Scientific Papers. Series A. Agronomy, Vol. LXII, No. 1, 2019
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

COMPARISON OF ENERGY CONSUMPTION IN CULTIVATION OPERATIONS FOR WHEAT PRODUCTION IN TURKEY

Hasan Huseyin OZTURK[1], Zinnur GOZUBUYUK[2], Mesut Cemal ADIGUZEL[3]

[1]University of Agriculture Cukurova, Faculty of Engineering of Agricultural Machinery and Technology, 01330, Adana, Turkey
[2]Ministry of Agriculture and Forestry, Directorate of Eastern Anatolia Agricultural Research Institute, 25400, Erzurum, Turkey
[3]Ministry of Agriculture and Forestry, 8th Regional Directorate of State Hydraulic Works, Erzurum, Turkey

Corresponding author email: hhozturk@cu.edu.tr

Abstract

The objective of this study was to compare energy consumptions under traditional cultivation system for wheat production in Turkey. The data used in this study were collected through a questionnaire by face to face interviews. The amount of energy that consumed in tillage, planting, fertilizing, agricultural spraying, harvesting and transport stages were calculated for wheat cultivation. The energy inputs such as human labor, tractors, tools/machineries, fuel/oil, fertilizers, pesticides, irrigation and seed obtainment processes were taken into consideration to determine the amount of energy that used in wheat cultivation. The total energy used in various farm inputs for wheat cultivation was 17159.5 MJ/ha. The energy output/input ratio, specific energy, energy productivity and net energy efficiency were found to be 2.21, 7.18 MJ/kg, 0.14 kg/MJ and 20746.5 MJ/ha, respectively.

Key words: *wheat, energy consumption, Turkey.*

INTRODUCTION

Energy consumption per unit area in agriculture is directly related with the development of technological level and cultivation. The inputs such as fuel, electricity, machinery, seed, fertilizer and chemical take significant share of the energy supplies to the cultivation system in modern agriculture. The use of intensive inputs in agriculture and access to plentiful fossil energy has provided an increase for standards of living and food production. However, some problems in agricultural production have been faced due to mainly high level dependency on fossil energy. The problems with the use of fossil energy have become into focus by oil embargo in 1973 and increase in energy prices. Nowadays environmental issues such as global warming are the major concerns related to the use of fossil energy. Furthermore considering that fossil energy is a limited resource, it has to be conserved for future generations by using efficiently in a sustainable manner. Energy is considered to be a key player in the generation of wealth and also a significant component in economic development. This makes energy resources extremely significant for every country in the world. Energy use has been a matter of policy concern since the 1970s. After the oil crises in 1973 and 1979, governments intensively promoted energy conservation measures. Then in 1980s, the primary focus shifted to air pollution caused by combustion of fossil fuels. In the recent years, energy use and associated greenhouse gas emissions and their potential impacts on the global climate change have been the worldwide concern. Improving the end-use energy efficiency is one of the most effective ways to reduce energy consumption in the industrial, commercial, transportation, utility, residential and agricultural sectors and their associated pollutant emissions (Dincer et al., 2004).

Efficient use of the energy resources is vital in terms of increasing production, productivity, competitiveness of agriculture as well as sustainability to rural living. Energy auditing is one of the most common approaches to examine energy efficiency and environmental impact of the cultivation system. It enables researchers to calculate input-output ratio, other relevant indicators and energy use pattern in an agricultural activity. Moreover, the energy audit provides sufficient data to establish functional forms to investigate the relationship between energy inputs and outputs. Estimating these functional forms is very useful in terms of determining elasticities of inputs on yield and production. Energy use pattern and contribution of energy inputs vary depending on farming systems, crop season and farming conditions. Considerable work has been conducted on the use of energy in agriculture with respect to efficient and economic use of energy for sustainable production. Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems. This analysis is important to perform necessary improvements that will lead to a more efficient and environment–friendly production system (Ozkan et al., 2003; 2004). Comprehensive studies have been performed on energy use in different agricultural products. Optimization of energy use in agriculture is reflected in two ways, i.e. an increase in productivity at the existing level of energy inputs or conserving the energy without affecting the productivity (Singh et al., 2004).

For that reason, energy use in wheat cultivation was examined in the present study. The main objective of this study is to evaluate the energy input and output for wheat cultivation in of Turkey. Data for the cultivation of wheat were collected from farms by using a face to face questionnaire method. This study seeks to analyze the effect of indirect and direct energy on yield using functional form. The energy ratio, specific energy, energy productivity and net energy efficiency as indicators for the determination of energy efficiency were calculated in the wheat cultivation.

MATERIALS AND METHODS

The basic characteristics of surveyed farms

The data included energy inputs from different sources, data input to various farm operations and yield. Taking actual farm size as the variable, the total 132 farms was randomly selected by using stratified random sampling. The permissible error was defined to be 5% for 95% reliability (Yamane, 1967).

$$n = \frac{\left(\sum N_h S_h\right)}{N^2 D^2 + \sum N_h S_h{}^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where: n is the required sample size; N is the number of holdings in target population; N_h is the number of population in h the stratified; S_h is the variance of h the stratified; D is the precision where (x-X).

The total agricultural land of the investigated 132 farms is 2413.7 hectares. Almost 30% of the farm land less than 5 hectares, and 50% less than 10 hectares. In spite of large number of small farms, less than 5 hectares, cultivate only 5% of total land, and 14% cultivates by the farms less than 10 hectares, cumulatively. Although, farms over 50 hectares which are only 6% of the total number of investigated farms, cultivate 28% of total land. The average size of farms is 18.3 hectares, and 37.2% of farm land is under irrigation. This proportion is relatively high at small farm groups.

In general, farm lands have been divided into many parcels. The average number of parcel is three. 80.3% of average operated land by farms is owned, 13.5% of it rented and rest (6.2%) is share cropped. Tenancy is more common at small farm groups. The share of rented land at small farm group (less than 5 hectares) increases up to 25%. Share cropping is not common in the region. Its share is only around 6%. This proportion is lower at small farm groups.

Analysis of energy use in wheat cultivation

A proforma questionnaire was prepared in order to collect the required information related to the land possessed by the farmers and the utilization pattern, crop yield, operation time, fuel consumptions, fertilizer, chemical and seed inputs. The energy inputs as direct and indirect inputs were studied in two groups for the wheat cultivation in the Southeast Anatolia region of Turkey.

Direct energy inputs

Direct energy inputs, which were calculated according to inputs that used directly and have high energy values in the cultivation of wheat. In this sense, during the cultivation process, fuel and oil energies that consumed by agricultural tools/machineries was evaluated as direct energy inputs. Thus,

$$EI_{direct} = E_{fuel} + E_{oil} \quad \text{..............................(2)}$$

where:

EI_{direct} = Direct energy input (MJ/ha);
E_{fuel} = Fuel energy consumption (MJ/ha);
E_{oil} = Oil energy consumption per area (MJ/ha).

Energy input of fuel and oil consumption

The amount of consumed fuel energy for unit cultivation area in the wheat cultivation (ha) is calculated depending on the amount of fuel that consumed by the tractor and the calorific value of diesel fuel, as it can be seen down below:

$$E_{fuel} = M_{fuel} \times FHV_{fuel} \quad \text{..........................(3)}$$

where:

E_{fuel} = Fuel energy consumption per area (MJ/ha);
M_{fuel} = Fuel consumption of the tractor (L/ha);
FHV_{fuel} = The lower calorific value of fuel (MJ/L).

The oil energy input which occurs due to engine oil consumption in wheat cultivation was determined by considering of the oil consumption of the farm tractor per hour, during the process of cultivation. The oil consumption of the farm tractor per hour was determined by depending on the highest PTO (power take off) shaft power of the tractor, which can be formulated as follows (Gungor & Ozturk, 2019):

$$OCT = 0{,}00059 \times HSP_{max} + 0{,}02169 \quad \text{.........(4)}$$

where:

OCT = The oil consumption of tractor (L/h);
HSP_{max} = PTO shaft power of the tractor (kW).

The maximum PTO shaft power (HSP_{max}) of the agricultural tractor that was used for the cultivation process of wheat was considered as 88% of its rated power (RPT, kW) and determined as follows (Ozturk, 2018):

$$HSP_{max} = 0{,}88 \times RPT \quad \text{..........................(5)}$$

The oil energy amount that consumed per unit area in wheat cultivation process was calculated depending on the amount of oil that consumed by the tractor per hour during the manufacturing process, the lower calorific value of consumed oil and work efficiency of the tractor per area, which is defined as:

$$E_{oil} = OCT \times OHV_{oil} \times WCT \quad \text{......................(6)}$$

Where:

E_{oil} = Oil energy consumption per area (MJ/ha);
OCT = Oil consumption of tractor per hour (L/h);
OHV_{oil} = The lower calorific value of oil (MJ/L);
WCT = Working capacity of the tractor (h/ha).

During cultivation operations in the field, the lower calorific value of engine oil (SAE 40) was taken into account as 38.2 MJ/kg.

Indirect energy inputs

In the cultivation of wheat, the amount of energy that consumed for human labor, agricultural tools/machineries, chemical fertilizers and the seed production were considered as indirect energy inputs. Therefore,

$$EI_{indirect} = HE + ME + EF + SE \quad \text{...............(7)}$$

where:

$EI_{indirect}$ = Indirect energy input (MJ/ha);
HE = Human labor energy (MJ/ha);
ME = Energy consumption for machines (MJ/ha);
EF = Energy input of fertilizer (MJ/ha);
SE = Seed energy per unit area (MJ/ha).

Energy input of human labor

Relating to these applications the human labor energy is determined as indirect energy consumption (Ozturk, 2016):

$$HE = \frac{NL \times WH}{CA} \times EEL \quad \text{.........................(8)}$$

where:

HE = Human labor energy (MJ/ha);
NL = Number of laborer (person);
WH = Working hours (h);
CA = Cultivated area (ha);
EEL = Energy equivalent of labor (MJ/h).

Indirect energy input for tools/machines

The energy amounts that related to indirect energy consumption of agricultural tools/machineries usage are taken into account, as follows (Ozturk, 2011):

- The amount of energy that consumed for the manufacturing of tools/machineries, including to their disinterment of the raw materials, transportation and forge,
- The amount of energy that used for the materials from raw condition in factory/workshop to design of tools/machineries and their manufacturing processes,
- The amount of energy that used for the process of mending/maintenance of tools/machineries and
- The amount of energy that used for transportation and distribution of the tools/machineries

During the cultivation of wheat, the indirect energy consumption related to farming tools/machineries for each field application was determined as (Ozturk, 2016),

$$IDEM = \frac{PEM + MME + TDE}{EL \times CEW} \times NT \ldots\ldots\ldots\ldots..(9)$$

where:

$IDEM$ = The indirect energy consumption related to farming tools/machineries per area (MJ/ha);
PEM = Manufacturing energy of machineries (MJ);
MME = Maintenance energy of machineries (MJ);
TDE = The amount of energy that used for transportation and distribution of the tools/machineries (MJ);
EL = Economic life of the tools/machineries (h);
CEW = The capacity of effective work (ha/h);
NT = The number transactions (quantity).

Indirect energy input for chemical fertilizer

Relating to these applications, the indirect energy consumption of chemical fertilizer usage can be expressed as:

$$EF = \sum_{l=1}^{l=s} [\sum_{n=1}^{n=u} \frac{\lfloor N \times N_{eq} \rfloor_n}{FA} + \sum_{n=1}^{n=u} \frac{\lfloor P_2O_5 \times P_{eq} \rfloor_n}{FA} + \sum_{n=1}^{n=u} \frac{\lfloor K_2O \times K_{eq} \rfloor_n}{FA}]_l \quad ..(10)$$

where:

EF = The total energy input of fertilizer (MJ/ha);
N = The amount of nitrogen fertilizer (kg);
N_{eq} = Energy consumed for N fertilizers (MJ/kg);
P_2O_5 = The amount of phosphorus fertilizer (kg);
P_{eq} = Energy consumed for P fertilizers (MJ/kg);
K_2O = The amount of potassium fertilizer (kg);
K_{eq} = Energy consumed for K fertilizers (MJ/kg);
FA = The fertilized area (ha);
n = The number of fertilizer application.

The production energy values of chemical fertilizers that used in wheat cultivation are given in Table 1.

Table 1. Energy Consumption Values for the Production of Pure Substance in Chemical Fertilizers (Ramirez & Worrel, 2006)

Chemical fertilizers	Energy consumption (MJ/kg)
Nitrogen (N)	45
Phosphorus (P_2O_5)	8
Potassium (K_2O)	5

Indirect energy input for seed

Relating to these applications, the indirect energy consumption of the seed usage can be determined from

$$SE = S\,(SPE+EPT)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(11)$$

where:

SE = The seed energy per unit area (MJ/ha);
S = Sowing ratio (kg/ha);
SPE = Energy consump. for seed product. (MJ/kg);
EPT = Energy consumption of packaging and transportation (MJ/kg).

The energy consumption for seed production and packaging/transportation equivalent was taken into account as 25 MJ/kg for determination of the seed energy per unit area (Oren & Ozturk, 2006).

Total energy input for wheat cultivation

In wheat cultivation, the direct and indirect energy inputs were taken into account as total energy input. Thus,

$$TEI = EI_{direct} + EI_{indirect} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

where:

TEI = Total energy input(MJ/ha);
EI_{direct} = Direct energy input (MJ/ha);
$EI_{indirect}$ = Indirect energy input (MJ/ha).

Energy output for wheat cultivation

Two major outcomes were obtained, the wheat seed (grain) as a main product and the stem part of plant as a subsidiary product. The total amount of energy that obtained from at the end of wheat cultivation, including main and subsidiary products can be calculated as follows (Ozturk, 2011):

$$TEI= (EMP \times E_{mp})+(ESP \times E_{sp})\ldots\ldots\ldots\ldots..(13)$$

where:

TEI = Total energy input (MJ/ha);
EMP = Amount of the main product (kg/ha);
E_{mp} = Energy of the main products (MJ/kg);
ESP = Amount of the subsidiary product (kg/ha);
E_{sp} = Energy of the subsidiary product (MJ/kg).

For the determination of the energy outputs in wheat cultivation, the energy equivalent were taken into account as 14.7 MJ/kg and for 12.5 MJ/kg for grain and wheat straw, respectively (Ozturk, 2016).

Energy efficiency for wheat cultivation

The indicators that were used for the determination of energy efficiency in the cultivation of wheat with the applications of the different mechanization techniques can be listed in Table 2.

RESULTS AND DISCUSSIONS

The energy equivalents of the input and output and indicators of energy efficiency in wheat cultivation are illustrated in Figures 1, 2 and 3, and Table 2. As can be seen from Figure 1, the total energy used in various farm inputs was 17159.5 MJ/ha for wheat cultivation. The results revealed that 7.6 h of machinery power per hectare were consumed to cultivate wheat in the research area. The human labor was 23.92 MJ/ha in wheat cultivation. The machine energy input was found to be of the order of 490.6 MJ/ha, while the man power 38.18 MJ/ha in wheat cultivation. Out of all the farm operations, seedbed preparation consumed the maximum energy followed by sowing and cultural practices, and harvesting.

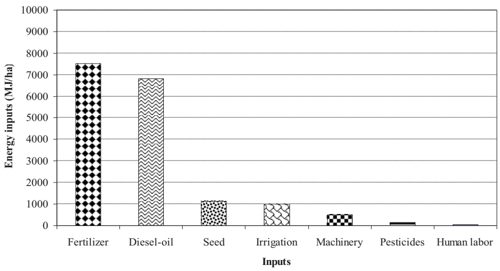

Figure 1. The Energy Inputs for Wheat Cultivation

In wheat cultivation, out of all the inputs, fertilizers have the biggest share in the total energy with a 43.8%. Fertilizer energy input is followed by the diesel-oil energy. According to Muhadar and Hignet (1982), energy used in the production of fertilizers accounts for about 40% of total energy used in agricultural production in developed countries. Most of this energy was consumed in the production of nitrogen, phosphorus and potassium fertilizers. In this study, nitrogen, phosphorus and potassium were considered as chemical fertilizer inputs. Results show that nitrogen is the most important energy source with a value of 6714.5 MJ/ha, whereas phosphorus accounted for 801.42 MJ/ha. The diesel-oil energy was mainly used for operating tractor for performing the various farm operations. The results showed that the average yield in wheat production was 2612.1 kg/ha and wheat cultivation consumed a total of 17159.5 MJ/ha input energy (Figure 2). Therefore, in wheat cultivation the energy output/input ratio, specific energy, energy productivity and net energy efficiency were 2.21, 7.18 MJ/kg, 0.14 kg/MJ and 20746.5 MJ/ha, respectively (Table 2).

However, Canakci et al. (2004) determined that the energy output/input ratio and specific energy for cultivating wheat were 2.8 and 5.24 MJ/kg in Antalya region of Turkey. Wheat is an energy frugal crop, compared to most other food crops. The energy inputs for wheat production in various regions of the U.S. calculated by Krummel and Chick of Cornell University. They found that the energy output/input ratios were 0.43, 1.66, 2.21, 3.36 and 3.75 for wheat production in Texas, New Mexico, North Dakota, Ohio and Nebraska, respectively (Briggle, 1980).

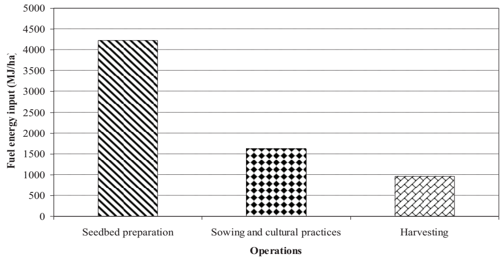

Figure 2. Fuel Energy Inputs for Wheat Cultivation

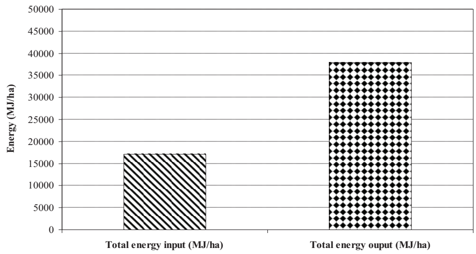

Figure 3. Energy Input and Output for Wheat Cultivation

Table 2. Energy Efficiency Indicators for Wheat Cultivation

Indicators	Definition	Unit
Energy ratio	Total achieved energy amount/Total consumed energy amount	2.21
Specific energy	The amount of total consumed energy/The total amount of harvested product	7.18 MJ/kg
Energy productivity	The total amount of harvested product/ The amount of total consumed energy	0.14 kg/MJ
Net energy efficiency	Total achieved energy amount/Total consumed energy amount	20746.5 MJ/ha

CONCLUSIONS

The total mean energy inputs as direct and indirect forms were examined in the wheat cultivation. Considerable savings could be obtained in machinery energy inputs by adopting a reduced tillage method. The average values of estimated energy output/input ratio was 2.21 for cultivation of wheat. The low level of energy output/input ratio indicated that all the farmers were not fully aware of the right production techniques or did not apply them at the proper time in the right quantity. The diesel-oil and the level of fertilizer input particularly nitrogen, were two of the most significant determinants of the total energy input for wheat cultivation. These results indicate that wheat cultivation in Turkey heavily depends on fossil fuels which in turn lead to many environmental problems. Therefore, policies should emphasize development of new technologies and alternative energy resources aiming efficient use of energy. In addition to these, the results imply that Turkish field crop production might be considered as sensitive to changes in prices and availability of fossil fuels due to mainly its significant share in total consumed energy in field crop production. The results of this study can be used by policy makers and other relevant agencies for recommendations to farmers in order to use energy more efficiently. Proper management of resources and their application at the right time can improve the efficiency of the farmers in the use of farm inputs.

REFERENCES

Briggle, L.W. (1980). *Introduction to energy use in wheat production*. Handbook of Energy Utilization in Agriculture (Editor: David Pimentel), 109–116. ISBN 0-8493-2661-3, CRC Press, Inc.

Canakci, M., Topakci, M., Akinci, I., Ozmerzi, A. (2004). Energy use pattern of some field crops and vegetable production: case study Antalya region, Turkey. *Energy Conversion and Management*, *46*, 655–666.

Dincer, I., Hussain, M.M., Al-Zahamah, I. (2004). Analysis of sectoral energy and exergy use of Saudi Arabia. *International Journal of Energy Research 28*(3), 205–243.

Gungor, C., Ozturk, H.H. (2019). Evaluation of fossil fuel consumption and environmental impacts in sugar beet production as a biofuel raw material. *Fresenius Environmental Bulletin*, *28*.

Muhadar, M.S., Hignett, T.P. (1982). Energy and Fertilizer: Policy implications and options for developing countries. International Fertilizer Centre, Muscle Shoals, Alabama.

Oren, M.N., Ozturk, H.H. (2006). An input-output energy analysis in field crop production in Southeastern Anatolia Region of Turkey. *Journal of Sustainable Agriculture*, *29*(1), 125–136.

Ozkan, B., Akcaoz, H., Karadeniz, F. (2003). Energy requirement and economic analysis of citrus production in Turkey. *Energy Conversion and Management*, *45*(11-12),1821–1830.

Ozkan, B., Akcaoz, H., Fert, C., (2004). Energy input-output analysis in Turkish agriculture. *Renewable Energy*, *29*, 39–51.

Ozturk, H.H. (2011). Energy management in plant production (In Turkish). HASAD Publication, Istanbul, ISBN 975-8377-78-7.

Ozturk, H.H. (2016). Energy use for wheat cultivation in Southeast Anatolia Region of Turkey. *Agricultural Mechanization in Asia, Africa and Latin America*, *47*(3), 47–53.

Ozturk, H.H. (2018). An assessment of carbon dioxide emissions related to fuel consumption for sunflower cultivation. *Fresenius Environmental Bulletin*, *27*(2), 710–719.

Ramirez, C.A., Worrell, E. (2006). Feeding fossil fuels to the soil an analysis of energy embedded and technological learning in the fertilizer industry. *Resources, Conservation and Recycling*, *46*, 75–93.

Singh, G., Singh, S., Sing, J. (2004). Optimization of energy input for wheat crop in Punjab. *Energy Conversion and Management*, *45*, 453–465.

Yamane, T. (1967). Elementary sampling theory, N.J., USA: Prentice Hall Englewood Cliffs.