Comparison of Manual and Manual-cum-Mechanical Energy Uses in Groundnut Production in a Semi-arid Environment

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Abstract

A study was conducted to evaluate and compare the inputs of manual energy only and manual-cum-mechanical energy in the production of groundnuts (*Arachis hypogaea*) in a semi arid region of Nigeria. Two groups of randomly selected farms were considered, each consisting of five small-scale farms. One group was made of farms on which only manual energy was used (FME) in the production process. The second group, denoted as FMME, had both manual and mechanical energy inputs.

To evaluate the energies invested, the following constants were used: (i) Manual energy of an adult male – 0.75 MJh^{-1} (10% less for a female adult); (ii) diesel fuel energy value – 47.78 MJL^{-1}, (iii) energy for manufacture, transport and repair (MTR) of machinery – 100.7 $MJkg^{-1}$.

Results show that the maximum, minimum and mean energy inputs for the FME group were 1271.1, 617.5 and 1047.8 $MJha^{-1}$ respectively. For the FMME category, the corresponding values were 2899.1, 1396.1 and 2285 $MJha^{-1}$ respectively. The two groups of farms were comparable in two respects. In both, land clearing had the least energy requirements (4% and 1% of the mean total energy inputs of FME and FMME respectively). Also, weeding had the most energy requirement (45% and 52% of the mean total energy inputs were expended in weeding the FME and FMME farms respectively).

For the FMME group, most of the energy expended was manual. Only 19% of the mean total input came from the mechanical source, which was rather too low from the mechanisation point of view. Ideally, mechanical energy should replace or significantly supplement manual energy in all operations, as it did in harrowing, the only mechanised operation for the FMME group where manual energy of the tractor operator was only 0.2% of the mean energy needed for tilling the land.

The mean quantities of groundnuts (in shells) harvested from the FME and FMME groups were 598 and 655 $kgha^{-1}$ respectively, while the mean values of the energies invested to produce a unit quantity of the crop in the two categories were 1.75 and 3.49 $MJkg^{-1}ha^{-1}$ respectively. It is recommended that further studies be conducted in order to relate yields with the types and intensities of energy invested in producing the crop.

Keywords: Manual energy, mechanical energy, groundnut production, semi-arid region

Introduction

Energy is one of the most valuable inputs in production agriculture. It is invested in various forms such as mechanical (from machines, human labour, animal draft), chemical (fertiliser, pesticides, herbicides), electrical, heat, etc. The amount of energy used in agricultural production, processing and distribution should be significantly high in order to feed the expanding population and to meet other social and economic goals. Sufficient availability of the right energy and its effective and efficient use are prerequisites for improved agricultural production. It was realised that crop yields and food supplies are directly linked to energy (Stout, 1990). Also, increases in yields per hectare in the developed countries were as a result of commercial energy inputs, in addition to improved varieties (Faidley, 1992).

Some studies on energy use and evaluation methods elsewhere were reported. Bridges and Smith (1979) developed a method for determining the total energy input for agricultural practices. The categories of energy considered were those of manufacture, transport and repairs (MTR), fuel and labour. Fluck (1985) developed two models to quantify energy sequestered in repairs and maintenance of agricultural machinery as compared with the energy input in new machinery. Different authors who used different methods reported several values of the energy content for human labour. Hence, there is no universally accepted energy value of human labour. However, for countries where agriculture is dominated by human energy, it is reasonable to adopt the value obtained by Norman (1978).

The primary objectives of mechanising crop production are to reduce human drudgery and to raise the output of farm by either increasing the yield per unit area or increasing the area under cultivation. These can only be done by supplementing the traditional energy input i.e. human labour with substantial investments in farm machinery, irrigation equipment, fertilisers, soil and water conservation practices, drying equipment, etc. These inputs and methods represent various energies that need to be evaluated so as ascertain their effectiveness and to know how to conserve them. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved agricultural production. It would identify production practices that are economical and effective. Other benefits of energy analysis are to determine the energy invested in every step of the production process (hence identifying the steps that require least energy inputs), to provide a basis for conservation and to aid in making sound management and policy decisions. For example, proper maintenance and operation of tractors and machinery or irrigation pumps reduce fuel costs.

Groundnut (*Arachis hypogaea*) is one of the major crops grown in the semi-arid region of Nigeria. The variety commonly cultivated by farmers in the region is Ex Dakar. Most farmers mainly produce the crop using only manual energy. Few producers of the crop use tractors for tillage during the land preparation stage. Apart from this single mechanical energy use, all other farm operations are executed using manual energy. This trend of limited mechanisation is common to other crops grown in the country.

In Nigeria, there is the lack of data on energy expenditure and returns in the agricultural sector. Consequently, it is neither possible to identify viable energy inputs and options in the production process nor plan for their conservation. Thus, the benefits associated with energy analysis, as mentioned earlier, cannot be realised. Information on comparative use of different energies is also lacking. This information is required in order to make deductions on the efficiencies of the energies and suggestions on which energy sources or their combinations need to be used and at what levels. The objective of this study was to compare the intensities of manual energy and manual-cum-mechanical energy inputs in groundnut production in the semi-arid region of Nigeria.

Materials and Methods

The study was conducted during the 2002 cropping season on private farms located around Maiduguri (latitude 11°50'N and longitude 13°05'E), the Borno State capital. The area lies within the semi-arid region of Nigeria and its soil type is sandy loam. Two categories of farms were considered – those where only manual energy was used (FME) and those where both manual energy and mechanical energy were used (FMME) in the production process. In each category, five farms (numbered A1, B1, …E1 for the FME category and A2, B2, …E2 for the FMME category) were randomly selected and energy inputs for all farm operations studied therefrom. Farms in the FMME category were located within the premises of the Maiduguri International Airport.

Materials/Equipment used

The following materials/equipment were used in the course of the study:

i. A flexible tape for measuring farm areas
ii. A stop watch for measuring field time parameters
iii. An *MF 375E* 2-WD tractor and an *MF 222* 18-disc offset harrow, weighing 2780 kg and 564 kg respectively, for tillage
iv. A measuring cylinder for quantifying the amount of fuel consumed during tillage

Methods

i. Evaluation of manual energy input – Manual energy was estimated based on the value recommended by Norman (1978), i.e. 0.75 MJh^{-1} for an adult male worker. An adult female was assumed to have a basal energy 10% less than that of her male counterpart (Ibu and Adeniyi, 1989). Hence a female worker was assumed to have an energy input of 0.68 MJh^{-1}. All other factors affecting manual energy were neglected. To determine the energy input of from worker (including the tractor operator), the time spent by the worker on each operation (from land clearing to harvesting) was recorded. This included the necessary intermittent resting periods. Thus for a male worker, the manual energy expended, E_m, was determined by:

$$E_m = 0.75T_a, \text{ MJ} \qquad 1$$

where 0.75 = energy input of an average adult male, MJh^{-1}
T_a = useful time spent by a worker on a farm activity, h

ii. Evaluation of mechanical energy use – This involved measurement of both direct and indirect energies. Direct mechanical energy input was evaluated by quantifying the amount of diesel fuel consumed during the only tillage operation conducted, i.e. harrowing. The energy input was based on the unit value of 47.78 MJL^{-1} (consisting of an enthalpy of 38.66 MJL^{-1} and production cost of 9.12 MJL^{-1}) as reported by Pimentel (1992). The quantity of diesel consumed for harrowing was determined by starting harrowing with a full tank and refilling the tank at the end of the operation. The amount of fuel used to refill the tank was then taken as the quantity consumed during the operation. Hence, for every farm, the diesel fuel energy input, E_f, was determined by:

$$E_f = 47.78D, \text{ MJ} \qquad 2$$

where 47.78 = unit energy value of diesel, MJL^{-1}
D = amount of diesel consumed per farm, L

Indirect mechanical energy was estimated by considering the energy expended to manufacture, transport and repair (*MTR*) a unit mass of the tractor and harrow used, the estimated wear out lives of the tractor and harrow (*L*), the area harrowed (*A*) and the effective field capacity (C_e). The *MTR* energy was taken as 100.7 $MJkg^{-1}$(Bridges and Smith, 1979) and the *L* values used were 12, 000 h and 2000 h for the tractor and harrow respectively (Bowers, 1992). The C_e for harrowing was taken as 1.21 hah^{-1} (Haque and Umar, 1997). Thus, indirect mechanical energy, E_{im}, was determined by:

$$E_{im} = \frac{MTR \times m \times A}{L \times C_e}, \text{ MJ} \qquad 3$$

where:
MTR = energy used to manufacture, transport and repair machinery (tractor or harrow), $MJkg^{-1}$
m = mass of machinery, kg
A = size of farm, ha
L = life of machinery, h
C_e = effective field capacity of harrowing, hah^{-1}

Equation 3 was used separately to determine the E_{im} for the tractor and harrow used on FMME farms. Hence for each of these farms, the total energy input was determined by:

$$E = E_m + E_f + E_{mi}(\text{tractor}) + E_{mi}(\text{harrow}) \qquad 4$$

For the FME category, the total energy was determined by using Equation 1 above.

Data Reduction
The data collected from individual farms within each of the FME and FMME categories were treated using descriptive statistics. This was done in terms of energy use (only manual or both manual and mechanical, as the case may be) per operation,

total energy input for the entire growing season, energy use per unit farm area and energy input per unit mass of unshelled groundnuts harvested.

Results and Discussion

Sizes of farms

All the farms considered were less than 1.5 ha in size, typical of peasant farmer holdings in the country. Three farms in the category where only manual energy was used (FME), i.e. A1, B1 and D1, were 1 ha each in size while the other two, C1 and E1 had sizes of 0.9 and 1.2 ha respectively. Each farm in the second category, i.e. those where both manual and mechanical energies were used (FMME), was 1 ha in size because they were so divided and apportioned to farmers.

Energy inputs

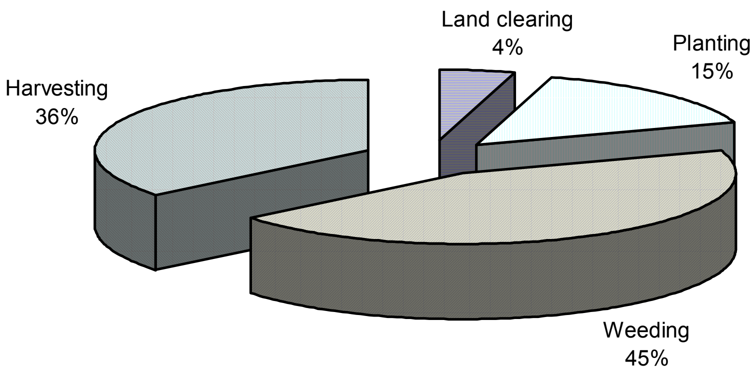
The amounts and percentages of energy used in various field practices on every farm are shown in Table 1 and Figure 1 respectively. Manual and mechanical total energy inputs were determined using Equations 1 – 4 above. All the FMME farms were tractor-harrowed while FME farms were not (zero tillage was practised in the latter category). All other farm operations were manually executed in both groups. Both within and between the FME and FMME categories, the amounts of human energy expended vary mainly because of two reasons, namely the amount of useful time spent on farm activities and the number of farm workers deployed to perform individual operations.

On average both farm categories studied had the least amount of energy input for land clearing – 4% and 1% of the mean total energy for FME and FMME respectively (Figure 1). The energy needed for this first farm operation was low for both categories because all the farmlands were previously cultivated. There was nothing much to do apart from collecting and burning sparse vegetative matter (mainly dry weeds) on the spot.

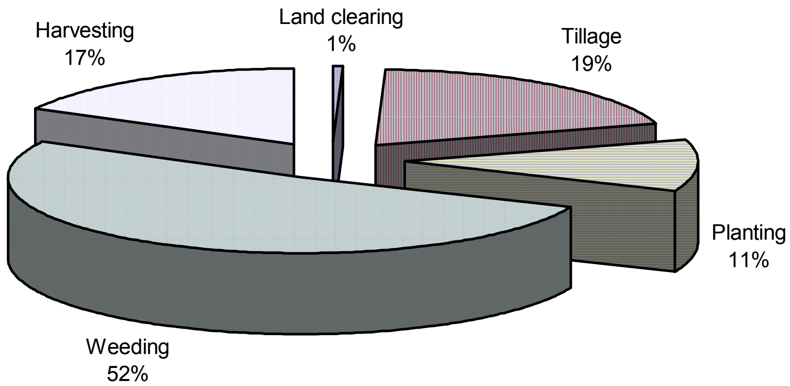
Table 1: Energy inputs for various field practices on FME and FMME farms

Field activity	*Farm category*	*Energy inputs on different farms (MJha^{-1})*				
		A*	B	C	D	E
Land clearing	FME	24	84.7	26.3	22.5	65
	FMME	14.9	5.8	11	22.5	23.7
Tillage	FME	-	-	-	-	-
	FMME	473.6	416.2	435.2	478.2	420.9
Planting	FME	96	123.5	274.7	196.2	105
	FMME	232.8	273	300.8	340.9	144.3
Weeding	FME	680.2	360	488.3	588.6	227.5
	FMME	1322.3	1735	1014.6	1274.1	522.4
Harvesting	FME	470.9	275.3	457.8	452.4	220
	FMME	340	469.1	337.1	531.6	284.8

*A in the table means Farms A1 in FME & A2 in FMME, B for B1 in FME & B2 in FMME, etc.



(a) FME



(b) FMME

Figure 1: Energy input (% of mean total) per operation in (a) FME and (b) FMME farms

The energy input for harrowing the FMME farms constituted 19% of the mean total energy. This energy consisted of mechanical (direct and indirect) and manual components. The direct mechanical or fuel energy inputs along with the quantities of fuel (diesel) consumed by the tractor in harrowing the five farms of FMME are shown in Table 2. The mean amount of diesel used and its corresponding energy were 8.4 Lha^{-1} and 401.35 $MJha^{-1}$ respectively.

Table 2: Fuel energy input for harrowing FMME farms

Farm	*Fuel consumed (D), Lha^{-1}*	*Fuel energy (E_f) *, $MJha^{-1}$*
A2	9.0	430.0
B2	7.8	372.7
C2	8.2	391.8
D2	9.1	434.8
E2	7.9	377.5
Mean	8.4±0.61	401.35±29.26

*Evaluated using Equation 2; ± Standard deviation

The indirect mechanical energy expended was evaluated as energy sequestered in the manufacture, transport and repair (MTR) of the tractor and harrow used. The combined MTR energy was 42.75 $MJha^{-1}$. The individual MTR energies and other parameters of the tractor and harrow are shown in Table 3.

Table 3: Tractor and harrow parameters and *MTR* energies (E_{mi})

Parameters	*Tractor*	*Harrow*
Mass (kg)	2780	564
Life (h)	12000	2000
Effective field capacity C_e (hah^{-1})	1.21	1.21
MTR energy, E_{mi} ($MJha^{-1}$)*	19.28	23.47

* See Equation 2

The manual energy expended in harrowing was that of the tractor operator and it was negligible compared to mechanical energy input. Subtracting the above mean fuel and MTR energies from 444.82 $MJha^{-1}$ (i.e. the mean energy input for harrowing) we obtain a mean manual energy of 0.72 $MJha^{-1}$ which is only 0.2% of mean energy spent in harrowing the FMME farms. As indicated earlier, none of the FME farms was tilled before planting, hence it was not possible to compare directly the levels of energy inputs for tillage under the two scenarios. Nevertheless, the mechanical energy used on the FMME farms made it possible to substantially reduce human energy that would have been used for tilling the farms to the barest minimum, thus fulfilling one objective of mechanisation, which is to reduce human drudgery in agricultural production.

Another similarity between the two categories is the highest intensities of energy used in weeding. Timeliness is important in accomplishing the task, otherwise the expected crop yield would be jeopardised by competitive weeds. Weeding is one of the most tedious manual operations in agricultural production. The above figure shows that 45% and 52% of the mean total energy were expended in weeding the FME and FMME farms respectively. This was because the operation was repeated twice on all the farms during the growing season, since herbicides were not used. Also, most farmers employed additional workers while weeding their farms to ensure timely completion of the operation.

Traditional harvesting of the groundnut crop involved uprooting the plants by hand or using a hoe, as well as plucking pods from the vines. This operation consumed the second and third highest energy proportions in FME and FMME farms respectively. The former constituted 35% and the latter 17% of the mean total energy inputs (Figure 1).

The total energies expended on each of the farms within the two categories are shown in Figure 2. The maximum, minimum and mean energy inputs for the FME group were 1271.1, 617.5 and 1047.8 $MJha^{-1}$ respectively. For the FMME category, the corresponding values were 2899.1, 1396.1 and 2285 $MJha^{-1}$ respectively.

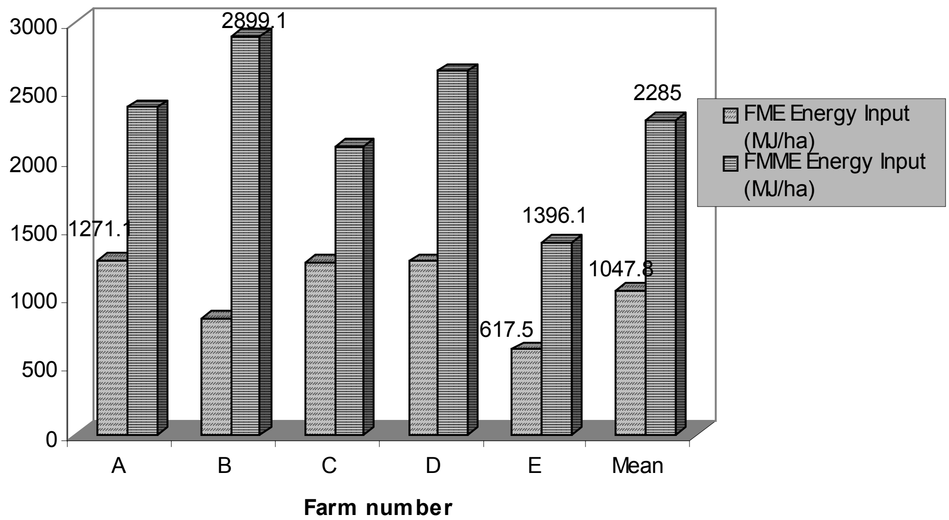


Figure 2: Total and mean energy inputs for various FME and FMME farms

It was thus evident, as expected, that more energy was expended on the farms where both manual and mechanical energies were used. Because mechanical energy was used in tillage only in this category, it constituted just 19% of the mean total energy expended per hectare per growing season (Figure 3). Thus, manual energy was predominantly used on farms where partial mechanisation is practised in the region.

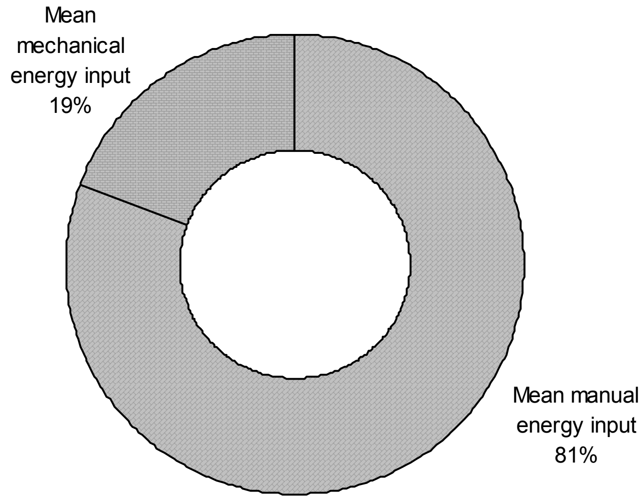


Figure 3. Proportions of mean manual and mechanical energy inputs for FMME farms

With this predominant use of manual energy and low level of mechanical energy, the full benefits of mechanisation would hardly be realised. Low quality and levels of energy use cannot bring about high yields per unit area or increased area of cultivation per farmer as desired.

The quantities of unshelled groundnuts harvested from all the farms considered and their respective means are shown in Table 4.

Table 4: Quantities of unshelled groundnuts harvested

Farm No.	Groundnuts produced ($kgha^{-1}$)	
	FME	FMME
A	650	783
B	706	700
C	500	563
D	553	580
E	582	650
Mean	598	655

On average, a higher yield was obtained from the farms on which the combination of manual and mechanical energy was used than from those where only manual energy was used. Since there was no closer look on the other factors that can influence yield, such as soil fertility, crop tendering, etc, one cannot attribute the higher yield of the FMME farms to their higher energy levels only. Another study is therefore necessary to establish more facts. It is worthy to note, however, that even this higher yield is lower than the mean of the three-year (1995 – 1997) estimates given by FAO (1996) for the yield of the crop in Nigeria (i.e. 1007 $kgha^{-1}$).

As indicated earlier, the mean total energy inputs of the FME and FMME categories were 1047.8 and 2285 $MJha^{-1}$ respectively. Hence with the above mean yields, the mean values of the energies invested to produce a unit quantity of produce per unit area in the two categories were 1.75 and 3.49 $MJkg^{-1}ha^{-1}$ respectively. Under full and ideal mechanisation conditions, both the energy input and the yield per unit area of a crop would be much higher than the values obtained by the study.

Conclusion

The study compared the use of only manual energy and that of a combination of manual and mechanical energies in the production of groundnuts by local farmers in a semi arid region of Nigeria. In the latter, mechanical energy was used only in tillage, in form of disc harrowing the farms before planting. All the other farm practices were carried out by using manual energy. The energy input for every operation and the yield from all the five farms in each group were evaluated.

The study revealed that the category of farms where both manual and mechanical energies were used (FMME) had a mean energy input of 2285 $MJha^{-1}$ (19% of which was mechanical energy comprising fuel energy and energy sequestered in the manufacture, transport and repair of machinery). For any meaningful improvement in food production, the mechanical energy component needs to be much higher than what the study revealed. The farms on which only manual energy was used (FME) had a mean energy input of 1047.8 $MJha^{-1}$.

In both groups of farms, land clearing had the least energy requirement (4% and 1 %), while weeding had highest requirement (45% and 52% of the total energy inputs). The mean quantities of groundnuts (in shells) harvested from the FME and FMME groups were 598 and 655 $kgha^{-1}$ respectively. These amounts are lower than what was reported earlier. It is hereby recommended the further studies be conducted in order to relate crop yields with energy invested in the production process.

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