# Energy Coefficient for Irrigated Wheat Production in Western Provinces in Iran

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**ABSTRACT:** The data for diesel fuel energy consumption on tillage, planting, cultivation, irrigation, harvesting and grain hauling as well as electricity for pumping water from wells obtained by questioners for four western provinces of Iran. The data was analyzed by SPSS software and then compared with the calculation results for the similar activities. Calculations were run for the worst case situation that is the hardest soil type for tillage, lowest forward speed and field efficiency for all. The results showed that the least energy consumption for every one of the practices was higher than the calculated figures; in some cases more than triple. The energy used for irrigation was the dominating. More energy was put into the water wells than for the hardest soil tillage. Statistics showed that the farmers in these provinces used 24.10-38.98 $GJha^{-1}$ to produce one hectare of irrigated wheat compared to 23.67 $GJha^{-1}$ calculated for the worst case. International data for semi tropical area in India for the drought years was cited as 15.289 $GJha^{-1.}$ experimental data for energy consumption for every practice was separately analyzed and compared with the calculated figures. Tillage with an average coefficient of 57.38 $lha^{-1}$ and planting with an average 34.16 $lha^{-1}$ showed no significant differences between the provinces at 5% probability level. Energy coefficient for the other activities that is cultivation, irrigation, harvesting and grain hauling did show significant differences between some of the provinces. The average energy consumption for these activities was 1.045, 21.268, 1.406 and 2.99 $GJha^{-1}$ respectively. The worst case calculated values were 0.232, 18.813, 0.680 and 1.748 $GJha^{-1}$ respectively. The energy coefficient per ton of produced wheat was also obtained.

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## 1. Introduction

The importance of energy consumption in agricultural is not only vital for reducing the production cost; especially with nearing WTO; to have competitive products but it shows the efficiency with witch we use the technology. Knowing the energy coefficients makes us able to suggest the ways and means of reducing energy consumption.

Research on energy coefficient for strategic products and especially for wheat has not been accomplished so far in Iran. The Iranian organization of fuel optimization in agriculture is the first to conduct such a research. In a state wide project, experimental data were gathered by questioners from different provinces which were then analyzed statistically in this presentation for four of the provinces namely Hamadan, Kordestan, Kermanshah and East Azerbayjan. The results were compared with calculated values and international literatures. Calculations were run for an assumed worst case situation that is a hard soil, lowest field efficiency and speed for comparison with experimental results. Experimental data were obtained for different field activities namely tillage, planting, cultivation, harvesting and transport. The energy use for pumping water from wells being high and costly in this semi arid region; was separately determined from the cultivation energy. Cultivation energy was thus divided into three components that are cultivation fuel consumption, irrigation fuel and electricity consumption. The calculations were performed accordingly and compared. The main objective of the research was to find out the mean energy consumption per hectare and per ton of wheat and comparing with the calculation results and international data. Such a comparison was necessary to determine the effectiveness of technology use in Iran.

## 2.Materials and Methods

Questioners were distributed to 30 farmers in each province but some of the returned answers were not valid. Thus SPSS analysis for unequal observations was used. The number of valid observations for each province is shown in second row of table 2. Calculation equations and methods were as follows:

### 2.1. Machine Operations

The fuel consumption for tillage as well as for other operations was calculated in two parts (1) energy for machine operation and (2) energy for prime mover that is tractor. Drawbar power for plowing and converted into equivalent PTO power was calculated from the following equation (Hunt, 1995),

$$P_{PTOm} = w \times b \times v(7 + 0.049 \times v^2)/(0.96 \times 0.77 \times 10 \times 3.6) \text{ W}$$
$$= w \times b \times v(7 + 0.049 \times v^2)/266 \quad (1)$$

here: $P_{PTOm}$= equivalent PTO power for drawbar power, kW

w= working width of machine, m

b= working depth, cm

v= forward speed, km/h

$(7+0.049 \times v^2)$= unit draft for a hard soil, $Ncm^{-2}$

The mostly used equipment in Iran for tillage (primary and secondary), planting, cultivation, harvesting and grain hauling have the specifications as outlined in table1. The figures in this table were used for the calculations. The results are shown in the last column of the table1.

The overwhelming tractors in Iran are MF285 with 47 kW PTO power (Anonymous, 2000). With the factory mounted weights, they weigh 3100 kg. (Nagy C.N. 1999) presented the following equation for fuel consumption of tractors per hour from Nebraska tractor test standards for tractors of 50-100 PTO hp (37.31-74.63 kW),

$$L/h = 4.93 + 0.199 \times 0.75 \times required\ P_{db} \quad (2)$$

which was used to calculate the hourly fuel consumption for tractor. Calculated power was divided by 2.60 $kWhl^{-1}$ and divided by farm capacity to obtain the energy consumption in $lha^{-1}$ (Anonymous, 2005 and Deere, 2001).

## 2.2 .Irrigation Water

About 49% of irrigation water in Iran is extracted from deep and semi deep wells and 51% from surface water sources such as rivers, Qanats and springs (Iran Water and Sewage Department, 2007). Out of all 458069 wells, 77.53% are diesel engine operated and 22.47% are operated by electric motors. Deep well is defined as one with dynamic depth of 75 m and flow of 23.5 $Ls^{-1}$ and semi deep well as one with 20 m deep and flow of 11 $Ls^{-1}$. Assuming the water was extracted with the above proportional factors, surface irrigation efficiency of 0.35, and using equation (3), the energy coefficient for irrigation water was developed as in equation (4) which must be noticed that it is applicable only for Iran and under the above mentioned assumptions (Anonymous, 2008):

$$P_{well} = \frac{Q \rho g h}{1000 \times e_p \times e_t \times e_m} \quad (3)$$

$$E_c = 0.162\ lm^{-3} + 0.067\ kWhm^{-3} \quad (4)$$

Where: $P_{well}$= required power for pumping water from well, kW

Q= water flow, $Ls^{-1}$

ρ = water density, $kgm^{-3}$

g= 9.81

h=dynamic depth, m

$e_p$= pump efficiency=0.8

$e_t$= transmission efficiency =0.6 for diesel and 1 for electric motors

$e_m$= 0.85 for diesel engine and 0.9 for electric motor

Ec=energy coefficient per cubic meter of water drawn from wells.

The wheat net irrigation water need for different provinces were obtained from a NET WAT software (Anonymous, 2006) as shown in the first line of fourth row in table 2. The relevant fuel and electric energy was calculated and shown in the fourth and fifth row in table 2.

## 2.3. Statistical Analysis

Due to inequality of experimental data, a completely random design with unequal number of observations was used and analyzed by SPSS software.

# 3. Results

Mean experimental and calculated fuel for all operations and electricity for irrigation as per hectare and per ton are shown in table 2 and depicted by barographs in figure1. The results for different operations were as follows:

## 3.1 Tillage

With minimum and maximum of 51.71 $lha^{-1}$ and 61.35 $lha^{-1}$, no significant differences were observed between the provinces. However the least experimental data was higher than the maximum calculated value.

## 3.2 Planting

No significant differences were observed at 5% level between the provinces. The least fuel consumption coefficient of 28.82 $lha^{-1}$ was more than twice the maximum calculated energy of 12.9 $lha^{-1}$

## 3.3. Irrigation

Net irrigation water need for the wheat (excluding any possible rain fall) for different provinces (Anonymous, 2006) and the relevant calculations are given in row seven in table 2. Significant differences were observed between the provinces with respect to energy use for irrigation. The fuel used in Hamedan and Kordestan provinces was less than the calculated value while for the Kermanshah and East Azarbaijan was greater.

The lower consumption for the first two provinces may be attributed to their colder weather and more rain. Besides the dynamic head of the wells may be less and the flow rate greater than what was indicated by the Water and Swage Department of Iran and which was assumed in the calculation. No valid data was available on these two characters. However, the rather high yields in these two provinces may indicate that the water was not a limiting factor. It may also be that more wells were operated electrically rather than by diesel engines. The low yield in Kordestan might have been the result of under irrigation as it is observed that the fuel and electric power consumption in this province is less than all other provinces.

The electric power usage of all the provinces was also greater than the calculated value.

Table1. Machine working specifications and energy coefficient

| Machine | Working width (m) | Working depth (cm) | Speed ($Kmh^{-1}$) | Field Efficiency % | Field Capacity ($hah^{-1}$) | PTO Power Equivalent $(kW)^{-1}$ | Energy coefficient $Lha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Moldboard plow | 0.9 | 20 | 4 | 0.74 | 0.27 | 24.53 | 31.8 |
| Tandem disk | 3.6 | 10 | 8 | 0.77 | 1.66 | 42.40 | 6.8 |
| Land plane | 3.0 | - | 8 | 0.77 | 1.39 | 42.56 | 8.1 |
| Total tillage | | | | | | | 46.7 |
| Sweep Cultivator | 5 row | - | | | | | 6.1 |
| Broadcaster | 10 | - | | | | | 3.1 |
| disking | 3.6 | 6 | 8 | - | - | - | 12.0 |
| Seed drill | 2.5 | 3-5 | | | | | 5.1 |
| Grain combine | 4.8 | - | | | | | 38.9 |
| Trailer in farm | 4 tones | - | | | | | 32.8 |
| Trailer on road | 4 tones | - | | | | | 13.2 |

[1]power for prime mover included

**3.4. Harvesting**

No significant differences were observed between the provinces with respect to their harvest energy coefficients and yields except for the Kordestan province. The higher yield the more energy consumption may be expected but interesting enough, the fuel used in Kordestan with the least yield is significantly higher than the other three with higher yields. No reasonable analysis may be drawn in this regard except for inaccuracy of the data. The higher energy used in Hamedan and East Azarbayjan may be attributed to improper combine engine injector pump, tire pressure, and unsuitable forward speed.

**3.5. Grain Hauling**

Significant differences were observed between three provinces that is Hamedan, Kermanshah and East Azarbaiyjan while the yield were not significantly different. The only reason that can be assumed is their respective unequal distance from the silo where the wheat was delivered to. The lower fuel consumption for Kordestan was expected due to its lowest yield. The lowest energy consumption for East Azarbaiyjan despite its rather high yield could be because of less distance of the farms from the silo.

**3.6 Energy Coefficient per Ton**

No significant differences were observed between the provinces except for Kordestan which was highly significant. This was expected because of its low yield, and the fact that its energy usage for the cultivation, electricity for irrigation, and harvesting was greater than the other provinces not to mention that its net irrigation water need was also higher.

**4. Discussion**

**4.1. Tillage**

The higher energy coefficient for this operation could be due to the following factors:

(a) Soil is mostly plowed dry because rain falls seldom at the time of plowing and irrigating the field to the its field capacity is not affordable.

(b) Tractor injection pump might have not been properly adjusted.

(c) Too much slippage.

(d) Improper tire pressure for prime movers.

(e) Improper use of tractor hydraulic system.

(f) Using foot pedal rather than hand throttle**.**

(e) Improper tillage depth adjustment.

Table 2. Calculated and experimental mean energy coefficient for the provinces, $Lha^{-1}$

| Practices | Calculated | Provinces | | | |
|---|---|---|---|---|---|
| | | Hamedan | Kordestan | Kermanshah | East Azarbayjan |
| No. of Observations | | 18 | 7 | 30 | 29 |
| Tillage | 46.78 | $57^{a}$ | $51.71^{a}$ | $61.35^{a}$ | $59.45^{a}$ |
| Min. | | 40 | 19 | 17 | 26 |
| Max. | | 96 | 99 | 145 | 90 |
| SD | | 16.16 | 29.26 | 34.23 | 16.19 |
| Planting | 12.9 | $35^{a}$ | $37.71^{a}$ | $28.82^{a}$ | $35.61^{a}$ |
| Min. | | 13 | 27 | 8 | 12 |
| Max. | | 24 | 65 | 63 | 75 |
| SD | | 8 | 15.09 | 17.51 | 14.39 |
| Cultivation | 6.10 | $20^{bc}$ | $49^{a}$ | $13.00^{c}$ | $28.00^{b}$ |
| Min. | | 8 | 18 | 4 | 10 |
| Max. | | 32 | 90 | 24 | 120 |
| SD | | 4.3 | 28.20 | 4.94 | 21.14 |
| Harvesting | 38.90 | $52b^{c}$ | $60.57^{a}$ | $32.15^{c}$ | $43.38^{bc}$ |
| Min. | | 24 | 10 | 14 | 24 |
| Max. | | 82 | 78 | 51 | 100 |
| SD | | 16 | 24.41 | 10.50 | 18.06 |
| Hauling grain | 46.00 | $116^{a}$ | $69.14^{b}$ | $96.90^{ab}$ | $32.55^{c}$ |
| Min. | | 60 | 57 | 18 | 6 |
| Max. | | 164 | 95 | 212 | 80 |
| SD | | 32 | 13.85 | 76.40 | 19.23 |
| Sub total | 128 | $280^{a}$ | $268^{a}$ | $232^{bc}$ | $199^{c}$ |
| Min. | | 212 | 206 | 100 | 123 |
| Max. | | 351 | 354 | 412 | 280 |
| SD | | 39.30 | 50.85 | 93.51 | 38.86 |
| Net water Req. ($m^{3}ha^{-1}$) | | 3388 | 3543 | 2207 | 2625 |
| Calculated fuel | | 548.85 | 573.97 | 357.53 | 425.25 |
| Fuel (irrigation) | 476.40 | $179.73^{d}$ | $268^{c}$ | $409.85^{b}$ | $587.86^{a}$ |
| Min. | | 116 | 206 | 210 | 592 |
| Max. | | 276 | 354 | 496 | 6300 |
| SD | | 34.3 | 50.85 | 61.85 | 1104.97 |
| Sub total | 604.26 | 459.73c | 536.13c | 642.07b | 786.85a |
| Min. | | 383 | 412 | 438 | 374 |
| Max. | | 531 | 708 | 841 | 1210 |
| SD | | 44.00 | 101.70 | 108.08 | 162.22 |
| Calculated Elec, $GJha^{-1}$ | | 0.82 | 0.85 | 0.53 | 0.62 |
| Elec.,$GJha^{-1}$ | 0.71 | $6.63^{bc}$ | $5.3^{c}$ | $12.93^{a}$ | $9.08^{b}$ |
| Min. | | 1100 | 258 | 972 | 592 |
| Max. | | 2640 | 3610 | 6750 | 6300 |
| SD | | 282.3 | 1305.42 | 1397.56 | 1104.97 |
| Total ($GJha^{-1}$) | 23.87 | 24.10 | 25.67 | 37.33 | 38.98 |
| Min. | | 19 | 17 | 30 | 23 |
| Max. | | 27 | 40 | 54 | 55 |
| SD | | 2.08 | 7.55 | 6.39 | 7.30 |
| Yield ($tha^{-1}$) | | $5.033^{a}$ | $1.100^{b}$ | $4.619^{a}$ | $5.472^{a}$ |
| Min. | | 3.200 | 0.900 | 1.000 | 1.600 |
| Max. | | 7.500 | 1.200 | 8.000 | 8.893 |
| SD | | 1.506 | 0.129 | 2.036 | 1.950 |
| Fuel ($Lt^{-1}$) | | $91.34^{c}$ | $487.39^{a}$ | $139.00^{bc}$ | $143.80^{bc}$ |
| Min. | | 55 | 343 | 67 | 56 |
| Max. | | 141 | 596 | 600 | 444 |
| SD | | 30.98 | 88.25 | 133.59 | 93.85 |
| Total ($GJt^{-1}$) | | $4.79^{c}$ | $23.34^{a}$ | $8.08^{bc}$ | $7.12^{bc}$ |
| Min. | | 2.853 | 14.287 | 4.504 | 3.262 |
| Max. | | 7.277 | 33.249 | 35.735 | 32.546 |
| SD | | 1.634 | 6.607 | 7.966 | 4.467 |

* Figures with the same letter were not significant at 5% level.

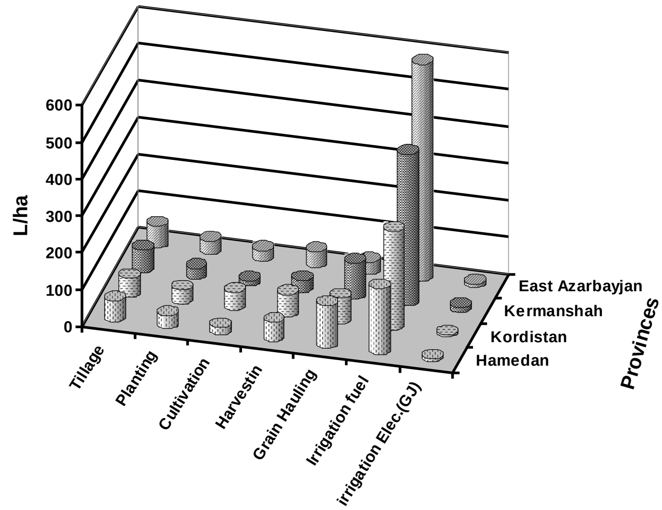


Figure 1. Barographs for the Fuel and Electricity coefficient for different operations and provinces

**4.2. Planting**

The possible reason for high energy consumption in planting may be as follows:

(a) Implementation of seed broadcasters instead of drill planters for which the farmer has to sow $1^{1/2}$ to twice as much grain as is recommended by expertise.

(b) Improper overlap.

(c) Extra disking needed with broadcasters to cover the seeds.

(d) Heavy and hard soil.

**4.3. Irrigation**

Higher energy consumption may be accounted for the following factors:

- Inaccurate experimental data
- Unmatched prime mover with the flow rate and dynamic head of the wells.
- The recommended efficiency coefficients used in equation 3 might have not been suitable for the provinces.

**4.4. Harvesting**

A non significant difference for the three provinces that is Hamedan, Kermanshah and East Azerbaijan was expected because the crop yield differences were insignificant and it is harvested by custom operators. Combine contractors start harvesting from the south and move toward north of Iran. Three different routes are taken. One strip in the west bank, second in the central and the third in the east side of the country.

**4.5. Grain Hauling**

Higher energy coefficient per hectare may be expected for higher yields as it seen for the two provinces of Hamedan and Kermanshah but for East Azerbaijan with the highest yield, the usage is not only lower than these two provinces, but even less than the calculation. The reason as it was mentioned can be due to the less distance of the farms in this province from the silo. Other factors besides greater distance from the silo; such as improper maintenance of the tractors and trailers may be considered for higher consumption in the other provinces.

**5. CONCLUSIONS**

The energy coefficient per hectare and per ton for all provinces was higher than the related calculated value which might be lowered by rectifying the possible remedies. The mean energy coefficient in producing winter wheat for all the provinces was 31.52 $GJha^{-1}$ and 430.77 $lt^{-1}$ (equivalent to 16.37 $GJt^{-1}$ (Srivatsava et al, 2001)) while for the same climate that is dry and hot places in India (Singh et al, 2002.) it has been 15.29 $GJha^{-1}$ for morocco (Baali and Van Ouwerkerk, 2005.) and 13.96 $GJha^{-1}$ and 19.58 $GJha^{-1}$ for another part of India (Sidhu, et al, 2004). Slotze et al, 2000 extracted data for conventional Wheat production from three references with means equal to 17.33 $GJh^{-1}$ and 3.10 $GJt^{-1}$.

Although the high figures of domestic energy coefficients may be due to the water supply but the mean machinery coefficient of 244.75 $lha^{-1}$ versus the

128 $lha^{-1}$ calculated for the worst case indicates that it is not all the water supply to blame for. It can surely be caused by low technology knowledge in using implements.

Another argument may be that high energy usage is due to hard soil and dry plowing; but the energy coefficient for cultivation, harvesting and hauling grain are also higher than the calculated value. These operations do not depend much on soil hardness. It is therefore clear that the technology is not being used to its universal efficiency. Main reason for that could be due to low educational level of the machinery operators and poor maintenance of machinery.

A main source of rather low yield is the combine losses. High combine losses of at least 12.5% (Behroozi Lar et al, 1995) are either because of machine improper adjustment or the delay in harvesting or both. It is reported that in some places in the north east of the country the combine reaches there about 60 days after wheat maturity. One of the problems in the country is harvesting chaff rather than mixing it with soil. This is one of the reasons for hard soil which causes the increase in energy coefficient for soil working machines.

All experimental energy coefficients per hectare and per ton were higher than the related worse case calculation and much higher than the international references.

It was concluded that agricultural technology in Iran can not be beneficially used without teaching the machine operators, and the irrigation method should be changed from surface to pressurized one.

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