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# Energy use of forage maize production under different irrigation scenarios

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**Abstract:** The purpose of this study was to determine the energy use in forage maize production under different irrigation scenarios. The data in present study were collected from 63 maize farms in Chaharmahal and bakhtiri province, Iran. Various water sources for forage maize production were used by farmers received the questionnaires. Results indicated that the minimum energy consumption in forage maize production was found in traditional irrigation systems followed by center pivot and sprinkler systems. Total input energy in forage maize production (quantity per hectare) under traditional irrigation was lower than that of under center pivot and sprinkler systems. Results also highlighted that in deep well-based on irrigation systems, the greatest proportion of the input energy was related to electricity energy. The maximum energy use efficiency was detected for traditional irrigation system, followed by center pivot and sprinkler systems. Net energy output in traditional irrigation system was the highest which was followed by sprinkler and center pivot irrigation systems.

**Key words:** Center pivot; Energy use efficiency; Forage maize; Net output energy

## 1. Introduction

Cereals have an important role in the food basket of world people. Maize or corn is a cereal crop that is grown widely throughout the world in a range of agroecological environments so that after wheat, barley and rice, corn is the most prominent crops that used as human food directly and cattle and birds food source indirectly (Abedi-Tizaki and Sabbagh, 2011). In Iran, corn is one of the most important crops which are cultivation in different areas such as chaharmahal-bakhtiari. In 2011, about 4, 227 hectares of lands of this province was under forage corn cultivation with an average yield of 41 tons per hectare. Forage corn is becoming an increasingly important forage crop in many regions of the world (Zerbini and Thomas, 2003).

Efficient use of energy is one of the basic needs of sustainable agriculture which causes saving in economic costs, conservation of fossil fuels and reduction in air pollution (Uhlin, 1998; Pervanchon et al., 2002). Energy consumption in agriculture has been increasing year by year in response to increasing population, limited supply of arable land, and a desire for higher standards of living. Continuous demand in increasing food production causes intensive use of chemical fertilizers, pesticides, agricultural machinery, and other natural resources. Nevertheless, intensive use of energy leads to problems threatening public health and environment. well-organized consumption of energy in agriculture minimize environmental problems, prevent destruction of natural resources, and encourage sustainable agriculture as an economical production system (Erdal et al., 2007).

Energy in agriculture is important because of crop production and agro processing for value adding. Human, animal and mechanical energies are widely used for crop production in agriculture. At the farm level, energy requirements are divided into two groups being direct and indirect. Direct energy is required to crop production includes crop production (e.g., cereal grains, oilseeds, pulses, fruits, and vegetables) processes such as land preparation, irrigation, interculture, threshing, harvesting and transportation of farm productions. In contrast, indirect energy consists of the energy used in the manufacture, packaging and transport of fertilizers, pesticides and farm machinery (Sebri, 2012).

According to Baruah and Bhattacharya (1995) calculation the energy input in agricultural production is more difficult compare to the industry part because of the large number of factors influencing agricultural production. However, considerable studies have been conducted in different countries on energy use in agriculture. A study conducted by Hatirli et al. (2006) in turkey showed that 34.4% of total consumed energy is related to diesel fuel, and agriculture energy productivity was 1.5MJ/ha. Pimetal (1993) found that wheat energy efficiency in organic and conventional farming was 3.49 and 2.38, respectively. In a study which set out to determine the energy use patterns of wheat, cotton, maize, sesame in Turkey, Canakci et al. (2005) found that that application of the fertilizer have the highest energy source in total inputs with share of 52.7% in maize production.

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Traditional farming is being substituted by modern farming. A huge amount of fossil fuel energy is utilized in modern agriculture. Cropping pattern, farm activities and level of technology define the energy requirements. Energy needs are not only increasing in the agricultural sector, but in all sectors involving human activities. There is a large need to balance the use and availability of energy especially in the agricultural sector, so that it does not adversely effect on production (Sing, 1999). There are many types of irrigation systems. Some systems use water and energy more efficiently, whereas others are designed to overcome limitations such as irregular field shapes, sloping land, or a limited water supply (Evans et al., 1996). Thus, efficient use of energy inputs has become important in terms of sustainable farming. The main purpose of this research was to quantify the energy use of forage maize production under different irrigation scenarios in Chaharmahal and bakhtiri province of Iran.

## 2. Material and method

The present study was conducted in shahrekord city, Chaharmahal and bakhtiri province of Iran using two filed and survey ways. Data were collected from 60 forage maize farms in Shahrekord region of Iran (31°9'-32°48' N, 49°28'-51°25' E, 2150 m) by using a face-to-face questionnaire in the production year 2011/2012. In addition to the data obtained by surveys, input used in forage maize production according to international standards such as fuel consumption was measured for each of the operations. the county was classified into five physiographic regions, three Villages in which forage corn is extensively grown were determined in the area studied and then five farmer were randomly selected.

Sixteen deep wells of which 6 deep wells had traditional irrigation system and 9 wells were connected to the pressurized irrigation system through the secondary pump after transfer well water to the pool. Furthermore, in one case, the submersible pump in addition to the transmission of water to the surface was able to provide a head for the pressurized irrigation system.

Twenty three semi-deep wells of which 6 wells had traditional irrigation system and 14 wells were connected to the pressurized irrigation system through the secondary pump after transfer well water to the pool. Also, in three cases submersible pump besides the transmission of water to the surface was able to provide a head for the pressurized irrigation system.

Fifteen fields supplied by the source of spring water. Nine fields supplied by the originating streams from the river with traditional irrigation system.

Based on the energy equivalents of the inputs and output (Table 1), the energy use efficiency) and energy productivity were calculated (Mandal et al., 2002; Singh et al., 1997).

$$E = \frac{Eout}{Ein}$$

E is efficiency or energy ratio, Eout is Total energy output of the system (MJ ha$^{-1}$), Ein is Total energy input (MJ ha$^{-1}$).

Energy Net Gain was calculated as follow:

$$E = E_{out} - E_{in}$$

In which E is energy Net Gain, Eout is Total energy output of the system (MJ ha$^{-1}$), Ein is Total energy input (MJ ha$^{-1}$).

$$EI = E_{in} / Y$$

EI is energy Productivity, Y is filed yield (kg ha$^{-1}$).

### 2.1. Data analysis

Initially, shahrekord city was divided into four regions, then the three villages of each region were selected and five farmers from each village were randomly selected. Cronbach α coefficient was used to determine the reliability of the questionnaire. Energy calculations, tables and graph drawing were done by Excel software. All data were initially subject to SPSS software.

## 3. Results and discussion

### 3.1. Maize water requirements

Pure water requirements and irrigation water volume used during the growing season of forage maize was determined using Netwat software (Table 1). Since about 40% of the studied area lands are covered with sprinkler irrigation systems and 60 % of lands have traditional irrigation systems, the volume of impure water used for irrigation systems is given in Table 1.

### 3.2. Energy inputs

Labor energy in agriculture has been calculated with the assumption that each person works 8 hours a day (Haterli et al., 2005). Because water use in irrigation systems is different, energy consumption for agricultural inputs is presented in the two parts: inputs used except water and energy consumed for water use.

### 3.3. Energy inputs (except water)

Energy inputs in forage corn production (physical quantity per hectare) are illustrated in Table 2 and Table 3. As shown. Inputs energy used in forage corn production was about 16487.4 MJ/ha of which 77 % (12765.3 MJ) was for chemical fertilizers, 16.7 % (2746.0 MJ) for seed, 3.2 % (520.2 MJ) for manure and 2.8 % (455.9 MJ) for herbicides.

**Table 1:** Pure water requirements and the volume of water used for forage maize

| Crop coefficients (Kc) at growth stage* | | | | Pure water requirement (m3/ha) | Irrigation efficiency (%) ** | | volume of impure water used (m³/ha) | |
|---|---|---|---|---|---|---|---|---|
| primary | development | middle | final | | Surface | pressurized | Surface | pressurized |
| 0.45 | 0.9 | 1.13 | 0.7 | 6000 | 40 | 70 | 15000 | 8570 |

*Ghamsari et al., (2005)

** Tehran Province Jihad Agriculture Organization of Chaharmahal and bakhtiri province.

**Table 2:** Main energy inputs used in forage maize production (except water)

| Input | Values used per hectare | Energy equivalent (MJ unit_1) | Reference | Energy Consumption |
|---|---|---|---|---|
| Fertilizers | | | | |
| Nitrogen (N) | 175.7 (kg /ha) | 6614 | (Mohammadi et al., 2008) | 11620.8 |
| Phosphorus (P2O5) | 92.0 (kg /ha) | 12.44 | (Mohammadi et al., 2008) | 1144.5 |
| Potassium (K2O) | 0 | 11.15 | (Esengun et al., 2007) | 0.0 |
| Manure | 1734 (kg /ha) | 0.3 | (Singh, 2002) | 520.2 |
| Chemicals | | | | |
| Herbicides | 3.799 (lit/ha) | 120 | (Mohammadi and Omid, 2010) | 455.9 |
| Fungicides | 0 | | | - |
| Insecticides | 0 | | | - |
| seeds | 27.46 | 100 | (Kitani , 1999) | 2746 |
| | | Total | | 1648.74 |

**Table 3:** Energy equivalent of water used in different irrigation systems

| Iirrigation systems | Water used (m3/ha) | Energy equivalent | reference | Energy used (MJ/ha) |
|---|---|---|---|---|
| Traditional | 15000 | 0.84 | Alcorn and wood, (1998) | 12600 |
| Pressurized | 8570 | 0.84 | | 7198.8 |

### 3.4. Water energy

As mentioned earlier (Table 1), the volume of water used in forage maize production under Pressurized irrigation systems is less than traditional irrigation systems due to increased irrigation efficiency. Table 3 shows Energy equivalent of water used in different irrigation systems. Accordingly, Energy equivalent of water used in forage maize production under traditional and sprinkler irrigation systems was 12600 MJ and 7199 MJ, respectively.

### 3.5. Total energy input

Total energy input in forage corn production (physical quantity per hectare) is illustrated in Table 4. As observed, total energy input in forage corn production under conventional irrigation systems based on the deep well, semi deep well and springs and streams sources were 46532, 29723 and 18294 MJ/ha, respectively,. Total energy input in forage corn production under sprinkler-based systems supplied by the deep well, semi deep well and springs and streams sources were 76485, 66836 and 60319 MJ/ha, respectively. Total energy input in forage corn production under sprinkler-based systems supplied by the deep well, semi deep well and springs and streams sources were 54700, 47140 and 42035 MJ/ha, respectively. According to Phips et al (1976) total energy used in forage corn production per hectare was 21400 MJ/ha. The total energy input in silage maize under conservation tillage systems production was 20 567 MJha-1.

The share of each input in forage corn production for irrigation and water supply scenarios is given in Table 5. As observed in all deep well-based scenarios represented the largest single energy input. Under conventional irrigation supplied by semi deep well and springs and streams sources, chemical fertilizers had the highest proportion of input energy. The share of electricity energy was higher than that of the chemical fertilizers in sprinkler irrigation system. Overall, the energy input of chemical fertilizer and electricity was >70 %. The share of weed and pests control (pesticides) ranged from 1.5-2.5. This finding is consistent with Please et al (1988) findings who reported that weed and pests control practices with share of 3 % had the lowest share within the total energy inputs. Amanloo and Ghasemi Mobtaker (2012) reported that the share of electricity energy and diesel fuel within the total energy inputs was 38.31% and 29.5 %, respectively. Kraatz et al. (2008) reported the energy inputs for corn grain production as 1.7 MJ kg-1 of which nitrogen fertilizer representing the largest single energy input.

**Table 4:** Total energy input to production of one hectare of forage corn

| input | Traditional | | | Sprinkler | | | Center Pivot | | |
|---|---|---|---|---|---|---|---|---|---|
| | Deep Well | Semi deep well | Springs and streams | Deep Well | Semi deep well | Springs and streams | Deep Well | Semi deep well | Springs and streams |
| Labor | 413.6 | 413.6 | 413.6 | 319.0 | 319.0 | 319.0 | 238.3 | 238.3 | 238.3 |
| Machinery construction | 62.8 | 62.8 | 62.8 | 62.8 | 62.8 | 62.8 | 62.8 | 62.8 | 62.8 |
| Fertilizers | 12765.3 | 12765.3 | 12765.3 | 12765.3 | 12765.3 | 12765.3 | 12765.3 | 12765.3 | 12765.3 |
| Chemicals | 455.9 | 455.9 | 455.9 | 455.9 | 455.9 | 455.9 | 455.9 | 455.9 | 455.9 |
| Manure | 520.2 | 520.2 | 520.2 | 520.2 | 520.2 | 520.2 | 520.2 | 520.2 | 520.2 |
| Seed | 2746 | 2746 | 2746 | 2746 | 2746 | 2746 | 2746 | 2746 | 2746 |
| Electricity | 27600 | 10700 | 0 | 54100 | 44400 | 38300 | 33300 | 25700 | 21000 |
| Machinery fuel | 1330 | 1330 | 1330 | 1330 | 1330 | 1330 | 1330 | 1330 | 1330 |
| Irrigation Equipment Construction | 638 | 729.5 | 0 | 4185.9 | 4236.3 | 3820 | 3281.7 | 3321.1 | 2916 |
| Total | 46532 | 29723 | 18294 | 76485 | 66836 | 60319 | 54700 | 47140 | 42035 |

**Table 5:** The share of energy input to production of one hectare of forage corn

| input | Traditional | | | Sprinkler | | | Center Pivot | | |
|---|---|---|---|---|---|---|---|---|---|
| | Deep Well | Semi deep well | Springs and streams | Deep Well | Semi deep well | Springs and streams | Deep Well | Semi deep well | Springs and streams |
| labor | 0.9 | 1.4 | 2.3 | 0.4 | 0.5 | 0.5 | 0.4 | 0.5 | 0.6 |
| Machinery construction | 0.1 | 0.2 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Fertilizers | 27.4 | 42.9 | 69.8 | 16.7 | 19.1 | 21.2 | 23.3 | 27.1 | 30.4 |
| Chemicals | 1 | 1.5 | 2.5 | 0.6 | 0.7 | 0.8 | 0.8 | 1 | 1.1 |
| Manure | 1.1 | 1.8 | 2.8 | 0.7 | 0.8 | 0.9 | 1 | 1.1 | 1.2 |
| Seed | 5.9 | 9.2 | 15 | 3.6 | 4.1 | 4.6 | 5 | 5.8 | 6.5 |
| Electricity | 59.3 | 36 | 0 | 70.7 | 66.4 | 63.5 | 60.9 | 54.5 | 5 |
| Machinery fuel | 2.9 | 4.5 | 7.3 | 1.7 | 2 | 2.2 | 2.4 | 2.8 | 3.2 |
| Irrigation equipment Construction | 1.4 | 2.5 | 0 | 5.5 | 6.3 | 6.3 | 6 | 7 | 6.9 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

### 3.6. Energy input

Labor energy in agriculture has been calculated with the assumption that each person works 8 hours a day (Hatirli et al., 2005). Because water use in irrigation systems is different, energy consumption for agricultural inputs is presented in the two parts: inputs used except water and energy consumed for water use.

### 3.7. Output energy

The product energy was calculated by obtaining the dry matter (ton / ha) and its multiplying by the energy value.

Energy value of forage corn was 10.3 MJ kg$^{-1}$ and this energy obtained from burning one kilogram of maize shoots dry matter with 5.58% of ash. The average corn yield was 50 tons ha$^{-1}$ in the studied field. The average moisture content of maize forage was about 80 %. Thus, the amount of maize dry matter was equivalent to about 10 ton ha$^{-1}$. Energy output of forage maize per hectare is presented in Table 6. Accordingly, the energy output of forage maize was 103 GJ/ha/year.

### 3.8. Energy consumption efficiency

Energy consumption efficiency, energy productivity, specific energy and net energy are illustrated in Table 7. Energy consumption efficiency is output–input energy ratios, energy productivity is yield production-input energy ratios, specific energy is input energy- yield production ratios and net energy is difference between output and input energy.

**Table 6:** Energy output of forage maize per hectare

| Trait | Yield | Energy equivalents (MJ/Kg) | Energy |
|---|---|---|---|
| Maize dry matter | 10000 | 10.3 (Phipps et al., 1976) | 103000 |

The highest energy consumption efficiency was for springs and streams -based on traditional irrigation, whereas Deep Well -based on sprinkler system had the lowest energy consumption efficiency. Traditional irrigation system based on different water sources had the maximum energy consumption efficiency, and followed by center pivot and sprinkler systems; respectively. The output net energy was the greatest in traditional irrigation system followed by sprinkler center pivot systems, respectively. Kraatz et al., (2008) reported the energy inputs for corn grain production as 1.7 MJkg$^{-1}$

of which nitrogen fertilizer representing the largest single energy input.

**Table 7:** Energy consumption efficiency for silage maize production

| Indicator | Traditional | | | Sprinkler | | | Center pivot | | |
|---|---|---|---|---|---|---|---|---|---|
| | Deep Well | Semi deep well | Springs and streams | Deep Well | Semi deep well | Springs and streams | Deep Well | Semi deep well | Springs and streams |
| Energy consumption efficiency (MJ/MJ) | 2.2 | 3.5 | 5.6 | 1.3 | 1.5 | 1.7 | 1.9 | 2.2 | 2.5 |
| Energy productivity (KG/MJ) | 1.1 | 1.6 | 2.7 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.2 |
| Specific energy (MJ/KG) | 0.9 | 0.6 | 0.4 | 1.6 | 1.4 | 1.2 | 1.1 | 1.0 | 0.9 |
| Net energy (MJ/ha) | 56468 | 73277 | 84760 | 26515 | 36164 | 42681 | 48300 | 55860 | 60965 |

## 4. Conclusion

In this study, energy use of inputs and output in silage maize production in Chaharmahal and bakhtiri province of Iran were established. This study was conducted on 63 farms in 8 plains of the province. The results showed that energy consumption is affected not only by consumed inputs but also by the type of water sources and irrigation scenarios used. The minimum energy consumption in forage maize production was found in traditional irrigation systems followed by center pivot and sprinkler systems. In deep well-based on irrigation systems, the greatest proportion of the input energy was related to electricity energy.

Therefore, a reduction in electricity energy consumption by reducing the working pressure of irrigation systems is the most important tool to decrease energy costs and also to increase energy efficiency. In recent years, the development of science and technology has led to the emergence of new sprinklers with low working pressure and thus the hopes has increased to reduce energy use in irrigation systems. The highest and lowest energy efficiency was found under traditional irrigation (use of springs and streams sources) and has deep well classic deep well- based on irrigation systems, respectively. Under using the different water sources, the maximum and minimum net energy output occurred in traditional and sprinkler irrigation systems, respectively. It is suggested that this research establish on other horticultural and crop plants and thus the optimal cropping patterns in Chaharmahal and bakhtiri province provide by analyzing the production and energy costs.

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