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ENERGY USE IN LEGUME CULTIVATION IN TURKEY

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ABSTRACT The aim of this study was to analyze the utilization of energy in the production of different legumes in eleven different regions of Turkey to improve the efficiency of its usage. Therefore, the data for the production of dry bean, chickpea and soybean under rainfed and irrigated conditions as well as lentil under rainfed conditions were collected and evaluated according to the energy use efficiency, energy productivity and specific energy for different regions of Turkey. The main energy sources are human, diesel, fertilizer, seed, machine, chemicals and water. The main agricultural operations are seedbed preparation, seeding, fertilization, hoeing, irrigation, spraying, harvesting, threshing and transporting. According to the results, total energy input ranged between 3361.5 and 25229.7 MJ/ha. Energy use efficiency varied between 0.96 and 4.32 based on product and their yields.

Keywords: energy analysis, energy use efficiency, energy productivity, legumes.

INTRODUCTION Agriculture is an important sector in Turkey, although its share in economy decreased over time. Turkey has agriculture area of 40.5 million ha and the proportion of arable land is 56.8% of it. Agricultural sector contributed 9.2% of gross domestic product (GDP) and the share of agricultural labour in total labour is 27.3% in 2006 (EUROSTAT, 2006). The total export of agricultural products is 9.8 billion USD and the share in total export is 11.4% in 2006.

There is a close relationship between agriculture and energy. While agriculture uses energy, it also supplies it in the bio-energy form. At the present time, the productivity and profitability of agriculture depend upon energy consumption. The total primary energy consumption was 106.3 million TEP and production was 29.3 million TEP in 2008. According to the predictions with yearly increasing rate of 4.3%, the total primary energy consumption will reach 220 million TEP in 2020. Thus, the main goals of Turkish energy policy is obtaining the sustainability of the energy with suitable costs and also increasing the energy efficiency in all sectors. The share of agriculture sector in primary energy consumption was 4.9%. The biggest rate was from petroleum with 86.1% in 2008. So greenhouse gases (GHGs) are very important factor for the environmental issue. The GHG emission of Turkey was 332.7 million tonnes CO_2 equivalent, where the 77.6% of it is a result of energy consumption in 2006 (TUIK, 2010).

Energy is required for land preparation, seeding, fertilization, spraying, irrigation, harvesting, post-harvest processing and transportation. The amount of energy used depends on the mechanization level, quantity of active agricultural work and arabel area. The yield of different crops can be increased up to 10% by using optimal level of energy input (Sidhu et al., 2004). Farmers generally use more energy to increase output, but they don't have enough information on more efficient energy inputs. Thus, an input-output energy analysis provides farm planners and policy makers an opportunity to evaluate economic intersection of energy use. Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction. Energy efficiency can be increased by decreasing energy use from inputs such as fertilizer or tillage operations or by increasing outputs such as crop yield.

In this study, the energy use pattern and energy input-output ratio for production of four important legumes (dry bean, chickpea, lentil and soybean) over Turkey rainfed and irrigated land conditions were examined to evaluate the efficiency and current situation for improved use of energy resources.

MATERIAL AND METHODS The data for production inputs such as human labour, fertilizer, chemicals, seeds, farm machines and yields were obtained from database of General Directorate of Rural Services (Koral and Altun, 1998). The values of inputs used in production and the obtained output energy all of which converted into the energy form were utilized in the energy analysis. Energy equivalents of the inputs and outputs used in the production were given in Table 1.

Table 1. Energy equivalences of inputs and output.

Energy Source	Units	MJ	References	
Human	hour	1.96	De et al., 2001	Singh, 2002
N	kg	60.6	De et al., 2001	Singh, 2002
P_2O_5	kg	11.1	De et al., 2001	Singh, 2002
K_20	kg	6.7	De et al., 2001	Singh, 2002
Diesel	Litre	47.8	Hetz, 1992	Hetz, 1992
Tractor	kg	93.61	Hetz, 1992	Hetz, 1992
Agr. Mach.	kg	62.7	De et al., 2001	Singh, 2002
Combine	kg	87.63	De et al., 2001	Singh, 2002
Chemical	kg	120	Singh, 2002	
Water	m^3	0.63	Yaldiz et al., 1993	
Seed	kg	14.7	Singh, 2002	
Output	kg	14.7	Singh, 2002	

According to the energy equivalents of inputs and outputs, energy ratio, specific energy and energy productivity were calculated by using following equations (Mandal et al., 2002; Baishya and Sharma, 1990; Burnett, 1982):

$$Energy\ use\ efficiency = \frac{Energy\ output\ (MJ/ha)}{Energy\ input\ (MJ/ha)} \quad (1)$$

$$Specific\ energy = \frac{Energy\ input\ (MJ\ /\ ha)}{Grain\ output\ (kg\ /\ ha)} \quad (2)$$

$$Energy\ \ productivity = \frac{Grain\ output\ (kg\ /\ ha)}{Energy\ input\ (MJ\ /\ ha)} \quad (3)$$

Energy use efficiency allows us to evaluate the influence of the inputs in obtaining consumer goods related to the production. The higher the energy use efficiency the more energy efficient that particular system is in producing food energy. Specific energy is the energy input per unit grain output. Energy productivity is an evaluator of how efficiently energy is utilized in different production systems.

The production energy of farm machineries was calculated by using the following equation (Gezer et al., 2003; Onal and Tozan, 1986; Yaldiz et al., 1993):

$$M_{pe} = \frac{(G\ M_p)}{(T\ W)} \quad (4)$$

where M_{pe} is the energy of machine for unit area (MJ/ha), G machinery mass (kg), M_p production energy of machine (MJ), T economic life (h) and W field capacity of machine (ha/h). Diesel fuel energy (MJ/ha) was determined by (Yaldiz et al., 1993):

$$Diesel\ \ fuel\ energy = TP\ x\ LR\ x\ SFC\ x WE\ x\ EED \quad (5)$$

where TP is tractor power (kW), LR loading rate (0.4), SFC specific fuel consumption, WE work efficiency (h/ha), EED energy equivalent of diesel fuel. Specific fuel consumption and average tractor power was taken as 0.30 l/kWh and 45 kW, respectively (Canakci and Akinci, 2006; Akinci et al., 2008).

In this study, production of dry bean, chickpea, lentil and soybean in rainfed and irrigated conditions over Turkey was investigated.

RESULTS AND DISCUSSIONS The operational energy for irrigated dry bean production ranged between 4011.5 and 7527.1 MJ/ha for irrigated bean production (Table 2). Seedbed preparation and harvesting and threshing are high energy consumed operations with the range of 67.9 and 80.6%. This energy amount was 4686.8 MJ/ha for dry bean production, where the seedbed preparation and harvesting and threshing are the main processes.

In chickpea production, total energy for agricultural operations were between 2604.6 and 6000.1 MJ/ha in irrigated conditions, 2312.5 and 3762.8 MJ/ha in rainfed conditions. While the highest energy consuming operation was seedbed preparation (46.7%) in

Eskisehir, it was harvesting and threshing (58.2%) in Konya. In rainfed condition, seedbed preparation and harvesting and threshing have the biggest share in operational energy usage.

Total energy for agricultural operations were ranged between 2112.0 and 4467.9 MJ/ha for rainfed lentil production. More than half of it consumed for harvesting and threshing operation. Seedbed preparation is also other high energy consuming process (23.4-35.6%).

In second crop soybean production, total energy of 3498.9 MJ/ha were consumed in seedbed preparation (35.6%), hoeing (22.9%) and harvesting and threshing (15.3%). This value was 5024.0 in rainfed condition and the biggest share belongs to seedbed preparation (54.0%), harvesting and threshing (24.3%) and seeding (13.9%).

Table 3 shows the energy inputs for different legume production. The total energy input changed between 14233.2 for Eskisehir and 25229.7 MJ/ha for Erzincan for irrigated dry beans, while this value was 9168.2 MJ/ha for Trakya for rainfed dry bean production. The biggest share is related with diesel, fertilizer and water sources in irrigated dry bean production and first two in rainfed dry bean production. The total output consists of product yield. While this value changed between 18963.0 for Konya and 27489.0 MJ/ha for Erzincan in irrigated dry bean production, it was only 8820 MJ/ha for rainfed dry bean production. The energy use efficiency by using grain output, output-input ratio was between 1.06 for Konya and 1.52 for Eskisehir for irrigated dry bean and lower as 0.96 for Trakya for rainfed dry bean. Specific energy and energy productivity values were also changed between between 9.68 for Eskisehir and 13.86 MJ/kg for Konya for irrigated dry bean production and 15.28 MJ/kg for Trakya for rainfed dry bean production, between 0.07 for Konya and 0.10 kg/MJ for Eskisehir in irrigated lands and 0.07 kg/MJ for Trakya in rainfed lands, respectively.

The diesel (32.0%), seed (25.6%), animal power (13.7%) and fertilizer (13.6%) were the main energy sources of dry bean production in Chile with total input of 1433 Mcal/ha and the energy efficiency rate of 3.3-5.9 (Hetz, 1992). In cluster bean production, the energy use efficiency and specific energy was 3.4 and 7.8 MJ/ha for India. The biggest share of input were seed preparation (36.6%), sowing (16.3%) and irrigation (14.4%) with total of 2728.9 MJ/ha. As sourcewise evaluation, the share of diesel (48%), human (12.6%) and fertilizer (11.4%) consumes the total of 3812 MJ/ha (Singh et al., 2003). In another study, operational processes of seedbed preparation consumed 62.5% of total 1261.9 MJ/ha for rainfed cluster bean and consumed 26.4% for seedbed preparation, 27.0% for irrigation and 22.9% for threshing with the total of 3576.4 MJ/ha for irrigated cluster bean. While diesel (54.1%), seed (22.1%) and human (17.0%) energy input was used for rainfed cluster bean, diesel (32.9%), fertilizer (19.5%) and human (14.1%) energy input was used for irrigated cluster bean. Seedbed preparation and sowing (64.0%), weeding (13.0%) and harvesting (13.3%) for rainfed moth bean, and irrigation (29.3%), seedbed preparation and sowing (29.2%) and harvesting (14.3%) for irrigated moth bean were the biggest energy consuming processes. When we consider the sourcewise energy input, while diesel (44.4%), human (26.1%) and seed (21.4%) were the main energy sources for rainfed moth bean, diesel (29.5%), human (24.6%) and fertilizer (12.5%) were the main for irrigated moth bean. The energy use efficiency and specific energy was 2.1 and 11.7 MJ/kg, 0.5 and 7.5 MJ/ha, 3.4 and 7.7 MJ/ha and 3.5 and 7.4 MJ/ha for rainfed and

Table 2. Energy use pattern for agricultural operations in legume crops (MJ/ha)

Crops	Region	Seedbad Preparation	Seeding	Fertilization	Hoeing	Irrigation	Spraying	Harvesting and Threshing	Transportation	Total
Irrigated dry bean	Ankara	2399.9 (42.6)	552.5 (9.8)	4.9 (0.1)	375.7 (6.7)	164.2 (2.9)	-	1424.2 (25.3)	709.7 (12.6)	5631.1 (100.0)
	Eskişehir	2171.8 (54.1)	404.6 (10.1)	8.2 (0.2)	191.3 (4.8)	124.1 (3.1)	-	926.3 (23.1)	185.1 (4.6)	4011.5 (100.0)
	Konya	1478.6 (22.4)	454.8 (6.9)	-	376.5 (5.7)	332.9 (5.1)	-	3575.5 (54.3)	370.3 (5.6)	6588.6 (100.0)
	Tokat	3264.1 (43.4)	551.5 (7.3)	15.3 (0.2)	306.2 (4.1)	89.8 (1.2)	-	2282.0 (30.3)	1018.3 (13.5)	7527.1 (100.0)
	Erzincan	2408.4 (47.8)	18.2 (0.4)	36.8 (0.7)	347.1 (6.9)	237.0 (4.7)	119.0 (2.4)	1653.1 (32.8)	216.0 (4.3)	5035.7 (100.0)
	Trakya	2278.0 (39.1)	778.5 (13.4)	8.6 (0.1)	182.9 (3.1)	164.1 (2.8)	-	2316.6 (39.8)	92.6 (1.6)	5821.2 (100.0)
Rainfed dry bean	Trakya	3177.3 (67.8)	100.2 (2.1)	7.1 (0.2)	206.0 (4.4)	-	-	1134.6 (24.2)	61.7 (1.3)	4686.8 (100.0)
Irrigated chickpea	Eskişehir	1217.5 (46.7)	272.9 (10.5)	7.1 (0.3)	142.1 (5.5)	48.0 (1.8)	-	762.8 (29.3)	154.3 (5.9)	2604.6 (100.0)
	Konya	1276.2 (21.3)	394.2 (6.6)	-	171.1 (2.9)	328.6 (5.5)	-	3490.6 (58.2)	339.4 (5.7)	6000.1 (100.0)
Rainfed chickpea	Ankara	925.2 (26.7)	1218.0 (35.2)	-	-	-	-	1162.3 (33.6)	154.3 (4.5)	3459.8 (100.0)
	Eskişehir	1823.3 (62.1)	212.3 (7.2)	-	91.5 (3.1)	-	-	685.5 (23.3)	123.4 (4.2)	2936.1 (100.0)
	Tokat	1040.9 (32.1)	412.2 (12.7)	-	182.1 (5.6)	-	-	1425.1 (43.9)	185.1 (5.7)	3245.4 (100.0)
	Yozgat	896.3 (38.8)	5.1 (0.2)	-	-	-	-	1256.8 (54.3)	154.3 (6.7)	2312.5 (100.0)
	Muş	1012.0 (26.9)	501.3 (13.3)	-	-	-	-	2126.0 (56.5)	123.4 (3.3)	3762.8 (100.0)
Rainfed lentil	Ankara	780.7 (23.4)	497.8 (14.9)	-	-	-	-	1686.3 (50.6)	370.3 (11.1)	3335.1 (100.0)
	Tokat	954.2 (24.8)	528.9 (13.7)	3.5 (0.1)	242.5 (6.3)	-	-	1998.8 (51.9)	123.4 (3.2)	3851.3 (100.0)
	Yozgat	751.8 (35.6)	4.7 (0.2)	-	-	-	-	1201.3 (56.9)	154.3 (7.3)	2112.0 (100.0)
	Şanlıurfa	1530.7 (34.3)	363.9 (8.1)	-	-	-	-	2511.7 (56.2)	61.7 (1.4)	4467.9 (100.0)
Second crop irrigated soybean	Çukurova	1244.1 (35.6)	363.9 (10.4)	172.5 (4.9)	800.2 (22.9)	141.4 (4.0)	87.7 (2.5)	534.8 (15.3)	154.3 (4.4)	3498.9 (100.0)
Rainfed soybean	Samsun	2711.6 (54.0)	697.4 (13.9)	-	273.2 (5.4)	-	-	1218.3 (24.3)	123.4 (2.5)	5024.0 (100.0)

Table 3. Energy use pattern for cultivating legume crops (MJ/ha)

Crops	Region	Energy Sources							Total Input Energy (MJ/ha)	Yield (kg/ha)	Output Energy (MJ/ha)	O/I	Specific energy (MJ/kg)	Energy productivitiy (kg/MJ)
		Human	Diesel	Seed	Fertilizer	Machines	Chemicals	Water						
Irrigated dry bean	Ankara	859.5 (5.6)	4129.9 (26.8)	1170.1 (7.6)	3714.8 (24.1)	641.7 (4.2)	-	4895.6 (31.8)	15411.6 (100.0)	1360.0	19992.0	1.30	11.33	0.09
	Eskişehir	578.4 (4.1)	2994.2 (21.0)	2058.0 (14.5)	2484.0 (17.5)	438.9 (3.1)	-	5679.7 (39.9)	14233.2 (100.0)	1470.0	21609.0	1.52	9.68	0.10
	Konya	789.9 (4.4)	4826.8 (27.0)	1323.0 (7.4)	4926.2 (27.6)	971.9 (5.4)	-	5035.1 (28.2)	17873.0 (100.0)	1290.0	18963.0	1.06	13.86	0.07
	Tokat	805.6 (4.4)	5781.9 (31.3)	1323.0 (7.2)	4554.6 (24.7)	939.7 (5.1)	-	5040.0 (27.3)	18444.7 (100.0)	1400.0	20580.0	1.12	13.17	0.08
	Erzincan	1275.0 (5.1)	3329.7 (13.2)	1323.0 (5.2)	12614.0 (50.0)	430.9 (1.7)	819.6 (3.2)	5437.4 (21.6)	25229.7 (100.0)	1870.0	27489.0	1.09	13.49	0.07
	Trakya	710.9 (4.3)	4439.7 (26.8)	1323.0 (8.0)	3614.0 (21.8)	670.7 (4.0)	819.6 (4.9)	4992.5 (30.1)	16570.3 (100.0)	1400.0	20580.0	1.24	11.84	0.08
Rainfed dry bean	Trakya	496.7 (5.4)	3691.1 (40.3)	1176.0 (12.8)	3305.4 (36.1)	499.0 (5.4)	-	-	9168.2 (100.0)	600.0	8820.0	0.96	15.28	0.07
Irrigated chickpea	Eskişehir	386.9 (4.7)	1910.1 (23.4)	1470.0 (18.0)	555.0 (6.8)	307.6 (3.8)	-	3518.3 (43.2)	8147.9 (100.0)	1400.0	20580.0	2.53	5.82	0.17
	Konya	558.0 (4.1)	4517.1 (33.0)	1323.0 (9.7)	2463.1 (18.0)	925.0 (6.8)	-	3883.7 (28.4)	13669.9 (100.0)	960.0	14112.0	1.03	14.24	0.07
Rainfed chickpea	Ankara	222.9 (4.1)	2839.3 (52.0)	1999.2 (36.6)	-	397.6 (7.3)	-	-	5459.0 (100.0)	810.0	11907.0	2.18	6.74	0.15
	Eskişehir	272.2 (5.5)	2323.1 (46.5)	2058.0 (41.2)	-	340.8 (6.8)	-	-	4994.1 (100.0)	930.0	13671.0	2.74	5.37	0.19
	Tokat	439.0 (8.3)	2400.5 (45.3)	2058.0 (38.8)	-	405.8 (7.7)	-	-	5303.4 (100.0)	1020.0	14994.0	2.83	5.20	0.19
	Yozgat	230.7 (5.4)	1781.0 (42.1)	1911.0 (45.1)	-	312.0 (7.4)	-	-	4234.7 (100.0)	920.0	13524.0	3.19	4.60	0.22
	Muş	255.6 (4.4)	2942.6 (51.0)	1617.0 (28.0)	-	955.0 (16.6)	-	-	5770.2 (100.0)	570.0	8379.0	1.45	10.12	0.10
Rainfed lentil	Ankara	297.1 (6.8)	2607.0 (59.7)	1029.0 (23.6)	-	430.9 (9.9)	-	-	4364.1 (100.0)	800.0	11760.0	2.69	5.46	0.18
	Tokat	588.0 (7.3)	2787.7 (34.8)	999.6 (12.5)	3169.2 (39.5)	475.6 (5.9)	-	-	8020.1 (100.0)	970.0	14259.0	1.78	8.27	0.12
	Yozgat	258.3 (7.7)	1574.5 (46.8)	1249.5 (37.2)	-	279.2 (8.3)	-	-	3361.5 (100.0)	900.0	13230.0	3.94	3.74	0.27
	Şanlıurfa	226.8 (2.6)	3613.7 (40.8)	2352.0 (26.5)	2041.6 (23.0)	627.5 (7.1)	-	-	8861.5 (100.0)	1170.0	17199.0	1.94	7.57	0.13
Second crop irrigated soybean	Çukurova	248.5 (1.0)	2684.4 (11.1)	1396.5 (5.8)	10986.2 (45.2)	666.3 (2.3)	360.0 (1.5)	8041.7 (33.1)	24383.7 (100.0)	2550.0	37485.0	1.54	9.56	0.10
Rainfed soybean	Samsun	576.0 (6.6)	3871.8 (44.5)	1176.0 (13.5)	2501.2 (28.7)	576.2 (6.6)	-	-	8701.2 (100.0)	2560.0	37632.0	4.32	3.40	0.29

irrigated cluster bean and moth bean, respectively (Singh et al., 2004).

The total energy input ranged between 8147.9 for Eskisehir and 13669.9 MJ/ha for Konya for irrigated chickpea, between 4234.7 for Yozgat and 5770.2 MJ/ha for Mus for rainfed chickpea production. The share of diesel and water changed between 23.4-33.0% and 28.4-43.2% for irrigated lands, respectively. In rainfed chickpea production, diesel and seed energy ranged from 42.1 to 52.0% and 28.0 to 45.1%, respectively. The energy output-input ratio values ranged from 1.03 to 2.53 for irrigated chickpea and 1.45 to 3.19 for rainfed chickpea cultivation. While the energy efficiency, specific energy and energy productivity was between 1.03-2.53, 5.82-14.24 MJ/kg and 0.07-0.17 kg/MJ in irrigated lands, these values between 1.45-3.19, 4.60-10.12 MJ/kg and 0.10-0.22 kg/MJ in rainfed lands, respectively.

In chickpea production, total energy input of 6004 MJ/ha were consumed for seedbed preparation (22.2%), fertilizing (30.8%) and sowing (29.6%). The energy efficiency, energy productivity and specific energy were 2.04, 0.14 kg/MJ and 7.2 MJ/kg (Mandal et al., 2002).

In rainfed lentil production, the total energy input ranged between 3361.5 for Yozgat and 8861.5 MJ/ha for Sanliurfa. This input energy comes from diesel, seed and fertilizer for Tokat and Sanlıurfa. The energy use efficiency was between 1.78 for Tokat and 3.94 for Yozgat for rainfed chickpea. Specific energy and energy productivity values were also changed between 3.74 and 8.27 MJ/kg and 0.12 kg/MJ and 0.27 kg/MJ, respectively.

The diesel (62.3%) and seed (21.5%) were the main energy sources of lentil production in Turkey. The energy efficiency, energy productivity and specific energy were 1.87, 0.09 kg/MJ and 11.67 MJ/kg, respectively (Oren and Ozturk, 2004).

The total energy input was 24.383.7 MJ/ha for second crop soybean cultivation and 8701.2 MJ/ha for rainfed soybean cultivation. While the biggest share belongs to fertilizer in second crop, it was diesel in rainfed production. The energy efficiency was 1.54 in second crop because of the high fertilizer and water input, 4.32 in rainfed conditions. The specific energy and energy productivity was 9.56 and 3.40 MJ/kg, 0.10 and 0.29 kg/MJ for second crop and rainfed production, respectively.

While the energy use efficiency was 3.31 with grain, it was 7.53 with total biomass for soybean with the total sourcewise energy input of 5902 MJ/ha (Singh et al. 1997). The specific energy was 20.5 MJ/kg for soybean. The energy inputs were tillage, harvesting and sowing for minimum, tillage, fertilizing and harvesting for maximum conditions. The energy efficiency was between 0.2-0.6 for without by products and 0.7-1.6 for with by products (Venturi and Venturi, 2003). The total energy input was 6267 MJ/ha for rainfed soybean and diesel (26.0%), seed (21.5%), fertilizer (19.5%) and human (15.3%) were the main energy sources with the energy productivity of 0.18 kg/MJ (De et al., 2001). The total energy input of 4910 MJ/hawere consumed as fertilizer (47.9%), seed (27.1%) and diesel (16.9%) for soybean (Thakur and Makan, 1997). The energy efficiency was 4.44 for conventional tillage, 4.23 for ridge tillage and 5.79 for no tillage soybean production (Borin et al., 1997). The fertilizing, seedbed preparation and sowing were the main energy consuming processes of the total of 9668 MJ/ha. The energy efficiency, energy productivity and specific energy were 1.60, 0.11 kg/MJ and 9.2 MJ/kg (Mandal et al., 2002).

CONCLUSIONS In this study, the energy analysis was performed for different legume production in different regions over Turkey. The main cultivated legumes such as dry bean, chickpea, lentil and soybean were evaluated according to the energy use efficiency, energy productivity and specific energy. The energy input consists of human labor, diesel, seed, fertilizer, machines, chemicals and water. Energy output is the yield of the product.

The results showed that, total energy input changed between 9168.2 MJ/ha for Trakya (rainfed) and 25229.7 MJ/ha for Erzincan (irrigated) for dry bean, 4234.7 MJ/ha for Yozgat (rainfed) and 13669.9 MJ/ha for Konya (irrigated) for chickpea, 3361.5 MJ/ha for Yozgat (rainfed) and 8861.5 MJ/ha for Sanliurfa (rainfed) for lentil, 8701.2 MJ/ha for Samsun (rainfed) and 24383.7 MJ/ha for Cukurova for second crop soybean production. The share of diesel, fertilizer and water were higher then the other energy inputs in bean production. While diesel and water have high usage rate in irrigated chickpea production, diesel and seed energy is high for rainfed chickpea production. Diesel, fertilizer and seed energy input were very important for lentil production. While fertilizer and water were the main energy inputs in second crop soybean production, diesel and fertilizer had the biggest share fort he rainfed soybean production.

The energy use efficiency was ranged between 0.96 for Trakya (rainfed) and 1.52 for Eskisehir (irrigated) for dry bean, 1.03 for Konya (irrigated) and 3.19 for Yozgat (rainfed) for chickpea, 1.78 for Tokat and 3.94 for Yozgat for lentil, 1.54 for Cukurova (second crop) and 4.32 for Samsun (rainfed) for soybean.

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