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Energy Input-Output Analysis for Production of Selected Crops in the Central Clay Vertisols of Gezira Agricultural Scheme (Sudan)

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Abstract: ***The main objective of this study was to analyze the energy input, energy output and energy output/input ratio of three selected crops viz, sorghum, wheat and cotton in Gezira agricultural scheme of Sudan during five growing seasons. The results showed that the total energy expenditures (input) were 12.64 GJ/ha, 18.52 GJ/ha and 18.72 GJ/ha, while the total energy outputs were 95.59 GJ/ha, 127.90 GJ/ha and 20.51 GJ/ha for sorghum, wheat and cotton respectively. Fertilizer application was the most energy consuming field operation for the three crops. It was about 52 – 68% of total energy inputs. Energy output/input ratios varied from 6.2-8.4 for sorghum, 5.9-7.4 for wheat and 0.9-1.2 for cotton. Linear relationship was found between crop production and energy output/input ratios with high correlations (R2 = 0.97 – 99) for the three crops.***

Keywords: Energy, input, output, energy ratio, vertisols, Gezira

1. Introduction

Agriculture is an important sector for production of food and raw materials in un-developed and developing countries. It is both consumer and producer of energy. All agricultural operations require energy in one form or another, human labour, animal power, fertilizer, machinery, chemicals, fuel and electricity.

To meet the growing demand of the increasing population and exports, the productivity of land to be increased, this would substantially require higher energy input and better management of production system [1]. Therefore, in order to sustain agricultural production, effective energy use is required, since it provides ultimate financial saving, preservation of fossil resources and reduction of environmental distortion [2].

Energy required in agricultural are divided into direct energy for performing various tasks related to crop production in the fields and indirect energy, which is not directly used on the farms such as fertilizer, seed and chemicals. Also it may be grouped into physical, chemical and biological energy. Many researches have studied energy use in agriculture and economic analysis to determine the energy use efficiency for crop production in many countries [3, 4, 5, 6, 7].

Energy utilization in farm level usually varies with farm size, crop growing, production practices and physical environmental [8]. A study showed no evidence that crop yield could be affected by the type of energy source used in a farm and that increase in yield was the integrated effect of all inputs. However, availability of mechanical power for high rate of application in specific time permitted farmers to use different production strategies and thus resulted in increased food and crop production. By the increase need for higher productivity per unit area and brining additional areas under high yielding crops, it is inevitable that the share of agriculture in the national energy consumption would increase [9, 10].

Sudan is ranked as one of the world greatest potential areas for agricultural production and the estimated arable land for agriculture is more than 8.4 million hectares, which is equivalent to about 32% of total arable land in Africa [11]. Out of this potential area only 20% is currently under cultivation. This cultivated area can be mainly classified into irrigated and rain-fed sectors. The main crops grown in these sectors are cotton, sorghum, millet, sesame, wheat, G/N and sunflower. The energy used for carrying out the field operations for production of most crops is derived from human, animal and mechanical power. It is mainly used for land preparation, planting, weeding, spraying, fertilizer application, harvesting and transportation.

Although most of energy input resources are used for crop production in Sudan, but still the output of these crops is low. This may need better energy input and production systems management for improved use of energy resources and higher yields. The study was intended to assess the energy inputs during field activities for different farm operations and the energy outputs for production of three crops, sorghum, wheat and cotton.

2. Materials and Methods

The primary data for energy input resources were collected by field surveys and personal interview of farmers and agricultural engineers through questionnaire. Secondary data for energy input resources and energy outputs were obtained from the available information in literatures and other resources (Table 1).

The major three crops planted in the Gezira area were selected viz, cotton as an export crop, wheat and sorghum as food crops for human and animals. All the three crops are produced in the scheme by surface irrigation.

The data collected for each crop included energy input resources for different farm operations, from land preparation up to crop harvesting. For the purpose of computation and energy analysis, three groups of energy resources were considered namely physical, chemical and biological energy as both direct and indirect energy inputs [12].

For energy computation purposes the following assumption were made:

a. One hour work by a person was assumed to be equivalent to 0.075 kW.ha energy.
b. One man-day was equivalent to 8 hrs work.
c. Energy output of a diver was negligible compared to energy input of a tractor.
d. The operation carried out and energy inputs during the study period (200/01 – 2004/05) were assumed the same.

Based on these assumptions, the energy consumptions were estimated.

Computation of energy inputs:

*Total energy inputs (MJ/ha) = ∑(physical + chemical + biological).

1- Physical energy inputs (MJ/ha)

Physical energy input = ∑(human labour + mechanical power)
a) Human energy inputs = ∑(0.27× Md ×Wh)

Where;

Md = number of man-days/ha for field operations

Table 1: Energy equivalents of different input and outputs

Inputs ($MJkg^{-1}$)		Outputs ($MJkg^{-1}$)	
1. Seed		1. Main product	
i) Sorghum	14.7	i) Sorghum	15.7
ii) Wheat	14.7	ii) Wheat	14.7
iii) Cotton	25.0	iii) Cotton	11.8
2. Agrochemicals		2. By-product	
i) Nitrogen	75.4	i) Sorghum straw	15.7
ii) Phosphorus	17.4	ii) Wheat straw	15.8
iii) Pesticides	120	iii) Cotton seed	25.0
3. Mechanical power			
i) Diesel	47.8 MJL^{-1}		
ii) Machinery	86.8		
4. Human labour	0.27 $MJhr^{-1}$		

Source; [1, 5, 13]

Wh = number of working hrs/man-day

0.27 = conversion factor (MJ/hr)

b) Mechanical energy input (MJ/ha) = ∑(fuel + sequester)

▪ Fuel energy (MJ/ha) = ∑(FC × EEd)

Where;

FC = fuel consumption rate of machine in operation (L/ha).
EEd = energy equivalent of diesel fuel (MJ/L)

▪ Energy sequestered in mechanical power = ∑[(MW × EEs)/Aa]

Where;
MW = weight of machinery (kg)
EEs = energy equivalent in sequester (MJ/kg)
Aa = annual planted area (ha)

2- Chemical energy inputs (MJ/ha)
Chemical energy inputs (MJ/ha) = ∑(Fert. energy + pesti. energy)
• Fertilizer energy (MJ/ha) = ∑(Fert. Rate ×EEf)

Where;
Fert. Rate = fertilizer application rate (kg/ha)
EEf = energy equivalent of fertilizer (MJ/kg)

• Pesticide energy (MJ/ha) = ∑(Pesti Rate ×EEp)

Where;
Pesti. Rate = pesticide application rate (kg/ha)
EEp = energy equivalent of pesticide (MJ/kg)

3- Biological energy inputs (MJ/ha)
Biological energy inputs (MJ/ha) = (Seed appl×EEsd).

Where;
Seed appl. = seed application rate (kg/ha)
EEsd = energy equivalent of seed (MJ/kg)

Computation of energy output:

Total energy output was considered as main product plus by-product.
Total energy output (MJ/ha) = (Crop yld×EEy) + (by-product ×EEb)

Where;
Crop yld = crop yield (kg/ha)
EEy = energy equivalent of crop yield (MJ/kg)
EEb = energy equivalent of crop by-product (MJ/kg)

Energy use efficiency:

It is the ratio between total energy output and total energy input. Based on the energy equivalents of the inputs and output, the energy ratio (energy use efficiency) calculated as in this relation [14].

Energy use efficiency =
Total output energy (MJ/ha) / Total input energy (MJ/ha)

3. Results and Discussion

The human energy computation based on man-days required to perform the different operations for crop production. The man-days requirement for production of sorghum, wheat and cotton after conversion into hours of work is given in table 2.

Table 2: Man-days and hours of work required per hectare for the different farm operation of the three crops

Field operations	Sorghum		Wheat		Cotton	
	man-days/ha	hrs/ha	man-days/ha	hrs/ha	man-days/ha	hrs/ha
Sowing	7	56	-	-	7	56
1st weeding	14.0	115	7	57.7	5	40
2nd weeding	9.5	77	5	40	14	115
Irrigation	9.5	77	12	96	19	153.5
Fertilizer app.	2.5	20	5	40	5	40
Cutting + threshing	14.0	115	2	16	-	-
Picking	-	-	-	-	43	345.5
Total	56.5	460	31	249.5	93	750

Source; [15]

Contribution of energy input components in farm operations for production of the three crops is shown in Figure 1.

It shows that energy input varied with the sources and for the crop cultivated. The chemical energy inputs contribution was the highest for the three crops (53 – 75%) compared with physical and biological energy inputs (Fig.2). This is in agreement with the output of [1]. The highest physical energy inputs (37.5%) was for wheat which means more mechanization compared to the other two crops, while the highest chemical energy input was for cotton (75.5%).

Physical energy input for farm operations:

Human energy input constitute the least portion for the three crops (0.5 – 1.0%), although, human power used in most farm operation. The labour working hours required per hectare for the three crops varied from 249 – 750 (Table2). The mechanical energy (fuel + machinery sequester) input for production of the three crops was varied, it was 4.0 GJ/ha for cotton, 4.2 GJ/ha for sorghum and 6.8 GJ/ha for wheat.

The contribution of mechanical input energy was generally higher for the three crops compared to the human energy and this is in line with the finding of [1, 7].

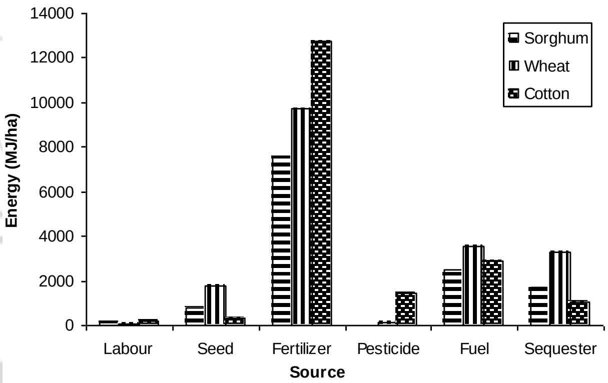
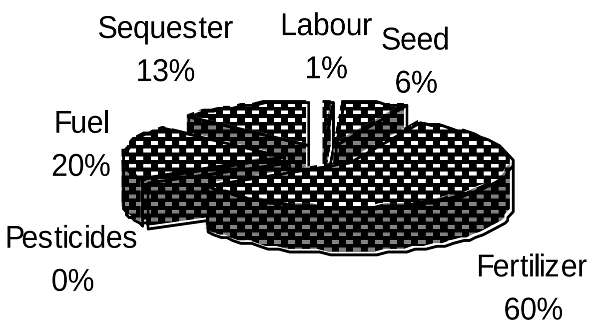


Fig. 1 Energy input sources for sorghum, wheat and cotton crops

[a]



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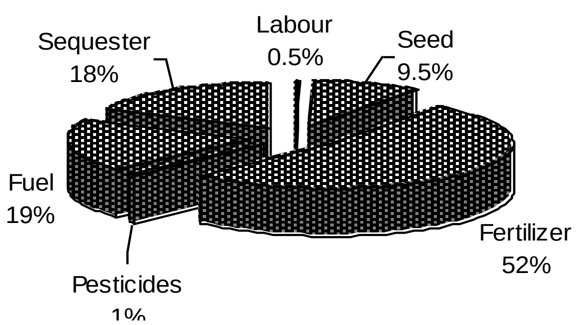
(b)



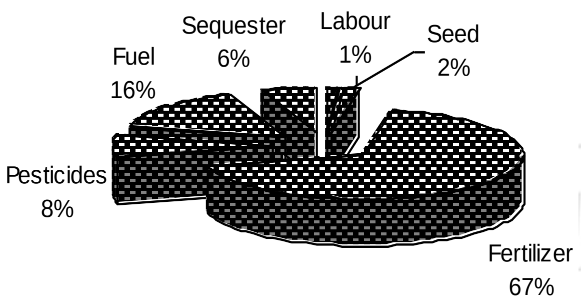


Fig. 2 Energy input percentages for (a) sorghum (b) wheat (c) cotton crop production

The mechanical energy input (fuel and machinery sequester) accounts for 33% of wheat and 22% of cotton production energy input in Gezira scheme. The major part of this energy is associated with land preparation. Selection of suitable tillage system, timing of tillage operation and matching of energy sources with the implements used could help in energy savings. The highest physical energy input was 6.9 GJ/ha for wheat followed by sorghum 4.3 GJ/ha and then cotton 4.2 GJ/ha. Out of this energy, the contribution of human labour for production of sorghum, wheat and cotton was 0.12 GJ/ha, 0.07 GJ/hr and 0.20 GJ/hr respectively. The variations in physical energy input between crops mainly depended on farm operations carried out and types of machinery used. Land preparation and harvesting operations mainly demanded higher physical energy input.

Contribution of human energy input for wheat production was less than that of sorghum and cotton, and this may be probably for higher mechanization levels used for production of this crop compared to other two crops [1].

Material energy inputs for farm operations:

Material energy inputs for field operations included chemical energy from fertilizer and pesticides and biological energy from seeds. Fig.1 shows that material energy inputs for production of the three crops was the highest compared to other sources. Its contribution ranged from 53% out of total input energy for wheat, 60% for sorghum and up to 75% for cotton. Energy input from fertilizer remained the highest contributor for the three crops. It was 7.5% GJ/ha for sorghum, 9.7 GJ/ha for wheat and 12.8 GJ/ha for cotton. Fertilizers are energy intensive especially nitrogen fertilizer which is used for production of most crops.

Total energy inputs for the three crops:

Total energy input for production of the three crops varies between 18.7 GJ/ha for cotton production followed by wheat 18.5 GJ/ha and then sorghum 12.6 GJ/ha. Total energy inputs for the three crops with their main resources are shown in Fig. 3. It can be observed that fertilizer was the main cause of variation of total energy input for the three crops. This is in line with the findings of [1, 13]).

Total energy output for different crops:

Total energy output included the main product and by-product of the crop. The total areas cultivated and production of the three crops during the five season period of study (2001-2005) is shown in Fig. 4. During these five seasons of study, crop production and area cultivated of the three crops was varied. The total energy output for wheat crop was the highest (average 127.9 GJ/ha) followed by sorghum (average 95.6 GJ/ha) and then the lowest was cotton (average 20.5 GJ/ha).

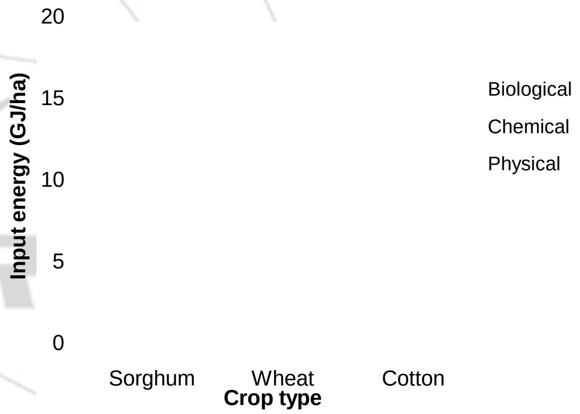


Fig. 3 Total input energy resources (GJ/ha) for the three crops

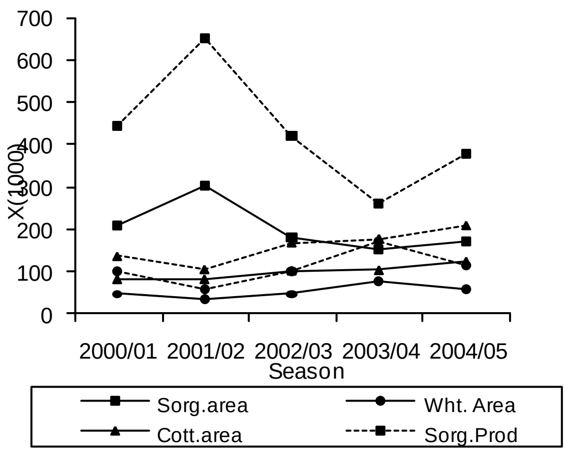


Fig. 4 Area planted and corresponding production for Sorghum, Wheat and Cotton

Energy use efficiency:

Energy ratio for the three crops varied between 0.9 – 8.4 (Fig. 5). The highest energy ratios during the period of study were recorded by the sorghum crop (6.2 – 8.4) followed by wheat crop (5.9 – 7.4), while the lowest was recorded by the cotton crop (0.4 – 1.2). High energy ratios were corresponding to high energy use efficiency which could be due to higher energy outputs or lower inputs. Energy ratio was found highly correlated with crop production per hectare for the three crops (R^2 = 0.97 – 0.99) and making linear relationships as follows:

Sorghum Y = 0.32x – 0.25, Wheat Y = 0.34x – 0.32, Cotton Y = 1.67x – 0.27

Where; x = energy output/input ratio, and Y = crop production (t/ha)

These findings are in line with those of [16].

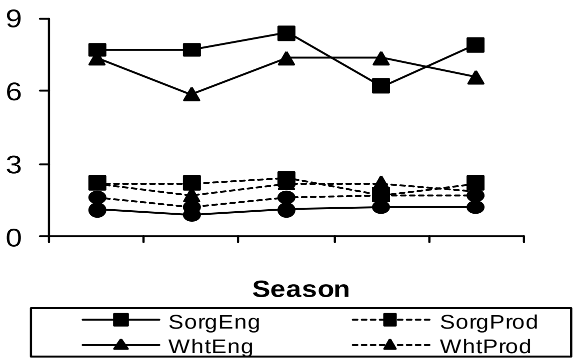


Fig. 5 Energy ratio versus production (t/ha) for Sorghum, Wheat and cotton

4. Conclusion

- Analysis of energy inputs for the three crops showed that energy input from fertilizer and mechanical power was the highest and the share of labor energy was very low.
- There is a linear relationship between energy output/input ration and crop production, which means that methods of farming with high energy output/input ratio must be used to accomplish greater production.
- Energy savings may be possible by using lower recommended doses of fertilizers and proper timing of field operations and matching the size and power of tractor with machinery for field operations.
- Since the energy inputs for production of crops is looking high, it is important to suggest methods and policies that may reduce the negative effect of high energy inputs such as pollution, global warming and to develop more efficient, economical and environment friendly agricultural production systems that increase energy use efficiency.

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