TÜRK
TARIM ve DOĞA BİLİMLERİ
DERGİSİ

TURKISH
JOURNAL of AGRICULTURAL
and NATURAL SCIENCES

www.turkjans.com

Determining Energy Consumption of Sprinkler Irrigation for Different Crops in Konya Plain

[a]Duran YAVUZ*, [a]Ramazan TOPAK, [a]Nurcan YAVUZ

[a]Selcuk University, Faculty of Agriculture, Farm Structure and Irrigation Department. Konya-Turkey
*Corresponding author: dyavuz@selcuk.edu.tr

Received: 13.01.2014 Received in Revised Form: 27.04.2014 Accepted: 15.05.2014

Abstract

This study was conducted to determine the energy requirement of sprinkler irrigation established in different crops in Konya-Çumra irrigation district. The properties such as water resource, pumping unit, systems equipments, operation pressure, sprinkler's spacing of the sprinkler systems were investigated and determined with regards to crops. The results showed that sprinkler irrigation systems operated and planned in five different-forms when considered their water resources and pumping units. The research was conducted on totally 69 sprinkler systems. In study, diesel fuel or electric energy, equipment manufacture energy and labour energy consumption of the sprinkler systems were determined. According to results; in sprinkler irrigation systems induced moto-pomp, the annual energy consumptions of per unit area (1 ha) for diesel fuel, equipment energy and labour energy were found as 14107, 923 and 44 MJ ha^{-1} year^{-1} on average, respectively. In centrifugal pumping systems induced by power take-off shaft, these values were computed to be 21458, 3700 and 41 MJ ha^{-1} year^{-1}, respectively. In vertical axle pump system induced by power take-off shaft, the annual energy consumptions of per unit area (1 ha) for diesel fuel, equipment energy and labour energy were computed as 35748, 3873 and 40 MJ ha^{-1} year^{-1}. In vertical axle pump induced by electric motor, this values were calculated to be 35491, 1164 and 42 MJ ha^{-1} year^{-1} and in submersible pumping systems this values were computed as 38850, 1321 and 37 MJ ha^{-1} year^{-1}, respectively.

Key words: Sprinkler irrigation; Energy consumption, Irrigation pumps, Konya Plain

Konya Ovası'nda, Farklı Bitkilerde Yağmurlama Sulamanın Enerji Tüketiminin Belirlenmesi

Özet

Bu çalışma, farklı bitkilerde, yağmurlama sulamanın enerji tüketimine tespit etmek amacıyla Konya-Çumra sulama şebekesi alanında yürütülmüştür. Bölgede uygulanan yağmurlama sistemlerinin su kaynağı, basınç kaynağı, sistem elemanları, işletme basınçları, başlık tertip esasları gibi özellikleri yerinde inceleme ve gözlemler yapılmak suretiyle belirlenmiştir. Su kaynağı ve basınç kaynağı dikkate alındığında beş farklı yağmurlama sisteminin planlanıp işletildiği tespit edilmiştir. Araştırma bu beş grup dikkate alınarak toplam 69 yağmurlama tesisi üzerinde yürütülmüştür. Çalışmada, sistemlerin dizel yakıt veya elektrik enerjisi, ekipman üretim enerjisi ve işgücü enerji tüketimi belirlenmiştir. Elde edilen sonuçlara göre; yüzey su kaynaklarından sulama yapan yağmurlama sistemlerinde birim alana yıllık enerji tüketimi; dizel veya elektrik enerjisi, ekipman üretim enerjisi ve insan işgücü enerjisi olarak sırasıyla motopomplu sistemlerde; ortalama 14107, 923 ve 44 MJ ha^{-1} yıl^{-1}, kuyruk mili ile tahrik edilen santrifüj pompalı sistemlerde; 21458, 3700 ve 41 MJ ha^{-1} yıl^{-1} olarak hesaplanmıştır. Aynı değerler yeraltı su kaynaklarından sulama yapan yağmurlama sistemlerinden kuyruk mili ile tahrik edilen düşey milli pompalı sistemlerde; 35748, 3873 ve 40 MJ ha^{-1} yıl^{-1}, elektrik motoru ile tahrik edilen düşey milli pompalı sistemlerde; 35491, 1164 ve 42 MJ ha^{-1} yıl^{-1}, dalgıç pompalı sistemlerde ise 38850, 1321 ve 37 MJ ha^{-1} yıl^{-1} olarak hesaplanmıştır.

Anahtar kelimeler: Yağmurlama sulama, Enerji tüketimi, Sulama pompaları, Konya Ovası

Introduction

Efficient use of energy especially in agriculture is one of the vital important issues in most countries through the world as in Turkey. Today's agricultural production relies greatly on the consumption of non-renewable energies such as fossil fuel. Consumption of fossil energy results in direct negative environmental effects through release of CO_2 and other burning gases (Jackson, 2009; Gallagher et al., 2009). Nevertheless, great amounts of inexpensive fossil energy have indirect negative impacts on the environment such as less diversified nature etc. Energy, economics, and the environment are commonly dependent together (Refsgaard et al., 1998; Gallagher et al., 2009). Moreover, there is a close relationship between agriculture and energy. Agriculture itself is an energy user and energy supplier in the form of bio-energy (Alam et al., 2005).

In Turkey, nearly 70% of the water sources which are being used are utilized in agriculture with the purpose of irrigation. The most important factor that limits the agricultural production in arid and semi-arid areas is irrigation water requirement. Irrigation in arid and semi-arid areas is one of the most significant factors increasing the fertility in agricultural production.

Konya is the largest province of Turkey with an area of 4,169,400 hectares, and 1,815,000 hectares are used for agriculture. The annual available water potential of the Konya Plain is 4.082 billion m^3, and 72% of this potential (2.932 billion m^3 $year^{-1}$) consists of surface water, 28**%** (1.150 billion $m^3 year^{-1}$) of this potential consists of ground water sources. However, the amount of water taken out from ground water is estimated as 1.840 billion m^3 $year^{-1}$. Because of water drawing from the ground water which is more than the reserve**,** the level of ground water decreases and the quality of the water alters. The amount of water that is required to irrigate all of the area which can be irrigated is nearly 8.2 billion m^3 $year^{-1}$ (Anonymous, 2009). 1,704,000 hectares (94%) of 1,815,000 hectares area which is appropriate for agriculture in The Konya Plain can be irrigated. Officially, the area which is open for irrigation is 377,000 ha. However, the area which is not recorded but irrigated is estimated as 140,000 ha and the total area which is irrigated is approximately 517,000 ha (Kara et al., 2008; Yavuz, 2011). There are 216,130 sprinkler facilities in Turkey and nearly 14%, which is 30,098, of these are in The Konya Plain. Konya holds the first place in Turkey in terms of sprinkler facilities that it possesses (Anonymous, 2011).

A great amount of water used for irrigation in the Konya region is used for sugar-beet production and there is an excessive water use. This situation increases energy expenses and handicaps the efficient use of insufficient water sources, and incapacitates the irrigation of larger areas through these insufficient water sources and prevents the benefit of more producers**.**

Excessive water use causes both extravagance of insufficient water sources and more energy supply to carry the water into the area which is going to be irrigated and to apply water within the area. Irrigation activity in agriculture especially in areas having arid and semi-arid climate is the activity in which the most energy is used.

The results of many conducted researches have shown that non-renewable energy sources such as fossil energy are highly used in agriculture, and irrigation needs highest energy in arid areas when comparing with other agriculture operations (Mittal et al., 1985; Mrini et al., 2001). Mrini et al. (2001) reported that 50% of energy in the field is consumed by sprinkler irrigation used in sugarcane production in Morocco. Mittal and Dhawan (1989) studied energy use for different surface irrigation systems, including the basin, flow and furrow irrigation. Authors reported that irrigation operation required about 35-50% of total energy input in growing field crops under different irrigation practices. Singh et al. (2002) found that irrigation always consumed the largest proportion of on-farm energy in their case studies of agricultural production in India's arid zone. Sprinkler systems have the highest energy cost, with an estimated requirement of up to 162.6 GJ ha^{-1} $year^{-1}$ when supplied by groundwater with a 100 m lift (Smerdon and Hiller, 1985).

In the context of Turkish agriculture sector, regional and national detailed studies have been conducted which are based on production systems, products and total energy use (Yaldiz et al., 1990; Barut and Ozturk, 2004; Ozkan et al., 2004; Canakci et al., 2005; Hatirli et al., 2005; Karkaciger and Goktolga, 2005; Ozturk and Barut, 2005; Ozturk and Oren, 2005; Yilmaz et al., 2005).

Energy inputs used in irrigation consist of diesel fuel (including oil), electricity, human labour-force and systems equipment inputs. Diesel fuel and electricity inputs are called direct energy, equipment input is called indirect energy (Dalgaard et al, 2001; Hulsbergen et al., 2001; Mrini et al., 2001).

The energy used for sprinkler irrigation is categorized into two groups which are direct and indirect energy. Direct energy is the energy which is consumed by the power resource of pumping unit that supplies the required pressure for the operation of the systems. Indirect energy, on the other hand, represents the energy used for the manufacture of equipment (pump, pipes, sprinkler and additional parts etc.,) constructing the sprinkler irrigation systems. In other words, it is the "equipment manufacturing energy". A great deal of energy consumed for sprinkler irrigation is direct energy (Yavuz, 2006; Yavuz et al., 2007).

The purpose of this research is to analyze the water and energy use in sprinkler irrigation method which is common in the Konya-Çumra Plain. Considering this purpose, the applied irrigation water amount and the energy consumption per unit area of sprinkler irrigation systems operating in different irrigation water sources and different crops such as sugar beet, dry bean and carrot were determined.

Materials and Methods

The Konya-Çumra Plain where the research was conducted is located in the south of Konya Province and between the 37° 35′ north latitude and 32° 47′ east longitude. The average altitude above sea level is 1013 m.

The average temperatures of irrigation season within the plant growth period in The Konya-Çumra Plain according to the long terms records range from 10.6 and 22.7˚C, and the average monthly precipitation ranges from 6.1 mm and 45.5 mm. According to the averages for long terms, the annual precipitation is 326 mm and only 40% of this amount falls in plant growth period.

Both ground water and surface water sources are used in Konya-Çumra Plain. The surface water source is Apa Dam, Beyşehir Lake, Suğla Lakes and Çarşamba Stream. In recent years, no more water can't be delivered from Beyşehir Lake to Çumra irrigation area. So that the water drafted from groundwater resources has increased.

Çumra, İçeri Çumra, Alemdar, Karkın, Küçükköy, Güvercinlik, Okçu, Kaşınhanı, Üçhüyük, Dedemoğlu, Abditolu and Fethiye were chosen as the pilot area. The project area and land studies were carried out in this pilot area.

First of all, examination and observation studies were conducted in this pilot area in order to determine the features of farmer irrigation sprinkler systems using surface water and groundwater. According to the research; when water source, pumping unit and energy source of the systems are taken into consideration, there are 5 different groups of sprinkler irrigation systems which are planned and operated in Çumra Plain. The systems are described as follows.

-Moto-pump systems taking water from irrigation channel (SI_1),

-The centrifuge pump systems induced by power take-off taking water from irrigation channel (SI_2),

-The line shaft vertical pump systems induced by power take-off taking water from ground water through (SI_3),

-The line shaft vertical pump systems induced by electrical motor taking water from ground water (SI_4),

-Electrical motor-submersible pump systems taking water from ground water through (SI_5).

The sample sprinkler facilities were selected considering these five groups, and the research was conducted on 11-16 samples for each group and totally 69 sprinkler facilities has examined.

The technical information related to the power resource, pump type, pump depth, main and lateral lines and sprinkler in the sample sprinkler systems; and correlated operational and technical data in the planned sprinkler systems such as main line length, lateral length, number and spacing of lateral lines, number and spacing of sprinkler**,** average operation pressure and flow rate, lateral operating duration were collected. Irrigated plant species were also determined in the examined sample sprinkler systems.

The average operation pressures of the systems were measured and determined through the glycerin manometer regarding the principles reported by Pereira (1990), and average sprinkler nozzle flow rate was measured and determined considering the principles reported by Keller and Bliesner (1990). The pump flow rate was calculated by multiplying average sprinkler nozzle flow rate by nozzle number. The amount of diesel fuel consumed per hour in the sprinkler irrigation systems were determined as $l\ h^{-1}$ according to tank fill method and the electricity amount was determined as $kWh\ h^{-1}$ by recording the electricity consumed per hour on the electrical board. Diesel or electricity consumption in pump systems was measured during irrigation operation.

Considering all of the energy inputs used in the sprinkler irrigation systems, the calculations were done. The energy inputs used in the operation of sprinkler irrigation consist of diesel fuel (including oil), electricity, human labour and systems equipment inputs. Diesel fuel and electrical inputs are called direct energy, and equipment input is called indirect energy (Dalgaard et al., 2001; Hülsbergen et al., 2001; Mrini et al., 2001).

The energy use of sprinkler irrigation was calculated as megajoule (MJ) per unit area (1 ha).

So that the total energy equivalence of inputs used for irrigation through sprinkler was stated in megajoule unit. In many researchers conducted studies on energy use in agriculture and irrigation, In this studies, the energy expended in agricultural activities have been calculated as megajoule(MJ) (MJ ha^{-1}) per unit area(1 ha) (Mittal and Dhawan, 1989; Refsgaard et al., 1998; Ercoli et al., 1999; Kuesters and Lammel, 1999; Dalgaard et al., 2001; Hülsbergen et al., 2001; Mrini et al., 2001; Singh et al., 2002; Bailey et al., 2003; Tzilivakis et al., 2004).

Considering these issues, the energy used in sprinkler irrigation was calculated through the following equations by taking each input into consideration separately.

Energy calculation according to the diesel norm use;

$$E_m = \frac{D_n \times D_e}{Q_d} \quad (Equation\ 1)$$

E_m = Specific energy consumption of pump systems (MJ m^{-3})

D_n = Diesel fuel consumption of the systems per hour (l h^{-1})

Q_d =Flow rate of the systems (m^3 h^{-1})

D_e =Energy equivalent of diesel fuel (including oil) per unit volume (MJ l^{-1})

$$E_M = E_m \times I_d \quad (Equation\ 2)$$

E_M = Energy equivalent of diesel fuel consumed for per unit area (MJ $ha^{-1}year^{-1}$)

I_d= Amount of applied irrigation water (m^3 $ha^{-1}year^{-1}$)

Calculating the electrical energy consumed;

$$E_d = \frac{E_n \times E_e}{Q_e} \quad (Equation\ 3)$$

E_d =Specific energy consumption of the electro-pumping systems (MJ m^{-3})

E_n =Electricity consumption of the pump per hour (kWh h^{-1})

Q_e =Flow rate of the pump (m^3 h^{-1})

E_e =Energy equivalent of one unit electricity (MJ kWh^{-1})

$$E_D = E_d \times I_d \quad (Equation\ 4)$$

E_D =Energy value of consumed electricity for a unit area (MJ ha^{-1} $year^{-1}$)

I_d = Amount of applied irrigation water (m^3 $ha^{-1}year^{-1}$)

Calculating the labour force;

$$E_i = N \times H \times H_e \quad (Equation\ 5)$$

E_i= Human labour energy (MJ ha^{-1} $year^{-1}$)

N= Number of irrigation per unit area (1 ha) (number $year^{-1}$)

H= Duration of human labour for each irrigation per unit area (hour $ha^{-1}number^{-1}$)

H_e = Unit of time energy equivalent of used labour force (MJ $hour^{-1}$)

Equipment energy calculation of the sprinkler facility;

$$E_s = \frac{G \times n}{T_t} \times T_y \quad (Equation\ 6)$$

E_s = Energy of sprinkler systems factors (MJ ha^{-1} $year^{-1}$)

G = Equipment weight (kg)

n = Manufacturing energy value of a unit of the equipment (MJ kg^{-1})

T_t = Economical life of the equipment (hour)

T_y = Annual usage duration of the equipment per unit area (hour $ha^{-1}year^{-1}$)

The calculation of human labour force energy equivalent that is needed to change the laterals in the sprinkler systems was done by considering the duration that is spent while changing a lateral from one location to another by a person (h), the number of required lateral sets, number of seasonal irrigation and the amount of energy that a person spends for an hour (MJ h^{-1}).

Equipment energy of sprinkler irrigation for per area (MJ ha^{-1}) was calculated by considering manufacturing energy of a unit of the equipment (MJ kg^{-1}), equipment weight (kg), economical life of the equipment (h) and required operation time to irrigate a hectare seasonally (h).

Energy equivalents of diesel fuel, electricity, human labour force and sprinkler systems equipment for per unit were collected from the literature and given in the Table 1, and the value found by taking the average of the values from the literature was used in energy consumption calculations.

Table 1. *The Energy Equivalents Used in the Research*

Inputs	Units	Energy Equivalent (MJ)	References
Diesel	Liter (*l*)	56.31	Singh, 2002
		37.0	Bailey ve ark, 2003
		35.9	Dalgaard ve ark, 2001
		45.8	Ercoli ve ark, 1999
		47.7	Cervinka, 1980
		39.6	Hulsbergen ve ark., 2001
		41.0	Kuesters ve Lammel, 1999
		Avg. = 43.33	
Electricity	kWh	11.93	Singh, 2002
		12.70	Fluck, 1992
		12.70	Bonnie, 1987
		Avg. = 12.44	
Human Labour	Hour (h)	1.96	Singh, 2002
		1.87	Smil, 1983
		Avg. = 1.91	
Mechanical Parts (Trailer, Pomps, Motors etc. l)	kg	108	Kalk ve Hülsbergen, 1996
		75.36	Ercoli ve ark, 1999
		Avg. = 91.68	
Plastic equipments	kg	120	Pellizzi, 1992

"Equipment utility physical lives" which are the base of the equipment energy calculation of sprinkler systems are collected from the literature. These values were calculated as 10 years for tractors and pumps (Keller and Bliesner, 1990; Ercoli et al., 1999; Kuesters and Lamel, 1999) which means 10 thousand hours for the conditions of Turkey, 15 years for pipes (Keller and Bliesner, 1990) which is 10 thousand hours for the conditions of Turkey.

The amount of irrigation water used in sugar beet, dry bean and carrot agriculture was calculated as m^3 ha^{-1} by considering the area that the sprinkler systems irrigate at a station (m^2), the flow rate of the systems (m^3 h^{-1}), duration of irrigation at the station and number of annual irrigation (number). The annual diesel or electrical energy (MJ ha^{-1}year^{-1}) consumed in unit area to irrigate sugar beet, dry bean and carrot through sprinkler systems planned in different types was calculated by considering annual irrigation water applied for the plants (m^3 ha^{-1}year^{-1}) and the required energy consumption for the systems to apply irrigation water for unit volume (MJ m^{-3}).

Result and Discussion

The energy values related to the portable sprinkler systems using surface water and groundwater sources for irrigation are given in Table 2.

Hourly fuel consumption and average pump flow rates of sprinkler systems taking water from surface water sources (irrigation canal) were calculated as 1.96 l h^{-1} and 50.11 m^3 h^{-1} for moto-pump systems (SI_1), 5.03 l h^{-1} and 106.91 m^3 h^{-1} for centrifuge pump systems induced by power take-off (SI_2) respectively. The required diesel fuel consumption and specific energy consumption to apply the average unit volume irrigation water in this kind of systems was calculated as 0.039 l m^{-3} and 1.69 MJ m^{-3} for moto-pumps, 0.047 l m^{-3} and 2.04 MJ m^{-3} for centrifuge pump systems induced by power take-off respectively.

For the sprinkler systems taking water from groundwater sources, it is seen that two different types of energy sources are used when considering the energy sources. Hourly diesel fuel consumption, average pump flow rate, the required fuel consumption to apply irrigation water for unit volume for the line shaft vertical pump systems induced by power take-off (SI_3) that consume diesel fuel were calculated as 7.40 l h^{-1}, 105.21 ton h^{-1}, 0.070 l m^{-3} and 3.03 MJ m^{-3} respectively. For the line shaft vertical pump systems induced by electrical motor taking water from ground water (SI_4), hourly electricity consumption, average pump flow rates, the required electricity consumption to apply irrigation water for unit volume and specific energy consumption were calculated as 33.87 kWh h^{-1}, 110.91 m^3 h^{-1}, 0.305 kWh m^{-3} and 3.79 MJ m^{-3} respectively, and calculations for electrical motor-submersible pump systems (SI_5) were 37.32 kWh h^{-1}, 119.07 ton h^{-1}, 0.313 kWh m^{-3} and 3.89 MJ m^{-3} .

Table 2. *Energy Consumption Sprinkler Systems Planned in Different Types*

Water Resource	Sprinkler Systems	Diesel or Electricity Consumption		Flow Rate	Diesel or Electricity consumption for applying per volume water		Energy Equivalent		Specific Energy Cons.
		$l\ h^{-1}$	$kwh\ h^{-1}$	$m^3\ h^{-1}$	$l\ m^{-3}$	$kWh\ m^{-3}$	$MJ\ l^{-1}$	$MJ\ kWh^{-1}$	$MJ\ m^{-3}$
Canal	SI_1	1.96	-	50.11	0.039	-	43.33	-	1.69
	SI_2	5.03	-	106.91	0.047	-	43.33	-	2.04
Groundwater	SI_3	7.40	-	105.21	0.070	-	43.33	-	3.03
	SI_4	-	33.87	110.91	-	0.305	-	12.44	3.79
	SI_5	-	37.32	119.07	-	0.313	-	12.44	3.89

One of the most important factors in evaluating sprinkler systems having different pumping units in terms of energy consumption is the required energy to apply irrigation water for unit volume-in other words specific energy consumption. When the Table 2 is examined by taking this issue into account, the average pumping flow rate of the centrifuge pump systems induced by power take-off taking water from irrigation channel is 106.91 $m^3\ h^{-1}$ and specific energy consumption is 2.04 MJ m^{-3}. The average pumping flow rate of the line shaft vertical pump systems induced by power take-off taking water from ground water is 105.21 $m^3\ h^{-1}$ and specific energy consumption is 3.03 MJ m^{-3}. In these two systems where pumping flow rates are very close, the type of the fuel is the same, one of the systems takes water from surface water (irrigation channel) and the other one takes water from the ground-water (depth of the pump is 20-30 m). In order to apply 1 m^3 irrigation water to the field after taking the irrigation water from the source, the energy consumption of the systems that takes water from ground water is more than the systems using the surface water, and the difference between two systems is nearly 49%.

Table 3. *Direct, Indirect and human labour energy consumptions of sprinkler systems (MJ ha^{-1} $year^{-1}$)*

Water Resource	Sprinkler Systems	Direct Energy Cons.	Indirect Energy Cons.	Human Labour	Total
Canal	SI_1	14107	923	44	15074
	SI_2	21458	3700	41	25199
Groundwater	SI_3	35748	3873	40	39661
	SI_4	35491	1164	42	36697
	SI_5	38850	1321	37	40208

Sprinkler irrigation systems induced moto-pomp, the annual energy consumptions of per unit area (1 ha) for diesel fuel, equipment energy and labour energy were found as 14107, 923 and 44 MJ ha^{-1} $year^{-1}$ on average, respectively. In centrifugal pumping systems induced by power take-off shaft, these values were computed to be 21458, 3700 and 41 MJ ha^{-1} $year^{-1}$, respectively. In the line shaft vertical pump systems induced by power take-off shaft, the annual energy consumptions of per unit area (1 ha) for diesel fuel, equipment energy and labour energy were computed as 35748, 3873 and 40 MJ ha^{-1} $year^{-1}$. In the line shaft vertical pump systems induced by electrical motor, this values were calculated to be 35491, 1164 and 42 MJ ha^{-1} $year^{-1}$ and in submersible pumping systems this values were computed as 38850, 1321 and 37 MJ ha^{-1} $year^{-1}$, respectively (Table 3). The irrigation water applied for sugar beet, dry bean and carrot plants through sprinkler systems having different pumping units and the direct energy spent for unit area (1 ha) is given in Table 4.

The average irrigation water amounts used for sugar beet, bean and carrot are 9790, 8180 and 10100 $m^3\ ha^{-1}$ $year^{-1}$ respectively. In sugar beet cultivation, the direct energy used by systems taking water from surface water sources (irrigation channels) is calculated as 16545 MJ ha^{-1} $year^{-1}$ for SI_1 systems and 19972 MJ ha^{-1} $year^{-1}$ for SI_2 systems. The direct energy used by systems taking water from ground water sources for sugar beet was found as 29664 for SI_3 systems, 37104 for SI_4 systems and 38083 MJ ha^{-1} $year^{-1}$ for SI_5 systems.

The direct energy used by systems taking water from ground water sources for dry bean was calculated as 13824 MJ ha^{-1} $year^{-1}$ for SI_1 systems and 16687 MJ ha^{-1} $year^{-1}$ for SI_2 systems. For bean, the direct energy consumed by the systems irrigating from ground water sources was computed as 24785 for SI_3 systems, 31002 for SI_4 and 31820 MJ ha^{-1} $year^{-1}$ for SI_5 respectively.

When surface water sources (irrigation channel) are used for irrigation of carrot cultivation, the direct energy consumed in SI_1 systems is 17069 MJ ha^{-1} $year^{-1}$ and it is 20604 MJ ha^{-1} $year^{-1}$ in SI_2 systems. The direct energy used for carrot in systems irrigating from ground water sources is 30603 for SI_3 systems, 38279 for SI_4 systems and 39289 MJ ha^{-1} $year^{-1}$ for SI_5 systems, respectively.

In case of irrigating 1 hectare area in which sugar beet cultivation is done through surface water sources in The Çumra Plain, the average of consumed diesel fuel energy input is found as 18259 MJ ha^{-1} $year^{-1}$. The diesel fuel energy input of irrigating an area at the same size from ground water source was calculated as 29674 MJ ha^{-1} $year^{-1}$. When the fuel type is taken into consideration, the energy consumption in irrigation of sugar beet which is planted intensively in the region through ground water source is nearly 63% more than the irrigation from surface water sources. Similar situation is observed in dry bean cultivation.

Calısır (2009) stated that average specific energy consumption in various pumping systems was found to be 2.93 MJ m^{-3} for submersible deep well pumps, and 2.85 MJ m^{-3} for centrifugal pumps in Turkey. Average energy consumption for drip irrigation in Spain was found as 0.95 kWh m^{-3} (Soto-Garcia et al., 2013). Similar results were obtained in Australia, where using a drip system supplied from open channel networks by means of on-farm pumping resulted in an energy consumption of 0.22 kWh m^{-3} (Ahmad and Khan 2009). Pimentel and Pimentel (2008) estimate that 15% of all energy expended for crop production is used to pump irrigation water. Hodges et al. (1994) and Lal (2004) found that approximately 23% of direct energy use for crop production in the US was used for on-farm pumping. Similar results were found in the arid zone of India, where irrigation always consumed the largest amount of energy in farming system, consuming between 33% and 48% of direct energy (Singh, 2002). The type of irrigation systems used obviously has an impact on the amount of energy consumed, even within pressurized systems, as the energy required for pumping depends on total dynamic head, flow rate and systems efficiency (Lal, 2004).

Table 4. *Direct energy consumption at sugar beet, dry bean and carrot irrigation.*

Plant Species	Irrigation Water and Direct Energy Consumption	Water Resource				
		Canal		Groundwater		
		SI_1	SI_2	SI_3	SI_4	SI_5
Sugar Beet	Irrigation Water (m^{-3} ha^{-1} $year^{-1}$)	9790	9790	9790	9790	9790
	Specific Energy Cons. (MJ m^{-3})	1.69	2.04	3.03	3.79	3.89
	Direct Energy Cons. per ha (MJ ha^{-1} $year^{-1}$)	16545	19972	29664	37104	38083
Dry Bean	Irrigation Water (m^{-3} ha^{-1} $year^{-1}$)	8180	8180	8180	8180	8180
	Specific Energy Cons. (MJ m^{-3})	1.69	2.04	3.03	3.79	3.89
	Direct Energy Cons. per ha (MJ ha^{-1} $year^{-1}$)	13824	16687	24785	31002	31820
Carrot	Irrigation Water (m^{-3} ha^{-1} $year^{-1}$)	10100	10100	10100	10100	10100
	Specific Energy Cons. (MJ m^{-3})	1.69	2.04	3.03	3.79	3.89
	Direct Energy Cons. per ha (MJ ha^{-1} $year^{-1}$)	17069	20604	30603	38279	39289

Conclusion

In this study, water and energy usages of appropriately planned and operated sprinkler irrigation which is easy to operate and has quite high water applying efficiency are evaluated, sprinkler systems that carry out irrigating operations from ground water and surface water sources are studied. As it is the same in the general of Turkey, portable sprinkler irrigation systems are used in Konya-Çumra irrigation network where the study was conducted.

In this study, necessary data were collected from 69 sprinkler irrigation facilities having different pumping units that use surface and ground water sources in sugar beet, dry bean and carrot cultivation. According to the collected results, the average irrigation water (when surface and ground water sources are evaluated together) that is applied for sugar beet is 979 mm, 818 mm for dry bean, 1010 mm for carrot.

When the source of the water is considered, the required energy to irrigate 1 ha area through sprinkler systems planned and operated in different types changes considerably.

Consequently, water and energy use of some plants cultivated in The Konya-Çumra Plain are determined and compared when they are irrigated through sprinkler systems that use surface water and ground-water sources. According to the collected results; the most energy and water consuming plants are sugar beet and carrot. The specific energy consumed in irrigation of ground-water sources was found 49% more than the irrigation from surface water sources. The data gathered from this study will both help the farmers of the region to calculate irrigation inputs as diesel or electrical energy and guide further scientific studies which will be conducted in relation to the topic.

Acknowledgements

*This study was extracted from Master's thesis of Duran Yavuz

*The authors thank S.U.B.A.P. (The Scientific Research Coordination Office of Selcuk University, Turkey) for kindly supporting the project No. BAP 05201004

References

Ahmad, A. and Khan, S., 2009. On comparison of water and energy productivities in pressurized irrigation systems. In: Anderssen RS, Braddock RD, Newham LTH, editors. 18th world IMACS congress and MODSIM09 international congress on modelling and simulation. Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation, ISBN 978-0-9758400-7-8 July, 2776-82.

Alam, M.S., Alam, M.R. and Islam, K.K., 2005. Energy flow in agriculture: Bangladesh. *Am J Environ Sci*, 1(3):213-220.

Anonymous, 2009. DSİ. IV. Bölge Müdürlüğü Verileri

Anonymous, 2011. http://www.tuik.gov.tr/bitkiselapp/tarimalet.zul

Bailey, A.P., Basford, W.D., Penlington, N., Park, J. R., Keatinge, J.D.H., Rehman, T., Tranter, R.B. and Yates, C.M., 2003. Comparison of energy use in conventional and integrated arable farming systems in the UK. *Agriculture, Ecosystems and Environment*, 87:241-253.

Barut, Z.B. and Öztürk, H.H., 2004. Evaluation of energy inputs in maize production in Çukurova Region of Turkey. *International Conference Science and Research- Tools of Global Development Strategy*, Czech University of Agriculture Prague, Technical Faculty, Prague, Czech Republic.

Calisir, S., 2009. Sulamada pompaj tesisleri. Tarım Makinaları, Editör: Gazanfer Ergunes, Nobel Yayınları; 351-413, Ankara, Turkey.

Canakci, M., Topakcİ, M., Akİncİ, I. and ozmerzi, A., 2005. Energy use pattern of some field crops and vegetable production case study Antalya region of Turkey. *Energy Conversion and Management*, 46(4): 655-666.

Dalgaard, T., Halberg, N. and Porter, R.F., 2001. A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. *Agriculture, Ecosystems and Environment*, 87:51-65.

Ercoli, L., Mariotti, M., Masoni, A. and Bonari, E., 1999. Effect of irrigation and nitrogen fertilization on biomass yield and efficiency of energy use in crop production of Miscanthus. *Field Crops Research*, 63(1):3-11.

Gallagher, R.V., Hughes, L. and Leishman, M.R., 2009. Phenological trends among Australian Alpine species: using Herbarium records to identify climate-change indicators. *Australian J of Botany,*: 57(1):1-9.

Hatirli, S.A., Ozkan, B. and Fert, C., 2005. An econometric analysis of energy input-output in Turkish agriculture. *Renewable and Sustainable Energy Reviews*, 9(6): 608-623.

Hodges, A.W., Lynne, G.D., Rahmani, M.R. and Casey, C.F., 1994. Adoption of energy and water conserving irrigation Technologies in Florida. Florida Cooperative Extension

Service, Institute of Food & Agric Sci, University of Florida.

Hülsbergen, K. J., Feil, B., Bierman, S., Rathke, G. W., Kalk, W. D. and Diepenbrock, W., 2001. A method of energy balancing in crop production and its application in a long-term fertilizer trial. *Agriculture, Ecosystems & Environment*, 86:303-321.

Jackson, T., 2009. An appraisal of the on-farm water and energy nexus in irrigated agriculture. (PhD thesis) School of Environmental Sciences Faculty of Science, Charles Sturt University, Australia.

Kara, M., Topak, R., Sahin, M., Suheri, S. ve Yavuz, D., 2008. Konya Ovası'nda sulamada yer altısuyu tüketimini azaltma çareleri. Konya Kapalı Havzası Yeraltısuyu ve Kuraklık konferansı, 11-12 Eylül, Konya, s. 51-56.

Karkaciger, O. and Goktolga, Z.G., 2005. Input-output analysis of energy use in agriculture. *Energy Conversion and Management,* 46(9-10): 1513-1521.

Keller, I. and Bliesner, R.D., 1990. Sprinkle and trickle irrigation. Chapman and Hall, *115 Fifth Avenue*, New York, NY 10003.

Kuesters, J. and Lammel, J., 1999. Investigations of the energy efficiency of the production of winter wheat and sugarbeet in Europe. *European Journal of Agronomy*, 11(1):35-43

Lal, R., 2004. Carbon emission from farm operations. *Environ Int*, 30:981-90.

Mittal, V.K. and Dhawan, K.C., 1989. Energy parameters for raising crops under various irrigation treatment in Indian agriculture. *Agriculture, Ecosystems and Environment*, 25(1):11-25.

Mittal, V.K., Mittal, J.P. and Dhawan, K.C., 1985. Research digest on energy requirements in agriculture sector (1971, 1982). Coordinating Cell, *All India Coordinated Research Project on Energy Requirements in Agricultural Sector*, Punjab Agricultural University. Ludhiana.

Mrini, M., Senhaji, F. and Pimentel, D., 2001. Energy analysis of sugarcane production in Morocco. *Environment, Development and Sustainability*, (3):109-126.

Ozkan, B., Akcagoz, H. and Fert, C., 2004. Energy input-output analysis in Turkish agriculture. *Renewable Energy,* 29: 39-51.

Ozturk, H.H. ve Barut, Z.B., 2005. Türkiye tarımında enerji kullanımı. *Türkiye Ziraat mühendisliği VI. Teknik Kongresi Bildiriler Kitabı*: 1253-1264, 3-7 Ocak 2005, Ankara.

Ozturk, H.H. ve Oren, M.N., 2005. Güneydoğu Anadolu Bölgesinde pamuk tarımı mekanizasyonunda enerji kullanımı. GAP IV. Tarım Kongresi, 21-23 Eylül, Şanlıurfa, s, 653-657.

Pereira, L.S., 1990. Sprinkler and trickle irrigation systems, Design and Evaluation. Notes for Students. Dept. Agricultural Engineering of Technical University of Lisbon, Bari.

Pimentel, D. and Pimentel, M., 2008. Food, energy and society (Third ed.). Boca Raton, FL:CRC Press.

Refsgaard, K., Halberg, N. and Kristensen, E.S., 1998. Energy utilization in crop and dairy production in organic and conventional livestock production systems. *Agric System*, 57:599-630.

Refsgaard, K., Halberg, N. and Kristensen, E.S., 1998. Energy utilization in crop and dairy production in organic and conventional livestock production systems. *Agricultural Systems*, 57:599-630.

Singh, J.M., 2002. On farm energy use pattern in different cropping systems in Haryana, India. International Institute of Management University of Flensburg, Sustain and Manage, Master of Science, Germany.

Smerdon, E.T. and Hiler, E.A., 1985. Energy in irrigation in developing countries. In: Proceeding of the International Conference an Water and Water Policy in World Food Supplies. May 26-30, Texas A & M University, USA.

Soto-Garcia, M., Martin-Gorriz, B., Garcia-Bastida, P,A., Alcon, F. and Martinez-Alverez, V., 2013. Energy consumption for crop irrigation in a semiarid climate (South-eastern Spain). *Energy*, 55:1084-1093.

Tzilivakis, J., Warner, D.J., May, M., Lewis, K.A. and Jaggard, K., 2004. An assessment of the energy inputs and greenhouse gas emissions in sugar beet prduction in the UK. *Agricultural Systems*; 85(2):101-119.

Yaldiz, O., Ozturk, H.H., Zeren, Y. ve Başçetinçelik, A., 1990. Türkiye tarla bitkileri üretiminde enerji kullanımı. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi*, 3(1):51-62.

Yavuz, D., 2006. Yağmurlama sulamanın enerji gereksinimi, Yüksek Lisans Tezi, Selçuk Üniv. Fen Bilimleri Ens., Konya.

Yavuz, D., Topak, R. ve Süheri, S., 2007. Yüzey Su Kaynaklarının Kullanıldığı Yağmurlama Sulama Sistemlerinde Enerji Kullanımının Belirlenmesi. *Selçuk Üniv., Ziraat Fakültesi Dergisi*, 21(41): 51-57.s

Yavuz, D., 2011. Patates Tarımında Farklı Sulama Yöntemlerinin Su Kullanımı, Verim ve Enerji Tüketimi Yönünden Karşılaştırılması.

Doktora tezi, Selcuk Üniversitesi, Fen Bil. Enst. p, 119. Konya
Yılmaz, I., Akcagoz, H. and Ozkan, B., 2005. An analysis of energy use and input costs for cotton production in Turkey. *Renewable Energy*, 30(2): 145-155.