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The Modeling of Weather Conditions and Wind Power in Cities of Western Black Sea Region by Using Linear Regression Method

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Abstract: In this study, weather condition data such as the monthly average temperature, relative moisture, wind speed, pressure and the calculated wind power values of Zonguldak, Sinop, Düzce, Bartın, Kastamonu, Bolu and Karabük cities located in western Black Sea region were examined for 10 year period (2001-2011). In the modeling of the weather conditions, linear regression analysis was used and the effect of temperature, relative moisture and pressure on wind speed was researched by non-linear regression method. Besides, in this study, the effect of roughness coefficient in cities of western Black Sea region was also taken into consideration and the wind power potentials in 10 m, 25 m and 50 m altitude were researched in detail with the help of WASP (Wind Atlas Analysis and Application) program. In the light of the values obtained by developed models and weather condition data, it was observed that some cities in the western Black Sea region have wind power potential with their effects on environment and energy.

Key words: Pressure, relative moisture, wind speed, wind power, Turkey.

Nomenclature

k	Roughness coefficient
R	Relative moisture (%)
Y	Years
T	Temperature (°C)
P	Wind power (W/m^2)
V	Wind speed (m/s)

1. Introduction

Today, renewable energy sources include solar, wind, geothermal, biomass and small-scale hydroelectric power plants. This interest in renewable energy sources has led to that the technology of wind energy has developed rapidly [1]. In the literatures, many researches regarding weather conditions and solar and wind energy have been conducted both in the world and in our country. In many of these researches about renewable energy, empirical correlations regarding the weather parameters such as solar radiation, wind energy, relative humidity, pressure and dust have been developed [2]. This project is asserted that Sinop was among the places which were suitable for wind energy production. For these reasons, Sinop, which was classified as a potential region in terms of wind energy, was taken in this research [3].

By looking at the data on recent ten years (2001-2010), weather conditions of the western Black Sea region, such as monthly average temperature, relative humidity, wind speed and pressure as seen in Fig. 1, the wind power potentials will be tried to be specified using linear regression method [4]. Later, using the WASP program, the wind power potentials at different heights will be examined in detail in the light of these data and considering the effect of roughness coefficient [5].

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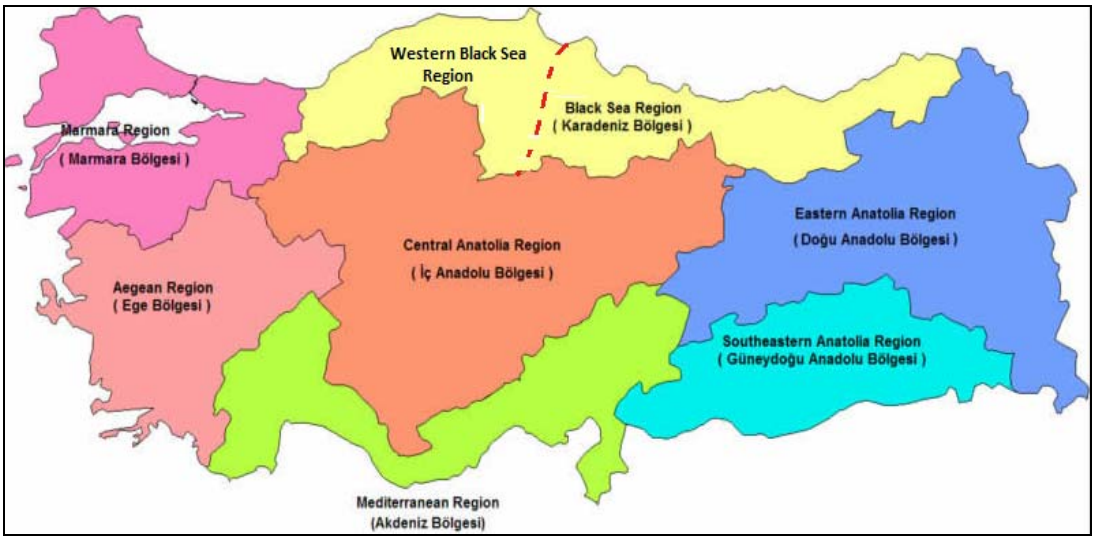

Fig. 1 Western Black Sea region [9].

2. Weather Conditions of Western Black Sea Region

The daily average temperature, wind speed, pressure and relative humidity values of the western Black Sea region between 2001 and 2010 were gathered from the General Directorate of Meteorology and the monthly and annual average values were found. The changes of temperature, relative humidity and wind speed values of the western Black Sea region according to years are seen in Fig. 2. The western Black Sea region's annual average temperature was found to be 18.2 °C, relative humidity value was found to be 7F.6% and wind speed value was found to be 1.78 m/s.

3. Linear Regression Method

Regression analysis is a statistical analysis that adapts curves to experimental data using least square method [6]. Regression is used in various applications in order to analyze how one or more independent variable affects one dependent variable [7]. In this research, the temperature, relative humidity, wind speed and pressure values belonging to a 10-year period (2001-2010) were modeled using linear regression analysis.

3.1 Temperature

The temperatures changed between 2001 and 2010 are presented in Fig. 3. Each data indicates the average temperature value for the whole year. The average temperature for the western Black Sea region was found to be 18.2 °C, the minimum average temperature value was found to be 12.1 °C in Kastamonu and the maximum average temperature value was found to be 28.9 °C in Sinop. In Fig. 3, it is seen that annual average temperatures for each year are close to each other.

The modeling of the western Black Sea region and the provinces in this region which had the maximum and minimum temperatures were conducted using linear regression method and the equations are given below. For Kastamonu $T = -0.338Y + 28.739$, for Sinop $T = 0.4978Y + 14.594$, for the western Black Sea region $T = -0.0079Y + 10.295$.

3.2 Relative Moisture

The relative humidity changed between 2001 and 2010 are presented in Fig. 4. The relative humidity value for the western Black Sea region was found to be 73.6%, the minimum average relative humidity was found to be 69.8% in Kastamonu and the maximum average relative humidity value was found to be 79.2% in Sinop. In Fig. 4, it is seen that the average relative humidity in Sinop is high.

The modeling of the western Black Sea region and

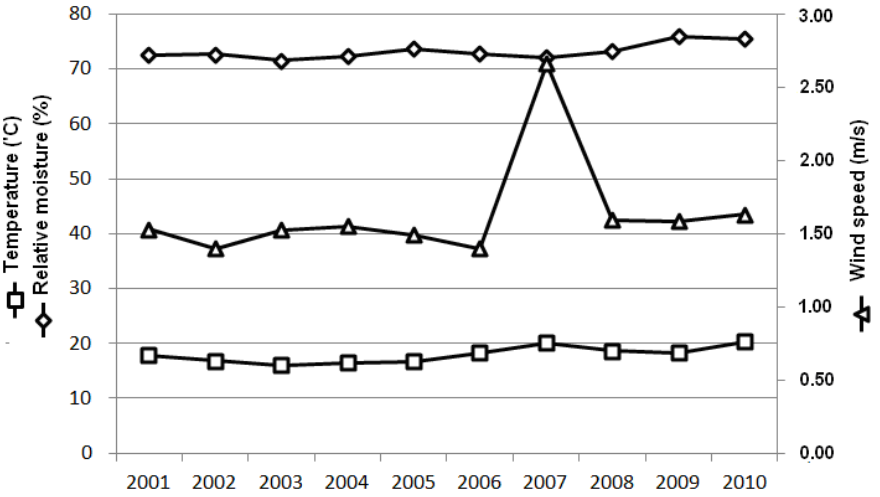

Fig. 2 Weather conditions of western Black Sea region.

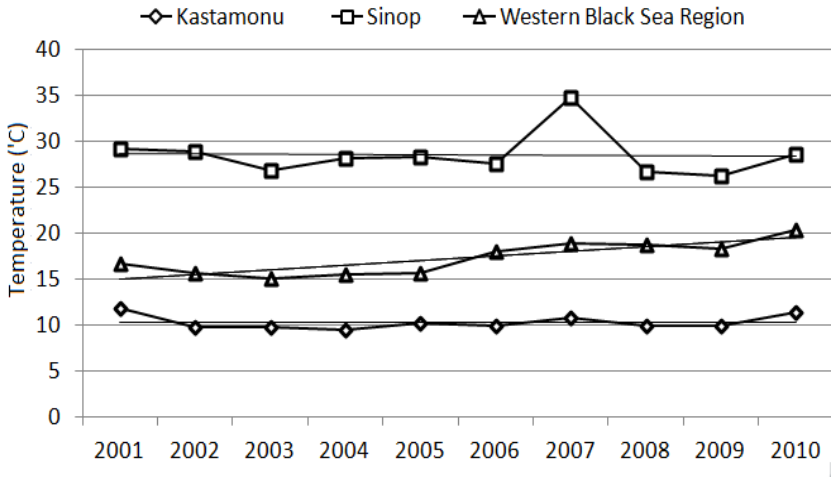

Fig. 3 Temperature distribution in last 10 years (T: Temperature, Y: Years).

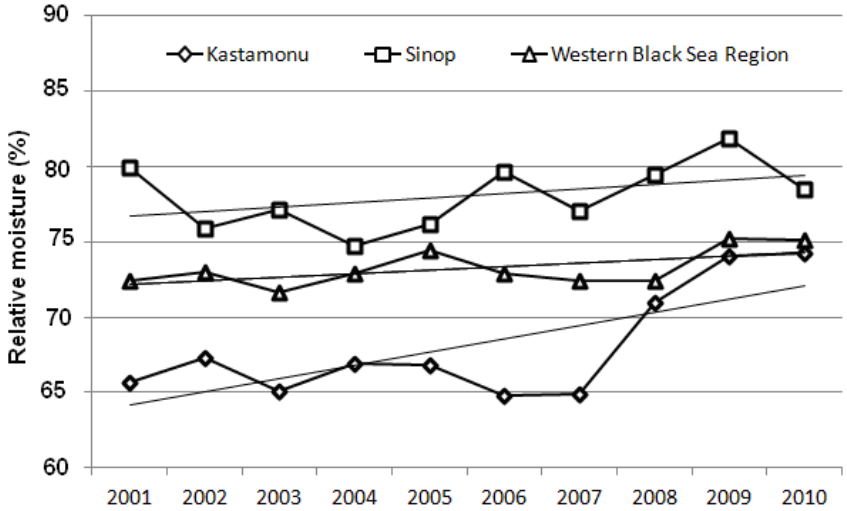

Fig. 4 Relative moisture distribution in last 10 years (RM: Relative Moisture, Y: Years).

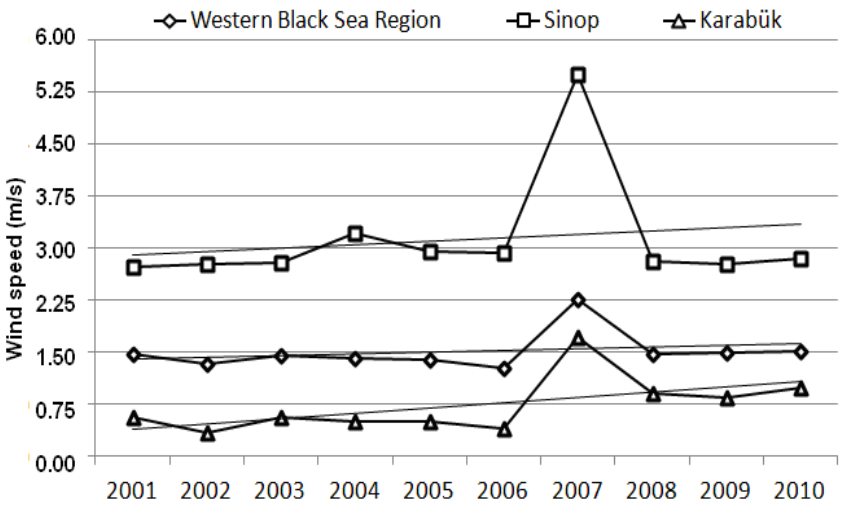

Fig. 5 Wind speed distribution in last 10 years (WS: Wind Speed, Y: Years).

the provinces in this region which had the maximum and minimum relative humidity rates were conducted using linear regression method and the equations are given below:

For Kastamonu $RM = 0.3064Y + 76.368$,

Sinop $RM = 0.245Y + 71.893$,

Western Black Sea region $RM = 0.8805Y + 63.234$.

3.3 Wind Speed

It is seen in Fig. 5 that the annual average wind speed values between 2001 and 2010 varied between 1.25 m/s and 2.5 m/s at 10-m-height. The total average wind speed value for this period was found to be 1.78 m/s.

The modeling of the western Black Sea region and the provinces in this region which had the maximum and minimum annual average wind speeds were conducted using linear regression method and the equations are given below. For Karabük $WS = 0.0496Y + 2.8635$, for Sinop $WS = 0.245Y + 1.3814$, for the western Black Sea region $WS = 0.024Y + 1.3814$.

4. The Modeling of Wind Power Potential by Using WASP

In the research, the data on monthly average wind speed in western Black Sea region between 2001 and 2010 and at 10-meter-height were used. Secondly, the WASP package program was used. WASP evaluates four different input data while conducting statistical analysis (Table 1). These are monthly wind data, immediate surroundings obstacles, region's roughness and topography data.

The data on immediate surroundings obstacles were collected by wandering in the immediate surroundings of the meteorology station [8]. The obstacles were grouped considering Table 2. Permeability was taken to be "0" for buildings and "0.50" for woodlands. If the distance between buildings was about one third of the buildings, permeability was to be taken to be "0.33" [9]. The height, length and permeability of the obstacle were considered in order to specify the obstacle's effect on wind speed [10].

Depending on the average wind speed in the western Black Sea region and in the Sinop province which had the highest wind power potential of the region, the

Table 1 WASP main menu [7].

WASP	Data of wind
	Obstacle
	Roughness
	Topography
	Atlas

Table 2 Roughness coefficient [5].

Type of obstacle	Roughness coefficient (k)
Solids	0
Very intense	<= 0.35
Intensive	0.35-0.50
Open	> 0.50

wind speed and wind power values at 10 m, 50 m, 100 m and 150 m were found using the WASP program. These values are presented in Tables 3 and 4.

Due to the fact that the western Black Sea region had woodland in general, roughness coefficient (k) was taken to be 0.50 and the maximum wind power value at 150 m was found to be 662.29 W/m^2 and the maximum wind speed value was found to be 10.3 m/s.

In Table 5, wind power was classified depending on its usability. According to this, for turbine establishment to be economical, it should be established in the regions classified as having "good" or "very good" wind power potentials.

5. Conclusions

In this research, the weather conditions such as wind speed, temperature, relative humidity and pressure and wind power in the provinces of Düzce, Kastamonu, Zonguldak, Bartın, Bolu, Karabük and Sinop in the western Black Sea region were examined in a 10-year-period (2001-2010) and modeling was conducted using linear regression method. According to this research, the parameter which affected the wind power most was wind speed. It was seen that wind speed increased as the height increased due to the reasons caused by the roughness of the surface.

Using the wind speed values at 10-m-height taken from the General Directorate of Meteorology, the wind power values at 50 m, 100 m and 150 m heights (taking roughness coefficient as k = 0.5) were calculated through the WASP program.

According to this research, the average maximum wind power in the western Black Sea region in 2007 was found to be 662.29 W/m^2 and the average

Table 3 Depending on the average of wind speeds (k = 0.5).

Average wind speed in the western Black Sea region (m/s)					Average wind speed in Sinop (m/s)			
	10 m	50 m	100 m	150 m	10 m	50 m	100 m	150 m
Yıllar	-	k = 0.5	k = 0.5	k = 0.5	-	k = 0.5	k = 0.50	k = 0.5
2001	1.53	3.42	4.84	5.92	2.69	6.09	8.62	10.55
2002	1.4	3.12	4.41	5.40	2.45	6.21	8.78	10.75
2003	1.53	3.41	4.82	5.91	2.68	6.24	8.83	10.81
2004	1.55	3.46	4.89	5.99	2.72	7.19	10.17	12.46
2005	1.49	3.33	4.71	5.77	2.62	6.62	9.36	11.46
2006	1.39	3.12	4.41	5.40	2.45	6.55	9.26	11.34
2007	2.66	5.95	8.41	10.30	4.67	12.34	17.45	21.37
2008	1.59	3.55	5.03	6.16	2.79	6.30	8.91	10.91
2009	1.58	3.54	5.00	6.13	2.78	6.22	8.80	10.78
2010	1.63	3.65	5.16	6.31	2.86	6.37	9.01	11.04

Table 4 Depending on the average of wind power (k = 0.5).

Average wind power in the western Black Sea region (W/m^2)				Average wind power in the Sinop (W/m^2)		
	50 m	100 m	150 m	50 m	100 m	150 m
Yıllar	k = 0.5	k = 0.5	k = 0.5	k = 0.5	k = 0.50	k = 0.5
2001	24.19	68.42	125.70	138.41	391.49	719.32
2002	18.46	52.20	95.90	146.45	414.23	760.99
2003	24.12	68.21	125.32	149.60	423.14	777.36
2004	25.18	71.21	130.82	228.34	645.83	1,186.47
2005	22.38	63.30	116.29	177.56	502.21	922.61
2006	18.40	52.05	95.62	172.39	487.59	895.77
2007	127.46	360.51	662.29	1,139.81	3,223.87	5,922.64
2008	27.23	77.03	141.52	153.99	435.54	800.4
2009	26.79	75.77	139.20	148.35	419.78	770.88
2010	29.17	82.50	151.56	158.44	448.2	823.28

Table 5 Classification of wind power [1].

Wind power (P)	Potential of wind power
$P < 100$ W/m^2	Low
100 W/m^2 <= $P < 300$ W/m^2	Near optimal
300 W/m^2 <= $P < 700$ W/m^2	Good
$P >= 700$ W/m^2	Very good

maximum wind power among the provinces in 2007 was found to be 5,922.64 W/m^2 for the Sinop province.

References

[1] G. Ambrosini, B. Benato, C. Garavaso, G. Botta, M. Cenerini, D. Comand, Wind Energy Potential in Emilia Romagna, J. of Wind Engineering and Industrial Aerodynamics 39 (1992) 211-220.

[2] E.K. Akpınar, Y. Biçer, HavaŞartları and modeling of wind power in Elazig, II. National Aegean Energy Symposium, Dumlupınar Üniversity, Kütahya, May 24-26, 2004, pp. 257-263.

[3] A.Z. Al-Garni, A.Z. Sahin, A. Al-Farayedhi, Modeling of weather characteristics and wind power in the eastern part of Saudi Arabia, International Journal of Energy Research 23 (1999) 805-812.

[4] Devlet, Meteoroloji, İşleri, Genel, Müdürlüğü, Batı Karadeniz, bölgesindeki illerin 2001-2010 yılları arasındaki hava dataları (Using the wind speed values at 10-m-height taken from the General Directorate of Meteorology for 2001-2010).

[5] M. Dündar, C. Bandırma, C. Bodrum, Determination of wind energy potential for the regions of Bozcaada and Cesme, MSc Thesis, Department of Environmental Sciences, Hacettepe Univ. Fen Bil. Institute, Ankara.

[6] E. Beytullah, E.K. Akpinar, Y. Biçer, Weather conditions in several cities in the east and wind power modeling, Plant Engineering Magazine 89 (2005) 58-64.

[7] D.C. Montgomery, E.A. Peck, G. Geoffrey, Introduction to Linear Regression Analysis, Wiley, New York, 1985.

[8] S. Rehman, Y. Hussain, T.O. Halawani, Radiative fluxes in the troposphere from upper air meteorological data in Saudi Arabia, Solar Energy 49 (1) (1992) 35-40.

[9] E.M.A. El-Salam, Correlation of solar radiation and sunshine duration in Riyadh, Pak. J. Sci. Ind. Res. 16 (1973) 16-18.

[10] S. Tağıl, Sinop and around the World Energy Council, Turkish National Committee for Wind Energy Potential of Turkey 8 Energy Congress.