PERFORMANCE AND ECONOMIC EVALUATION OF PUMPED IRRIGATION SYSTEM: A CASE OF SMALLHOLDER HORTICULTURAL FARMERS

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Abstract
The study was carried out with the objectives evaluating the technical performance of the pumps used in smallholder irrigated agriculture, studying the energy uses during pumping and identifying the possible causes of inefficient energy use, and evaluating the costs of pumping used during irrigation. Observational study to identify occurrence of pumped irrigation systems in Kakuzi Division in Thika and Yatta Division in Yatta District was done. Semi structured questionnaires were administered to 80 respondents in the study areas to investigate the challenges of pumped irrigation as well as find the socio-economic status of the people and the agricultural practices carried out. A detailed study was carried out on 10 different pumps during irrigation to evaluate their efficiency as well as energy uses. The results showed that numerous challenges faced smallholder pumped irrigation systems some of which are irrigation component selection, design and operation as well as irrigation water management. 60% of the pumps evaluated operated below the recommended design efficiency. The pumps further showed different fuel consumption rates, while the cost of fuel used to irrigate an hectare of land varied for all the 10 pumps assessed. The lowest and highest fuel consuming pump used fuel valued at 350 ksh/ha and 8,426 ksh/ha, respectively. The huge difference is as a result of several factors such as pump consumption rate, farmer's irrigation timing among others. The result therefore means that some enterprises made huge profits while others operated at marginal profits or no profit at all. The results imply that without proper selection of the irrigation equipments, poor designs as well as lack of operational and management skills, the farming enterprises can be rendered uneconomical. This calls for embracing of the engineering, agronomic as well as management techniques at farm level in order to ensure sustainability of irrigated agriculture as well as enhance its economic viability.

Key words: Pump performance, economic evaluation, pumped irrigation, Kenya

1.0 Introduction

1.1 General

Irrigation is vitally important in meeting the food and fiber needs for a rapidly expanding world population (Terry, 2001). Investments in water for agriculture have made a positive contribution to rural livelihoods, food security and poverty reduction (Molden, 2007). During the second half of the 20th century, food production outpaced population growth, with some 78% of the production growth over the period 1961–1999 deriving from yield increases (Bruinsma, 2003) as opposed to agricultural land expansion. Higher yields have been achieved, in part, due to the expansion of irrigated areas and improvements in water management on irrigated lands. The area equipped with irrigation expanded from 139 million ha in 1961 to 277 million ha in 2003 (FAO, 2007).

In Kenya, irrigation development has been on the increase, particularly the smallholder irrigated agriculture.

Current estimates indicate that Kenya has a potential for irrigation of 540 000 ha (MOWRMD 2003). About 106 600 ha have been put under irrigation, comprising 20% of the potentially irrigable area. Large commercial farms cultivate 40% of irrigated land; government-managed schemes cover 18%, while smallholder individual and group schemes take up 42% of irrigated land (Republic of Kenya, 2004). Smallholder irrigated agriculture produces the bulk of local horticultural produce consumed in Kenya, as well as some export crops, and a substantial amount of dairy products. In the medium and high rainfall areas, supplementary irrigation based on surface flows has been instrumental in increasing productivity of high-value crops (Herdijk *et al*., 1990 and Mati, 2002). Due to the increase in irrigated area, numerous challenges facing smallholder farmers have emanated. The major constraints facing smallholder irrigation in Kenya include shortage of water as well as market availability, instability and unpredictability, both locally and abroad. In addition with over 80% of the smallholder irrigation schemes in Kenya being furrow-based, irrigation efficiency is very low hence the need for water saving techniques in the ASAL regions (Kibe *et al*., 2006). Further earlier estimates indicated that the irrigation efficiency for furrow based irrigation system hardly went beyond 40% with a loss that may exceed 60%. Moreover, research has shown that saving of water of between 30-40% can be achieved by using new irrigation methods.

Other challenges facing the smallholder farmers include the lack of a national irrigation policy, while inadequate investments have led to poor development of irrigation infrastructure and water storage facilities (Irrigation and Drainage Department, 2006). There is also inadequate technical capacity affecting farmers' organization and participation (Mati, 2008). Majority of smallholder farmers still rely on traditional methods of irrigation such as bucket irrigation systems which are most often inefficient in water use while most farmers do not irrigate their crops (Kibe *et al*., 2006).

It is due to the above findings that a study was commenced to study the performance of smallholder pumped irrigated agriculture and their economic performance.

2.0 Materials and Methods

2.1 Study Area

1.2.1 Location of the Study Area

Two study areas, i.e., Mitubiri location IN Kakuzi Division and Kithimani sublocation were chosen as the study sites where smallholder farmers practised pumped irrigation systems. Kakuzi division is located in Thika district of Central Province while Yatta division is located in Yatta district of Eastern province. Kakuzi division lies between longitudes of 36^0 40''w, 37^0, 21^0E and latitudes -1^0,20^0 N, -1^0,15^0S while Yatta division lies between longitudes of -0.8^0W, -1.27^0E and latitudes of 36.66^0N, 37.10^0S. Kakuzi division is approximately 5 km and 52 km from Thika and Nairobi town respectively while Yatta division is 45 km and 81 km from Thika town and Nairobi town respectively. Kakuzi and Yatta division are on the north east and eastern direction from Nairobi town respectively. The location of the study area is presented in Figure 1.

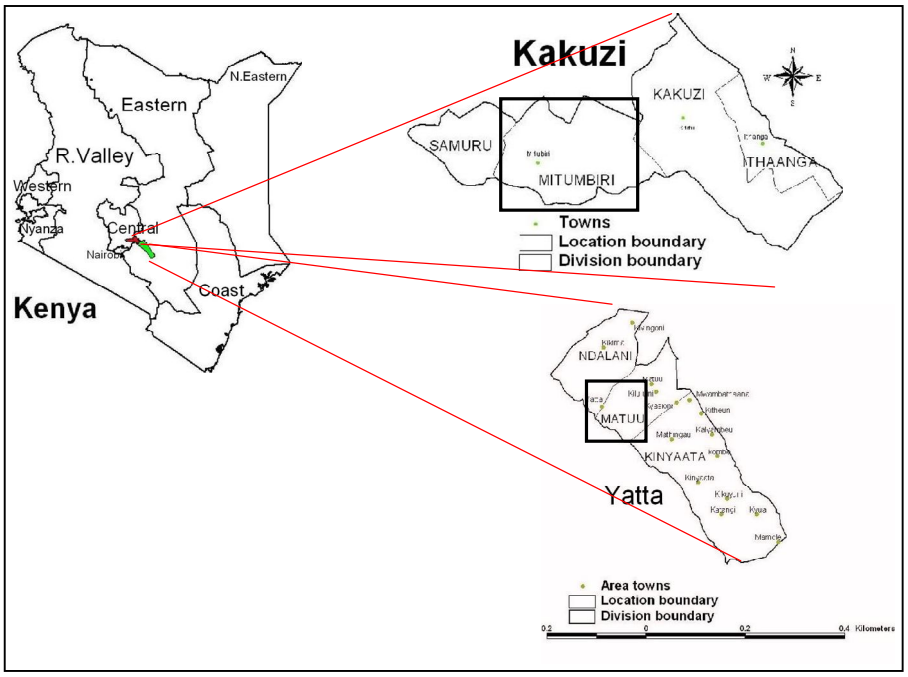

Figure 1: Location maps of Kakuzi and Yatta division with area towns and location boundaries

2.1.2 Population Density

The population density of Yatta division ranges from 152 Persons/km^2 (Frederick *et al*., 2000) while that of kakuzi division is approximately 71,622 persons and covers an area of about 481.2 Km^2 hence the population density is approximately 149 persons/ Km^2 (Robinson *et al*., 2005).

2.1.3 Water Sources

The available water sources in Yatta division are the Yatta furrow with its intake in Thika River at Mavoloni area. Yatta furrow plays a significant role in water supply to the residents of this area who practice both subsistence farming as well as horticultural farming for both local and export market. Its envisaged coverage was 60 kilometers but it covers an area of approximately 40 kilometers from the intake point due to water losses and misuse. The available water sources in Kakuzi division ranges from rivers, streams, springs and shallow wells. River Thika and Kabuku are the main water sources for the division since they are permanent while river Samuru is seasonal and highly polluted. Other springs such as Kasioni spring in Ithanga location is widely used by the residents.

2.1.4 Climatic Conditions

Rainfall patterns in parts of Eastern province exhibits distinct bimodal distribution. The first rains fall between mid-March and end of May and are locally known as the long rains (LR). The second rains, the short rains (SR), are received between mid October and end of December. Average seasonal rainfall is between 250-400 mm. Inter-seasonal rainfall variation is large with a coefficient of variation ranging between 45-58 per cent, while temperature ranges between 17-24^{0}C. Evapo-transpiration rates are high and exceed the amount of rainfall most of the year except the month of November (Fredrick *et al*., 2000). Kakuzi Division rainfall distribution is bimodal with high peaks from March to May (long rains), and October to December (short rains). Annual rainfall varies from about 800 mm at an altitude of about 1525 m above sea level (ASL). The annual evapotranspiration increases from about 1250 mm at an altitude of 2400m ASL to about 1800mm at 1100m ASL (Gathenya, 1999). The temperatures are high at the lower altitudes ranging from 25^{o}C to 30^{o}C but reduce to between 18^{o}C and 20^{o}C towards the higher altitudes of 3500 m ASL. Mean annual evaporation which is 1485mm and 1625mm in Kakuzi and Yatta division respectively exceeds the rainfall (MOALD, 1998).

2.1.5 Agricultural Activities

Irrigated agriculture dominates the two areas due to unreliability of the rainfall. Few farmers practice subsistence agriculture during the short rain period and later on switch to irrigation. Only those farmers near the water sources benefit greatly as they practice supplemental irrigation to their crops. Pump fed agriculture is widely practiced by the residents in the two study areas.

2.2 Collection of Technical and Socio-Economic Data

Transect walks in the two study sites identified the agricultural activities of the farming community, the irrigation methods used as well as the socio-economic status of the people. Questionnaires were used to gather socio-economic data in the study areas. The questionnaire detailed the socio-economic status of the people, crops irrigated by the farming community, technical information such as irrigation methods used (water abstraction technologies, conveyance and application methods), irrigation equipments used i.e. pumps, pipes, hosepipes and other fittings and their selection procedure. The costs incurred during irrigation of horticultural crops were also identified through the questionnaire. A total of 80 farmers were interviewed, 50 in Kakuzi and 30 in Yatta Division.

2.3 Detailed Study of Pumping Units

Detailed study of the pumping units used in the study area was done. The make and model of 10 pumps was established and detailed evaluation of their efficiency, fuel use and power requirements during pumping was carried out. Economic evaluation of pumped irrigation systems was done and the overall seasonal energy cost computed.

2.3.1 Pump Working Efficiency

Pump efficiencies were calculated by first evaluating the pump specific speed from equation 1. In the equation, N_S is pump specific speed (rpm), N is pump speed (RPM) and is discharge (L/M.) and it is the total head (M). The pump speed was measured using a hand held tachometer at different levels of acceleration while the discharge and head were measured using a bucket and a quickset level respectively. The results of the calculations were read in the graph shown in Figure 2. The age of each pump was established through the questionnaire.

$$N_s = 0.2108N\left[\frac{Q^{0.5}}{H^{0.75}}\right] \quad \text{.....(1)}$$

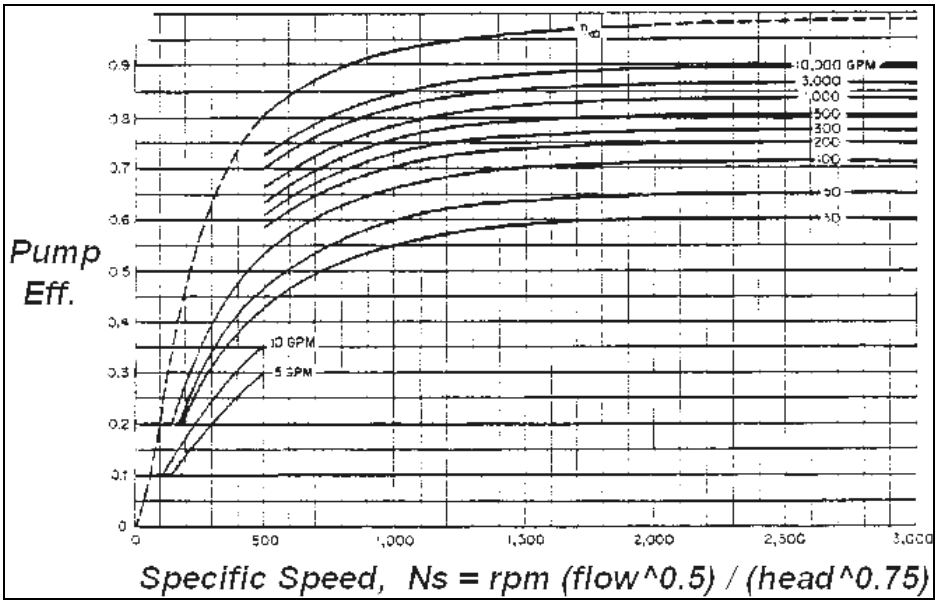

Figure 2: The graph of pump efficiency showing the pump specific speed
Source: Michael 1983

2.2.2 Fuel use Efficiency

The fuel consumption rate for the 10 pumps was measured at different pump operating speeds. Fuel consumption rate was measured concurrently with water discharge in order to evaluate the fuel used per volume of water pumped. The pumping time was measured using a stop watch.

The values for the fuel consumption rate of the different pumps were compared with the standards already set by manufacturers (Davis and shirtliff, 2001 and HondaAtlas Power Products Ltd,HAPPL),

2.2.3. Power Requirement Determination

Pump power requirements for the 10 irrigation setups was calculated from equation 2, which include power (KW) = Power requirements, Q = Discharge (m^3/hr), H = Head (m), Ep = Pump efficiency.

$$power\ (KW) = \frac{Q * H}{360 * Ep} * 1.2 \quad \text{.....(2)}$$

2.2.4 Economic Evaluation of Pumped Irrigation Systems

Pump fuel use during irrigation was evaluated for the 10 pumps used in different irrigation setups. This was further converted to the costs incurred during irrigation.

The overall seasonal energy cost was calculated from the seasonal energy demand, the fuel consumption of the pump, and the cost of fuel using equation 3. In this equation, OSEC – Overall seasonal cost, SED is Seasonal energy demand, F_UC is Fuel consumption, CF is Cost of fuel. The cost of fuel was determined from the local market rate at the time of project implementation.

$$OSEC(Ksh) = SED(Kwh) * F_U C(L/Kwh) * CF(Ksh) \quad \text{.....(3)}$$

where

SED was computed from equation 4, in which Q - volume of water (m^3), H - Head (m), Ep - pumping plant efficiency .

$$SED(Kwh) = \frac{Q * H}{367 * Ep} \quad \text{.....(4)}$$

EP is evaluated as shown in equation 5, where EP is pumping plant efficiency, PUE is Pumping plant efficiency, TE isTransmission efficiency, PE is Pump efficiency.

$$EP(\%) = PUE * TE * PE * 100 \quad \text{.....(5)}$$

The values for fuel efficiency varies from 90 -100% hence an average value of 95 % was used and the power unit efficiency for petrol pumps is 10% while for diesel engines it is 15-35 %, (FAO,1992). Therefore an average value of 25% was used for the diesel pumps.

Evaluation of fuel consumption was based on 0.09L = 1 Kwh for diesel and 0.11 L = 1 Kwh for petrol (FAO, 1992). Transmission efficiency for the pumps used is usually 100% due to direct coupling. The different crops grown were also put into consideration while comparing the total cost of production and the overall seasonal energy cost.

2.2.4 Gross Margin Analysis

The "gross margin" for an item is the sales revenue obtained from the item sold, minus the direct costs of producing (or in the case of a reseller, the cost of acquiring) and selling the item. The direct costs are the variable costs that go up or down based upon the number of units sold.

From the questionnaire, different parameters were obtained from the smallholder farmers. These included agricultural practices, crops grown, quantity and costs of various inputs used during farming and the output as well as sales of the farm produce. Other data regarding the farming enterprise were obtained from farmers records. From the data obtained, the gross margin analysis for the farming enterprise was computed. Crops considered were French beans, Tomatoes, Water melon and Baby corns.

3.0 Results and Discussion

3.1. Agricultural Activities in Yatta and Kakuzi Divisions

From the preliminary survey done in the two study areas, smallholder farming dominated the agricultural sector with majority of the farmers practicing irrigated horticultural farming. Most of the horticultural crops are grown for both local and export market. Table 2 summarizes the findings from the two study areas.

Table 2: Findings in the two study areas

	Mitubiri location of Thika District	*Kithimani Sub location of Yatta District*
Crops grown	Water melons, french beans, baby corns, vegetables, bananas, tomatoes, mangoes, and subsistence crops.	water melons, French beans, vegetables, baby corns, bananas, tomatoes, Baby corns, Vegetables, bananas, tomatoes, mangoes and subsistence crops
Pumping systems used	Small motorized pumps used to pump water.	Gravity fed systems common for most farmers while pumping was done in some farms.
Main water users	Small holder farmers, few large scale farmers, Few large scale farmers.	Small holder farmers, few large scale farmers
Natural vegetation	Indigenous trees	Shrub land dominates the area

3.2 Irrigation Practices in the Two Study Areas

The percentages of the farmers using different methods of irrigation in the study area are shown in figure 6. The study shows that very few farmers used modern irrigation technologies in the study area. This would be due to lack of advice on appropriate technologies available or financial limitations to obtain modern equipments for irrigation.

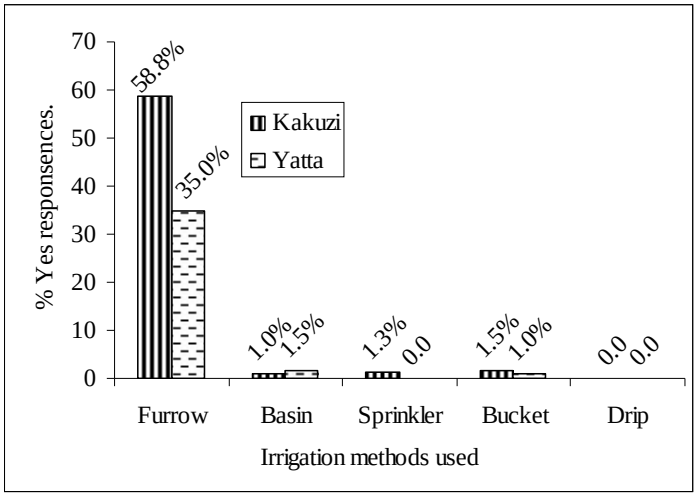

Figure 3: Smallholder irrigation methods used in the study sites

It was also found out that different on farm irrigation set ups were being used in the two areas. Majority of smallholder farmers 97.5% of respondents in the study areas use small motorized petrol pumps while 2.5% use diesel engine pumps. The farmers using petroll powered pumps gave the reason as the high cost of buying the diesel pumps as compared to petrol pumps. From the findings, it was concluded that there was low adoption of modern irrigation technologies by farmers. Few farmers used sprinkler irrigation in their farms while majority continued to rely on furrow irrigation method which apparently has very low water use efficiency (Hayrettin et al, 2008). The survey also found out that different on on-farm irrigation set ups were being used in the two areas (Table 3). A large percentage of the farmers pumped water using small motorized pumps and conveyed it through pipes and then applied it directly in the furrows. The result shows that simple irrigation setups were being used by the farmers which they could probably understand and afford.

Table 3: On farm irrigation setups used by smallholder farmers

On farm irrigation set up	*No. of respondents*	*Percentage*
A) Pump-pipes-sprinklers	1	1.3
B) Pump-pipes – hosepipe – furrow	52	65
C) Pump – pipe –sub canal - furrow	8	10
D) Pipe- sub canal – furrow	15	18.8
E) Bucket	2	2.5
F) Pump – pipe – hosepipe – basin	2	2.5
	80	100%

3.3 Sources of Information in Purchasing Irrigation Equipments

Figure 4 shows different sources of information on where to purchase the irrigation equipments for the farmers in the study areas. 60% of the farmers get information on where to purchase the irrigation equipments from other farmers who have experience in using them.

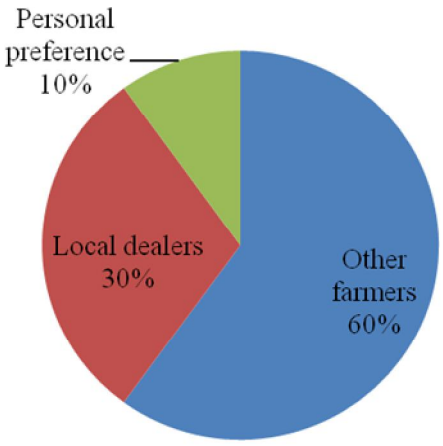

Figure 4: Source of information in purchasing irrigation equipment

Further information revealed that the farmers depended on past experiences in dealing with irrigation equipments and that no information was provided by irrigation personnel's or engineers in the two areas. This therefore indicates that there was no engineering approach that was adopted in selection, design and operation of the irrigation equipments. It was also found that the local dealers who sell the irrigation equipments provided

information on the best equipments to use. The problem of lack of proper selection of irrigation equipments hence poor design were further cited by Kay et al., (1992) and FAO (1992).

3.4 Limitations of Pumped Irrigated Smallholder Agriculture

Several factors were found to have a negative influence in smallholder irrigated agriculture. Figure 5 shows in percentage the factors that limit pumped irrigated agriculture as cited by respondents in Mitubiri location and Kithimani sublocation.

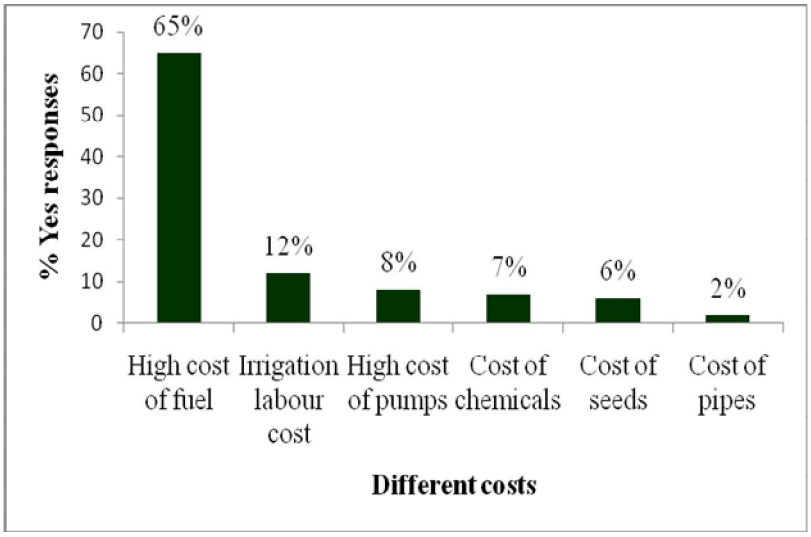

Figure 5: Limitations of smallholder pumped irrigation systems

High cost of fuel as cited by 65 % of the respondents was found to be the most limiting factor in pumped irrigated agriculture. Past studies done showed that there are several ways of reducing the high cost of irrigation such as embracing the agronomic, engineering and management techniques (Seckler, 1996).

3.5 Challenges Facing Smallholder Pump Fed Agriculture

Problems experienced by smallholder irrigated agriculture were given as poor markets for their produce, water shortages, lack of irrigation infrastructures, and high cost of inputs among others. Some of the challenges cited are shown in figure 6.

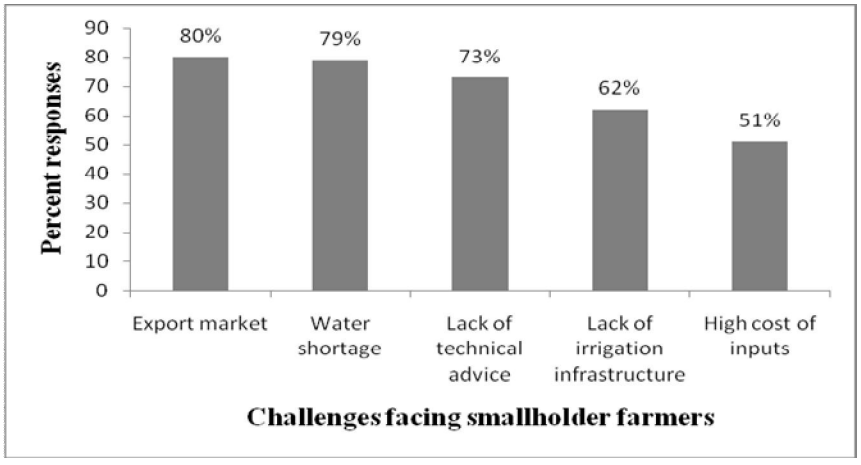

Figure 6: Challenges facing smallholder farmers

The challenges shown in figure 6 coincide with those shown by Mati et al., (2005) and Kulecho et al., (2006). Technical advice regarding irrigation equipment selection, design and operation was generally lacking in the two study areas. Inadequate technical capacity affecting farmers' organization and participation was also common which is further indicated by past studies done by Mati (2008). Export market for horticultural crops posed a major problem for most smallholder farmers which was indicated by 80% of the respondents. This was further aggravated by unreliable market prices and middlemen who swindle them of the profits they make. Water shortage during times of high demand of the horticultural crops was prominent in the study areas. It was further found that traditional methods of irrigation such as furrow irrigation was most common and could be the major contributor of water shortage due to its high water use inefficiency.

3.6 Technical and Economic Evaluation of Smallholder Pumped Irrigation Systems

3.6.1 The Pumps Used In the 10 Farms

Different types, makes and models of pumps were found in the two study areas. All the pumps used in the 10 farms were small motorized centrifugal pumps run by petrol and ranging from 4.0 to 6.6 horsepower. The total head for the different pumps ranged from 28 to 32m while the discharge rate varied from 520 L/min to 1100L/min. The pumps had varied inlet and outlet diameters ranging from 1.5 inches to 3 inches respectively. All the pumps had varied fuel consumption rate.

3.6.2 Pumps Working Efficiencies

The results showed that most pumps operated below the manufacturers recommended optimal design efficiency of 60% or higher (FAO, 1992). A pump operating at 60% efficiency is considered to be operating within its recommended range. Of the 10 pumps assessed, 6 of them operated below the recommended efficiency. Figure 7 shows the graph of pump efficiency for the 10 pumps assessed.

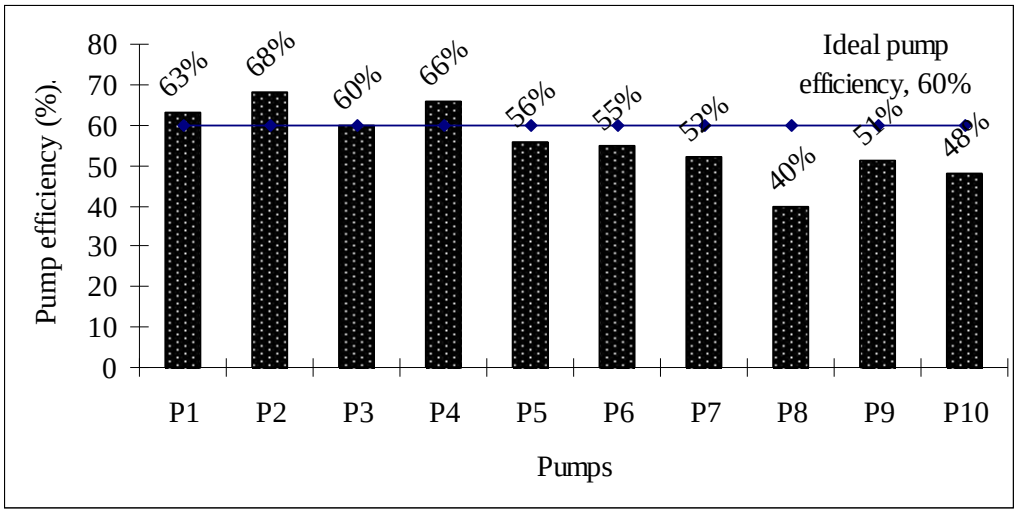

Figure 7: Efficiencies of different pumps used by smallholder farmers

Pump efficiency is a factor of many components such as pump specific speed, water discharge rate, rotating speed of the pump impeller and total dynamic head. An increase in the pump rotating speed and discharge rate of the pump results to an increase in pump specific speed which in effect results to increased pump operating efficiency. On the other hand, an increase in the total dynamic head results to reduced pump specific speed which then lowers the pump operating speed. It is therefore important to match all the pump parameters in order to ensure that the pump operates at the highest level of efficiency as possible. Despite the fact that the pumps were of different makes and model, the operational factors should be such that they ensure its operating efficiency remains as high as possible. Table 4 shows the operating conditions for the 10 pumps used in the study area.

Table 4: Operating conditions for the 10 pumps used in the study area

Pump	*Calculated specific speed, Ns*	*Operating pump speed N (RPM)*	*Average water discharge (L/s)*	*Total dynamic head (m)*
P1	1834	1800	3.0	6.3
P2	1730	2250	5.3	10.3
P3	1884	2200	2.2	6.4
P4	3115	2300	4.7	5.2
P5	1178	2400	2.4	11.0
P6	858	3200	2.8	24.3
P7	753	2550	2.9	21.9
P8	351	3000	0.2	13.8
P9	1172	2750	1.6	9.8
P10	1083	2600	1.5	9.4

From table 4, the total dynamic head for farm setups using pumps 6, 7 and 8 were higher compared to the other pumps used in other farm setups. This could have possibly lowered the pumps operating efficiency. The discharge rate for the farm setups using pumps 3 and 6 exceeded the design limit hence could have resulted to poor pumps operating efficiency. Further investigation on relationship between pumps age versus efficiency showed that pumps age did not affect its efficiency. Some old pumps had a higher efficiency than the new pumps. Several factors that could have contributed to this anomaly were either repair or maintenance, pumps make and model as well as proper operation of the pumps.

3.6.3 Fuel use Efficiency

The running speed of the pump was found to have a big influence on fuel use. Figures 8 and 9 shows the fuel use versus running speed of 10 pumps.

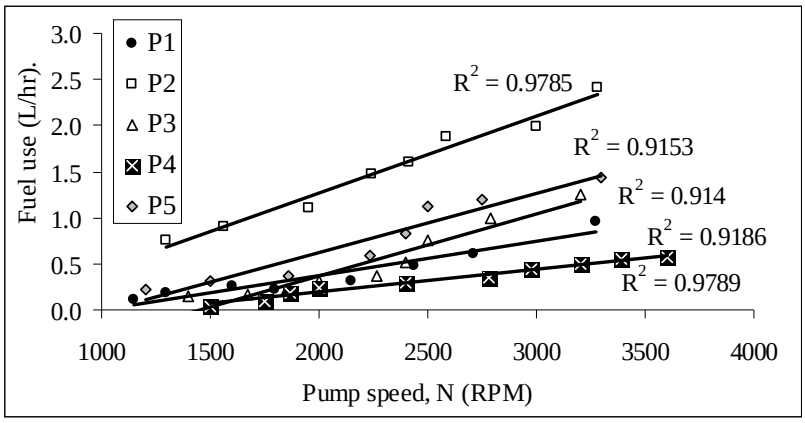

Figure 8: Fuel use versus pump speed for different pumps in Kithimani Sub location

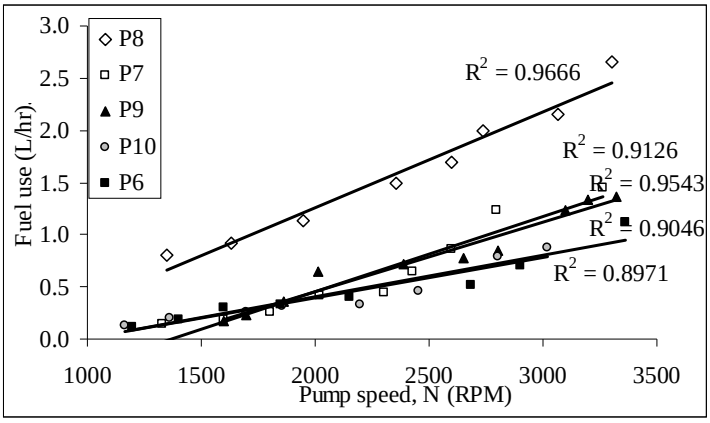

Figure 9: Fuel use versus pump speed for different pumps in Mitubiri Location

A regression analysis indicated that the fuel consumption rate of the pump depended on the pump running speed. The relation is actually linear with R^2 for the pumps lying between 0.89 to 0.98. A slight change in pump running speed greatly results to increased fuel consumption rates of the pumps. Increase in pump speed results to increase in fuel use while water discharge rate is increased. As a result, by increasing the discharge rate, irrigation time is shortened. Farmers should operate their pumps at a speed that results to considerable fuel use while discharging manageable water.

Comparison of manufacturer's pumps fuel consumption rate versus the measured fuel consumption rate is shown in Table 5.

Table 5: Comparison of fuel consumption rate

Pump	*Manufacturers fuel consumption rate (L/hr)*	*Measured fuel consumption rate at optimum pump speed (L/hr)*
P1	1.25	0.96±0.14
P2	1.25	2.41±0.09
P3	1.50	1.26±0.10
P4	1.25	0.60±0.11
P5	1.25	1.44±0.13
P6	0.90	1.12±0.11
P7	0.90	1.45±0.12
P8	1.25	2.65±0.08
P9	0.90	1.36±0.15
P10	1.25	0.87±0.14

Mean ± STDEV

The manufacturers fuel consumption rates are the values when the pump operates at full throttle (maximum speed). Fuel consumption rate of the different pumps was measured at the pump operating speed. The farmers could not operate their pumps at full throttle considering the maximum allowable pipe discharge rates. Pumps 1, 4 and 10 representing 30% of the studied pumps consumed fuel at a rate slightly closer to the manufacturer's rated fuel consumption rate at full throttle. This indicates that the pumps were functioning normally during the time of assessment. The remaining pumps consumed slightly more fuel than the manufacturers prescribed rate. The reason for higher fuel consumption rate could be due to poor system maintenance or some broken down parts. It

is therefore necessary to monitor the fuel consumption rate of the pumps more frequently in order to correct any arising anomaly. This could be as a result lead to lowered energy uses during pumping.

3.6.4. Fuel use and Cost

Figure 10 shows the fuel used in litres per hectare for the 10 farms assessed using different pumps with different fuel consumption rates while Table 6 classifies the fuel use range for the different farm setups.

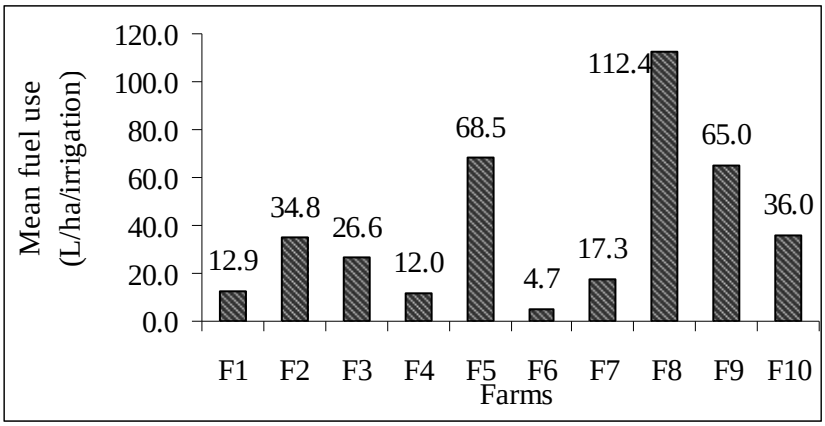

Figure 10: Mean fuel used per irrigation (L/ha) in the 10 farms

Table 6: Quantity of fuel used during irrigation

Fuel use range (L/ha/irrigation)	Farm irrigation setup
<5	F6
10-20	F1,F4,F7
20-40	F2,F3,F10
>60	F5,F8,F9

The 10 farm set ups showed wide variation in the amount of fuel used per irrigation for 1 hectare of land. Only one farm irrigation setup used less than 5 litres per hectare during irrigation while 3 setups used between 10 to 20 litres and a further 3 setups used greater than 60 litres per hectare during irrigation. This shows a wide variation in fuel use in irrigating the 10 different farms and the possible causes of this variation could be due to use of different makes and models of the pumps with differences in fuel consumption rates, different sizes of pipes and fittings used, farm orientation (elevation, length) and irrigators perception on the amount of water to apply and irrigation time. Different crops at different growth stages have different water requirements and this could have led to variation in irrigation time for the 10 farm setups, and the wide variation in fuel cost used (Figure 11). The differences could result to some farms operating at a loss or on marginal profit with others having more returns on investment. Matching the pump to the farm conditions is another factor in consideration. Frequent repair and maintenance as well as routine checkups of the pumps devices and irrigation equipments used would ensure reduced operating costs as well as higher returns on investments.

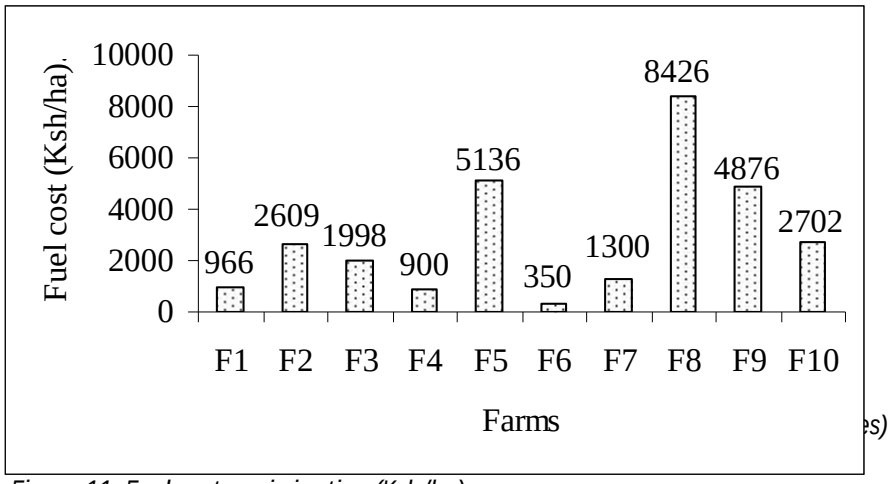

Figure 11: Fuel cost per irrigation (Ksh/ha)

3.6.5 Evaluation of Overall Seasonal Energy Cost

The overall seasonal energy cost (OSEC) for the crops whose gross margin analysis was done was evaluated. Figure 12 compares the values for OSEC/ha for the three crops considered.

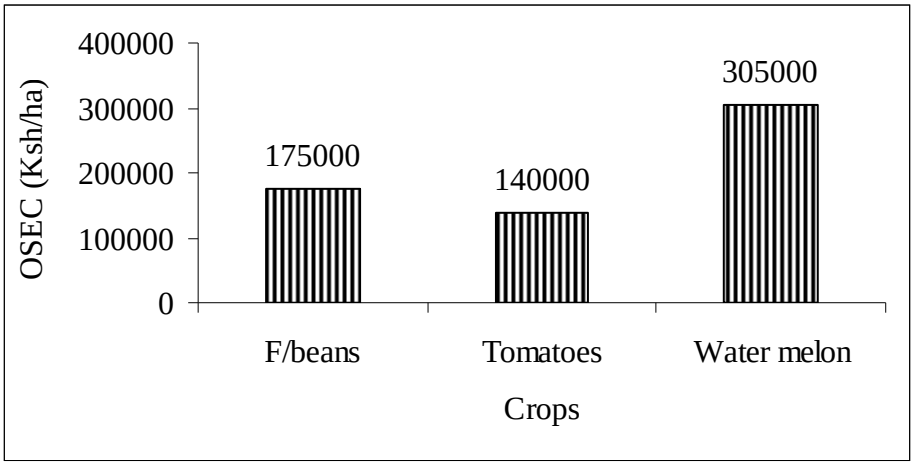

Figure 12: Average values for OSEC/ha for different crops grown by different smallholder farmer

The OSEC for water melon was almost double that of French beans. Tomatoes yielded the least OSEC/ha for the period considered in crop production. OSEC is a function of different factors such as pump operating efficiency, fuel consumption rate of the pump, cost of fuel, volume of water used during irrigation, total dynamic head, transmission efficiency and power unit efficiency. Among these factors, only the cost of fuel, transmission efficiency and power unit efficiency were constant while the rest varied from one farm setup to the other. Farmers should therefore aim at ensuring the varying constants operate as close to an ideal case.

3.6.6 Gross Margin Analysis of Smallholder Pumped Irrigation Systems

Gross margin analysis for smallholder pumped irrigation systems was carried out to assess the profitability of this type of farming with a view of identifying the most limiting factors.

Gross margin analysis of three different crops i.e. tomatoes, French beans and water melons was done. Six farmers growing French beans and had adopted the same crop spacing of 5cm by 30cm were selected randomly from Mitubiri location. Similar crop spacing was to minimize variation in total production from the different farms. Two farmers growing tomatoes and water melons were considered in computation of gross margin analysis. The

spacing considered for tomatoes and water melons was 45 cm by 60 cm and 0.7 m by 1.6 m respectively for all the farmers. Table 7 shows the mean production per hectare versus net returns for each of the crops considered.

Table 7: Mean production per hectare versus net returns for different crops

Crop	*Production/ha*	*Units*	*Unitcost (Ksh/kg)*	*Totalcost (Ksh)*
French beans	11,800	Kilogrammes	40.00	214,840.00
Tomatoes	38,300	Kilogrammes	20.00	765,658.50
Water melons	16,900	Kilogrammes	15.00	253,690.00

Figure 13 shows the summary of gross margin costs for the different crops assessed in the field.

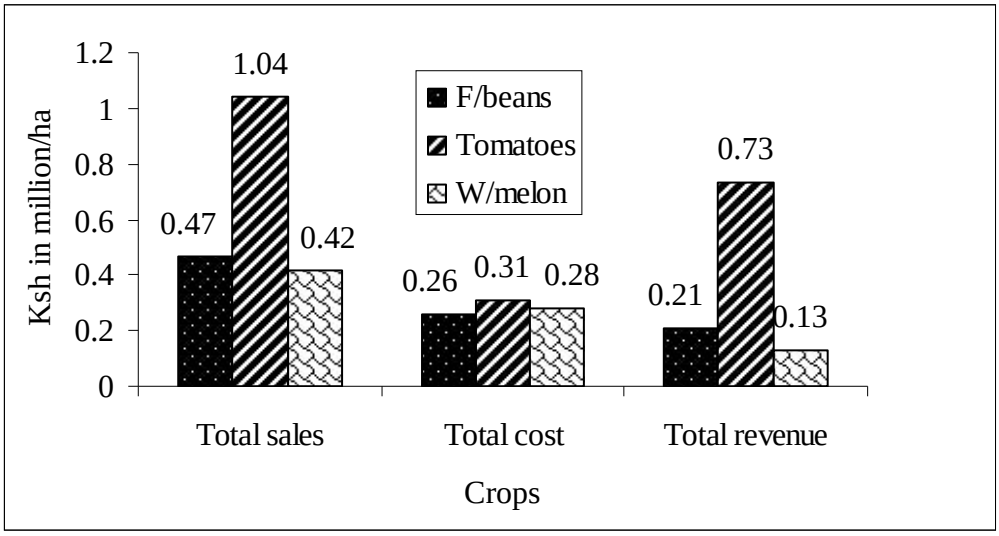

Figure 13: Gross margin analysis for different crops frown in the field

From the findings, tomatoes gave the highest returns per hectare of land while French beans and water melon were 2nd and 3rd respectively. Although the returns from Tomatoes were high as compared to the other crops considered, French beans were widely grown by the farmers in the study areas. This indicates that crop production for export market still plays a significant role in the agricultural sector and ought to be given the highest priority ever. Horticultural crops for the local markets generally fetched low prices with poor marketing structures hence resulting to farmers focusing on the export market despite its numerous challenges such as exploitation from the middlemen and at times lack of price awareness for their produce.

4.0 Conclusion and Recommendation

Despite the high uptake of smallholder pumped irrigation systems, it was found to have numerous challenges which ranged from engineering to management aspect. The numerous challenges that bedeviled the smallholder pumped irrigation systems were poor irrigation system component selection, design, inappropriate skills in running the systems as well as lack of technical support in selection and operation of these systems.

From the study, smallholder farmers were found to continually rely on traditional irrigation methods such as furrow system with few having modern irrigation systems. Lack of technical support in irrigation system selection, design and operation, further compounds the problems in smallholder irrigation systems. Some of the challenges affecting smallholder farmers operating pumped irrigation systems were poor market, high cost of fuel, water shortage, and lack of technical support as cited by 80%, 65%, 79% and 73% respectively as cited by the respondents.

6 of the 10 pumps assessed operated below the recommended design efficiency of 60% while fuel use for the 10 pumps varied from on pump to the other. The result of the variances in fuel consumption rates lend to some farming systems incurring more costs per unit of land irrigated.
The cost of fuel used per hectare varied from 350 Ksh/ha to 8426 Ksh/ha. The big discrepancy shows that it is possible to operate at a more hgher profit if all the factors leading poor performance are well thought of.

In general, smallholder pumped irrigation systems can be greatly improved by combining all the necessary factors ranging from engineering, agronomic and management.

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