



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

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### 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<sup>-1</sup> year<sup>-1</sup> 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<sup>-1</sup> year<sup>-1</sup>, 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<sup>-1</sup> year<sup>-1</sup>. In vertical axle pump induced by electric motor, this values were calculated to be 35491, 1164 and 42 MJ ha<sup>-1</sup> year<sup>-1</sup> and in submersible pumping systems this values were computed as 38850, 1321 and 37 MJ ha<sup>-1</sup> year<sup>-1</sup>, respectively.

Keywords: Sprinkler irrigation; Energy consumption, Irrigation pumps, Konya Plain

### Konya Ovası Farklı Bitkilerde Yağmurlama Sulama

#### 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<sup>-1</sup> yıl<sup>-1</sup>, kuyruk mili ile tahrik edilen santrifüj pompalı sistemlerde; 21458, 3700 ve 41 MJ ha<sup>-1</sup> yıl<sup>-1</sup> 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<sup>-1</sup> yıl<sup>-1</sup>, elektrik motoru ile tahrik edilen düşey milli pompalı sistemlerde; 35491, 1164 ve 42 MJ ha<sup>-1</sup> yıl<sup>-1</sup>, dalgıç pompalı sistemlerde ise 38850, 1321 ve 37 MJ ha<sup>-1</sup> yıl<sup>-1</sup> 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<sub>2</sub> 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<sup>3</sup>, and 72% of this potential (2.932 billion m<sup>3</sup> year<sup>-1</sup>) consists of surface water, 28% (1.150 billion m<sup>3</sup> year<sup>-1</sup>) 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<sup>3</sup> year<sup>-1</sup>. 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<sup>3</sup> year<sup>-1</sup> (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<sup>-1</sup> year<sup>-1</sup> 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.

#### Material and Method

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<sub>1</sub>),

-The centrifuge pump systems induced by power take-off taking water from irrigation channel (SI<sub>2</sub>),

-The line shaft vertical pump systems induced by power take-off taking water from ground water through (SI<sub>3</sub>),

-The line shaft vertical pump systems induced by electrical motor taking water from ground water (SI<sub>4</sub>),

-Electrical motor-submersible pump systems taking water from ground water through (SI<sub>5</sub>).

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 Bliessner (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<sup>-1</sup> according to tank fill method and the electricity amount was determined as kWh h<sup>-1</sup> 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 sprinklers 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<sup>-1</sup>) 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; Hülbergen 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;

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

- $E_m$  = Specific energy consumption of pump systems (MJ m<sup>-3</sup>)
- $D_n$  = Diesel fuel consumption of the systems per hour (l h<sup>-1</sup>)
- $Q_d$  =Flow rate of the systems (m<sup>3</sup> h<sup>-1</sup>)
- $D_e$  =Energy equivalent of diesel fuel (including oil) per unit volume (MJ l<sup>-1</sup>)

$$E_M = E_m \times l \quad (\text{Equation 2})$$

$E_M$  = Energy equivalent of diesel fuel consumed for per unit area (MJ ha<sup>-1</sup>year<sup>-1</sup>)

$l_d$ = Amount of applied irrigation water (m<sup>3</sup> ha<sup>-1</sup>year<sup>-1</sup>)

Calculating the electrical energy consumed;

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

$E_d$  =Specific energy consumption of the electro-pumping systems (MJ m<sup>-3</sup>)

$E_n$  =Electricity consumption of the pump per hour (kWh h<sup>-1</sup>)

$Q_e$  =Flow rate of the pump (m<sup>3</sup> h<sup>-1</sup>)

$E_e$  =Energy equivalent of one unit electricity (MJ kWh<sup>-1</sup>)

$$E_D = E_d \times l \quad (\text{Equation 4})$$

$E_D$  =Energy value of consumed electricity for a unit area (MJ ha<sup>-1</sup> year<sup>-1</sup>)

$l_d$  = Amount of applied irrigation water (m<sup>3</sup> ha<sup>-1</sup>year<sup>-1</sup>)

Calculating the labour force;

$$E_{H\#} = N \times H \times H_e \quad (\text{Equation 5})$$

$E_{H\#}$  Human labour energy (MJ ha<sup>-1</sup> year<sup>-1</sup>)

$N$ = Number of irrigation per unit area (1 ha) (number year<sup>-1</sup>)

$H$ = Duration of human labour for each irrigation per unit area (hour ha<sup>-1</sup>number<sup>-1</sup>)

$H_e$  = Unit of time energy equivalent of used labour force (MJ hour<sup>-1</sup>)

Equipment energy calculation of the sprinkler facility;

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

$E_s$  = Energy of sprinkler systems factors (MJ ha<sup>-1</sup> year<sup>-1</sup>)

$G$  = Equipment weight (kg)

$n$  = Manufacturing energy value of a unit of the equipment (MJ kg<sup>-1</sup>)

$T_t$  = Economical life of the equipment (hour)

$T_y$  = Annual usage duration of the equipment per unit area (hour ha<sup>-1</sup>year<sup>-1</sup>)

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<sup>-1</sup>).

Equipment energy of sprinkler irrigation for per area (MJ ha<sup>-1</sup>) was calculated by considering manufacturing energy of a unit of the equipment (MJ kg<sup>-1</sup>), 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 Equivalent 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, Pumps, 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 $m^3 h^{-1}$	Diesel or Electricity consumption for applying per volume water		Energy Equivalent		Specific Energy Cons. $MJ m^{-3}$
		$l h^{-1}$	$kwh h^{-1}$		$l m^{-3}$	$kWh m^{-3}$	$MJ l^{-1}$	$MJ kWh^{-1}$	
Canal	Sl <sub>1</sub>	1.96	-	50.11	0.039	-	43.33	-	1.69
	Sl <sub>2</sub>	5.03	-	106.91	0.047	-	43.33	-	2.04
	Sl <sub>3</sub>	7.40	-	105.21	0.070	-	43.33	-	3.03
Groundwater	Sl <sub>4</sub>	-	33.87	110.91	-	0.305	-	12.44	3.79
	Sl <sub>5</sub>	-	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)

Water Resource	Sprinkler Systems	Direct Energy Cons.	Indirect Energy Cons.	Human Labour	Total
Canal	Sl <sub>1</sub>	14107	923	44	15074
	Sl <sub>2</sub>	21458	3700	41	25199
	Sl <sub>3</sub>	35748	3873	40	39661
Groundwater	Sl <sub>4</sub>	35491	1164	42	36697
	Sl <sub>5</sub>	38850	1321	37	40208

Sprinkler irrigation systems induced moto-pump, 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 Sl<sub>1</sub> systems and  $19972 MJ ha^{-1} year^{-1}$  for Sl<sub>2</sub> systems. The direct energy used by systems taking water from ground water sources for sugar beet was found as 29664 for Sl<sub>3</sub> systems, 37104 for Sl<sub>4</sub> systems and  $38083 MJ ha^{-1} year^{-1}$  for Sl<sub>5</sub> systems.

The direct energy used by systems taking water from ground water sources for dry bean was calculated as 13824 MJ ha<sup>-1</sup> year<sup>-1</sup> for SI<sub>1</sub> systems and 16687 MJ ha<sup>-1</sup> year<sup>-1</sup> for SI<sub>2</sub> systems. For bean, the direct energy consumed by the systems irrigating from ground water sources was computed as 24785 for SI<sub>3</sub> systems, 31002 for SI<sub>4</sub> and 31820 MJ ha<sup>-1</sup> year<sup>-1</sup> for SI<sub>5</sub> respectively.

When surface water sources (irrigation channel) are used for irrigation of carrot cultivation, the direct energy consumed in SI<sub>1</sub> systems is 17069 MJ ha<sup>-1</sup> year<sup>-1</sup> and it is 20604 MJ ha<sup>-1</sup> year<sup>-1</sup> in SI<sub>2</sub> systems. The direct energy used for carrot in systems irrigating from ground water sources is 30603 for SI<sub>3</sub> systems, 38279 for SI<sub>4</sub> systems and 39289 MJ ha<sup>-1</sup> year<sup>-1</sup> for SI<sub>5</sub> 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<sup>-1</sup> year<sup>-1</sup>. The diesel fuel energy input of irrigating an area at the same size from ground water source was calculated as 29674 MJ ha<sup>-1</sup> year<sup>-1</sup>. 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<sup>-3</sup> for submersible deep well pumps, and 2.85 MJ m<sup>-3</sup> for centrifugal pumps in Turkey. Average energy consumption for drip irrigation in Spain was found as 0.95 kWh m<sup>-3</sup> (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<sup>-3</sup> (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 <sub>1</sub>	SI <sub>2</sub>	SI <sub>3</sub>	SI <sub>4</sub>	SI <sub>5</sub>
Sugar Beet	Irrigation Water (m <sup>3</sup> ha <sup>-1</sup> year <sup>-1</sup> )	9790	9790	9790	9790	9790
	Specific Energy Cons. (MJ m <sup>-3</sup> )	1.69	2.04	3.03	3.79	3.89
	Direct Energy Cons. per ha (MJ ha <sup>-1</sup> year <sup>-1</sup> )	16545	19972	29664	37104	38083
Dry Bean	Irrigation Water (m <sup>3</sup> ha <sup>-1</sup> year <sup>-1</sup> )	8180	8180	8180	8180	8180
	Specific Energy Cons. (MJ m <sup>-3</sup> )	1.69	2.04	3.03	3.79	3.89
	Direct Energy Cons. per ha (MJ ha <sup>-1</sup> year <sup>-1</sup> )	13824	16687	24785	31002	31820
Carrot	Irrigation Water (m <sup>3</sup> ha <sup>-1</sup> year <sup>-1</sup> )	10100	10100	10100	10100	10100
	Specific Energy Cons. (MJ m <sup>-3</sup> )	1.69	2.04	3.03	3.79	3.89
	Direct Energy Cons. per ha (MJ ha <sup>-1</sup> year <sup>-1</sup> )	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.

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