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COMPARATIVE PERFORMANCE OF WIND AND ELECTRIC PUMPS FOR IRRIGATION

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Abstract: Wind energy technology may turn out to be the best alternative compared to the use of hydro electric power for pumping water for irrigation in certain parts of Ghana during the dry season. This paper focuses on evaluating the performance of wind and electric pump through the mounting of an experiment in order to do a comparative evaluation of the investment cost of running the two energy-based pumping systems in the Keta District which provides one of the best wind regimes in Ghana. Farmers in these coastal communities may have engaged in the use of wind energy for water pumping but for its high initial cost. Despite the high initial cost farmers could form cooperative societies in order to run a wind energy pumping system. The high electricity tariff paid every month for power consumption deters majority of the farmers using hydro electricity technology for pumping. A total investment cost of ¢4095.80 per hectare was incurred by farmers using the electric power whilst ¢929.80 per hectare by those using the wind power technology for every farming season. A difference of ¢3166.00 could be saved for other uses by farmers practicing the wind energy technology.

Key words*: wind, electricity, pumps, irrigation, energy, performance*

INTRODUCTION

There is increasing demand for water for domestic purposes and crop irrigation as a result surface water is becoming very scarce worldwide [1]. Though diesel, petrol and sometimes kerosene powered pumps have traditionally been used to pump water [1], electric and wind energy are emerging as attractive sources of energy for water pumping for irrigation and domestic use. Most of the worlds energy needs is met by fossil and nuclear power plants, however the global search and the rise in the cost of conventional fossil fuel is making supply-demand of electricity product almost impossible especially in some remote areas [2]. Wind energy systems for irrigation and milling have been in

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use since ancient times and at the beginning of the 20th century it is being used to generate electric power. Windmills for water pumping have been installed in many countries particularly in the rural areas [2]. Wind power is able to feed both energy production and demand in the rural areas. It is used to run a windmill which in turn drives a wind generator or wind turbine to produce electricity [3]. Wind turbine has significant benefit in the areas where there is a shorter rainy season and hence demand for pumped water. After installing wind turbine water pumps in a farm, one can raise higher value crops throughout the year and also supply water to the livestock [4].

There are various energy alternatives, which may be non-renewable options such as clean coal, nuclear, and renewable options such as hydroelectric, biomass / biofuels, geothermal, thermal energy conversion, wave, tidal, wind, solar, and other [5], however Solar and wind are renewable and non-polluting, and is optional alternative resources for power generation [6]. Also the awareness in saving of direct energy has grown rapidly in this sector due to continues increase in energy prices (for example fuel) in the last couple of years [7].

For the purposes of this research, much emphasis is laid on the supply of irrigation water for vegetable production; and thus focused on comparing and choosing the most economically viable and affordable pumps operated on wind and electric energy sources for vegetable production in the Anloga community in the Keta District of the Volta Region of Ghana.

Description of Research Area. Geographically, Keta District is located in the southern sector of the Volta Region of Ghana. The District lies within longitude 0.3°E and 1.05°E and latitude 5.45°N and 6.005°N. It is sandwiched between two major surface water bodies – the Keta lagoon and the Gulf of Guinea. It is a flat land full of sandy soil owing to its proximity to the Keta beach.

The indigenous Anlo communities basically engage in vegetable production and salt winning on commercial scale since time immemorial. They mainly produce shallot, pepper, tomato and okro. More often than not, some of these farmers cultivate other crops such as corn, cassava and coconut on subsistence bases.

Wells are drilled to a depth of about 1-9 m to provide water for irrigation. Buckets and/or watering cans are used to draw water manually from the wells. These buckets of water are sprinkled manually on the vegetable beds two times a day (morning and evening) as a form of irrigation. Where pumps are used, rubber hoses are used for irrigation. In this case pressure is exerted on the open end of the hose with the fingers by way of apparently reducing the diameter. This action mimics rainfall or sprinkler discharges.

Problem Statement. Recent power rationing exercise in the country due to the unavailability of enough water in the Akosombo dam to generate effectively the needed hydro-electric power also affects power supply to the pumps. This situation is a setback on constant supply of water to the crops. A wind speed of 5.8 $m \cdot s^{-1}$ for the critical season in the community can supply the energy needs of 0.25 kJ to the windmill for irrigating the desired areas [8], however the initial cost of setting a wind energy driven pump for irrigation also presents a constraint.

Objectives. The prime objective of this paper is to compare the economic operation of the wind and electric pump (capital/investment and operation costs) of the for vegetable production in the farming communities of the Keta District in the Volta Region of Ghana as a basis for making informed decision on profitable irrigation.

MATERIAL AND METHODS

Relevant parameters on a windmill installed on pilot basis with a distance of 250 m away from the sea to provide power for pumping water from 9 m deep borehole for irrigation was measured as energy source for pumping of water in the area understudy.

Secondary data from the Ghana Energy Foundation [8] indicating that the windmill operates under a pressure of about 20.69 $N \cdot m^{-2}$ and discharges minimum water of about 12 $m^3 \cdot s^{-1}$ during the critical farming season (September/October) was obtained. Water is pumped into 10.91 l storage tank raised 2.7 m above the ground. This quantity of water is used to irrigate 0.5 ha of land everyday by drip system of irrigation. The stored water is discharged directly to the root zone of crops by gravity through the laterals to the emitters which are laid directly beside the crops.

In addition, well structured questionnaire were designed and randomly administered to ten of farmers in the area to solicit responses on their farm land sizes, income generated and the investment involved in using energy sources such wind and electric in pumping water to irrigate their respective farm lands. The data obtained was then subjected to critical cost analysis.

RESULTS AND DISCUSSION

Cost Analysis

The Fig. 1 indicates ten randomly selected farmers with total investment cost / expenditure against the corresponding farm size.

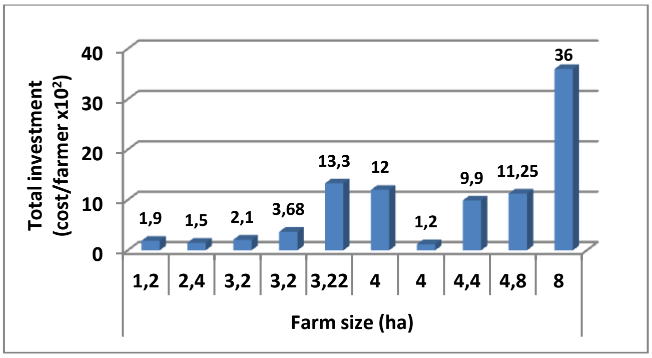

Figure 1. A graph of total investment cost against farm size

From Fig. 1, the larger the farm size, the greater the investment cost. Thus where all conditions seemed equal, a farmer with a farm size of 4 ha is required to invest a total amount of ¢15193.34 whilst a farmer with farm size of 4.4 ha and 8 ha needed to invest a total of ¢22212.7710 and ¢96402.70 respectively. Farm sizes 3.2, 3.22, 4, 4.4 and 4.8 ha showed certain disparities that can be explained. The differences in the total investment cost of the farm sizes are due to unequal initial investment cost invested by the farmers. It can also be attributed to the following: differences in the quantity of electric power consumed; differences in the number of centrifugal pumps purchased. Thus a farmer could purchase one pump which cost ¢260.00 for a sizeable hectares of land where as the other farmer could use three pumps which cost a total of ¢750.00 on a similar farm size. The difference in the number of sprinkler heads and hence the cost of sprinklers.

Cost Analysis of the two Farming Practices as at 2013/2014

From the interviews, farmers who engaged in both the modern sprinkler and drip irrigation farming usually lease a hectare of land for ¢25.00. They are obliged to repay the rent after one year of farming. This implies that farmers who might have engaged more than a hectare of land are indebted to pay proportional amount which corresponds to the acquired farm size. For a farm size of 2 ha, the farmer pays 2 by ¢25.00 per annum (¢50.00). As at July, 2014, a borehole was drilled at a cost of ¢100.00. For a hectare of land, a total of ¢125.00 was spent on purchasing vegetable seedlings. In effect the total capital cost was ¢250.00. A farmer practicing sprinkler irrigation farming system is likely to spend a total of ¢2666.00 as the system cost. In that cost of PVC materials (main pipelines, lateral pipelines and riser pipes) amount to a total of ¢2250.00 per hectare. One rotating impeller sprinkler as at July, 2014 cost ¢12.00. A research interview conducted showed that 13 sprinkler heads operate a hectare of land. A centrifugal pump also cost ¢260.00.

Table 1. Electric powered (sprinkler) technology

Element Data		
A hectare of Land/annum	*Capital cost (¢)*	*25.00*
A Borehole		*100.00*
Vegetable Seedling/ha		*125.00*
Total		*250.00*
Cost of PVC Materials/ha	*System cost (¢)*	
Main Pipe Lines		*1250.00*
Lateral Pipe Lines		*1000.00*
13 Rotating Impeller Sprinkler		*156.00*
A 50mm diameter Centrifugal Pump		*260.00*
Total		*2666.00*
Land Clearing/ha	*Operational cost (¢)*	*50.00*
Labour		
Cost/Person/Hour		*0.6000*
Cost/Person/Month		*100.80*
Cost/Person /Year (for 6 Month)		*604.80*
Repair & Maintenance		
Pump Repairs/year		*200.00*
Well Repairs/year		*25.00*
Cost of Electric Power Consumed		
Pumping Cost/ha/Month		*50.00*
Pumping Cost/ha/Year		*300.00*
Total		*1179.80*
Total Investment Cost		*4095.80*

It is obvious that the same element data are available in both the electric and wind-powered technology. Under the wind powered technology, the total capital cost is also ¢260.00. A total of ¢7473.00 was invested as the system cost under this technology. The system cost included drip materials, 11 m^3 water storage tank and the windmill. The overall cost of the drip materials/ha was ¢3000.00 and that of the water storage tank was ¢1323.00. The windmill was purchased at the total cost of ¢3150.00. This cost included a clearance charge of 2% of the purchasing price of $3500.00 (US).

Table 2. Wind powered (drip) system

Element data		
A hectare of land/annum	*Capital cost (¢)*	*25.00*
A borehole		*100.00*
Vegetable seedling/ha		*125.00*
Total		*250.00*
Drip materials/ha (main & lateral lines, emitters and filters)	*System cost (¢)*	*3000.00*
11 m^3 water storage system		*1323.00*
Windmill		*3150.00*
Total		*7473.00*
Land clearing (pouching)/ha	*Operational cost (¢)*	*50.00*
Windmill installation		*6.00*
Reservoir installation		*100.0*
Labour		
Cost/person/hour		*6000.00*
Cost/person/month		*100.80*
Cost/person /year (for 6 months)		*604.80*
Repair & maintenance		
Pump repairs/year		*0*
Well repairs		*25.00*
Cost of electric power consumed		
Pumping cost/acre/month		*0*
Pumping cost/acre/year		*0*
Total		*839.80*
Total Investment Cost		*8562.80*

The operation cost of the windmill system encompassed the following elements: land clearing (plowing), windmill installation, reservoir installation, labor and repair and maintenance cost. Labor cost included the expenditure on a laborer per working season (6 months) per year. Repair and maintenance included borehole repairs. Only a small or no amount of money may be spent on the repair of the windmill. From Tab. 2, cost of land clearing (plowing) per hectare, windmill installation and reservoir installation are shown. Total cost of labor per working season (6 months) per year is ¢604.80. The overall cost of operations of this system of farming was ¢839.80. The total investment cost of the wind powered (drip) technology was ¢8562.80.

Assessment of the Financial Performance of Farmers

Profitability ratio is used to critically assess the performance of most farmers who are involved in using the electric power for irrigation compared the wind powered (windmill) technology. The Fig.2 is a graphical representation of the financial performance of farmers against the corresponding farm size in hectares cultivated.

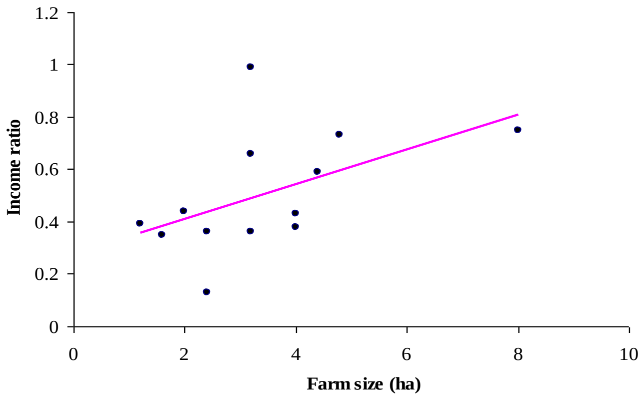

Figure 2. A graph of income ratio against farm size

Fig. 2 illustrates the relationship between the income ratio and the farm size. An indication of correlation coefficient, r = 0.503 proved that there is a strong positive relationship between the income ratio and the farm size. Correlation coefficient, r, also known as Pearson product moment correlation coefficient (PPMC) from a sample data is the measure of the strength and direction of a linear relationship between two variables [8]. From Fig. 2, a larger farm size correlate with a larger income ratio. The income ration 0.38, 0.35, 0.44, 0.99, 0.63, 0.39, 0.75, 0.59, 0.73, 0.66 and 0.43 clearly presupposed that there is significant amount of income generated per farm size.

Table 3. Demonstration of the relationship between income ratio and farm size

Farm size, F (ha)	*Income ratio, IR*	*FIR*	F^2	IR^2
4	0.38	1.52	16	0.1444
1.6	0.35	0.56	2.56	0.1225
2	0.44	0.88	4	0.1936
3.2	0.99	3.168	10.24	0.9801
3.2	0.63	2.016	10.24	0.3969
2.4	0.13	0.312	5.76	0.0169
1.2	0.39	0.468	1.44	0.1521
8	0.75	6	64	0.5625
4.4	0.59	2.596	19.36	0.3481
4.8	0.73	3.504	23.04	0.5329
3.2	0.66	2.112	10.24	0.4356
4	0.43	1.72	16	0.1849
2.4	0.36	0.864	5.76	0.1296
$\sum F=44.4$	$\sum IR= 6.83$	$\sum FIR= 25.72$	$\sum F^2= 188.64$	$\sum IR^2= 4.2001$

Unlike the electric pump, the wind pump has a life span of 30 – 50 years. One wind pump can be used efficiently and effectively for several years to serve not less than 5 ha of farmland. In this regard farmers who engaged the use of wind pump would not have to border their heads on the purchase of more wind pump every farming season. The purchase, installation and repairs of water storage reservoirs, the drip materials and cost of drilling boreholes are non-perennial/non-seasonal practices since the already purchased and installed items can serve their purpose for several years. Elements such as the wind pump and the water storage reservoir have their service life longer than 5 years compared to the electric powered system where the life span of the centrifugal pump is not more than 5 years. A non-consideration of the fixed system costs (drip materials, windmill, water storage tank and installations) would bring the total investment cost of the wind powered system considerably down from ¢8562.80 to ¢929.80 as indicated on the Tab. 4.

The correlation coefficient, r is calculated as follows:

$$r=\frac{n\left(\sum FIR\right)-\left(\sum F\right)\left(\sum IR\right)}{\sqrt{\left[n\left(\sum F^{2}\right)-\left(\sum F\right)^{2}\right]\left[n\left(\sum IR^{2}\right)-\left(\sum IR\right)^{2}\right]}}$$

$$=\frac{13(25.72)-(44.4)(6.83)}{\sqrt{\left[13(188.64)-(44.4)^{2}\right]\left[13(4.2001)-(6.83)^{2}\right]}} \qquad (1)$$

$$=\frac{31.108}{61.8449}$$

$$\therefore r=\underline{\underline{0.503}}$$

Table 4. Subsequent seasonal cost analysis of the wind powered system

Element data		
A hectare of land/annum	*Capital cost (¢)*	*25.00*
A borehole		*100.00*
Vegetable seedling/ha		*125.00*
Total		*250.00*
Drip materials/ha (main & lateral lines, emitters and filters)	*System cost (¢)*	*0.00*
11 m^3 water storage system		*0.00*
Windmill		*0.00*
Total		*0.00*
Land clearing (pouching)/ha	*Operational cost (¢)*	*50.00*
Windmill installation		*0.00*
Reservoir installation		*0.00*
Labour		
Cost/person/hour		*0.60*
Cost/person/month		*100.80*
Cost/person /year (for 6 months)		*604.80*
Repair & maintenance		
Pump repairs/year		*0.00*
Well repairs		*25.00*
Cost of electric power consumed		
Pumping cost/acre/month		*0.00*
Pumping cost/acre/year		*0.00*
Total		*679.80*
Total Investment Cost		*929.80*

A difference of about ¢3166 is saved compared to the practice of the electric powered technology.

Studies show that the Poldaw windmill locally manufactured in Ghana by MoFA could be purchased at the cost of ¢5000 [6]. This seemed a huge expense for a single farmer to bear. In a more reasonable and economically strategic way, co-operative groups could be formed by the local farmers in a group of ten for instance. These co-operative groups could purchase the windmill by way of individual contributions, accessing bank loans, or by any other governmental or nongovernmental assisted funds to that effect.

CONCLUSIONS

Although the electrically powered system has gained ground in the communities, many farmers are unable to use the technology. Some of the problems they face are the high cost of electric power consumptions, instability of the system as a result of the on-going intensive power rationing exercise and the short service life of the centrifugal pumps (2 to 5 years). In general, the relatively high investment cost deters most farmers from fully embracing the practice.

Recommendations. The high system cost (GH¢7473) of the windmill technology seemed to prevent most farmers from considering the wind as an alternative source of energy for vegetable production. To overcome this fear, it is recommended that farmers form co-operative societies, so they can purchase the locally manufactured Poldaw wind pump at a current cost of ¢5000. For economic and agronomic reasons, the system of irrigation which reduces strain on the part of farmers and moreover, boosts the income generation of both the farmers and the manufacturers of the irrigation materials is the wind powered technology. This technology is also environmentally friendly.

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UPOREDNE PERFORMANSE PUMPI ZA NAVODNJAVANJE NA ELEKTRIČNI I VETRO POGON

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Sažetak: Tehnologija energije vetra može da postane najbolja alternativa hidro električnom pogonu pumpi za navodnjavanje određenih delova Gane tokom sušne sezone. Ovaj rad se bavi ocenom performansi pumpi sa vetro i električnim pogonom kroz ogled u kome se uporedno ispituju investicioni troškovi rada pumpnih sistema sa ova dva pogona u oblasti Keta, koji ima najbolje režime vetra u Gani. Farmeri u ovim obalnim zajednicama su pokušali upotrebu vetro-pogona za vodene pumpe, ali sa velikim inicijalnim troškovima. Uprkos visokim troškovima, farmer mogu da osnuju kooperative da bi pokrenuli system pumpi sa vetro-pogonom. Visoka cena električne energije koju plaćaju svakog meseca odvraća većinu farmera od upotrebe hidro-električne tehnologije za pumpanje. Ukupna investicija kod farmera koji su koristili elektro pogon je iznosila ¢4095.80 po hektaru, dok je kod farmera koji su koristili vetro pogon u svakoj sezoni investicija iznosila ¢929.80 po hektaru. Razlika od ¢3166.00 se može uštedeti i upotrebiti za druge namene.

Ključne reči*: vetar, električna struja, pumpe, navodnjavanje, energija, performanse*

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