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ESTIMATION OF WIND ENERGY POTENTIAL USING WAsP IN HATAY AIRPORT REGION

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Abstract

The main purpose of this study is to determine the possible wind power generation in Hatay airport region using the wind data measured by Meteorology Station of Hatay airport during the year 2012 and included direction-speed values. The airport area was simulated by WAsP (Wind Atlas Analyses and Application Program) program. Based on post-processed wind data, the climatology of the region, the local orography and roughness were determined by WAsP. In this study, in view of effective electricity generation, two types of micro-sitting form for wind turbines also selected and compared. Based on Weibull parameters, wind speed characteristics, wind frequency of occurrence, power density, and the amounts of the total annual energy producing was calculated. As a result of the study indicated that the investigated area has fairly satisfactory wind energy potential for the utilization of Hatay airport.

Keywords: **Wind energy, wind potential, Hatay Airport, WAsP.**

1. INTRODUCTION

Energy resource diversification is one of the indicators of industrialization. Energy resources can be divided into two groups, primary and secondary energy resources. Primary energy source family contents two types of energy that are non renewable energy sources like, petroleum, natural gas, coals, boron and nuclear energy; These types of non-renewable energies have been heavily used last two hundred years with 95% percent. However, while the non-renewable sources getting loses their capacity, they have been caused both environmental pollution and negative effects on ozone layer with greenhouse gas. On the other hand, as the secondary resources, the renewable energy is playing an important role in energy market and developing itself day by day. Also, they have limitless capacity, after and during usage, they have no environmental pollution. Additionally, for the cost analyze approach renewable energy sources have more competitive costs than non-renewable energy sources.

According to 2013 data, Turkey imports 72% of its energy needs by 28% provide their own production. At this perspective, our country's energy policy has to be turned to renewable energy sources. Renewable energy sources, especially wind is a valuable form of renewable energy resources that does not cause water or air pollution and our country's energy demand meets 4.7% with this type of energy [1].

Turkey has very high wind potential. According to the "Turkey Wind Map" obtained from General Directorate of Electrical Power Resources, wind speed at 50 m above sea level and outside the residential areas, at East Mediterranean coasts and inner parts of this region are 6.0–7.0, 4.5–5.0 m/s, respectively [2].

Because of this high wind capacity of Turkey, many numerical and experimental studies are executed for wind energy potential and wind energy characteristics, by investigators. [3-8]. In those studies, they reported the items of availability of wind turbines, wind characteristics of regions, electricity capabilities and cost analyses of this technology. In addition, they used different methods for getting knowledge about the wind speed and energy characteristics. Especially Hatay region which located in southern Turkey has 6 m/s wind speed and reaching 300 days of the year steady wind breeze, constitute an ideal ambient for wind turbines. In this study, the wind characteristics and

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wind energy potential of the region of Hatay Airport simulated with two types sitting form of selected wind turbines.

2. METARIALS AND METHODS

2.1. Brief Description Of Hatay Airport And Meteorological Measurement Results

Hatay airport opened to transportation in 2007, and it is located on 36 ° 22 '20 "North, 36 ° 17'55" East, and has 8m altitude and placed in a region with an area of 43,688 m^2. As geographical structure, the airport has an approximately flat area. Fig.1 illustrated the topographic map of airport that was taken from the Google Earth program. Fig.2 shows the map of Hatay Wind Energy Potential Atlas (REPA) that prepared by General Directorate of Renewable Energy [2].

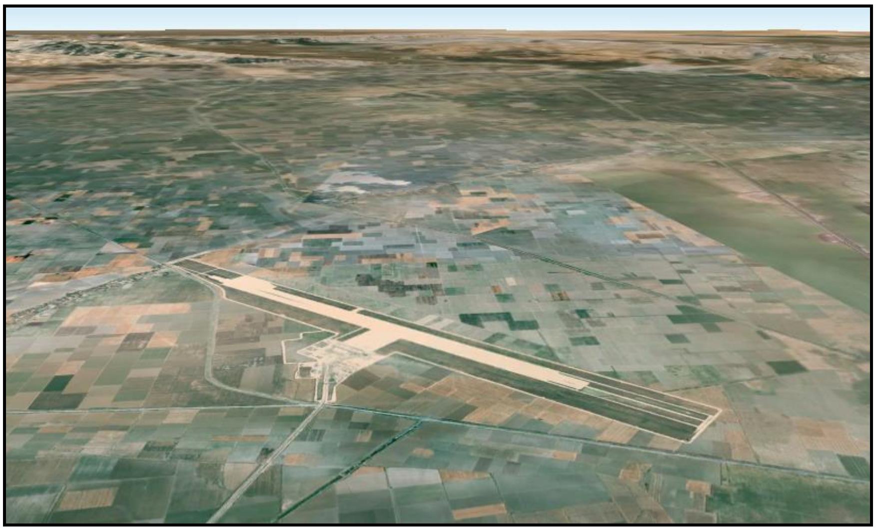

Fig. 1 Topographic map of Hatay Airport

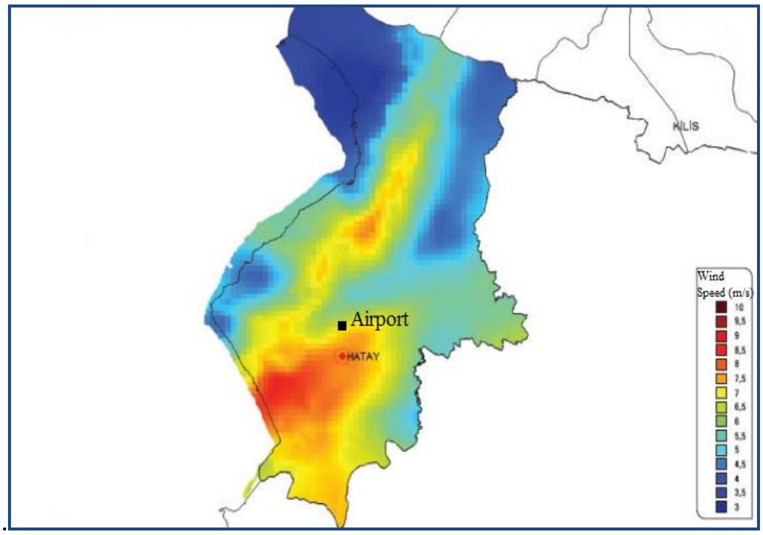

Fig. 2 Hatay REPA map [2]

On the other hand the wind data in the airport area measured at 10 m above ground level (AGL). These data were taken from the Meteorological department with period of three-hour slices daily and period of 12 months.

Fig. 3 represented the monthly average wind speed values in a 10 meter high. And wind speed of 12

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month average value is 4.08 m/s. Average wind speed values ranged between from 1.5 to 7.1 m/s values. Analysis was performed using annual and monthly data. The average wind speed is highest in the months of June, July and August; whereas the lowest wind speeds levels were measured during the months of February and November.

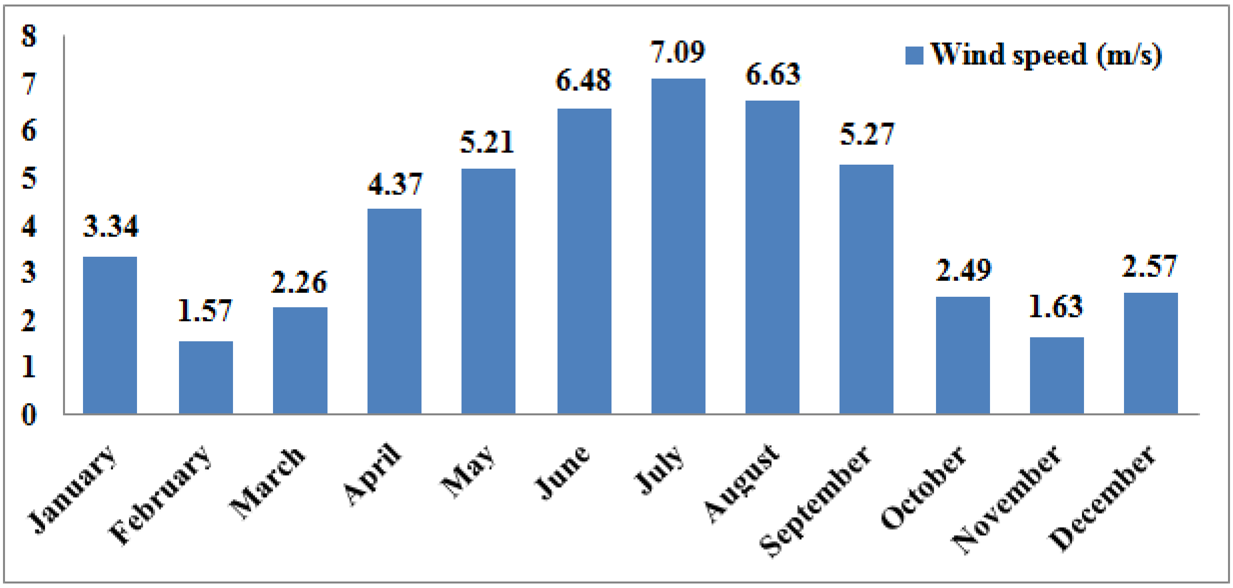

Fig. 3 Monthly average values of wind speed

2.2. WAsP and Mathematical Approach

WAsP (Wind Atlas Analysis and Application Program) software has prepared and developed by Danish Meteorological Organization's Riso to estimate wind characteristics and power productions from wind turbines. European Wind Atlas (European Wind Atlas) was prepared using WAsP. Nowadays, many studies related to wind energy continues to be used with this simulation program [3].Program considering the effect of roughness and topographical barriers, by analyzing the wind data and the results are stored as being horizontal and vertical extrapolation.10-year wind speed and direction with 87600-character, recording a very short time by the program and read 1 m/s at intervals of 30° direction sector for breezing values calculated each direction for the sector 1000 to normalize and gives their cumulative frequency as %.These breezing values also calculates in frequency table for each direction sector Weibull parameters (*a*, *k*) and calculate the average wind speed identify m/s unit, and serve the calculated average wind power density value unit of W/m^2[4].

In the program the topographical barriers and roughness are playing an important role to obtain the perfect values. In this case, there is an important situation which be touched upon is the distances and dimensions of the wind turbines around the airport. Although wind turbines which has stated around airports, may have adverse effects, but this problem can solve with obey the dimensions carefully. More clearly expression, protruding structure contains a large amount of metal is particularly important if the radio, TV, broadcast, communication links, such as is the cause electromagnetic interference to signals. The rotating blades of wind energy conversion systems can cause interference in the use of electromagnetic communication devices such as, radio, television, satellite services, and radars. If a wind turbines need to be placed close to the airport (5km distance from the runway) is required to assess the impact of the publication in the air-space communication system (ILS). However, a small wind farm stated in near the Denmark Copenhagen International Airport has not been faced with the any attempt problem until now [5,6].

Developing the technological features, mostly in engineering applications, feasibility study criteria advance his necessity cause of minimizing the errors and irreversible mistakes with carried out computer aided simulation programs. For that reason, all simulation and computed aided programs have mathematical infrastructure. For wind energy applications and WAsP program the mathematical

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infrastructure equations give us more understanding specifications.

Determining wind frequency distribution and probability density function of this distribution for the wind energy potential of a region is the most important key for understanding the wind model. In the literature, wind speed frequency distributions are modeled with using different distributions as Weibull, Gamma, log-normal, Rayleigh. In turn two-parameter Weibull distribution represents the distribution of the world wind instrument has been used for modeling a lot in recent years. This method commonly using because of such factors, its different regions belonging to the wind distributions can represent with flexible structure, for parameter setting multitude of methods for the development of the parameters, after determination for a height it can be prediction in the different heights.

Weibull distribution has a two-parameter namely dimensionless shape (k) and scale parameter (a, (m/s)).

Probability density function of two-parameter Weibull distribution general expression is expressed by the "(1)" equation;

$$F(V) = \frac{k}{a}\left[\frac{V}{a}\right]^{k-1} e^{-\left(\frac{V}{a}\right)^k} \quad (1)$$

The Probability density function, $F(v)$ gives the probability of observed wind speed at any time. Weibull distribution scale parameter (a) has an approximate value of wind data. Shape parameter, k, is usually expected to be between 1and 3. Cumulative distribution function $F(v)$ observed of the rate at any time less than or equal to speed V, and indicates the possibility that is expressed by equation"(2)" [3, 7].

$$F(v) = 1 - e^{-(v/a)^k} \quad (2)$$

In this study, the Weibull parameters k, and a, values and standard deviations with the medium wind speed values are obtained by using the moment method.

3. RESULTS and DISCUSSION

3.1. Wind Characteristics for one Turbine

In this study, wind characteristics were examined for the region Hatay airport, within the airport anemometer determine wind characteristics data by simulating taken with the help of the WAsP program. In this simulating study, obtained the affecting roughness area and surrounding structures entered program and wind turbine selections were made for wind characteristics (Bonus 600 kW Mk IV). Then the wind farm system has established with vertical and scattered positions with 5 turbines.

WAsP program give the wind atlas contains data for 5 reference roughness lengths (0,000 m, 0,030 m, 0,100 m, 0,400 m, 1,500 m) and 5 reference heights (10 m, 25 m, 50 m, 100 m, 200 m) above ground level.In the airport region, the wind speed values measured divided into 16 equal parts and each part is calculated separately for at intervals of 22.5 degrees. Regional wind climate summary data is given in Table 1.

The region's wind speed frequency distribution and modeled by the Weibull distribution frequency curves are shown in Fig.4. As seen Fig.4,at the top of the graph the average values of wind speed values indicate the most common values. In this study, the k parameter of Weibull function and the "a" scale parameter calculated values are k=1.07, a=6.9 m/s, respectively.

In addition, the annual average wind speed of the area value is obtained 6.45 m/s. According to these values power density is calculated and has taken 937 W/m^2. According to the data obtained from the calculation,16 different directions map of the wind rose is given in Fig.5. As a result, the prevailing wind direction is in the region of the south-west that is clearly seen in Fig.5.

Table 1. Regional wind climate summary

Height	Parameter	0.00 m	0.03 m	0.10 m	0.40 m	1.50 m
10.0 m	Weibull A [m/s]	9.38	6.69	5.79	4.52	3.01
	Weibull k	1.06	1.05	1.06	1.06	1.08
	Mean speed U [m/s]	9.17	6.57	5.67	4.41	2.92
	Power density E [W/m²]	2459	926	586	272	76
25.0 m	Weibull A [m/s]	10.23	7.86	7.03	5.87	4.51
	Weibull k	1.07	1.06	1.07	1.07	1.09
	Mean speed U [m/s]	9.97	7.67	6.86	5.71	4.36
	Power density E [W/m²]	3108	1428	1010	580	250
50.0 m	Weibull A [m/s]	10.89	8.85	8.06	6.97	5.69

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	Weibull k Mean speed U [m/s] Power density E [W/m²]	1.07 10.60 3705	1.08 8.58 1916	1.08 7.81 1446	1.09 6.74 914	1.10 5.49 482
100.0 m	Weibull A [m/s] Weibull k Mean speed U [m/s] Power density E [W/m²]	11.61 1.08 11.27 4381	10.00 1.12 9.61 2528	9.24 1.12 8.87 1973	8.18 1.12 7.85 1367	6.97 1.13 6.68 829
200.0 m	Weibull A [m/s] Weibull k Mean speed U [m/s] Power density E [W/m²]	12.41 1.09 12.01 5219	11.44 1.16 10.85 3335	10.64 1.16 10.10 2712	9.57 1.15 9.10 1993	8.40 1.16 7.97 1321

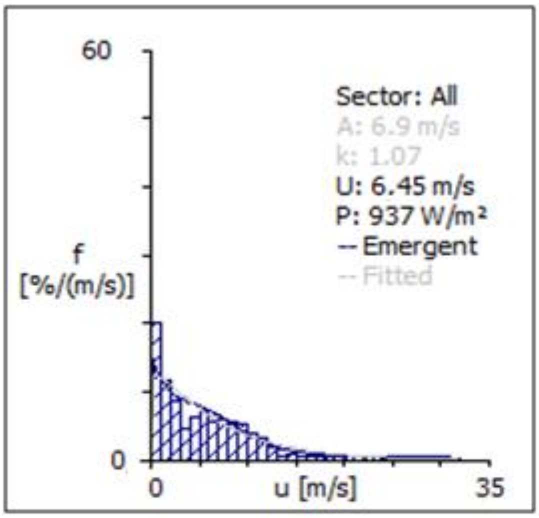

Fig.4 Weibull distribution for airport region

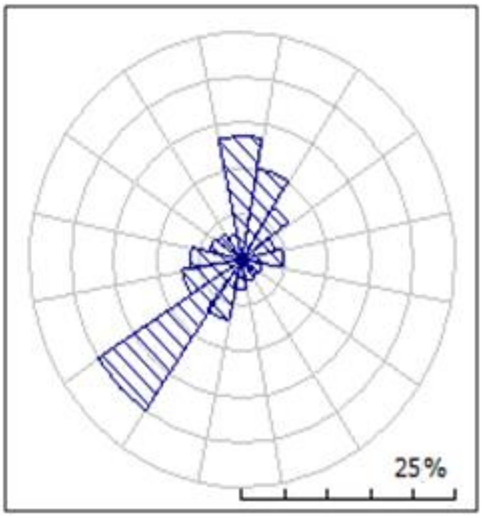

Fig. 5 Wind rose map in airport

Understanding the wind systems characteristic of the region, inserted wind turbine characteristics are given in Table 2. According to calculations, which use in the region and features suitable for airport the turbine is placed around the 5 km outside that the roughness level at least into that point.

Table 2. Calculated data for the wind turbine

Site	Location	Turbine	Elevation [m]	Height [m]	Net AEP [GWh]	Wake loss [%]
Turbine site 001	36°21'45"N, 36°16'43"E	Bonus 600 kW Mk IV	72.21358	40	1.634	0.0

3.2. Wind Characteristics for Vertical and Scattered Turbine Farm

In this section, wind potential effects of the wind farm were examined with the previous sections data which received from the data station for establishment of the turbine farm. The promotion of wind farms and one of the causes of excess demand brings many advantages. Some of these benefits can be listed like; wind farms use only 1% part of the field, wind farms, will have achieved an economically competitive level between power plants, thermal, hydraulic, etc.., these farms are not have to need foreign dependency about economically and environmentally.

Therefore, in this study wind farms established with five turbines placed in the airport area. The status of energy efficiency and availability of these vertical and

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scattered turbine farms determined and compared each other. In Fig 6, topographic maps of vertical wind farm are given.

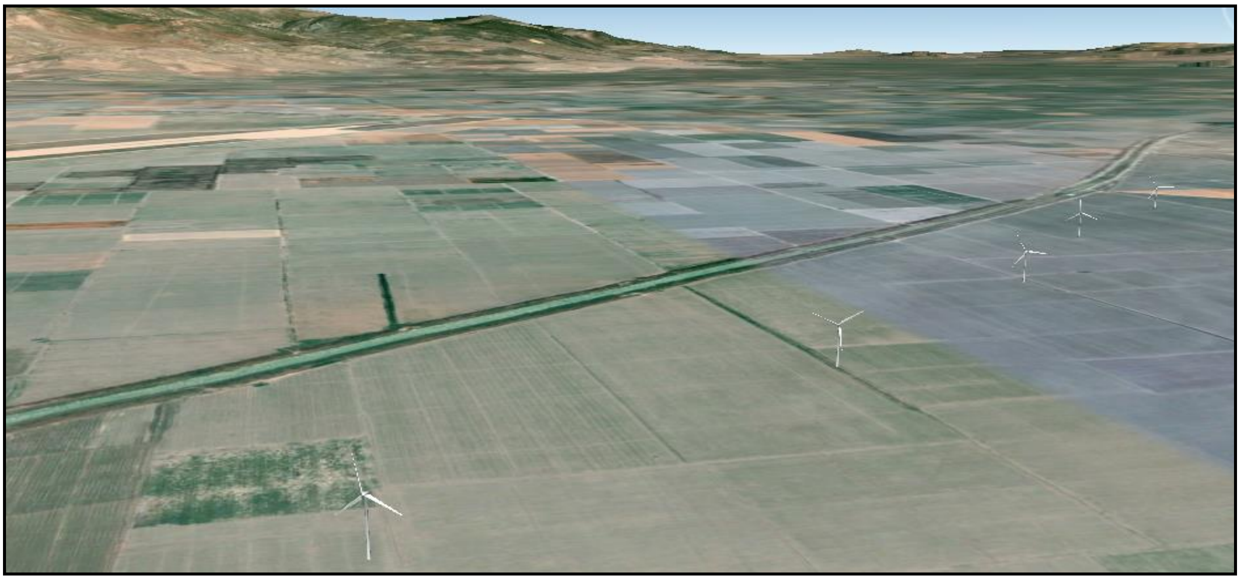

Fig. 6 Topographic maps of vertical wind farm

Vertical wind farm are designated for as a result of wind distribution, in the system 5 pieces selected Bonus 600 kW Mk IV value used with WAsP and wind turbine analysis summary report is provided in Table 3. Also vertical turbine farm efficiency values are illustrated in Table 3.

Table 3. Turbine site report of vertical wind farm

Site	Location [m] N, E	Turbine kW	Height [m]	Net AEP [GWh]	Wake loss [%]	MWh (free)	MWh (park)	Eff. [%]
V_1	36°21'03”,36°18'44”	Bonus 600	40	1.609	1.54	1634.189	1609.050	98.46
V_2	36°20'55”,36°18'31”	Bonus 600		1.598	2.38	1637,185	1598,240	97.62
V_3	36°20'46”,36°18'22"	Bonus 600		1.605	1.93	1636.969	1605.400	98.07
V_4	36°20'46”,36°18'22"	Bonus 600		1.613	1.31	1634.077	1612.634	98.69
V_5	36°20'28”,36°17'57”	Bonus 600		1,630	0,44	1637,374	1630,181	99.56
Wind farm						8179.794	8055.504	98.48

As a result of these turbine values, the average wind speed distributions are given in Fig.7. Overall efficiency of the vertical wind farm was found to be 98.48%. 1.52% like each other masking effect of the turbine consists of the difference.

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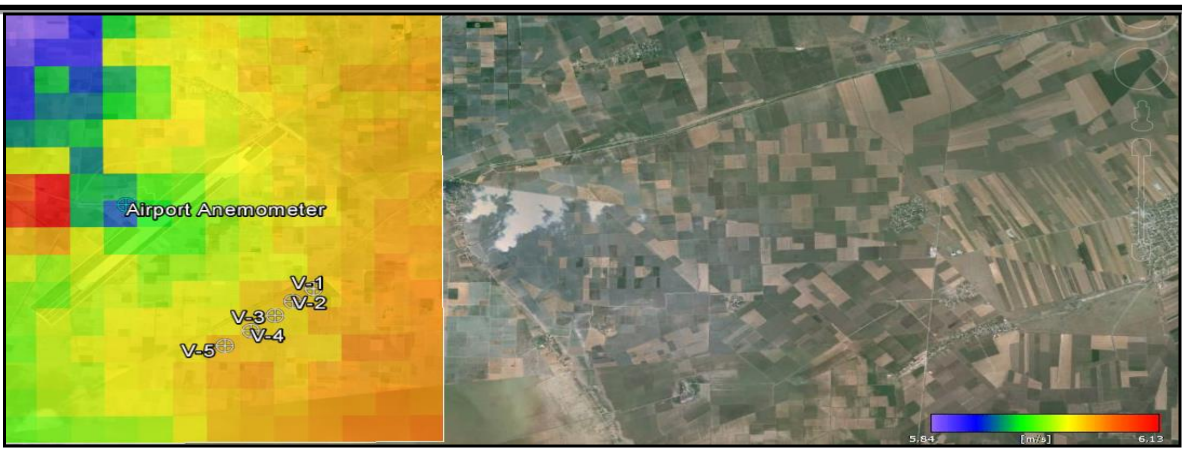

Fig. 7 Average wind speed distributions of vertical wind farm

Scattered wind farms have to state in micro-positioning. This positioning is relevant with wind wanes and wind destination. Topographic maps of scattered wind farm are given in Fig 8. Scattered wind farm are designated for as a result of wind distribution, in the system 5 pieces selected Bonus 600 kW Mk IV value used with WAsP and wind turbine analysis summary report is provided in Table 4. Also scattered turbine farm efficiency values are illustrated in Table 4.

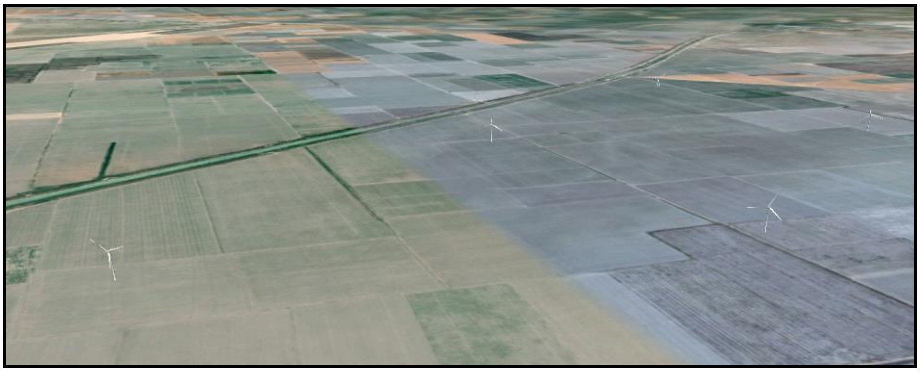

Fig. 8 Topographic maps of scattered wind farm

Table 4 Turbine site report of scattered wind farm

Site	Location [m] N, E	Turbine kW	Height [m]	Net AEP [GWh]	Wake loss [%]	MWh (free)	MWh (park)	Eff. [%]
S_1	36°21'02”,36°18'44”	Bonus 600		1.624	0.60	1633.829	1623.999	99.40
S_2	36°20'42”,36°18'46”	Bonus 600		1.622	1.02	1638.676	1621.963	98.98
S_3	36°20'47”,36°18'19”	Bonus 600	40	1.623	0.73	1634.627	1622.727	99.27
S_4	36°20'26”,36°18'23”	Bonus 600		1.622	0.94	1637.069	1621.725	99.06
S_5	36°20'29”,36°17'56”	Bonus 600		1.631	0.29	1635.872	1631.112	99.71
Wind farm	1631.112					8180.073	8121.525	99.28

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Result of these turbine values, the average wind speed distributions are given in Fig. 9. Overall efficiency of the scattered wind farm was found to be 99.28%. 0.72% like each other masking effect of the turbine consists of the difference. As can be seen here, in scattered wind farms, less shielding is observed.

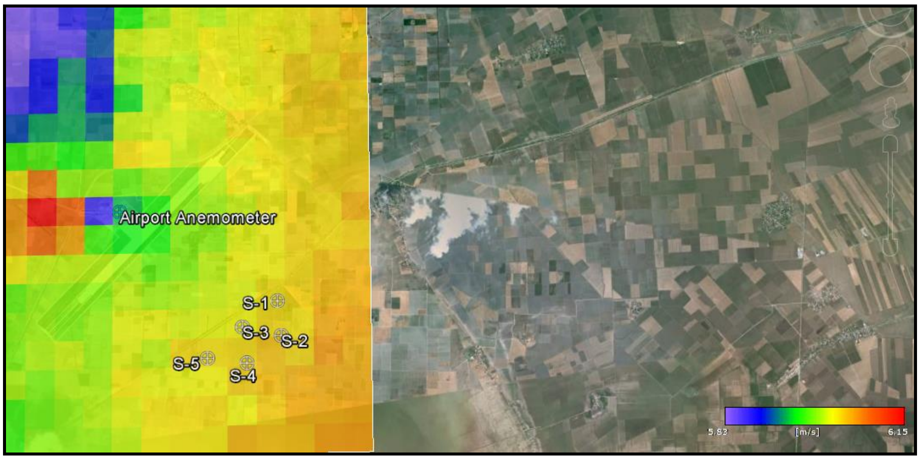

Fig. 9 Average wind speed distributions of scattered wind farm

4. CONCLUSION

In this study, the wind energy potential and characteristics of Hatay Airport, examined using data from the average speed of the wind which has belong to 2012 year and undertaken from the permission of Meteorology Station of Hatay airport. The airport area was simulated by WAsP (Wind Atlas Analyses and Application Program) program. Based on post-processed wind data, the climatology of the region, the local orography and roughnesses were determined by WAsP. On the other hand, as an application, two different situations were used for wind farms. Both the vertical and scattered sitting forms of wind farms were examined separately with 5 Bonus 600 kW Mk IV wind turbines in the same conditions. Several conclusions can be listed like;

-The average annual wind was estimated positioned 10 m. Observed average wind speed was 4.08 m/s and estimated wind speed value was 6.45 m/s by WASP program.

-In the region, high wind speeds occur during the summer months.

-Prevailing wind directions were South-west and North.

-In the area, if one wind turbine used, harvested average power density and an average annual production of electrical energy were 937 W/m^2 and 1634 GWh/year, respectively.

-Vertically positioned wind turbines area has average power density was 937 W/m^2 and annually average electric power generations from turbines was 8055 GWh/year respectively. In addition, general turbine efficiency was calculated as 98.48%. These values were changing for scattered wind farm except average power density. For this situation, average power density was 937 W/m^2 and annually average electric power generation from turbines was 8121GWh/year, respectively. Also, general turbine efficiency was calculated as 99.28%.

As a result of the study, the investigated area with scattering sitting form of turbines was fairly satisfactory wind energy potential for the utilization of Hatay airport.

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