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A Statistical Analysis of Sunshine Duration inDiyarbakir, Turkey

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Abstract- *In this study, it is aimed to find out the significant climate elements estimating the sunshine duration. Daily sunshine duration and climate elements such as cloudiness, relative humidty, wind speed, atmospheric pressure, evaporation, precipitation and air temperaure were provided from ground-based observation station of Turkish State Meteorological Service for long-term records. Sunshine duration andeach climate elementdata were arranged as seasonal and annual average values and analyzed statistically significant (p<0.5) using Pearson correlation analysis method. According to the results, pairwise relations were shown that climate elements were associated withsunshine duration. Relations were found commonly as moderate and good levels but in annual as weak levels.*
Keywords:*Sunshine duration, Climate elements, Pearson correlation analysis.*

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I. INTRODUCTION

Knowing of solar radiation at a given location is significant because of widely usage in many applications. Solar energy related to the quantity of sunshine duration is one of the renewable energy sources. The life on earth depends on the solar energy which is the most important energy source. Solar energy is essential for survivors because of being clean, environment friendly and great potential. The energy of solar radiation affects the physical formations in the atmosphere and earth. Furthermore, it is highly associated with sunshine duration via Angström-Prescott model predicting the amount of solar radiation. Sunshine duration measurements are reliable and available, so used in many applications such as agriculture, tourism, power plant planning etc. In many countries, sunshine duration has been measured in the ground-based stationsfor a long time. However, sunshine duration cannot be measured in some areas where remote and exist no station. In such a way, statistical methods can be employed to estimate the amount of sunshine duration using various climate elements. These elements can differ due to seasonal climatic variations and topography. According to the studies, sunshine duration was associated with cloudiness negatively [1-6]. Similarly, relative humidity has negative effects on sunshine duration [7-9]. Wind speed and atmospheric pressure, againist cloudiness and relative humidity, have positive effects on sunshine duration [2,9,10]. Precipitation influences sunshine duration negatively [8].

Additionally, air pollutant concentrations may affect on sunshine duration. A relation between sunshine duration and air pollutants was examined by Zateroglu [11]. Futhermore, latitude and atmospheric circulations influence the sunshine duration spatially [12].

Sunshine duration (SD), cloudiness (CLDN), wind speed (WSPD), relative humidity (RHUM), precipitation (PREC), atmospheric pressure (PRES), evaporation (EVAP), minimum air temperature (TMIN), maximum air temperature (TMAX) were used and analyzed via statistical methods.

The aim of this study is to evaluate the statistically significantcorrelations between the sunshine duration and other climate variables mentioned above in Diyarbakir.

II. STUDY AREA and DATA

The data of Diyarbakir (latitude 37.897, longitude 40.203, altitude 674m) extending over the period 1960-2008 was provided from the Turkish State Meteorological Service. The sunshine duration datawas taken from heliograph (Campbell-Stokes sunshine recorder), cloudiness from visual observation, the relative humidity from hygrograph, the air temperature from dry-bulb thermometers, the wind speed from anemograph, the precipitation from pluviograph, evaporation from evaporation pool, the atmospheric pressure from barometer.

III. METHODS

Statistical approach was used to determine the relations between relative sunshine duration (RSD) and climate elements. RSD corresponds to S/S_o (between 0 and 1). S, represents the measured value.$S_o$determines the daylength (maximum sunshine duration) as shown in Eqn. (1). φis latitude angle ($-90 \leq \varphi \leq +90$) and depends on the location. Declination angle (δ)is estimated by Eqn.(3) and represents the angle which is between the equatorial plane and the incoming solar rays. n,determines the Julien number of days (between 1 and 365).

$$S_0 = \left(\frac{2}{15}\right) cos^{-1}(-tan\delta tan\varphi) \quad (1)$$

$$\delta = 0.409 * sin\left(\frac{2*\pi*n}{365} - 1.39\right) \quad (2)$$

Pearson correlation values of each dataset owing to the different terms were acquired to evaluate the grade of pairwise relations between the RSD and other climate variables. This value represents the direction and measure of the relation between pairwise variables. The quantity of coefficient may have negative (which means negative correlation and smaller than 0 and bigger than -1), or positive (which means positive correlation and smaller than 1 and bigger than 0) values. The Pearson correlation coefficient is computed by formula as shown in Eqn. (3).

$$r(x, y) = \frac{\overline{(x-\bar{x})(y-\bar{y})}}{\sigma_x \sigma_y} \quad (3)$$

where thetwo variables, x and y denote the measured values, $\bar{x}$ and$\bar{y}$determine the mean values of the measured values of variables,σ_x and $\sigma_y$express the standard deviations of x and y respectively.

To define the scale of the relation, Pearson correlation coeeficient can be categorized to three levels such as low for below 0.49, moderate for bigger than 0.49 and smaller than 0.7, high for bigger than 0.7 and smaller than 1.

The relations between RSD and the other climate datai.e. CLDN, RHUM, WSPD, EVAP, PREC, PRES, TMIN, TMAX provided from ground observation station during 1990-2008 were analyzed via Pearson correlation analysis methodby using SPSS software programme. As a result, the major climate elements related to the RSD were revealedas statistically significant.

IV. RESULTS AND DISCUSSION

Descriptive statistics for all climate elements such as SD, CLDN, RHUM, WSPD, PREC, EVAP, PRES, TMIN and TMAX were presented for seasonal and annual periods in Table 1-3.The Statistics such as minimum (Min), maximum (Max), mean (Mean) and standard deviation (Std. D.) values for each variable and term were expressed. The amounts of all values were changed according to different terms. For Table 1 and 2, SD has maximum values in summer whereas minimum values in winter, as expected. In contrary to SD, CLDN has minimum values in summer and maximum in winter. SD was associated with CLDN oppositely. RHUM has the highest value in winter and lowest value in summer. For WSPD, the higher values were seen in spring and summer than autumn and winter. PREC has big values in winter and spring and small values in autumn and summer. For EVAP, the data was not available in winter. But for the other periods, EVAP has maximum value in summer and minimum in spring. PRES values were seen as maximum in winter and autumn against in spring and summer. TMIN and TMAX have high values in summer and autumn whereas low values in spring and winter.

Table 1. Descriptive statistics for spring and summer

Term	Variable	Min	Max	Mean	Std. D.	Term	Variable	Min	Max	Mean	Std. D.
SPRING	SD	172,73	271,67	227,9316	22,03966	SUMMER	SD	343,63	397,77	375,1965	12,14574
	CLDN	3,17	6,27	4,706471	0,654751		CLDN	0,5	2,1	1,147451	0,318539
	RHUM	42,03	76,07	62,06776	7,816167		RHUM	16,43	48,5	30,41714	7,675529
	WSPD	0,23	3,4	2,154898	0,684724		WSPD	0,7	4,2	2,859388	0,829549
	PREC	14,37	133,77	59,22735	26,51534		PREC	0,05	33,1	5,477292	7,328089
	EVAP	85,1	253,3	145,0202	32,15387		EVAP	94,37	527	364,5496	67,29713
	PRES	932,93	938,47	935,6424	1,031449		PRES	926,47	931,5	929,3024	1,000203
	TMIN	-3,77	4,8	1,054286	1,948911		TMIN	12,6	17,73	14,95469	1,09841
	TMAX	23,8	32,97	27,20878	1,696223		TMAX	38,07	43,27	40,94143	1,058842

Table 2. Descriptive statistics for autumn and winter

Term	Variable	Min	Max	Mean	Std. D.	Term	Variable	Min	Max	Mean	Std. D.
AUTUMN	SD	201,2	273,9	232,4855	14,67465	WINTER	SD	89,7	188,17	124	21,44217
	CLDN	1,6	3,77	2,856667	0,48456		CLDN	3,67	7,03	5,610784	0,886207
	RHUM	33,5	66,57	50,01	7,499572		RHUM	54,5	83,8	74,47347	5,68288
	WSPD	0,43	3	1,894082	0,566016		WSPD	0,3	2,93	1,797959	0,579659
	PREC	2,8	78,95	33,22673	18,42117		PREC	17	116	69,82	22,65242
	EVAP	111,35	261,55	180,6781	38,67762		EVAP	No Available Data			
	PRES	936,17	940,03	938,0518	0,683464		PRES	938,23	942,87	940,3961	1,032262
	TMIN	1,2	7,57	4,33449	1,568368		TMIN	-17,67	-2,07	-8,46898	3,427807
	TMAX	27,97	33,57	30,85531	1,11518		TMAX	8,37	17	14,26143	1,732383

Table 3. Descriptive statistics for annual

Term	Variable	Min	Max	Mean	Std. D.
ANNUAL	SD	216,59	268,96	240,5276	11,86165
	CLDN	2,63	4,38	3,5763	0,431
	RHUM	39,63	64,93	54,168	5,83306
	WSPD	0,44	3,3	2,178	0,62706
	PREC	16,26	73,45	45,7678	12,35753
	EVAP	97	352,96	243,4255	42,49251
	PRES	934,53	937,09	935,8488	0,60276
	TMIN	-0,99	5,81	2,9694	1,46631
	TMAX	25,31	30,07	28,3182	0,97375

Prior to analyzing dataset, SD values were transformed and arranged as RSD values. A statistical analysis referred to Pearson correlation analysis was used to represent how closely related RSD tothe climate parameters.Table 4 represents the Pearson correlation coefficients of RSD with other climate variables in this study. The statistically significant (for $p<0.05$ and for $p<0.01$) correlation values were emphasized in bold. For annual term, the amount of RSD was correlated with CLDN, RHUM, PREC negativelyand PRES, TMAX positively as weak. Also, the statistically significant cross correlation values between variables were also expressed in Table 4 as; CLDN related to RHUM (weak) and PREC (moderate) positively whereas EVAP (weak) and TMAX (weak) negatively. RHUM was related to PREC (weak), EVAP (moderate) and TMAX (weak). WSPD was related to EVAP and TMIN weakly. PREC was related to PRES and TMAX negatively (weak). EVAP wasassociated with PRES and TMIN negatively but TMAX positively (weak). TMIN was correlated with TMAXpositively. In winter, RSD was highly associated with CLDN and PREC, moderately with RHUM and PRES. Furthermore, the cross correlations between different variables; for instance, CLDN moderately related to RHUM and PREC, weakly PRES and TMIN.

Table 4. Pearson correlation matrix of RSD with other climate variables

Term	Variable	RSD	CLDN	RHUM	WSPD	PREC	EVAP	PRES	TMIN	TMAX
ANNUAL	RSD	1	**-,433****	**-,311***	-0,002	**-,493****	0,094	**,316***	0,166	**,394****
	CLDN		1	**,444****	0,102	**,519****	**-,325***	0,249	0,2	**-,405****
	RHUM			1	-0,079	**,374****	**-,515****	0,15	0,101	**-,425****
	WSPD				1	-0,024	**,384****	-0,084	**-,443****	-0,033
	PREC					1	0,014	**-,287***	0,048	**-,338***
	EVAP						1	**-,459****	**-,312***	**,304***
	PRES							1	0,114	-0,089

	TMIN								1	**,373****
	TMAX									1
WINTER	RSD	1	**-,855****	**-,592****	0	**-,717****		**,611****	-0,276	0,068
	CLDN		1	**,627****	-0,023	**,697****		**-,463****	**,474****	0,066
	RHUM			1	-0,194	**,479****		-0,264	0,194	-0,124
	WSPD				1	0,047		-0,142	-0,103	-0,037
	PREC					1		**-,677****	**,285***	-0,046
	EVAP									
	PRES							1	**-,381****	-0,034
	TMIN								1	**,507****
	TMAX									1
SPRING	RSD	1	**-,663****	**-,493****	0,093	**-,588****	0,272	**,304***	0,123	**,574****
	CLDN		1	**,550****	-0,075	**,649****	**-,420****	-0,007	0,177	**-,635****
	RHUM			1	-0,106	**,569****	**-,600****	-0,122	0,172	**-,559****
	WSPD				1	-0,182	0,102	0,042	**-,611****	0,114
	PREC					1	**-,405****	-0,174	0,22	**-,639****
	EVAP						1	-0,219	-0,032	**,509****
	PRES							1	0,098	0,064
	TMIN								1	-0,051
	TMAX									1
SUMMER	RSD	1	-0,23	-0,054	-0,214	**-,386****	-0,001	**,369****	0,183	-0,058
	CLDN		1	0,261	0,208	-0,041	-0,12	0,18	-0,16	**-,335***
	RHUM			1	-0,194	-0,013	**-,546****	0,123	-0,019	**-,372****
	WSPD				1	0,037	**,451****	-0,083	**-,495****	-0,133
	PREC					1	-0,064	-0,139	-0,11	-0,168
	EVAP						1	**-,324***	-0,277	0,264
	PRES							1	-0,03	-0,139
	TMIN								1	0,28
	TMAX									1
AUTUMN	RSD	1	**-,523****	**-,542****	0,161	**-,417****	0,175	0,229	-0,111	0,109
	CLDN		1	**,701****	0,022	**,503****	**-,439****	**,310***	0,263	-0,186
	RHUM			1	-0,001	**,468****	**-,462****	0,093	0,242	**-,309***
	WSPD				1	0,141	**,376***	-0,175	**-,487****	-0,045
	PREC					1	0,008	-0,037	0,032	-0,151
	EVAP						1	**-,302***	**-,527****	0,121
	PRES							1	**,336***	-0,092
	TMIN								1	0,176
	TMAX									1

**. Correlation is significant at the 0.01 level ($p<0.01$) & *. Correlation is significant at the 0.05 level ($p<0.05$).

According to the spring term, the correlations were generally moderate such as CLDN, PREC and TMAX and weak such as RHUM and PRES. Additionally, for cross correlations; for instance,the correlations between CLDN and RHUM also CLDN and PREC were positive moderately, CLDN and EVAP weakly also CLDN and TMAX negative moderately. During the summer term, RSD was correlated as weak level with PREC negatively and with PRESpositively. For cross correlations, as shown in Table 4, RHUM was associated with EVAP moderately and TMAX weakly. Finally, in autumn, the scale of correlation between RSD and climate variables was moderate for CLDN and RHUM, whereas weak for PREC. Additionally, CLDN was highly correlated with RHUM.

These results were shown that RSD was related to various climate elements despite the level of significance was changed due to the periods. The estimation of RSD was not main scope of this study, but this analysis can be deeply examined in further analysis.

V. CONCLUSION

This study presented that, RSD was related to various climate elements over different levels according to the seasonal and annual periods. Monthly average daily values for each variable dataset during 1960-2008 was analyzed via Pearson correlation analysis method. RSD was commonly associated with cloudiness moderately in seasonal periods. Relations between RSD and climate variables were found commonly as moderate and good levels but in winter term, all significant correlations were weakly. It would be probably more clear and more understandable if examining the relations for each month in further studies.

During the period 1960-2008, there exist statistically significant correlations between the RSD and several climate parameters. RSD was correlated with cloudiness, precipitation and relative humiditynegatively and additionally,with air temperature, atmospheric pressure, wind speed and evaporation positively.

Besides, topographical structure and atmospheric circulations are related to RSD spatially. Furthermore, urbanization and urban planning, natural and anthropogenic emission sources of air pollutants may influence the RSD.

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