Mausam, (1990). **41**, 4, 621-626

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Wind power utilization in semi-arid regions

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(*Received 12 September 1989*)

सार — दक्षिण पठार क्षेत्र में बेलारी के पवन आंकड़ों के विश्लेषण से यह 5 मीटर रोटार व्यास की पवन चक्की द्वारा प्रतिवर्ष 93127 घन मी० के प्रसंभाव्य निर्गम का पता चला। यह निर्गम जल के 21533, 25610 और 21663 घन मीटर निर्गम के साथ जून, जुलाई में और उसके बाद जल के 8593 और 9193 घन मीटर निर्गम के साथ क्रमश: मई और सितम्बर के दौरान अधिकतम होता है। खरीफ और ग्रीष्म ऋतु मे फसलों की सिचाई के लिए पवन चक्की का प्रयोग मोटर चालित पम्पों के स्थान पर किया जा सकता है और रबी मौसम में पवनचक्की का प्रयोग जल की सीमित मात्रा की आवश्यकता वाले फलोद्यान को जल देने के लिए किया जा सकता है जिसमें क्योंकि नवम्बर से फरवरी तक के महीनों में जल का निर्गम 1000 घन मीटर होगा। पवन चक्कियों का प्रयोग, नहरों के सिरे पर स्थित क्षेत्रों में सिचाई के लिए और पठार को कम करने के लिए जल निकास के जल को बाहर निकालने के लिए, करने पर भी विचार-विमर्श किया गया।

ABSTRACT. Analysis of wind data of Bellary, in the Deccan Plateau region, revealed a probable output of 93127 cu. m water per year by a wind mill of 5 m rotor diameter. The output is maximum during June-August with 21533, 25610 and 21653 cu. m of water followed by May and September with 8593 and 9193 cu. m of water respectively. The wind mill can replace motor driven pumps for irrigating crops in the *kharif* and summer seasons and in *rabi* season wind mill can be used for watering orchards requiring limited quantity of water, as the output of water would be 1000 cu. m per month from November to February. The use of wind mills for irrigation in the tail-end areas of canals and for pumping out drainage water to reduce the water table is also discussed.

1. Introduction

The operation of pumpsets for agricultural purposes with conventional energy sources, like diesel and petrol is becoming more and more uneconomical due continuous price hike in petroleum products. On the other hand, the use of hydro-electric power is becoming undependable due to either recurrent failures of monsoon or non-availability of sufficient storage in the reservoirs due to reduction in the storage capacity consequent to siltation (Dhruvanarayana and Ram Babu 1983) coupled with unscientific irrigation practices. As a result, the current interest in the field of energy development shifted to utilisation of natural resources like solar radiation and wind power. The possibility of using wind mills for water lifting as on alternative to engine driven pumps is receiving considerable attention. Srivastava *et al.* (1981), (Anonymous 1976) reported that wind mills can be successfully run in areas having wind speed ranging from 5 to 20 km/hr with a 5 m rotor diameter and a water head of 6 m. Van Veldhuizen (1981) reviewed the efficiency of different types of wind mills as water lifting devices for small scale irrigation and observed that a minimum wind speed of 9.0 km/hr is required for economic viability of wind mills for irrigation in agriculture. The wind mills manufactured in India by the Community Polytechnic Institute (Anonymous 1985) have been found to be successfully working at a wind speed of 7 km/hr.

After the 1973 oil crisis, India along with other countries like USA, Australia, Japan, Britain, New Zealand and France concentrated on design and development of wind mills for different uses both under public & private sectors.

The wind energy farm established at Mullaikadu in Tamil Nadu by the Dept. of Non-Conventional Energy Source in collaboration with Tamil Nadu Electricity Board proved its feasibility by adding 8.53 lakh units of power into the grid during 1st year, comprising its cost effectiveness favourably with new hydel schemes. A minimum wind speed of 4 m/sec was reported to be necessary to activate the generator, below which the rotor blades do not rotate (Anonymous 1987).

Sherman's Madurai wind mill adopted after Cretan sail wind mill with a 10 m rotor diameter, designed to operate in low velocities (8 km/hr) is reported to be capable of producing 0.8 kwh/day. Savonias rotor type developed by Indian Institute of Science, Bangalore in 1977 is capable of delivering 2500 litre of water every day. The 'Banyans' wind mill erected on a 8 m tower could pump on an average 10 cu. m water daily from a depth of 27 m with an average wind speed of 6 to 8 km/hr while the APOLY-12 PH 500 water pumping wind mill developed by Institute of Engineering & Rural Technology, Allahabad has a cut in speed of 2.5 m/s (Jagadeesh 1988).

TABLE 1

Average values of climatic parameters, estimated wind mill output and water deficit for different months

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	1.2	1.4	4.8	21.1	49.7	55.9	37.2	53.0	120.5	92.5	32.1	8.4	
Max. Temperature (°C)	29.6	32.9	36.7	37.9	37.9	34.4	33.2	32.1	32.4	32.2	30.6	29.6	
Wind velocity (km/hr)	6.1	7.8	7.8	8.8	14.2	20.2	21.1	20.6	15.0	7.8	7.7	5.6	
Pan evaporation (mm/day)	6.3	8.2	10.7	11.4	12.5	10.6	8.9	8.7	8.0	7.0	5.6	5.6	
Pan evaporation (m^3/month)	18	24	33	36	39	33	27	27	24	21	18	18	
Wind mill output (m^3)	421	758	987	1732	8593	21533	25610	21663	9193	1593	699	345	93127
Net output after the evaporation loss (m^3)	403	734	954	1696	8554	21500	25583	21636	9169	1572	681	327	92809
Monthwise water deficits (mm)	100	119	154	157	161	139	121	123	43	70	70	93	

*The monthly evaporation losses have been calculated, based on the daily values (mm/day) of an assumed tank surface of 100 m^2

Generalising the above, it can be stated that wind mills can successfully be run in areas where wind speeds vary from 5 to 20 km/hr for lifting water having water heads 6 to 30 m. It is, therefore, essential to know the wind speeds and their duration across the year, in relation to water availability and evaporation rates for developing an effective irrigation system before popularising their use in a given area. Hence a study was taken up to analyse wind speeds along with other related climatological parameters which influence the use of wind mills at Bellary representing the semi-arid region and is presented in this paper.

2. Materials and method

The data reported in this paper are collected from the meteorological observatory of Soil Conservation Research Farm, Central Soil & Water Conservation Research & Training Institute, Research Centre, Bellary for the period 1956-85. The firm is located at a latitude of 15°09′N longitude of 76°51′E and 445 m above mean sea level. The weather conditions recorded at the farm is representative of the region comprising of Anantapur, Kurnool & Cuddapah districts of A.P. Bellary, Raichur & Bijapur districts of Karnataka and Sholapur and Ahmednagar districts of Maharashtra and classified as arid to semi-arid. The similarity with respect to wind and its velocity, temperatures—maximum and minimum, sunshine hours and evaporation and humidity is maximum while the rainfall varies from 500 to 700 mm in the region. Hence, data collected on the above parameters for the years from 1956 to 1985 was subjected to analyse to assess the wind potential for establishing wind mills, evaporation rates for determining storage efficiency in surface tanks and the feasibility of wind mills for agricultural purposes.

3. Wind analysis

The average wind velocities recorded daily at 0730 IST by using the anemometer were used to calculate the average wind velocity for a given month. The water output by the wind mill of a given rotor diameter has been calculated using the formula used by Van Veldhuizen (1981), *viz.*, :

$Q = P/P_w gH$ where, $P = 0.1\ \bar{V}^3 A$

where, Q — Water output in m^3/sec,

P — Wind mill power in watts,

P_w — Density of water in kg/m^3,

g — Acceleration due to gravity m/sec^2,

H — The total head in m,

$\bar{V}$ — Average wind velocity in m/sec,

A — Area of the rotor in m^2,

The above formula can be written as :

$Q = \dfrac{P}{9800\,H}$ m^3/sec by substituting the values of P_w as 1000 and g as 9.8.

Converting Q to litre/hr

$$Q = \frac{P}{9800\ H} \times 1000 \times 3600 = 367.3\ \frac{P}{H}$$

But, $P = 0.1\ \bar{V}^3 A$ where $\bar{V}$ is m/sec

$= 0.1\ (0.278\ \bar{V})^3 A$

$= 0.002148\ \bar{V}^3 A$ where $\bar{V}$ is km/hr

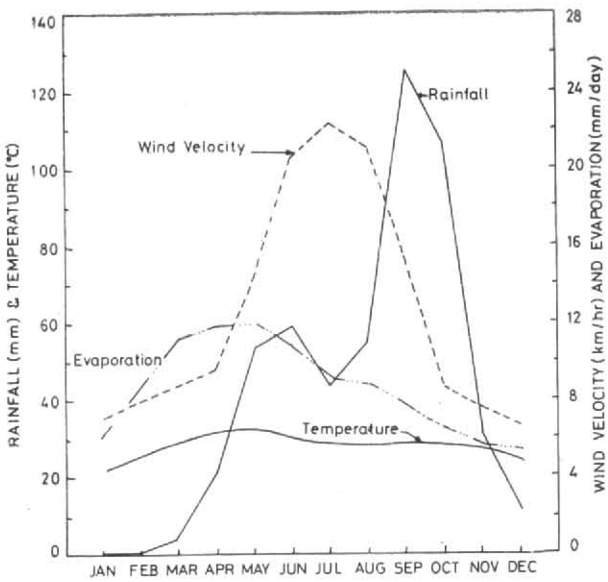

Fig. 1. Monthly mean values of rainfall, wind velocity, evaporation and temperature

By substituting the value of P in the equation

$$Q = 367.3 \frac{P}{H}$$

$$Q = 367.3 \times \frac{0.002148\ \bar{V}^3\ A}{H} \quad \text{litre/hr.}$$

Using the above formula, discharge for different months was calculated. Assuming a rotor diameter of 5 m and a water head of 6 m the formula becomes :

$Q=2.583\ \bar{V}^3$ litre/hr or $0.002583\ \bar{V}^3$ m³/hr.

4. Water deficit analysis

Using the estimated potential evaportranspiration (PE) data, water balance was calculated by the modified Thornthwaite water balance technique and the estimated average monthwise water deficits are calculated and presented in Table 1.

5. Results and discussions

The values of different weather parameters as recorded at the research farm are presented in Table 1 and Fig. 1. From the observed values it could be seen that the average monthly rainfall from May to October is more than 50 mm except for the month of July and this period could be considered for cropping depending upon the soil conditions. The evaporation rates are very high from March to June (beyond 10.0 mm per day) and is least during November to January (5 to 6 mm per day). There is no appreciable variation in the average temperatures from March to December from the crop growth point of view. Thus, there is no distinct *kharif* & *rabi* in the region and the area falls under *kharif-rabi* continuum. However, temperatures are high causing high evaporation from March to June. In general, the wind velocities are high, the least being 6.0 kmph during December and January and high velocities of 14 km or more per hour are recorded from May to September. These high velocities of wind suggest the feasibility of wind mills in the tract as the cut off speed for agricultural purposes is found to be 5 kmph with reference to some designs available from Columbia (Jagadeesh 1988) and 7 kmph with 12-PU-350 and 12-PU-500 wind mills (Anonymous 1985).

The number of hours of wind velocities greater than 10 kmph in different months are calculated by adding up the number of days under each year when the wind velocity was more than 10, 11, 12,..........kmph and dividing the same by the number of years for which the data is considered and multiplying the average by 24. For example, for October there were total 59 days in 28 years when the average wind velocity was 10 km or on an average there were 2.11 days or when multiplied by 24, there would be 51 number of hours when the wind would be blowing at 10 kmph. Similarly there were 56, 21, 17,........hours during October when wind speeds were 11, 12, 13, 14,......kmph.

The lowest wind speed of 5.6 km/hr was observed for the month of December followed by 6.1 km/hr for the month of January. According to Jagadeesh (1988), certain wind mills specifically designed in Columbia and costing only Rs. 10,000/- would operate to 5.0 km/hr. The average wind velocities for the months of February, March, April, October and November vary between 7 and 9 km/hr. 'Banyans' wind mill erected at Auroville, Pondicherry on 8 m tower pumping on an average, 10 cu. m of water daily from a depth of 27 m at average wind speeds of 6 to 8 km/hr suggests the feasibility of wind mills in the tract. The average wind speed during May to September vary from 14 to 21 km/hr when high quantities of water can be pumped either from open wells or bore wells or tanks using wind mills.

TABLE 2

No. of hours in each month with different wind speeds and the estimated water output with wind mill of 5 m rotor dia and 6 m head

Wind velocity (km/h)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
10	23	60	65	75	54	8	3	9	22	51	41	28	
11	43	59	63	78	60	13	7	11	36	56	35	17	
12	17	26	33	57	40	10	12	10	42	20	26	15	
13	4	14	20	34	65	16	12	10	33	21	10	8	
14	6	14	22	32	47	17	11	15	28	17	10	5	
15	—	7	7	22	44	28	15	27	42	8	6	3	
16	3	3	6	10	35	30	20	27	37	5	4	—	
17	2	1	2	7	35	37	32	31	45	12	3	1	
18	1	—	—	7	35	30	39	45	45	7	—	—	
19	—	—	2	2	34	40	45	44	38	5	1	—	
20	—	—	—	2	33	64	69	60	49	1	—	—	
21	—	—	—	—	27	52	46	57	24	3	1	—	
22	—	—	—	1	18	59	51	59	27	3	2	1	
23	—	—	—	—	19	50	49	45	20	1	—	—	
24	—	—	—	—	20	45	48	43	21	1	—	—	
25	—	—	—	—	13	63	57	56	14	3	—	—	
26	—	—	—	—	5	22	41	37	7	—	—	—	
27	—	—	—	—	4	26	43	32	9	1	—	—	
28	—	—	—	—	3	24	27	30	4	1	—	—	
29	—	—	—	—	3	17	32	18	5	—	—	—	
30	—	—	—	—	2	19	27	15	—	—	—	—	
31	—	—	—	—	2	13	10	9	—	—	—	—	
32	—	—	—	—	1	11	15	8	2	—	—	—	
33	—	—	—	—	1	1	4	5	—	—	—	—	
34	—	—	—	—	—	3	6	2	—	—	—	—	
35	—	—	—	—	—	3	5	1	—	—	—	—	
36	—	—	—	—	1	2	1	1	—	—	—	—	
37	—	—	—	—	—	1	1	1	—	—	—	—	
38	—	—	—	—	—	—	—	—	—	—	—	—	
39	—	—	—	—	—	—	3	—	—	—	—	—	
Water output (m^3)	421	758	987	1732	8593	21533	25610	21663	9193	1593	699	345	93127

The water output with a wind mill of 6 m head and 5 m rotor dia is then calculated using the formula $Q=0.002583\,\bar{V}^3$. Thus for the month of October the water output (Q) would be :

$$Q=0.002583\ (51\times10^3+56\times11^3+20\times12^3+21\times13^3+17\times14^3+8\times15^3+5\times16^3+12\times17^3+7\times18^3+5\times19^3+1\times20^3+3\times21^3+3\times22^3+1\times23^3+1\times24^3+3\times25^3+1\times27^3+1\times28^3)$$

$$=0.002583\ (616664)=1593.$$

The water output for individual months is computed and is presented in Table 2 and in Fig. 2. It could be seen that the water output for January, February, March,............December have been calculated as 421, 758, 987,..........345 cu. m of water. Maximum water output is observed during June, July & August being 21533, 25610 and 21663 cu. m with an abrupt fall to 9193 cu.m in September and is least (345 cu.m) in December. The power output in relation to wind speed is presented in Fig. 3. As the rotor diameter increases the power output increases

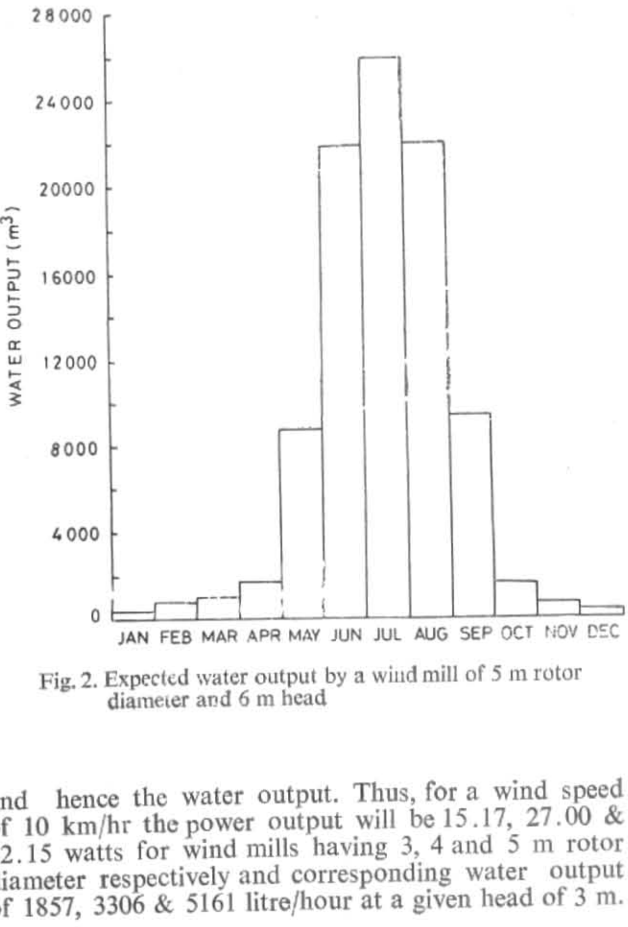

Fig. 2. Expected water output by a wind mill of 5 m rotor diameter and 6 m head

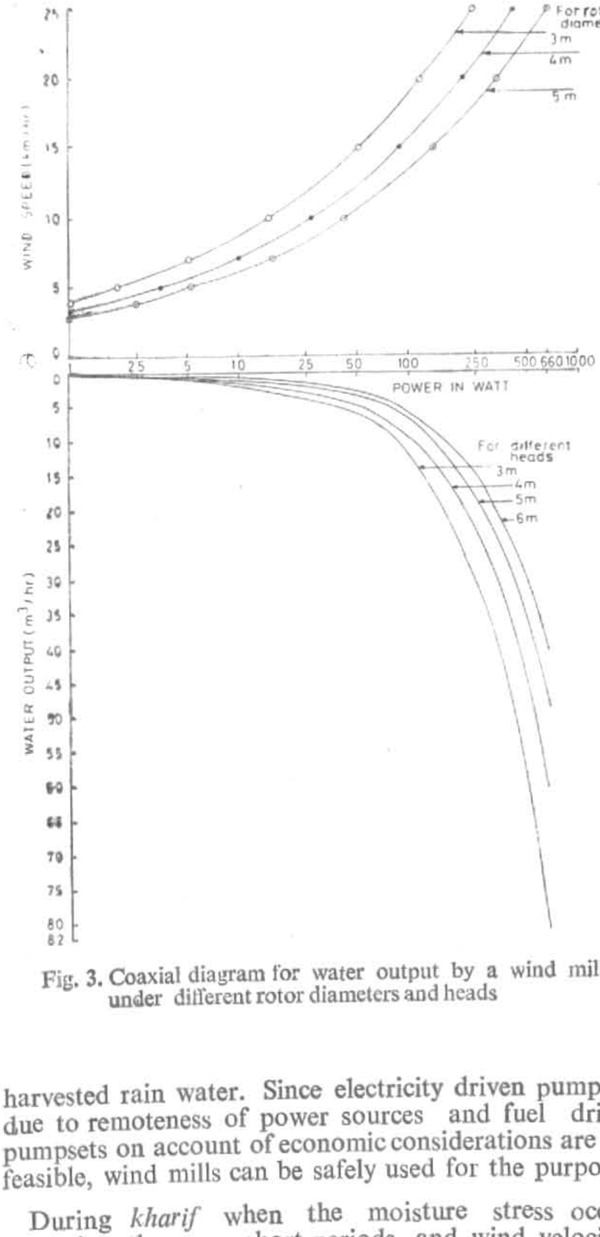

Fig. 3. Coaxial diagram for water output by a wind mill under different rotor diameters and heads

and hence the water output. Thus, for a wind speed of 10 km/hr the power output will be 15.17, 27.00 & 42.15 watts for wind mills having 3, 4 and 5 m rotor diameter respectively and corresponding water output of 1857, 3306 & 5161 litre/hour at a given head of 3 m.

It is evident from the above that wind power can be successfully utilised for pumping water for agricultural purposes through the right choice of the wind mill. The wind mills 12-PU-350 & 12-PU-500 costing Rs. 9000/- & Rs. 12000/- respectively manufactured by the Community Polytechnic Institute, Porbandar pump 2010 litre of water at wind speeds of 7 km/hr (Anonymous 1985). In the semi-arid region, *kharif* cropping is done in light soils and *rabi* crops are grown in deep black soils under dryland conditions inspite of low rainfall, considerable runoff takes place varying from 20 to 30% of the total rainfall, which could be safely harvested into dugout ponds and recycled during moisture stress (Chittaranjan *et al.* 1981). In the semi-arid region the concurrence of dry periods of 15 days and more were found to be around 60% between 15 June and 15 July during entire August and beyond 15 October (Ramanath *et al.* 1973). As a result of this, crop failures are common and could be avoided by supplementing rainfall with harvested rain water. Since electricity driven pumpsets due to remoteness of power sources and fuel driven pumpsets on account of economic considerations are not feasible, wind mills can be safely used for the purpose.

During *kharif* when the moisture stress occurs intermittently over short periods and wind velocities are in the range of 15 to 20 kmph, one can safely deploy wind mills for irrigating the crops as the water output for a wind mill having 5 m rotor diameter will be 700 to 800 cu. m/day.

Suplemental irrigation to *rabi* crops in black soils was found to be highly economical (Chittaranjan *et al.* 1981) and the benefit cost ratio in case of *jowar* was found to be 3.4. The need for such supplemental irrigation arises some time during either late October or late November at which time the wind velocities are in the range of 7 to 8 km/hr. As it is not possible to give less that 5 cm water in a single irrigation in case of black soils, it is required to construct storage tanks of 100 cu. m which can be filled by the wind mill and used for irrigating by gravity following other improved water conveyance methods for economising water. Even such tanks can carry water through summer if evaporation is reduced by planting trees around

The semi-arid region suffers 5 number of droughts of varying intensities in a normal decade. Alternate land use involving dryland horticulture with protective irrigation in summer & *kharif* from harvested or well water through drip, will help to evade droughts and stabilise economy. The wind energy can conveniently be utilized for this as wind velocities are in the range of 7 to 14 km/hr. In addition, the tail ends in the command areas can be successfully irrigated using wind mills by establishing storage tanks. Similarly wind mills can be deployed for reducing water table level to avoid water logging and prevent salinity in the irrigated areas of the region.

The wind mills thus, hold promise in the semi-arid region for irrigation. However, they are required to be used in conjunction with other improved techniques in the field of irrigation and agronomy. To make it with in the reach of farmers, looking to the socio-economic conditions, credit support should be extended. However, research on the development of cheap and efficient designs of wind mill is essential for making it popular.

Acknowledgements

The authors are grateful to Dr. V. V. Dhruvanarayana, Director, Central Soil & Water Conservation Research & Training Institute, Dehra Dun for his encouragement to take up this study. The authors are also thankful to Shri B. Ramanath, Technical Officer, of this centre, for his assistance in preparation of this paper.

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