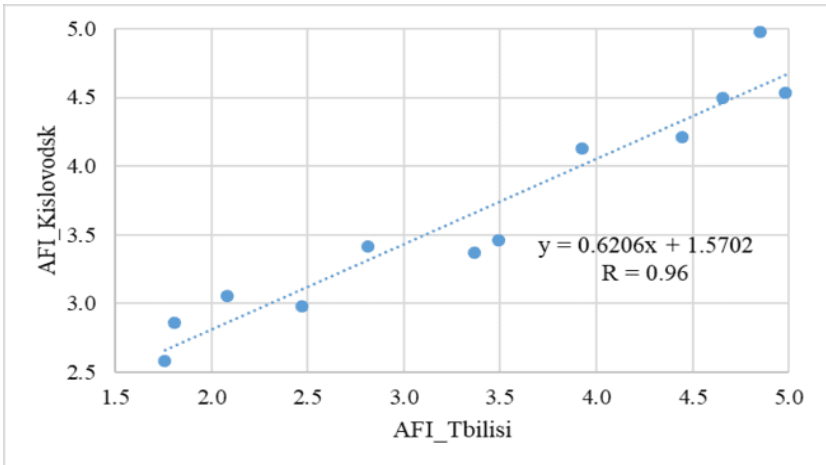

Fig.3. Linear correlation and regression between mean monthly values of AFI in Tbilisi and Kislovodsk.

In fig. 2 and 3 for examples of linear correlation and regression between daily and mean monthly values of AIF in Tbilisi and Kislovodsk are presented.

Table 2. Repetition of AFI in Tbilisi and Kislovodsk in different months for five gradations in 2011-2020.

Location	Tbilisi					Kislovodsk				
AFI	**≥ 4.1**	**4.0 – 3.0**	**2.9 – 2.5**	**2.4 – 2.0**	**< 2.0**	**≥ 4.1**	**4.0 – 3.0**	**2.9 – 2.5**	**2.4 – 2.0**	**< 2.0**
Jan	80.3	19.0	0.6	0.0	0.0	71.3	22.3	5.8	0.6	0.0
Feb	70.7	25.1	2.8	1.1	0.4	61.5	20.1	9.9	5.3	3.2
Mar	44.5	40.3	8.7	4.8	1.6	52.6	22.3	9.0	6.8	9.4
Apr	25.3	36.3	16.7	14.0	7.7	30.3	21.7	16.3	15.7	16.0
May	11.0	29.0	22.9	18.4	18.7	27.4	41.9	10.0	10.6	10.0
Jun	2.3	13.7	16.3	24.0	43.7	13.0	42.0	20.0	14.0	11.0
Jul	1.3	7.1	11.6	20.6	59.4	8.4	38.7	23.2	16.5	13.2
Aug	1.6	8.1	10.0	18.1	62.3	7.4	24.5	20.6	20.0	27.4
Sep	5.7	18.7	23.3	22.7	29.7	17.3	32.7	17.3	13.0	19.7
Oct	27.7	36.5	21.9	10.0	3.9	36.5	21.9	12.6	10.6	18.4
Nov	62.0	32.3	3.3	1.7	0.7	54.7	21.0	6.7	9.7	8.0
Dec	89.4	9.4	0.3	0.6	0.3	59.7	24.5	9.7	3.9	2.3

In table 2 data about repetition of AFI in Tbilisi and Kislovodsk in different months for five gradations is presented. As follows from table 2 on average in Tbilisi in the majority of the cases extreme fire hazard from June to September is observed (repetition are 43.7, 59.4, 62.3% and 29.7 % respectively). In January the values of AFI<2.0 is not observed. From November through March in the majority of the cases fire hazard is low (repetition of AFI> 4.1 changes from 44.5% for March to 89.4% for December).

In Kislovodsk (table 2) on average in the majority of the cases extreme fire hazard in August is observed (repetition is 27.4%. In January, as in Tbilisi, the values of AFI<2.0 is not observed. From October through April in the majority of the cases fire hazard is low (repetition of AFI> 4.1 changes from 30.3 % for April to 71.3% for January).

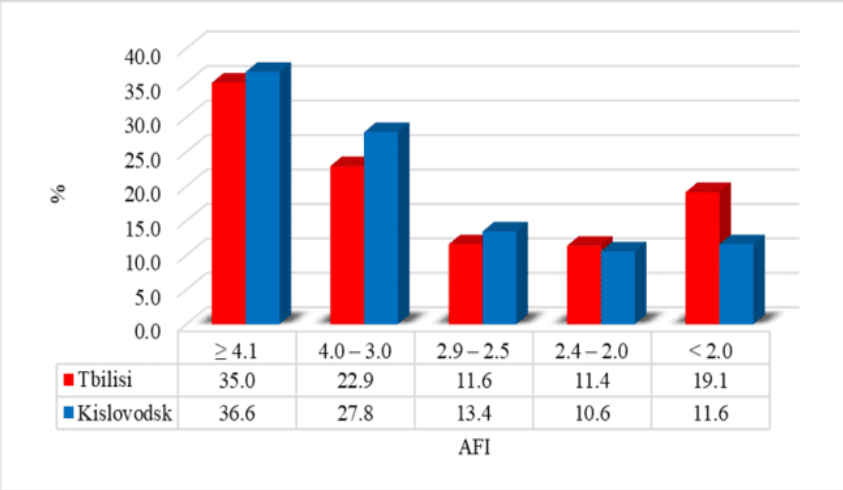

Fig. 4. Repetition of AFI in Tbilisi and Kislovodsk (full data).

An extreme fire hazard in Tbilisi (fig. 4) is observed on average within 70 days a year (repetition – 19.1 %), and very high - within 42 days a year (repetition – 11.4 %). In Kislovodsk an extreme fire hazard is observed on average within 42 days a year (repetition – 11.6 %), and very high - within 39 days a year (repetition – 10.6 %).

Thus, the level of the extreme and very high forests fire hazard under the conditions of Tbilisi is higher than under the conditions of Kislovodsk.

Conclusion

Further, it is planned to expand work on this issue (using other more complex fire hazard indices, studying their trends in connection with climate change, etc.).

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