Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. III, 2014
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, ISSN-L 2285-6064

THE DETERMINATION OF WIND-POWERED IRRIGATION POTENTIAL IN TURKEY

Onur TAŞKIN[1], Gülşah ÜĞLÜ[2], Hakan BÜYÜKCANGAZ[1], Ali VARDAR[1]

[1]Department of Biosystems Engineering, Faculty of Agriculture, Uludag University, 16059 Bursa/Turkey
[2]Ataturk Central Horticultural Research Institute, 77102Yalova/Turkey

Corresponding author email: onurtaskins@gmail.com

Abstract

Irrigation is considered a common need for agricultural production in all around the world. Instead of the high priced fossil fuels, wind-powered agricultural irrigation is an alternative usage of renewable energy in Turkey. However, it is necessary to be researched technically and economically before the implementation. In this paper; crop types, geographical frame, and groundwater quantity were taken into consideration in the context of technical feasibility. A cost analysis was done by consideration of the costs of water storage tanks, wind turbine, and pump as an economic feasibility study. The results of feasibility study provided that there is enough irrigation potential based on wind power in Marmara, Aegean and East Mediterranean regions. The increase in wind-powered irrigation will optimize the agricultural water use and preserve the environment from adverse impacts of greenhouse gases.

***Key words**:Wind Energy, Irrigation, Groundwater.*

INTRODUCTION

History for utilization from wind power goes to the ancient times. The wind power was used for irrigation in Mesopotamia, drying of polders in the Netherlands and the removal of groundwater accumulated in mines from Roman period and reuse for agricultural purposes. In addition, it was also exploited as a mechanical strength, running of water pumps and water abstraction for domestic and agricultural water use (Doganay, 1991).
Gradual increase in energy consumption due to the global increase in population and urbanization movements in parallel to the developing industry and advancing technology force people to search for new and environment friendly energy sources. On-time, economic, safe, constant and clean energy procurement has become one of the most important problems of the day when energy requirement has increasingly more significant. As to the aforementioned importance of energy, the gradual increase in the demand towards energy causes fossil energy sources to be rapidly consumed (Akova, 2011). Besides, fossil fuel power is a major contribution to carbon-based climate change and air pollution. In addition, rising fossil fuel costs and energy self-sufficiency have made the development of viable sources of clean energy critical for many parts of the world (Kelley et al., 2010).
Irrigation water pumping is one of the most important direct commercial energy end use in agriculture. Groundwater is used for the irrigation needs via by pumps. The present contribution of groundwater to irrigation is very high in terms of area. For irrigation purposes, the water is lifted by traditional means or lifted by diesel and electric pump sets. Diesel and electricity are commonly used for meeting irrigation energy demand in the country. There were reportedly 186 503 electricity driven pumps and 194 776 diesel pumps in operation in the agriculture sector in the year 2012 (Tuik, 2013). For better exploitation of the groundwater potential to meet the increasing irrigation water demand more and more wells would be dug and energized thus increasing the demand of electricity.
In view of the increasing global climate change concerns, interest in the development and dissemination of renewable energy technologies has again been renewed (Kumar and Kandpal, 2007). Wind-powered pumping

for irrigation has been suggested as an application, as it is an energy intensive activity that is well suited for implementation with renewable energy sources. However, to be practical, wind-powered irrigation, like all alternative energy applications, must be both technically and economically feasible. For irrigation, this feasibility is dependent on many factors, such as wind speed data, groundwater resources, irrigated land and crop pattern, unit cost of irrigation water, cost of wind turbine devices, and pumps.
In this study, we are going to match the wind power and groundwater potential of Turkey. The wind-powered water pumping systems offer the appropriate solution to supply water for irrigation in remote regions.

MATERIALS AND METHODS

Wind Energy Potential in the Turkey

The territory of Turkey is more than 1 600 kilometers long and 800 km wide, with a roughly rectangular shape. It lies between latitudes 35 and 43 N, and longitudes 25 and 45 E. Turkey's area occupies 783 562 square kilometers, of which 755 688 square kilometers are in Southwest Asia and 23 764 square kilometers in Europe. Turkey is the world's 37th-largest country in terms of area. The country is encircled by seas on three sides: the Aegean Sea to the west, the Black Sea to the north and the Mediterranean to the south. Turkey also contains the Sea of Marmara in the northwest (Wikipedia, 2013).
Turkey’s wind energy potential can be calculated as such: we can assume that the area of Turkey is 783 562 Km^2. 783 562 hectares of land would be used, if only 1 pct (international standard, 0,5 pct for Europe) of the overall area will be opened to wind energy production. Considering overall 77 600 turbines would be used for 10 hectares of land (technical standard), a turbine of 1 MW capacity produces around 2 500 000 - 3 000 000 kWh of energy annually. This would amount to overall 200 billion kWh of energy production (Akin and Zeybek, 2005). An economic RES investment requires wind speed of at least 7 m.s^{-1} (Caliskan, 2011).When considering the wind speeds higher than 7 m.s^{-1} at 50 m high from the sea level in a country-wide examination, the highest wind potentials are available in Marmara, Aegean and Eastern Mediterranean regions as it is indicated in Figure 1 (Altuntasoglu, 2011).

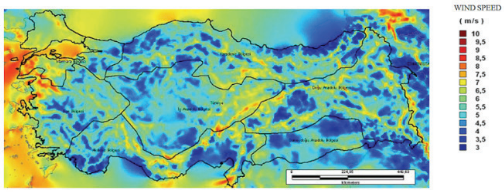

Figure 1. The Distribution of Average Wind Speed (Caliskan, 2011)

The Amount of Groundwater Resources

The water potential of countries emerges from latitude, longitude, geological and topographical frame and also climatic (rainfall) conditions (Bilgin, 1997; Ozguler, 1997). Annual water potential of Turkey was calculated under technical and economic considerations.
In Turkey, the arithmetical average of annual precipitation (80 years data) is 643 mm, ranging from 250 mm in the southeastern part of the country to over 3000 mm in the northeastern Black Sea coastal area. This average annual precipitation figure for Turkey corresponds to an average of 501 km^3 of water per year. Of 501 km^3 of annual precipitation, 274 km^3 is assumed to evaporate from surface and transpire through plants. Out of the remaining 227 km^3 average annual precipitation, 69 km^3 is lost to deep seepage and, therefore, represents a direct recharge to local aquifers, whereas 158 km^3 forms the precipitation runoff. Since it is estimated that a net 28 km^3 of groundwater feeds the rivers, average annual surface water potential is 186 km^3, with the surface runoff of 7 km^3 coming from neighboring countries, total surface runoff within the country reaches 193 km^3. Exploitable portions of surface runoff and groundwater are 98 and 12 km^3, respectively. Thus, the total of exploitable water resources amount to 110 km^3 (Burak et al., 1997; Buyukcangaz et al., 2007;Ozis et al., 1997).
Marmara, Aegean, and Eastern Mediterranean regions which are rich in terms of wind power potential are also well-endowed with

groundwater resources (Figure 2). Away from the coast, wind potential is descending and groundwater potential is also decreasing in Aegean region. The main reason for that is mountains lies parallel to the coasts.

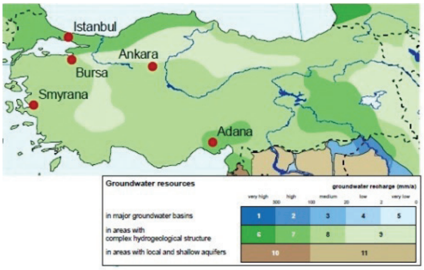

Figure 2. Groundwater Resources of Turkey (Whymap, 2008)

How much water do we need for agricultural production?

Agriculture is major water user in Turkey. Of all freshwater diverted forhuman use in Turkey, industrial and household usesaccount for 12 % and 16 %, respectively, while irrigatedagriculture consumes on average around 72 % andmuch more in specific locations (State Hydraulic Works, 2014). Therefore, exploitation of tools and techniques aiming efficient water use in agriculture would be a major priority amongst many others. More agricultural production may be achieved by environmental-friendly advanced irrigation technologies using less water and manpower. Sustainable use of country's natural resources would only be possible by planning and design of optimal irrigation schemes regarding technical and economic considerations of the country.

Out of the agricultural area of 28 million hectares (mha), the total amount of irrigable land is 25.85 mha.The amount of irrigable land by existing water potential and irrigation technologies is only 8.5 mha (State Hydraulic Works, 2014). However, only a total of 5.5 mha has been equipped with irrigation in Turkey. Although the use of groundwater resources in irrigation is less compared to surface water use, farmers tend to use groundwater resources in meeting water needs of the crops when there is water shortage in surface water resources. There is a tremendous effort by government to raise the total amount of irrigated area throughout the country. The production of high valued crops is also aimed by the extension of irrigation services in Turkey.

Although realized crop pattern in Turkey does not match with planned crop pattern in irrigated areas, there is a huge potential in agricultural production. Spatial distribution of agricultural crops was given by Turkish Statistical Institute (TUIK) based upon 2012 data. Tables 1-3 indicate major crops and their water needs in selected regions (Turkish Statistical Institute, 2012).

Table 1. Monthly net irrigation required (mm) for fully irrigated crops in Marmara region

Month	**Crops**			
	Wheat	**Barley**	**Maize**	**Tomato**
Jan	35.9	35.9		
Feb	39.4	39.4		
March	58.5	58.5		
April	107.5	107.5	52.9	
May	183.2	183.2	80.9	63.0
June	170.8	170.8	164.3	113.0
July	33.5	33.5	292.2	163.0
Aug			193.1	165.0
Sept			84.8	110.0
Oct	32.1	32.1		19.0
Nov	49.5	49.5		
Dec	36.9	36.9		
Totals	**747.3**	**747.3**	**868.2**	**633.0**
L/h/ha	2462.4	2462.4	3927.4	2217.7

Table 2. Monthly net irrigation required (mm) for fully irrigated crops in Eagen region

Month	**Crops**			
	Wheat	**Grape**	**Maize**	**Chickpea**
Jan	16.5			
Feb	25.7			
March	46.5			
April	85.6	66.8		
May	156.2	105.6	84.5	
June	143.0	140.2	155.8	74.8
July	29.5	172.2	200.9	127.6
Aug		196.9	186.7	91.8
Sept		65.6	120.5	
Oct	27.7	41.0		
Nov	30.6			
Dec	22.3			
Totals	**583.6**	**788.3**	**748.4**	**294.2**
L/h/ha	2099.5	2700.3	2646.5	1715.05

Table 3. Monthly net irrigation required (mm) for fully irrigated crops in East Mediterrenaen region

Month	**Crops**			
	Wheat	**Maize**	**Cotton**	**Orange**
Jan	48.0			28.0
Feb	61.0			32.0
March	100.0			54.0
April	146.0		66.0	80.0
May	161.0	94.0	117.0	79.0
June		174.0	158.0	114.0
July		183.0	233.0	129.0
Aug		215.0	144.0	125.0

Sept		137.0	75.0	104.0
Oct			44.0	76.0
Nov				49.0
Dec				35.0
Totals	**516**	**803**	**837**	**905**
L/h/ha	2164.0	2889.8	3131.7	1733.9

When the Tables 1-3 and the crop patterns reviewed, irrigation water is mostly needed for maize production in July in Marmara, grape production in August in Aegean, and cotton production in July in Eastern Mediterranean regions.

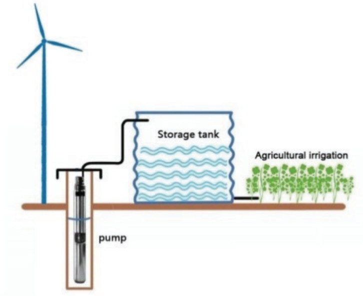

Figure 3. Wind-Powered Irrigation System

Pump and wind turbine selection

The affordability of energy sources is of major concern in utilizing them in agricultural sector. In recent years, solutions for employment of affordable and environmental friendly energy sources have been sought against environmental pollution and increasing energy costs. These conditions dictated the new search on alternative energy sources. Although they were neglected for long time, wind and solar energy potentials are really high considering geological and geographical characteristics of Turkey.

Irrigation is one of the most energy consuming processes in agricultural production phases. Some considerations such as needed time for irrigation, water supply status, amount of water needed, the depth of wells and water storage tank capacity should carefully be examined when the wind energy is employed in agricultural irrigation.

The power generation of a wind turbine at different wind speeds is determined by following equations (Shata and Hanitsch, 2006; Ilinca et al., 2003).

The effective parameters are air density, rotor cross-section area, wind speed, rotor power coefficient of wind turbine and mechanical efficiency. A circular shaped rotor cross section is related with the diameter of rotors (Piggott, 2004).

$$P = 0{,}5 \cdot \rho \cdot A \cdot v^3 \cdot C_P \cdot \eta \quad (1)$$

$$A = \frac{\pi \cdot D^2}{4} \quad (2)$$

In these equations;

v : Wind speed, m/s
P : The power of wind turbine, kW
ρ : Density of air, 1,225 kg/m^3
A :Rotor cross-section area of wind turbine, m^2
D : Rotor diameter of wind turbine, m
C_P : Ideal power coefficient of rotor
η : Mechanical efficiency of wind turbine.

Technical specifications of different pumps which were examined in this research are given in Table 4.

Table 4. Specifications of Pumps (Grundfos, 2013)

Model	Engine Power (kW)	Capacity							
		lt/h	1000	1800	3600	5400	7200	9000	10800
4SP8/5	0.75	Head (m)	30	28	26	24	21	17	12
4SP8/7	1.1		42	39	36	33	29	24	17
4SP8/10	1.5		60	55	51	48	42	35	24
4SP8/15	2.2		90	84	78	72	65	54	36
4SP8/18	3		108	100	93	85	76	63	44
4SP8/25	4		150	140	130	117	105	86	60

System Cost

Initial cost consisting water tank (5 tones), wind turbine with 10 kW, and use of various pump combinations may be calculated as follows:

$$\text{Cost} = \text{Water Tank} + \text{Wind Turbine} + \text{Selected Pump} \quad (3)$$

RESULTS AND DISCUSSIONS

Wind power may be utilized as an alternative energy source based upon wind speed at area of wind turbine installation, water demands of agricultural crops and the elevation of which water needed to be raised.

Power created by a wind turbine with 10 kW will be varied upon speed of prevalent wind at the region (Table 5). Accordingly, this variation will impact the selection of the pump employed at the system. The amount of irrigable area will also be changed by selected pump and crop type. When considering the water obtained from 30 m deep water well to irrigate most preferred crops in the area of interest, the amount of irrigable area based upon different pump types and wind potential was given in Table 6.

Table 5. Power performances of wind turbine swith 10 kW at different wind speeds

Wind speed (m/s) h=50 m	Outlet power (kW)
6	***1.68***
6.5	***2.14***
7	***2.67***
7.5	***3.28***
8	***4***
8.5	***4.78***
9	***5.67***
9.5	***6.67***
10	***7.78***
10.5	***9***
11	***10***

High potential regions in terms of wind power and groundwater resources were matched by the feasibility study. Crop types, geographical frame, and groundwater quantity were taken into consideration in the context of technical feasibility. A cost analysis was done by consideration of the costs of water storage tanks, wind turbine, and pump as an economic feasibility study. As a result of calculations, initial system cost was estimated as 17 170 euros to irrigate maize at 5.5 hectares in Marmara, grape at 8 hectares in Aegean, and cotton at 6.9 hectares in Eastern Mediterranean Regions at optimal conditions.

CONCLUSIONS

Wind power potential which was neglected at past is recently becoming current issue due to energy shortage experienced in Turkey. Various methods were developed to encourage the exploitation of wind power in recent years. Wind energy seems to be a reasonable option to satisfy the energy demands of agricultural sector. Particularly, farmer income is getting down due to increasing fuel cost in agricultural irrigation. Irrigation practices with renewable energy technologies should be disseminated by extension to the farmers to eliminate negative economic conditions.

As a result of study, it can be stated that Marmara, Aegean, and Eastern Mediterranean regions of Turkey offer a suitable option for wind-powered irrigation practices instead of using high-cost pumps with diesel oils. Also, surplus of electrical energy produced by wind may be directed to the non-irrigational agricultural practices. Thus, this could improve the living conditions of the farmer with the help of the development of the local farming.

Table 6. Irrigable area by pumps (ha)

	Marmara (Maize)			Aegean (Grape)			Eastern Mediterranean (Cotton)		
	8 m/s	7 m/s	6 m/s	8 m/s	7 m/s	6 m/s	8 m/s	7 m/s	6 m/s
4SP8/5	0.25	0.25	0.25	0.37	0.37	0.37	0.32	0.32	0.32
4SP8/7	1.8	1.8	1.8	2.60	2.60	2.60	2.23	2.23	2.23
4SP8/10	2.4	2.4	2.4	3.5	3.5	3.5	3.03	3.03	3.03
4SP8/15	3.05	3.05	-	4.44	4.44	-	3.83	3.83	-
4SP8/18	4.58	-	-	6.6	-	-	5.74	-	-
4SP8/25	5.5	-	-	8	-	-	6.9	-	-

REFERENCES

Akin S., Zeybek O., 2005.Rüzgardan Elektrik Üretimi III. Yenilenebilir Enerji Kaynakları Sempozyumu 19-21.10.2005, Mersin.

Akova I., 2011. Development potential of wind energy in Turkey. EchoGéo16.

Altuntasoglu Z.T., 2011. Türkiye'de Rüzgâr Enerjisi, Mevcut Durum, Sorunlar. Mühendis Ve Makine Dergisi. Sayi: 617.

Bilgin R., 1997. Türkiye'de su sorunları ve çözüm önerileri. Meteoroloji Mühendisliği TMMOB Meteoroloji Mühendisleri Odası Yayın Organı. Sayı 2: 18.

Burak S., Duranyıldız İ., Yetis U., 1997. Ulusal Çevre Eylem Planı: Su KaynaklarınınYönetimi. Odak Noktası Kuruluş: Devlet Su İşleri Genel Müdürlüğü.

Buyukcangaz H., Demirtas C., Yazgan S., and Korukcu A., 2007. Efficient Water Use in Agriculture in Turkey: The Need for Pressurized Irrigation Systems, IWRA, Water International, Volume 32, Number 5, Supplemental Issue 2007.

Caliskan M., 2011 .Türkiye Rüzgar Enerjisi Potansiyeli ve Mevcut Yatırımlar. Rüzgar Enerjisi Ve Santralleri Semineri, İstanbul.

Doganay H., 1991. Enerji Kaynakları, Atatürk Üniv. Yay. No:707, Kazım Karabekir Eğitim Fak. Yay. No:18, Ders Kitapları Serisi No:13, ERZURUM.

Grundfos, 2013.Pompa Katalogları, Dalgıç pompalar. Url Adress: http://www.yakislar.net/yakis/UNAL-PDF/grundfos.pdf

Ilinca A., McCarthy E., Chaumel J.L., Retiveau J.L., 2003. Wind potential assessment of Quebec Province. Renewable Energy 28 (2003) 1881-1897.

Kelley L.C., Gilbertson E., Sheikh A., Eppinger S.D., Dubowsky S., 2010. On the feasibility of solar-powered irrigation. Renewable and Sustainable Energy Reviews 14, 2669–2682.

Kumar A., Kandpal T.C., 2007. Renewable energy technologies for irrigation water pumping in India: A preliminary attempt towards potential estimation. Energy 32, 861–870.

Ozguler H., 1997. Su, su kaynakları ve çevresel konular. Meteoroloji Mühendisliği. TMMOB Meteoroloji Mühendisleri Odası Yayın Organı Sayı 2: 57-63.

Oziş U., Durnabasi B.T., OzdemirI.Y., 1997. Türkiye'nin su kaynakları potansiyeli. Meteoroloji Mühendisliği. TMMOB Meteoroloji Mühendisleri Odası Yayın Organı. Sayı 2: 40-45.

Piggott H., 2004. Small Wind Turbine Design Notes, http://www.scoraigwind.com, Danimarka.

Shata A.S., Hanitsch R., 2006. Evaluation of wind energy potential and electricity generation on the coast of Mediterranean Sea in Egypt. Renewable Energy 31, 1183-1202.

State Hydraulic Works, 2014. Url Adress: http://www.dsi.gov.tr/toprak-ve-su-kaynaklari

Turkish Statistical Institute (2012). Url Adress: http://tuik.gov.tr

Whymap, 2013.Global Groundwater Maps. UrlAdress: http://www.whymap.org/whymap/EN/Downloads/Global_maps/globalmaps_node_en.html

Wikipedia, 2013.Geography of Turkey. UrlAdress: http://en.wikipedia.org/wiki/Turkey#Geography