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Energy use pattern in some field and horticulturalcrops production in the Gezira Scheme, Gezira State, Sudan

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Abstract

This study examined the energy use patterns and energy input–output analysis of some field and vegetable crops, in the Gezira Scheme. For cotton crop, 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 water was the highest input (71.25%), followed by seeds (8.56%). Energy efficiency, energy productivity, specific energy and water productivity were 5.59, 0.40kg/MJ,2.51MJ/kg, 3.50kg/m^3, respectively. Results of wheat showed that the energy use efficiency, specific energy and energy productivity were 5.26, 4.91MJ/kg and 0.203kg/MJ, respectively. The share of renewable energy was 21.54% and 78.46 nonrenewable, 40.23% was direct energy and 59.77 as indirect energy. Results showed that the energy use efficiency and productivity, specific energy for sorghum were and 8.62, 0.17kg/MJ and 5.76MJ/kg. The share of renewable energy is 3.05% and nonrenewable energy is 96.95% of the total input energy. For onion and tomato more than 69% of the energy input was generated by fertilizers. Water constitutes 20.61% and 24.66% of the input energy and water productivity were 1.10 and 2.14 kg/m^{3}for onion and tomato respectively. These crops highly dependent on nonrenewable energy which may not be sustainable in the long run. The ratios of energy outputs to energy inputs were found to be 0.18 and 0.41, energy productivity were 0.22 and 0.52 kg/MJ and the specific energy were 4.50 and 1.93 MJ/kg for onion and tomato, respectively.

Keywords: Energy; Efficiency; renewable energy, nonrenewable, direct energy; indirect energy.

Introduction

Agriculture is the cornerstone to Sudan's economy. The country is blessed with a wealth of cultivable area ranges from 84 to 105 million hectares (UNEP 2007) with reasonably fertile soils and the terrain is generally flat. The agricultural sector employs over 80% of the work force and accounts for nearly 40% of the Gross Domestic Product.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 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.Energy needs for agricultural production are about 3% of the national energy consumption in developed countries and about 3.6% in developing countries (Karkacier et al., 2006; Sauerbeck, 2001; Stout, 1990). However, the energy input per hectare in developing countries for agricultural production is about7,700 MJ and in developed countries, it is about 37,900 MJ. In developing

countries, human labor is the major cost item of energy; while, in developed countries, mechanization and fertilizers are major energy inputs (Pimentel & Pimentel, 2008). According to various studies done in this field, the process of production between 60% and 90% of consumer energy is non-renewable (Canakci et al., 2005; Ozkan et al., 2004). Many studies have shown the reduction in the productivity and the efficiency of energy consumption in common agriculture in contrast to the agriculture based on natural inputs (Gundogmus, 2006; Guzman and Alonso, 2008; Hoeppner et al., 2005; Pimentel et al., 1983).
Chemical fertilizers, pesticides, agricultural machinery, and other farm inputs are used extensively in modern agriculture. Efficient use of energy inputs in agriculture will reduce environmental impacts, prevent damage to natural resources, and improve the sustainability of agriculture as an economical production system (Kizilaslan, 2008). Energy management is an important issue in terms of efficient, sustainable and economic use of energy. Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction (Uhlin, 1998). 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). 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, 2008).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). 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.

Study Objective: The objective of this study was to:

a) Determines the input and output energy used in some field and vegetable crop production in Sudan.

b) Identifies operations where energy savings could be realized.

c) Proposes improvements to reduce energy consumption for field crop production.

Materials and method

Study areas: This study was carried out in the Gezira scheme, Sudan during theseason 017-2018, 2018-2019 to investigate the energy use pattern in some field and vegetable crops production. The total area of the Gezira scheme is 0.9 million ha. The scheme lies in the central clay plain and irrigated through surface irrigation from the Blue Nile.

Data collection and analysis: 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 covered farmer's socio-economic variables, inputs as well as outputs data. The total energy per production unit (ha) was established by the addition of the partial energies of each input referenced to the unit of production. Energy inputs were human labor, diesel fuel, machinery, irrigation, chemical fertilizers consisting of nitrogen and phosphorous. The data collected were analyzed using descriptive statistics. The energy equivalents of inputs used and output obtained are illustrated in Table 1. 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 2011).

Energy use efficiency: Energy use efficiency or energy ratio is calculated by dividing the energy output by the energy input, it is found using the following formula; (Sartori et al., 2005)

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

Energy Productivity

Energy productivity is the term used to estimate the yield of marketable product received on per unit of energy consumed (kg/MJ). Demircan et al., 2006

$$\text{Energy productivity} = \frac{\text{Yield (kg/ha)}}{\text{Energy input (MJ/ha)}} \quad \ldots. (2)$$

Specific Energy: Specific energy shows the amount of energy spent to produce a unit of marketable product (MJ/kg). Shahan et al., 2008).

$$\text{Specific energy} = \frac{\text{Energy input (MJ/ha)}}{\text{Yield (kg/ha)}} \quad \ldots\ldots\ldots\ldots (3)$$

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 (kg/m^3) (Mali, 2016).

$$\text{Water productivity} = \frac{\text{yield ((kg/ha)}}{\text{water conumption}(\text{m}^3/\text{ha})} \ldots. \ (4)$$

Net energy: It is the difference between the output energy and input energy.

$$\text{Net energy} = \text{output energy} - \text{input energy} \ldots (5)$$

Table 1. Energy equivalent of inputs

Item	Unit	Energy equivalent (MJ/unit)	Reference
1. Human labor	H	1.96	Yilmaz et al. 2005; Ozkan et al. 2004; Mohammadi et al. 2008.
2. Machinery	H	62.70	Mohammadi et al. 2008; Erdal et al. 2007; Giampietro et al. 1992; Singh et al., 2002; Singh,2002;
3. tractor	H	68.40	Mohammadi et al. 2008; Erdal et al. 2007; Giampietro et al. 1992; Erdal et al., 2007; Singh et al., 2002; Singh,2002;
4. Diesel fuel	L	56.31	(Mohammadi et al. 2008; Erdal et al. 2007; Singh et al., 2002;
5. Fertilizers			
Nitrogen	kg	66.14	Esengun et al. 2007; Yilmaz et al. 2005; Mohammadi and Omid 2010;
Phoshate	kg	12.44	
6.Pesticides	kg	20.90	
7. Water	M^3	1.02	Shahan et al. 2008; Acaroglu and Askoy 2005; Mohammadi and Omid 2010;
8. Seeds	Kg		
Cotton	Kg	11.80	Yaldiz et. al.1993; Singh, 2000
Wheat	kg	14.48	Ozkan et al.2004; Giampietro et al. 1992.
Groundnut	kg	25.00	(Kitani, 1998)
Sorghum	kg	12.60	
Onion	kg	0.80	Singh & Mittal,1992; Ozkan et al., 2004; Giampietro et al. 1992.
Tomato	kg	0.80	

Table 2. Energy equivalent output

Crop	Output (kg/ha)		Reference
	Yield	(Residue	
Cotton	11.80	2.25	Yaldizet. al.1993; Singh, 2002, Zahedi et al. 2014
Wheat	14.48	9.25	Singh and Mittal, 1992; Ozkan et al., 2004; Giammetro et al 1992
Sorghum	12.60	13.38	Bazaluk et. al., 2021
Groundnut	25.00	11.60	(Kitani, 1999); Ibrahim et. al., 2016.
Onion	0.80	-	Hatrili et al., 2006
Tomato	0.80	-	Hatrili et al., 2006, Shresta,Ozkan et al., 2004.

Results and Discussion

Socioeconomic structure: For the socioeconomic structure, 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.

Cotton

The energy inputs used in cotton production and their energy equivalents, as well as the energy equivalent of the yield were presented in Table 3. 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. 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). Output–input energy ratio for cotton production under the Gezira conditions was 1.01 (Table 4), compared to Turkey (0.74), china (1.51) and Iran (0.71). The energy productivity was calculated as 0.09kg/MJ (Table 4), which is closer to Iran (0.10kg/ha) lower than China (0.21) and higher than Turkey (0.06). Specific energy It was found to be 11.62MJ/kg (Table 4), which is higher than China (4.76MJ/kg) and Iran (9.7MJ/kg). Netenergy was calculated as 424.72MJ/ha (Table 4), compared to 7372.48MJ/ha in Iran and (-13007MJ/ha) in turkey. 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 4). 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). The use of direct energy for cotton production is (31.37%) (Table 5), which is lower than Isfahan, Iran (68.3%), higher than China (14%). 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).

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

	Cotton		Groundnut		Wheat		Sorghum	
	Total (MJ/ha)	%	Total (MJ/lha)	%	Total (MJ/lha)	%	Total (MJ/lha)	%
Total Inputs	**27659.28**		**10222.83**		**13493.36**		**16469.35**	
Labor	504.24	1.82	504.24	4.95	93.10	0.69	436.68	2.65
Machinery	298.45	1.08	522.29	5.11	404.42	3.00	104.71	0.64
Tractor	325.58	1.18	569.77	5.57	509.58	3.78	342.36	2.08
Fuel	402.05	1.45	407.12	3.98	1765.32	13.08	1447.17	8.79
Fertilizer	17228.91	62.29	-	-	4292.84	31.81	7272.00	44.15
Pesticide	963.42	3.48	59.57	0.58	44.10	0.33	0.28	-
Water	7771.43	28.10	7284.84	71.25	3570	26.46	6800	41.29
Seed	165.20	0.60	875	8.56	2814	20.85	66.15	0.40
Total Outputs	28084		**56872**	100	**71038.75**	100	**142000**	
Yield energy (MJ)	28084		52000	83.20	39820.00	56.05	42000	29.58
Straw energy (MJ)			4872	16.80	31218.75	43.95	100000	70.42

Table 4.Various Energy performance parameters in field crops production

Parameter	**Cotton**	**Wheat**	**sorghum**	**Groundnut**
Total Input Energy (MJ/ha)	27659.28	13493.36	16469.35	10222.83
Total Output Energy (MJ/ha)	28084	71038.75	142000.00	56872
Energy use efficiency	1.01	5.26	8.62	5.59
Grain (kg/ha)	2380	2750	2857	2080
Specific energy (MJ/kg)	11.62	4.91	5.76	4.91
Energy Productivity (kg/MJ)	0.09	0.203	0.17	0.20
Water productivity (kg/m^3)	0.31	1.30	2.38	3.5
Net energy (MJ/ha)	424.72	57545.39	125530.65	46649.17

Wheat

The inputs and output used in wheat production is shown in Table 3. 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%. 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 harveting. Average annual grain yield was 2750 kg/ha and the calculated total energy output was 71038.75MJ/ha. It was observed that 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 performance parameters 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*etal*.2008). In this study, the average energy productivity of farms was 0.203 kg/MJ compared to 0.077kg/MJ in Uttar Pradesh, India (Rouf et al, 2015). This means that 0.203kg of grain was obtained per one MJ 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).

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Table 5.Various Energy performance parameters in field crop production

Parameter	Cotton		Wheat		Sorghum		Groundnut	
	Amount (MJ/ha)	%	Amount (MJ/ha)	%	Amount (MJ/ha)	%	Amount (MJ/ha)	%
Direct Energy	8677.72	31.37	5428.42	40.23	7579.04	46.00	8186.20	80.18
Indirect Energy	18981.56	68.63	8064.84	59.77	8890.28	54.00	2026.63	19.82
Renewable Energy	669.44	2.42	2907.10	21.54	502.83	3.05	1379.24	13.49
Nonrenewable energy	26989.84	97.58	10766.3	78.46	15966.42	96.95	8843.59	86.51
Total	27659.28	100	13493.4	100	16469.32	100	10222.83	100

Table 6.Amount and percentage of different inputs and output energy equivalent.

Particular	Onion		Tomato	
	Total (MJ/lha)	%	Total (MJ/lha)	%
A. Inputs				
Labor (hr/ha)	1907.90	4.05	795.25	1.35
Machinery (hr/ha)	373.06	0.79	447.68	0.76
Tractor (hr/ha)	407.98	0.87	488.38	0.83
Fuel (l/ha)	737.10	1.56	169.06	0.79
Fertilizer (kg/ha)	39975.95	69.96	40850.10	69.16
Pesticide (kg)	1012.00	2.15	1446.15	2.44
Water (m^3)	9714.29	20.61	14571.43	24.66
Seeds (kg)	6.00	0.01	0.50	0.01
B. Outputs				
Yield (kg)	8371.20	-	14480	-

Groundnut: The inputs used and their energy equivalents, output energy equivalent are illustrated in Table 3. About 504.24M/ha 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. Water had the highest share (71.25%) 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 52000 MJ, the straw production was 420kg/ha equivalent to 4872MJ/ha resulting in a total energy output of 56872MJ/ha. Based on these values, output–input energy ratio was found to be 5.59, energy productivity was 0.20 kg/MJ, specific energy 4.91MJ/kg and water productivity was calculated as 3.50kg/m^3 whereas the net energy was calculated as 46649.17MJ (Table 6). Table 5 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 5 It is clear that groundnut production is heavily dependent on direct and nonrenewable energy which may not be sustainable in the long run.

Sorghum: In the irrigated sorghum, land preparation is usually carried out using disk plow and ridging using a 56kw tractor. No pesticides application is done except for seed coating. Harvesting is partially mechanized that is, the crop is manually cut with the use of a cutting knife, followed by threshing using power operated thresher having an average capacity of 2 ton/hr. Despite the availability of modern technology for sowing, large areas in the irrigated sorghum is sown manually using the digging hoe that results in uncontrolled within row spacing and consequently poor plant population. Table 3 shows the energy input and output for sorghum. Diesel and fertilizers contribute more than 53% of the total energy input. Water contributes about 41.29% of the total input.The energy performance parameters reveal that the energy use efficiency for sorghum production is very low (Table 4). From simple calculations, it can be shown that the average energy input in the rainfed sorghum is about

11.39% of that of the irrigated sorghum while the output is 21% of that sorghum (excluding straw energy). Including the straw energy, the rainfed sorghum produces 84.94% of the energy produced by irrigated sorghum.

Table 7.Various Energy performance parameters in vegetable crops production

Parameter	Onion	Tomato
Total Input Energy (MJ/ha)	47134.28	59068.60
Total Output Energy (MJ/ha)	8371.2	24480
Energy use efficiency	0.18	0.41
Yield (kg/ha)	10464	30600
Specific energy (MJ/kg)	4.50	1.93
Energy Productivity (kg/MJ)	0.22	0.52
Water productivity (kg/m^3)	1.10	2.14
Net energy (MJ/ha)	-(38763.08)	-(34588.60)

Table 8.Various Energy performance parameters in vegetable crop

Parameter	Onion		Tomato	
	Amount (MJ/ha)	%	Amount (MJ/ha)	%
Direct Energy	12359.29	26.22	15835.74	26.81
Indirect Energy	34774.99	73.78	43232.86	73.19
Renewable Energy	1913.9	4.06	795.75	1.35
Nonrenewable energy	45220.38	95.94	58272.85	98.65
Total	47134.28	100	59068.60	100

Referring to Table 5, sorghum uses 46% of its energy input in the form of direct energy and 54% in the form of indirect energy. Sorghum production in Sudan uses a large amount of non-renewable energy, 84.80% for rainfed and 96.95% for irrigated sorghum. This represents an environmental threat to Sudan agriculture. Therefore, the country should go to produce sorghum in the rainfed areas and replacing the irrigated sorghum with other cash crop. Bearing in mind the low productivity can be increased by development of improved genotype. This could be achieved by breeding for higher yielding varieties suitable for the different environments and improved cultural practices to improve crop establishment and yield for the diverse farming systems. Of special interest will be seedbed preparation and suitable seeding methods.

Onion: The inputs and output and their energy equivalents used in onion production in the area of survey can be seen in Table 6. Table 6 also shows the percentage of each item from the total energy input. Results revealed that 1907.9 hour of human power and 373.06 hour of machine power were required per hectare of onion production in the research area, indicating that onion is highly dependent on manual labor. The average amount of fertilizers used for onion growing was 476.19 kg/ha of nitrogen and 119.05kg/ha of phosphorus. The energy input and output, yield, energy use efficiency, specific energy, energy productivity, water productivity and net energy of onion production are shown in Table 7. Energy use efficiency (energy ratio) and energy productivity were calculated as 0.18 and 0.22 respectively which were substantially lower than those obtained by Moore (2010) in Pennsylvania (51.5 and 32.2kg/MJ), also lower than the values obtained by Alalli et al. (2017) in Morocco (0.78 and 0.54), but these values are in line with the values obtained by Ibrahim (2011) in Nigeria (0.2 and 0.25). Water productivity was found to be 1.10kg/m^3.Total energy input used in various farm operations during onion production was 47134.28 MJ/ha. Average annual yield of farms investigated was 10464 kg/ha compared to 49570 kg/ha in Pennsylvania, 58098 in Morocco and 3616kg/ha in Nigeria. Calculated total energy output was 8371.20MJ/ha. Fertilizers were the largest energy input for onion production with 39975.95 MJ/ha (69.96% of the total sequestered energy), followed by water 9714.29 MJ/ha (20.61%) as shown in Table 7. Diesel energy consumes 1.56% of the total energy inputs. Diesel energy was mainly consumed for land preparation. The distribution of total energy input as direct, indirect, renewable and non-renewable forms are shown in Table 8. The total energy input could be classified as direct energy (26.22%), indirect energy (73.78%) and renewable energy (4.06%) and nonrenewable energy (95.94%).

Tomato: The inputs, used in tomato production and their energy equivalents, as well as the energy equivalent of the yield were presented in Table 5. As indicated in the table, about 595.24 kg/ha of nitrogen and 119.05 kg/ha of phosphorous fertilizer were used for tomato production. The use of human power was about 795.25 MJ/ha. Average tomato yield was 30600 kg/ha compared to 40000 kg/ha in Italy (Kanakci et al 2005), 2653 kg/ha in Nigeria (Ibrahim, 2011), 57905 kg/ha in Turkey (Ozkan et al, 2011) and 48227.30 kg/ha in Iran (Jadidi et al. 2012). The total energy input was calculated as 59068.60 MJ/ha. Fertilizer was the dominant energy input with a share of 69.16% of the total energy inputs. Followed by water (24.66%), pesticides (2.44%). Based on these values energy ratio, energy productivity and water productivity for tomato production were found to be 0.41, 0.52kg/MJand 2.14kg/m^3, respectively, which were higher than 0.2 and 0.25 that found in Nigeria by Ibrahim (2011), but lower than 0.59 and 0.74 obtained by Jadidi et al. (2012) in Iran and 0.80 and 0.91 found by Ozkan et al (2011) in Turkey for energy ratio and productivity, respectively. Water productivity was calculated as 2.14kg/m^3. Between the vegetables investigated, tomato had the highest energy output–input ratio (0.410), while onion had the lowest (0.18). The energy ratios obtained for the two vegetables are quite low. Tomato production was the most energy intensive than onion. A total of 59068.60MJ/ha of energy was used for tomato production, while 47134.28 MJ/ha was used for onion. Fertilizers had the highest share among the inputs for the two vegetables. This was due to the fact that farmers apply nitrogen double the recommended dose. 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). The second most important input was water. For the two vegetables, the usage of nonrenewable energy inputs such as fertilizers and water was quite substantial. This implies that vegetable production in the study area depends heavily on fertilizers which in the long run, may inevitably lead to environmental problems associated with energy use such as nutrient loading and ground water pollution. Agrochemical use for pests was not at very significant levels. However, biological control has to be introduced to reduce the energy inputs from the chemicals and to protect humans and the environment.

Results

a) Crop production in the study area is highly dependent on non-renewable energy inputs which may not be sustainable in the long run.

b) Energy efficiency and productivity for the crops in the research area were very low.

c) There is a bad need for improving water productivity because of rising competition of finite

d) The use of renewable energy especially organic manure should be promoted.

e) There is also a need to use high yielding varieties to increase energy use efficiency and energy productivity.

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