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Optimum Crop Productivity in Rain Fed Area of Thana Boula Khan, Sindh, by Application of Wind Energy

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ABSTRACT
The energy and food security are crisis at global level. Various sources for generating energy are under exploitation but except of renewable energy are almost costly. Hence, proper exploration and exploitation renewable energy is cheaper in comparison of fossil fuels source. In this connection, wind energy source mostly is available in the southern region of Sindh province of Pakistan. Renewable energy and agricultural farming are a winning combination. Wind, solar, and biomass energy can be harvested forever, providing farmers with a long-term source of income. The net farm returns can significantly be enhanced if available stronger winds are effectively utilized as an alternative energy resource. The project has successfully been introduced by locally manufactured windmill driven pumping units. The wind speed probability analysis based upon limited data availability indicated that during almost 92% of operational time, a wind speed of 2.5 m/s (9 km/hr) or more was available in project area. The operational analysis of windmill during 2007 indicated average 9.38 liter/min discharge was extracted, with role of 95.5 m^3 of water was pumped in Kharif season, which is sufficient to irrigate 0.096 hectare of land through surface irrigation method by maintaining 10 cm depth of applied water. However, modern and efficient irrigation methods like drip and sprinkler be employed alongside windmill introduction for getting optimum agricultural productivity.
***Keywords* -** Crop productivity, Renewable energy, Windmill, T. B. Khan, Micro Irrigation system

I. INTRODUCTION

The global economy has brought nations to the world of advancement associated with a mass destruction to the environment. The continuing rise of recession, inflation, financial crisis, energy crisis, stock market downfall and private industry depletion causes the main stream to react accordingly. The uprising demand of oil affects most home owners even the smallest unit of the family in terms of their electricity consumption. The on growing awareness about environmental concerns uplifts the use of renewable energy for making those economic problems more manageable [1].

Renewable energy for farming includes generation of power to do a number of farm tasks: pumping water for irrigation, livestock and for domestic use; lighting farm buildings; powering processing operations and others.

The forms of renewable energy include solar energy, wind and water power, oil from plants, wood from sustainable sources, other forms of biomass (plant material), and biogas (gas produced from fermentation of manure and crop residues [2].

Today, three energy inputs (diesel fuel, fertilizer, and electricity) account for more than three-quarters of farm energy use [3]. The limited source of fossil fuels is not last beyond the human existence. Almost all the technologically advanced countries use renewable energy especially the wind energy to help minimize the mass production of pollution that mainly causes the world to warm. Fossil fuels reserve is very limited for use during a period of years. In addition of, the oils is one of the most expensive of country's budget. This perhaps, led nation to actively explore renewable energy sources [4].

Several European countries are successfully accommodating significantly higher shares of wind energy in to their networks and that the Japanese grid is capable of coping with large conventional power stations disconnecting unexpectedly due to faults; on the other hand, it is true that integrating wind power or unreliable conventional power stations in to island grids is more difficult than into continent-wide inter-connected grids. In Bangladesh, only 30% population has access to electricity, while the share of traditional energy including wind energy is about 60% [5].

Farmers are in a unique position to benefit from the growth in the wind industry. To tap this market, farmers can use the wind to generate power for their farms, or become wind power producers themselves. Farmers can generate their own power from the wind. Small wind generators, ranging from 400 watts to 40 kilowatts or more, can meet the needs of an entire farm or can be targeted to specific applications. In agricultural systems, energy is available from different sources as human, animal, sun, wind, biomass, coal, fertilizer, seed, agro-chemicals, petroleum products, electricity etc. Energy sources that release available energy directly to the system are classified as direct energy sources [6].

The small wind turbine (see Plate 1) industry estimates that 60 percent of the United States has enough wind resources for small turbine use, and 24 percent of the population lives in rural areas where zoning permits installation. The economic efficiency of wind energy, agricultural producers are likely to increase their use of wind power to lower energy costs and become more energy self-sufficient [7]. Windmills do not produce harmful environmental emissions [8]

In several developing countries, irrigation represents up to 95% of all water uses, and plays a major role in food production and food security. Future agricultural development strategies of most of these countries depend on the possibility to maintain, improve and expand irrigated agriculture [2].

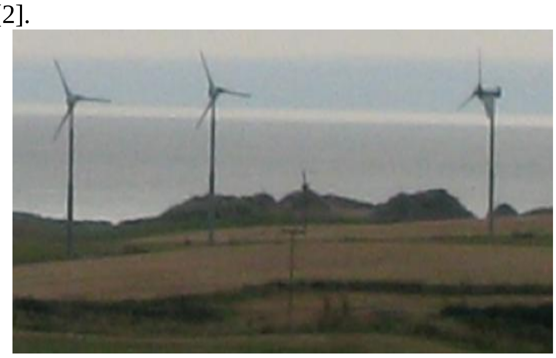

Plate 1: Windmill Turbines

Pakistan decided to develop wind power energy sources due to problems supplying energy to the southern coastal regions of Sindh and Balochistan, the project was undertaken with assistance from the Government of China. Another area with potential is Swat which shows good wind conditions for wind power investment [5]. There is significant potential for agricultural involvement in the production and consumption of solar, biomass and wind energy. Renewable sources are quite abundant throughout Pakistan.

In agriculture, an energy supply disruption of even a short duration could mean a substantial reduction or the complete loss of an entire growing season [9]

Renewable energy can address many concerns related to fossil energy use. It produces little or no environmental emissions and does not rely on imported fuels. Renewable resources are not finite (as fossil fuels are) and many are available in country. Price competitive has been a concern, but costs have decreased significantly since the initial wave of interest in renewable energy [8].

As the capital cost is not strongly dependent on wind speed, the sensitivity of the project economics to wind speed is clear. The sensitivity of energy yield to wind speed variation varies with the wind speed [10].

Renewable source of energy are estimated to meet between 15 to 20% of current final world energy consumption, predominantly from hydro-power, fuel wood, biomass and geothermal [11]. Scenario analyses by Shell, which assume pressure towards sustainability, show renewable meeting around 40% of world energy needs by the middle of the century [12]. This prognosis is based on the reducing role for fossil fuels as they become scarcer, the need to contain fossil fuels use because of their emissions and the need to reduce their impact on climate change.

II. STUDY AREA

The windmill project was introduced in Thana Bolua Khan (T. B. Khan) area which is a spate irrigated located in Jamshoro district of Sindh Province (see Fig. 1). Climatologically, area has been characterized as arid to hyper arid with mean annual rainfall of around 100 mm in Southwest to 300 mm in Northwest.

Fig.1 Study Area at Thana Bola Khan of District Jamshoro, Sindh, Pakistan

The annual evapo-transpiration rates in area are confined between ranges of 1800-2000 mm which is far greater than mean annual rainfall. Therefore, necessitates the requirement of irrigation to sustain agricultural activities in area. The soils in areas are generally light textured and ranges from sandy loam to pure sandy soils and therefore having higher infiltration rates with lesser moisture holding capacities. Another important feature of this area is that strong winds are available during most of time in a year [13].

The agricultural activities are stretched over an area of about 1600 sq km. The major crops grown in area include onion, wheat, seasonal vegetables, cotton and fodder crops like berseem and millet including sunflower, which is a successful low delta crop. Most of the irrigation requirements are being met through the diversion of spate flows which are generally available only during the monsoon period and consequently reliability of water availability throughout the cropping year is a big issue [14].

To address the issues of fuel cost hike and associated implications on agricultural productivities in the research area. In order to exploit the available stronger winds as an alternative energy resource to lift water from dug wells. Hence, locally manufactured low capacity windmill has been installed at one selected dug well of the project area and water was pumped successfully with zero operational cost.

III. MATERIAL AND METHODS

A dug well having diameter of 5.2 m has been selected. The groundwater is at about 29m from ground surface. The static water level in dug well was at 22 m from ground surface having a net water column of 7 m available for pumpage. The specifications of installed windmill at Thana Bola Khan, district Jamshoro, Sindh, Pakistan, are summarized in Table 1. The windmill installed at Thana Boula Khan is in operation (see Plate 2).

Table 1: Specifications of Local Manufactured Windmill Installed at Thana Boula Khan

S. No.	Component Name	Specifications
1.	Rotor Dia.	3.5 m
2.	Blades	12 (No)
3.	Blade Length	1.22 m
4.	Blade Thickness	20.00 cm
5	Tower Height	9.45 m
6	Suction Pipe Length	33.84 m
7	Delivery Pipe Length	8.54 m
8	Pipe Dia.	5.1 cm
9	Length of Pump Rod	38.72 m
10	Tail Length	3.7 m

3.1 WINDMILL OPERATIONAL ANALYSIS

Data has been observed regarding the daily operation of the windmill. The volume of water collected in the storage tank was observed. Once the tank was filled, water was discharged by gravity through pipe flow and surface ditch to irrigate the farm field for a depth of 10 cm (normal local practice of surface irrigation). The cultivated crop in the area is showing through Plate 3.

Plate 2: Windmill pumping out water for an Agricultural land at T.B Khan

Plate 3: Crop area cultivated in project area

The operation of the windmill was monitored throughout the study year of 2007. Monthly wind speed was measured by digital anemometer. ,

IV. RESULTS AND DISCUSSIONS

The windmill was averagely operated for 8 hours per day and pumped water in initially stored in an overhead tank having total storage capacity of 8.85 m^3 (L= 2.84 m, B = 1.52 m and D = 2.04 m). The corresponding discharge of windmill is presented as Table 2.

Collected data show a seasonal variation in wind speed. The stronger wind speeds (more than 3 m/s) was observed during almost summer season stretching from March to September but low wind trends was observed during June and December (average monthly speed of 2.50 m/s and 2.65 m/s respectively). While during almost entire winter period (November to February), relatively weaker wind speeds (below 2.8 m/s) were recorded, except for the month of January when average monthly wind speed was 3.05 m/s. However, operational period of windmill was resulted, the monthly mean wind speed was 3.03 m/s and corresponding mean discharge comes 9.38 liter/ min during year 2007.

Table 2: Wind Speed and Discharge of Windmill at Thana Boula Khan during year 2007

Month	Monthly Wind Velocity (m/sec)			Mean Discharge (l/min)
	Min.	Max.	Average	
January	2.59	3.50	3.05	9.67
February	1.86	3.70	2.78	10.35
March	2.56	3.47	3.02	5.70
April	4. 24	4. 70	4.47	12.13
May	2.53	3.79	3.16	10.35
June	1.35	3.65	2.50	10.14
July	2.90	3.20	3.05	7.48
August	1.76	4.40	3.08	11.60
September	2.50	3.20	2.85	8.50
October	Windmill was closed due to repair requirements			
November	1.76	3.68	2.72	9.58
December	1.93	3.36	2.65	7.67
Monthly Mean			3.03	9.38

Based on data collected; probability of Exceedance through plotting Wind Speed Flow Duration Curve (WSFDC) of the times during 2007 comes 91.67% (see Fig. 2), wind speed either equal to or greater than 2.5 m/ s was recorded. Therefore, velocity of 2.5 m/s seems to be the potential wind speed that can be utilized as an alternative energy resource to pump groundwater from dug well.

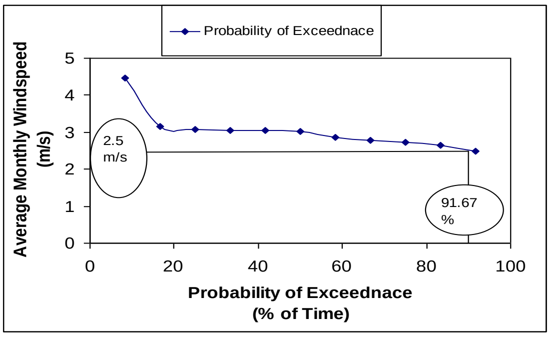

Figure 2: Monthly Wind Speed Flow Duration Curve at Thana Boula Khan Project Area

The WSFDC was plotted using limited monthly average wind speed data. If wind speed data is available for longer time periods, this probability analysis can certainly be helpful in proper designing of the windmill so that optimum yield can be ensured during most of the time in any given operational year. In this paper, the windmill is selected for 2.5 m/s wind speed that is mostly available data in the project area.

The Figure 3 demonstrates the windmill output (i.e. discharge) which did not exhibit linearly growth with increasing in wind speed. To variation in both data sets is almost matching i.e. significantly except for February, June, July and November.

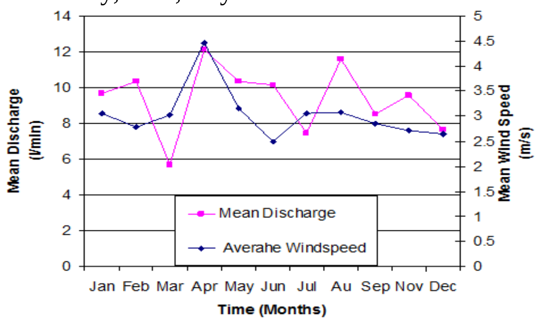

Figure 3: Relationship of Average Monthly Wind Speed and Windmill Mean discharge for various Months at Thana Boula Khan

The wind speed is not the only factor which governs the discharge from dug well. The water levels available in dug well before pumping and water level fluctuations during windmill operation (which in turn depends upon aquifer yields and are very low in these areas) have also impact on windmill discharge.

If the initial water level in dug well was deeper, no matter what wind speed was available at surface, the discharge would be smaller and vice versa. Ideally to validate this hypothesis, additional analysis of water table fluctuation, wind speed and windmill discharge is required. However, since water table fluctuation data was missing, so it is perceived that reduced discharges against stronger winds might be due to lower water levels in the dug well which produced many ideal strokes. The reduced water levels in dug well may be attributed to the fact that same dug well is also fitted with a diesel operated centrifugal pump having much greater discharge capacity than windmill. So when farmer operate this pump first, the water levels in dug well reduces and subsequent windmill operation will produced smaller discharges regardless of surface wind speeds.

3.2 WINDMILL IRRIGATED AREAS

As described earlier that windmill was operated for 8 hours and pumped water was first stored in an overhead tank. The operational analysis of the windmill indicated that averagely 9.38 l/min discharge was extracted from the dug well and about 2 days were required to fill that overhead storage tank. From this filled reservoir, irrigation was made i.e. applying depth of 10 cm (local practice for surface irrigation method) over the area.

The monthly windmill operational days, extracted volumes of water and corresponding irrigated area have been computed for summer crop season i.e. Kharif (see Table 2).

Table 2 Windmill Extracted Monthly Volumes of Water and Irrigated areas

Month	Operational Days	Total Volume Pumped (m^3)	Depth (cm)	Irrigated Area (ha)
April	19	110.6	10	0.1106
May	15	75.48	10	0.0755
June	19	92.5	10	0.0925
July	17	61	10	0.0610
Aug.	13	72.48	10	0.0724
Sept.	16	65.28	10	0.0652
Total volume		95.47	Aver. area	0.0955

From above Table, average volume of water of 95.47 m^3 was extracted from the dug well through Windmill energy resource. This pumped water can irrigate an area of 0.0955 hectares (0.236 acres) of land with 10 cm water depth during average month in the summer season (Kharif). The monthly windmill pumped water and corresponding irrigated area for is shown in Figure 4.

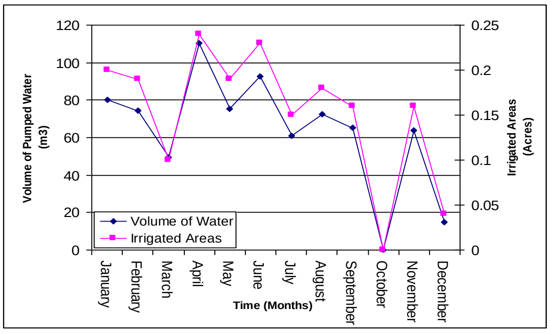

Figure 4: Monthly Windmill Pumped Water and Corresponding Irrigated Areas

The observed data also show that maximum volume of water was extracted in April which is 110.6 m^3 and corresponding extent of irrigated area was 0.1106 ha (0.27 acres).

The above Figure show that in winter season, volume of water the wind speed is less; hence the volume of water pumped out is less as compared to that of summer season. It is also the fact that during winter season, the consumptive use i.e. evapo-transpiration requirement for the crop is also less in these days. Hence there is no negative impact of wind speed in summer season.

3.3 Economic Analysis

The same dug well is used through fitting and diesel operated centrifugal pump can extract discharge of 0.5 cusecs. The fuel consumption of diesel pump was measured i.e. 1.76 liters per hour. To irrigate one acre of land through diesel pump, it requires 8.07 hours of operation; hence net fuel consumption of 14.2 liters are needed to irrigate one acre of land. At present, the cost of diesel is at the rate of Rs.110/= per liter. Keeping in view the increasing the cost of diesel engine, the cost of one irrigation in present value terms, it comes Rs.1562.35. If an average 6 irrigations are applied to grow crop on one acre field using diesel pump, the cost of irrigation would be about Rs. 9375/=. If the same field is irrigated using renewable energy resource like wind, at least this much amount is saved per acre. The reduced fuel consumption will not only increase the net farm returns, but will also contribute towards climate change stabilization due to reduced greenhouse gas emissions. As per summary in Thana Boula Khan area there are total 25 dug wells in the project area and if other farmers can also install windmill driven pumping units of sufficient capacity so as averagely 6 acres are irrigated, the worth of economic saving during one crop growing season having 6 irrigations would be Rs.56,250/= which is quite significant.

It is also to mention here that this wind speed is calculated at 13 to 19 optimum working days per month with only 8 hours per day. Keeping the same optimum working days and increasing operational hours from 8 to 24 hours, then three times land can be cultivated and above amount can be increased three times i.e. Rs.168,750/= with irrigating 18 acres (i.e. 7.29 hectares) of land.

V. Conclusions

From above analysis, following conclusions are made:

The wind speed probability analysis, based on present data indicates almost 92% of operational time, a wind speed of 2.5 m/s or higher available in project area.

The operational analysis of windmill during entire year of 2007 indicated an average 9.38 liter/min discharge was extracted, while 69 m^3 of water was averagely pumped which was sufficient to irrigate 0.17 acres of land through surface irrigation method by maintaining 10 cm water depth.

Based upon optimum windmill designs, i.e. if all 25 dug wells are running over this optimal design i.e. each can irrigate 3 acres of land with 5 or 6 irrigations during a crop growing season. Hence a net saving of Rs.168,750/= can be achieved which is quite significant for a poor resource base community.

If modern and efficient irrigation methods, like drip and sprinkler are common in these areas which can be used to increase agricultural productivity.

The successful demonstration of renewable energy resource has opened new era by both private and public sector to harness this potential on larger and better planned manner. This will certainly help in alleviating poverty in the most ignored areas viz. rain-fed areas by improving their social status.

VI. Acknowledgements

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