Energy use Pattern in Cotton and Groundnut Production in the Gezira scheme,

Gezira State, Sudan

ABSTRACT: This research examines the energy use patterns and energy input–output analysis of cotton, and groundnut in the Gezira Scheme which is the largest irrigated scheme in Sudan. Inputs and energy sources were determined by a face to face questionnaire applied to 200 farmers. For the cotton crop, the inputs and output energy were calculated as 27659.28MJ/ha and 28084MJ/ha, respectively. Fertilizer was the highest input (62.29%), followed by water (28.10%). Energy efficiency, energy productivity, specific energy and water productivity were 1.01, 0.09kg/MJ,11.62MJ/kg, 0.31kg/m^3, respectively. For the groundnut crop, the inputs and output energy were calculated as10222.83MJ/ha and 67372MJ/ha, respectively. Water was the highest input (72.25%), followed by seeds (8.56%). Energy efficiency, energy productivity, specific energy and water productivity were 6.59, 0.40kg/MJ,2.51MJ/kg, 0.29kg/m^3, respectively.it could be concluded that these crops are heavily dependent on nonrenewable energy.

Keywords: Energy, Gezira Scheme, energy efficiency, specific energy, energy productivity.

1. INTRODUCTION

Sudan is primarily an agricultural nation. Agriculture employs over 70% of the country's population. High yielding cultivars, pesticides, fertilisers, automation, and other energy inputs all affect crop productivity. Field crops are grown using a variety of energy sources, including human and animal power as well as heavy machinery. The eventual output–input ratio is influenced by the energy input and yield of each system. Agriculture and energy have a very strong relationship. Agriculture is both a consumer and a supplier of energy in the form of bio-energy (Alam et al., 2005). Agriculture's usage of energy has evolved in reaction to rising population, dwindling arable land, and a desire for a higher standard of living. These reasons have supported a rise in energy inputs in all societies in order to maximise yields, minimise labor-intensive practises, or both (Esengun et al., 2007). Increased usage of fertiliser, irrigation water, diesel, and plant protection chemicals necessitates more energy from humans, animals, and machinery. The rising cost of energy, particularly crude oil, has a considerable impact on agricultural profitability. The cost of production in agriculture is projected to rise as the use of energy-based inputs increases and oil prices rise. Effective energy usage in agriculture is one of the criteria for long-term agricultural productivity since it saves money, preserves fossil resources, and reduces pollution (Uhlin, 1998). Agriculture's energy requirement can be classified into direct and indirect, renewable and non-renewable energies for growth and development (Alam et al., 2005). The energy ratio between output and input has been used to assess the agricultural system's energetic efficiency. The energy ratio was calculated using human labour, machinery, diesel oil, fertiliser, pesticides, seed quantity, and agricultural output yield data.

In industrialised countries, agricultural energy consumption accounts for roughly 3% of total energy consumption, whereas in developing countries, it accounts for about 3.6 percent (Karkacier et al., 2006; Sauerbeck, 2001). However, the energy input per hectare for agricultural output in developing countries is around 7700 MJ, while it is around 37,900 MJ in developed ones. Human labour is the most expensive energy input in underdeveloped countries, whereas mechanisation and fertilisers are the most expensive energy inputs in developed countries (Pimentel and Pimentel, 2008). The entire food system, including production, processing, packing, and transportation, could consume 15% to 20% or more of a country's total energy (Stout, 1990; Ziesemer, 2007). According to numerous research in this sector, between 60% and 90% of consumer energy is produced by non-renewable processes (Canakci et al., 2005; Ozkan et al., 2004). Modern agriculture makes considerable use of chemical fertilisers, herbicides, agricultural machinery, and other farm inputs. The use of crop-specific fertiliser and inputs may help to assure profitable output (Sultana et al. 2015; Hossain and Siddique, 2015). Agriculture's efficient use of energy inputs will lessen environmental consequences, prevent harm to natural resources, and increase agriculture's long-term viability as a profitable production system (Kizilaslan, 2008). Any rise in energy use will be accompanied by an increase in negative environmental effects. It is widely acknowledged that greenhouse gas emissions from fossil fuel combustion are the primary source of air pollution, acid rain, and, most importantly, global climate change. Furthermore, certain renewable energy sources are costly to utilise and, in addition to having technological constraints, may have negative environmental consequences (Boyle, 2004). In a conventional cropping system, the use of mineral fertilisers and pesticides results in larger yields, but it also requires more energy inputs than organic systems (Dalgaard et al. 2001; Grastina et al. 1995). Optimizing fertiliser use in agriculture for productivity, soil management, soil quality, resource utilisation, and avoiding land degradation are all essential considerations (Siddique et al. 2017; Hossain and Siddique, 2015;). Farmers add extra nutrients to their crops to help them grow faster. In agriculture, three types of fertiliser are used: chemical, organic, and biological. Chemical fertilisers have raised yields more than previous agricultural technologies (Smil, 2008). Many researchers in various countries studied energy analysis to determine the energy efficiency of field crop production, such as sugarcane in Morocco (Mrini et al. 2001), soybean, maize and wheat in Italy (Sartori et al. 2005), wheat, maize, sorghum in USA (Franzluebbers, Francis 1995), field crops in Turkey (Canacki et al,2005,) soybean in India (Mandal, 2002), millet in Nigeria (Abubakr and Ahmed, 2010) wheat and sorghum in Sudan (Elfadil, 2018, a and b). There is a shortage of data on energy expenditure and returns in agricultural production systems in Sudan, as in any other developing nation. The productivity of agricultural inputs would require greater management of food production systems to fulfil the increasing demands of the growing population and for exports. As a result, an assessment of energy use for crop production is required to better understand the existing situation, as well as future initiatives to be made to improve vegetable production.

The aim of this study was to

1. Determine the energy input and output used in cotton and groundnut production.
2. Identifies operations where energy savings could be realized by changing applied practices in order to increase the energy ratio.
3. Propose improvements to reduce energy consumption for these crops.

2. MATERIALS AND METHODS

The study was carried out in 200 cotton and groundnut producers in the study area. Data were collected from the growers by using a face-to-face questionnaire. The data collected belonged to the production period of 2019–2020. The data covered farmer’s socio-economic variables, inputs as well as outputs data. By adding the partial energies of each input related to the unit of production, the total energy per production unit (ha) was calculated. Human labour, diesel fuel, machinery, irrigation, and nitrogen and phosphorous chemical fertilisers were all used as energy inputs. Excel spreadsheets were used to enter basic data on energy inputs and yields. Based on the energy equivalents of the inputs and output (Table 1), the energy ratio (energy use efficiency), energy productivity and the specific energy were calculated (Sartori et al., 2005; Demircan et al., 2006; Shahan et al., 2008).

Chart 1. Distribution of energy input and output

Energy use efficiency (energy ratio)	=	$\frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$	……..…...…….(1)
Energy productivity (kg/Mj)	=	$\frac{\text{Yield (kg/ha)}}{\text{Energy input (MJ/ha)}}$	……....…….(2)
specific energy (MJ/kg)	=	$\frac{\text{Energy input (MJ/ha)}}{\text{Yield (kg/ha)}}$	………....…….(3)
Water productivity (kg/m^3)	=	$\frac{\text{Yield (kg)}}{\text{water applied (m}^3\text{)}}$	……….....…….(4)
Net Energy (MJ/ha)	=	Energy outp − Energy input	…….....…….(5)

Table 1. Energy equivalent of inputs and outputs in field crop production.

Item	Unit	Energy equivalent (MJ/unit)	Reference
A. Input			
1. Human labor	Hr	2.30	(Yaldiz et al. 1993).
2. Machinery 3. Tractor	Hr Hr	62.70 68.40	(Mohammadi et al. 2008; Erdal et al. 2007; Giampietro et al. 1992; Singh et al., 2002; Singh,2002; Singh & Mittal 1992)
4.Fuel	L	56.31	(Erdalet al., 2007; Singh et al., 2002; Mohammadi et al 2008).
5.Fertilizer			
Nitrogen Phosphate	Kg Kg	66.14 12.44	(Esengun et al. 2007; Yilmaz et al. 2005; Mohammadi and Omid 2010).
6.Pesticides	Kg L	20.90 101.20	(Canakci et al., 2005; Singh, 2002)
7.Water	m^3	1.02	(Shahan et al.,2008; Acaroglu and Aksoy, 2005; Mohammadi et al. 2008).
8.Seeds			
Cotton	Kg	11.80	Yaldiz et. al.1993; Singh, 200
Groundnut	Kg	25.00	(Kitani, 1999)
B. Output			
9.Yield			
Cotton Stalk	Kg Kg	11.8 2.25	Yaldiz et. al.1993; Singh, 2002, Zahedi et al. 2014
Groundnut seed Straw	Kg Kg	25.00 11.60	(Kitani, 1999) Ibrahim et. al. 2016.

2.1. Data analysis

The data collected were analyzed using descriptive statistics. The energy equivalents of inputs used and output obtained are illustrated in Table 1. The data on energy use have been taken from a number of sources, as indicated in the table. Based on the energy equivalents of the inputs and output, the energy ratio (energy use efficiency) and energy productivity were calculated using equations 2 and 3.
The input energy was divided into direct energy (labor, fuel and water) and indirect energy (seeds, fertilizer, chemicals, machinery and tractors). Further, the input energy was divided into renewable energy including labor and seeds, and nonrenewable energy including fuel, chemicals, fertilizers, machinery, tractors and water (Rauf et al 2015).
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3. RESULTS AND DISCUSSION

3.1. Socioeconomic structure:

For cotton, the maximum area grown was 6.3 ha with an average of 1.1 ha. For groundnut, the area grown ranges from 0.4 to 6.70 ha with an average of 2 ha The education level was: 42.72 percent of the farmers were *khalwa*, 19.42 percent preliminary school, 27.18 secondary schools, 9.71 percent university graduates and 0.97 percent were post-graduates. About 70% of the farmers were below 50 years in age and about 11.65% were above 60. About 6.80% of the sample were females with *khalwa* education. 5.83% of the respondent agriculture is not their main job. Land preparation and soil tillage, opening furrows for manually planting of seeds, and inter-row weeding operations are mechanically carried out. Other operations are performed by hand. Land preparation and tillage were mostly accomplished by 70hp tractor along with using disk plow, harrows ditcher and ridger. Fertilizer is mainly applied through broadcasting. Spraying is done with the use of hand operated knapsack sprayer. Harvesting of cotton is done manually by direct picking. Groundnut is manually pulled from the soil, windrowed for drying and then collected in heaps and threshed mechanically.

3.2. Energy use in cotton production

3.2.1. Energy input output

The energy inputs used in cotton production and their energy equivalents, as well as the energy equivalent of the yield were presented in Table 2. As indicated in the table, the total energy input and output for cotton production in the study area was found to be 27659.28 and 28084MJ/ha, respectively, compared to 34424.19 and 41496.67 in Iran (Sami and Habib,2018) and 49736.9 and 36729.90 in Turkey (Yilmaz et al.,2005). Average cotton yield in the study area was 2380kg/ha which is lower than Iran (3517kg/ha) and higher than 1994kg/ha in China (Khan et al, 2007).

Fertilizer was the highest energy input for cotton production. About 357.06 kg of fertilizer in the form of urea and phosphorus were used on a hectare basis. This amount is equivalent to 62.29% of the total input energy used. This value is lower than 76% % in China (Khan et al,2007), but higher than 28.86% in Turkey (Yilmaz et al, 2005) and 20% in Isfahan, Iran (Zahedi, et al, 2014).

3.2.2. Energy efficiency (Energy ratio)

Based on these values output–input energy ratio for cotton production under the Gezira conditions was 1.01 (Table 3), compared to Turkey (0.74), china (1.51) and Iran (0.71).

3.2.3. Energy Productivity

Energy productivity is the term used to estimate the yield of marketable product received on per unit of energy consumed (kg/MJ). The energy productivity was calculated as 0.09kg/MJ (Table 3), which is closer to Iran (0.10kg/ha) lower than China (0.21) and higher than Turkey (0.06)

3.2.4. Specific Energy

Specific energy shows the amount of energy spent to produce a unit of marketable product (MJ/kg). It was found to be 11.62MJ/kg (Table 3), which is higher than China (4.76MJ/kg) and Iran (9.7MJ/kg).

3.2.5. Net energy

It is the difference between the output energy and input energy. It was calculated as 424.72MJ/ha (Table 3), compared to 7372.48MJ/ha in Iran and (-13007MJ/ha) in turkey.

3.2.6. Water Productivity

Water productivity is generally defined as crop yield per cubic meter of water consumption. Water productivity defined as above varies from region to region and from field to field, depending on many factors, such as crop patterns and climate patterns, irrigation technology and field water management, land and infrastructure, and input, including labor, fertilizer and machinery. In this study, water is the second highest input (7771.43 liter/ha) equivalent to 28.10% of the total energy input share. Water productivity was calculated as 0.31kg/m^3(Table 3). This value is closer to Iran and Turkey, (0.44 kg/m^3 and 0.37 kg/m^3), respectively but lower than China (0.8 kg/m^3)

Table 2. Amount and percentage of different inputs and output energy equivalent for cotton

A. Inputs	Unit/ha	MJ/ha	Percent of total input energy
Labor (hr/ha)	116.64	504.24	1.82
Machinery (hr/ha)	4.76	298.45	1.08
Tractor (hr/ha)	4.76	325.58	1.18
Fuel (l/ha)	7.14	402.05	1.45
Fertilizer (kg/ha)	357.06	17228.91	62.29
Pesticide (kg)	9.52	963.42	3.48
Water (m^3)	7619.05	7771.43	28.10
Seeds (kg)	14	165.20	0.60
B. Outputs			
Yield (kg)	2380	28084	

Table 3. Various Energy performance parameters in cotton production

Parameter	Unit	
Total Input Energy	MJ/ha	27659.28
Total Output Energy	MJ/ha	28084
Energy use efficiency	-	1.01
Yield	kg/ha	2380
Specific energy	MJ/kg	11.62
Energy Productivity	kg/MJ	0.09
Net energy (MJ/ha)	MJ/ha	424.72

Table 4. Total energy input categories for cotton production

Form of Energy	Amount (MJ/ha)	%
Direct Energy	8677.72	31.37
Indirect Energy	18981.56	68.63
Renewable Energy	669.44	2.42
Non-Renewable	26989.84	97.58
Total energy input	27659.28	100

The use of direct energy for cotton production is very high (68.63%) (Table 4), which is closer to Isfahan, Iran (68.3%), higher than China (14%) and Turkey (42.5%). There is a very extensive use of nonrenewable energy (97.58%) compared to 87.4% in Turkey,90% in China and 77.7% in Isfahan, Iran. Fertilizer is the highest among the inputs. This excessive use suggests that the nitrogen not consumed by the plant may pollute the underground water and the environment as noted by Kaplan et al. (1999).

3.3. Energy use in groundnut production:

The inputs used and their energy equivalents, output energy equivalent are illustrated in Table 5. About 220.10 of man-hrs are needed for growing one hectare of groundnut. No fertilizers were applied, only small amount of pesticides for seed coating was used. The total energy equivalent of inputs was calculated as 10222.83MJ/ha compared to 19248.04MJ/ha in Iran.

Table 5. Amount and percentage of different inputs and output energy equivalent for groundnut.

A. Inputs	Unit/ha	MJ/ha	Percent of total input energy
Labor (hr/ha)	220.10	504.24	4.95
Machinery (hr/ha)	8.33	522.29	5.11
Tractor (hr/ha)	8.33	569.77	5.57
Fuel (l/ha)	7.23	407.12	3.98
Fertilizer (kg/ha)	-	-	-
Pesticide (kg)	2.85	59.57	0.58
Water (m^3)	7142	7284.84	71.25
Seeds (kg)	35	875	8.56
B. Outputs		62500	
Yield (kg)	2080	52000	
Straw (kg)	420	10500	

Water had the highest share (72.25%) followed by seed (8.56%), tractor (5.57%) and machinery (5.11%), respectively. The energy inputs of pesticides were very low (0.58%) relative to the other inputs used in production. The average yield of groundnut was about 2080 kg/ha and its energy equivalent was calculated to be 62500 MJ, the straw production was 420kg/ha equivalent to 487MJ/ha resulting in a total energy output of 67372MJ/ha. Based on these values, output–input energy ratio was found to be 6.59, energy productivity was 0.40 kg/MJ, specific energy 2.51MJ/kg and water productivity was calculated as 0.57MJ/kg whereas the net energy was calculated as 57149.17MJ (Table 6).

Table 6. Various Energy performance parameters in groundnut production

Parameter	Unit	
Total Input Energy	MJ/ha	10222.83
Total Output Energy	MJ/ha	67372
Energy use efficiency	Ratio	6.59
Yield	kg/ha	2080
Specific energy	MJ/kg	2.51
Energy Productivity	kg/MJ	0.40
Water productivity	kg/m^3	0.57
Net energy (MJ/ha)	MJ/ha	57149.17

Table 7. Total energy input classifications for groundnut production

Form of Energy	Amount (MJ/ha)	%
Direct Energy	8186.20	80.18
Indirect Energy	2026.63	19.82
Renewable Energy	1379.24	13.49
Non-Renewable	8843.59	86.51
Total energy input	10222.83	100

Table 7. shows that the direct energy inputs (labor, fuel and water) was 80.18% and the indirect energy (seeds, fertilizer, chemicals, machinery and tractors) was 19.82%. Further, the input energy was divided into renewable energy 13.49% (labor and seeds) and nonrenewable energy 86.51% (fuel, chemicals, fertilizers, machinery, tractors and water). From Table 7. It is clear that groundnut production is heavily dependent on direct and nonrenewable energy which may not be sustainable in the long run.

4. CONCLUSIONS

1. The production of cotton and groundnut in the study area is highly dependent on non-renewable energy inputs which may not be sustainable in the long run.
2. Energy efficiency and productivity for the two crops in the research area were very low.
3. There is a need to use high yielding varieties to increase energy use efficiency and energy productivity.
4. There is a bad need for improving water productivity because of rising competition of finite water resources, rising demand of agriculture and devastating impact of climate change.

Consent

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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