ENERGY REQUIREMENTS FOR IRRIGATION WATER SUPPLY OF SELECTED SCHEMES IN NIGERIA

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ABSTRACT

Irrigation water supply in agricultural production can be energy intensive because of large electric motors utilized and the length of time required for such operations. The present study investigates the energy requirement for irrigation water supply in five different schemes in the North Central Nigeria. The use of well-structured questionnaires was employed alongside other study techniques to obtain information about the structural and operational characteristics of the irrigation schemes visited. In this study, important field operations were performed on one hectare of land selected as reference field. The average quantity of fuel used on one hectare of land by the five schemes is 391.2 litres per season while on other hand he quantity of fuel used on the reference field is 360 litres per season. The cost of energy used in irrigation of one hectare of land, when diesel fuel is used as source of power as obtained from the average cost of fuel consumed by the five irrigation schemes, is ₦39,120 per season and the cost of fuel consumed when diesel fuel is used as source of power on the reference field is ₦36,000 per season. It is concluded that irrigation farmers should ensure that energy required for irrigation water supply should be properly planned for, and monitored with fairly managing ability, which produces a satisfactory result.

Keywords: *Energy; Irrigation; Water Supply; Schemes; Nigeria*

1. INTRODUCTION

Energy has always been an essential input to all aspects of the modern age. It is indeed the life wire of industrial and agricultural production, the fuel for transportation as well as for the generation of electricity in conventional thermal plants (Jekayinfa, 2001).

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Energy is at the heart of all human activities, especially those concerning the production of goods and services. It was observed (Anjorin and Atoyebi, 2001) that energy efficiency is probably the most straight forward criterion for evaluating production systems from energy point of view. The energy required to pump irrigation water for crop production is measured in terms of fuel use or electric power. Energy used depends on the amount of water pumped and on the fuel or electric power required to pump unit of water. Water has to be pumped to get to where it is needed. In surface irrigation (e.g. Basin, Boarder, Furrow, e.t.c) water has to be supplied into canals where it is siphoned into the fields. To do this, there is need to pump it from the source. Water for irrigation can be obtained from a variety of sources. According to Stern (1984), it can be directed from springs, streams or lifted from rivers and lakes or drawn from wells and boreholes. Similarly, for supply through pipes to sprinkler, you need the pump to provide the pressure, not only to drive the water through pipes and fittings, but to provide operating pressure to the sprinkler. Substantial advancement has been made in the design of pumps. The earliest irrigation schemes in history depended only on the gravity flow of water. It was not long before man became aware of the need to lift water for irrigation (Stern, 1984). For this purpose, many devices were developed in various parts of the world using man or animal power. The advent of mechanical power and modern machinery revolutionized the technology of water lifting, enabling water to be raised to heights and in quantity enormously greater than had either being possible, cheap oil fuel and hydro-electric power, where available contributed to the popularity of driven pump. A pump is defined as a device used to add energy to the flow of fluid in a pipeline. Pumps are usually rated at a certain capacity. Where discharge, Q in meter cube per seconds for a given head (H) in meters of fluid flowing. Pumps can be either of the centrifugal or turbine type. Centrifugal pumps (which may be self priming or non-self priming) are used to pump water for surface sources and shallow wells. Turbine pumps (either vertical shaft or submersible) are used to pump from deep wells.

Irrigation consumes large quantity of energy. Irrigation equipment may cost more than half as much as the land in which it is used. When irrigation systems are poorly maintained and operated, energy cost may be too high. Costs are greatly reduced by obtaining the necessary energy for pumping from fuel rather than from human efforts or by use of animals. This is a major reason why irrigation is mechanized in countries of high labour cost. The power delivered by an electric motor or by an engine to the shaft of the pump, in turn, is called brake power (BP). The ratio of useful water hydraulic power delivered by a pump (the output) to BP (the input) is known as the pump efficiency. The rating of a pump may be controlled by the pump design or by the size of the driver. The product of the head developed by the pump and the flow rate in horsepower (or in kW) units is called the water horsepower (WHP 0r WkW):

$$\boldsymbol{WP = \frac{YQH}{U}} \qquad (1)$$

Where: *Y* = specific weight of water (N/m^3),

Q = volumetric flow rate m^3/sec.

H = head in (m) of fluid.

*WP could be in kW units when "U" = 1000, or in HP units when "U" = 750.

Some pumps are more efficient than others. However, most types of pumps are available over a wide range of operating efficiencies. The efficiency of a pump is a direct measure of its hydraulic and mechanical performers, and is defined as the ratio of energy input applied to the pump. The energy input is applied to the pump shaft. Its rate is the water power (WP), as previously defined, and the energy input is the Brake Horse Power (BHP) or Brake kW (BkW).

$$\text{The efficiency, \%} = WP/kW \times 100 \qquad (2)$$

There are many types of irrigation systems. These include solid set, permanent, manual – move, lateral – move, roll – wheel move, and sub-irrigation types. Micro irrigation systems, including drip irrigation system, have high potential application. Because water is applied very near or directly into the crop root zone, evaporation and wind drift losses are minimized. Water application can be limited to the amount that is needed by the crop, and efficiency can be as high as 85% (Smajstrla *et al*., 2008). For a given system, an increase in water – use results in a proportional increase in energy consumption. The step to reducing energy – use is to apply just enough water to satisfy crop needs. This can be accomplished by selecting the system that minimizes water – use and then properly maintains and manages that system as mentioned earlier. The amount of irrigation water pumped depends on many factors. These include type of irrigation system, crop physiology, climate and management factors. Consideration should also be given to capital cost; crop to be irrigated, availability of labour, the need for environmental modification, chemigation or fertigation, and dealer availability and service. After these factors have been evaluated, one or two systems will usually emerge that most effectively satisfy the irrigation need of the site. Thus this study analyzed the energy requirement for irrigation water supply for some typical schemes.

2. MATERIALS AND METHODS

2.1 Study Area

This research work was carried out at lower Niger Basin Ilorin, Nigeria. The work is limited to surface irrigation; flood type. The lower Niger River Basin and rural development authority is one of the twelve river basins and rural development authorities in Nigeria. It is a parastatal under the Federal Ministry of Agriculture and Water Resources with its area of coverage comprising Kwara State and some part of Kogi State west of the Niger river.

2.2 Data Collection Techniques

The irrigation schemes were visited to facilitate cordial interaction with the irrigation personnel. Necessary information as it affects their efficiency and their constraints was gathered. A questionnaire was thereafter designed and administered to obtain information about the structural and operational characteristics of the irrigation schemes visited. Information collected includes: type of energy source being used in each irrigation scheme; the source of water for irrigation in each scheme; the method of water lifting adopted in each irrigation scheme; total area irrigated; and types of crops cultivated. Other information includes energy costs, total area cultivated, required energy per hectare for flood type irrigation system and equipment utilized for lifting and delivering water.

Developed Reference Field

An experimental reference site (an irrigation basin system) was developed. In the surface method of irrigation, water was applied directly to the soil surface from a channel located at the upper reach of the field. The essential features of the developed site include: graded field size, type of soil, soil infiltration, soil W.H.C, source of water, delivery system, source of energy, energy costs, crops cultivated and management expertise (planning and monitoring capacity).

2.3 Evaluation of Fuel Consumed

The quantity of fuel consumed by the pumping machine was estimated at different intervals till the end of every discharge distribution. The energy required to pump irrigation water for crop production was measured in terms of fuel use, based on the total irrigable area.

Experimental Procedure

Before the commencement of the experiment, known quantity of fuel was metered into the empty tank of a pumping machine. At the end of lifting and delivering of desired quantity of water to the farmland, the quantity of fuel left in the pumping machine was taken. The differences in these readings represent the quantity of fuel used (in litres). For each of the operations, the irrigated area was measured and recorded. All the irrigation schemes visited were evaluated over the same period and season. The apparatus for the study includes: the pumping machines (surface pumps); fuel; a stop watches for measuring time taken to supply the required quantity of water; and a measuring cylinder for quantifying the amount of fuel consumed during lifting and delivering of water to the farmland.

3. RESULTS AND DISCUSSION

The information gathered concerning crops planted, source of water, source of energy, irrigation delivery system, quantity of fuel used was analyzed to determine the energy required per unit land area with respect to crops cultivated, and are summarized in the Table 1.

Ilorin Irrigation Scheme Fuel Consumption

The data collected as regard Ilorin irrigation pumping costs showed that 15,840 litres of diesel fuel were consumed during the operating season. From Table 1 (in the appendix), 1 litre of diesel fuel = N250.00, Cost of energy consumption per litre of fuel will be 15,840 x 250 = N 3,960,000 litres per season. That is N3,960,000 will be spent on 15,840 litres of diesel fuel per operating season on an area of 40 ha of land.

$$\text{If } 40 \text{ ha} = \text{N}3{,}960{,}000 \text{ litres per season}$$

Also, per hectare value will be:

$$1 \text{ ha} = \frac{\text{N}3{,}960{,}000}{40} = \text{N}99,000 \text{ litres per season}$$

In terms of fuel consumed:

Since 1 litre of fuel = N250.00

Therefore 1 ha $= \frac{\text{N}99{,}000}{\text{N}250} = 396 \text{ litres/season}$

1 ha of land will require 396 litres for the operation of irrigation pumps per season.

Oke-Oyi Irrigation Scheme Fuel Consumption

From the data collected, as regard Oke-Oyi irrigation pumping costs, it was observed that 19,200 litres of fuel were consumed during the operation season. Cost of energy consumption per season at N250 per litre of fuel will be N4,800,000 litres per season.

$$19,200 \times \text{N}250 = \text{N}4{,}800{,}000 \text{ litres/season}$$

Therefore, a total of N4,800,000 will be consumed per operating season on 50 ha of land.

Also, if 50 ha = N4,800,000 litre/season

$$1 \text{ ha} = \frac{\text{N}4{,}800{,}000}{50} = \text{N}96{,}000 \text{ litres/ha/ season}$$

In terms of fuel consumption:

Since 1 litre of fuel = N250, 1 ha of land will require = $\frac{\text{N}96{,}000}{\text{N}250} =$ $384 \text{ litres/season}$

Giriyan Irrigation Scheme Fuel Consumption

From the data collected as regard Giriyan irrigation pumping costs. It was observed that 6,120 litres of diesel fuel were consumed during the operating season. The equivalent cost of energy consumption per litre of fuel was thus: 6,120 x N250 = N1,530,000. That means that N1,530,000 litre/season of diesel fuel is required in consumption on an area of 15 ha of land.

If 15 ha = N1,530,000

Then, 1 ha = $\frac{\text{N } 1{,}530{,}000}{15} = \ \text{N}102{,}000 \text{ litres/season}$

In terms of fuel consumed, 1 ha of land will require: $\frac{40,800}{250} = 408 \text{ litres/season}$

Shonga Irrigation Scheme Fuel Consumption

From the data collected regarding Shonga irrigation pumping costs, it was observed that 10,920 litres of fuel was consumed during the operation season. Cost of energy consumption per season at N250 per litre of fuel will be N2,730,000 litres per season.

$$10,920 \times \text{N}250 = \text{N}2,730,000 \text{ litres/season}$$

Therefore, a total of N2,730,000 will be consumed per operating season on 28 ha of land.

Also, if 28 ha = N2,730,000 litre/season

$$1 \text{ ha} = \frac{\text{N}2,730,000}{28} = \text{N}97,500 \text{ litres/ha/ season}$$

In terms of fuel consumption:

Since 1 litre of fuel = N250, 1 ha of land will require = $\frac{\text{N}97,500}{\text{N}250} = 390 \text{ litres/season}$

Erin-Ile Irrigation Scheme Fuel Consumption

From the data collected as regard Erin-Ile irrigation umping costs, it was observed that 20,790 litres of diesel fuel was consumed during the operating season. As a result, the cost of energy consumption per litre of fuel was: 20790 x N250 = N5,197,500 per season. That is, the cost of energy consumption on an area of 55 ha of land was N 5,197,500 litres/season.

Also, If 55ha requires N5,197,500 of diesel fuel per season.

Then, 1 ha of land will use $\frac{\text{N}5,197,500}{55} = \text{N}94,500$ litres of fuel per season.

Since 1 litre of fuel costs N250.00, then the fuel consumed on1 ha $= \frac{\text{N}94,500}{250} = 378 \text{ litres/season}$

From the Table 2 (in the appendix), one can estimate the average energy consumption (cost of pumping machine + diesel fuel) when diesel fuel is used for irrigating cultivated crops per hectare to be:

Average fuel consumption per hectare when using diesel

$$= \frac{396 + 384 + 408 + 390 + 378}{5} = \frac{1956}{5} = 391.2 litres / ha / season$$

Therefore, the monetary equivalent of this is = 391.2 x N 250 = N97,800 litres/ha/season

The average cost of diesel consumed per hectare using diesel engine = N97,800 litres/hectare/season.

3.2 DEVELOPMENT OF REFERENCE FIELD

To effectively satisfy the irrigation requirement of the site, important field operations were performed on one hectare of land selected as reference field. The following field operations were carried out.

3.2.1 LAND OPERATION

Land preparation which involves land clearing of bushes, so that it is possible to make use of equipment to carry out series of operation on land. The clearing was done with the aim of conserving and minimizing loss of nutrient and other mineral element from the top soil by water or air or erosion.

3.2.2 LAND GRADING /LEVELING

Land grading operation was performed on the selected portion of land as it is necessary in making a suitable field surface to control the flow of water, to check soil erosion and provide for surface drainage. Although, the field is not graded to a thoroughly leveled surface, but a gentle uniform slope is maintained to meet the requirement of irrigation and drainage. The uniform grades allow field to be laid out into irrigation runs of the proper length. The land surface was properly graded to ensure unobstructed, smooth flow of water into the land, without eroding the soil and ensure distribution of water throughout the field. Land leveling operations adopted were grouped into three phases: primary, final and harrowing: primary leveling was done by the removal of obstruct irregularities such as moulds, ditches and rings, and filling of its depression and gully. Primary leveling is followed by final leveling, which involved the reshaping of the land surface to a plant grade. Leveling was done to determine height relative to other point. So to carry out leveling work, the whole area was reduced to a reference point as a datum. The datum point is a known level in which all other points are referred to (always the mean sea level). A large quantity of earth was moved over a considerable distance as leveling is required. Irregularities are removed and a plane surface is obtained by land smoothing (harrowing) which is the final operation in land leveling. Land smoothing was done prior to seeding as regular land preparation practice.

3.3 DEVELOPMENT BASIN SRUCTURE

The whole field is divided into smaller units (i.e 2 x 2 meter-square) with cross or longitudinal slope. Each unit is a level area of land surrounded by earth bunds in which water can be pounded until it is infiltrated into the soil. The height of the ridge was constructed on expected water depth to be pounded as much as soil ridge can stand when watered. However, as it is important to use the right size and shape of basins and good water management for the method to work well, appropriate basin size was taken depending on: field size, soil type, land slope, farming practice and water source (storage size). There is no simple calculation to help an irrigator to select the best basin size for irrigation depth and soil type. In place where basin irrigation is practiced, the experience of local irrigators often provided a good guide to the best size.

3.4 WATER RESERVOIR

A water swamp (temporary reservoir) was developed and located at a strategic place on the reference field, excavated to a predetermined depth and width. Relatively large stones were placed at the bottom and lateral side of its wall. So, the occurrence of scouring can be prevented, and also, to effectively serve as energy dissipator on the remaining part of the field in order to ensure free flow of water under gravity force where it is required. The swamp is made of earth materials and it is 20 meters away from the soil (well). Water is conveyed by means of delivery pipe supported by prepared earth canals (distributaries and tertiary canal).

The reference crop, maize has the following data:

Root zone depth = 120 cm

Crop use co-efficient (mid season) = 1.1

Harvest = 0.55 (c.f. Michael, 1978).

Crop use coefficient for germination is 0.4

Growing period for longest and shortest cycle is 90 – 145 days (Dupriez, 1982).

100 days assumed to contain the short cycle specie soil type is sandy loan.

Water holding capacity of soil in root depth zone: 0.9 ÷1.0 x 120 = 108 mm

Net irrigation requirement = assuming 50% depletion water holding capacity x depletion

=> 108 mm x 50% = 54 mm

=> Gross requirement (G.R.), assuming 30% loss to seepage and deep percolation:

$$G.R. = \frac{NIR}{EFF} = \frac{54mm}{0.7} = 77.14mm,$$

Where NIR = Net Irrigation Requirement in mm

$$Irrigation\ frequency = \frac{NIR}{[E_{to}max/day]} = \frac{54mm}{8.52mm} = 6.33days$$

$$Depth\ of\ application/day = \frac{Gross\ requirement}{Irrigation\ frequency} = \frac{77.14}{6.33}$$

$$= 12.17mm/day$$

Irrigation water requirement is 0.000986 m^3/s/ha,

Time of irrigation required is 6.17 h/day = 22,212 secs/day,

Area to be irrigated is 1 hectare,

Therefore, the amount of water required per day:

= 0.000986m^3/s/ha x 22,212 secs/day x 1ha = 21.30 m^3/day

Thus, the expected water demand is 21.30 m^3/day.

Based on type of engine in use and irrigation system, averagely 30 litres of fuel was required to pump 21.30 m^3/day of water.

The irrigation water requirement for the reference crop (maize) is shown in Figure 1.

3.5 COST ANALYSIS OF ENERGY USED ON THE REFERENCE FIELD

For 12 irrigation days

30 x 12 = 360 litres of diesel fuel

From Table 1, 1 litre of diesel of fuel = N250

Quantity consumed per day:

30 litres = 30 x 250 = N7,500 per hectare

Amount consumed per operating season

30 litres x 12 irrigation days = 360 litres/ ha/season

360 litres = 360 x 250 = N90,000/ha/season

3.6 DISCUSSION

A survey of all the irrigation schemes visited, based on the cost analysis of energy used per hectare cost, reveals the non challant of the irrigation personnel towards energy requirement planning and failure to determine the most appropriate system and the way it is operated, maintained and managed. From the result obtained on energy requirement of irrigation water supply at the study area, it was observed that the increase in water use results in a proportional increase in energy consumption. And also the larger the area irrigated the lesser the per hectare use of fuel. Furthermore, energy consumption will increase as the quantity of water required is increased. Having considered the cost analysis of energy consumed on the reference field, the quantity of fuel consumed (360 litres of fuel per hectare per season) is of great benefit and profitable compared to the average quantity of fuel consumed (i.e. 391.2 l/ha/season) by the five irrigation schmes visited. Energy saving is obtained from the reference cost analysis when irrigation system is properly maintained and operated. Costs are greatly reduced by obtaining the necessary energy for pumping from fuel.

4. CONCLUSION

The average result of the various analyses carried out on energy requirement for irrigation water at the five irrigation schemes visited at a developed field is compared to know the quantity of fuel required to irrigate one hectare of land per season. This study shows that energy required for water supply varies depending with delivery system, energy cost, water source, energy source, pump capacity and management ability. Investigation reveals that management of this scheme did not account for the cost of irrigating versus the benefit received, and this is becuase no conscious effort has been made to monitor energy required for irrigation scheme resulting to high cost. The study also reveals that energy used depends on the amount of water pumped and the area of land to be irrigated. Energy used in irrigated agriculture is heavily dependent on diesel fuel, since most pumps used for irrigation are powered by diesel engine. Thus, diesel fuel prices have a crucial effect on the overall cost (total input cost) of crop production. Land grading/leveling operations were used on different fields whereby the field surface was reconstructed to a plane grade. Consequently, it ensures uniform distribution of water throughout the field and, reduces pumping water into the field to make energy just enough to satisfy crop needs. The reference field developed was used to demonstrate how energy required for irrigation after supply can be properly planned for, and monitored with fair management to give a satisfactory result. It is recommended that irrigation personnel should compare the cost of irrigating with the benefit received in order to reduce energy. The habit of adequate record keeping by both small and large scale irrigation schemes should be encouraged and cultivated for further analysis in the future. Also, the energy used should be monitored by irrigation personnel to avoid wastage of energy and increase in cost. Lastly, future research should try to make the energy source to be either solar or electrical which are more economical than diesel fuel.

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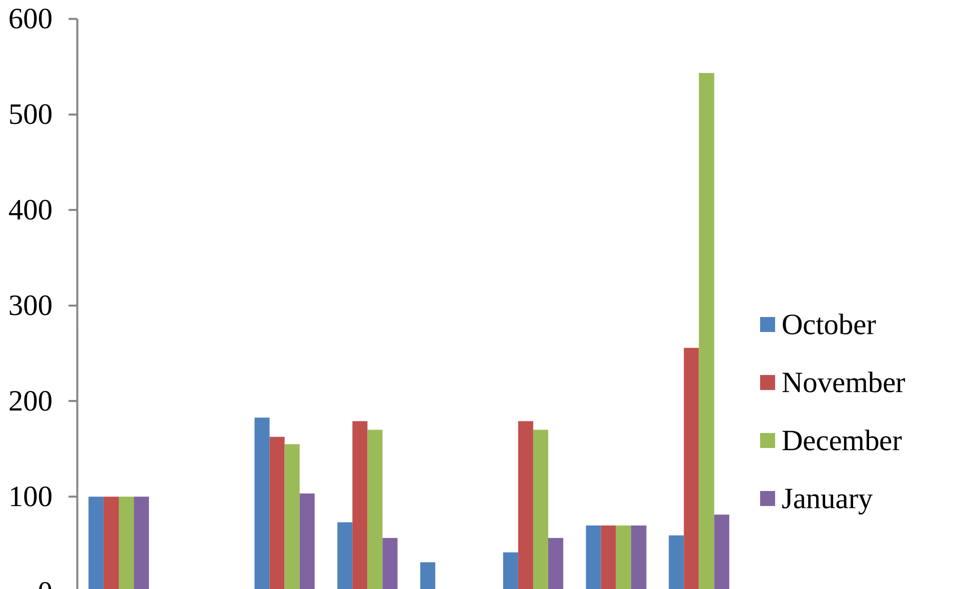
APPENDICES

Table 1: Energy requirement analysis of five typical irrigation schemes

Serial Number	Irrigation State	Irrigation delivery system	Total area irrigated (ha)	Source of water	Source of fuel	Cost per litre (₦)	Energy Cost of litres per season (₦)
1	Ilorin	Flood Irrigation	40	Dam	Diesel Fuel	250	3,960,000
2	Oke-Oyi	Flood Irrigation	50	Dam	Diesel Fuel	250	4,800,000
3	Giriyan	Flood Irrigation	15	River	Diesel Fuel	250	1,530,000
4	Shonga	Flood Irrigation	28	River	Diesel Fuel	250	2,730,000
5	Erin-Ile	Flood Irrigation	55	Dam	Diesel Fuel	250	5,197,500

Table 2: Fuel Consumption for the Irrigation Schemes

Irrigation	The equivalent fuel consumed per total area irrigated (L/ha/season)		
Site	**For 1 ha (litres)**	**Total area (ha)**	**Equivalent litres for total area**
Ilorin	396	40	15,840
Oke_oyi	384	50	19,200
Giriyan	408	15	6,120
Shonga	390	28	10,920
Erin-Ile	378	55	20,790



	Land use	Crop K	Etm m/month	Eta	Effective Rainfall	N/R	%EFF	FIR	mm/day	l/s/ha	m3/s/ha
October	100	0.4	182.8	73.12	31.5	41.62	70	59.46	2E-04	0.222	2E-04
November	100	1.1	162.7	179	0	179	70	255.7	1E-03	0.986	1E-03
December	100	1.1	155	170.1	0	170.1	70	543.6	9E-04	0.909	9E-04
January	100	0.55	103.3	56.82	0	56.82	70	81.16	3E-04	0.303	3E-04

Irrigation water - requirements

Figure 1: Irrigation water requirement for maize (Reference crop)

QUESTIONNAIRE ON IR. ENERGY
LADOKE AKINTOLA UNIVERSITY OF TECHNOLOGY, OGBOMOSO
(LAUTECH)

Department of Agricultural Engineering
Topic: Energy requirement for irrigation water supply

Instruction:
The purpose of this questionnaire is to evaluate the cost of energy required in irrigation pumping station in order to reduce the cost of production.
Your objective contribution in completing the questionnaire will be highly appreciated, so as to enable the researcher derive data that would be most useful for the research.

1. Name of Organization
2. Year of Establishment
3. Name of Officer
4. Status/Post
5. Profession: (a) Engineering [ ]

Discipline……………………………………………
(b) Agriculture [ ]
Areas of specialization…………………………….
(c) Other
Specify………………………………………
6. Total Area Cultivated
   (i) At the beginning of Scheme………………………….
   (ii) Currently…………………………………………………….
7. Year of Commencement of irrigation scheme……………………………
8. Crop Cultivated Irrigated or not
   (i) ………………………. [ ] Yes[ ] No
   (ii) ………………………. [ ] Yes[ ] No
   (iii) ……………………… [ ] Yes[ ] No
   (iv) ……………………… [ ] Yes[ ] No
   (v) ……………………… [ ] Yes[ ] No
9. Total Area irrigated…………………………………..Ha
10 What Method(s) of irrigation is/are practices on the shame?
   (i) Surface [ ] Total area irrigated………………………..Ha
   Please specify:
   Basin [ ] Area covered……………………………Ha
   Border [ ] Area Covered…………………………..Ha

Furrow [ ] Area Covered…………………………Ha
(ii) Sprinkler [ ] Area Covered……………………....Ha
(iii) Drip [ ] area Covered………………………………Ha
(iv) Other specify

11. Source(s) of water for irrigation on scheme
    (i) Dam Reservoir [ ]
    (ii) Stream [ ]
    (iii) Borehole [ ]
    (iv) Other specify [ ]
    (v) Other specify [ ]
12. What is the method of lifting?
    ……………………………………………………………
13. What is the type of energy source being used in your pumping station?
    ………………………………………………………………….
14. What is the discharge distribution throughout the irrigation season?
    ………………………………………………………………….
15. Energy – use of different energy sources for operation of irrigation system (Ha)

Irrigation	System	Electricity	Diesel Engine	Gravity Force
Surface				
Micro				
Sprinkler				

16. Required energy per hectare for different irrigation systems

Irrigation	Electricity		Diesel Engine	
	Demand Power kW/ha	Energy consumption kW.h/ha/year	Demand power (kW/ha)	Fuel Consumption (lit/ha/year)
Surface				
Sprinkler				
Solid set				
Semi Movable				
Fully Movable				

17 Energy costs in ₦
(a) For electricity
    Implementation cost per kW =
    Subscription fee per kW =
    Costs of active power per kW =
    Cost of reactive power per kVA =
    Costs of consumption
(b) For diesel engine/petrol, costs of consumption energy per 1.h =