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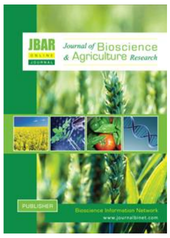

Energy use pattern in wheat production in the Gezira and Rahad Schemes, Sudan

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ABSTRACT

This study was conducted to investigate the energy use pattern for wheat production in the Gezira and Rahad Agricultural schemes, Sudan in relation to various aspects of energy consumption. Input data and yield of wheat were collected from the record of the schemes. Results showed that the total energy inputs and output of wheat were 13493.36 and 71038.75 MJ/ha, respectively. Based on these results the amount of energy use efficiency and the specific energy were 5.26 and 14.91, respectively, and the amount of energy productivity and net energy were 0.203kg/MJ and 57545.39MJ, respectively. The share of renewable energy as one of the sustainability indexes of agricultural systems was 21.54% (man labor and seeds) and 78.46 nonrenewable (fuel, chemicals, machinery and water). 40.27% was direct energy (human labor, fuel and water) and 59.46 as indirect energy (seeds chemicals and machinery). Therefore, for sustainability, the country should increase the share of renewable energy through using animal manure and agricultural residue compost.

Key Words: *Wheat, Energy use, Inputs, Output and Sustainability*

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I. Introduction

Cereal grains are the most important calorie source in the Sudanese diet (Abdelrahman, 1998). The majority of grain in the Sudan is grown in the rainfed subsector. More than 80 percent of sorghum and millet are grown in the rainfed subsector (Faki et al. 1995). On the other hand, the irrigated subsector monopolizes wheat production in addition to producing a sizeable amount of sorghum. Wheat imports have exerted a heavy burden on the Sudan's meager and deteriorating foreign exchange resources and have worsened its negative trade balance. Therefore, the domestic resources for wheat production should be fully utilized. The gap between potential yield and farmers' yields needs to be closed (Abdelrahman, 1998). Energy and environment are two sides of the same coin; increasing energy consumption anywhere will be accompanied by increased negative effects on the environment. It is accepted that air pollution, acid rain, and especially, global climate change has been mostly caused by greenhouse gas emissions from fossil fuel combustion. In addition, use of some renewable energy sources is expensive and, as well as having technological limitations, may cause environmental impacts (Boyle, 2004). The energy input per hectare in developing countries for agricultural production is about

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7,700 MJ and in developed countries, it is about 37,900 MJ. In developing countries, human labour is the major cost item of energy; while, in developed countries, mechanization and fertilizers are major energy inputs (Pimentel and Pimentel, 2008). The entire food system including production, processing, packaging, and transportation could require about 15% to 20% or more of a nation's energy consumption (Pimentel & Pimentel, 2008; Stout, 1990; Ziesemer, 2007) High consumption of non-renewable energies will reduce the energy use efficiency in production systems, because production of chemicals and using of machinery as the main index of common systems require large amounts of energy consumption (Pimentel et al. 1983). According to the report of Moore (2010), to achieve a sustainable system of food production, the amount of energy efficiency and the share of renewable energies should be increased in agricultural systems.

The use of mineral fertilizers and pesticides lead to higher yields in a conventional cropping system, but also requires higher energy inputs compared with organic systems (Alfoldi et al. 1994; Dalgaard et al. 2001; Grastina et al. 1995). The important consideration involving fertilizer use is optimize use of fertilizers in agriculture for yield, soil management, soil quality, resource utilization and avoid land degradation (Siddique et al. 2017; Hossain and Siddique, 2015; Ahmed et al. 2014; Kamaruzzaman et al. 2014; Sultana et al. 2014; Siddique et al. 2014). Next to water, soil nutrients are the most important barrier for crop productivity (Pimentel & Pimentel, 2008). For better growth, farmers use extra nutrients that are named fertilizers. Around 60% of world fertilizer demand comes from developing countries where it is used, mainly in cereal production (FAO, 2000b). Three different kinds of fertilizer are used in agriculture: chemical (mineral), organic and biological. Chemical fertilizers have increased the yield more than other innovations in agriculture (Smil, 1991, 2008) but its judicious application if very important for sustainability (Sultana et al. 2015).

The available evidence suggests that the excessive consumption of certain agricultural inputs, not only has inhibited the increase in production, but also reduced it in some cases (Omani and Chizari, 2008). According to various studies done in this field 60% and 90% of consumer energy is non-renewable (Canakci et al. 2005; Ozkan et al. 2004). The study of energy has been done in agricultural system in different parts of the world, including the apricots (Esengun et al. 2007), cotton (Tsatsarelis, 1991; Yilmazet al. 2005), cherry (Demircan et al. 2006), tomato (Esengun et al. 2007), sugar beet (Erdal et al. 2007), citrus (Ozkan et al. 2004), potato (Hosseinpanahi and Kafi, 2012; Mohammadi et al. 2008), greenhouse cucumber (Mohammadi and Omid, 2010), sugar cane (Karimi et al. 2008), barley (Mobtaker et al. 2010), pea (Salimi and Ahmadi, 2010), and wheat (Hosseinpanahi and Kafi, 2012). No single study exists for energy use pattern for crop production in Sudan so far. Hence the objective of this study were to determines the input and output energy used in wheat production in Sudan, to identifies operations where energy savings could be realized and to proposes improvements to reduce energy consumption for wheat production.

II. Materials and Methods

Study area: This study was carried out in the Gezira and Rahad schemes, Sudan during the winter season 017-2018 to investigate the energy use pattern in wheat production. The total area of the Gezira and Rahad scheme is 0.9 and 0.3 million ha, respectively. The area under wheat was about 0.17 million ha. Both schemes lie in the central clay plain and the irrigated through surface irrigation from the Blue Nile.

Data collection: The central agricultural engineering directorate carries out most of the operations. The information used in this study was collected from these directorates and from the agricultural directorate records. All agricultural operations are mechanized except irrigation, which is carried out by the farmer. The amount of energy consumption in each group of inputs was calculated from the multiplication of the amount of the input consumption and its energy equivalent per unit (Table 1). Then according to energy input and output, energy use efficiency, energy productivity, specific energy, and net energy were calculated using the following formula:

$$\text{Energy use efficiency (\%)} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}} \times 100 \qquad \text{............ (1)}$$

$$\text{Energy productivity (kg/Mj)} = \frac{\text{Grain output (kg/ha)}}{\text{Energy input (MJ/ha)}} \qquad \text{............ (2)}$$

$$\text{specific energy (MJ/kg)} = \frac{\text{Energy input (MJ/ha)}}{\text{Grain ouput (kg/ha)}} \qquad \text{............ (3)}$$

$$\text{Net Energy (MJ/ha)} = \text{Energy output} - \text{Energy input} \qquad \text{............ (4)}$$

Table 1. Energy equivalent of inputs and outputs in wheat production.

Items	Unit	Energy equivalent (MJ/unit)	Reference
A. Inputs			
1. Human labor	H	1.96	(Yilmaz et al. 2005; Ozkan et al. 2004; Mohammadi et al. 2008).
2. Machinery	H	62.7	(Mohammadi et al. 2008; Erdal et al. 2007; Giampietro et al. 1992; Erdal et al. 2007; Singh
3. tractor	H	68.4	et al. 2002; Singh,2002; Singh & Mittal 1992)
4. Diesel fuel	L	56.31	(Erdal et al. 2007; Singh et al. 2002; Mohammadi et al. 2008).
5. Chemicals			
(a) Nitrogen (N)	Kg	66.14	(Esengun et al. 2007; Yilmaz et al. 2005;
(b) Phosphate (P_2O_3)	Kg	12.44	Mohammadi and Omid 2010).
6.Pesticides		20.9	
7. Water	M^3	1.02	(Shahan et al.2008; Acaroglu and Aksoy, 2005; Mohammadi et al. 2008).
8. Seeds	Kg	20.1	(Singh & Mittal,1992; Ozkan et al. 2004; Giampietro et al. 1992).
B. Outputs			
1. Wheat grain yield	Kg	14.48	(Singh & Mittal,1992; Ozkan et al. 2004; Giampietro et al. 1992).
2. Wheat straw yield	Kg	9.25	Mobtaker et al. (2010)

III. Results and Discussion

Cultural practices: The agronomic practices during the growing of wheat along with the periods relevant to these preparations are shown in Table 2. Land preparation and soil tillage were mostly accomplished by 50-56kw tractor along with using disk harrows, ridger, toolbar leveller. Land preparation was followed by fertilizer application and sowing with seed drill having a capacity of 2 ha/h. Irrigation water is applied about eight times during the whole growing period by gravity irrigation. Harvesting is done mechanically using combine harvesters having a capacity of 2-4 ha/hr depending on the crop condition.

Table 2. Management practices for wheat production in Sudan

Operations	Period	Method
Land preparation	15/9-31/10	ridging, disk harrow, leveler
Fertilizer application	1/11-30/11	Broadcasting
Sowing	1/11-30/11	Seed drill
Average number of irrigation	8	Surface irrigation (gravity)
Harvesting	1-30 April	Combine harvester

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The inputs and output used in wheat production is shown in Table 3. Results revealed that only 47.50 hours of human power and 13.90 hours of machine power were required per one hectare of wheat production in the research areas. The amount of fertilizers used for wheat growing was 106.80 kg/ha that constitutes mainly nitrogen and phosphorus.

Table 3. Amount and percentage of different inputs and output energy equivalent

Items	Quantity per ha	Total energy Equivalent (MJ/ha)	% of total energy Input
A. Inputs			
1.Labor	47.50	93.10	0.69
land preparation	5	9.80	0.08
Sowing	1.5	2.94	0.02
Irrigation	32	62.72	0.46
Fertilizer application	3	5.88	0.04
Harvesting	6	11.76	0.09
2.Machinery (hr/ha)	6.45	404.42	3.00
land preparation	3.5	219.45	1.63
Sowing	0.75	47.03	0.34
Irrigation	0	0	0
Fertilizer application	1.5	94.05	0.70
Harvesting	0.7	43.89	0.33
3.Tractor (hr/ha)	7.45	509.58	3.78
4.Fuel (l/ha)	31.15	1765.32	13.08
land preparation	18.30	1041.74	7.72
Sowing	3.84	216.23	1.60
Irrigation	0	0	0
Fertilizer application	4.81	270.85	2.01
Harvesting	4.20	236.50	1.75
5.Fertilizer (kg/ha)	106.80	4292.84	31.81
(a) Nitrogen	55.20	3650.93	27.06
(b) Phosphorous	51.60	641.91	4.75
6. Pesticide (kg/ha)	2.11	44.10	0.33
7.Water	3500	3570	26.46
8.Seeds (kg/ha)	143	2814	20.85
B. Outputs		71038.75	
1.Seed (kg/ha)	2750	39820.00	56.05%
2.Straw (kg/ha)	3375	31218.75	43.95%

Total energy used in various farm operations during wheat production was 13493.36MJ/ha. Fertilzer energy consumes 31.81% of total energy inputs followed by water 26.46% during production period. This result is inline with (Safa, 2011) who found that fertilizers, mainly nitrogen, have a significant influence on energy consumption, accounting for 47% of total energy consumption in Canterbury Province, New Zealand. Hosseinpanahi and Kafi (2012) and Giampietro et al. (1992) have demonstrated that nitrogen fertilizer allocated the largest part of energy consumption among chemicals. Diesel energy was mainly consumed for land preparation, sowing and harvesting. Average annual grain yield was 2750 kg/ha and the calculated total energy output was 71038.75MJ/ha. It was observed that chemicals (pesticides) were the least demanding energy input for wheat production with 44.10 MJ/ha (only 0.33% of the total input energy), followed by human labor by 93.10 MJ /ha (0.69%) as shown in Table 3. Yield, energy input and output in wheat farming were 2750 kg/ha, 13493.36 and 71038.75 MJ/ha, respectively, compared to 4514.8 kg/ha, 47078.5 and 92785.56 MJ/ha, in Iran (Shahan *et al.*2008). In another study in Europe, Kuesters & Lammel (1999) found that total energy input in wheat production were between 7.5 and 17.5 GJ ha. The energy input and output, yield, energy use efficiency, specific energy, energy productivity and net energy of wheat production are shown in Table 4. Energy use efficiency (energy ratio) was calculated as 5.26 compared to 2.80 in Turkey (Canakci *et al.*2005) and 1.97 in Iran (Shahan *et al.*2008). In this study, the average energy productivity of farms was 0.203 compared to 0.077 in Uttar Pradesh, India (Rouf et al, 2015). This means that 0.203kg of grain was obtained per one kJ energy input. Specific energy is the reversal of energy productivity hence its lower amounts show that lesser energy is used for the production of each yield unit and here it was found to be 4.91 MJ/kg compared to 12.87MJ/kg in Uttar Pradesh, India (Rouf et al, 2015) and 17.8 in Sistan and Baluchestan province, Iran (Ziaei, et al,2013).

Table 4. Various energy performance parameters in sorghum production

Parameters	Unit	Energy (MJ/ha)
Total Input Energy	MJ/ha	13493.36
Total Output Energy	MJ/ha	71038.75
Energy use efficiency	-	5.26
Grain	kg/ha	2750
Specific energy	MJ/kg	4.91
Energy Productivity	kg/MJ	0.203
Net energy (MJ/ha)	MJ/ha	57545.39

Table 5. Total energy input in the form of direct, indirect, renewable and nonrenewable for wheat production (MJ/ha)

Form of Energy	Amount (MJ/ha)	%
Direct Energy	5428.42	40.23
Indirect Energy	8064.94	59.77
Renewable Energy	2907.10	21.54
Non-Renewable	10766.26	78.46
Total energy input	13493.36	100

The distribution of total energy input as direct, indirect, renewable and non-renewable forms is shown in Table 5. The classification of energy as direct and indirect, renewable and nonrenewable energy was found to be 40.23%, 59.77%, 21.54% and 78.46% respectively, compared to 43.67, 56.32, 19.60 and 80.39 in Sistan and Baluchestan province, Iran (Ziaei, et al,2013) and 30.26%, 69.74%, 31.30% and 68.70% in Uttar Pradesh, India (Rouf et al, 2.015).

In Sudan, water and fertilizer constitute large portion of nonrenewable energy. For sustainability, the country should increase the share of renewable energy by encouraging the use of natural fertilizer (implement the proposal of integration of animal into the crop rotation) and improve irrigation and water conveyance system, combining the sowing and fertilizer application in one operation.

IV. Conclusion

Energy use in wheat production can be detrimental to the environment due to mainly high non-renewable energy use. About 45% of the output energy is grain and the rest is straw. Use of farmyard manure can reduce the fertilizer energy use. Reducing fuel consumption in tractor and equipment in field operations along with optimum nutrient application method and efficient irrigation system in addition, breeding for high yielding varieties can help to improve the energy efficiency of wheat.

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