World Applied Sciences Journal 3 (3): 353-358, 2008
ISSN 1818-4952


# Comparison of Direct and Indirect Energy Coefficients for Seeding and Fertilizing in Irrigated Wheat Production

[1]Seyed Saeid Mohtasebi, [1]Mansour Behroozi Lar, [2]Majid Safa and Mohammad Reza Chaichi

[1]Department of Bio System Engineering, College of Agriculture, University of Tehran, Karaj, Iran
[2]Department of Agricultural Machinery, Azad University, Saveh, Iran
[3]Department of Agronomy, College of Agriculture, University of Tehran, Karaj, Iran

**Abstract:** Data was gathered by questioning 150 farmers and contractors in an agricultural area near the capital, Tehran. The area although may not be a representative of the arable lands in the country but serves as a good example for the problems that we may face in the future research works. Energy coefficients were calculated as a comparison basis for the experimental data. Literature data was also compared with the experimental results. Data on four different farm sizes; A<2, 2≤A<5, 5≤A<20 and A≥20 hectares were collected and analyzed for direct and indirect energy coefficients of planting, fertilizing and irrigation for irrigated wheat in Saveh, a city in the central province in Iran. No significant differences were observed with respect to different farm sizes. The results showed that drilling consumed more than 1.9 times the maximum calculated. Seed sown was 1.93 times the value recommended by the agronomy expertise recommendation which amount to equivalent 234 kg $ha^{-1}$, direct energy for broadcasting was 0.75 times the calculated figure but 1.16 times the references' average. Fertilizer used amounted to 0.93% the references and irrigation energy coefficient was 1.69 times the calculated results.

**Key words:** Energy coefficient · planting energy · fertilizing energy · irrigation energy · irrigated wheat

## INTRODUCTION

It has long been known that energy coefficient in Iran far exceeds the average international use in developed countries but no scientific research has been implemented on the matter. To reason the influencing factors, thought was given to the wide differences in farm sizes. Therefore data was collected for 150 farms of different sizes and grouped into 4 categories that is; A<2, 2≤A<5, 5≤A<20 and A≥20 hectares. The city of Saveh, some 100 km south west of the capital Tehran in the central province of Iran was chosen for the experiment because it was more reachable and believed that the farmers there are more concerned about the energy usage and cost effectives. Indirect energy coefficient was extracted from the literatures and used because such data are hard to get by in Iran.

## MATERIALS AND METHODS

Data on the different farm inputs were collected from 150 farmers and or contractors through questioners. For the three inputs, i.e. seed, fertilizer and irrigation water; the amount of seed and fertilizer (N, P, K) distributed in kg $ha^{-1}$ in each farm and the fuel used for extracting water from wells were questioned. The hours spent for spreading seed and fertilizer and the tractor fuel use in L/h were other three questions. The tractor fuel use was multiplied by the hours and divided by the farm size to obtain the energy use in L $ha^{-1}$ for the processes. Total diesel fuel used in a season for irrigation and the hours spent for irrigation were also asked. The fuel used for irrigation in L $ha^{-1}$ was then obtained by dividing the fuel used by the farm size. The irrigation water energy coefficient in L/h was calculated by dividing the total fuel use by the irrigation duration in hours. The number of farms was as follows:

| No. of farms | Farm size, A (ha) |
|---|---|
| 42 | 2<A |
| 59 | 2≤A<5 |
| 35 | 5≤A<20 |
| 14 | 20≤A |

To determine the stance of direct energy use, the energy coefficients for seeding and fertilizing as well as

**Corresponding Author:** Dr. Seyed Saeid Mohtasebi, P.O. Box 4111, Postal Code 31587-11167, Karaj, Iran

Table 1: Indirect energy for fertilizers and sown wheat MJ kg $^{-1}$

| Material | [7] | [4] | [2] | [1] | [3] | Used in this paper |
|---|---|---|---|---|---|---|
| N-$NH_3^-$ | - | 65 | 75.63 | 59.00 | - | 65 |
| $P_2O_5$ | - | 15 | 4.00 | 17.00 | - | 15 |
| $K_2O$ | - | 10 | 9.85 | 10.00 | - | 10 |
| Sown wheat | - | - | - | 13.86 | - | 13.86 |
| electricity | 2.27 kWh/ kWh consumer | | | | | |

Table 2: Unit draft, speed and field efficiency at 4.8 km/h [8]

| Machine | Draft force kN | Speed range km/h | Field efficiency % |
|---|---|---|---|
| Grain drill | 1.0-1.6 | 5-10 | 80-65 |
| Broadcast distributor | 0.7-2 kW | 7-10 | 70-65 |

the water pumping from wells had to be calculated and compared.

Indirect energy coefficients for seed and fertilizer in Iran, however, were hard to come by and therefore the figures from the references were used for these inputs as shown in Table 2. Indirect energy was necessary and compared because it is firmly believed that more seed and fertilizer is used than it is needed.

**Indirect energy:** From the indirect energy given by Sartori [1], Nagi [2], Zentner [3] and Islam [4], the values in Table 1 were provided for calculations in this paper.

Agronomy expertise in Iran recommends 120 kg $ha^{-1}$ wheat seed. Multiplying this value by 13.8 from Table 1, the indirect seed energy coefficient amounts to 1663.2 MJ $ha^{-1}$.

Recommended nitrogen fertilizer for optimum wheat yield is 170 kg $ha^{-1}$ as shown in Fig. 1 [5]. Multiplying by 65 from Table 1 it amounts to 11050 MJ $ha^{-1}$.

Recommended $P_2O_5$ and $K_2O$ fertilizers for poor soils are 45 kg $ha^{-1}$ and 34 kg $ha^{-1}$ respectively [6]. Multiplying these values by their respective energy contents from Table 1, the energy coefficients will run to 675 and 340 MJ $ha^{-1}$.

MAF [7] specifies indirect electric power as 2.27 kWh/kWh consumer energy which is shown in Table 1.

**Direct energy:** Numerous data exist on energy consumption in agriculture. Those data depend on the manner they have been measured, on the matching of tractor and implement, on the load rate of the tractor and on several parameters which are difficult to evaluate. These parameters are related to the soil (type, composition, moisture content and etc.), to the machine

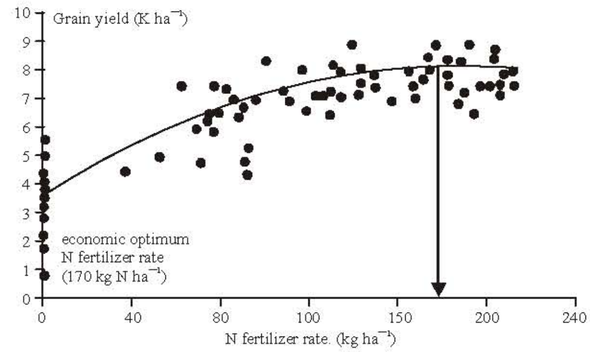


Fig. 1: Fertilizer for optimum wheat yield

employed (type, weight, tires, etc.) and finally to the crop itself. We therefore do expertise judgment when using referenced data.

Field distributor was used for both seeding and fertilizing in the farms. Afterwards a tandem disk harrow was run on the farm for covering the seed. Only 11 farms in the range of $5 \leq A < 20$ and 7 in the range of $A \geq 20$ used grain drills.

Figures from Hunt [8] were used to determine the energy coefficient for seeding and fertilizing.

**Calculations for grain drill power requirement:** The required tractor PTO power was calculated from the following formula [8]:

$$P_{db} = F.v/3.6 \quad (1)$$

$$P_{PTO} = P_{db}/(0.96*0.77) = P_{db}/0.74 \quad (2)$$

Where:
$P_{db}$ = Drawbar power, kW
F = Unit draft, kN
v = Speed, km/h
$P_{PTO}$ = PTO power, kW
0.77 = Tractive efficiency (%)
0.96 = Ratio of axle power to PTO power

Iran is a temperate zone with hard soil. So the higher value of 1.6 kN from Table 2 was used for F. Speed and field efficiency both are usually low and thus 5 km/h and 65% were chosen for the respective values. Noting that the unit draft in Table 6 is for 4.8 km/h, equation 2 must be multiplied by a factor of 5/4.8 = 1.04 to account for the difference in speed. Therefore,

$$P_{dbmachine} = 1.6*5*1.04/3.6 = 2.3 \text{ kW}$$
$$P_{PTOmchaine} = 2.3/(0.96*0.77) = 3.1 \text{ kW}$$

Table 3: Diesel fuel efficiency (kW-h/L)

| Loading % max. PTO power | Naturally aspirated | Turbo | Turbo and coolant |
|---|---|---|---|
| 100 | 2.90 | 3.07 | 3.09 |
| 80 | 2.84 | 2.82 | 2.86 |
| 60 | 2.60 | 2.55 | 2.59 |
| 40 | 2.13 | 2.10 | 2.15 |
| 20 | 1.38 | 1.36 | 1.42 |

Table 4: Energy input for planting on combination manual mechanical farms ($MJ\ ha^{-1}$)

| | Energy input on different farm sizes | | | | | |
|---|---|---|---|---|---|---|
| Operation | 0.9 ha | 1 ha | 1 ha | 1 ha | 1.2 ha | Mean |
| planting | 300.8 | 232.8 | 273 | 340.9 | 144.3 | 258.36 |

Driving power for the pulling tractor should also be calculated and added. The required tractor drawbar power may be calculated from the following equation,

$$P_{db\ tractor} = 9.81\ f\ m\ v/3600 \quad (3)$$

f, the coefficient of rolling resistance against tractor tiers on tilled soil is generally assumed to be 0.15% [8].

MF285 tractors with a mass of 2500 kg without ballast and with 47 kW maximum PTO power is commonly used in Iran. The respective drawbar power for the tractor is thus,

$$P_{db\ tractor} = 9.81 * 0.15 * 2500 * 5/3600 = 5.1\ kW$$

Inserting this value in the equation 2,

$$P_{PTOtractor} = 5.1/0.74 = 6.9\ kW$$

The total power is the sum of the two powers for machine and tractor

$$P_{PTO\ total} = P_{PTOmchaine} + P_{db\ tractor} = 3.1 + 6.9 = 10\ kW \quad (4)$$

Fuel efficiency is needed to calculate the fuel consumption per hour. To determine the fuel efficiency, the load factor, %L, must be calculated which is,

%L = PTO power required/tractor maximum PTO power (5)

and for the MF285 tractors in Iran,

$$\%L = 10/47*100=21.28\%$$

by interpolation from Table 3 [8], fuel efficiency is $e_{fuel}$= 1.43 kWh/L.

Dividing equation (4) by fuel efficiency, the diesel fuel consumption in L/h, is obtained,

$$E\ (L/h) = P_{PTO\ total}/e_{fuel} \quad (6)$$

To convert the figure to L/ha, the field capacity must be known [8],

$$C = w\ v\ e/10\ ha/h \quad (7)$$

Where C = field capacity, ha/h
w = theoretical width of machine, m
e = field efficiency, in decimals from Table 6

$$E\ (L/ha)= E(L/h)/C \quad (8)$$

Energy coefficient for No. 2 Diesel fuel is 38 MJ $L^{-1}$ [9] and if we may,

$$E(MJ/ha) = E(L/ha) * 38\ MJ/ha \quad (9)$$

Drill width in Iran is commonly about 2.5 m. Choosing a speed of 5 km/h, a field efficiency of 65% from Table 6 and substituting in the above equations, calculated fuel use for drilling in Iran would be as follows:

E(L/h) = 3.1 L/h = 3.81 L/ha = 144.98 MJ/ha
excluding tractor fuel use

E(L/h) = 10 L/h = 12.3 L/ha = 467.4 MJ/ha
including tractor fuel use.

Which are entered in Table 8.

**Calculations for broadcast distributor power requirement:** From Table 2, the maximum power requirement for this machine (noting that the power is given in equivalent PTO power) is 2.0 kW. Adding the 6.9 kW power required for the pulling tractor that was calculated in previous section,

$$P_{PTO\ total} = 2.0 + 6.9 = 8.9\ kW$$

Choosing a 8 km/h speed and a 65% field efficiency from Table 2 for Iran, following the procedures in previous section and considering the effective width of 4 m for broadcasters in Iran,

%L = 8.9/47 = 0.2, $e_{fuel}$= 1.38, E(L/h)=6.96, C= 2.08, E(L/ha)=3.35

Table 5: Diesel fuel consumption (L/ha)

| | Sources (# referring to references) | | | | | | |
|---|---|---|---|---|---|---|---|
| Machine | [13] | [14] | [7] | [15] | [10] | Mean | Mean equivalent MJ |
| grain drill | 2.84 | 3.3 | 10 | 4.0 | 6.8 | 4.79 | 182.08 |
| broadcaster | 1.42 | - | 3 | 1.8 | - | 2.07 | 78.79 |

Table 6: Number of irrigation well in Iran

| | Type of power | | Volume of | |
|---|---|---|---|---|
| Well depth | Diesel | Electric | Water extracted $10^9 m^3$ annually | Sum well type |
| Semi deep | 255726 | 74543 | 13 | 330269 |
| deep | 99432 | 28368 | 29 | 127800 |
| Total | 355158 | 102911 | 42 | 458069 |

**Direct energy data from different sources:** Umar [10] for an experiment in five different farm sizes and combination of manual and manual mechanical work has given the data in Table 4 for planting. The conditions may more resemble to what is observed in Iran. The mean value from this table is converted to L/ha by dividing by 38 to match the data in Table 5 and entered into that table.

Table 5 shows the values of direct energy for planting machines from different sources. The discrepancy between the data could mostly be due to the working width, speed and field efficiency. Moreover, it seems that the fuel requirement for the pulling tractor has not been included.

**Calculation for irrigation direct energy:** Irrigation is the most energy consuming item in Iran's agriculture. A mean average of 3059 $m^3$/ha water is needed for irrigated wheat. Water is mostly drawn by diesel engines from deep or semi deep wells. Deep well in Iran is defined as 75 m deep with 23.5 l/sec flow rate. Semi deep well is defined as 20 m deep with 11 l/sec flow rate. Diesel fuel engines however are replacing with electro motors. A census of irrigation wells in Iran is shown in Table 6. Surface irrigation efficiency according to the information from Power department in Iran [11] is about 40%. That is a 60% loss of water. From the same source, only 49% of irrigation water is obtained from the wells. Considering these information and using the following general formulae,

$$P=\frac{hQ}{e}=\frac{9.81\,hQ}{1000*0.378}=\frac{hQ}{38.5}\ \text{kW} \qquad (10)$$

Where: P = required power, kW
h = Dynamic depth of water surface in well, m
Q = Flow rate, l/sec
e = multiplication of three efficiency coefficients, $e_p$, $e_t$, $e_m$ in decimal.

The three coefficients for pump, $e_p$, transmission, $e_t$ and diesel engine, $e_m$, were respectively estimated as 0.7, 0.6 and 0.9 according to Power department in Iran. Assuming a load factor of 70%, the fuel efficiency from Table 3 for naturally aspirated diesel engine amounts to 2.7 kW-h/L. Inserting the values in Eq. 10.

$$E_{diesel}=\frac{hQ}{38.5*2.7}=\frac{hQ}{104}\ \text{L/h} \qquad (11)$$

For electric power, the same equation (10) holds except that the transmission efficiency coefficient, $e_t$, will be omitted,

$$P_{electric}=\frac{9.81\,hQ}{1000*0.9*0.7}=\frac{hQ}{64.22}\ \text{kW} \qquad (12)$$

Considering all the aspects discussed, the following equation was derived for energy consumption for water extraction from wells in Iran [12],

$$E_{water} = 0.15\ \text{L m}^{-3} + 0.067\ \text{kWh m}^{-3} \qquad (13)$$

Where: $E_{water}$ = energy used to draw one cubic meter of water from wells

The following assumptions were made in deriving the Eq. 13.

1. Surface irrigation efficiency 40%
2. Only 49% of total irrigation water in Iran is obtained from wells
3. Water is extracted from diesel and electric powered wells according to the ratio of numbers of wells as shown in Table 6.

Direct energy coefficient for drawing water can be calculated by multiplying 3059 by each term on the right side of equation 13 which amounts to 458.85L/ha gas and 205 kWh $ha^{-1}$ electricity with a total equivalent of 18174.3 MJ $ha^{-1}$.

## RESULTS AND DISCUSSION

The experimental data and related bar graphs are shown in Table 7 and Fig. 2-4 respectively. Non were significant with respect to the farm size. Therefore the mean values of 887, 3244, 274.26, 11188 and 28987.5 MJ/ha

Table 7: Experimental energy coefficients input for irrigated wheat, MJ/ha

| Farm size | A<2 | 2≤A<5 | 5≤A<20 | A≥20 | Mean |
|---|---|---|---|---|---|
| Seeding | 752.85 | 845.04 | 1032.48 | 917.76 | 887.03 |
| Seed | 3721.25 | 3361.43 | 2903.33 | 2990.00 | 3244.00 |
| Fertilizing | 250.95 | 310.70 | 245.37 | 290.00 | 274.26 |
| Fertilizer | 11882.44 | 10998.43 | 10532.32 | 11338.35 | 11187.89 |
| Irrigation | 29712.23 | 32089.53 | 25882.25 | 28266.10 | 28987.53 |

Table 8: Summary of results. All inputs in (MJ/ha)

| Process | Experimental tractor incl. | Calculated Tractor excl. | Calculated Tractor Incl. | References tractor excl. |
|---|---|---|---|---|
| Seed drill | 887.03 | 144.98 | 467.4 | 156.18 |
| Seeds | 3244 | - | - | 1663.2 |
| Fertilizer broadcasting | 274.26 | 102.6 | 364.8 | 66.12 |
| Fertilizer total | 11187.89 | 12065 | | 12065 |
| N | | 11050 | | 11050 |
| P | | 675 | | 675 |
| K | | 340 | | 340 |
| Irrigation | 28987.53 | 18174.3 | | - |

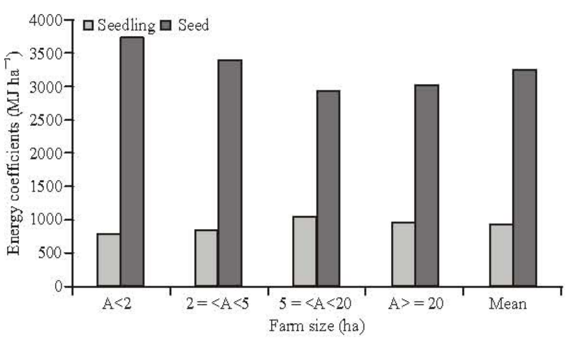


Fig. 2: Seed and seeding energy coefficient for diffrent farm size

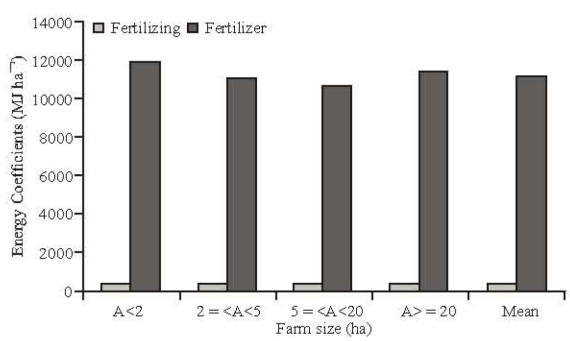


Fig. 3: Fertilizer and fertilizing energy coefficient for diffrent farm size

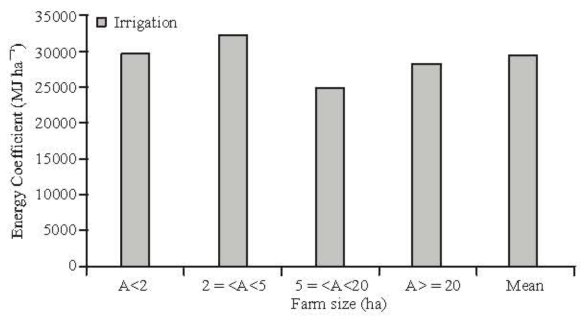


Fig. 4: Irrigation energy coefficient for diffrent farm size

from this table may be assumed for seeding, seeds, fertilizing, fertilizers and irrigation as their respective energy consumption in Saveh. From Table 8 and 5 it was concluded that:

1. Drill seeding energy consumption was 1.9 time as much as the maximum calculated energy and some less than that as the average use from references. Many factors may contribute to this high consumption of energy as follows:

- Low fuel efficiency of 1.43 kWh/L which is the result of mismatching tractor power with the machine.
- Lack of enough operators' knowledge on the drills.
- Non uniform depth of plowing.

2. About 1.93 times more seed sawn as compared to recommended agronomy expertise. This amounts to an average of 234 kg $ha^{-1}$. This value is a combination of seed sown by drill and broadcaster. Farmers usually saw much more seeds than needed when broadcasting because they expect high seed losses. Sowing by drills can cut this loss to a very lower amount.
3. Direct energy use for fertilizer broadcasting was 0.75 times the calculated value. Although this indicator may lead us to a hopeful prospect of broadcast efficiency but we think that it is the result of not enough overlapping of broadcasting paths than anything else. Comparatively low yield of wheat is a supporting argument behind the subject. It is however more than 1.16 times the references.
4. The amount of fertilizers used in the farms compares closely and even is less than the average references use at 0.93%. However there are indications that farmers are using more nitrogen fertilizer than is needed for the plants. High nitrogen content in potato produced in Iran may be an indication of this

conclusion. The nitrogen content is so high that most potato export to middle Asia countries is rejected.

5. Irrigation energy consumption was 1.69 times the calculated results. This could be the result of either more than 60% water loss in irrigation, deepening under ground water dynamic head, inappropriate maintenance and injection pump adjustment and/or aged engines. Reports indicate that under ground surface in most part of the country is lowering by about 1.5 meters a year.

## ACKNOLWEDEGMENTS

The authors would like to thank the Research Deputy, University of Tehran for providing technical assistance and financial support.

## REFERENCES

1. Sartori, L., Ba sso B., Bertocco and G. Olivier, 2005. Energy Use and Economic Evaluation of a Three Year Crop Rotation for Conservation and Organic Farming in NE Italy. Biosys. Eng., 91 (2): 245-256.
2. Nagy N. Cecil, 1999. Coefficient of energy for Agriculture Inputs in Western Canada. Research Associate. Canadian Agricultural Energy End-Use Data Analysis Centre (CAEEDAC).
3. Zentner, R.P., G.P. Lafond, D.A. Derksen, C.N. Nagy, D.D. Wall and W.E. May, 2003. Effects of tillage method and crop rotation on non-renewable energy use efficiency for a thin Black Chernozem in the Canadian Prairies. Agricultural Energy End-Use Data Analysis Centre (CAEEDAC).
4. Islam, A.S. and M.A. Rahman *et al.*, 2001. Energy Audit for Rice Production under Power tiller and Bullock Farming Systems in Bangladesh. Online J. Biol. Sci., 1 (9): 873-876.
5. Anonymous, 2006. Harvesting Energy with Fertilizers. European Fertilizer manufacturers Association. Avenue E. van Nieuwenhuyse 4 • B-1160 Brussels Belgium.
6. Davis, J.G., D.G. Westfall, J.J. Mortvedt and J.F. Shanahan, 2007. Fertilizing Winter Wheat. Colorado State University. Extension Services, USA
7. Anonymous. 2006. Total Energy Indication for Agricultural Stability. The Ministry of Agriculture and Forestry (MAF) Pastoral House, New Zealand.
8. Hunt, D., 1995. Farm Power and Machinery Management. 9th Edn. Iowa State University Press. Ames, Iowa USA.
9. Srivatsava, K.A., C.E. Goering and R.P. Rohrbach, 1993. Engineering Principles of Agricultural Machines. ASAE. Elsevier Publishing Co., USA.
10. Umar B. May, 2003. Comparison of Manual and Manual-cum-Mechanical Energy Uses in Groundnut Production in a Semi-arid Environment. CIGR J. Sci. Res. Develop. Manuscript. EE.0f.00f3. Renewable Energy, 29 (2004): 861-871
11. Anonymous. 2005. Census of irrigation wells. Iranian power department. Tehran, Iran.
12. Behroozi Lar, M., 2007. Final report on energy optimization in agriculture. Department of Fuel Use Optimization, Iran.
13. Anonymous, 2001. Fuel Required for Field Operations. Iowa State University. University Extension, USA.
14. Downs, H.W. and R.W. Hansen, 2006. Estimating Farm Fuel Requirements. Colorado State University Extension. Colorado University, USA.
15. Audsley, E., 2000. Systematic procedures for calculating agricultural performance data for comparing systems. Silsoe Research Institute. Wrest Park. Silsoe, UK.