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# Energy Efficiency and Econometric Analysis of Hops Production in Turkey

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**Abstract:** The aim of this study is to determine the energy input/output ratio and parameter values of inputs affecting production amount. The data for this study were obtained from 25 hops producing households in Bilecik Province in Turkey. A face-to-face questionnaire was conducted in the production year 2011/2012. From the questionnaire, data to determine the cost of hops production, farmers' selling prices, the productivity and profitability of fruit, the usage level of labour, machinery, diesel-fuel, chemical fertilisers, pesticides, water for irrigation and electricity, were analysed. A total energy input of 37,258.65 MJ ha$^{-1}$ was required for hops production. Chemical fertilizer, the single highest source of energy input, accounted for 38.86% of the total energy input. The two next highest energy sources were human labor (20.227%) and electricity (19.24%). The values of energy efficiency, energy productivity, specific energy and net energy were 1.59, 0.19, 5.36 and 21,875.13 MJ ha$^{-1}$, respectively. Estimates made using econometric models showed that human labor, machinery and pesticides energy inputs had significantly positive effects on energy yield. The results of a sensitivity analysis of the energy inputs showed that the Marginal Physical Productivity (MPP) value of human labor was the highest, followed by pesticides and machinery.

**Key words:** Energy efficiency, econometric model, benefit/cost ratio, hops plantations, Turkey

## INTRODUCTION

Hops have been known to mankind for a very long time. The female inflorescence of the hop plant have been used for flavoring fermented malt beverages at least since the Middle Age (Neve, 1991). Depending on the cultivar, hops will produce various levels of alpha acids, beta acids and oils. The level of these compounds classifies each hop cultivar as either an aromatic hop (for aroma) or a bittering hop (for flavour).

The main hops producing countries are Germany, Ethiopia, USA and China. Although hops are also produced in Czech Republic, Poland, Slovenia and Turkey, these countries do not have a major input in the world hops trade. The world hops production shows fluctuations depending on the climatic conditions from year to year. Total hops production in the world has increased in parallel with Germany's production. While Germany's average hops production is 34,429 tones, this value has reached up to 39,675 tones in recent years. The production of Ethiopia, additional important producing country, varies between 22,000 and 32,000 tones (FAO, 2012). World hops production is approximately 130,000 tones and every year 40,000 tones are subject to foreign trade with 350 million US dollars (FAO, 2012).

The main objective in agricultural production is to increase yield and decrease production costs. In this respect, the energy budget is important. Energy budget is the numerical comparison of the relationship between input and output of a system in terms of energy units. In general, increases in the agricultural production on a sustainable basis and at a competitive cost are vital to improve the farmer's economic condition.

Although many previous experimental studies have investigated the use of energy in fruit production, no previous studies have analyzed the energetics of hops production (Gezer *et al*., 2003; Ozkan *et al*., 2004; Gundogmus, 2006; Goktolga *et al*., 2006; Demircan *et al*., 2006; Akcaoz *et al*., 2009; Rafiee *et al*., 2010; Mohammad *et al*., 2010; Banaeian and Zangeneh, 2011). The main aims of this study are to analyze the energy used in hops production, to evaluate the associated relationship between inputs and output and to compare input energy use with input costs, using data from hops plantations in Bilecik Province, Turkey.

## MATERIALS AND METHODS

The selection of case study farms, the methods of data collection, energetics of hops production and methods of econometric model were explained in the following sub-headings.

**Selection of case study farms and data collection:** The data for this study were obtained from 25 hops producing households in Bilecik Province. The only hops production is in Bilecik Province in Turkey. A face-to-face questionnaire was administered in the production year

Table 1: Components of a hope cone

| Components | Percentage |
|---|---|
| Water | 10.0 |
| Total resins | 15.0 |
| Essential oil | 0.50 |
| Tannins | 4.00 |
| Monosaccharides | 2.00 |
| Pectins | 2.00 |
| Amino acid | 0.10 |
| Lipids and wax | 3.00 |
| Proteins | 15.0 |
| Ash | 8.00 |
| Residual carbohydrate (cellulose, lignin) | 40.4 |

(Parkes, 2002). Hops chemistry: Homebrew science, http://byo.com/stories/article/indi,ces/18-brewing-science/853-hop-chemistry- homebrew-science, available at 15.10.2012

2011/2012. A stratified random sampling method was used. The sample size was calculated using the Neyman method (Yamane, 1967):

$$n = \frac{N.\sum N_h.S^2_h}{N^2D^2 + \sum N_h.S^2_h} \tag{1}$$

where, $N_h$ is the number of producers in the $h^{th}$ stratum, $S^2_h$ is the variance of the $h^{th}$ stratum, $D^2$ is the value of $(d/t)^2$, d is the amount of permissible error around the population mean and t =1.96 for 95% confidence limits. The number of total hops producer is 457. A sample size of 25 was obtained with the use of this method. Accordingly, 25 hops producers were randomly selected from the population.

**Energetics of producing hops:** Hops yield (kg $ha^{-1}$) was used as the output. Hops energy was determined by using Eq. 2:

$$\text{Hops energy} = \frac{P.f_P + F.f_F + C.f_C}{100} DM.Y \tag{2}$$

where, Y is the hops yield (kg $ha^{-1}$), DM is the dry matter (%), P is the protein content (%), $f_P$ is the protein enclosed energy, F is the fat content (%), $f_F$ is the fat enclosed energy, C is the Carbohydrate content (%) and $f_C$ is the Carbohydrate enclosed energy.

All the enclosed energies presented at Eq. 2 were referred in FAO (2012). In order to calculate hops energy, the components of a hope cone was shown in Table 1. According to protein, fat and carbohydrates contents of a hope cone, the energy coefficient of hops is calculated.

In the survey area, the input energy sources for hops production were human labor, machinery, diesel-fuel, electricity, chemicals, electricity, cotton rope and irrigation water. Energy equivalents shown in Table 2 were used for estimating hops energy inputs and output. The total input energy equivalent can be calculated by adding up the energy equivalences of all inputs in Mega Joule (MJ).

Table 2: Energy equivalents of inputs and outputs on hops production

| Equipment/input | Unit | Energy coefficients (MJ/unit) | Reference |
|---|---|---|---|
| **Inputs** | | | |
| Human labor | h | 1.96 | Singh and Singh (1992) |
| Machinery (h) | h | 62.70 | Singh and Singh (1992) |
| Chemical fertilizers | kg | | Singh and Singh (1992) |
| Nitrogen | | 60.60 | Singh and Singh (1992) |
| Phosphorus | | 11.10 | Singh and Singh (1992) |
| Pesticides | kg | | |
| Fungicides | | 92.00 | Hessel (1992) |
| Herbicides | | 238.00 | Hessel (1992) |
| Diesel-fuel | L | 56.31 | Singh and Singh (1992) |
| Water for irrigation | $m^3$ | 0.63 | Yaldiz *et al.* (1993) |
| Electricity | kWh | 11.93 | Singh and Singh (1992) |
| Cotton rope | kg | 143.00 | Alcom (2001) |
| **Output** | | | |
| Hops (cone) | kg | 8.51 | Calculated |

The input energy in agricultural systems can be divided into direct and indirect or renewable and non-renewable forms. The sources of direct energy include human labor, diesel-fuel, electricity and water for irrigation, whereas the indirect energy sources include chemical fertilizers, pesticides, electricity cotton rope and machinery.

Renewable energy includes human labor. The sources of nonrenewable energy are machinery, diesel-fuel, pesticides, electricity, water for irrigation, cotton rope and chemical fertilizers. The energy input-output ratio (energy use efficiency), energy productivity, specific energy and net energy were calculated by using the total energy equivalent of inputs and outputs per unit area (MJ $ha^{-1}$) and fruit yield (kg $ha^{-1}$) according to the following equations (Gundogmus, 2006):

$$\text{Energy use efficiency} = \frac{\text{Energy output}(\text{MJ ha}^{-1})}{\text{Energy input}(\text{MJ ha}^{-1})} \tag{3}$$

$$\text{Energy productivity} = \frac{\text{Hops output}(\text{kg ha}^{-1})}{\text{Energy input}(\text{MJ ha}^{-1})} \tag{4}$$

$$\text{Specific energy} = \frac{\text{Energy input}(\text{MJ ha}^{-1})}{\text{Hops output}(\text{MJ ha}^{-1})} \tag{5}$$

$$\text{Net energy} = \text{energy output (Mj ha}^{-1}\text{)-Energy input (Mj ha}^{-1}\text{)} \tag{6}$$

**Econometric model:** A mathematical function is needed to specify an exact relationship between input energies and yield. The Cobb-Douglass production function was considered to be the best function for this purpose. It represents an attractive choice in terms of the statistical significance and expected signs of the parameters.

The Cobb-Douglass function has been used by several authors to investigate the relationship between input energies and production yield (Banaeian and Zangeneh, 2011; Heidari and Omid, 2011). The Cobb-Douglass production function is expressed as follows:

$$Y = f(x) \exp(u) \tag{7}$$

This function can be expressed as a linear relationship by taking the natural logarithms of both sides of the Cobb-Douglas equation and substituting as follows:

$$\ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \quad i = 1, 2, \ldots\ldots, n \tag{8}$$

where, $Y_i$ denotes the yield by the $i^{th}$ farmer, $X_{ij}$ is the vector of inputs used in the production process, a is a constant term, the $\alpha_j$ represent coefficients of inputs which are estimated from the model and $e_i$ is the error term. This model assumes that yield is a function of the input energies and allows the impact of each source of input energy on hops yield to be investigated. For each farmer i, Eq. 8 can be expanded in the following form:

$$\begin{aligned} \ln Y_i = \alpha_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 \\ \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + e_i \end{aligned} \tag{9}$$

where the $X_i$ (i = 1,2,...,7) represent the input energies from human labor ($X_1$), machinery ($X_2$), chemical fertilizer ($X_3$), pesticides ($X_4$), diesel-fuel ($X_5$), electricity ($X_6$), water for irrigation ($X_7$) and cotton rope ($X_8$). In addition, the impacts of DE and IDE sources and RE and NRE sources on the yield were investigated. For this purpose, the Cobb-Douglass function was again selected and used in the following forms:

$$\text{In}Y_i = \beta_0 + \beta_1 \text{ In DE} + \beta_2 \text{ In IDE} + e_i \tag{10}$$

$$\text{In}Y_i = \gamma_0 + \gamma_1 \text{ In DE} + \gamma_2 \text{ In IDE} + e_i \tag{11}$$

where, $Y_i$ is the $i^{th}$ farmer's yield and $\beta_i$ and $\gamma_i$ are the coefficients of the exogenous variables. DE and IDE are direct and indirect energies, respectively. RE is renewable energy and NRE is nonrenewable energy.

In this study, the return-to-scale index was determined in order to analyze the proportional changes in output due to a proportional change in all the inputs (supposing that all inputs increase by a constant factor). The values of the return to scale for Eq. (9-11) were determined by computing the elasticities. These quantities correspond to the regression coefficients in the Cobb-Douglas production function. A sum greater than, equal to, or less than unity implies increasing, constant, or decreasing returns to scale, respectively (Rafiee *et al.*, 2010).

A finding of increasing, constant or decreasing returns to scale indicates that when the energy inputs are increased by a factor X, then the yield of hops production increases by more than, exactly or less than X, respectively.

In the final portion of the research, the Marginal Physical Productivity (MPP) method, based on the response coefficients of the inputs, was used to analyze the sensitivity of hops yield to the energy inputs. The MPP of a factor indicates the change in the total output with a unit change in the factor input, assuming that all other factors are fixed at their geometric mean value. A positive value of MPP for any input variable shows that the total output is increasing with an increase in input. This property implies that one should not stop increasing the use of variable inputs so long as the fixed resource is not fully utilized. A negative value of MPP of any variable input indicates that every additional unit of input starts to diminish the total output of previous units. It is therefore preferable to keep the variable resource in surplus rather than utilizing it as a fixed resource. The MPP of the various inputs was calculated using the $\alpha_j$ of the various energy inputs as follows (Rafiee *et al.*, 2010):

$$MPP_{xj} = \frac{GM(Y)}{GM(X_j)} \times \alpha_j \tag{12}$$

where, $MPP_{xj}$ is the marginal physical productivity of $j^{th}$ input, $\alpha_j$ is the regression coefficient of the $j^{th}$ input, GM(Y) is the geometric mean of the yield and GM($X_j$) is the geometric mean of $j^{th}$ input on a per-hectare basis. Eqs. (9)-(12) were estimated using the Ordinary Least Squares (OLS) technique.

## RESULTS AND DISCUSSION

**Management practices for hops production in turkey:** The first documented instance of hop cultivation was in 736, in the Hallertau region of present-day Germany, although the first mention of the use of hops in brewing in that country was 1079 (Unger, 2004) Not until the 13th century in Germany did hops begin to start threatening the use of gruit for flavoring. In Britain, hopped beer was first imported from Holland around 1400, but hops were condemned in 1519 as a "wicked and pernicious weed" (Bamforth, 1998). In 1471, Norwich, England, banned use of the plant in the brewing of ale (beer was the name for fermented malt liquors bittered with hops; only in recent times are the words often used as synonyms) and not until 1524 were hops first grown in southeast England. It was another century before hop cultivation began in the present-day United States, in 1629. The cultivation of hops in Turkey started in 1965 (Oruc, 1989). The need for this plant has increased rapidly in parallel with the development of beer industry. In recent years, hops have been used in pharmaceutical and cosmetic industry. The single hops producing province is Bilecik. Today totally 1759 tones hops cone is produced in 357 ha production area (TSI, 2012).

Hops are a climbing plant. They are trained to grow up strings or wires which support the plants and allow them significantly greater growth with the same sunlight profile. As with all perennial vines, hops die back in the winter and come back in the spring.

Hop is adapted to a wide range of climatic conditions; ample moisture early followed by warm, dry weather is ideal. In areas where rainfall is lacking and the water table is more than 5 ft deep, irrigation may be required. A deep sandy loam is best. Poorly drained, strongly alkaline or saline soils should be avoided.

Hop plants are propagated from runners that arise from the crown just below the soil surface. The runners are cut into pieces 6 to 8 in. long, each bearing at least two sets of buds. Cuttings should be planted immediately or if not, stored in a cool, moist, well ventilated place.

The soil should be tilled to create a weed-free field prior to planting. Cuttings are planted in hills with a spacing of approximately 8×8 ft at a planting density of between 4,800 and 5,200 seedlings per hectare. Hop is grown on an overhead trellis system that may be designed to facilitate mechanical harvest.

When the young vines are about 2 ft long, two to six vigorously growing vines are selected for each hill and the rest are removed. One to three vines may be trained up each of two strings staked to the hill and extending up to the stringing wires of the trellis overhead. When the vines reach the stringing wires, the lowest 4 ft of foliage and lateral branches are removed to aid in prevention of disease, especially downy mildew. The removal of lower leaves (stripping) must be done carefully to avoid damaging the stem. Shoots arising from the crown are continually removed early in the season in order to promote the growth of the selected vines. Allowing the suckers to remain later in the season seems to promote hardiness of the crown.

Fertilizer should be applied and incorporated prior to planting. Mechanical cultivation should begin early and continue until the lateral branches are well developed. Deep cultivation (6 to 10 in.) early is recommended to incorporate surface organic matter, followed by shallow cultivation (2 to 4 in.) later in the season to avoid damaging the shallow feeder root system.

Table 3: Management practices of hops plantations

| Production processes | Hops plantations |
|---|---|
| Common variety | Brewers Gold, Cluster |
| Number of seedlings (ha) | 4,800-5,200 |
| Soil cultivations | First tilling is applied between March and April, the second is applied between September-October using garden hoeing machine |
| Average tilling number | 2.3 |
| Pruning period | March-April |
| Fertilization period | April-May |
| Average number of fertilization | 2.1 |
| Spraying period | April-June |
| Average number of spraying | 2.7 |
| Hoeing period | March-April |
| Average number of hoeing | 2.0 |
| Irrigation period | May-July |
| Average number of irrigation | 3.8 |
| Harvesting period | August-September |

The pesticide applications are made between April and June and while it is done 3.9 times (Table 3). Chemical weed control in hop is usually necessary. Only one herbicide is registered for use in this crop in Bilecik. Hand hoeing is done twice in the period between March and May. Weed control normally lasts 4 to 6 weeks or more. When weeds appear, cultivate as necessary.

Disease problems can be minimized by selection of resistant varieties and removal of diseased plant tissues. Removing lower leaves on the bines at training time will help prevent the spread of disease. Pruning should be performed with clean tools. The hop downy mildew fungus survives the winter as winter spores in infected roots or crowns. The Cluster varieties are particularly susceptible to root and crown infection.

Hop harvest in Bilecik usually runs from mid-August to mid-September. Hop cones are picked by hand. Hop is in prime condition for picking for only 5 to 10 days. Premature harvest results in loss to the grower from dry-down (weight loss during drying). After the crop has reached full ripeness, shattering loss increases and cones rapidly become discolored. Because harvesting can be a lengthy process, growing varieties of differing maturities allows for a longer season of harvest.

**Analysis of the input-output energy used in hops production:** Table 4 presents the amounts of inputs and output associated with hops production and their energy equivalents. The study found that the quantities of labor and machine power required for hops production were 3,843.54 and 12.32 h ha$^{-1}$, respectively. Most human labor was used during harvesting (65%). Likewise, most of the use of machinery occurred during cultivation (76%). The study also found that 70.28 L diesel-fuel, 189.55 kg nitrogen, 269.87 kg phosphate, 2.10 kg fungicides, 1.50 kg herbicides, 1,594.08 m$^3$ irrigation water, 600.86 kWh electricity and 12.52 kg cotton rope per

Table 4: Amount of inputs, outputs and their energy equivalences in hops production

| Input | Quantity per unit area (ha) | Total energy equivalent (MJ ha $^{-1}$) | Percentage of total energy input (%) |
|---|---|---|---|
| **Inputs** | | | |
| Human labor (h) | 3,843.54 | 7,533.34 | 20.22 |
| Machinery (h) | 12.32 | 772.46 | 2.070 |
| Chemical fertilizers (kg) | | 14,482.29 | 38.86 |
| Nitrogen | 189.55 | 11,486.73 | |
| Phosphorus | 269.87 | 2,995.56 | |
| Pesticides (kg) | | 550.20 | 1.48 |
| Fungicides | 2.10 | 193.20 | |
| Herbicides | 1.50 | 357.00 | |
| Diesel-fuel (l) | 70.28 | 3,957.47 | 10.62 |
| Water for irrigation ($m^3$) | 1,594.08 | 1,004.27 | 2.700 |
| Electricity (kWh) | 600.86 | 7,168.26 | 19.24 |
| Cotton rope (kg) | 12.52 | 1,790.36 | 4.81 |
| Total energy input (MJ) | | 37,258.65 | 100.00 |
| **Output** | | | |
| Hops (cone) | 6,948.74 | 59,133.78 | |

Table 5: Energy input-output ratio in hops production

| Items | Unit | Quantity[e] |
|---|---|---|
| Energy use efficiency | - | 1.59 |
| Energy productivity | kg MJ $^{-1}$ | 0.19 |
| Specific energy | MJ kg $^{-1}$ | 5.36 |
| Net energy | MJ ha $^{-1}$ | 21,875.13 |
| Direct energy [a] | MJ ha $^{-1}$ | 19,663.54 (52.78%) |
| Indirect energy [b] | MJ ha $^{-1}$ | 17,595.11 (47.22%) |
| Renewable energy [c] | MJ ha $^{-1}$ | 7,533.54 (20.22%) |
| Non-renewable energy [d] | MJ ha $^{-1}$ | 29,725.11 (79.78%) |
| Total energy input | MJ ha $^{-1}$ | 37,258.65 |

[a]Includes human, diesel fuel, electricity and water for irrigation, [b]Includes fertilizers, pesticides, cotton rope and machinery energy sources, [c]Includes human labour, [d]Includes diesel fuel, electricity, pesticides, fertilizers, machinery, cotton rope and water for irrigation, [e]Figures in parentheses indicate percentage of total energy input

hectare were used for hops production. The average hops yield in the study area was approximately 6,948.74 kg ha$^{-1}$. The total energy equivalents of the inputs and output were calculated by multiplying the quantity per unit area by the equivalent energy value. The total energy input and energy output were calculated as 37,258.65 and 59,133.78 MJ ha$^{-1}$, respectively.

The relative percentages of energy consumption for hops production were 38.86% for chemical fertilizer, 20.22% for human labor, 19.24% for electricity, 10.62% for diesel-fuel, 4.81% for cotton rope used, 2.70% for irrigation water, 2.07% for machinery and 1.48% for pesticides (Table 4). Chemical fertilizers accounted for the largest share of the energy input. This result is consistent with the published findings of Gundogmus (2006), Goktolga *et al.* (2006), Demircan *et al.* (2006), Mohammad *et al.* (2010) and Banaeian and Zangeneh (2011) for apricot, peach, cherry, kiwi fruit and walnut production, respectively. The results showed that in terms of energy input, the consumption of chemical fertilizer and diesel-fuel was high for hops production in the region studied.

The energy efficiency, energy productivity, specific energy and net energy found for hops production are listed in Table 5. A value of 1.59 was found for the energy use efficiency (energy ratio). This value indicates that the energy consumption of hops production in the region was efficient, i.e., that energy production was greater than energy utilization.

Several authors have reported the energy ratio for different crops and fruits. These values include 0.96 for cherry production (Demircan *et al.*, 2006) and 0.93 for peach production (Goktolga *et al.*, 2006) in Turkey, 1.54 for kiwi fruit (Mohammad *et al.*, 2010) and 2.90 for walnut in Iran (Banaeian and Zangeneh, 2011), 1.25 for orange, 1.06 for lemon and 1.17 for mandarin in Turkey (Ozkan *et al.*, 2004).

The energy productivity, specific energy and net energy for hops production were found to be 0.19, 5.36 and 21,875.13 MJ ha$^{-1}$, respectively.

The distribution of input energy in hops production in terms of direct, indirect, renewable and nonrenewable energy forms is shown in Table 5. Direct and indirect energy account for 52.78 and 47.22% of the total energy input, respectively. Chemical fertilizer exhibits the highest share (81.16%) of indirect energy, followed by machinery (10.82%). Renewable and nonrenewable energy account for 3.97 and 96.93% of the total energy input, respectively. Several studies have shown that the contribution of indirect energy is higher than that of direct energy and that the share of nonrenewable energy is more than that of renewable energy in the production of different agricultural products (Gundogmus, 2006; Goktolga *et al.*, 2006; Banaeian and Zangeneh, 2011; Akcaoz *et al.*, 2009).

**Econometric model estimation of energy inputs for hops production:** To investigate the relationship between the energy inputs and the yield associated with hops production, the Cobb-Douglas production function was chosen and its parameters estimated using the ordinary least squares (OLS) technique. This model assumed that the hops yield (endogenous variable) was a function of human labor, machinery, pesticides, chemical fertilizers, diesel-fuel, electricity, cotton rope and water for irrigation (exogenous variables). The Durbin-Watson test was used to test for autocorrelation in the residuals from the regression analysis of the data used in this analysis. The value of the Durbin-Watson test statistic was 2.15 for Eq. 9. This result indicated (at a 1% significance level) that no autocorrelation was present in the estimated model. The $R^2$ (coefficient of determination) was 0.91 for this linear regression model. The regression results of Eq. 9 (Table 6) revealed that the contribution of human

Table 6: Econometric estimation results of inputs affecting hops production

| Exogenous variables | Coefficient | t-ratio | MPP |
|---|---|---|---|
| ***Model 1** | | | |
| Constant | 0.28 | 0.37 | |
| Human labour | 1.97 | 7.83[a] | |
| Machinery | 0.16 | 0.37[a] | |
| Chemical fertilizers | -0.05 | -1.74[b] | -0.06 |
| Pesticides | 0.24 | 8.33[a] | 0.41 |
| Diesel-fuel | -0.25 | -3.35[a] | -0.33 |
| Electricity | -0.61 | -9.02[a] | -0.75 |
| Water for irrigation | -0.23 | -2.73[a] | -0.36 |
| Cotton rope | -0.02 | -4.13[a] | -0.03 |
| Durbin-Watson | 2.15 | | |
| $R^2$ | 0.91 | | |
| Return to scale | 1.21 | | |

*Model 1: $\ln Y_i = \alpha_0+\alpha_1 \ln X_1+\alpha_2 \ln X_2+\alpha_3 \ln X_3+\alpha_4 \ln X_4+\alpha_5 \ln X_5+\alpha_6 \ln X_6+\alpha_7 \ln X_7+\alpha_8 \ln X_8+e_i$, [a]Indicates significance at 1% level., [b]Indicates significance at 10% level

labor, machinery, pesticides, diesel-fuel, electricity, cotton rope and water for irrigation were statistically significant at the 1% level. The impact of chemical fertilizer input was significant at the 5% level. The values of the estimated coefficients indicated that all energy inputs except those associated with human labor, machinery and pesticides had negative impacts on hops yield. These results show that excessive amounts of chemical fertilizer, diesel-fuel, electricity, water for irrigation and cotton rope were used in hops production. Human labor had the highest impact (1.97) of all the inputs analyzed for hops production. This result indicates that under the conditions of the study, an increase in the input energy associated with human labor tended to increase the yield. The results showed that a 100% increase in the energy value of human labor corresponded to a 197% increase in hops output. The second important input, pesticides were found to have an elasticity of 0.24. Mohammad *et al.* (2010) analyzed an econometric model for kiwi fruit production in Iran. They reported that human labor, machinery, total fertilizer and water for irrigation produced significant improvements in the yield of kiwi fruit. In a study of walnut production, Banaeian and Zangeneh (2011) found that human labor, transportation, farmyard manure, chemical fertilizer, electricity and water for irrigation had significant impacts on fruit yield.

The MPP values of the variables in the model are shown in the last column of Table 6. The MPP of human labor, pesticides and machinery were found to be 2.42, 0.41 and 0.26, respectively. These findings indicate that an increase of 1 MJ in each input of human labor, pesticides and machinery would lead to an additional increase in yield of 2.42, 0.41 and 0.26 kg ha$^{-1}$, respectively. The value of return to scale for the model (1), calculated from the regression coefficients, was 1.21.

Table 7: Econometric estimation results of direct, indirect, renewable and non-renewable energies

| Exogenous variables | Coefficient | T-ratio | MPP |
|---|---|---|---|
| **Model 2:** $\ln Y_i = \beta_0+\beta_1 \ln DE+\beta_2 \ln IDE+e_i$ | | | |
| Constant | 6.23 | 46.19[a] | |
| Direct energy | 0.29 | 12.16[a] | 0.32 |
| Indirect energy | 0.05 | 3.46[a] | 0.06 |
| Durbin-Watson | 2.16 | | |
| $R^2$ | 0.87 | | |
| **Model 3:** $\ln Y_i = \gamma_0+\gamma_1 \ln RE+\gamma_2 \ln NRE+e_i$ | | | |
| Constant | 6.35 | 34.43[a] | |
| Renewable energy | 0.31 | 9.82 [a] | 0.38 |
| Non-renewable energy | 0.09 | 3.15 [a] | 0.09 |
| Durbin-Watson | 2.57 | | |
| $R^2$ | 0.82 | | |

[a]Indicates significance at 1% level, [b]Indicates significance at 5% level

The regression coefficients of direct, indirect, renewable and nonrenewable forms of energy input in relationship to the yield of hops production in models (2) and (3) were estimated using Eq. (10 and 11), respectively. The results of this analysis are shown in Table 6. The regression coefficients of the direct, indirect, renewable and non-renewable energy forms were positive and significant at the 1% level.

The impact of direct energy was higher than that of indirect energy (0.29 versus 0.05). This result implies that a 100% increase in direct energy inputs produced a 129% increase in yield, whereas a 100% increase in indirect energy produced an 5% increase in yield. The results also show that the impact of renewable energy (0.31) was more than that of non-renewable energy (0.09) in hops production.

Several authors have reported that the impact of direct energy is higher than that of indirect energy (Banaeian and Zangeneh, 2011) and that the impact of renewable energy is higher than that of non-renewable energy (Mohammad *et al.*, 2010).

The statistical results for models (2) and (3) are shown in Table 7. The values of the Durbin-Watson were 2.16 and 2.57 for Eq. (10 and 11), respectively. These results indicate that no autocorrelation occurred (1% significance level) in the estimated models. The $R^2$ values were 0.87 and 0.82, respectively.

Table 7 shows that the MPP values of direct, indirect, renewable and non-renewable energies were 0.32, 0.06, 0.38 and 0.09, respectively. These results indicate that an additional use of 1 MJ in the direct, indirect, renewable and non-renewable energies would lead to additional increases in yield of 0.32, 0.06, 0.38 and 0.09 kg ha$^{-1}$, respectively.

The results revealed that the cost of production per hectare was 11,296.13 /ha$^{-1}$. The net profit of hops was calculated by subtracting the production cost from the gross product value. The net profit value for hops production was found to be 6,560.97 \$ ha$^{-1}$. In the research, the benefit–cost ratio (B/C) of hops production was calculated by dividing the gross value of the product by the total cost to determine economic efficiency. The results indicate that hops production has higher (1.58) B/C ratio.

Several investigations have done in economic analysis of crops production and benefit-cost ratio was concluded (2.37 for orange, 1.89 for lemon and 1.88 for mandarin (Ozkan *et al.*, 2004), 1.11 and 1.19 for small and large farms of apricot, respectively (Gezer *et al.*, 2003) and 1.83 and 2.21 for greenhouse and open-field grape, respectively (Ozkan *et al.*, 2007), 2.13 and 2.14 for organic and conventional dried apricot production (Gundogmus, 2006), 1.94 for kiwi-fruit in Iran (Mohammad *et al.*, 2010), 2.1 for walnut production (Banaeian and Zangeneh, 2011).

## CONCLUSION

According to the econometric results of this study, hops producers should reduce their uses of especially chemical fertilizers, electricity, diesel-fuel, irrigation water and cotton rope to attain optimal values for their plantations. This optimization scheme can be expressed in mathematical form as a linear programming problem. The current study can be extended to distinguish efficient growers from inefficient ones, identify wasteful uses of energy inputs by inefficient growers and suggest the quantities of input from each energy source that should be used by each inefficient grower. Further studies of these questions are currently underway.

Optimum energy use in agricultural systems is reflected in two ways. Productivity can increase at the existing energy input levels. Alternatively, energy can be conserved without affecting productivity. Energy management acquires increasing importance if the energy used must be economical, sustainable and productive.

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**Nomenclature**

n = Required sample size

N = No. of holdings in target population

s = Standard deviation

D = Acceptable error (permissible error was chosen as 5%)

T = Confidence limit (1.96 in the case of 95% reliability)

$Y_i$ = Yield level of the ith farmer

$X_1$ = Energy input from human labor

$X_2$ = Energy input from machinery

$X_3$ = Energy input from chemical fertilizer

$X_4$ = Energy input from pesticide use productivity of j$^{th}$ input

$X_5$ = Energy input from diesel-fuel

$X_6$ = Energy input from electricity

$X_7$ = Energy input associated with use of irrigation water

$X_8$ = Energy input from cotton rope

$e_i$ = Error term

$a_i$ = Coefficients of the variables

$\beta_i$ = Coefficients of the variables

$\gamma_i$ = Coefficients of the variables

DE = Direct energy

IDE = Indirect energy

RE = Renewable energy

NRE = Nonrenewable energy

$MPP_{xj}$ = Marginal physical

$a_j$ = Regression coefficient of j$^{th}$ input

GM(Y) = Geometric mean of yield

GM(Xj) = Geometric mean of j$^{th}$ input energy

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