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Research Article

Water Pumping Systems with Wind Turbines in Sinop

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Abstract

In meeting the increasing energy need in recent years; Environmental pollution caused by production with fossil energy sources has an important place today. Wind energy, one of the renewable energy sources; It is a clean, reliable, inexhaustible and low operating cost energy source. There is a great interest in clean and renewable energy sources in the world and Turkey. Wind energy is a renewable energy source that progresses day by day. With the use of renewable energy sources, which have a great potential in the agricultural sector, contribution can be made to agricultural activities. It is used in many fields such as wind energy, electricity generation, processing of agricultural products and agricultural water pumps. The aim of this study is to emphasize the increasing importance of wind energy, to evaluate the wind energy potential in Sinop Province and a study has been conducted on the active use of wind energy for farmers to pump agricultural water. Studies on wind energy, water pumping systems and wind data of the city were analyzed. The water pumping capacities depending on various wind forces that can be obtained by using these analyzes were calculated with Visual Basic 6.0 computer program.

Keywords: Renewable energy, Water pumping, Computer programs, Wind turbines, Agricultural irrigation.

Sinop'ta Rüzgâr Türbinli Su Pompalama Sistemleri

Öz

Son yıllarda artan enerji ihtiyacının karşılanmasında; Fosil enerji kaynakları ile üretimin neden olduğu çevre kirliliği günümüzde önemli bir yere sahiptir. Yenilenebilir enerji kaynaklarından biri olan rüzgar enerjisi; Temiz, güvenilir, tükenmez ve işletme maliyeti düşük bir enerji kaynağıdır. Dünyada ve Türkiye'de temiz ve yenilenebilir enerji kaynaklarına büyük ilgi vardır. Rüzgar enerjisi her geçen gün artan yenilenebilir bir enerji kaynağıdır. Tarım sektöründe büyük bir potansiyele sahip olan yenilenebilir enerji kaynaklarının kullanımı ile tarımsal faaliyetlere katkı sağlanabilmektedir. Rüzgar enerjisi, elektrik üretimi, tarım ürünlerinin işlenmesi ve tarımsal su pompaları gibi birçok alanda kullanılmaktadır. Bu çalışmanın amacı, rüzgar enerjisinin artan önemini vurgulamak, Sinop ilindeki rüzgar enerjisi potansiyelini değerlendirmek ve çiftçilerin tarımsal su pompalamalarında rüzgar enerjisinin aktif kullanımı üzerine bir çalışma yapılmıştır. Şehrin rüzgar enerjisi, su pompalama sistemleri ve rüzgar verileri üzerine yapılan çalışmalar analiz edilmiştir. Bu analizler kullanılarak elde edilebilecek çeşitli rüzgar kuvvetlerine bağlı olarak su pompalama kapasiteleri Visual Basic 6.0 bilgisayar programı ile hesaplanmıştır.

Anahtar Kelimeler: Yenilenebilir enerji, Su pompalama, Bilgisayar programları, Rüzgâr türbinleri, Tarımsal sulama.

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1. Introduction

One of the most fundamental elements of the economic and social development of countries is energy [1]. Demand for energy will continue to increase in the future. Compared to today, in 2030; energy consumption rate in the world and Turkey are expected to increase [2]. It is known that fossil fuels that meet most of the current energy need will be exhausted in the coming years [3]. The need for energy resources is increasing day by day. The demand for energy is increasing every year due to the increase in population, the development of industrialization, the increase in the welfare level of people, and technological developments. Wind energy is preferred because it is a renewable energy source. Decreasing of fossil fuels, negative effects of such fuels on the environment and increasing costs; increased the use of alternative and natural energy sources [4]. It is not a new phenomenon that mankind started to benefit from wind energy, which has an important place among renewable energy sources. Utilization of wind power; first of all sailing ships and windmills, then grain grinding and pumping of water, etc. were used in systems. B.C.17. At the beginning of the century, during the Hammurabi King of Babylon; Wind energy used for irrigation in Mesopatamia; It is known that it was also used in China in the same period. Windmills were first established near Alexandria [5]. In countries such as America, Russia, and Australia, the population of which is spread over a wide area, wind energy; it was used by farmers to extract water [6]. Despite the completion of the European Wind Atlas, studies for determining wind potential for stations not included in this study are still in progress [7]. Wind potential determination studies are also conducted in countries other than developed countries. Studies conducted for Nigeria, Morocco, India, Greece and Cyprus indicate that wind energy can be utilized adequately [8-12]. In the studies carried out by Electrical Works Survey Administration, Bandırma, Antakya, Kumköy, Mardin, Sinop, Gökçeada, Çorlu and Çanakkale were identified as rich regions in terms of wind energy[13]. Additionally, local wind potential determination studies such as Bandırma, Bozcaada, Çeşme, Gökçeada, Çanakkale, Karadeniz Ereğlisi, Florya and Siverek have also been conducted [14-18]. In Turkey, wind energy investment was first held in Çeşme in 1998 (8.7 MW). In 2000, a wind energy investment of 10.2 MW was made in Bozcaada [19]. However, as a result of the increase in the population and the developments in the industry, interest and investments in wind energy are increasing in geographically suitable regions in order to increase the electricity production needed by the countries.

As a result of the new investments made; By the end of the year 2011 in Turkey, with 1806 MW of installed wind power, 2312 MW in 2012, the year 2013 has also reached 2604.1 MW [20]. However, intense population growth, as in other developing countries, in Turkey again; The efforts to increase industrialization and support investments for the development of technology are increasing the energy demand day by day. Turkey, 72% of the energy supply is provided from outside [21].

Renewable energy sources continue to become widespread worldwide with increasing electrical energy demands and environmental concerns arising from meeting these demands with conventional energy sources. Among these sources, wind turbines and wind farms are the most used renewable energy sources today, as they have higher power generation capacities and lower operating costs compared to other sources. According to the reports of the end of 2016, wind energy has reached approximately 500 GW worldwide with an average increase of 21% in the last decade [22]. With wind energy, electricity generation, water pumping etc. for operations, the average wind speed and regional energy potential must be determined. During the mechanization of agricultural production, direct energy is used. However, in order to prevent environmental problems arising from the use of fossil fuels effectively, it has become necessary to use renewable energy sources in the agricultural sector [23]. Agricultural irrigation in Turkey; It is carried out using water pumps operating with conventional energy sources such as electricity, diesel oil or oil. Diesel and oil pumps are used in agricultural areas that are not electricity or difficult to take electricity and expensive [24].

The main method of providing water for irrigation is the transmission of water between the water source and the irrigated field. This movement of water requires energy. All of the mechanical tools and equipment used for the transmission of water between the source and the field constitute the pumping plant. The design, selection, installation, operation and maintenance of the pumping plant includes important engineering issues. If wind energy is used as a renewable energy source for agricultural irrigation, the production costs will decrease along with the irrigation expenses, which have a large place in total production expenses. Due to the high cost of energy obtained from fossil fuel energy sources, it has become important to use renewable energy sources for agricultural irrigation. Different power sources such as human energy, animal power, wind, solar and fossil fuels have been used in the methods used for pumping water in the past centuries [25].

In water extraction from the underground with wind energy; Turbines with high blades can be used efficiently and economically in water pumping. Underground water can be extracted using the pump and by using the power of the wind. Since wind energy is an intermittent energy source, it is used with storage systems to meet the water demand continuously. In practice, water pumping time at 4 m / s to 7 m / s wind speeds is estimated to be 6–8 hours on average [26]. Wind energy, which is also used in agricultural irrigation, can be used efficiently in active land irrigation operations through systems called wind pumps.

Turkey Electrical Works Survey Administration's mechanical wind energy water pumping system is located. These systems, which are on a pole with a 6 m high steel rope, are 6 bladed and with the help of a suction compression pump; It can be flooded from a maximum depth of 7 m to a height of 5 m. The system starts pumping water at a wind speed of 3 m / s. This system has been installed in the Renewable Energy Resources Park of the Electrical Works Survey Administration. In addition, wind water pumping system was designed and manufactured by Electrical Works Survey Administration. The rotor diameter of this system is 2 m, the number of blades is 16, the diameter of the piston is 10 cm, the stroke is 32 mm and the pumping height is 4 m. This system installed in Didim (Aydın) Solar and Wind Energy Research Center can pump 5.3 m^3/ day water at a wind speed of 3 m / s [27]. According to Turkey's wind map, Turkey's top wind field regions; Marmara is the Southeastern Anatolia and Aegean region (Table 1). Wind Power Potential Map of Turkey (WPPM) in Figure 1 are given.

Table 1. Turkey's wind energy potential in different regions [28]

Region	Average Annual Wind Speed (m/s)	Annual Average Wind Density (W/m^2)
Marmara Region	3,29	51,91
Aegean Region	2,65	23,47
Mediterranean Region	2,45	21,36
Central Anatolia Region	2,46	20,14
Black Sea region	2,38	21,31
Eastern Anatolia Region	2,12	13,19
Southeastern Anatolia R.	2,69	29,33
Average	2,58	25,82

In terms of producing wind energy, the average wind speed is; 6.5 m/s is considered as 'medium level', 7.5 m/s is 'good' and wind at 8.5 m/s is considered 'very good' [29]. For an economical wind power plant investment, the wind speed must be higher than 7 m/s [30]. Under this wind speed, electricity cannot be produced economically. For this reason, wind turbines are built in areas with an average wind speed of more than 7 m/s. When Wind Power Potential Map of Turkey (WPPM) examined (Figure 1), it consists of two types of turbines as a horizontal or vertical axis. The most used ones are the ones with horizontal axis. These turbines can be 1,2,3 or multi-bladed. They are called wind turbines from the front and back. Today, most of the electrical power generation applications in various countries are turbines with 2 or 3 blades, horizontal axis and front wind [30].

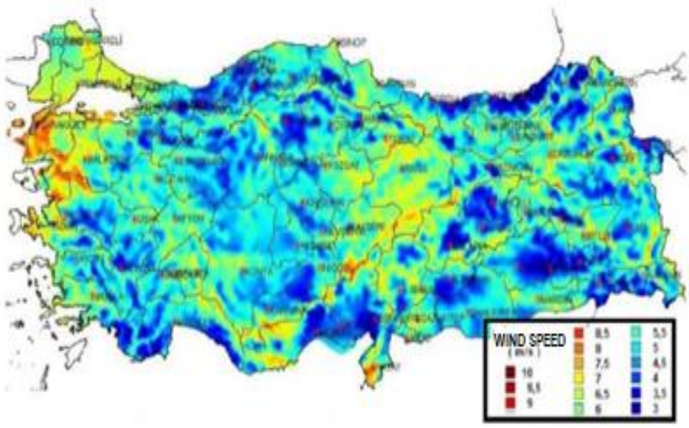

Figure 1. Wind power potential map of Turkey (WPPM) [31]

Horizontal Axis Turbines; These types of turbines work with their rotational axes parallel to the wind direction and their blades perpendicular to the wind direction. Such turbines are brought to this position by rotating them on the rotor tower [32]. The movement of the horizontal axis turbines on the tower in the direction of the horizontal axis is provided by a guide tail in the parts that see the wind and the conical angle created in the parts that see the wind from behind (Figure 2). Vertical Axis Turbines; The blades of these turbines whose rotational axes are perpendicular to the wind direction and are vertical are also vertical. These turbines have the advantage of taking the wind from all directions. In order for the wings to produce power; Since they have to spin faster than the wind, their first move is not safe (Figure 3).

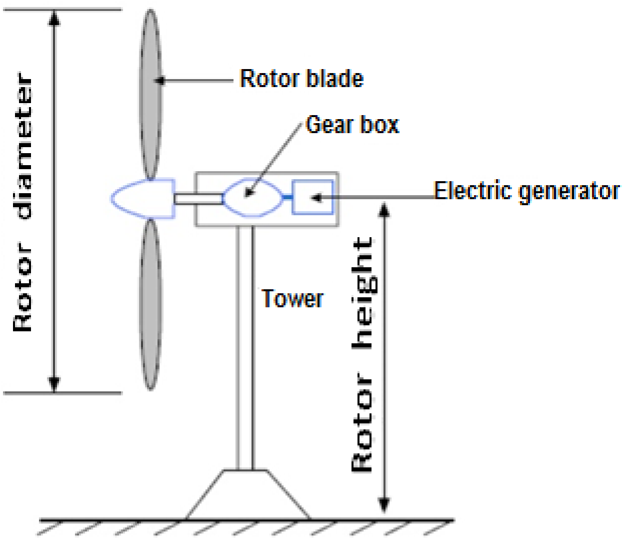

Figure 2. Horizontal axis wind turbine [32]

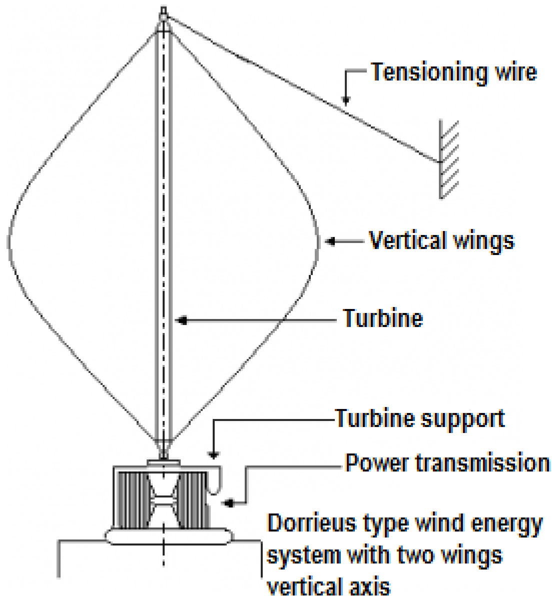

Figure 3. Vertical axis wind turbine [33]

Wind turbine is a system that converts kinetic energy in wind to mechanical energy and then to electrical energy [34]. A wind turbine generally consists of the tower, generator, speed converters (gearbox), electrical-electronic elements and propeller. The kinetic energy of the wind is converted into mechanical energy in the rotor. The rotational movement of the rotor shaft is accelerated and transferred to the generator. The electrical energy obtained from the generator is stored by means of batteries or delivered directly to the receivers [34]. Wind turbines are classified according to their rotational axes, revolutions, powers, blade numbers, wind effect, gear characteristics and installation locations.

Use of wind energy in agricultural activities. One of the most important issues in agricultural production is energy use. Especially with the widespread use of mechanization in agriculture, the increase in agricultural production further increased the need for energy use [35]. Especially diesel fuel and electricity are the most used energy types in agriculture. Wind energy is a resource that can be used in regions with agricultural activities as well as being clean, abundant and renewable energy. Wind energy has many uses in agriculture such as electrical applications, greenhouse air conditioning, irrigation and drainage applications, heat pump applications, cooling applications and wind mill facilities. In situations where sufficient wind speed is available, the energy requirement needed in the agricultural sector can be met easily through windrose turbines used in small farms and wind turbines that respond to larger energy needs [36]. For example, diameter of a 10 KW wind turbine is 550 mm. Due to the small projection of the turbines, it does not affect agricultural activities and productivity [37]. Today, wind turbines can generate electricity for a few cents per kilowatt hour and compete with the unit production cost of fossil fuel power plants [38]. It can serve many agricultural processes that are needed in the use of mechanical energy, such as electrical power generation with small wind systems, pumping of water, or grain grinding. In the agricultural areas, the energy production costs decrease considerably by means of the windrose turbines to be installed in each farm or settlements and such systems to be installed in areas remote to the transmission lines are economical in all aspects [39]. Irrigation water in agricultural production increases costs especially in regions where water is extracted from underground by water engines. In such cases, with the help of wind energy; The water is extracted through the pump placed in the underground waters [40]. In cases where the wind speed is on average 4-7 m / s, the water pumping time is around 6-8 hours [41]. In addition, with the energy obtained from wind turbines, the electricity needs of small farms can be met [42,43].

In this study, the use of wind energy systems in agricultural irrigation was investigated in order to evaluate the wind energy potential in Sinop province. For wind energy irrigation system (various pumping heights); necessary calculations were made with Visual Basic 6.0 computer program.

2. Material and Method

The wind data used in this study was measured and recorded hourly at a height of 10 m above ground level at the State Meteorological Service Sinop province station between 2005-2014. Sinop is located between 41 ° 12 'and 42 ° 06' north latitudes and 34 ° 14 'and 35 ° 26' east longitudes in the middle of the Black Sea region. Figure 4 gives the location of Sinop province.

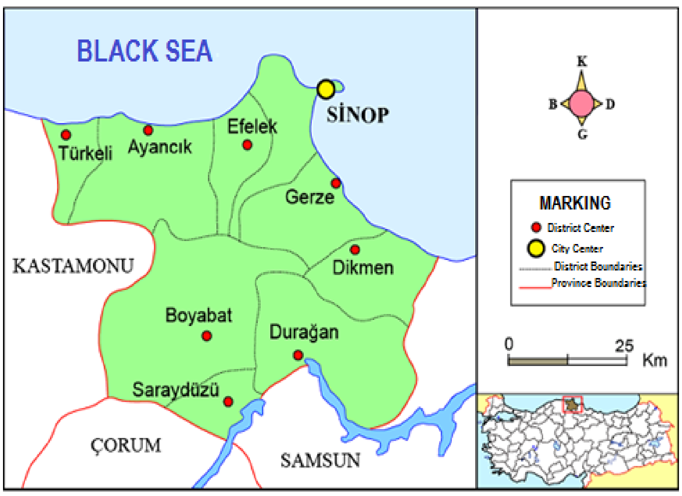

Figure 4. Location of Sinop on Turkey Map[44]

The annual average temperature of the districts on the coastal part of Sinop varies between 13-15 ° C and 12-14 ° C in the inland settlements. The seasons do not have much difference in temperature. In the coastline, the dominant wind direction is north west (karayel) and the average annual wind speed is 3,5 m/s. In places far from the coastline, the dominant wind is west-oriented, and it is slightly lighter than the coastline, with an average of 1 m/s and 2 m/s. The population of Sinop province is 204,133 [45]. In Table 2, power capacities based on wind speeds of 50 m height in Sinop province are given. For the economic Wind Power Plant investment planned to be established in a place, the speed of the prevailing wind must be at least 7 m/s or more in that place. As can be seen in Figure 5, WPP can be said to be an economic investment since the dominant wind speed in Sinop is between 6,8 m/s and 7,5 m/s.

Table 2. Wind power plant power capacity that can be installed in Sinop province [46]

WindPower(50m) (W/m^2)	WindSpeed(50m) (m/s)	Total Area (km^2)	Total Power Capacity (MW)
300-400	6,8-7,5	289,63	1448,16
400-500	7,5-8,1	8,59	42,96
500-600	8,1-8,6	0,00	0,00
600-800	8,6-9,5	0,00	0,00
>800	>9,5	0,00	0,00
Total		298,22	1491,12

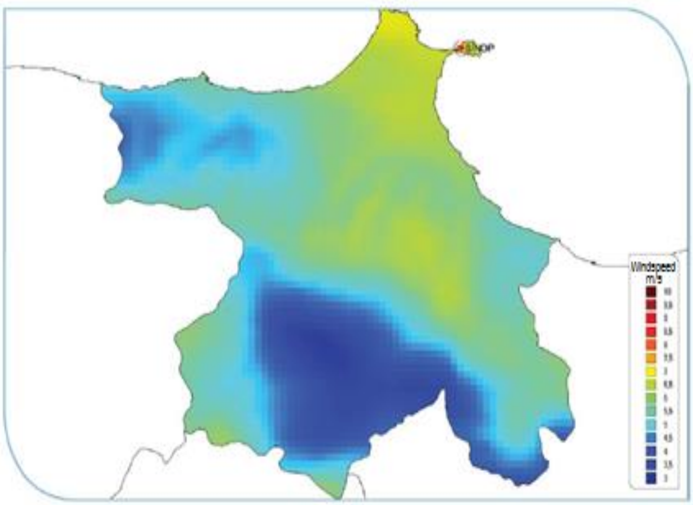

Figure 5. Wind speed distribution of Sinop province (50m) [47]

Coordinates whose wind data are taken into consideration in the study; 42.0025513345238 north latitude, 35.0127371674451 east longitude, a point in Dibekli village of Sinop province, central district was determined. This point is 78 m above sea level and its direction is north west. The priority process in the selection of Wind Power Plant turbines is to determine the dominant wind direction belonging to that place. The dominant wind direction in Sinop is 150º; 300º in June and August only; It is 330º in July (Figure 6). The east of Sinop is limited to the high plains of Boztepe peninsula; the west is surrounded by the skirts of Küre Mountains [47].

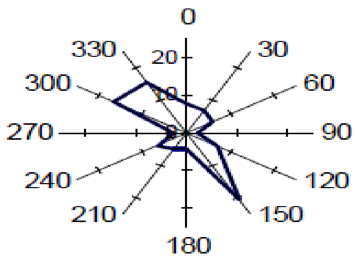

Figure 6. Dominant wind direction in Sinop [48]

Wind Pumps and System components. Wind energy water pumping systems are the systems used for pumping water to certain heights and storing the pumped water by making use of the existing wind energy in the region. Wind energy pumping systems generally include multi-blade rotor, piston water pump, gearbox, storage tank and auxiliary mechanisms. As a principle of operation, it transmits circular motion to the rotor gearbox, which starts rotating at various wind speeds.After the speed is increased in the gearbox or the same speed is turned into a linear motion, the piston of the piston pump in the water source is moved up and down.In the meantime, the water in the source is transmitted to the storage tank through the clapper system on the piston pump and the up and down movements of the piston. The variation of the water obtained over time is directly proportional to the wind speed, and in order for these systems to operate, the wind speeds must be above 3 m/s. A system diagram of multi-vane wind pumps is shown in Figure 7, and an example of piston pumps used in the system is shown in Figure 8.

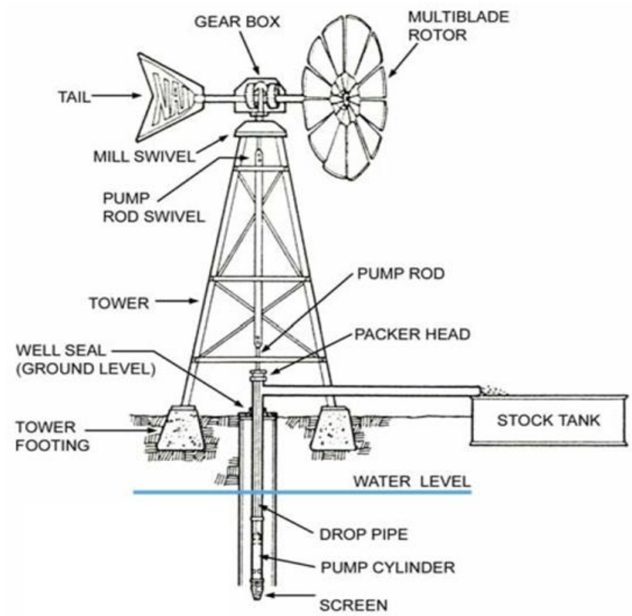

Figure 7. Components of a multiblade windmill for pumping water wind energy potential[49]

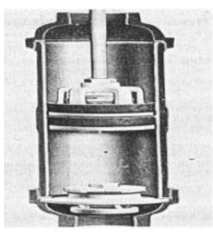

Figure 8. Diagram of piston pump(courtesy of dempster industries, beatrice, Nebrasca) [50]

Electrical Power Resources Survey and Development Administration as a result of measurements made by the Authority obtained and shown in Table 3. The Sinop monthly wind average monthly wind energy value with Visual Basic 6.0 program utilizing data are calculated. The following tables and equations are used to calculate monthly water pumping amounts according to the wind energy values and features that can be changed from the wind pump program menus.

Table 3. Average monthly wind speed of Sinop city (m/s) [51]

Months	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Average	4,3	4,5	4,7	4,9	5	5	4,5	4,1	4,2	4,4	4,6	4,4

During the movement of the piston of the wind pump, the equations that give the amount of water absorbed and transmitted to the tank are as follows [50]. In these equations, the amount of water pressed in one revolution of the D wind pump rotor, Ap piston cross-sectional area, Lp piston stroke length (stroke),   wind pump shaft speed in 1 second, dp piston diameter, the amount of water obtained in Qp system losses, s piston pump is the coefficient of loss and s = 0.03 or 0.05 is taken.

$$D = A_P . L_P . f \ (m^3 / s) \tag{1}$$

$$A_P = \pi \frac{(d_P)^2}{4} \ (m^2) \tag{2}$$

$$Q_P = D.(1-s) (m^3 / s) \tag{3}$$

In wind energy systems, the number of wings differs according to the usage purposes of the system.Generally, electric power generating wind turbines are single blades, two or three blades, while water pumping systems are 6-8 blades or more. While few blades are used in high speed wind systems, many blades are used in low speed wind turbines. Therefore, there is an inverse proportion between the wind speed coefficient and the number of wings. Speed coefficients of different wing numbers are shown in Table 4 [52].

Table 4. The relationship between the number of wings and the speed coefficient [52]

Number of wings	Speed coefficient (λ)
8-24	1
6-12	2
3-6	3
2-4	4
2-3	5

Various wing numbers, wind speed, rotor radius etc. Equations used in calculating the amount of energy that can be obtained from wind turbines according to the system features such as:

$$\lambda = Vç / V \tag{4}$$

$$V_Ç = V \, . \, \lambda \; (\mathrm{m/s}) \qquad (5)$$

$$L_Ç = 2 . \pi . r \; (\mathrm{m}) \qquad (6)$$

$$n_R = V_R / L_Ç = f \; (\mathrm{cycles/s}) \qquad (7)$$

$$A_R = \pi . r^2 \; (\mathrm{m}^2) \qquad (8)$$

$$P_R = \frac{1}{2} . \rho . A_R . V^3 . C_P \; (\mathrm{watt}) \qquad (9)$$

Here r rotor radius V velocity coefficient, Vç rotor circumferential speed, V regional wind speed, Lç rotor circumference length, NR rotor speed, power that can be obtained from PR turbine, AR rotor sweep surface area, PP air density, Cp is the power factor of the system. The system power factor is used as approximately 0.35 for multi-blade wind pumps [50,52]. By means of the program written, the height and flow rate of the wind pump, which will be used for pumping water, is calculated according to the monthly wind data of Sinop. By means of the program prepared, the results can be obtained according to the months by entering the rotor radius, number of blades, piston diameter of the piston pump to be used in the system and the progression length values of the wind pump. As can be seen from the program, the change of each system element affects the flow and the height values at which it can extract the water. Through the program written; The results obtained according to various blade number, rotor radius, piston stroke length and piston diameter values are given in Figure 9, Figure 10, Figure 11 and Figure 12.

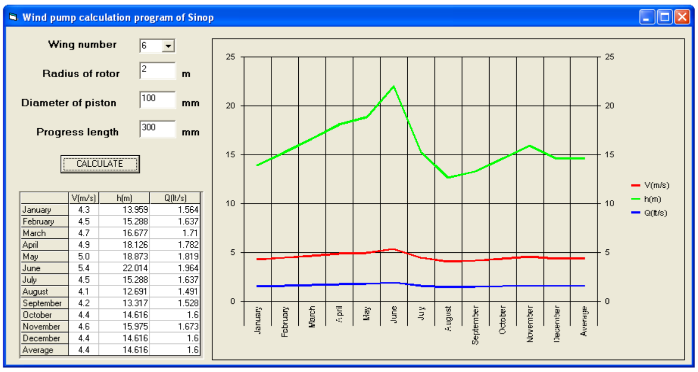

Figure 9. Sinop province wind pump selection program and system variables screenshot

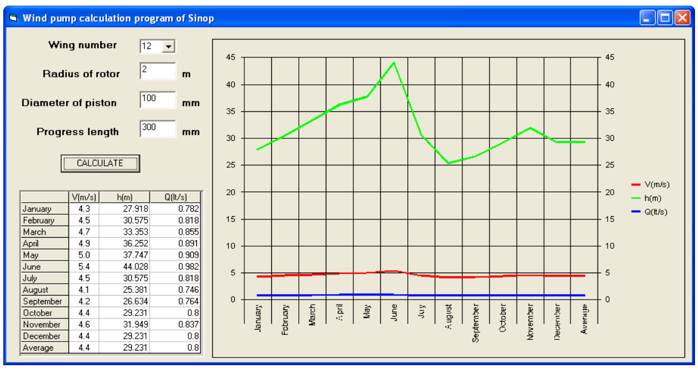

Figure 10. Sinop province wind pump selection program and system variables screenshot

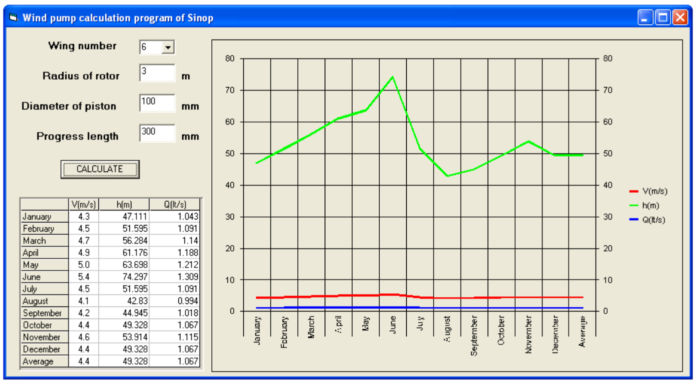

Figure 11. Sinop province wind pump selection program and system variables screenshot

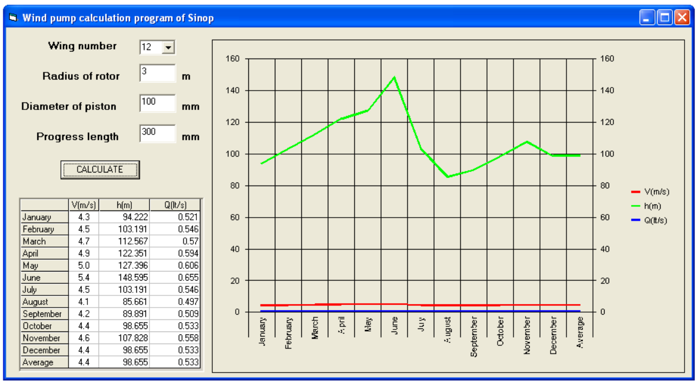

Figure 12. Sinop province wind pump selection program and system variables screenshot

4. Conclusions and Recommendations

With this study, in order to prevent environmental problems arising from direct or indirect use of fossil fuels and to ensure sustainable development; It aimed to emphasize the need for renewable energy sources in the agricultural sector. In this context, solution suggestions have been brought to provide rural development by providing renewable energy sources that can be used in the agricultural sector, ensuring environmental quality, increasing employment in rural areas and increasing the welfare of the local population. In agricultural production, especially in regions where irrigation water is extracted from underground by electric or diesel engines, energy costs are an important burden on farmers economically and increase production costs. The use of wind energy systems, which are generally used for electricity generation, in agricultural irrigation areas is of great importance. A program has been written for farmers to calculate various pumping heights in agricultural irrigation, according to the use of wind energy systems in the province, by considering the monthly average wind speeds of Sinop. At various monthly wind speeds written and tested through Visual Basic 6.0 computer program; By entering the technical data of the wind pump, the amount of water that can be transmitted to certain heights is calculated in lt/s. When the results of June, which is the highest wind speed average, are analyzed; It has been observed that the system with 6 blades, rotor radius of 2 m, piston diameter and course length of 100 mm and 300 mm respectively can deliver water at a flow of 1,964 lt / s to a height of 22,014 m. When the number of blades was selected as 12 for the system with the same feature, it was observed that the pumping height value increased to 44.028 m and the flow rate decreased to 0.982 lt/s. When the rotor radius is 3 m, the pumping height for the 6-blade rotor is 74.297m, the flow is 1.309 lt / s, the number of blades is increased to 12 in the same system; While the pumping height increases to 148.595 m, the flow rate decreases to 0.655 lt / s. As can be seen from the results; Through this program developed for Sinop province, it has been observed that the increase in the number of wind pump blades in the selection of wind pump components increases the pumping height and decreases the water flow value. In such systems, in order to increase the water from the depths of the soil layer to higher points; Increasing the rotor radius and wing number of the system is an important criterion and it is important to store it in the water tank, which is a part of the system in the pumped water, and use it when necessary. As a result, the design and assembly processes of wind turbines, which are one of the most important factors of electricity generation from wind energy, are extremely important. The development of this study is of great importance. Agricultural irrigation systems with wind energy system should be started as soon as possible, and farmers should be made conscious and encouraged. Study, the use of wind energy systems in agricultural irrigation was investigated in order to evaluate the wind energy potential in Sinop province. For wind energy irrigation system; necessary calculations were made with Visual Basic 6.0 computer program.

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